# DIATOMS AS INDICATORS OF ENVIRONMENTAL AND CLIMATIC CHANGE IN PEATLANDS AND LAKES LOCATED ACROSS THE BOREAL SHIELD AND HUDSON BAY LOWLANDS OF CANADA

by

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# Abstract

Long-term monitoring data and paleoecological records are lacking in the Far North of Ontario (~50-57°N, 79-94°W), a region of ecological and economic significance to Canada. As a landscape covered by extensive peatland complexes, accumulating vegetation (and carbon) since de-glaciation, and tens of thousands of lakes, there is an opportunity to interpret past environmental changes from paleoecological records, and place current climatic and other environmental changes within a longer-term perspective. This thesis addresses this knowledge gap by using archives from peatlands and lakes in the Far North of Ontario to understand environmental changes over the past ~100 to 2000 years.

Given that peatlands act as an interface between terrestrial and aquatic environments, finding reliable biotic proxies with well-defined ecological optima is challenging. I use diatoms primarily to track changes in macro-vegetation type, pH and water table position across northern peatlands. Diatom assemblage composition was influenced by both the broader peatland type (i.e., bog, rich and poor fens) and microhabitats within peatland formations (e.g., hummock, hollows). The responsiveness of diatoms to chemical and moisture gradients was used to infer past environmental information archived in peat deposits. Changes in diatom composition from three peat cores reflect hydrosere succession, including past fluctuations in connectivity to the water table and pH. Approximately 600 years ago, synchronous changes in diatoms and testate amoebae infer drying conditions and subsequent microhabitat variations.

To understand the response of aquatic biota to climate change over the past ~150 years, and provide detailed baseline ecological information prior to impacts from future mineral extraction and infrastructure development, sedimentary chlorophyll-*a*, diatom and cladoceran assemblage composition were examined in four lakes across the “Ring of Fire”. Over the past ~150 years, the most notable change was a shift from littoral/benthic dominated assemblages to greater abundances of pelagic Cladocera and planktonic diatom taxa. An increase in planktonic taxa is consistent with warming-induced changes in lake properties including longer ice-free periods and changes in aquatic habitat availability. Collectively, these results help distinguish the ecological response to anthropogenic warming from both natural variation and future resource extraction.

# Co-Authorship

**Chapter 2** was co-authored by Kathleen Rühland, Andrew Paterson, Sarah Finkelstein, James Holmquist, Glen MacDonald, Bill Keller and John Smol, and represents original work as part of my PhD thesis. I designed the project, collected a third of the peat samples, analyzed all diatom samples, conducted all statistical analyses and was the primary author on this paper. This chapter has been published separately.

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**Chapter 3** was co-authored by Kathleen Rühland, Andrew Paterson, Sarah Finkelstein, Joan Bunbury, James Holmquist, Glen MacDonald, and John Smol, and represents original work as part of my PhD thesis. I designed the project, analyzed all diatom samples, conducted all statistical analyses and was the primary author on this paper. This chapter has been published separately.

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**Chapter 4** was co-authored by Clare Nelligan, Adam Jeziorski, Kathleen Rühland, Andrew Paterson, Bill Keller, and John Smol, and represents original work as part of my PhD thesis. I designed the project, performed the fieldwork, analyzed all diatom samples and chlorophyll-*a* intervals, conducted all statistical analysis and I am the primary author on the paper. The Cladocera data collection and analysis was performed by Clare Nelligan as part of her Honours thesis project in Environmental Sciences, Queen's University.

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# List of Abbreviations

asl – above sea level
JBL – James Bay Lowlands
CCA – canonical correspondence analysis
CONISS – constrained incremental sums of squares cluster analysis
CRS – constant rate of supply
DCA – detrended correspondence analysis
DO – dissolved oxygen
DOC – dissolved organic carbon
DWT – depth to water table
HBL – Hudson Bay Lowlands
MAAT – mean annual air temperature
MRT – multivariate regression tree
PCA – principal components analysis
PEARL – Paleolimnological and Environmental Assessment Research Laboratory
RoF – Ring of Fire
TKN – total Kjeldahl nitrogen
TP – total phosphorus
VRS – visual reflectance spectroscopy
$Z_{max}$ – maximum lake depth

# Chapter 1

# Introduction and Literature Review

## 1.1 General Introduction

Global temperatures are rising largely due to the increasing emission of greenhouse gases, a trend tightly coupled to human activities (Stocker et al. 2013). Many ecosystems north of the Arctic Circle have experienced amplified, accelerated impacts due to positive feedback mechanisms involving cryosphere processes and surface albedo, identifying them as particularly susceptible to climate warming (Overpeck et al. 1997; Smol et al. 2005; Kaufman et al. 2009; Catalan et al. 2013). However, the timing, magnitude and environmental impacts of climate warming are not synchronous or similar across the globe. Ecosystems in different climatic zones will have markedly different physical, chemical and biological features, and thus may exhibit different rates of ecological response to climate change.

Identifying factors that influence both regional and local differences in biotic responses to climatic change is an important step to understanding the sensitivity of an ecosystem to environmental changes, and potential mechanisms for adaptation. Arctic conditions can extend far south of the Arctic Circle. For example, as a result of atmospheric flow patterns and cooling by the world's largest polar inland sea (i.e., Hudson Bay), the treeline, southern permafrost limit, and non-alpine tundra occur considerably further south in northern Ontario, Canada ('the Far North of Ontario') (Schindler and Smol 2006; Keller et al. 2014). The southern region of the Far North of Ontario is located at the same latitude as Amsterdam, The Netherlands and spans north to latitude roughly equivalent to northern Scotland. Yet, this region of Canada is home to the southernmost population of polar bears (*Ursus maritimus*), living and breeding in James Bay (Peacock et al. 2010; Keller et al. 2014). Importantly, the Far North of Ontario harbours North America's largest continuous wetland complex (~325,000 km$^2$), second in size only to the west Siberian Plain (Abraham and Keddy 2005; Martini 2006; McLaughlin and Webster 2013).

In general, northern peatlands have been an atmospheric carbon sink since the end of the last glacial maximum, storing over 30% of the global soil carbon and yet covering only 2-3% of the Earth's land surface (Gorham 1991; Yu et al. 2010). The persistence of immense peatlands and thousands of small lakes in northern Ontario is due, in part, to a flat topography and cooler climate that is linked to permafrost presence, which maintains a waterlogged landscape. Despite the importance of the Far North of Ontario, its ecosystems have been largely understudied (Keller et al. 2014), and yet require attention due to the impacts from climate change anticipated in this region.

### 1.1.1 The Far North of Ontario

The Far North of Ontario (50-57°N and 79-94°W) represents ~40% of the province's area and is divided almost evenly between two physiographic regions: the Boreal Shield (46%) and the Hudson Bay Lowlands (HBL) (54%), the latter of which contains Ontario's largest protected area, Polar Bear Provincial Park. The Boreal Shield consists of irregular topography underlain by Precambrian igneous and metamorphic rocks, whereas the HBL consists of relatively flat terrain underlain by sedimentary rocks of Paleozoic and Mesozoic age covered by loose glacial and marine clay (Far North Science Advisory Panel 2010). Postglacial emergence occurs in the HBL as the land continues to rise following the retreat of glaciers from the last glacial period (Stewart and Barber 2010), yielding the highest rates of isostatic rebound in the world occurring at a 1.2 to 1.3 m vertical increase per century (Webber et al. 1970).

Across the Boreal Shield, drainage patterns are complex and dependent on local topography and landforms. Many of the large river systems flowing through the HBL have their headwaters on the northern Ontario Shield, which contains the divide between the Hudson Bay and Great Lakes Watersheds (Crins et al. 2009; Far North Science Advisory Panel 2010). The low-elevation terrain (average slope of 0.5m/km) and poor drainage in the HBL promotes standing or slowly moving water through this region, and has resulted in the development of the largest wetland complex in North America with ~90% of the landscape dominated by saturated peatland plains (Riley 2003; Martini 2006). The HBL is characterized by several major river systems (e.g., the Severn, Winisk, Attawapiskat, and Albany rivers), with less large and deep lakes, except in the vicinity of bedrock outcrops (e.g., Sutton and Aquatuk lakes).

The Far North of Ontario has a small population (~24,000) distributed among 34 communities; as a result, population density in this vast area is one of the lowest on Earth (Far North Science Advisory Panel 2010; Keller et al. 2014). Due to the remoteness of the Far North, coupled with the lack of an all-weather transportation infrastructure, the area is relatively inaccessible and largely undisturbed by anthropogenic activities. Currently, the region has a paucity of community-based industries and manufacturing (also limiting population growth). However, with increasing interest in developing resources of the north, particularly hydropower generation and minerals, the Far North Act (2010) was created to specify land-use planning while supporting the environmental, social and economic aims of the peoples of the Far North of Ontario.

### *Climate*

The HBL climate is relatively cold and semi-arid with long and cold winters. Mean annual temperature is approximately -1°C in the south (between 52° and 50° N latitude) and -4°C in the north (between 58°40' and 52°N) (Martini 2006; Riley 2011). The winters are cold with January temperatures ranging between mean daily maxima of -15°C in the south and -18°C in the north. Summers can be relatively warm with July average temperatures between 12 and 18°C (Martini 2006). Annual snow precipitation varies between 241 and 203 mm from south to north and total precipitation between 660 and 610 mm (Crins et al. 2009). Despite the more continental location of the Boreal Shield in the Far North of Ontario, the climate in this region is relatively cold with long, cold winters and short summers, much like the HBL. From north to south across this physiographic region, mean annual temperatures range between -4.1 and -0.1°C, and mean annual precipitation between 550 to 786 mm (Crins et al. 2009).

The maintenance of this cool climate in the Far North of Ontario is due to the southern movement of Arctic air masses unimpeded by mountain ranges, the strong influence of cold ocean currents from Hudson Strait and Labrador, and the cooling westerly winds that prolong the duration of sea ice on Hudson Bay (Martini 2006). The western shoreline of Hudson Bay has historically been the last part of Hudson Bay to become ice-free in the summer due to counterclockwise currents in the Hudson Bay that substantially cool the western coasts of Hudson Bay and James Bay (Martini 2006; Hochheim and Barber 2010, 2014; Stewart and Barber 2010). As a result, the HBL has maintained a relatively cool climate even with respect to regions at higher latitudes (Finney et al. 2004). The large-scale cold air masses that originate over the Hudson Bay, along with land-sea breezes that impose cold air temperatures on the adjacent terrestrial environment, are evident from a sharp transition in zones of permafrost development that occur inland from the Hudson Bay coast (Rouse 1991; Gough and Leung 2002). This is the most southern limit of both continuous and discontinuous permafrost in Canada. In subarctic Ontario, peat and permafrost formation can be closely related as peatland surface vegetation and soils promote the development and maintenance of permafrost due to their insulative properties in summers and high conductance in the fall and winter (Beilman et al. 2001; Turetsky et al. 2007).

### 1.1.2 Peatlands

Peatlands are organic wetlands that, according to the Canadian classification system, acquire the status of peatlands when at least 30 cm of peat has accumulated (National Wetlands Working Group 1997). Peat is a highly variable substance that can be defined as the composition of partially decomposed remains of plants with over 65% organic matter (dry weight) and less than 20-35% inorganic content (Charman 2002). Plant communities are principal in differentiating peat into four broad categories: moss, herbaceous, wood, and detrital or humified peat. The two most common moss groups that can form peat are *Sphagnum* (Family Sphagnaceae – peat mosses) and the brown mosses.

The formation of peatlands requires that organic production is greater than decay, thus plant matter accumulation exceeds that of oxidation and consumption by organisms (Beilman et al. 2009). There are two main processes that form peatlands, paludification (plant colonization of poorly drained lands) and terrestrialization (slow infilling of ponds and shallow lakes) (Martini et al. 2006). Most of the boreal peatlands in Canada are the result of paludification, where peat formation occurred on drier habitats situated over inorganic soils, and associated with higher water tables and climatic conditions (Vitt 2006). In contrast, within the HBL most peatlands are the result of primary formation, with peat accumulating directly on the water-saturated mineral ground (Sjörs 1959), as peat colonization and expansion took place rapidly after glacio-isostatic emergence (Vitt 2006; Packalen et al. 2014).

### *Bogs and fens*

The most common wetlands across the Boreal Shield and in the HBL are bogs and fens, covering over >60% of the HBL landscape (Riley 2011). Bogs are ombrotrophic peatlands, receiving all water and nutrients from atmospheric sources including precipitation, fog and snowmelt. Bog ombrotrophy is largely due to the bog surface, which is raised or level with the surrounding terrain, and thus effectively unaffected by runoff water or groundwater from the surrounding mineral soils (National Wetlands Working Group 1997; Martini et al. 2006). Because precipitation contains very few dissolved minerals and is mildly acidic, the surface bog waters are consequently low in dissolved minerals and acidic. Bog water acidity, typically pH of 3.0- 5.2 (Riley 2011), is enhanced due to the organic acids that form during decomposition of the peat and the acids present within *Sphagnum* (Rydin et al. 2006).

Fens are rich in dissolved minerals (i.e., minerotrophic) (National Wetlands Working Group 1997), and generally have fluctuating water tables with the vegetation surface close to level with the water table. Groundwater and surface-water movement is a common characteristic of fens, and thus they receive nutrients from groundwater as well as the atmosphere (Martini et al. 2006). The vegetation in fens is closely related to the depth of the water table and water chemistry, but is typically decomposed sedge or brown moss peat. Fens with waters extremely low in dissolved minerals (and often pH <5.2) are poor fens and have *Sphagnum* mosses and ericaceous shrubs (Riley 2011). Fens with slightly higher concentrations of dissolved minerals are moderately-rich fens and are dominated by sedges and brown mosses (e.g., *Drepanocladus* sp.) (National Wetlands Working Group 1997).

### *Micropatterning*

Microtopographic formation or patterning within bogs and fens is important to understanding peatland dynamics. Within bogs, microhabitat types include hollows, where the acrotelm (layer of aerobic peat) is absent or very thin, and hummocks, which are elevated above hollows because of a relatively thick acrotelm (Figure 1-1) (Charman 2002). Below the acrotelm is the water-saturated peat layer or catotelm, making the 'actrotelm-catotelm' an important boundary in differentiating bog microforms. Development of pattern formation involves two principal types of process: physical disturbance and biotic changes. Physical disturbance is most important when permafrost is present as formation of ground ice raises the ground in some areas and the collapse of ground ice causes water-filled depressions in others. On non-permafrost peatlands, hollow and pool development is thought to be primarily a result of differences in accumulation rates and feedback mechanisms that amplify relatively small initial differences in peat growth rate (Charman 2002; Kuhry and Turunen 2006). For example, slight differences between wetter and drier sites can be amplified by the increased production of vascular plants that occur on the drier sites (Belyea and Clymo 2001; Rietkerk et al. 2004; Rydin et al. 2006) which, in turn, increases evapotranspiration, concentrates nutrients and acts as a positive feedback mechanism, promoting greater growth on hummocks (Eppinga et al. 2008).

Many high-latitude peatlands are typified by bogs covered by continuous mats of *Sphagnum* with different species of *Sphagnum* occupying well-defined ecological niches (Figure 1-1) (Rydin et al. 2006). These niches are primarily based on peatland surface-moisture conditions and, to a lesser degree, pH, with dry-adapted *Sphagnum* species forming hummocks, wet-adapted species colonizing hollows, and intermediate species growing in ephemeral zones (Karlin and Bliss 1984; Gignac and Vitt 1990; Vitt 2006). The environmental gradients (e.g., moisture, pH, and vegetation) across these microforms establish important habitats to many microorganisms including algae, rotifers, and testate amoebae (Hájková et al. 2011). It is not always clear if microorganisms residing in peatlands are present due to associations to particular vegetation species or more closely influenced by local moisture and chemical variability.

### *Autogenic and allogenic development*

Long-term changes in peatlands in the Far North of Ontario may arise from both autogenic (internal) and allogenic (external) forces (Charman 2002; Kuhry and Turunen 2006). Hydroseral succession, the transition from limnetic sediment to terrestrial peat, is the most frequent and typical form of autogenic development in peatlands. Succession often follows the basic pathway of aquatic-fen-bog ecosystem transition, although there is considerable variability in the possible pathways of change that could occur to reach the present peatland community (Charman 2002; Glaser et al. 2004). The succession from fen to bog is the result of local peat accumulation that gradually lifts the surface of the peatland above the influence of the groundwater. Under oligotrophic and ombrogenic conditions, *Sphagnum* mosses often become dominant, further acidifying their local environment. The rate of hydroseral succession varies within peatlands and regions depending on climatic, topography, soil and other factors (Klinger and Short 1996; Glaser et al. 2004). Additionally, the general pathways of hydroseral succession can be reverted as a result of allogenic influences such as tectonic change, climatic change and flooding (Glaser et al. 1996, 2004; Bauer et al. 2003).

A critical allogenic factor influencing peatland initiation, development, and decay is regional climate. Rapid warming in the early Holocene, increased summer insolation, and strong seasonality promoted the development of most northern peatlands following the Younger Dryas (MacDonald et al. 2006). This large-scale development of peatlands in turn contributed to atmospheric fluctuations of $CH_4$ and $CO_2$, and the net sequestration of $CO_2$ stored in peatlands today (Yu et al. 2010, 2013). Thus, many of the existing subarctic peatlands that are currently largely frozen developed under conditions closer to a Boreal climate that prevailed during the warmer early-to-middle Holocene. Neoglacial cooling since the mid-Holocene has limited peat accumulation in many Canadian subarctic regions (Vardy et al. 2000; Kuhry and Turunen 2006; Martini et al. 2006).

Recent evidence has shown that peat initiation in the HBL is tightly coupled with glacial isostatic rebound, and when isostatic rebound was most rapid in the mid-Holocene, the climate was cooler and drier (Bunbury et al. 2012; Holmquist et al. 2014; Packalen et al. 2014). The weaker relationship between climate and peat initiation and expansion in the HBL is linked to reduced drainage and sustained water-logged conditions that occurred with rapid land emergence, and promoted peat initiation and development even under more subarctic-like conditions (Packalen et al. 2014). The weaker control of climate on peatland initiation and development in the HBL was also suggested in an earlier study by Glaser et al. (2004) who found that the pace and pathway of peatland succession in southern HBL seemed to be driven by tectonic drivers (i.e. isostatic rebound) rather than climatic forcing.

### 1.1.3 Paleoecology and Paleolimnology

As lakes and peatlands may change over hundreds of years due to natural climatic and successional changes, it is important to understand their developmental history in order to quantify natural variability in these sensitive ecosystems. From this, the effects of human activities, including recent warming in the 'Anthropocene', can be distinguished from natural, long-term changes. Past environmental assessments can be made from a combination of different approaches including historical measurements, space-for-time substitutions, hindcasting past environmental conditions using models, and paleoenvironmental reconstructions (Smol 2010). Paleolimnology uses a variety of physical, chemical and biological approaches to track past changes in ecosystems using proxy data archived in lake sediments (Smol 2008). In lakes, materials accumulate in relatively undisturbed stratigraphic sequences and as such, there are well-established methods for recovering information achieved in depth-time profiles (Last and Smol 2001). Generally, a single sediment core collected from the deepest basin of a lake should integrate information from many regions of the water body, and capture broad environmental signals. The information contained in the sediment core and other natural achieves is called proxy data, as they are used to provide indirect measures of past lake and catchment processes and conditions (Smol 2008).

Lakes can be considered 'sentinels' of climate change as they integrate the effects of regional warming from the atmosphere, the catchment and within lake processes (Williamson et al. 2009). Many long-term monitoring records of lake chemical (e.g., Keller et al. 2008), physical (e.g., Bhiry et al. 2011) and biological (e.g., Winder et al. 2009) data, as well as paleolimnological records (e.g., Smol et al. 2005; Catalan et al. 2013), have observed changes to lakes closely associated to climatic warming, although the linkages may be indirect and complex (see Adrian et al. 2009). In general, as temperatures warm, there is a decline in both ice thickness and the duration of the ice-cover on lakes (Latifovic and Pouliot 2007), influencing many physical variables such as the depth of light penetration, strength of thermal stratification (or depth of epilimnion-hypolimnion boundaries), and UV exposure (Pienitz and Vincent 2000; Vincent et al. 2013). In turn, these physical changes induced from climatic change are influencing the seasonality, productivity and composition of algal assemblages (Rühland et al. 2008; Winder and Sommer 2012). Specifically, in many Arctic and subarctic lakes, a longer growing season increases the availability of planktonic habitat and allows time for more complex habitats to develop (e.g., mosses and macrophytes) in lakes that are typically dominated by rock and sediment substrates.

In addition to lake sediments, a variety of natural archives (e.g. tree rings, ice cores and ocean corals) preserve proxy data of past environmental and ecological changes. In North America, peatland archives have not yet been as widely used as ice cores, tree rings, or lake sediments, despite being a valuable source of information on past climatic variability (Booth 2010). Ombrotrophic bogs are most likely to contain a complete successional history within the HBL and believed to be the most sensitive recorders of climate change as they receive water solely from precipitation (Aaby 1986; Barber et al. 1998). Surface-moisture conditions in bogs are closely associated with changes in precipitation and evapotranspiration, and therefore should be particularly responsive to hydroclimate variability (Charman et al. 2009; Booth 2010). As discussed previously, there are two reasons to examine the peat archive: 1) as a receptacle of information about the surrounding environment (i.e. typically climate inferences); and 2) as a recorder of the ecological and hydrological development of the peatland. Most studies are primarily interested in obtaining information on climate from the peat achieve; however, peatland development must be considered. Interactions between climate and peatland developmental succession are the norm, and it is common for several factors to contribute to the same sequence of change.

### *Diatoms as paleoecological proxies*

Diatoms (Bacillariophyceae) are siliceous, microscopic algae that are often the dominant algal group in most freshwater systems (Smol and Stoermer 2010). Currently there are >24,000 diatoms with valid scientific names, most often distinguished based on the size, shape and sculpturing of their siliceous cell walls (Smol 2010; Julius and Theriot 2010). Due to both their fast migration rates (i.e. ability to colonize new habitats quickly) and the varying optima and tolerances of different taxa, diatoms have been used in a variety of applications, such as indicators of historical lake acidity (Battarbee et al. 2010), nutrient concentrations (Hall and Smol 2010), and water levels (Wolin and Stone 2010) (see Smol and Stoermer 2010 for more applications of diatoms). In regions where little is known about the diatom flora and their associations to particular environments, calibration models can be developed. Calibration of proxies has generally occurred in two ways: either by examining the present-day correlation structure among proxies and environmental conditions (i.e., space for-time substitution) or comparing time series of instrumental and proxy records during the recent past (i.e., temporal calibration) (Booth 2010). Most often instrumental records are short, especially in the Arctic, and ‘the present is the key to the past’, where a better understanding of the variables that influence the distribution of diatom assemblages across modern environments improves inferences of past environments.

To date, the majority of peatland paleoecological studies have focused on the environmental niches of well-established peatland proxies including bryophytes, testate amoebae, and pollen (Charman 2002). Comprehensive studies of diatom flora from peatland systems remain scarce, particularly in northern latitudes (Gaiser and Rühland 2010). Given the sensitive response of diatoms to peatland microhabitat conditions (Rühland et al. 2000), there is considerable potential for using diatoms to increase our understanding of the changing north, particularly when used in tandem with other common biotic indicators. Presently, there are several studies that have examined associations between diatom taxa and aquatic vegetation, including a few that are focused on peatland diatom ecology (Flensburg and Sparling 1973; Kingston 1982; Cochran-Stafira and Andersen 1984; Poulíèková et al. 2004; Hamilton and Siver 2010), but none have presented diatom calibration training sets for inferring past chemical and/or hydrological changes in peatlands.

Through modern calibration or training sets, it is possible to use the distribution of diatom assemblages from surface (i.e. modern) peat samples across a gradient of peat types to provide analogs that allow inferences of past peat environments based on downcore assemblages. Although diatom-based calibration models are commonly applied to lake records to infer past environmental changes, they have rarely been applied to peatland cores. In the few cases where inference models have been applied to diatom peatland records, these models were based on lake calibration sets (Campbell et al. 1997; Kienel et al. 1999; Brugam and Swain 2000), as peatland diatom calibration sets do not yet exist. Exploring modern diatom-bryophyte relationships together with diatom responses across chemical and physical gradients among peat types is an important step to gaining a more comprehensive knowledge of peatland developmental history and the possible responses to changing climates.

The approach for collecting samples for a peatland diatom calibration set differs from a lake calibration set in a number of ways. Unlike lake sediment samples that can represent an integration of all aquatic habitats within a lake, peat does not accumulate in the same manner (i.e. sediment focusing toward the center of the depositional basin), thus requiring the collection of numerous samples across the heterogeneous peatland environment to capture the substantial variability in microtopography within a given peatland. In peat calibration sets using testate amoebae, the full range of surface moisture variability is best represented by selecting peatlands that span the gradient from ombrotrophic to minerotrophic, and by sampling the microhabitats within each peatland (e.g., hummocks, hollows, pools) (Booth 2002).

Using multi-proxy approaches to reconstruct environments of the Far North of Ontario would yield a more complete assessment of past environmental conditions. Commonly, a wide range of biological fossil groups are examined, either with the aim of obtaining information on a broader range of paleoenvironmental parameters or to crosscheck inferences from particular lines of evidence (Charman 2001). Given that testate amoebae (Protozoa: Rhizopoda) are frequently the most common protists living in bog vegetation, they are a more widely studied biological indicator in ombrotrophic peatlands than diatoms, with calibration models developed to reconstruct the hydrological conditions. However, a more extensive literature and understanding of diatom autoecology and taxonomy are available, suggesting that when present, diatoms should contribute meaningfully to inferences of past environments. Mitchell et al. (2008) highlighted that, with a few exceptions, studies that have combined the results of testate amoebae with independent lines of evidence provided by other proxies are scarce.

### 1.1.4 Climate change and human impact in the Far North of Ontario

Unlike other circum-Arctic regions, where instrumental and modeling evidence (Chapman and Walsh 1993; Serreze et al. 2000) and the paleolimnological record (Smol et al. 2005) show that anthropogenic climate warming occurred as early as the mid-19th century, the HBL is part of the eastern Canadian Arctic that has remained relatively cool (Chapman and Walsh 1993; Macrae et al. 2014). From the onset of neoglacial cooling into the late 20th century both diatom-based paleolimnological studies in northern Quebec (Laing et al. 2002; Ponader et al. 2002) and Labrador (Paterson et al. 2003), as well as tree-ring records (Lescop-Sinclair and Payette 1995), indicate little ecological response to broad Northern-Hemisphere climatic changes.

Since the ~mid-1990s, however, the moderating effect of Hudson Bay sea-ice has diminished substantially due to significant increases in land surface air temperatures, Hudson Bay sea-ice temperatures, sea-ice thickness and extent, and sea ice phenology (Gough et al. 2004; Hochheim and Barber 2010; 2014). A rapid, threshold response of lake ecosystems to warming temperatures has occurred over the past few decades, resulting in events such as a large-scale fish die-off event from abnormally warm conditions in the Sutton River in 2001 (Gunn and Snucins 2010), evaporation and desiccation of lakes following winters of very low snowfall (Bouchard et al. 2013), and abrupt algal community shifts and increased aquatic primary production linked to changes in aquatic habitat availability and lake water properties resulting from shorter duration of lake ice cover (Rühland et al. 2013, 2014; Friel et al. 2014). Longer ice-free seasons for the Hudson Bay are projected to continue and to accelerate (Gough et al. 2004; Gagnon and Gough 2005; McKenney et al. 2010; French and Slaymaker 2012; Hochheim et al. 2010), likely promoting further environmental changes in the Far North of Ontario.

Anthropogenic climatic change may directly and indirectly affect peatlands in complex ways. For example, warming is expected to cause a rise in sea level, and flooding is predicted to occur on low-lying coastal peatlands such as those in the HBL and other Arctic coastal areas (Tarnocai and Stolbovoy 2006). In nearby northern Manitoba, Dyke and Sladen (2010) report that there are early signs that continued warming will result in expansion of thawed zones, subsidence at bog plateau margins, and possible collapse of plateau surfaces, resulting in conversion to fen peat, with additional loss of peat plateau bog by wave erosion along lake shorelines. In these cases, researchers have shown that, initially, climate warming may promote carbon sequestration in current subarctic and arctic peatlands by increasing primary production more than decomposition (through both a longer growing season and warmer temperatures) (Beilman et al. 2009; Charman et al. 2012). Although precipitation increases are predicted in some regions of northern Ontario and Manitoba, disproportionate future temperature increases (i.e. faster than precipitation increases) may result in reduced carbon storage (Packalen et al. 2014), with losses enhanced from fires (Tarnocai 2006) and potential infrastructure development. Currently, it is unlikely that the recent warming trend in the HBL has had notable effects on permafrost thaw as modeling shows a substantial lag between increases in air temperature and increases in soil temperature in permafrost (Gough and Leung 2002) and because ground temperatures may not reach a critical point for permafrost degradation until the end of the century (Tam et al. 2014).

Interest in northern Ontario has spiked over the past decade due to the discovery of extensive mineral deposits, predominantly chromite as well as considerable amounts of gold, zinc, nickel, copper and platinum (Dyer and Burke 2012). The proposed mining and infrastructure development needed to remove and transport these minerals is of great economic importance to the province of Ontario as the "Ring of Fire" region is estimated to contain 220 tonnes of extractable chromite, making it the fourth largest chromite deposit in the world (Hjartarson et al. 2014). Future resource development combined with the conservation of these unique northern wetland and lake environments will require a detailed understanding of the regional ecology and ongoing natural processes and environmental change. Currently, Ontario is committed to protecting 50% of its northern boreal landscape (Bill 191, The Far North Act; Far North Science Advisory Panel 2010), and thus it is essential that the biota of these unaltered ecosystems be characterized, and vulnerable habitats identified.

## 1.2 Thesis objectives

The main objective of this thesis is to assess the limnology and paleoecology of lakes and wetlands in the Far North of Ontario, with particular emphasis on environmental change over the last ~100 to 6000 years (or since de-glaciation). The thesis is composed of five chapters, including this introductory chapter, three data chapters, and a final discussion chapter. Chapter 2 and 3 examine spatial patterns and temporal changes in diatom assemblages of peatland habitats, and Chapter 4 focuses on the response of both diatoms and Cladocera to climate warming in lakes located across the diverse northern Ontario landscape slated for future mining development (named the “Ring of Fire”). In Chapter 2, I address the following questions: Are there clear associations between diatom assemblages and different peatland types (e.g., bog, poor fen, rich fen)? Do these associations differ across ecozones (e.g., do fens in subarctic and Boreal Shield regions contain different diatom assemblages)? Across northern peatlands and within these ecozones, how do pH and moisture availability structure diatom assemblages? Is there a relationship between diatom species richness and differences in peat microhabitats (e.g., hummock, hollows)? Is there potential to develop calibration functions based on peatland diatom assemblages to estimate past environmental conditions in peatlands?

This research is novel as there have been limited modern floristic and faunistic surveys of the varying peatland environments within Canada’s Boreal Shield and HBL, and these surveys have been largely descriptive (e.g., Sjors 1959). Currently, there are no studies on the diatom flora of the peatlands of northern Ontario. Thus, there is an opportunity to improve our understanding of environmental changes captured by diatom assemblages preserved within peatland archives. To gain insights into the ecological distribution of diatom taxa across the Boreal Shield of northern Ontario and into the Ontario and Manitoba HBL (a ~1,200 km latitudinal transect), 113 surface peat samples were collected along wide vegetation (e.g., rich fen, poor fen, bog and associated bryophytes), chemical (e.g., pH range from ~3 to 8), and moisture gradients. Key insights on the relative importance of taxon-specific relationships to either the chemical (pH) or the physical environment (e.g., moisture, and/or specific vegetation types, *Sphagnum* spp.) are central to this research chapter.

In Chapter 3, a multi-proxy paleoecological approach is used to track environmental change in three peat deposits from the Boreal Shield and HBL to address the following questions: (1) Do diatoms track environmental and successional changes in peat deposits of northern Ontario? (2) Does the apparent sensitivity of diatom and testate amoebae assemblages to hydrological, chemical and associated bryophyte changes vary between proxies? (3) Is there synchrony (shared sensitivity) in observed changes among the various biological proxies, and what are the potential reasons for the similarity (or differences) in their responses? (4) How does the simultaneous analysis of these proxies in the same core improve our reconstruction and understanding of past peatland environments? and (5) What are the potential reasons for observed preservation differences among proxies? Based on multi-proxy data I interpret the allogenic and autogenic changes in bog environments, considering potential drivers and implications for current climatic change impacts. This research aims to help untangle and derive reliable and robust paleoenvironmental inferences from multiple proxies, which is often very complex, but strengthens our overall understanding of past environmental change.

In Chapter 4, paleolimnological techniques were used to examine the diatom and cladoceran assemblage response to climatic warming in four lakes in the Far North of Ontario. The goals for this chapter were to determine whether different trophic levels respond at similar times to climate change in the “Ring of Fire” and whether diatoms and cladocerans infer similar aquatic ecosystem changes. Diatoms are largely influenced by bottom-up lake controls (e.g., water chemistry and physical lake changes), whereas Cladocera may be influenced and respond to bottom-up controls, as well as top-down controls (e.g., fish and invertebrate predation). Thus Cladocera may not always track similar ecosystem responses to warming as diatoms, and may provide additional information on environmental changes. Additionally, research questions as to whether there are differences in the aquatic ecosystem response across physiographic boundaries, and within deep and shallow lakes located across the diverse “Ring of Fire” landscape were addressed. Lastly, this chapter examines how the timing of and response to climatic change recorded in lake sediments in the “Ring of Fire” of northern Ontario compares to both lakes located in closer proximity to the Hudson Bay (e.g., Rühland et al. 2013, 2014; Friel et al. 2014), temperate lakes in Ontario (e.g., Lavery et al. 2014), and Arctic lakes (e.g., Smol et al. 2005). Two large, deep, oligotrophic lakes situated on the Ontario Boreal Shield and two shallow, slightly more nutrient-rich, closed-basin lakes located in the HBL where chosen for paleolimnological analyses. Finally, Chapter 5 contains a general discussion of the results of this investigation and suggests possible future research directions.

Collectively this thesis provides an assessment of the response of northern lakes and peatlands to climatic change. Thus, our understanding of the factors that shape the current ecology of northern Ontario lakes and peatlands are improved, and our interpretations of environmental change over the past ~6000 years (or since de-glaciation in the HBL) and predictions of future responses to warming are strengthened. This work further highlights the diverse applications of diatoms to environmental research, the strength of multi-proxy approaches, and the valuable ecological information that indirect analyses of biological archives can provide in remote locations where historical data are lacking.

## 1.3 Literature cited

Aaby, B. 1986. Palaeoecological studies of mires. In Handbook of Holocene Palaeoecology and Palaeohydrology. Edited by B.E. Berglund. John Wiley and Sons, New York, New York. pp. 145–164.

Abraham, K.F., and Keddy, P.A. 2005. The Hudson Bay Lowland. In The World's Largest Wetlands: The Hudson Bay Lowlands. Edited by L.H. Fraser, and P.A. Keddy. Cambridge University Press, Cambridge, pp. 118–148.

Adrian, R., O'Reilly, C.M., Zagarese, H., Baines, S.B., Hessen, D.O., Keller, W., Livingstone, D.M., Sommaruga, R., Straile, D., Van Donk, E., Weyhenmeyer, G.A., and Winder, M. 2009. Lakes as sentinels of climate change. *Limnology and Oceanography* 54: 2283–2297.

Barber, K., Dumayne-Peaty, L., Hughes, P., Mauquoy, D., and Scaife, R. 1998. Replicability and variability of the recent macrofossil and proxy-climate record from raised bogs: field stratigraphy and macrofossil data from Bolton Fell Moss and Walton Moss, Cumbria, England. *Journal of Quaternary Science* 13: 515–528.

Battarbee, R.W., Charles, D.F., and Bigler, C., Cumming, B.F., and Renberg, I. 2010. Diatoms as indicators of surface-water acidity. In The Diatoms: Applications for the Environmental and

Earth Sciences. Edited by J.P. Smol, and E.F. Stoermer. Cambridge University Press, New York. pp. 98–121.

Bauer, I.E., Gignac, L.D., and Vitt, D.H. 2003. Development of a peatland complex in boreal western Canada: lateral site expansion and local variability in vegetation succession and long-term peat accumulation. *Canadian Journal of Botany* 81: 833–847.

Beilman, D.W., Vitt, D.H., and Halsey, L.A. 2001. Localized permafrost peatlands in western Canada: definition, distributions, and degradation. *Arctic, Antarctic, and Alpine Research* 33: 70–77.

Beilman, D.W., MacDonald, G.M., Smith, L.C., and Reimer, P.J. 2009. Carbon accumulation in peatlands of West Siberia over the last 2000 years. *Global Biogeochemical Cycles* 23: GB1012.

Belyea, L.R., and Clymo, R.S. 2001. Feedback control of the rate of peat formation. *Proceedings of the Royal Society of London Series B* 268: 1315–1321.

Bhiry, N., Delwaide, A., Allard, M., Begin, Y., Fillon, L., Lavoie, M., Nozais, C., Payette, S., Pienitz, R., Saulnier-Talbot, E., and Vincent, W.F. 2011. Environmental change in the Great Whale River region, Hudson Bay: Five decades of multidisciplinary research by Centre D'études Nordiques (CEN). *Ecoscience* 18: 182–203.

Booth, R.K. 2002. Testate amoebae as paleoindicators of surface-moisture changes on Michigan peatlands: modern ecology and hydrological calibration. *Journal of Paleolimnology* 28: 329–348.

Booth, R.K. 2010. Testing the climate sensitivity of peat-based paleoclimate reconstructions in mid-continental North America. *Quaternary Science Reviews* 29: 720–731.

Bouchard, F., Turner, K.W., MacDonald, L.A., Deakin, C., White, H., Farquharson, N., Medeiros, A.S., Wolfe, B.B., Hall, R.I., Pienitz, R., and Edwards, T.W.D. 2013. Vulnerability of shallow subarctic lakes to evaporate and desiccate when snowmelt runoff is low. *Geophysical Research Letters* 40: 6112–6117.

Brugam, R.B., and Swain, P. 2000. Diatom indicators of peatland development at Pogonia Bog Pond, Minnesota, USA. *The Holocene* 10: 453–464.

Bunbury, J., Finkelstein, S.A., and Bollmann, J. 2012. Holocene hydro-climatic change and effects on carbon accumulation inferred from a peat bog in the Attawapiskat River watershed, Hudson Bay Lowlands, Canada. *Quaternary Research* 78: 275–284.

Campbell, D.R., Dutchie, H.C., and Warner, B.G. 1997. Post-glacial development of a kettle-hole peatland in southern Ontario. *Ecoscience* 4: 404–418.

Catalan, J., Pla-Rabés, S., Wolfe, A.P., Smol, J.P., Rühland, K.M., Anderson, N.J., Kopáček, J., Stuchlík, E., Schmidt, R., Koinig, K.A., Camarero, L., Flower, R.J., Heiri, O., Kamenik, C., Korhola, A., Leavitt, P.R., Psenner, R., and Renberg, I. 2013 Global change revealed by palaeolimnological records from remote lakes: a review. *Journal of Paleolimnology* 49: 513–535.

Chapman, W.L., and Walsh, J.E. 1993. Recent variations of sea ice and air temperature in high latitudes. *Bulletin American Meteorological Society* 74: 33–47.

Charman, D.J. 2002. Peatlands and Environmental Change. John Wiley Sons Ltd., West Sussix, England.

Charman, D.J. 2001. Biostratigraphic and palaeoenvironmental applications of testate amoebae. *Quaternary Science Reviews* 20: 1753–1764.

Charman, D.J., Barber, K.E., Blaauw, M., Langdon, P.G., Mauquoy, D., Daley, T.J., Hughes, P.D.M., and Karofeld, E. 2009. Climate drivers for peatland palaeoclimate records. *Quaternary Science Reviews* 28: 1811–1819.

Charman, D.J., Beilman, D.W., Blaauw, M. Booth, R.K., Brewer, S., Chamber, F.M., Christen, J.A., Gallego-Sala, A., Harrison, S.P., Hughes, P.D.M., Jackson, S.T., Korhola, A., Mauquoy, D., Mitchell, F.J.G., Prentice, I.C., van der Linden, M., De Vleeschouwer, F., Yu, Z.C., Alm, J., Bauer, I.C., Corish, Y.M.C., Garneau, M., Hohl, V., Huang, Y., Karofeld, E., Le Roux, G., Loisel, J., Moschen, R., Nichols, J.E., Nieminene, T.M., MacDonald, G.M., Phadtare, N.R., Rausch, N., Sillasoo, Ü., Swindles, G.T., Tuittila, E.-S., Ukonmaanaho, L., Väliranta, M., van Bellen, S., van Geel, B., Vitt, D.H., and Zhao, Y. 2012. Climate-related changes in peatland carbon accumulation during the last millennium. *Biogeosciences Discussions* 9: 14327–14364.

Cochran-Stafira, D.L., and Andersen, R.A. 1984. Diatom flora of a kettle-hole bog in relation to hydrarch succession zones. *Hydrobiologia* 109: 265–273.

Crins, W.J., Gray, P.A., Uhlig, P.W.C., and Wester, M.C. 2009. The ecosystems of Ontario, Part 1: ecozones and ecoregions. Ministry of Natural Resources, Peterborough Ontario, Inventory, Monitoring and Assessment, SIB TER IMA TR- 01. 71 pp.

Dyer, R.D. and Burke, H.E. 2012. Preliminary results from the McFaulds Lake (“Ring of Fire”) area lake sediment geochemistry pilot study, northern Ontario. Ontario Geological Survey, Open File Report 6269.

Dyke, L.D., and Sladen, W.E. 2010. Permafrost and peatland evolution in the northern Hudson Bay Lowland, Manitoba. *Arctic* 63: 429–441.

Eppinga, M.B., Rietkerk, M., Borren, W., Lapshina, E.D., Bleuten, W., and Wassen, M.J. 2008. Regular surface patterning of peatlands: confronting theory with field data. *Ecosystems* 11: 520–536.

Far North Science Advisory Panel (Ontario) 2010. Science for a Changing Far North. The Report of the Far North Science Advisory Panel. Far North Branch, Ontario Ministry of Natural Resources.

Far North Act. 2010. *Bill 191 An Act with respect to land use planning and protection in the Far North*. Legislative Assembly of Ontario, 39th Legislature, 2nd session.

Finney, B.P., Rühland, K.M., Smol, J.P., and Fallu, M.-A. 2004. Paleolimnology of North American Subarctic. In Long-term Environmental Change in Arctic and Antarctic lakes, Vol. 8. Edited by R. Pienitz, M.S.V. Douglas, and J.P. Smol. Springer, The Netherlands. pp. 269–318.

Flensburg, T., and Sparling, J.H. 1973. The algal microflora of a string mire in relation to the chemical composition of water. *Canadian Journal of Botany* 51:743–749.

French, H., and Slaymaker, O. 2012. Changing Cold Environments: a Canadian Perspective. Wiley-Blackwell, New York. 321 pp.

Friel, C.E., Finkelstein, S.A., and Davis, A.M. 2014. Relative importance of hydrological and climatic controls on Holocene paleoenvironments inferred using diatom and pollen records from a lake in the central Hudson Bay Lowlands, Canada. *The Holocene* 1: 1–12.

Gagnon, A. and Gough, W. 2005. Trends in the dates of ice freeze-up and breakup over Hudson Bay, Canada. *Arctic* 58: 370–382.

Gaiser, E., and Rühland, K.M. 2010. In The Diatoms: Applications for the Environmental and Earth Sciences. Edited by J.P. Smol, and E.F. Stoermer. Cambridge University Press, New York. pp. 473–496.

Gignac, L.D., and Vitt, D.H. 1990. Habitat limitations of *Sphagnum* along climatic, chemical, and physical gradients in mires of western Canada. *The Bryologist* 93: 7−22.

Glaser, P.H., Bennett, P.C., Siegel, D.I., and Romanowicz, E.A. 1996. Palaeo-reversals in groundwater flow and peatland development at Lost River, Minnesota, USA. *The Holocene* 6: 413–421.

Glaser, P.H., Hansen, B.C.S., Siegel, D.I., Reeve, A.S., and Morin, P.J. 2004. Rates, pathways and drivers for peatland development in the Hudson Bay Lowlands, northern Ontario, Canada. *Journal of Ecology* 92: 1036–1053.

Gough, W.A., and Leung, A. 2002. Nature and fate of Hudson Bay permafrost. *Regional Environmental Change* 2: 177–184.

Gough, W.A., Cornwell, A.R., and Tsuji, L.J.S. 2004. Trends in seasonal sea ice duration in southwestern Hudson Bay. *Arctic* 57: 299–305.

Gorham, E. 1991. Northern peatlands: role in the carbon cycle and probable responses to climatic warming. *Ecological Applications* 1: 182−195.

Gunn, J. and Snucins, E. 2010. Brook charr mortalities during extreme temperature events in Sutton River, Hudson Bay Lowlands, Canada. *Hydrobiologia* 650: 79–84

Hajková, P., Bojková, J., Fránková, M., Opravilová, V., Hájek, M., Kintrová, K., and Horsák, M. 2011. Disentangling the effects of water chemistry and substratum structure on moss-dwelling unicellular and multicellular micro-organisms in spring-fens. *Journal of Limnology* 70: 54–61.

Hall, R.I., and Smol, J.P. 2010. Diatoms as indicators of lake eutrophication. In The Diatoms: Applications for the Environmental and Earth Sciences. Edited by J.P. Smol and E.F. Stoermer. Cambridge University Press, New York. pp. 122–151.

Hamilton, P.B., and Siver, P.A. 2010. A morphological investigation of *Eunotia fennica* (Bacillariophyceae) from a freshwater acidic pond in Newfoundland, Canada. *Proceedings of the Academy of Natural Sciences of Philadelphia* 160: 89–98.

Hawryshyn, J., Rühland, K.M., Quinlan, R., and Smol, J.P. 2012. Long-term water quality changes in a multiple stressor system: a diatom-based paleolimnological study of Lake Simcoe (Ontario, Canada). *Canadian Journal of Fisheries and Aquatic Sciences* 69: 24–40.

Hjartarson, J., McGuinty, L., Boutilier, S., and Marjernikova, E. 2014. Beneath the Surface: Uncovering the Economic Potential of Ontario's Ring of Fire. Ontario Chamber of Commerce.

Hochheim, K.P., and Barber, D.G. 2010. Atmospheric forcing of sea ice in Hudson Bay during the fall period, 1980–2005. *Journal of Geophysical Research* 115: C05009.

Hochheim, K., Barber, D.G., and Lukovich, J.V. 2010. Changing Sea Ice Conditions in Hudson Bay, 1980–2005. In A Little Less Arctic. Edited by S.H. Ferguson, L.L. Loseto, and M.L. Mallory. Springer, Heidelberg, Germany. pp. 39–52.

Hochheim, K.P. and Barber, D.G. 2014. An update on the ice climatology of the Hudson Bay system. *Arctic, Antarctic, and Alpine Research* 46: 66–83.

Holmquist, J.R., MacDonald, G.M., and Gallego-Sala, A. 2014. Peatland initiation, carbon accumulation, and 2 ka depth in the James Bay Lowland and adjacent regions. *Arctic, Antarctic, and Alpine Research* 46: 19–39.

Julius, M.L., and Theriot, E.C. 2010. In The Diatoms: Applications for the Environmental and Earth Sciences. Edited by J.P. Smol, and E.F. Stoermer. Cambridge University Press, New York. pp. 8–22.

Karlin, E.F., and Bliss, L.C. 1984. Variation in substrate chemistry along microtopographical and water-chemistry gradients in peatlands. *Canadian Journal of Botany* 62: 142–153.

Kaufman, D.S., Schneider, D.P., McKay, N.P., Ammann, C.M., Bradley, R.S., Briffa, K.R., Miller, G.H., Otto-Bliesner, B.L., Overpeck, J.T., Vinther, B.M., and Arctic Lakes 2k Project Members. 2009. Recent warming reverses long-term Arctic cooling. *Science* 325: 1236–1239.

Keller, W., Paterson, A.M., Somers, K.M., Dillon, P.J., Heneberry, J., and Ford, A. 2008. Relationships between dissolved organic carbon concentrations, weather, and acidification in small Boreal Shield lakes. *Canadian Journal of Fisheries and Aquatic Sciences* 65: 786–795.

Keller, W., Paterson, A.M., Rühland, K.M., and Blais, J.M. 2014. Introduction–environmental change in the Hudson and James Bay region. *Arctic, Antarctic, and Alpine Research* 46: 2–5.

Kienel, U., Siegert, C., and Hahne, J. 1999. Late Quaternary palaeoenvironmental reconstructions from a permafrost sequence (North Siberian Lowland, SE Taymyr Peninsula) – a multidisciplinary case study. *Boreas* 28: 181–193.

Kingston, J.C. 1982. Association and distribution of common diatoms in surface samples from northern Minnesota peatlands. *Nova Hedwigia* 73: 333–346.

Klinger, L.F., and Short, S.K. 1996. Succession in the Hudson Bay Lowland, northern Ontario, Canada. *Arctic and Alpine Research* 28: 172–183.

Kuhry, P., and Turunen, J. 2006. The postglacial development of boreal and subarctic peatlands. In Ecological Studies Vol. 188 Boreal Peatland Ecosystems. Edited by R.K. Wieder, and D.H. Vitt. Springer-Verlag, Berlin. pp 25–46.

Laing, T.E., Pienitz, R. and Payette, S. 2002. Evaluation of limnological responses to recent environmental change and caribou activity in the Riviere George Region, Northern Quebec, Canada. *Arctic, Antarctic, and Alpine Research* 34: 454–464.

Latifovic, R., and Pouliot, D. 2007. Analysis of climate change impacts on lake ice phenology in Canada using the historical satellite data record. *Remote Sensing of Environment* 106: 492–507.

Last, W.M., and Smol, J.P. 2001. Tracking Environmental Change Using Lake Sediments. Volume 1: Basin Analysis, Coring, and Chronological Techniques. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Lavery, J.M., Kurek, J., Rühland, K.M., Gillis, C.A., Pisaric, M.F.J., and Smol, J.P. 2014. Exploring the environmental context of recent *Didymosphenia geminata* proliferation in Gaspsie, Quebec, using paleolimnology. *Canadian Journal of Fisheries and Aquatic Science* 71: 1–11.

Lescop-Sinclair, K., and Payette, S. 1995. Recent advance of the arctic treeline along the eastern coast of Hudson Bay. *Journal of Ecology* 83: 929–936.

MacDonald, G.M., Beilman, D.W., Kremenetski, K.V., Sheng, Y., Smith, L.C., and Velichko, A.A. 2006. Rapid early development of circumarctic peatlands and atmospheric $CH_4$ and $CO_2$ variations. *Science* 314: 285–288.

Macrae, M.L., Brown, L.C., Duguay, C.R., Parrott, J.A., and Petrone, R.M. 2014. Observed and projected climate change in the Churchill region of the Hudson Bay Lowlands and implications for pond sustainability. *Arctic, Antarctic, and Alpine Research* 46: 272–285.

Martini, I.P. 2006. The cold-climate peatlands of the Hudson Bay Lowland, Canada: brief overview of recent work. In Peatlands: Evolution and Records of Environmental and Climate Changes. Edited by I.P. Martini, A. Martinez Cortizas, and W. Chesworth. Elsevier B.V., Amsterdam. pp. 53–84.

Martini, I.P., Martinez Cortizas, A., and Chesworth, W. 2006. Peatlands: Evolution and Records of Environmental and Climate Changes. Elsevier B.V, Amsterdam.

McKenney, D.W., Pedlar, J.H., Lawrence, K., Gray, P.A., Colombo, S.J., and Crins, W.J. 2010. Current and projected future climatic conditions for ecoregions and selected natural heritage areas in Ontario. Ontario Ministry of Natural Resources. Climate Change Research Report CCRR-16.

McLaughlin, J., and Webster, K. 2014. Effects of climate change on peatlands in the Far North of Ontario, Canada: a synthesis. *Arctic, Antarctic, and Alpine Research* 46: 84–102.

Mitchell, E.A.D., Charman, D.J., and Warner, B.G. 2008. Testate amoebae analysis in ecological and paleoecological studies of wetlands: past, present and future. *Biodiversity and Conservation* 17: 2115–2137.

National Wetlands Working Group. 1988. Wetlands of Canada. Ecological Land Classification Series, No. 24. Sustainable Development Branch, Environment Canada, Ottawa, Ontario, and Polyscience Publications Inc., Montreal, Quebec. 452 pp.

Overpeck, J., Hughen, K., Hardy, D., Bradley, R., Case, R., Douglas, M., Finney, B., Gajewski, K., Jacoby, G., Jennings, A., Lamoureux, S., Lasca, A., MacDonald, G., Moore, J., Retelle, M., Smith, S., Wolfe, A., and Zielinski, G. 1997. Arctic environmental change of the last four centuries. *Science* 278: 1251–1256.

Packalen, M.S., Finkelstein, S.A., and McLaughlin, J.W. 2014. Carbon storage and potential methane production in the Hudson Bay Lowlands since mid-Holocene peat initiation. *Nature*

*Communications* 5: 4078.

Paterson, A.M., Betts-Piper, A., Smol, J.P., and Zeeb, B.A. 2003. Diatom and chrysophyte algal response to long-term PCB contamination from a point-source in northern Labrador, Canada. *Water, Air, Soil Pollution* 145: 377–393.

Peacock, E., Derocher, A.E., Lunn, N.J., and Obbard, M.E. 2010. Polar Bear ecology and management in Hudson Bay in the face of climate change. In A Little Less Arctic Top Predators in the World's Largest Northern Inland Sea, Hudson Bay. Edited by S.H. Ferguson, L.L. Loseto, and M.L. Mallory. Springer, Heidelberg, Germany. pp. 93–116.

Pienitz, R., and Vincent, W.F. 2000. Effect of climate change relative to ozone depletion on UV exposure in subarctic lakes. *Letters to Nature* 404: 484–488.

Ponader, K., Pienitz, R., Vincent, W., and Gajewski, K. 2002. Limnological conditions in a subarctic lake (northern Quebec, Canada) during the late Holocene: analyses based on fossil diatoms. *Journal of Paleolimnology* 27: 353–366.

Poulíèková, A., Hájková, P., Krenková, P., and Hájek, M. 2004. Distribution of diatoms and bryophytes on linear transects through spring fens. *Nova Hedwigia* 78: 411–424.

Rietkerk, M., Dekker, S.C., Wassen, M.J., Verkroost, A.W.M., and Bierkens, M.F.P. 2004. A putative mechanism for bog patterning. *The American Naturalist* 163: 699–708.

Riley, J.L. 2003. Flora of the Hudson Bay Lowland and its postglacial origins. NRC Research Press Canada.

Riley, J.L. 2011. Wetlands of the Hudson Bay Lowland: An Ontario Overview. Nature Conservancy of Canada, Toronto.

Rouse, W.R. 1991. Impacts of Hudson Bay on the terrestrial climate of the Hudson Bay Lowlands. *Arctic and Alpine Research* 23: 24–30.

Rühland, K.M., Hargan, K.E., Jeziorski, A., Paterson, A.M., Keller, W. and Smol, J.P. 2014. A multi-trophic exploratory survey of recent environmental change using lake sediments in the Hudson Bay Lowlands, Ontario, Canada. *Arctic, Antarctic and Alpine Research* 46: 139–158.

Rühland, K.M., Paterson, A.M., and Smol, J.P. 2008. Hemispheric-scale patterns of climate-related increases in planktonic diatoms from North American and European lakes. *Global Change Biology* 14: 2740–2754.

Rühland, K.M., Paterson, A.M., Keller, W., Michelutti, N. and Smol, J.P. 2013. Global warming triggers the loss of a key Arctic refugium. *Proceedings of the Royal Society Series B* 280: 20131887.

Rühland, K.M., Smol, J.P., Jasinski, J.P.P., and Warner, B.G. 2000. Response of diatoms and other siliceous indicators to the developmental history of a peatland in the Tiksi forest, Siberia, Russia. *Arctic, Antarctic, and Alpine Research* 32: 167–178.

Rydin, H., Gunnarsson, U., and Sundbery, S. 2006. The Role of Sphagnum in Peatland Development and Persistence. In Ecological Studies Vol. 188 Boreal Peatland Ecosystems. Edited by R.K. Wieder and D.H. Vitt. Springer-Verlag, Berlin. pp. 1−19.

Schindler, D.W., and Smol, J.P. 2006. Cumulative effects of climate warming and other human activities on freshwaters of Arctic and subarctic North America. *AMBIO: A Journal of the Human Environment* 35: 160–168.

Serreze, M.C., Walsh, J.E., Chaplin III, F.S., Osterkamp, T., Dyurgerov, M., Romanovsky, V., Oechel, W.C., Morison, J., Zhang, T., and Barry, G. 2000. Observational evidence of recent change in the northern high-latitude environment. *Climatic Change* 49: 159–207.

Sjörs, H. 1959. Bogs and fens in the Hudson Bay Lowlands. *Arctic* 12: 1–19.

Smol, J.P., Wolfe, A.P., Birks, H.J.B., Douglas, M.S.V., Jones, V.J., Korhola, A., Pienitz, R., Rühland, K., Sorvari, S., Antoniades, D., Brooks, S.J., Fallu, M., Hughes, M., Keatley, B.E., Laing, T.E., Michelutti, N., Nazarova, L., Nyman, M., Paterson, A.M., Perren, B., Quinlan, R., Rautio, M., Saulnier-Talbot, E., Siitonen, S., Solovieva, N., and Weckström, J. 2005. Climate-driven regime shifts in the biological communities of arctic lakes. *Proceedings of the National Academy of Science* 12: 4397–4402.

Smol, J.P. 2008. Pollution of lakes and rivers: a paleoenvironmental perspective, 2nd ed. Wiley-Blackwell, Oxford, UK.

Smol, J.P. 2010. The power of the past: using sediments to track the effects of multiple stressors on lake ecosystems. *Freshwater Biology* 55: 43–59.

Smol, J.P., and Stoermer, E.F. 2010. The Diatoms: Applications for the Environmental and Earth Sciences. Cambridge University Press, New York.

Stewart, D.B., and Barber, D.G. 2010. The ocean–sea–ice– atmosphere system of the Hudson Bay complex. In A little less Arctic: top predators in the world's largest northern inland sea, Hudson Bay. Edited by S.H. Ferguson, L.L. Loseto, and M.L. Mallory. Springer, Heidelberg, Germany. pp. 1–38.

Stocker, T., Qin, D., Platner, G. et al. (eds) 2013. Climate Change 2013: the physical science basis. Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.

Tam, A., Gough, W.A., Kowal, S., and Xie, C. 2014. The fate of Hudson Bay Lowlands palsas in a changing climate. *Arctic, Antarctic and Alpine Research* 46(1): 114–120.

Tarnocai, C., and Stolbovoy, V. 2006. Northern Peatlands: their characteristics, development and sensitivity to climate change. In Peatlands: Evolution and Records of Environmental and Climate Changes. Edited by I.P. Martini, A. Martinez Cortizas, and W. Chesworth. Elsevier B.V., Amsterdam. pp. 17–51.

Tarnocai, C. 2006. The effect of climate change on carbon in Canadian peatlands. *Global Planetary Change* 53: 222–232.

Turetsky, M., Wieder, K., Vitt, D.H., Evans, R.J., and Scott, K.D. 2007. Current disturbance and the diminishing peatland carbon sink. *Global Change Biology* 13: 1922–1934.

Vardy, S.R., Warner, B.G., Turunen, J. and Aravena, R. 2000. Carbon accumulation in permafrost peatlands in the Northwest Territories and Nunavut, Canada. *The Holocene* 10: 273–280.

Vincent, W.F., Laurion, I., Pienitz, R., and Walter Anthony, K.M. 2013. Climate impacts on Arctic lake ecosystems. In Climatic Change and Global Warming of Inland Waters: Impacts and Mitigation for Ecosystems and Societies. Edited by C.R. Goldman, M. Kumagai, and R.D. Robarts. John Wiley & Sons, New York, pp. 27–42.

Vitt, D.H. 2006. Functional Characteristics and Indicators of Boreal Peatlands. In Ecological Studies Vol. 188 Boreal Peatland Ecosystems. Edited by R.K. Wieder, and D.H. Vitt. Springer-Verlag, Berlin. pp. 9–24.

Webber, P.J., Richardson, J.W., and Andrews, J.T. 1970. Post-glacial uplift and substrate age at Cape Henrietta Maria, southeastern Hudson Bay, Canada. *Canadian Journal of Earth Sciences* 7: 317–325.

Williamson, C.E., Saros, J.E., Vincent, W.F., and Smol, J.P. 2009. Lakes and reservoirs as sentinels, integrators, and regulators of climate change. *Limnology and Oceanography* 54: 2273–2282.

Winder, M., Reuter, J.E., and Schladow, S.G. 2009. Lake warming favours small-sized planktonic diatom species. *Proceedings of the Royal Society Series B* 276: 427–435.

Winder, M., and Sommer, U. 2012. Phytoplankton response to a changing climate. *Hydrobiologia* 698: 5–16.

Wolin, J.A., and Stone, J.R. 2010. Diatoms as indicators of water-level change in freshwater lakes. In The Diatoms: Applications for the Environmental and Earth Sciences. Edited by J.P. Smol and E.F. Stoermer. Cambridge University Press, New York. pp. 174–185.

Yu, Z., Loisel, J., Brosseau, D.P., Beilman, D.W., and Hunt, S.J. 2010. Global peatland dynamics since the Last Glacial Maximum. *Geophysical Research Letters* 37: L13402.

Yu, Z., Loisel, J., Turetsky, M.R., Cai, S., Zhao, Y., Frolking, S., MacDonald, G.M., and Bubier, J.L. 2013. Evidence for elevated emissions from high-latitude wetlands contributing to high atmospheric $CH_4$ concentration in the early Holocene. *Global Biogeochemical Cycles* 27: 131–140.

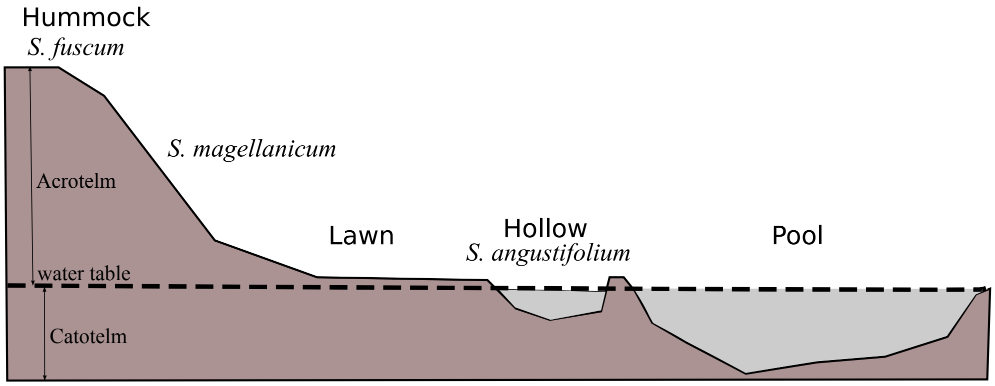

Figure 1-1 Peatland microforms, their position relative to the actotelm-catotelm boundary (with the water table delineated by the dashed line) and commonly associated *Sphagnum* species with each microform.

# Chapter 2

## The influence of water table depth and pH on the spatial distribution of diatom species in peatlands of the Boreal Shield and Hudson Plains, Canada

### 2.1 Abstract

Diatoms collected from 113 surface peat samples from the Boreal Shield and Hudson Plains show taxonomic distributions that are associated with macro-vegetation type, pH, and position relative to the water table, the main environmental variables measured in this study. The overall goal of our research was to determine the ecological distribution and response of diatoms to microhabitat conditions, and to assess the potential for diatoms to be applied as indicators of long-term environmental change in northern peatlands. Our results indicate that diatom assemblage composition was determined by both the broader peatland type (i.e., bog, rich and poor fens) and microhabitats within peatland formations (e.g., hummock, hollow). The diatom assemblages were primarily influenced by pH with the sites divided at a critical pH of 5.5, and secondarily by the depth of the water table. Acidic bog hollow and hummock microhabitats were species-poor and dominated almost exclusively by *Eunotia paludosa* A.Grunow and (or) *Eunotia mucophila* (H.Lange-Bertalot, M.Nörpel-Schempp & E.Alles) H.Lange-Bertalot. These acidophilic and aerophilic diatom species were associated with the narrow pH optima of the dominant *Sphagnum* species (e.g., *Sphagnum fuscum* (Schimp.) Klinggr, *Sphagnum angustifolium* (C.E.O.Jensen ex Russow) C.E.O.Jensen found in these bog habitats. Rich and poor fen samples, which were less acidic, supported a more diverse diatom assemblage (>30 species) with greater variability in both diatom and bryophyte pH tolerances. The diatom assemblages recorded in the bogs and fens of our study are similar to those found in peatlands around the world, demonstrating that diatom species are very specialized to exist in these often harsh, semi-aquatic environments. Diatoms from peatlands have great potential as biomonitors of environmental change in these important ecosystems.

*Keywords:* diatoms, peatlands, pH and moisture gradient, microhabitat, bryophytes

## 2.2 Introduction

With climate change, studies of northern peatlands are now more important than ever owing to the vast quantities of carbon stored within these regions and their future role as net carbon sinks (Roulet 2000; Waddington et al. 2009; Dunn and Freeman 2011). Therefore, attention needs to be directed towards an improved understanding of past peatland successional changes and responses to climate, to more accurately forecast future changes within these sensitive environments. Currently, only a few biological proxies (e.g., macrofossils, testate amoebae, pollen, and humification) are used widely to study historical moisture changes and impacts within northern peatlands, and the full potential archive of peatland biological proxies has not been fully exploited. Diatoms (Bacillariophyceae) are unicellular, siliceous algae that have been used extensively in lake and wetland studies as environmental indicators (Smol and Stoermer 2010). However, diatoms have rarely been used to study past peatland responses to environmental change, despite their presence in peatland systems and their prevalence across a wide range of aquatic habitats, from open water to non-submerged mosses that experience periodic drying (typical of wetland environments) (Gaiser and Rühland 2010; Johansen 2010). Spatial studies exploring modern-day associations between diatoms and differing peatland types are required to interpret long-term peatland changes from diatom stratigraphies.

In the early to mid- 20th century, several taxonomic studies examined diatoms found in peatlands, including early work by Hustedt (1927-1966), Krasske (1932-1936) and Foged (1951), and in early paleoecological studies by Sears and Couch (1932) and Patrick (1954). Later, Kingston (1982) identified characteristic peatland diatom assemblages that were dependent on macro-vegetation type, trophic status and position relative to the water table, concluding that diatoms are sensitive to microhabitat conditions, and they can be utilized beneficially to analyze environmental gradients in peatlands. Recently, diatom studies have shown that moss-inhabiting diatoms are sensitive to varying moisture conditions and pH (Van de Vijver and Beyens 1997; Poulíčková et al. 2004; Van de Vijver et al. 2008; Chen et al. 2012).

Some studies have also emphasized that there may be specific relationships between diatom assemblages and moss species composition, independent of other measured factors (e.g., moisture) (Kingston 1982; Poulíčková et al. 2004; Buczkó 2006; Hájková et al. 2011).

Diatoms have been shown to respond independently to changes in bryophyte assemblages. For example, shifts in diatom assemblages have been found to occur in peat records that are dominated by one moss species (Brown et al. 1994). As well, diatom assemblage shifts have been shown to substantially pre-date shifts in the moss communities, suggesting that diatoms are responding more sensitively to changes in the chemical environment than directly to changes in bryophyte composition (Rühland et al. 2000; Poulíčková et al. 2004). From these few paleoecological studies using diatoms, there appears to be considerable potential for the analysis of the commonly preserved remains of these algae to increase our understanding of the present and historical dynamics of northern environments, particularly when used in tandem with other biotic indicators. In the Boreal Shield and Hudson Plains of Canada, there have been limited modern floristic and faunistic surveys across the varying peatland environments, and those that exist are largely descriptive in nature (e.g., Sjörs 1959; Riley 2011). To our knowledge, there are no current studies on the diatoms living in the peatlands of northern Ontario, which include North America’s largest continuous peatland, the Hudson Bay Lowlands.

Modern calibration or training sets explore the distribution of diatom assemblages from surface (i.e. modern) peat samples across a gradient of peat types and provide analogs that can be used to infer past peat environments from downcore assemblages. Diatom-based calibration models are commonly applied to lake records to infer past environmental changes (Smol and Stoermer 2010), but have rarely been applied to peatland cores. In the few cases where inference models have been applied to diatom peatland records, these models were based on lake calibration sets (Campbell et al. 1997; Kienel et al. 1999; Brugam and Swain 2000), as peatland diatom calibration sets do not yet exist. Exploring modern diatom-bryophyte relationships, together with diatom responses across chemical and physical gradients among peat types, is an important step to gaining a more comprehensive knowledge of peatland developmental history, and possible responses to a changing climate.

The approach for collecting samples for a peatland diatom calibration set differs from the approach for a lake calibration set in a number of ways. Unlike lake sediment samples that represent an integration of all aquatic habitats within a lake (because of sediment focusing toward the center of the depositional basin), numerous samples are typically required to capture the variability in microtopography that exists within a given peatland. In peat calibration sets using testate amoebae, the full range of surface moisture variability is best represented by selecting peatlands that span the gradient from ombrotrophic to minerotrophic, and by sampling the microhabitats within each peatland (e.g., hummocks, hollows, pools) (Booth 2002). This sampling approach should also work best for capturing the full range of diatom microhabitats within peatlands; our methods have been adapted from testate amoebae calibration sets.

To gain insights into the ecological distribution of diatom taxa across the Boreal Shield of northern Ontario and into the Ontario and Manitoba Hudson Plains (a ~1,200 km latitudinal transect), 113 surface peat samples were collected along wide vegetation (e.g., rich fen, poor fen, bog, and associated bryophytes), chemical (e.g., pH range from ~3 to 8), and moisture gradients. Key insights into the relative importance of taxon-specific relationships to either the chemical (pH) or the physical environment (e.g., moisture, and/or specific vegetation types, *Sphagnum* spp. - *sensu* Kingston 1982) will be central to this study. This study aims to assess the usefulness of diatoms as an environmental proxy for tracking climatic and hydroseral changes in peatlands in the Ontario Boreal Shield and Hudson Plains, Canada. Specifically, the study addresses the following questions: (1) Are there clear associations between diatom assemblages and peatland types? (2) What are the relationships between diatom associations and microhabitat differences observed in the peatlands? (3) Do these associations differ across ecozones (e.g., do fens in subarctic and Boreal Shield regions contain different assemblages)? If so, what are the main environmental variables that may explain these differences? (4) Is there a relationship between diatom species richness and differences in peat microhabitats (e.g., hummocks, hollows)? (5) Is there potential to develop calibration functions based on diatom assemblages to estimate past environmental conditions in peatlands, particularly hydrology?

## 2.3 Materials and Methods

### 2.3.1 Site Description

Surface peat samples were collected across a broad latitudinal gradient from northern Ontario near Thunder Bay in the Ontario Boreal Shield, and crossing the Hudson Bay Lowlands from James Bay in Ontario into northern Manitoba near Churchill (48°50’ to 58°43’ N and 83°55’ to 93°50’ W; Fig. 1). The study area spans two main ecozones within Canada known as the Boreal Shield and Hudson Plains (Ecological Stratification Working Group 1996; Fig. 1). The study sites cross a number of environmental gradients both within and across these ecozones including climate, permafrost, vegetation and bedrock (Holmquist et al. 2014), and are discussed below.

The study region transitions from a continental to a marine climate, as well as from a temperate to a subarctic climate from the Boreal Shield to the Hudson Plains. The climate of the Hudson Plains is characterized by a humid, microthermal Arctic climate with relatively short, mild summers and long, cold winters (Martini 2006). Across the Hudson Plains, from south (southern James Bay region) to north (Churchill region), mean annual temperatures are -1°C and -5°C respectively, with mean daily winter minima reaching -27°C in the south and -30°C in the north (Martini 2006; McKenney et al. 2010; Holmquist et al. 2014). The climate of the Hudson Plains is influenced by both Arctic air masses that move south, and sea and fluvial currents that move counterclockwise in the Hudson Bay resulting in a cooling effect along the western coasts of Hudson Bay and James Bay (Martini 2006). In Polar Bear Provincial Park, located on the western shores of Hudson Bay in Ontario, mean annual precipitation (1970-2000) is 519 mm and is predicted to increase to 542 mm over the next three decades (McKenney et al. 2010). West of the Hudson Plains, in the northern limits of the Boreal Shield ecozone within Ontario, temperatures are similar to those of the southern James Bay region with a mean annual temperature (1970-2000) of -1.7°C, annual average temperature maxima of 23°C (July) and minima of -29°C (January); mean annual precipitation however, is higher at 630 mm (McKenney et al. 2010). Compared with the rest of our study area, Thunder Bay (Ontario), where the most southern peatlands were sampled, has warmer and longer summers, a higher mean annual temperature (0.7°C) and a greater mean annual precipitation (739 mm) (McKenney et al. 2010).

### Boreal Shield Ecozone

The sampled peatlands within this region have been designated JBL1, JBL2, JBL3, and JBL9 (Holmquist et al. 2014) and are situated on Precambrian Shield, composed primarily of granitic bedrock. Surficial deposits include extensive areas of bare rock with thin veneers of Laurentide till to variably thick deposits of till, glaciomarine and transgressive marine sediments and glaciolacustrine sediments from glacial lakes Agassiz and Ojibway (Fulton 1995). Across this ecozone (part of the Canadian Shield physiographic region), permafrost is absent in the south and is sporadic at its northern limit. North-central Ontario (JBL1, JBL2, JBL3) is characterized by low ridges of clay and sand, and extensive peatlands in low-lying areas. Within this region of Ontario, forest cover is sparse (~ 21.4%) and more than 30% of the area is covered by wetlands (Crins et al. 2009). The depth of peat accumulation within these peatlands ranges between ~285 to 421 cm with estimated basal peat ages between ~6242 and 7835 (JBL3) cal. yr. BP (Holmquist et al. 2014). The most southern peatland sampled in the Boreal Shield (JBL9), located just north of Lake Superior, has climatic differences between immediately adjacent areas of similar latitude, exhibiting a stronger boreal climate with lower mean annual temperatures (-1.7 to 2.1°C) (Crins et al. 2009). This region of the Ontario Boreal Shield is distinct from more northern Boreal Shield sites (JBL1, JBL2, JBL3) due to temperature and precipitation gradients and associated changes in estimated net primary productivity (Crins et al. 2009). Further details on the JBL sites and their environmental setting are available from Holmquist et al. (2014).

### Hudson Plains Ecozone

Peatlands were sampled in four regions of the Hudson Plains Ecozone (also known as the Hudson Bay Lowlands physiogeographic region, HBL): the Attawapiskat River watershed (MVRT, MVT5, MVMS), the Hawley Lake area (HLM1-18), the Severn River watershed (JBL4), and Churchill, Manitoba (CH1-4) (Table 1). The Hudson Plains contains steep transitions across sporadic, discontinuous and a narrow band of continuous permafrost close to the Hudson Bay coast and into Manitoba (Brown et al.

2001). The area just inland of Hudson Bay (MVRT, MVT5, MVMS, HLM peatlands) is characterized by sporadic and discontinuous permafrost linked to peat plateaus in the north, and patterned bogs and fens (without permafrost) in the south (Tam et al. 2014). Basal dates from both a 256 cm long fen core and a 303 cm long bog core collected from the Attawapiskat watershed estimate that peatland accumulation began ~6700 years ago (Bunbury et al. 2012; O'Reilly et al. 2014). The lowlands located west of James Bay (JBL4 peatlands) are characteristic of open patterned bogs and ribbed and netted fens, underlain by sporadic permafrost. Wooded peat plateaus and palsa fields occur northward, with evident collapse features and initiation phases (Riley 2011). The peat in the JBL4 core was ~175 cm deep and had an estimated basal age of ~5570 cal. yr BP (Holmquist et al. 2014). At the most northern site in the Manitoba region of the Hudson Plains (CH1-4 peatlands), broad areas of polygonal peat plateaus, immature fens, and shore fen and inter-ridge fen cover the landscape (Riley 2011). Initial stages of peat accumulation and palsa development are typical of immature fens, with deeper peatlands maturing to peat plateaus (Riley 2011). The northern extent of the Hudson Plains contains continuous permafrost and the northward shift towards greater fen than bog peat reflects the cooler climate, which decelerates peat growth (Riley 2011). Although the basal ages for CH1-4 peatlands sampled in this study are not known, as they have not been $^{14}$C dated, a study by Dredge and Mott (2003) estimated the peatlands in this region to be slightly younger than northern Ontario peatlands with basal ages estimated between 3120 and 6280 yrs. BP. Along the Hudson Bay coast, fens also rim the coastal freshwater marshes and cover the area slightly inland, which drains many of the major rivers of the Hudson Plains (Martini 2006). Bedrock of the Hudson Plains consists predominantly of sedimentary carbonate rock (dolostone and limestone), with some sandstone, shale, and siltstone, and is of Middle to Lower Silurian age (Ontario Geological Survey 1991). Much of the HBL was flooded by the post-glacial Tyrrell Sea marine incursion (Peltier and Andrews 1983; Dredge and Cowan 1989), which laid down silty clays of lacustrine or marine origin, and these deposits underlie peat sections of 2-3 m thickness (Fulton 1995).

### 2.3.2 Sample Collection

From 2008 to 2011, 113 peat samples were collected from eight locations across the two large ecozones (Table 1, Fig. 1). In 2008, an extensive peatland survey (Holmquist et al. 2014) yielded a total of 64 surface peat samples from Ontario's Boreal Shield (samples within areas labeled JBL1, JBL2, JBL3, and JBL9 in Fig. 1), Ontario's northwestern Hudson Plains (JBL4 in Fig. 1) and the most northerly point of the Hudson Plains located near Churchill, Manitoba (CH1-4 in Fig. 1). These samples were collected using a steel knife, sealed in plastic sample bags and stored in a cooler until they were transferred to a laboratory refrigerator. Water table depth was measured with a meter stick several minutes after removing the surface sample to allow recharge. For JBL2 and JBL7, pH was measured in the field using a handheld Fisher Scientific accumet® pH and conductivity meter, calibrated at pH 4.0 and 7.0. For samples near Churchill, pH was measured in the field using an Ecotestr pH2. The dominant vegetation collected with the sample was identified to the genus or species level. Sampling was organized so as to collect material from the range of water depths and peatland types encountered at each site.

In 2010, a total of 31 surface peat samples were collected from the Hudson Plains ecozone in the area surrounding the Victor Diamond Mine, within the Attawapiskat River watershed (samples labeled MVRT, MVT5, MVMS; Table 1, Fig. 1). The sampling approach was designed to maximize our ability to capture the variability in the community across multiple scales in a given peatland. For example, when visiting these peatlands, sample points were organized along transects. At each point along the transect, samples were collected to capture variability across wetland mesoform types; however, at some sample points, only one mesoform type was present so only one sample was taken. At other sample points, multiple mesoform types were present in immediate proximity, so multiple samples were taken (e.g., MVRT-02 hummock, hollow and pool habitats were present, and so individuals samples were taken from each of these). Sample points where only one sample was taken were relatively uniform in terms of mesoform type on the scale of 1-3 m.

In 2011, 17 surface peat samples were collected from the Hawley Lake area within the Sutton River watershed (samples labeled HLM1-18; Table 1, Fig. 1). For both of these field sampling seasons (2010, 2011), a 10x10x10 cm of surface peat (i.e., peat sampling depth was 10 cm) was removed using a steel knife, placed in plastic Ziploc® bags, and stored in coolers until they were transported to the laboratory cold room where they were kept at <10°C until the samples were processed. If the water table was lower than 10 cm (the depth of the peat collection), the hole was deepened to allow measurement of the depth to the water table (DWT) and pH (using Hanna handheld pH meters that were calibrated with buffers at a pH of 4.0 and 7.0). Negative values were assigned to water table depths that were above the vegetation surface (i.e., standing water was present and the collected sample was submerged). The dominant vegetation type at each microsite was determined by placing a 1 $m^2$ quadrat centered around the sample location and ranking the dominance of the vegetation (to the genus level) within this quadrat on a scale from 1 to 5.

### 2.3.3 Diatom sample preparation

At the Paleoecological Environmental Assessment and Research Laboratory (PEARL), Queen's University, approximately 0.3 g of peat was digested in 10 mL of concentrated nitric acid ($HNO_3$) using a microwave digestion technique that is well suited for digesting highly organic material such as peat samples (Parr et al. 2004). Digested samples were transferred from the Teflon tubes to glass scintillation vials. The resulting slurries were allowed to settle for 24 hours, the supernatant was removed, and the sample was rinsed by adding deionized water. This procedure was repeated until the diatom samples contained no acid. Slurries were concentrated by aspirating most of the water from the glass vials prior to making diatom strews. Concentrated strews were dried on cover slips and mounted onto microscope slides using the mounting medium Naphrax®. Diatoms were identified to the lowest taxonomic level possible (often variety) using an assortment of taxonomic references, including, Krammer and Lange-Bertalot (1986-1991); Camburn and Charles (2000); Kulikovskiy et al. (2010); Hamilton and Siver (2010); and Antoniades et al. (2008). A minimum of 400 diatom valves were counted for each sample, unless diatoms were scarce and species richness was low (<10 species), in which case a minimum of 200 valves were counted. Samples that yielded counts fewer than 200 diatom valves were not included in the data analyses. Photomicrographs of the most common diatom taxa, including diatom species identified as indicator taxa for each cluster, were constructed to increase taxonomic clarity and comparisons among researchers.

### 2.3.4 Data analysis

All statistical analyses were completed using CANOCO version 4.5 (ter Braak and Šmilauer 2002) and R version 2.11.1 (R Development Core Team 2010). The following R packages were used: (1) vegan (Oksanen et al. 2010) for transformations, CCA and associated permutation tests, (2) ade4 (Chessel et al. 2004; Dray et al. 2007) and mvpart (De'ath 2002) for a multivariate regression tree, and (3) labdsv to identify indicator species (Dufrêne and Legendre 1997; Roberts 2010).

To eliminate rare taxa, a cutoff criterion of at least 1% relative abundance in at least one site was applied to the diatom data. To explore the distribution of diatoms among peatland habitats and to help visualize the differences and similarities amongst sites, we examined several methods of multivariate analyses, including a multivariate regression tree approach (MRT), indicator species analysis, and canonical correspondence analysis (CCA).

Prior to clustering and indicator species analysis, diatom count data were converted to percent relative abundances and were Hellinger transformed to minimize the effects of the large number of zeroes that are common to species relative abundance data (Legendre and Gallagher 2001) and to give low weight to rare species. A MRT approach (De'ath 2002) was applied to allow for the inclusion of the two measured variables (DWT and pH). Strong environmental interactions between the diatom assemblages and each of the two variables were therefore modeled. The MRT technique employs Euclidean distance to summarize between-site differences in assemblage composition (De'ath 2002). The method identifies splits along measured environmental gradients that explain the greatest amount of variation in the species assemblages, and minimizes the sum of squared Euclidean distance (SSD) within the resultant groups. The indicator value method (Ind-Val; Dufrêne and Legendre 1997) was then used to identify indicator diatom taxa within each of these groups of sites. Ind-Val is a method used to identify indicator species and species assemblages that characterize groups of samples (Dufrêne and Legendre 1997). The indicator value of a species in a particular group of sites is the product of both specificity, which estimates to what extent a species is found only in one specific group, and fidelity, which measures what proportion of the sites of that specific group the species of interest is found in. The indicator value of a species is then the largest value found for that species among all groups identified in the study (Legendre and Birks 2012). A p-value with a cut-off criterion of $p \leq 0.05$ was used to select significant indicator diatom taxa and the Ind-Val indicator values are reported for each species.

CCA using the program CANOCO, version 4.5 (ter Braak and Šmilauer 2002) was used to examine DWT, pH, and vegetation type in relation to the diatom data (including those diatoms not identified as significant indicator taxa in the Ind-Val analysis). Vegetation data were treated as nominal variables and transformed into an absence-presence matrix for each site and plotted passively (i.e. were treated as 'supplementary data') in the ordination analysis. Diatom percent relative abundance data were square-root transformed prior to applying this unimodal ordination method. For the JBL and Churchill samples, only one vegetation species was sampled (see Supplementary Table S1), whereas for all other samples from the Hudson Plains, dominant species within the 1 $m^2$ quadrat (ranked between 3 and 4) were given a '1' in the matrix. Species scores, site constraints (linear combinations of the constraining variables), and supplementary vegetation data from the CCA analyses were plotted in the ordination with the sites and species identified based on the MRT groups.

## 2.4 Results

The study sites span broad gradients in pH (3.3 to 8.5) and DWT (-37 cm (water table above the vegetation surface) to 59 cm) (Supplementary Table S1). Across all peatland samples (including those excluded from diatom analyses), the mean pH value and DWT were 5.1 and 13 cm, respectively (Supplementary Table S1).

A total of 208 diatom taxa were identified from 32 genera. Photomicrographs of 20 common *Eunotia* taxa, and diatom species from 18 other genera are depicted in Figures 2 and 3 (Plany authorities for the common diatom species in this study are presented in Table 2). Diatoms were present in all but 20 surface peat samples where they were very rare or occurred in low abundances, although there was little evidence of dissolution in the few valves encountered (Supplementary Table S1). After eliminating these 20 samples, 93 surface peat samples were amenable for further data analyses. Approximately half (~10) of the surface peat samples that were removed from further data analysis were composed primarily of club lichen, specifically *Cladonia* P.Browne spp., and the other half removed were composed of the ribbed bog moss *Aulacomnium* Schwägr. Of the 93 peat samples with diatoms present, acidophilous and epiphytic taxa, mainly from the genera *Eunotia* (25 taxa) and *Pinnularia* (11 species), were best represented across peat samples, although not present in every sample. Cosmopolitan aerophilic diatom taxa (e.g., *Luticola mutica, Hantzschia amphioxys,* and *Pinnularia borealis*) were present across many peat samples, but were never the dominant species.

Based on cross validation within one SE, the best predictive model relating diatom assemblages to peatland habitats identified by the MRT analysis (De'ath 2002) was a model with five clusters (four splits) (Fig. 4a). This model therefore captures five distinct peatland habitats that were associated with distinct diatom assemblages. The MRT shows that pH is a more important variable than DWT at explaining diatom distributions across these peatland habitats, with a pH value of 5.5 identified as the critical threshold value splitting the classes of peatlands. This initial split in the MRT thus separates the diatom assemblages that occurred in highly acidic and bog-like sites from those found in the more pH neutral fen-like sites (Fig. 4b). Clusters 1 to 5 follow a gradient of pH, with Cluster 1 and 2 containing the most acidic sites and Clusters 3 to 5 containing slightly alkaline to circum-neutral sites respectively. Following this first split, all preceding splits are defined based on DWT. There is an overlap in the DWT of Clusters 3 to 5 with Clusters 1 and 2, indicating that DWT was less distinct between peatland habitats (Fig. 4c). However, Cluster 1 contained the driest microhabitats, and Cluster 5 the wettest microhabitats. The mean pH of Cluster 1 through 5 was 4.0, 4.2, 7.0, 6.8, and 6.1, and DWT was 34.2, 4.5, 22, 5.1, and -5.6 cm, respectively (Supplementary Table S1). Sites are not evenly distributed throughout the clusters, with approximately twice as many bog-like samples (n=61) in Clusters 1 and 2 than fen-like samples (n=32) in Clusters 3 to 5.

CCA axis 1 separated sites and species along the pH gradient and explained 65% of the diatom variation (Fig. 5a-c). Cluster 4 sites are most strongly linked to a circum-neutral pH (and moderate surface wetness), composed largely of *Aulacomnium* and *Drepanocladus* (Müll. Hal.) G.Roth vegetation, and represented by more circum-neutral epiphytic diatom taxa (Fig. 5a-c). CCA axis 2 separated sites and species along the DWT gradient, and explains 21% of the variation in diatom assemblage composition. This gradient distinguishes the driest, acidic sites of Cluster 1 from Cluster 2 and the wetter sites of Cluster 5 from Cluster 4 sites (Fig. 5a). *Cladina* spp. and *Sphagnum fuscum* (Schimp.) Klinggr. were the dominant vegetation types sampled for the Cluster 1 sites and *Sphagnum angustifolium* (C.E.O.Jensen ex Russow) and *Sphagnum magellanicum* Brid. were the main vegetation types sampled in Cluster 2 sites. Although Cluster 3 sites and species scores have the greatest variability in pH and DTW, the largest overlap with sites in this group occurs with the hollow sites of Cluster 2 and the hummock sites of Cluster 1. It is difficult to identify Cluster 3 sites as belonging to one particular peatland type, and it is possible they represent an intermediate microhabitat between bog hollows and hummocks. The shrub *Chamaedaphne calyculata* (L.) Moench plots between the bog hollow and hummock sites in ordination space. Cluster 5 sites are distinct from other clusters and form a tight grouping in the bottom left quadrant of the CCA (Fig. 5a) and are associated with slightly acidic pH and higher DWT, and are mainly composed of sedges (Cyperaceae).

The number of significant indicator species ($p \leq 0.05$) increases substantially from Cluster 1 to Cluster 5 (Table 2). Bog-hummock sites of Cluster 1 (n=24) were dominated almost exclusively by *Eunotia paludosa* (Fig. 2), and thus this diatom was the sole indicator species for Cluster 1. However, aerophilic taxa (e.g., *P. borealis, L. mutica, H. amphioxys*; Fig. 3) plot in the upper right quadrant of the CCA, closely tied to DWT or the low moisture levels associated with sites grouped in Cluster 1 (Fig. 5c). The bog-hollow Cluster 2 sites (n=37) were represented by two significant indicator taxa: acidophilous and aerophilic *Eunotia mucophila* (van Dam et al. 1994) followed by marginally significant indicator *E. paludosa* var. *trinacria* (p=0.05, Table 2, Fig. 2). The more acid-neutral sites in Clusters 3 to 5 had a greater diversity and abundance of diatoms that commonly co-occur across all sites within a cluster (Table 2). Cluster 3 (n=4) contains five significant indicator species that had a wide spread in the CCA ordination space including: benthic fragilarioid taxa, *Aulacoseira subarctica*, *Eunotia exigua*, and *Gomphonema* cf. *bohemicum,* (Table 2; Fig. 2 and 3). Significant indicator species in Cluster 4 fen sites (n=19) are largely epiphytic species that prefer acid-neutral conditions from the genera *Cymbopleura*, *Encyonema, Encyonopsis*, *Gomphonema*, and *Nitzschia* (van Dam et al. 1994; Fig. 3). However, many indicator taxa in this cluster have a wide range of tolerance for pH. Cluster 5 wet fen sites (n=9) were mainly characterized by acidophilic *Eunotia* and *Tabellaria* indicator taxa (Table 2, Fig. 5c). Diatom species that plotted together in the CCA ordination space tended to be the same species the MRT identified as belonging to a specific cluster of the tree (Fig. 5c). The ordination visually demonstrates which diatom species, both indicator and non-indicator species, are more closely associated with a particular habitat and vegetation type.

## 2.5 Discussion

Diatoms are sensitive to the differing environmental conditions found in broad peatland types (bog, rich and poor fens) and microhabitats (hummocks, hollows) at both the Boreal Shield and Hudson Plains ecozone sites. This consistent environmental sensitivity within both the Boreal Shield and Hudson Plains ecozones demonstrates that diatoms have potential to be powerful paleoecological proxies of local peatland type and hydrological conditions. The five distinct peatland habitat types identified by MRT distinguish the diatom assemblages found in true bog sites from more fen-like sites, which is primarily based on pH differences between habitats. Subsequent habitat types are distinguished based on DWT. Both the MRT and CCA analyses identify pH as a more important variable than moisture in explaining the variation among diatom assemblages and distinguishing the peatland sites. The extreme environment of the dry, acidic bog sites contain depauperate diatom assemblages that are dominated by one or two species of *Eunotia*, whereas the wetter, less acidic fen sites support a relatively rich variety of diatom taxa.

The reported importance of pH versus moisture in structuring bryophyte and microorganism assemblages in peatlands varies across the literature. A critical pH value of 5.5 has been described previously for explaining the separation of brown mosses (higher pH) and *Sphagnum* spp. (lower pH) abundances (Gignac and Vitt 1990), as well as for the separation of acidophilous taxa within diatom (Battarbee et al. 2010) and chrysophyte (Smol 1995) lake calibration sets. Generally, many *Sphagnum* species have optima within a small pH range, but have broader tolerances to water table depth (Booth 2002), whereas brown mosses have a relatively wide range in pH and water table depth. In contrast to testate amoebae, a common microorganism found in peat environments that has been shown to be sensitive to moisture (e.g., Booth 2002; Charman et al. 2007), diatoms respond sensitively to both physical (e.g. vegetation type, moisture) and chemical (e.g. pH and nutrients) environmental factors. It is thus not surprising that there have been variable findings regarding diatom distributions across peat environments, with reports of moisture being the primary gradient influencing diatom assemblages in some studies (Chen et al. 2012) and water chemistry, especially pH, being important in other studies (Poulíčková et al. 2004; Fránková et al. 2009). In our study, although somewhat limited in terms of measured variables, diatoms appear to respond primarily to pH and secondarily to moisture, regardless of the dominant bryophyte type. It is important to note that DWT measurements are more likely to vary through the year and between years depending on changes in hydrology (e.g., precipitation, runoff, etc.), and thus pH is probably a more consistent and reliable measurement to base inferences. Nevertheless, it is likely that both are important as some microhabitats (e.g., bog sites) contain diatom species that are able to withstand both a dry and a very acidic environment, indicating that they are both aerophilic and acidophilous.

### 2.5.1 Habitats with depauperate diatom flora

The dry bog hummock environments across our study region contained depauperate diatom flora that were typically dominated by one or two *Eunotia* species (*E. paludosa* and (or) *E. mucophila*). These diatom species are likely tolerant of both the extreme dry and acidic conditions of this peat habitat. The lack of species-rich assemblages, and in some cases the complete absence of diatoms from certain peat deposits, have been noted in other studies and is likely due to a variety of reasons including harsh (i.e., dry) environments unsuitable for diatom survival, low availability of silica that limits growth, and (or) taphonomic processes that may lead to the dissolution of siliceous diatom valves. In environments with these conditions, diatoms may be a difficult proxy to examine within peat deposits, and their absence during certain portions of peat cores do pose problems for paleoecological reconstructions. However, this study demonstrates that diatoms are highly sensitive to the main chemical gradients across peat habitats and, when present, could be a valuable supplementary biological proxy for inferring environmental changes in peatlands.

Of the 20 samples in which diatoms were absent or occurred in very low abundances (Supplementary Table S1) in this study, 10 were composed primarily of club lichen, specifically *Cladonia* spp. In the Hudson Plains, *Cladonia* is often indicative of the extensive permafrost peatlands called peat plateaus and palsas where the hummocks typically freeze (Riley 2011). The freezing of hummocks draws down water, minimizing surface water availability and resulting in very dry and possibly silica-depleted environments. The remaining 10 peat samples with insufficient diatoms were collected from fens in the northern-most part of the study region near Churchill (Manitoba) and one sample from a rich fen near Hawley Lake (Ontario). Interestingly, these sites would not be considered environmentally harsh (pH and moisture) for the growth of diatoms as they were circum-neutral to slightly alkaline. Unlike the *Cladonia*-dominated bog samples, they did not experience extreme dry conditions as the water tables were higher. Given that the physical and chemical environments from these particular samples should be suitable for diatoms to occur, it is not clear why diatoms are sparse or absent within these samples. It is possible that diatom valves did not preserve at these sites because dissolution and solubility of silicate minerals (including diatom valves) is greatly enhanced under environments that are anoxic and highly organic with a circum-neutral pH (Bennett et al. 1991), conditions that may occur seasonally within these fen peat habitats. However, there was no evidence of etched valves, which may occur with silica dissolution.

### 2.5.2 Bog-Hummock Microhabitats

The driest (mean DWT=34 cm) and most acidic (mean pH =4.0) peatland habitats that contained diatoms (i.e., Cluster 1, n=24) were dominated by *Sphagnum,* particularly *S. fuscum*. This species is commonly found in dense hummocks in boreal regions (Bauer et al. 2007). All of our bog hummock microhabitat samples contained depauperate diatom floras that were dominated by one particular species: *Eunotia paludosa*. Diatom communities associated with the specific bryophyte *S. fuscum* have not been studied previously, but *E. paludosa* has been documented to be associated with other *Sphagnum* species such as *S. fibriatum* in Hungary (Buczkó 2006) and *S. papillosum* in the Czech Republic (Poulíčková et al. 2004). Although this association between *Sphagnum* and *E. paludosa* has been reported in the literature, it is still unclear whether this diatom species is truly “bryophytic/sphagnophilous”, or has a preference for the acidic and dry habitats that are closely linked to *Sphagnum* hummocks (Kingston 1982; De Vries 1984; Van de Vijver and Beyens 1997; Poulíčková et al. 2004; Novakova and Poulíčková 2004; Buczkó 2006). De Vries (1984) noted that, although *E. paludosa* was dominant in the ombrotrophic habitat of emerged (i.e. dry) peat moss (mean pH value was 3.1), it was also present (but not dominant) in *Sphagnum* zones occurring above the water table of fen lakes, irrespective of the floral composition of their aquatic habitats. This suggests that the species may be more closely linked to the dry and acidic habitat provided by *Sphagnum* mosses.

Aside from *E. paludosa* and *E. paludosa* var. *trinacria*, we were also able to distinguish a third form of *E. paludosa* in our samples (Figure 2) that Hamilton and Siver (2010) named *E. paludosa* morphotype 2, based on its larger size and more prominent striae. This taxon was identified as a significant indicator taxon for Cyperaceae-dominated rich fens (i.e. Cluster 5). Aside from reports of multiple forms of *E. paludosa*, large variations in cell size have also been attributed to differences in microhabitat moisture. For example, dry habitats can limit sexual reproduction and associated cell size restoration and/or small-sized diatoms can acclimate to moisture-limited habitats owing to their high resources absorption efficiencies (Chen et al. 2012). In our study, *E. paludosa* morphotype 2 was present in the drier microhabitats within rich fen sites, similar to that observed in the fen sites studied by De Vries (1984).

It is likely that the dominance of *E. paludosa* in dry, acidic, bog habitats stems from the fact that *Sphagnum* species are able to retain moisture through capillarity, and that *E. paludosa* secretes a copious external sheath (Beyens 1985; Chen et al. 2012). *S. fuscum* and other *Sphagnum* species provide the greatest competitive microhabitat for this diatom species and allow it to resist periods of desiccation.

Although *E. paludosa* is often the dominant taxon in dry, acidic bog environments, it may also occur in a variety of peat habitats that are not necessarily dominated by *Sphagnum* species. In these less extreme peat habitats, other acidophilous and aerophilous diatoms will be able to compete and may therefore be better indicator taxa. For example, in this study *E. paludosa* co-occurs with widespread euterrestrial (present in environments/soils that periodically dry out) species, albeit in low relative abundances: *Hantzschia amphioxys*, *Luticola mutica*, and *Pinnularia borealis* (Johansen 2010; Gaiser and Rühland 2010; Fig. 5c). Aside from these aerophilic taxa, *E. paludosa* was also found to co-occur with *Pinnularia rupestris* and *Achnanthes lanceolata* in Czech Republic peatlands (Poulíčková et al. 2004), and with *E. exigua* in sub-Antarctic mosses (Van de Vijver and Beyens 1997). All three of these taxa are found mainly in water bodies, but also occur regularly on wet and moist places, suggesting they are tolerant of some drying or emergent environments (van Dam et al. 1994). Although we consider the samples with close to 100% abundance of *E. paludosa* to be the driest microhabitats in this study, other diatom peatland studies with even drier microhabitats have reported dominance by euterrestrial diatom species (Van de Vijver and Beyens 1997). This is also true for coastal marshlands, where Gaiser et al. (1998, 2001) found that *L. mutica*, *P. borealis,* and *H. amphioxys* are diatoms that can withstand the shortest hydroperiod or time without flooding. In our peat samples, it is possible that the hummock sites were too acidic for these particular euterrestrial diatom species to dominate. For example, although *H. amphioxys* is considered to have a circum-neutral pH optimum (van Dam et al. 1994) and a broad pH tolerance, it is rarer in acidic soils and reaches high densities in dry, neutral to slightly alkaline soils (Johanson 2010). Additionally, the low abundance or absence of common euterrestrial species has also been attributed to lack of sufficient mineral material (Lund 1945; Van de Vijver and Beyens 1998, 1999).

### 2.5.3 Bog-Hollow microhabitats

Wet, acidic bog sites in our study (i.e. Cluster 2 identified by the MRT analysis) differ from the dry, acidic bog sites described above (i.e. Cluster 1) in that they have a water table closer to the vegetation surface (mean DWT=4.5 cm). The less extreme periodic drying in these sites will likely provide a more amenable environment for diatoms to grow than bog-hummock microhabitats. Despite the relatively large number of peat samples (n=37) containing a greater variety of vegetation types (e.g., *Carex* spp., *S. angustifolium*, *S. magellanicum*), these samples share only two diatom indicator species, dominant across the 36 samples: *E. mucophila* and *E. paludosa* var. *trinacria* (Table 2). This suggests that, although these wetter microhabitats were not as harsh as the raised bog-hummock microhabitats (Cluster 1), they are nevertheless challenging environments for diatom survival.

It is plausible that *E. mucophila* and *E. paludosa* var. *trinacria* occur in these microhabitats because the pH and mineral content is optimal for their survival, and their association to these bryophyte species occurs because of overlap in their ranges of pH and moisture tolerance. Alternatively, bog-hollow microhabitats may not be optimal conditions for these diatom species, but they are still capable of outcompeting other diatom taxa in dry and acidic environments. It is possible that *E. mucophila* and *E. paludosa* are opportunists for these particularly harsh peat environments and thus occur at abundances close to 100%, but can also survive in other less acidic and dry environments where they are found at lower abundances in this study. *Sphagnum angustifolium*, often associated with *S. magellanicum*, is found in poor fen lawns, the hollows of bogs, and open bog pools with discontinuous permafrost, but rarely grows in carpets and on bog hummocks sampled in Cluster 1 (Bauer et al. 2007; Riley 2011). Given the higher water table, and that the dominant bryophytes sampled in this study tend to grow in more moist environments, the diatom species identified in Cluster 2 are indicative of the hollow microhabitats found within bogs, but likely do not have a particular affinity to a given bryophyte type as these diatoms were found in association with all vegetation types within these acidic (pH<5.5) bog samples.

Cluster 2 samples are distinguished from Cluster 1 samples by the appearance and high abundances of the rarely cited but morphologically distinct *E. mucophila*. Our study suggests that *E. mucophila* maintains a close association to particular *Sphagnum* species found growing in bog hollows due to overlap in pH and moisture preferences. For example, this species was found in our habitats with pH values of about 4.2, and *S. angustifolium* and *S. magellanicum* have reported narrow pH optima, often between 3.6 and 4.0 (Booth 2002). When identified, *E. mucophila* has been found in a fen dominated by *S. angustifolium* (Buczkó 2006), and in association with *Sphagnum* species but independent of the moisture regime (Poulíčková et al. 2004). In general, bog diatoms in our study are responding to chemical cues in their environment, and secondarily to changes in moisture regime, both of which can influence the moss communities. Similar to what we suggest for the two diatom taxa, *E. paludosa* and *E. mucophila*, Hájková et al. (2011) found for the entire diatom assemblage that the highest proportion of diatom variation was explained by water chemistry rather than bryophyte characteristics.

In our northern Ontario peatland sites, other diatom species that also show possible associations to peat hollow microhabitats include *Eunotia lapponica*, *E. fennica*, and *Caloneis bacillum*. These species were often found to co-occur with *E. mucophila* and may be other potential indicator species for hollow microhabitats. Similar to this study, *E. lapponica* has previously been found to co-occur with *E. mucophila* and was associated with bogs containing *S. angustifolium* as well as *Carex* by Buczkó (2006) and Chen et al. (2012). *Eunotia fennica* is also commonly found in *Sphagnum* ponds, and thus may also be associated with the bryophytes growing in bog hollows or share a similar pH optima to hollow *Sphagnum* spp. (Hamilton and Siver 2010). Although this species was not common across all samples, it was found in three highly acidic samples (pH~4) with varying DWT at relative abundances exceeding 30%, suggesting that it has a narrow optimum and tolerance for pH. *Caloneis bacillum* was also often found with the hollow-indicator diatom taxa in the species ordination plot (Fig. 5c). This species has been reported to be able to sustain large osmotic changes from increasing dryness but cannot support long periods of desiccation (Van de Vijver et al. 2003), and thus may be more common in hollow habitats that are transitioning to drier hummock microhabitats. Collectively, our results suggest that *E. mucophila* is the best diatom indicator of bog hollow microhabitats, but its occurrence with some of the other aforementioned diatom species (e.g., *E. lapponica, E. fennica, C. bacillum*) may provide further details on the specific hollow microhabitat.

### 2.5.4 Hollow-hummock transition microhabitats

Samples that were dominated by the bryophyte *S. magellanicum* (i.e., Cluster 3, n=4) may capture microhabitats occurring between bog hummock and hollow environments. The occurrence of *S. magellanicum* in this transitional habitat is consistent with its broad ecological range, occurring in relatively acidic habitats, on the tops and sides of hummocks in older bogs, as well as in pioneering sites in wetter, more mineral-rich habitats that are more strongly connected to the water table (Gignac and Vitt 1990). Given that *S. magellanicum* is considered a generalist species found in a wide variety of peat habitats, it is not surprising that the diatom indicator species associated with this group of peat sites likewise vary substantially in their autecology. The five indicator diatom species for hollow-hummock transition microhabitats (widely scattered in the CCA ordination plot) include: acidobiontic *Eunotia exigua* and *Gomphonema* cf. *bohemicum*; benthic, often alkalphilious fragilarioid taxa; and *Aulacoseira subarctica* (Fig. 5c). In our study, *E. exigua* was associated with acidic but wetter sites associated with rich fen habitats (Cluster 5; Fig. 5c). Although, *E. exigua* has been reported extensively in floristic surveys of wetlands (e.g., de Vries 1984; Buczkó 2006), it has also been found to thrive in a variety of acidic, low-mineral habitats such as in acid mine drainage with high mineral content and particularly high metal loads (van Dam et al. 1981; DeNicola 2000; Liu et al. 2011). Therefore, it is doubtful that this diatom species has an affiliation with *S. magellanicum,* but rather the acidic and wet microhabitats of these peat sites were ideal for its growth. In contrast to *E. exigua*, indicator taxon *Gomphonema* cf. *bohemicum,* classified as acidobiontic by van Dam et al. (1994), occurs with other epiphytic diatom taxa associated with more circum-neutral to slightly acidic pH (i.e. Cluster 4). *Gomphonema bohemicum* has previously been reported in the literature to be acidobiontic but in the spatial distribution of this taxon across peatland habitats in our study suggest that it may also be limited by moisture. The present study adds to the known autecology of this species, as it clearly has a preference for sites that are less acidic and have a water table higher than bog sites and co-occurs with *S. magellanicum*.

Benthic indicator species, such as *Staurosira construens* and *Staurosirella pinnata*, are more commonly found in standing water, which suggests fluctuations in water table depth within the hollow-hummock transition sites. *S. construens* and, to a lesser degree *S. pinnata*, are positively influenced by shallow water tables. Small benthic fragilarioid taxa are known to be opportunistic, pioneering diatoms that tend to outcompete other diatoms when conditions are unfavourable (e.g., low light availability, short growing seasons, low nutrients; Lotter and Bigler 2000; Smol and Douglas 2007; Finkelstein and Gajewski 2008), and also found in very high abundances in not only alkaline conditions but also circum-neutral and slightly acidic lakes and ponds across temperate to arctic regions (Smol et al. 2005; Karst-Riddoch et al. 2009). It is also not uncommon for these taxa to be present in depleted nutrient and mineral environments (e.g. ombrotrophic conditions), provided that there is sufficient moisture to survive (Rühland et al. 2009). Low-lying regions of the Hudson Plains are common and local connections to groundwater across small distances can be sporadic (Wolfe et al. 2011), yielding areas that have periodic contact with groundwater allowing the formation and disappearance of surface pools. This is consistent with the findings of Weilhoefer and Pan (2007), who found that *S. construens* and *S. pinnata* were the dominant diatom species in wetlands with relatively high water tables.

*Aulacoseira subarctica* is present within hummock-hollow transition microhabitats, albeit in low abundances (maximum of 5% mean abundance in one sample) with a low indicator F-value (Table 2). The occurrence of this tychoplanktonic diatom in our peat sample is somewhat surprising as it has been reported to occur in the open-water environment of well-mixed, relatively deep lakes with low light conditions (Kilham et al. 1996; Gibson et al. 2003) as well as in lakes with high concentrations of dissolved organic carbon (DOC) (Rühland and Smol 2002). The occurrence of *Aulacoseira* species in this peat environment is likely due to its ability to survive in low light environments, similar to the benthic fragilarioid taxa mentioned above. *Aulacoseira species* were also found in peat cores collected from the HBL, and attributed to a wetter, more fen-like environment prior to bog hollow establishment (Hargan et al. in press). In addition, higher DOC may result from the humification of older peat, and/or groundwater contact with the surface vegetation, both of which would further limit light penetration.

*Kobayasiella subtilissima*, although not a significant indicator species for these habitats (p=0.053), was dominant (mean abundance 48%) in Cluster 3 samples. This species was likely not an indicator taxon for these microhabitats due to its incidence across many other peat types. This species occurs most often with the bog hollow species suggesting its preference for more acidic environments than typically found in fen habitats, but wetter conditions than bog hummock sites (Table 2, Fig. 5c). Similar to our observations of *Kobayasiella subtilissima* in this study, this diatom is considered to be an acidobiontic species typically inhabiting bogs and nutrient-poor lakes and often co-occurs with small species of *Eunotia* (van Dam et al. 1981; Walker and Paterson 1986; Dixit et al. 1993). Unlike the epiphytic *Eunotia* taxa, *K. subtilissima* is an unattached benthic species and thus is likely more closely associated to the pH and DWT (as well as nutrients, although not measured) that the bog hollow microhabitats yield as opposed to a bryophytic association (Fig. 5c).

Given that *S. magellanicum* can grow in a variety of peat habitats, the low pH tolerances of *E. exigua*, *K. subtilissima*, and *G.* cf. *bohemicum,* and low-light adaptations of small, benthic fragilarioid taxa and *A. subarctica*, it is most likely that these acidic microhabitats were either humified, thereby reducing the clarity of surface water (and also potentially further increasing acidity), and/or receiving some nutrient and mineral inputs from groundwater sources or overland flow. The strong association of a few of the diatom species to either low or high water tables also suggests that water tables are unstable and these habitats may be prone to periodic drying.

### 2.5.5 *Aulacomnium* poor-fen habitats

Circum-neutral, poor-fen peat samples dominated by the moss *Aulacomnium* or by *Carex* contained distinct diatom assemblages (i.e. Cluster 4 MRT analysis; n=19) and a rich variety of significant indicator species. All but one of these samples (HLM16) were collected in the Hudson Plains ecozone near coastal Churchill within continuous permafrost. *Aulacomnium palustre* is known to be a common moss species of western Canadian peatlands that tends to occur frequently in drier fen microsites (Bauer et al. 2007), but has also been reported to grow on a variety of microhabitats with a wide-range of canopy and moisture conditions (Gignac 1992; Bauer et al. 2007). *Aulacomnium palustre* and species of the brown moss, *Drepanocladus*, are known as 'strong fen indicators' in the Hudson Plains (Riley 2011). These have been observed to occur in peatlands close to the Hudson Bay coast that typically have a pH above 6.0 and a range in DWT, varying between 0.5 and 20 cm (Riley 2011). In this study, *Aulacomnium*-dominated sites had a mean pH value of 6.8 and although relatively dry, were wetter than the bog-hummock sites with a mean of DWT of 5.1 cm (i.e., water table slightly below the living vegetation surface), representing habitats more indicative of poor fens (Zoltai and Vitt 1995; Riley 2011).

A total of 33 significant diatom indicator taxa represent this group of poor-fen samples (Cluster 4), which includes distinct diatom assemblages consisting of a variety of mostly epiphytic taxa from the genera *Encyonema*, *Gomphonema,* and *Nitzschia* (Table 2). Given that many of the significant species within this cluster are either pH-indifferent, (e.g., *Achnanthidium minutissimum*; van Dam et al. 1981), or alkaliphilous (e.g., *Navicula* taxa particularly *N. cryptocephala, N. vulpina,* and *N. radiosa*; van Dam et al. 1981; Rühland et al. 2000; Weilhoefer and Pan 2007), diatom assemblage composition appears to be most strongly associated with the greater connection to the water table in these fen peat sites and related chemical characteristics such as relatively high levels of conductivity, minerals, and nutrients. The high number of diatom indicator taxa (e.g., *Achnanthidium minutissimum*, *Denticula kuetzingii*, *Epithemia adnata*, *Diatoma tenuis*, *Nitzschia perminuta,* and *Fragilaria capucina*) that are common in environments that are not as chemically restrictive as in bog environments such as ponds and lakes, is consistent with the stronger connection to ground water.

All of the coastal fens from the Churchill region shared similar diatom assemblages but were distinct from the rest of our study samples, suggesting that coastal peatlands of this region are both relatively homogeneous and yet dissimilar to the other peatlands in the study region. Many of the poor fen, epiphytic indicator diatom taxa found at Churchill have been commonly reported from other wetland types (particularly fens) across the globe. For example, *Encyonopsis microcephala* was co-dominant with

*Achnanthidium minutissimum* in Dutch moorland pools (van Dam et al. 1981), *Gomphonema* and *Nitzschia* taxa were found to typically co-occur in peat records from Siberia and Alaska during fen periods dominated by sedge peat (Rühland et al. 2000; Myers-Smith et al. 2007), and *A. minutissimum* and *Fragilaria capucina* co-occurred during a section in an Ontario peatland core when *Drepanocladus* and *Carex* macrofossils were present (i.e. fen stages) (Campbell et al. 1997). Additionally, *Fragilaria tenera* was identified as a significant indicator species occurring in Arctic moss substrates (Michelutti et al. 2003), and although it is often considered planktonic, its presence in our subarctic brown moss environments appears to be common across the Arctic.

In general, there are more fens along the Hudson Bay coast than bogs, as the shore of Hudson Bay represents the most recent state of peat and substrate in the study region, whereas regions farther inland from the coast have experienced a lengthened period of emergence from the Tyrrell Sea and hence a longer period for peat to accumulate and ombrotrophication to occur (Martini 2006; Crins et al. 2009; Holmquist et al. 2014). It is of interest to note that coastal fens occur throughout the Hudson Plains along the coast of Hudson Bay (Riley 2011), but in this study this fen type was only sampled near Churchill. If homogeneity of coastal fens is indeed the case in the Hudson Plains, then we might expect to find similar diatom assemblages throughout both the Ontario and Manitoba coastal fen sites.

### 2.5.6 Wet fen habitats

Wet fen habitats (Cluster 5; n=9) had the greatest connection to the water table with the living vegetation at the surface typically submerged (mean DWT=-5.6 cm). These samples had the highest diatom diversity of all of our samples and yielded the largest number of significant indicator taxa, despite having a mean pH lower than the hummock-hollow transition microhabitats and poor fen habitats (i.e. Clusters 3 and 4). This is interesting considering that pH is driving most of the clusters and secondarily DWT, but here it seems that the stronger connection to the water table prevails for species richness. However, pH data are probably more reliable than the water table depth data, as the DWT varies considerably through the year. Given the DWT and vegetation, these sites are likely rich fens, however, the pH is more acidic than typical rich fen habitats, which tend to have a pH >7. The high diatom diversity observed in these peat samples is consistent with the flora reported in other rich fen environments (Kingston 1982; Poulíčková et al. 2004). The dominant vegetation type sampled was Cyperaceae, but fen samples also included *Drepanocladus, Equisetum*, and *Carex*, taxa typical of a rich fen environment (Riley 2011). A total of 34 significant diatom taxa from 10 genera represent this habitat including 17 *Eunotia* taxa, 3 *Pinnularia* taxa, 3 *Tabellaria* taxa, 2 *Brachysira* taxa, and *Frustulia rhomboides* (Table 2). The high number of indicator taxa identified in this group was likely due to more favourable conditions for diatom growth, including a higher water table, less acidic pH than bogs, and higher nutrients and minerals, for both vegetation and diatom growth resulting in a more diverse and complex variety of peat vegetation types and thus a greater assortment of diatom microhabitats.

In these wet, poor to rich fen environments, diatom species appear to be generalists in their preference for pH, as they tend to occur over a relatively wide range of pH from alkaliphilous to acidophilous environments. Several of the taxa dominant in these fens have previously been reported to be closely associated with fen peatland habitats, including *Tabellaria flocculosa, Eunotia hexaglyphis, E. incisa,* and *Pinnularia brevicostata*, which are often indicative of wetter and more acidic conditions (Fukumoto et al. 2012). Many diatom calibration sets and studies on peatland carbon corroborate the presence of many of these indicator diatom taxa in slightly acidic and humic sedge environments. For example, *Frustulia rhomboides, Brachysira brebissonii* and *Chamaepinnularia soehrensis* were associated with humic waters and frequently found in mosses growing on rocks in modern peat samples and peat core records (Kokfelt et al. 2009). Many *Eunotia* taxa (*E. praerupta, E. incisa, E. tenella, E. hexaglyphis, E. arcus, and E. subarcuatoides*), *Stauroneis phoenicenteron, and Pinnularia* taxa were present in both modern sedge peat samples and during the sedge-dominant period depicted in a peat cores (Myers-Smith et al. 2007; Kokfelt et al. 2009). Pienitz and Smol (1993) found that coloured lakes located in peaty areas contained benthic acidophilic diatoms, such as *Brachysira* spp*., Encyonopsis microcephala, E. exigua, E. praerupta, Frustulia rhomboides, Chamaepinnularia mediocris, C. soehrensis, K. subtilissima, Neidium ampliatum,* and *Stauroneis phoenicenteron*. Although dissolved organic carbon

(DOC) was not measured, groundwater flow is significant in the redistribution of carbon and determining spatial patterns of carbon concentration (Waddington and Roulet 1997), indicating that higher DOC concentrations at these rich fen sites, as indicated by the diatom assemblages, are highly probable. As well, decomposition rates are much higher in sedges than in *Sphagnum* mosses (Moore and Basiliko 2006), which could contribute to higher DOC or humic waters in these rich fens. Although we suggest that pH is the main driver clustering our sites, and secondarily DWT, the diatom assemblages highlight the strong importance of groundwater connection in fens, which has a strong influence on species richness.

## 2.6 Conclusions

We demonstrate striking microhabitat specificity of diatom assemblages across the Boreal Shield and subarctic peatlands of Ontario and Manitoba. The uniformity in diatom preferences for these microhabitats across the large expanse of our study region (~800 km) suggests that the temperature and precipitation differences associated with the Boreal Shield or Hudson Plains ecozones have minor influences on diatom distributions in these surface peat samples. Distinct diatom assemblages captured the transition between *Sphagnum*-dominated bog microhabitats and *Aulacomnium* and brown-moss dominated fens. Diatom species diversity and richness decreased from rich-fen to bog environments and from hummocks to hollows. MRT analysis was particularly well suited to identifying associations between diatom assemblages and peat type at each site. Water table depth and pH were found to clearly define microhabitat type and the diatoms associated with these. This study demonstrates that diatoms are highly sensitive to peat microhabitat environments and can and should be more widely used for paleoecological studies to track peatland hydroseral changes.

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## 2.8 References

Antoniades, D., Hamilton, P.B., Douglas, M.S.V., and Smol, J.P. 2008. Diatoms of North America: The Freshwater Floras of Prince Patrick, Ellef Ringnes, and Northern Ellesmere Islands from the Canadian Arctic Archipelago. Iconographia Diatomologica 17.

Battarbee, R.W., Charles, D.F., Bigler, C., Cumming, B.F., and Renberg, I. 2010. Diatoms as indicators of surface-water acidity. *In* The Diatoms: Applications for the Environmental and Earth Sciences. *Edited by* J.P. Smol, and E.F. Stoermer. Cambridge University Press, New York, pp. 98–121.

Bauer, I.E., Tirlea, D., Bhatti, J.S., and Errington, R.C. 2007. Environmental and biotic controls on bryophyte productivity along forest to peatland ecotones. Can. J. Bot. 85: 463–475. doi:10.1139/B07-045

Bennett, P.C., Siegel, D.I., Hill, B.M., and Glaser, P.H. 1991. Fate of silicate minerals in a peat bog. Geology, 19: 328–331. doi:10.1130/0091-7613(1991)019<0328:FOSMIA>2.3.CO;2.

Beyens, L. 1985. On the subboreal climate of the Belgian Campine as deduced from diatom and testate amoebae analyses. Review of Palaeobotany and Palynology 46: 9-31.

Booth, R.K. 2002. Testate amoebae as paleoindicators of surface-moisture changes on Michigan peatlands: modern ecology and hydrological calibration. J. Paleolimnol. 28: 329–348. doi:10.1023/A:1021675225099.

Brown, K., Douglas, M.S.V., and Smol, J.P. 1994. Siliceous microfossils in a Holocene, High Arctic peat deposit (Nordvestø, northwestern Greenland). Can. J. Bot. 72: 208–216.

Brugam, R.B., and Swain, P. 2000. Diatom indicators of peatland development at Pogonia Bog Pond, Minnesota, USA. Holocene, 10(4): 453–464. doi:10.1191/095968300668251084

Buczkó, K. 2006. Bryophytic diatoms from Hungary. Eighteenth International Diatom Symposium 2004: 1-15.

Bunbury, J., Finkelstein, S.A., and Bollmann, J. 2012. Holocene hydro-climatic change and effects on carbon accumulation inferred from a peat bog in the Attawapiskat River watershed, Hudson Bay Lowlands, Canada. Quaternary Res. 78(2): 275–284. doi:10.1016/j.yqres.2012.05.013.

Camburn, K. E., and Charles, D. F. 2000. Diatoms of Low Alkalinity Lakes in the Northeastern United States. The Academy of Natural Sciences of Philadelphia. Philadelphia: Scientific Publications. 152 pp.

Campbell, D.R., Dutchie, H.C., and Warner, B.G. 1997. Post-glacial development of a kettle-hole peatland in southern Ontario. Ecoscience, 4(3): 404–418.

Charman, D.J., Blundell, A., and Members, A. 2007. A new European testate amoebae transfer function for palaeohydrological reconstruction on ombrotrophic peatlands. J. Quaternary Sci. 22(3): 209–221. doi:10.1002/jqs.1026

Chen, X., Bu, Z., Yang, X., and Wang, S. 2012. Epiphytic diatoms and their relation to moisture and moss composition in two montane mires, Northeast China. Fund. Appl. Limnol. 181(3): 197–206. doi:10.1127/1863-9135/2012/0369

Chessel, D., Dufour, A.B., and Thioulouse, J. 2004. The ade4 package – I: one-table methods. R News 4: 5-10.

Crins, W.J., Gray, P.A., Uhlig, P.W.C., and Wester, M.C. 2009. The ecosystems of Ontario, Part 1: ecozones and ecoregions. Ministry of Natural Resources, Peterborough Ontario, Inventory, Monitoring and Assessment, SIB TER IMA TR- 01. 71 pp.

De'ath, G. 2002. Multivariate regression trees: a new technique for modeling species-environment relationships. Ecology, 83(4): 1105–1117.

DeNicola, D.M. 2000. A review of diatoms found in highly acidic environments. Hydrobiologia, 433: 111–122. doi:10.2307/3071917.

De Vries, B.J. 1984. Diatom assemblages in some moorland pools in the Drenthian District (The Netherlands). Hydrobiol. Bull. 18(1): 3–10. doi:10.1007/BF02256667.

Dixit, S.S., Cumming, B.F., Birks, H. J. B., Smol, J.P., Kingston, J.C., Uutala, A.J., Charles, D.F, and Camburn, K.E. 1993. Diatom assemblages from Adirondack lakes (New York, USA) and the development of inference models for retrospective environmental assessment. J. Paleolimnol. 8: 27–47.

Dray, S., Dufour, A.B., and Chessel, D. 2007. The ade4 package – II: two-table and K-table methods. R News 7: 47-52.

Dredge, L., and Cowan, W.R. 1989. Quaternary geology of the southwestern Canadian Shield. *In* Quaternary geology of Canada and Greenland. Geological Survey of Canada. *Edited by* Fulton, R.J. Geology of Canada, No. 1. 214–249.

Dredge, L.A., and Mott, R.J. 2003. Holocene Pollen Records and Peatland Development, Northeastern Manitoba. Géographie physique et Quaternaire 57(1): 7–19. doi:10.7202/010328ar.

Dufrêne, M., and Legendre, P. 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecol. Monogr. 67: 345–366. doi:10.1890/0012-9615(1997)067[0345:SAAIST]2.0.CO;2.

Dunn, C., and Freeman, C. 2011. Peatlands: our greatest source of carbon credits? Carbon Management 2(3): 289–301. doi:10.4155/cmt.11.23.

Ecological Stratification Working Group. 1996. A national ecological framework for Canada. Environment Canada, 132 pp.

Finkelstein, S.M., and Gajewski, K. 2008. Responses of Fragilarioid-dominated diatom assemblages in a small Arctic lake to Holocene climatic changes, Russell Island, Nunavut, Canada. J. Paleolimnol. 40: 1079–1095. doi:10.1007/s10933-008-9215-5.

Foged, N. 1951. The diatom flora of some Danish springs. Natura Jutlandica 4–5: 1–84.

Fránková, M., Bojková, J., Poulíčková, A. and Hájek, M. 2009. The structure and species richness of the diatom assemblages of the Western Carpathian spring fens along the gradient of mineral richness. Fottea, 9: 355–368.

Fukumoto, Y., Kashima, K., Orkhonselenge, A., and Ganzorig, U. 2012. Holocene environmental changes in northern Mongolia inferred from diatom and pollen records of peat sediment. Quatern. Int. 254: 83–91. doi:10.1016/j.quaint.2011.10.014.

Fulton, R.J. 1995. Surficial Materials of Canada, Geological Survey of Canada, Map 1880A.

Gaiser, E.E., and Rühland, K.M. 2010. Diatoms as indicators of environmental change in wetlands and peatlands. *In* The Diatoms: Applications for the Environmental and Earth Sciences. *Edited by* J.P. Smol, and E.F. Stoermer. Cambridge University Press, New York, pp. 473–496.

Gaiser, E.E., Philippi, T.E., and Taylor, B.E. 1998. Distribution of diatoms among intermittent ponds on the Atlantic Coastal Plain: development of a model to predict drought periodicity from surface sediment assemblages. J. Paleolimnol. 20: 71–90. doi:10.1023/A:1007969500673.

Gaiser, E.E., Taylor, B.E., and Brooks, M.J. 2001. Establishment of wetlands on the southeastern Atlantic Coastal Plain: paleolimnological evidence of a mid-Holocene hydrologic threshold from a South Carolina pond. J. Paleolimnol. 26: 373–391. doi:10.1023/A:1012645302945.

Gibson, C.E., Anderson, N.J., and Haworth, E.Y. 2003. *Aulacoseira subarctica*: taxonomy, physiology, ecology and palaeoecology. Eur. J. Phycol. 38(2): 83–101. doi:10.1080/0967026031000094102.

Gignac, L.D. 1992. Niche structure, resource partitioning, and species interactions of mire bryophytes relative to climatic and ecological gradients in western Canada. Bryologist, 95(4): 406-418. doi:10.2307/3243564.

Gignac, L.D., and Vitt, D.H. 1990. Habitat limitations of *Sphagnum* along climatic, chemical, and physical gradients in mires of western Canada. Bryologist 93(1): 7-22. doi:10.2307/3243541.

Hájková, P., Bojková, J., Fránková, M., Opravilová, V., Hájek, M., Kintrová, K. and Horsák, M. 2011. Disentangling the effects of water chemistry and substratum structure on moss dwelling unicellular and multicellular micro-organisms in spring-fens. J. Limnol. 70 (Suppl. 1): 54–64. doi:10.3274/JL11-70-S1-04

Hamilton, P.B., and Siver, P.A. 2010. A Morphological Investigation of *Eunotia fennica* (Bacillariophyceae) from a Freshwater Acidic Pond in Newfoundland, Canada. P. Acad. Nat. Sci. Phila. 160: 89–98.

Hargan, K., Rühland, K.M., Paterson, A.M., Holmquist, J., MacDonald, G.M., Bunbury, J., Finkelstein, S.A., and Smol, J.P. 2015. Long-term successional changes in peatlands of the Hudson Bay Lowlands inferred by the ecological dynamics of multiple proxies. Holocene, 25: 92-108. doi:10.1177/0959683614556384

Holmquist, J.R., MacDonald, G.M., and Gallego-Sala, A. 2014. Peatland initiation, carbon accumulation, and 2 ka depth in the James Bay Lowland and adjacent regions. Arct. Antarct. Alp. Res. 46: 19–39. doi:10.1657/1938-4246-46.1.19

Hustedt, F. 1927–1966. Die Kieselalgen Deutschlands, Osterreichs und der Schweiz unter Berucksichtigung der ubrigen Lander Europas sowie der angrenzenden Meeresgebiete. In Dr. L. Rabenhorst's Kryptogamen-Flora von Deutschland, Osterreich und der Schweiz.

Johansen, J.R. 2010. Diatoms of aerial habitats. *In* The Diatoms: Applications for the Environmental and Earth Sciences. *Edited by* J.P. Smol, and E.F. Stoermer. Cambridge University Press, New York, pp. 465–472.

Karst-Riddoch, T.L., Malmquist, H.J., and Smol, J.P. 2009. Relationships between freshwater sedimentary diatoms and environmental variables in Subarctic Icelandic lakes. Fund. Appl. Limnol. 175(1): 1–28. doi:10.1127/1863-9135/2009/0175-0001

Kienel, U., Sigert, C., and Hahne, J. 1999. Late Quaternary palaeoenvironmental reconstructions from a permafrost sequence (North Siberian Lowland, SE Taymyr Peninsula) – a multidisciplinary case study. Boreas, 28: 181–93.

Kilham, S.S., Theriot, E.C., and Fritz, S.C. 1996. Linking planktonic diatoms and climate change in the large lakes of the Yellowstone ecosystem using resource theory. Limnol. Oceanogr. 41(5): 1052–1062. doi:10.4319/lo.1996.41.5.1052.

Kingston, J.C. 1982. Association and distribution of common diatoms in surface samples from northern Minnesota peatlands. Nova Hedwigia, 73: 333–346.

Kokfelt, U., Struyf, E., and Randsalu, L. 2009. Diatoms in peat – Dominant producers in a changing environment? Soil Biol. Biochem. 41: 1764–1766. doi:10.1016/j.soilbio.2009.05.012

Krammer, K., and Lange-Bertalot, H. 1986–1991. Bacillariophyceae. *In* Süßwasserflora von Mitteleuropa*,* Volume 2 (1–4). *Edited by* H. Ettl, J. Gerloff, H. Heynig, and D. Mollenhauer. Stuttgart/Jena: Gustav Fischer Verlag.

Krasske, G. 1932. Beitrage zur Kenntnis der Diatomoceenflora der Alpen. Hedwigia 72: 92–134.

Krasske, G. 1936. Die Diatomeenflora der Moosrasen des Wilhelmshoher Parkes. *In* Festschrift des Vereins fur Naturkunde zu Kassel zum hundertjahrigen Bestehen, pp. 151–64.

Kulikovskiy, M.S., Lange-Bertalot, H., Witkowski, A., Dorofeyuk, N.I., and Genkal, S.I. 2010. Diatom assemblages from *Sphagnum* bogs of the world. I. Nur bog in northern Mongolia. Bibliotheca Diatomologica, 55: 1–326.

Legendre, P., and Birks, H.B.H. 2012. Chapter 7: Clustering and Partitioning. *In* Tracking Environmental Change Using Lake Sediments: Data handling and numerical techniques, 5. *Edited by* H.J.B. Birks, A.F. Lotter, S. Juggins, and J.P. Smol. 745 pp. doi:10.1007/978-94-007-2745-8 7.

Legendre, P., and Gallagher, E.D. 2001. Ecologically meaningful transformations for ordination of species data. Oecologia, 129(2): 271–280. doi:10.1007/s004420100716.

Liu, Y., Wang, Q., and Fu, C. 2011. Taxonomy and distribution of diatoms in the genus *Eunotia* from the Da'erbin Lake and Surrounding Bogs in the Great Xing'an Mountains, China. Nova Hedwigia, 92(1–2): 205–232. doi:10.1127/0029-5035/2011/0092-0205.

Lotter, A.F., and Bigler, C. 2000. Do diatoms in the Swiss Alps reflect the length of ice-cover? Aquat. Sci. 62: 125–141. doi:1015-1621/00/020125-17.

Lund, J.W.G. 1945. Observations on soil algae. I. The ecology, size and taxonomy of British soil diatoms. Part 1. New Phytol. 44: 196–219.

Martini, I.P. 2006. The cold-climate peatlands of the Hudson Bay Lowland, Canada: brief overview of recent work. *In* Peatlands: Evolution and Records of Environmental and Climate Change. *Edited by* I.P. Martini, A. Martinez Cortizas, and W. Chesworth. Springer pp. 53–83.

McAndrews, J.H., Riley, J.L., and Davis, A.M. 1982. Vegetation history of the Hudson Bay Lowland: a postglacial pollen diagram from the Sutton Ridge. Natural. Canad. 109: 597–608.

McKenney, D.W., Pedlar, J.H., Lawrence, K., Gray, P.A., Colombo, S.J., and Crins, W.J. 2010. Current and projected future climatic conditions for ecoregions and selected natural heritage areas in Ontario. Cimate Change Research Report CCR-16. Ontario Ministry of Natural Resources, 54 pp.

Michelutti, N., Holtham, A.J., Douglas, M.S.V., and Smol, J.P. 2003. Periphytic diatom assemblages from ultra-oligotrophic and UV transparent lakes and ponds on Victoria Island and comparisons with other diatom surveys in the Canadian arctic. J. Phycol. 39: 465–480. doi:10.1046/j.1529-8817.2003.02153.x.

Moore, T., and Basiliko, N. 2006. Decomposition in Boreal Peatlands. *In* Ecological Studies, Vol. 188: Boreal Peatland Ecosystems. *Edited by* R.K. Wieder and D.H. Vitt. Springer-Verlag Berlin Heidelberg, pp. 125–143.

Myers-Smith, I.H., Harden, J.W., Wilmking, M., Fuller, C.C., McGuire, A.D., and Chapin III, F.S. 2007. Wetland succession in a permafrost collapse: interactions between fire and thermokarst. Biogeosciences Discuss. 4: 4507–4538. doi:10.5194/bgd-4-4507-2007.

Novakova, J., and Poulíčková, A. 2004. Moss diatom (Bacillariophyceae) flora of the nature reserve Adršpašsko-Teplické Rocks (Czech Republic). Czech Phycology, Olomouc 4: 75–86.

O’Reilly, B.C., Finkelstein, S.A., and Bunbury, J. 2014. Pollen-derived paleovegetation reconstruction and long-term carbon accumulation at a fen site in the Attawapiskat River watershed, Hudson Bay Lowlands, Canada. Arct. Antarct. Alp. Res. 46(1): 6–18. doi: http://dx.doi.org/10.1657/1938-4246-46.1.6

Oksanen, J., Blanchet, F.G., Kindt, R., Legendre, P., O’Hara, R.B., Simpson, G.L., Solymos, P., Stevens, M.H.H., and Wagner, H. 2010. vegan: community ecology package. R package version 1.17-4. Available from http://cran.r-project.org/web/packages/vegan/index.html.

Ontario Geological Survey. 1991. Bedrock of Ontario, Northern Sheet. Ottawa: Ontario Geological Survey, Map 2541, scale 1:1,000,000, 1 sheet.

Parr, J.F., Taffs, K.H., and Lane, C.M. 2004. A microwave digestion techniques for the extraction of fossil diatoms from coastal lake and swamp sediments. J. Paleolimnol. 31: 383–390. doi:10.1023/B:JOPL.0000021857.32734.c6.

Patrick, R. 1954. The diatom flora of Bethany Bog. J. Protozool. 1: 34–7. doi:10.1111/j.1550-7408.1954.tb00791.x.

Peltier, W.R., and Andrews, J.T. 1983. Glacial geology and glacial isostasy of the Hudson Bay region. *In* Shorelines and isostasy. *Edited by* D.E. Smith and A.G. Dawson, Academic Press Institute of British Geographers Special Publication, London 16, pp. 285–319.

Pienitz, R., and Smol, J. 1993. Diatom assemblages and their relationship to environmental variables in lakes from the boreal forest-tundra ecotone near Yellowknife, Northwest Territories, Canada. Hydrobiologia, 269–270: 391–404. doi:10.1007/BF00028037.

Poulíčková, A., Hájková, P., Křenková, P., and Hájek, M. 2004. Distribution of diatoms and bryophytes on linear transects through spring fens. Nova Hedwigia, 78: 411–424. doi:10.1127/0029-5035/2004/0078-0411.

R Development Core Team. 2010. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, Available: http://www.R-project.org.

Riley, J. 2011. Wetlands of the Hudson Bay Lowlands: an Ontario overview. Nature Conservancy of Canada and the Ontario Ministry of Natural Resources.

Roberts, D.W. 2010. labdsv: Ordination and multivariate analysis for ecology. R package version 1.4-1. Available: http://CRAN.R-project.org/package= labdsv.

Roulet, N.T. 2000. Peatlands, carbon storage, greenhouse gases, and the Kyoto Protocol: prospects and significance for Canada. Wetlands, 20(4): 605–615. doi:10.1672/0277-5212(2000)020[0605:PCSGGA]2.0.CO;2.

Rühland, K.M., and Smol, J.P. 2002. Freshwater diatoms from the Canadian Arctic treeline and development of paleolimnological inference models. J. Phycol. 38: 249–264. doi:10.1046/j.1529-8817.2002.01129.x.

Rühland, K.M., Smol, J.P., Jasinski, J.P.P., and Warner, B.G. 2000. Response of diatoms and other siliceous indicators to the developmental history of a peatland in the Tiksi Forest, Siberia, Russia. Arct. Antarct. Alp. Res. 32: 167–178. doi:10.2307/1552448.

Rühland, K., St. Jacques, J-M., Beierle, B.D., Lamoureux, S.F., Dyke, A.S., and Smol, J.P. 2009. Lateglacial and Holocene paleoenvironmental changes recorded in lake sediments, Brock Plateau (Melville Hills), Northwest Territories, Canada. Holocene, 19(7): 1005–1016. doi:10.1177/0959683609340999.

Sears, P.B., and Couch, G.C. 1932. Microfossils in an Arkansas peat and their significance. Ohio J. Sci. 32: 63–68.

Sjörs, H. 1959. Bogs and fens in the Hudson Bay lowlands. Arctic 12: 3–19.

Smol, J.P. 1995. Application of chrysophytes to problems in paleoecology. *In* Chrysophyte Algae: Ecology, phylogeny and development. *Edited by* Sandgren, C.D., Smol, J.P., and Kristiansen, J. Cambridge University Press, New York, pp. 303–329.

Smol, J.P., and Douglas, M.S.V. 2007. From controversy to consensus: making the case for recent climate change in the Arctic using lake sediments Front. Ecol. Environ. 5(9): 466–474. doi:10.1890/060162

Smol, J.P., and Stoermer, E.F. 2010. The Diatoms: Applications for the Environmental and Earth Sciences. Cambridge University Press, New York.

Smol, J.P., Wolfe, A.P., Birks, H.J.B., Douglas, M.S.V., Jones, V.J., Korhola, A., Pienitz, R., Rühland, K., Sorvari, S., Antoniades, D., Brooks, S.J., Fallu, M.A., Hughes, M., Keatley, B.E., Laing, T.E., Michelutti, N., Nazarova, L., Nyman, M., Paterson, A.M., Perren, B., Quinlan, R., Rautio, M., Saulnier-Talbot, E., Siitonen, S., Solovieva, N., and Weckström, J. 2005. Climate-driven regime shifts in the biological communities of arctic lakes. P. Natl. A. Sci. 102(12): 4397–4402. doi:10.1073/pnas.0500245102.

Tam, A., Gough, W.A., Kowal, S. and Xie, C. 2014. The fate of Hudson Bay Lowlands palsas in a changing climate. Arct. Antarct. Alp. Res. 46: 114–120. doi:10.1657/1938-4246-46.1.114.

ter Braak, C. J. F., and Šmilauer, P. 2002. CANOCO Reference Manual and CanoDraw for Windows User's Guide: Software for Canonical Community Ordination (version 4.5). Ithaca, New York: Microcomputer Power, 500 pp.

Van de Vijver, B. and Beyens, L. 1997. The epiphytic diatom flora of mosses from Strømness Bay area, South Georgia. Polar Biol. 17: 492–501. doi:10.1007/s003000050148.

Van de Vijver, B., and Beyens, L. 1998. A preliminary study on the soil diatom assemblages from Ile de la Possession (Crozet, Subantarctica). Eur. J. Soil Biol. 34: 133–141.

Van de Vijver, B., and Beyens, L. 1999. Moss diatom communities from Ile de la Possession (Crozet, Subantarctica) and their relationship with moisture. Polar Biol. 22: 219–231. doi:10.1016/S1164-5563(00)88650-1.

Van de Vijver, B., Van Kerckvoorde, A., and Beyens, L. 2003. Freshwater and terrestrial moss diatom assemblages of the Cambridge Bay area, Victoria Island (Nunavut, Canada). Nova Hedwigia, 76: 225–243. doi:10.1127/0029-5035/2003/0076-0225.

Van de Vijver, B., Gremmen, N., and Smith, V. 2008. Diatom communities from the sub-Antarctic Prince Edward Islands: diversity and distribution patterns. Polar Biol. 31: 795–808. doi:10.1007/s00300-008-

0418-z

van Dam, H., Suurmond, G., and ter Braake, C.J.F. 1981. Impact of acidification on diatoms and chemistry of Dutch moorland pools. Hydrobiologia, 83: 425–459. doi:10.1007/BF02187040.

van Dam, H., Mertens, A., and Sinkeldam, J. 1994. A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands. Netherlands J. Aquat. Ecol. 28(1): 117-133. doi:10.1007/BF02334251.

Waddington, J.M., and Roulet, N.T. 1997. Groundwater flow and dissolved carbon in a boreal peatland. J. Hydrol. 191: 122–138. doi:10.1016/S0022-1694(96)03075-2.

Waddington, J. M., Plach, J., Cagampan, J. P., Lucchese, M., and Strack, M. 2009. Reducing the carbon footprint of Canadian peat extraction and restoration. AMBIO J. 38(4): 194–200. doi:10.1579/0044-7447-38.4.194.

Walker, I.R., and Paterson, C.G. 1986. Associations of diatoms in the surficial sediments of lakes and peat pools in Atlantic Canada. Hydrobiologia, 134: 265–272. doi:10.1007/BF00008495.

Weilhoefer, C.L., and Pan, Y. 2007. Relationships between diatoms and environmental variables in wetlands in the Willamette Valley, Oregon. Wetlands, 27(3): 668–682. doi:10.1672/0277-5212(2007)27[668:RBDAEV]2.0.CO;2

Wolfe, B.B., Light, E.M., Macrae, M.L., Hall, R.I., Eichel, K., Jasechko, S., White, J., Fishback, L., and Edwards, T.W.D. 2011. Divergent hydrological responses to 20th century climate change in shallow tundra ponds, western Hudson Bay Lowlands. Geophys. Res. Lett. 28: L23402. doi:10.1029/2011GL049766

Zoltai, S.C., and Vitt, D.H. 1995. Canadian wetlands: Environmental gradients and classification. Vegetatio, 118: 131–137. doi:10.1007/BF00045195.

Table 2-1 Peatland sampling locations across Ontario and Manitoba, and corresponding latitude, longitude, elevation, and number of samples collected at each peatland.

| **Region** | **Province** | **Year** | **Peatland site code** | **Latitude** ($^{O}$N) | **Long** ($^{O}$W) | **Elevation** m a.s.l. | **No. of samples** |
|---|---|---|---|---|---|---|---|
| Attawapiskat watershed | ON | 2010 | MVRT-01 | 52.8519 | -83.9242 | 87 | 1 |
| | ON | 2010 | MVRT-02 | 52.8507 | -83.9252 | 124 | 3 |
| | ON | 2010 | MVRT-03 | 52.8467 | -83.9272 | 83 | 1 |
| | ON | 2010 | MVRT-04 | 52.8455 | -83.9272 | 78 | 2 |
| | ON | 2010 | MVRT-05 | 52.8438 | -83.9285 | 78 | 3 |
| | ON | 2010 | MVRT-06 | 52.8435 | -83.9285 | 81 | 2 |
| | ON | 2010 | MVRT-07 | 52.8417 | -83.9263 | 82 | 1 |
| | ON | 2010 | MVRT-08 | 52.8398 | -83.9303 | 53 | 1 |
| | ON | 2010 | MVT5-01 | 52.7201 | -83.9426 | 87 | 2 |
| | ON | 2010 | MVT5-02 | 52.7205 | -83.9431 | 84 | 2 |
| | ON | 2010 | MVT5-03 | 52.7205 | -83.9418 | 89 | 2 |
| | ON | 2010 | MVT5-04 | 52.7211 | -83.9390 | 87 | 2 |
| | ON | 2010 | MVMS-01 | 52.7126 | -84.1752 | 104 | 4 |
| | ON | 2010 | MVMS-02 | 52.7119 | -84.1743 | 103 | 3 |
| | ON | 2010 | MVMS-03 | 52.7130 | -84.1753 | 102 | 2 |
| | ON | 2010 | MVM-01 | 52.8502 | -83.9292 | 83 | 1 |
| Hawley Lake area | ON | 2011 | HLM1-3 | 54.5992 | -84.6403 | 135 | 3 |
| | ON | 2011 | HLM4-9 | 54.6100 | -84.6088 | 103 | 6 |
| | ON | 2011 | HLM10-15 | 54.6771 | -84.5995 | 105 | 6 |
| | ON | 2011 | HLM16,18 | 54.7528 | -84.5274 | 87 | 2 |
| Churchill | MB | 2008 | CH1 | 58.7261 | -93.8416 | 18 | 4 |
| | MB | 2008 | CH2 | 58.7343 | -93.8051 | 16 | 6 |
| | MB | 2008 | CH3 | 58.7293 | -93.7937 | 17 | 20 |
| | MB | 2008 | CH4 | 58.6181 | -93.8322 | 24 | 3 |
| Boreal Shield | ON | 2008 | JBL 1 | 51.0648 | -89.7926 | 371 | 6 |
| | ON | 2008 | JBL 2 | 52.0185 | -90.1313 | 362 | 8 |
| | ON | 2008 | JBL 3 | 52.8604 | -89.9293 | 270 | 5 |
| Severn River watershed | ON | 2008 | JBL 4 | 55.2692 | -88.9306 | 108 | 6 |
| Boreal Shield | ON | 2008 | JBL 9 | 48.8400 | -89.1200 | 488 | 6 |

Table 2-2 Common diatom species (present in at least 1% relative abundance in 1 site) and taxonomic authority found in peatland habitats across the Ontario Boreal Shield and the Hudson Plains. The numbers in the first column refer to diatom taxa that were identified by Ind-Val (i.e. diatom indicator species) for each cluster of the Multivariate Regression Tree (MRT) up until 5viii. Species numbers (6 to 51) below the horizontal line, refer to diatom taxa not identified as an indicator species by Ind-Val, but that were included in the canonical correspondence analysis (CCA) ordination plot (Figure 2.5c). Ind-Val indicator value, associated p-value, and mean percent relative abundance of each species in each cluster are also included in the table.

| **CCA Abbrev.** | **Diatom species followed by authority** | **Indicator value** | **P-value** | **Ave. % Clus.1** | **Ave. % Clus.2** | **Ave. % Clus.3** | **Ave. % Clus.4** | **Ave. % Clus.5** |
|---|---|---|---|---|---|---|---|---|
| 1 | *Eunotia paludosa* Grunow | 0.48 | 0.001 | 95.5 | 66.7 | 34.5 | 0.6 | 0.0 |
| 2a | *Eunotia mucophila* (Lange-Bertalot & Nörpel Schempp) Metzeltin, Lange-Bertalot & Garcia-Rodrigu | 0.60 | 0.001 | 1.9 | 19.4 | 3.3 | 0.0 | 0.0 |
| 2b | *Eunotia paludosa* v. *trinacria* (Krasske) Nörpel & Alles | 0.26 | 0.05 | 0.0 | 3.8 | 0.0 | 0.0 | 0.0 |
| 3a | *Aulacoseira subarctica* (O.F.Müller) E.Y.Haworth | 0.20 | 0.035 | 0.5 | 0.3 | 4.7 | 0.2 | 0.0 |
| 3b | *Staurosira construens* Ehrenberg | 0.25 | 0.043 | 1.3 | 1.0 | 4.5 | 2.3 | 0.0 |
| 3c | *Eunotia exigua* (Brébisson ex Kützing) Rabenhorst | 0.52 | 0.005 | 1.9 | 4.9 | 22.7 | 0.2 | 3.3 |
| 3d | *Staurosirella pinnata* (Ehrenberg) D.M.Williams & Round | 0.35 | 0.016 | 0.7 | 1.7 | 8.9 | 0.8 | 0.7 |
| 3e | *Gomphonema bohemicum* Hustedt | 0.23 | 0.041 | 0.0 | 0.0 | 3.7 | 0.4 | 0.0 |
| 4a | *Achnanthidium minutissimum* (Kützing) Czarnecki | 0.72 | 0.001 | 0.0 | 0.7 | 8.4 | 23.9 | 0.0 |
| 4b | *Rossithidium petersenii* (Hustedt) Round & Bukhtiyarova | 0.37 | 0.015 | 0.0 | 0.0 | 0.0 | 3.4 | 0.0 |
| 4c | *Cymbopleura angustata* (W.Smith) Krammer | 0.32 | 0.015 | 0.0 | 0.0 | 0.0 | 3.4 | 0.0 |
| 4d | *Encyonema aueri* (Krasske) Krammer | 0.21 | 0.009 | 0.0 | 0.0 | 0.0 | 3.7 | 0.0 |
| 4e | *Cymbella cistula* (Ehrenberg) O.Kirchner | 0.19 | 0.04 | 0.0 | 0.0 | 1.5 | 2.3 | 0.0 |
| 4f | *Cymbopleura incerta* (Grunow) K.Krammer | 0.57 | 0.001 | 0.0 | 0.2 | 0.0 | 7.9 | 0.0 |
| 4g | *Encyonema latens* (Krasske) D.G.Mann | 0.32 | 0.019 | 0.0 | 0.0 | 0.0 | 2.1 | 0.0 |
| 4h | *Encyonopsis microcephala* (Grunow) Krammer | 0.55 | 0.002 | 0.0 | 0.2 | 10.7 | 18.7 | 0.0 |
| 4i | *Encyonema paucistriatum* (Cleve-Euler) D.G.Mann | 0.21 | 0.014 | 0.0 | 0.0 | 0.0 | 3.0 | 0.0 |
| 4j | *Encyonema silesiacum* (Bleisch) D.G.Mann | 0.73 | 0.001 | 0.0 | 0.7 | 0.0 | 16.3 | 1.9 |
| 4k | *Cymbopleura subaequalis* (Grunow) Krammer | 0.42 | 0.004 | 0.0 | 0.0 | 0.0 | 3.7 | 0.0 |
| 4l | *Denticula kuetzingii* Grunow | 0.59 | 0.001 | 0.3 | 0.2 | 9.9 | 17.2 | 0.0 |
| 4m | *Diatoma tenuis* C.Agardh | 0.31 | 0.026 | 0.0 | 0.0 | 3.4 | 4.9 | 0.0 |
| 4n | *Epithemia adnata* (Kützing) Brébisson | 0.30 | 0.026 | 0.2 | 0.2 | 0.0 | 5.3 | 0.0 |
| 4o | *Fragilaria capucina* Desmazières | 0.45 | 0.005 | 0.0 | 0.4 | 6.7 | 9.7 | 1.4 |
| 4p | *Fragilaria tenera* (W.Smith) Lange-Bertalot | 0.82 | 0.001 | 0.2 | 0.5 | 1.5 | 14.0 | 0.0 |
| 4q | *Gomphonema acuminatum* Ehrenberg | 0.29 | 0.025 | 0.0 | 0.2 | 0.0 | 5.6 | 1.3 |
| 4r | *Gomphonema angustatum* (Kützing) Rabenhorst | 0.41 | 0.004 | 0.0 | 0.2 | 0.0 | 4.3 | 0.0 |

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|---|---|---|---|---|---|---|---|---|
| 4s | *G. angustatum* v. *undulatum* | 0.29 | 0.015 | 0.0 | 0.8 | 0.0 | 7.6 | 0.0 |
| 4t | *Gomphonema gracile* Ehrenberg | 0.59 | 0.001 | 0.0 | 0.6 | 0.0 | 10.1 | 0.0 |
| 4u | *Gomphonema lagerheimii* A.Cleve | 0.32 | 0.019 | 0.0 | 0.0 | 0.0 | 2.9 | 0.0 |
| 4v | *Adlafia bryophila* (J.B.Petersen) Gerd Moser, Lange-Bertalot & D.Metzeltin | 0.37 | 0.013 | 0.0 | 0.0 | 0.0 | 3.9 | 0.0 |
| 4w | *Navicula cryptocephala* Kützing | 0.72 | 0.001 | 0.0 | 0.2 | 4.3 | 14.6 | 0.0 |
| 4x | *Navicula cryptotenella* Lange-Bertalot | 0.24 | 0.026 | 0.0 | 0.2 | 0.0 | 2.2 | 0.0 |
| 4y | *Sellaphora pupula* (Kützing) Mereschkovsky | 0.29 | 0.024 | 0.0 | 0.4 | 1.5 | 3.0 | 0.0 |
| 4z | *Navicula radiosa* Kützing | 0.63 | 0.001 | 0.0 | 0.0 | 0.0 | 5.7 | 0.0 |
| 4i | *Navicula tuscula* (Ehrenberg) Grunow | 0.42 | 0.004 | 0.0 | 0.0 | 0.0 | 2.5 | 0.0 |
| 4ii | *Nitzschia frustulum* (Kützing) Grunow | 0.46 | 0.002 | 0.0 | 0.3 | 0.0 | 6.0 | 0.0 |
| 4iii | *Nitzschia intermedia* Hantzsch ex Cleve & Grunow | 0.47 | 0.002 | 0.0 | 0.0 | 0.0 | 4.5 | 0.0 |
| 4iv | *Nitzschia linearis* W.Smith | 0.37 | 0.007 | 0.0 | 0.2 | 2.1 | 5.5 | 0.0 |
| 4*v* | *Nitzschia perminuta* (Grunow) M.Peragallo | 0.65 | 0.001 | 0.0 | 2.0 | 8.6 | 54.7 | 14.9 |
| 4vi | *Rhopalodia gibba* (Ehrenberg) Otto Müller | 0.25 | 0.026 | 0.0 | 0.1 | 0.0 | 3.0 | 0.0 |
| 4vii | *Stauroneis phoenicenteron* (Nitzsch) Ehrenberg | 0.28 | 0.04 | 0.3 | 0.2 | 2.1 | 4.7 | 3.5 |
| 5a | *Brachysira brebissonii* R.Ross | 0.51 | 0.003 | 0.0 | 1.5 | 0.0 | 0.0 | 16.2 |
| 5b | *Brachysira hofmanniae* Lange-Bertalot | 0.22 | 0.05 | 0.0 | 0.0 | 0.0 | 0.0 | 1.8 |
| 5c | *Caloneis tenuis* (W.Gregory) Krammer | 0.40 | 0.004 | 0.0 | 0.0 | 0.0 | 2.7 | 6.5 |
| 5d | *Encyonema gracile* Kirchner | 0.76 | 0.002 | 0.0 | 0.2 | 0.0 | 2.9 | 18.6 |
| 5e | *Eunotia arcus* Ehrenberg | 0.31 | 0.005 | 0.0 | 0.0 | 0.0 | 0.4 | 5.1 |
| 5f | *Eunotia argus* Ehrenberg | 0.76 | 0.001 | 0.0 | 0.0 | 0.0 | 0.3 | 12.5 |
| 5g | *Eunotia bilunaris* (Ehrenberg) Schaarschmidt | 0.58 | 0.003 | 1.1 | 2.0 | 2.4 | 2.4 | 14.8 |
| 5h | *Eunotia faba* (Ehrenberg) Grunow | 0.54 | 0.001 | 0.0 | 0.1 | 0.0 | 0.0 | 4.4 |
| 5i | *Eunotia fallax* A.Cleve | 0.33 | 0.022 | 0.0 | 1.3 | 0.0 | 0.0 | 3.9 |
| 5j | *Eunotia flexuosa* (Brébisson ex Kützing) Kützing | 0.70 | 0.002 | 0.0 | 0.7 | 0.0 | 0.3 | 9.3 |
| 5k | *Eunotia glacialis* Meister | 0.85 | 0.001 | 0.0 | 0.2 | 0.0 | 2.6 | 16.0 |
| 5l | *Eunotia hexaglyphis* Ehrenberg | 0.67 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 | 5.9 |
| 5m | *Eunotia incisa* W.Smith ex W.Gregory | 0.67 | 0.002 | 0.0 | 0.0 | 0.0 | 0.0 | 13.9 |
| 5n | *Eunotia maior* (Smith) Rabenhorst | 0.33 | 0.007 | 0.0 | 0.0 | 0.0 | 0.0 | 3.3 |
| 5o | *Eunotia naegelli* Migula | 0.43 | 0.006 | 0.0 | 0.1 | 0.0 | 0.0 | 3.8 |
| 5p | *Eunotia nymanniana* Grunow | 0.42 | 0.007 | 0.3 | 3.7 | 0.0 | 2.5 | 11.4 |
| 5q | *Eunotia paludosa* morphotype 2 *sensu lato* Hamilton and Siver 2010 | 0.54 | 0.004 | 0.4 | 3.4 | 3.7 | 2.6 | 15.2 |
| 5r | *Eunotia pectinalis* (Kützing) Rabenhorst | 0.32 | 0.01 | 0.0 | 0.0 | 1.5 | 0.2 | 4.3 |
| 5s | *Eunotia praerupta* Ehrenberg | 0.84 | 0.001 | 0.0 | 0.0 | 0.0 | 3.8 | 19.5 |
| 5t | *Eunotia septentrionalis* Østrup | 0.85 | 0.001 | 0.0 | 0.8 | 0.0 | 0.0 | 16.5 |

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|---|---|---|---|---|---|---|---|---|
| 5u | *Eunotia serra* Ehrenberg | 0.56 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 | 5.7 |
| 5v | *Fragilaria ulna* (Nitzsch) Lange-Bertalot | 0.64 | 0.001 | 0.3 | 0.6 | 2.4 | 2.2 | 13.6 |
| 5w | *Frustulua rhomboides* (Ehrenberg) De Toni | 0.57 | 0.003 | 0.3 | 1.6 | 1.7 | 0.3 | 23.5 |
| 5x | *Gomphonema intricatum* Kützing | 0.72 | 0.001 | 0.0 | 0.1 | 0.0 | 0.6 | 9.3 |
| 5y | *Gomphonema parvulum* (Kützing) Kützing | 0.64 | 0.001 | 0.0 | 0.0 | 1.5 | 2.1 | 9.0 |
| 5z | *Diadesmis gallica* (W.Smith) Lagerstedt | 0.33 | 0.014 | 1.2 | 0.1 | 2.1 | 0.6 | 6.2 |
| 5i | *Chamaepinnularia mediocris* Krasske | 0.53 | 0.002 | 0.0 | 1.1 | 2.4 | 0.0 | 13.5 |
| 5ii | *Chamaepinnularia soehrensis* Krasske | 0.55 | 0.001 | 0.3 | 1.1 | 0.0 | 0.0 | 6.5 |
| 5iii | *Pinnularia divergens* W.Smith | 0.29 | 0.012 | 0.0 | 0.1 | 0.0 | 0.3 | 2.9 |
| 5iv | *Pinnularia microstauron* (Ehrenberg) Cleve | 0.27 | 0.05 | 0.9 | 0.8 | 2.4 | 0.9 | 4.5 |
| 5*v* | *Pinnularia streptoraphe* Cleve | 0.72 | 0.001 | 0.0 | 0.4 | 0.0 | 0.3 | 7.5 |
| 5vi | *Tabellaria fenestrata* (Lyngbye) Kützing | 0.67 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 | 7.2 |
| 5vii | *Tabellaria flocculosa* (Roth) Kützing | 0.70 | 0.001 | 0.7 | 0.4 | 3.3 | 2.1 | 24.8 |
| 5viii | *Tabellaria flocculosa* v. *linearis* J.D.Koppen | 0.67 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 | 15.4 |
| 6 | *Aulacoseira* spp. Thwaites |  |  | 1.5 | 0.9 | 3.3 | 1.1 | 0.7 |
| 7 | *Aulacoseira ambigua* (Grunow) Simonsen |  |  | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 |
| 8 | *Brachysira zellensis* (Grunow) Round & D.G.Mann |  |  | 0.2 | 0.2 | 4.4 | 3.4 | 12.0 |
| 9 | *Caloneis bacillum* (Grunow) Cleve |  |  | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 |
| 10 | *Caloneis molaris* (Grunow) Krammer |  |  | 0.0 | 0.0 | 0.0 | 3.4 | 0.0 |
| 11 | *Caloneis undulata* (Gregory) Krammer |  |  | 0.0 | 0.0 | 0.0 | 1.6 | 2.5 |
| 12 | *Encyonopsis descripta* (Hustedt) Krammer |  |  | 4.4 | 0.0 | 4.0 | 4.7 | 0.0 |
| 13 | *Cymbopleura lapponica* (Grunow) Krammer |  |  | 0.0 | 0.0 | 4.3 | 4.1 | 0.0 |
| 14 | *Encyonema minutum* (Hilse) D.G.Mann |  |  | 0.0 | 0.1 | 5.2 | 6.4 | 3.9 |
| 15 | *Cymbella naviculacea* Grunow |  |  | 0.0 | 0.0 | 0.0 | 0.4 | 3.4 |
| 16 | *Cymbopleura naviculiformis* (Auerswald) Krammer |  |  | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 |
| 17 | *Encyonema norvegicum* (Grunow in A.Schmidt et al.) Bukhtiyarova |  |  | 0.0 | 0.2 | 1.5 | 4.7 | 1.4 |
| 18 | *Cymbella subarctica* Krammer |  |  | 0.0 | 0.0 | 0.0 | 0.6 | 0.0 |
| 19 | *Eunotia arculus* (Grunow) Lange-Bertalot & Nörpel |  |  | 0.0 | 0.0 | 0.0 | 0.0 | 1.4 |
| 20 | *Eunotia fennica* (Hustedt) Lange-Bertalot |  |  | 0.0 | 7.9 | 2.9 | 0.0 | 0.4 |
| 21 | *Gomphonema subtile* Ehrenberg |  |  | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 |
| 22 | *Eunotia implicata* Nörpel, Lange-Bertalot & Alles |  |  | 0.0 | 0.0 | 0.0 | 0.0 | 3.6 |
| 23 | *Eunotia lapponica* Grunow |  |  | 0.3 | 2.9 | 0.0 | 0.0 | 0.0 |
| 24 | *Staurosira brevistriata* (Grunow) Grunow |  |  | 0.4 | 0.2 | 0.0 | 0.0 | 0.0 |
| 25 | *Gomphonema amoenum* Lange-Bertalot |  |  | 0.0 | 0.0 | 0.0 | 0.8 | 0.0 |
| 26 | *Gomphonema angustum* C.Agardh |  |  | 0.2 | 0.0 | 0.0 | 1.1 | 0.0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 27 | *Gomphonema clavatum* Ehrenberg | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 |
| 28 | *Gomphonema hebridense* W.Gregory | 0.0 | 0.0 | 0.0 | 0.6 | 0.0 |
| 29 | *Gomphonema longiceps* Ehrenberg | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 |
| 30 | *Hantzschia amphioxys* (Ehrenberg) Grunow | 3.9 | 4.9 | 5.6 | 7.5 | 0.0 |
| 31 | *Navicula eidrigiana* J.R.Carter | 0.0 | 0.0 | 0.0 | 0.9 | 0.0 |
| 32 | *Navicula festiva* Krasske | 0.0 | 1.5 | 0.0 | 0.0 | 0.0 |
| 33 | *Kobayasiella jaegii* (Meister) Lange-Bertalot | 0.0 | 0.0 | 0.0 | 1.5 | 1.7 |
| 34 | *Navicula lanceolata* (Agardh) Edrenberg | 0.0 | 0.0 | 0.0 | 0.7 | 0.0 |
| 35 | *Luticola mutica* (Kützing) D.G.Mann | 3.9 | 4.8 | 2.6 | 5.4 | 1.8 |
| 36 | *Navicula peregrina* (Ehrenberg) Kutzing | 0.0 | 0.0 | 3.7 | 2.6 | 0.0 |
| 37 | *Navicula rhynchocephala* Ehrenberg | 0.0 | 0.2 | 0.0 | 0.8 | 0.0 |
| 38 | *Navicula striolata* (Grunow) Lange-Bertalot | 0.0 | 0.0 | 0.0 | 1.3 | 0.0 |
| 39 | *Kobayasiella subtilissima* (Cleve) Lange-Bertalot 1999 | 1.9 | 36.2 | 48.3 | 1.3 | 22.6 |
| 40 | *Navicula viridula* (Kutzing) Ehrenberg | 0.0 | 0.0 | 3.0 | 3.6 | 0.0 |
| 41 | *Navicula vulpina* Kutzing | 0.0 | 0.0 | 0.0 | 0.6 | 0.0 |
| 42 | *Neidium* spp. Pfitzer | 0.0 | 0.0 | 0.0 | 0.8 | 0.4 |
| 43 | *Nitzschia alpina* Hustedt | 0.3 | 0.0 | 3.0 | 1.4 | 0.0 |
| 44 | *Pinnularia biceps* W.Gregory | 1.0 | 0.1 | 0.0 | 0.0 | 0.0 |
| 45 | *Pinnularia borealis* Ehrenberg | 1.3 | 2.8 | 3.9 | 4.3 | 0.0 |
| 46 | *Pinnularia gibba* Ehrenberg | 0.0 | 0.6 | 0.0 | 0.0 | 1.1 |
| 47 | *Pinnularia interrupta* W.Smith | 1.8 | 0.5 | 1.5 | 0.0 | 0.5 |
| 48 | *Pinnularia maior* (Kützing) Cleve | 0.0 | 3.7 | 0.0 | 0.4 | 0.6 |
| 49 | *Pinnularia* cf. *microstauron* (small size) | 2.1 | 0.6 | 0.0 | 0.0 | 0.0 |
| 50 | *Pinnularia rupestris* Hantzsch | 0.0 | 2.3 | 0.0 | 0.3 | 0.0 |
| 51 | *Pinnularis supcapitata* W.Gregory | 0.5 | 0.4 | 0.0 | 0.0 | 0.0 |

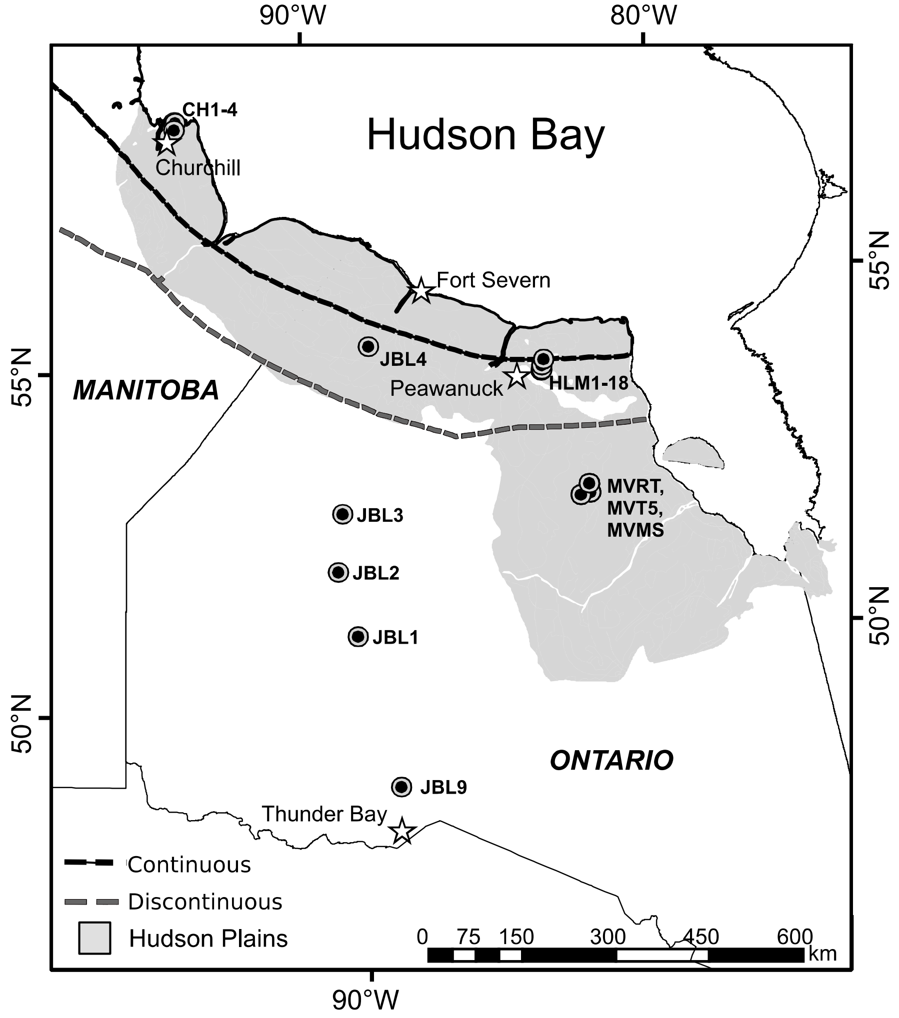

Figure 2-1 Locations of peatland sampling sites across Ontario and Manitoba with the Hudson Plains and the southern permafrost boundaries delineated.

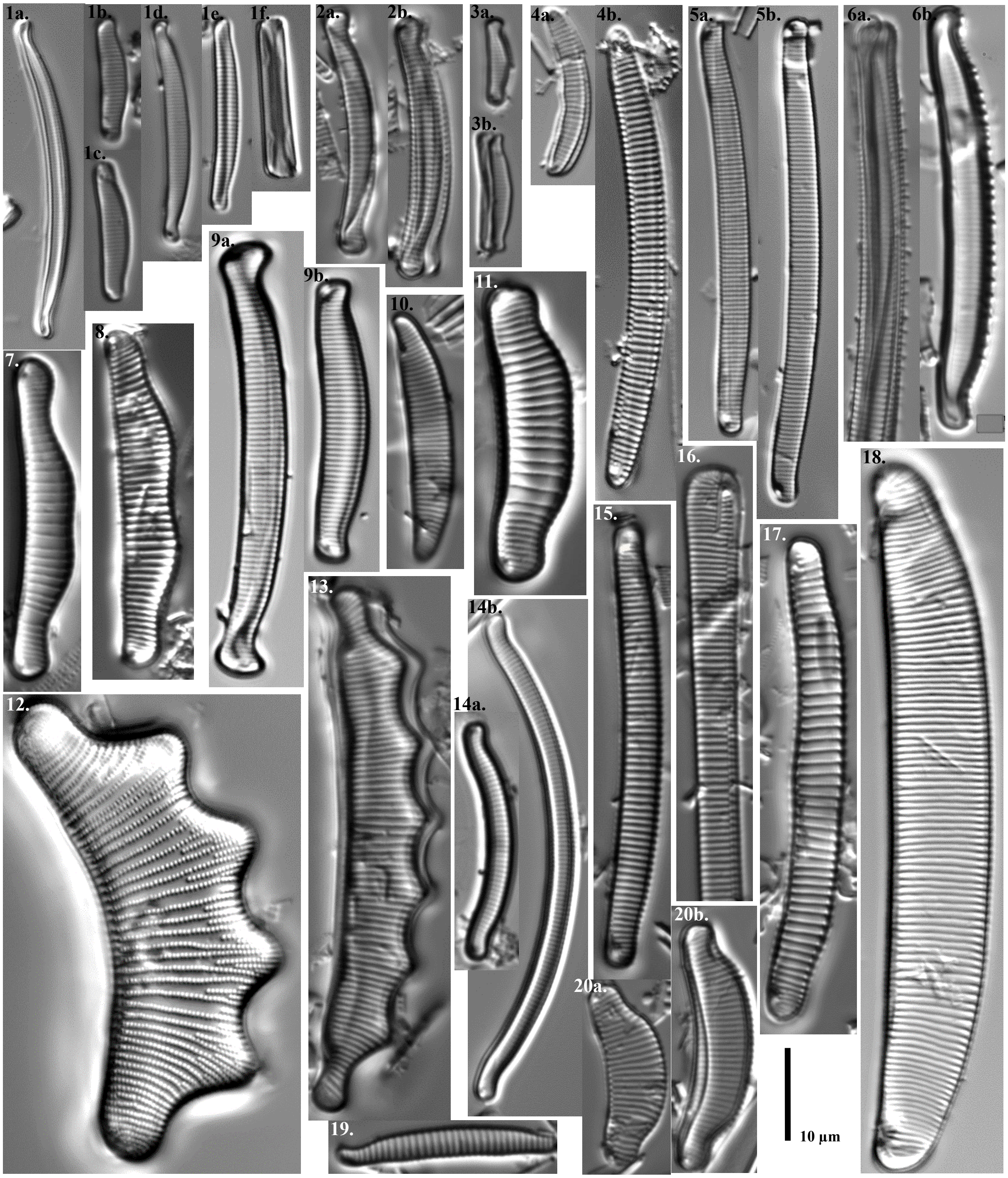

Figure 2-2 Common *Eunotia* taxa encountered in northern Ontario peatlands. Photo1a-f. *Eunotia paludosa*; 2a-b. *Eunotia paludosa* morphotype 2; 3a-b. *Eunotia paludosa* v. *trinacria*; 4a-b. *Eunotia bilunaris*; 5a-b. *Eunotia mucophila*; 6a.-b. *Eunotia fennica*; 7. *Eunotia implicata*; 8. *Eunotia argus*; 9a-b. *Eunotia nymanniana*; 10. *Eunotia incisa*; 11. *Eunotia praerupta*; 12. *Eunotia serra*; 13. *Eunotia hexaglyphis*; 14a-b. *Eunotia exigua*; 15. *Eunotia glacialis*; 16. *Eunotia flexuosa*; 17. *Eunotia pectinalis*; 18. *Eunotia lapponica*; 19. *Eunotia fallax*; 20a-b. *Eunotia septentrionalis*.

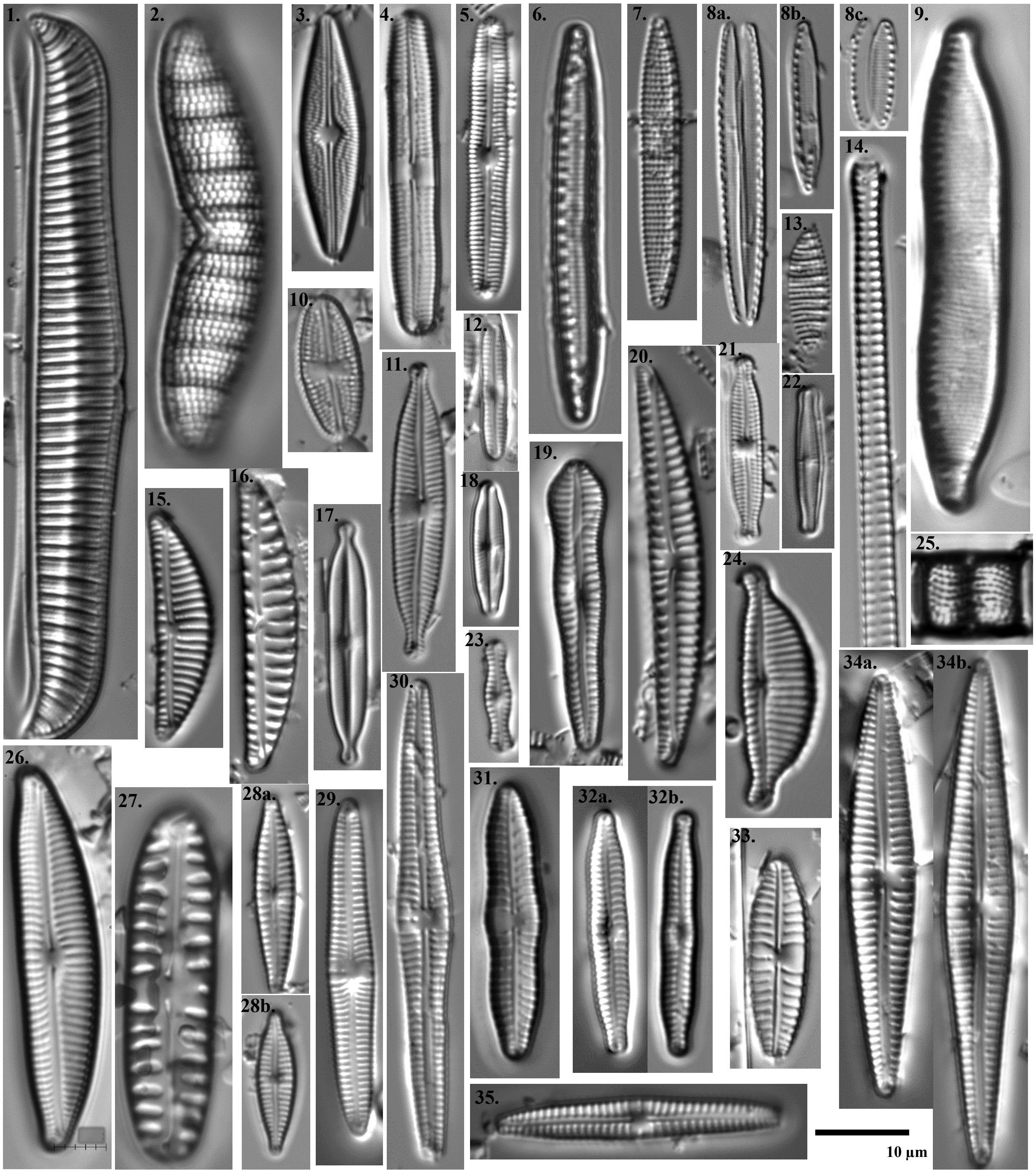

Figure 2-3 Common diatom taxa found in northern Ontario peatlands. Photo1. *Rhopalodia gibba*; 2. *Epithemia adnata*; 3. *Brachysira brebissonii*; 4. *Caloneis undulata*; 5. *Caloneis tenuis*; 6. *Nitzschia alpina*; 7. *Nitzschia frustulum*; 8a-c. *Nitzschia perminuta*; 9. *Hantzschia amphioxys*; 10. *Luticola mutica*; 11. *Encyonopsis descripta*; 12. *Chamaepinnularia mediocris*; 13. *Denticula kuetzingii*; 14. *Fragilaria ulna*; 15. *Encyonema silesiacum*; 16. *Encyonema paucistriata*; 17. *Kobayasiella subtilissima*; 18. *Adlafia bryophila*; 19. *Gomphonema acuminatum*; 20. *Encyonema gracile*; 21. *Encyonopsis microcephala*; 22. *Achnanthidium minutissimum*; 23. *Chamaepinnularia soehrensis*; 24. *Encyonema latens*; 25. *Aulacoseira subarctica*; 26. *Encyonema norvegicum*; 27. *Pinnularia borealis*; 28a-b. *Gomphonema parvulum*; 29. *Gomphonema intricatum*; 30. *Gomphonema hebridense*; 31. *Gomphonema lagerheimii*; 32a-b. *Gomphonema angustatum* v. *undulatum*; 33. *Gomphonema angustatum*; 34a-b. *Gomphonema gracile*; 35. *Gomphonema* cf. *bohemicum*.

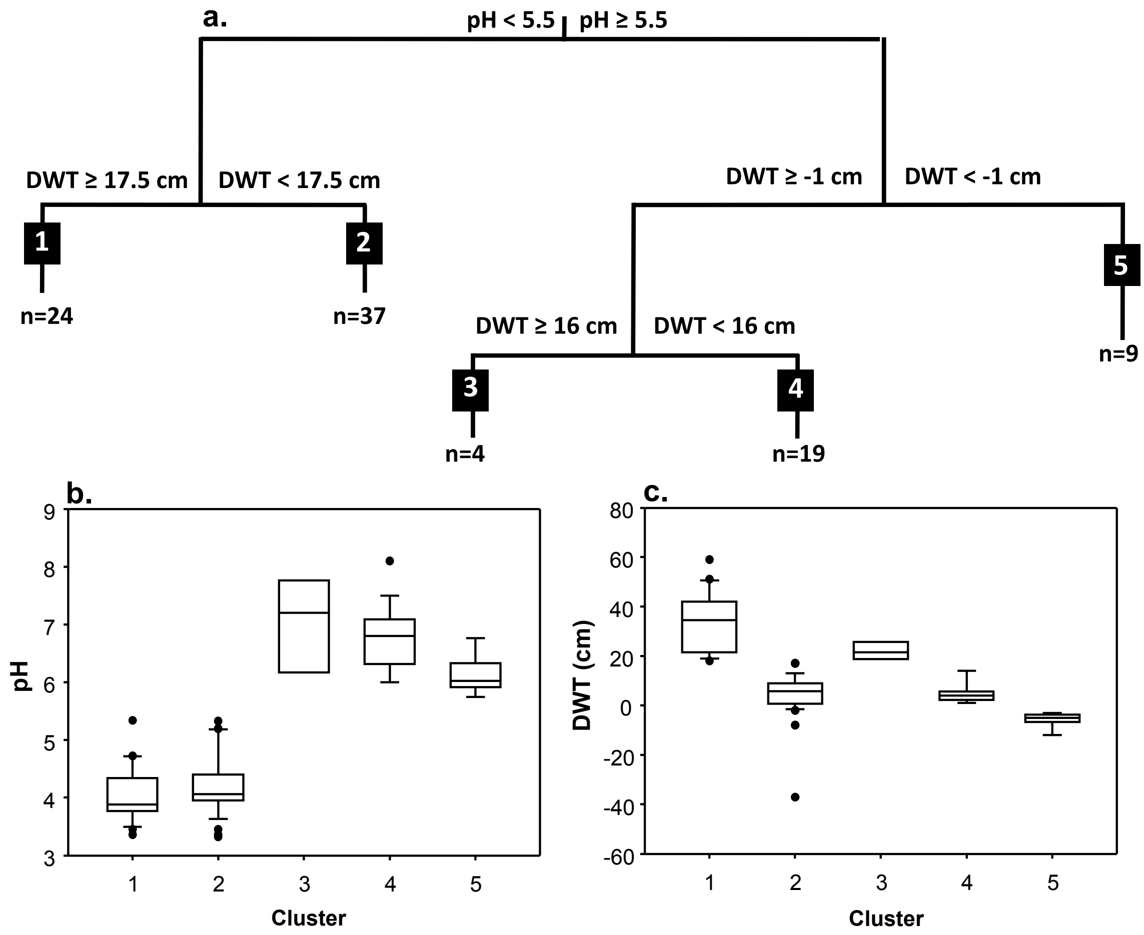

Figure 2-4 (a) Multivariate regression tree (MRT) for the diatom assemblages from the 93 surface peat data set with the measured environmental variables pH and depth to water table (DWT). For each cluster, the number of samples (n=x) are identified below, (b) and (c) Boxplots of pH and DWT organized by MRT cluster.

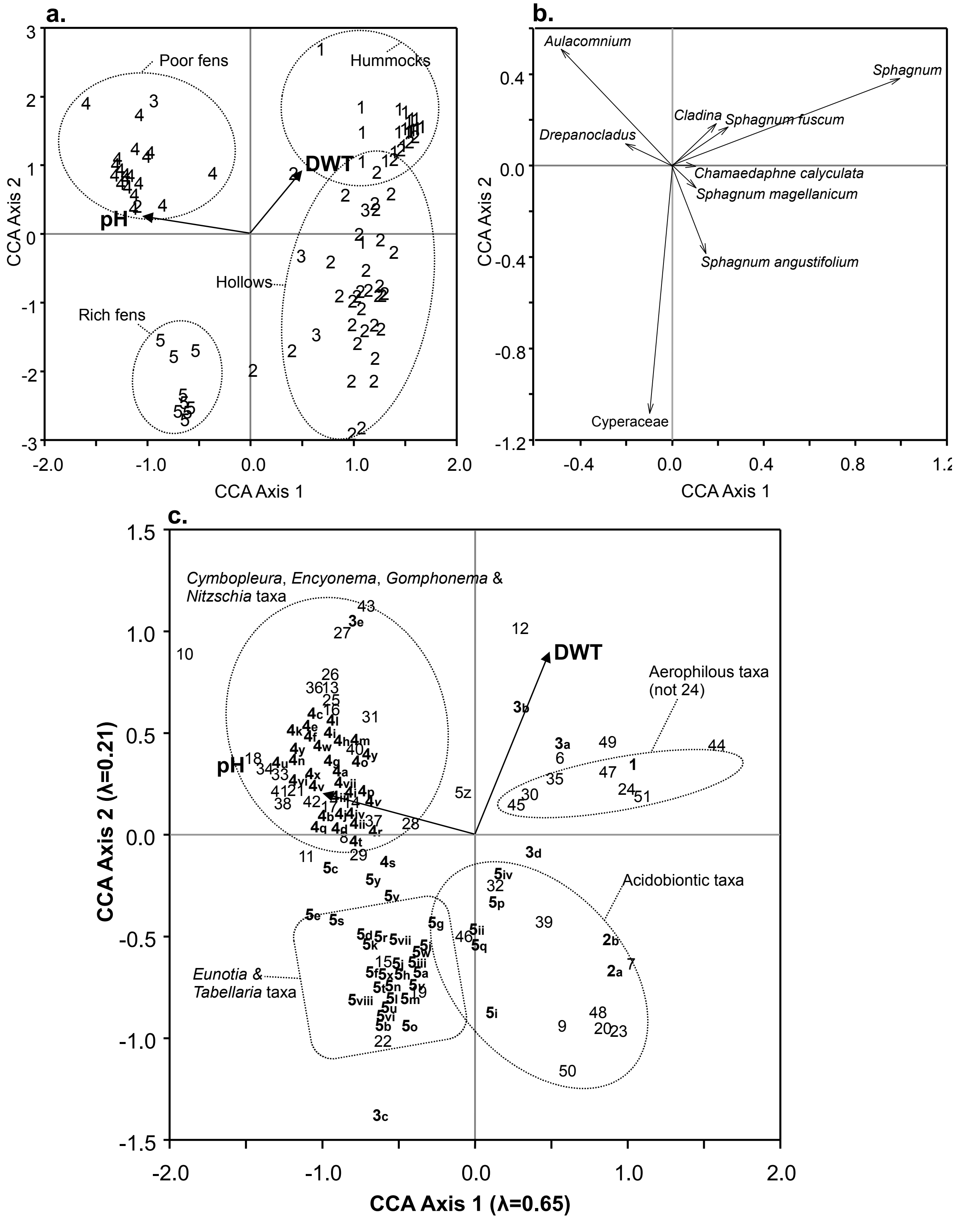

Figure 2-5 Canonical correspondence analysis (CCA) ordination plots for: (a) sites scores with numbers representing multivariate regression tree (MRT) clusters; (b) supplementary vegetation data for the dominant vegetation sampled at each site; and (c) diatom species scores with significant species for each cluster bolded. Species scores are represented with numbers, letters, and roman numerals and the corresponding names can be found in Table 2.2.

Supplemental Table 1-1 Specific site data including: associated cluster from the multivariate regression tree (MRT) or samples with no diatoms (N.D.) present, pH, depth to water table (DWT) values, and dominant vegetation type sampled.

| Cluster | Site Name | DWT (cm) | pH | Dominant vegetation type |
|---|---|---|---|---|
| 1 | HLM01 | 29 | 4.3 | *Sphagnum, Andromeda polifolia, Vaccinium* |
| 1 | HLM04 | 22 | 4.37 | *Cladina, Chamaedaphne calyculata* |
| 1 | HLM10 | 21 | 3.82 | *Sphagnum, Chamaedaphne calyculata* |
| 1 | JBL1-1A | 39 | 4.72 | *Sphagnum fuscum* |
| 1 | JBL1-1B | 32 | 5.34 | *Sphagnum fuscum* |
| 1 | JBL1-1C | 38 | 4.71 | *Sphagnum fuscum* |
| 1 | JBL2-1A | 45 | 3.81 | *Sphagnum fuscum* |
| 1 | JBL2-1C | 50 | 3.79 | *Sphagnum fuscum* |
| 1 | JBL2-2B | 19 | 4.4 | *Sphagnum fuscum* |
| 1 | JBL2-2C | 20 | 4.44 | *Sphagnum angustifolium* |
| 1 | JBL3-1A | 59 | 3.89 | *Sphagnum fuscum* |
| 1 | JBL3-1C | 40 | 4.26 | *Sphagnum fuscum* |
| 1 | JBL4-1A | 32 | 3.45 | *Sphagnum fuscum* |
| 1 | JBL4-1B | 27 | 3.53 | *Sphagnum fuscum* |
| 1 | JBL4-1C | 32 | 3.36 | *Sphagnum fuscum* |
| 1 | JBL9-1A | 51 | 3.61 | *Sphagnum fuscum* |
| 1 | JBL9-1B | 48 | 3.96 | *Sphagnum fuscum* |
| 1 | JBL9-1C | 37 | 3.74 | *Sphagnum fuscum* |
| 1 | JBL9-2B | 19 | 3.92 | *Sphagnum angustifolium* |
| 1 | MVT5-01-01 | 43 | 3.87 | *Sphagnum, Chamaedaphne calyculata, Cladina* |
| 1 | MVT5-02-01 | 40 | 3.82 | *Sphagnum, Chamaedaphne calyculata, Cladina* |
| 1 | MVT5-02-02 | 18 | 3.87 | *Sphagnum, Chamaedaphne calyculata, Cladina* |
| 1 | MVT5-03-01 | 40 | 3.92 | *Sphagnum, Chamaedaphne calyculata,* Cyperaceae |
| 1 | MVT5-04-01 | 20 | 3.73 | *Sphagnum* |
| 2 | CH3-22 | 0.5 | 5.2 | *Aulacomnium* |
| 2 | HLM02 | 12 | 4.06 | *Cladina* |
| 2 | HLM05 | 0 | 4.05 | *Sphagnum, Cladina* |

|  |  |  |  |  |
|---|---|---|---|---|
| 2 | HLM06 | -2 | 4.06 | *Sphagnum* |
| 2 | HLM07 | 6 | 4.38 | *Sphagnum, Chamaedaphne calyculata*, sedges |
| 2 | HLM08 | -8 | 4.44 | *Sphagnum*, sedges |
| 2 | HLM09 | 8 | 4.37 | *Sphagnum*, sedges |
| 2 | HLM11 | 0 | 4.29 | *Sphagnum, Chamaedaphne calyculata*, Cyperaceae |
| 2 | HLM12 | 13 | 4.03 | *Sphagnum, Cladina* |
| 2 | HLM14 | 13 | 3.99 | *Sphagnum, Chamaedaphne calyculata, Cladonia, Rubus chamaemorus* |
| 2 | HLM15 | 0 | 4.35 | *Sphagnum* |
| 2 | JBL1-2A | 9 | 5.33 | *Sphagnum fuscum* |
| 2 | JBL1-2B | 6 | 5.19 | Carex |
| 2 | JBL1-2C | 4 | 5.18 | Carex |
| 2 | JBL2-2A | 17 | 4.44 | *Sphagnum angustifolium* |
| 2 | JBL2-3A | 1 | 4.48 | *Sphagnum angustifolium* |
| 2 | JBL2-3B | 1 | 3.32 | *Sphagnum angustifolium* |
| 2 | JBL2-3C | 1 | 4.23 | *Sphagnum angustifolium* |
| 2 | JBL3-2A | 10 | 4.28 | *Sphagnum angustifolium* |
| 2 | JBL3-2B | 13 | 4.4 | *Sphagnum angustifolium* |
| 2 | JBL3-2C | 17 | 4.46 | *Sphagnum angustifolium* |
| 2 | JBL4-2A | 9 | 3.36 | *Sphagnum magellanicum* |
| 2 | JBL4-2B | 8 | 3.65 | *Sphagnum magellanicum* |
| 2 | JBL4-2C | 5 | 3.45 | *Sphagnum magellanicum* |
| 2 | JBL9-2A | 12 | 3.95 | *Sphagnum angustifolium* |
| 2 | JBL9-2C | 9 | 4.59 | *Sphagnum angustifolium* |
| 2 | MVM-01-01 | 5.5 | 4.03 | *Cladina, Chamaedaphne calyculata* |
| 2 | MVMS-01-01 | 3 | 3.94 | *Sphagnum*, Cyperaceae |
| 2 | MVMS-01-02 | 0.1 | 3.99 | *Sphagnum*, Cyperaceae |
| 2 | MVMS-01-04 | 4 | 3.82 | *Sphagnum, Chamaedaphne calyculata* |
| 2 | MVRT-02-02 | 8 | 3.94 | *Sphagnum* |
| 2 | MVRT-02-03 | -1.5 | 3.94 | *Sphagnum*, Cyperaceae |
| 2 | MVRT-04-02 | 10 | 4.11 | *Sphagnum*, Cyperaceae, *Cladina* |
| 2 | MVRT-07-01 | 7 | 4.01 | *Sphagnum*, Cyperaceae |
| 2 | MVRT-08-01 | -37 | 4.03 | *Sphagnum, Chamaedaphne calyculata* |
| 2 | MVT5-03-02 | 2 | 3.86 | *Sphagnum, Chamaedaphne calyculata,* Cyperaceae |
| 2 | MVT5-04-02 | 0.1 | 3.73 | *Sphagnum*, Cyperaceae |

| | | | | |
|---|---|---|---|---|
| 3 | CH3-18 | 20 | 7 | *Aulacomnium* |
| 3 | CH4-1 | 23 | 7.9 | *Sphagnum magellanicum* |
| 3 | CH4-3 | 27 | 7.4 | *Sphagnum magellanicum* |
| 3 | MVMS-02-01 | 18 | 5.87 | *Sphagnum*, Cyperaceae |
| 4 | CH1-1 | 9 | 6.8 | *Aulacomnium* |
| 4 | CH1-2 | 4 | 7 | *Aulacomnium* |
| 4 | CH1-3 | 10 | 7.5 | *Aulacomnium* |
| 4 | CH1-4 | 2 | 6.9 | *Aulacomnium* |
| 4 | CH2-2 | 3 | 7.4 | *Aulacomnium* |
| 4 | CH2-7 | 3 | 7 | *Aulacomnium* |
| 4 | CH3-10 | 6 | 8.1 | humified |
| 4 | CH3-11 | 5 | 7.1 | *Aulacomnium* |
| 4 | CH3-12 | 6 | 6 | *Aulacomnium* |
| 4 | CH3-13 | 3 | 6.1 | *Aulacomnium* |
| 4 | CH3-15 | 14 | 6.8 | *Aulacomnium* |
| 4 | CH3-17 | 1 | 6.5 | Carex |
| 4 | CH3-20 | 1 | 6.7 | *Aulacomnium* |
| 4 | CH3-21 | 5 | 6.1 | *Aulacomnium* |
| 4 | CH3-25 | 14 | 6 | *Aulacomnium* |
| 4 | CH3-28 | 1 | 6.7 | humified |
| 4 | CH3-29 | 2 | 6.3 | *Aulacomnium* |
| 4 | CH3-30 | 2 | 6.4 | Carex |
| 4 | HLM16 | 6 | 7.17 | *Drepanocladus*, Cyperaceae, *Sphagnum* |
| 5 | HLM03 | -4 | 5.9 | *Drepanocladus*, Cyperaceae |
| 5 | MVMS-02-02 | -5 | 6.61 | Cyperaceae |
| 5 | MVMS-02-03 | -5 | 6.76 | *Drepanocladus*, Cyperaceae |
| 5 | MVRT-03-01 | -12 | 5.91 | Cyperaceae, *Chamaedaphne calyculata* |
| 5 | MVRT-05-01 | -3.5 | 6.07 | *Drepanocladus*, Cyperaceae |
| 5 | MVRT-05-02 | -3 | 5.75 | *Drepanocladus*, Cyperaceae |
| 5 | MVRT-05-03 | -6 | 6.02 | *Drepanocladus*, Cyperaceae |
| 5 | MVRT-06-01 | -8 | 6.02 | Cyperaceae |
| 5 | MVRT-06-02 | -3.5 | 5.98 | Cyperaceae |
| N.D. | CH2-1 | 7 | 8.5 | humified |
| N.D. | CH2-3 | 6 | 7.8 | *Aulacomnium* |

|  |  |  |  |  |
|---|---|---|---|---|
| N.D. | CH2-6 | 12 | 7.2 | *Aulacomnium* |
| N.D. | CH2-9 | 7 | 7.9 | *Aulacomnium* |
| N.D. | CH3-14 | 19 | 6.5 | *Aulacomnium* |
| N.D. | CH3-16 | 16 | 7.3 | *Aulacomnium* |
| N.D. | CH3-19 | 12 | 7.3 | *Aulacomnium* |
| N.D. | CH3-23 | 24 | 6.3 | *Aulacomnium* |
| N.D. | CH3-24 | 12 | 5.9 | humified |
| N.D. | CH3-26 | 7 | 5.7 | *Aulacomnium* |
| N.D. | CH4-2 | 19 | 7.7 | *Sphagnum magellanicum* |
| N.D. | HLM13 | 33 | 3.94 | *Sphagnum, Cladina, Chamaedaphne calyculata, Empetrum nigrum, Rubus chamaemorus* |
| N.D. | HLM18 | 7 | 7.22 | *Drepanocladus,* Cyperaceae |
| N.D. | MVMS-01-03 | 34 | 3.72 | *Sphagnum, Chamaedaphne calyculata, Cladina* |
| N.D. | MVMS-03-01 | 35 | 3.72 | *Sphagnum, Chamaedaphne calyculata, Cladina, Ledum groenlandicum* |
| N.D. | MVMS-03-02 | 9 | 3.8 | *Sphagnum, Chamaedaphne calyculata, Cladina, Ledum groenlandicum* |
| N.D. | MVRT-01-01 | 17 | 3.9 | *Cladina, Chamaedaphne calyculata* |
| N.D. | MVRT-02-01 | 36 | 3.76 | *Sphagnum, Chamaedaphne calyculata, Cladina* |
| N.D. | MVRT-04-01 | 32 | 3.69 | *Sphagnum, Chamaedaphne calyculata, Cladina* |
| N.D. | MVT5-01-02 | 10 | 3.97 | *Cladina* |

# Chapter 3

## Long-term successional changes in peatlands of the Hudson Bay Lowlands, Canada inferred from the ecological dynamics of multiple proxies

### 3.1 Abstract

Peatlands in northern Ontario, Canada, archive multiple biological indicators including macrofossils, algae, testate amoebae, and pollen. These proxies can provide insights concerning the timing and nature of long-term climatic and environmental changes. The Hudson Bay Lowlands (HBL) of central Canada contain one of Earth's largest continuous peatland complexes, and thus, comprehensive spatial and temporal studies are needed to understand the implications of climate change on carbon cycling. Diatom assemblages were examined in three cores retrieved from ombrotrophic bogs across two Canadian terrestrial ecozones. Comparisons were made to testate amoebae and macrofossil data previously analyzed from these cores, as well as to regional pollen records from surrounding peatlands. From ~2000 to ~600 cal. BP, changes in diatom composition likely reflect hydrosere succession within the peatland including fluctuations in connectivity to the water table and pH changes. From ~600 cal. BP to present, the synchronous timing of changes in diatoms and testate amoebae are tracking drying conditions and subsequent microhabitat variations that occur within bogs. It is possible that diatoms are tracking subtle changes in the stability of peat microforms including bog hollows and hummocks, highlighting their sensitivity to small chemical change, whereas testate amoebae are tracking the lowering of a peatland water table and subsequent drying of the peatland. The use of multiple proxies provides a more holistic approach to interpreting past ecological succession and responses to climate within peatlands. When present and well-preserved, diatoms can be applied to track drying conditions in bogs, in term of both hydrosere succession and present climatic change.

**Keywords:** Hudson Bay Lowlands, diatoms, testate amoebae, peatlands, hydrosere succession

## 3.2 Introduction

Organic wetlands, or peatlands, are a dominant feature of boreal forests, covering 25-30% of these ecoregions worldwide (Vitt, 2006; Turetsky et al., 2007). Within Canada, peatlands account for ~12% of the landscape (most of which lie within boreal and subarctic regions), but contain about 56% of the organic carbon (or ~147 Gt of carbon) stored in all Canadian soils (Tarnocai, 2006). A cool climate and the presence of sporadic and discontinuous permafrost provide ideal conditions for peatland development (Gaiser and Rühland, 2010), and account for the wide distribution of peatlands in latitudes between 45ºN and 60ºN (Charman, 2002).

Within peatlands, decomposition is often impeded by waterlogged, low-oxygen conditions, and thus plant production commonly exceeds that of plant decomposition resulting in the formation and accumulation of highly organic and partially decayed plant material. The accumulation of carbon-rich peat deposits can yield continuous records of peat growth and sometimes archive climatic changes with a high temporal resolution (often decadal scale). Specifically, these records can be used to infer changes in carbon sequestration rates, temperature and surface moisture balance over the Holocene (e.g., Beilman et al., 2009). However, peat accumulation can reflect hydroseral succession within peatlands and is often driven by local factors that must be accounted for before making interpretations on climate-induced changes (Charman, 2002).

Peatlands are characterized by micro- and meso-scale topographic features, which provide a diversity of habitat types (Rydin et al., 2006). Within bogs, microhabitat types include hollows, where the acrotelm (layer of aerobic peat) is absent or very thin, and hummocks, which are elevated above hollows because of a relatively thick acrotelm overlying the anaerobic catotelm (Charman, 2002). Slight differences between wetter and drier sites can be amplified by the increased production of vascular plants that occur on the drier sites (Belyea and Clymo, 2001; Rietkerk et al., 2004) leading to spatial patterning in bogs. Hummock-hollow patterning may also be a result of nutrient accumulation under hummock ridges, which is driven by increased evapotranspiration rates by vascular plants that grow on ridges. With higher evapotranspiration rates, there is a net flow of water and dissolved nutrients towards ridges, thus further promoting higher plant diversity and growth on bog hummocks (Eppinga et al., 2009). Paleoecological proxies offer much potential for explaining the origin and maintenance of complex surface patterning in peatlands.

Biotic and abiotic indicators for surface moisture and peatland chemistry are commonly preserved within peat sequences and, when combined with appropriate dating methods, can be used to infer past ecological and climatological changes. A multiple indicator approach is often required to untangle complex signals, as peatlands respond to both external (i.e. climatic) and internal changes (i.e., vegetation succession) (e.g. Korhola, 1990; Rühland et al., 2000; Myers-Smith et al., 2007). All indicators are limited by their responses to environmental factors (e.g. moisture, pH, etc.) and these responses will differ among proxies. A multi-proxy approach allows comparisons and corroboration among the indicators, thereby strengthening paleoecological interpretations (Birks and Birks, 2006).

Diatoms (Class Bacillariophyceae) are siliceous, microscopic algae that have been used in a variety of applications due to their broad range in environmental optima and tolerances (Smol and Stoermer, 2010). Diatoms can thrive in diverse habitats, including terrestrial or “non-submerged” habitats such as mosses (Kingston, 1982; Brown et al., 1994; Gaiser and Rühland, 2010; Johansen, 2010). Different *Sphagnum* species have the capability of increasing moisture levels and changing the chemical environment thereby providing microhabitat niches that are suitable to the survival of specialized diatom species in this otherwise harsh environment (Kingston, 1982; Beyens, 1985; Poulíčková et al., 2004; Chen et al., 2012). Comprehensive studies of diatom flora from both modern and Holocene peatland systems remain scarce, particularly in northern latitudes.

When present and well-preserved, diatoms can provide additional environmental information on peatland development as they often respond differently to a given environmental cue than other proxies, such as macrofossils and pollen examined from the same peat sequence (Rühland et al., 2000, 2006; Myers-Smith et al., 2007; Fukumoto et al., 2012). Although peatlands provide a challenging and harsh environment, fossil diatom assemblages preserved in peat sequences have been used successfully to further understanding of autogenic processes and climatic changes over the Holocene (Brown et al., 1994; Campbell et al., 1997; Rühland et al., 2000; Rühland et al., 2006; Myers-Smith et al., 2007).

Testate amoebae (Protozoa: Rhizopoda), or thecaomoebians, are frequently the most common protists living in bog vegetation, with estimated concentrations as high as $1.6 \times 10^6$ individuals per $m^2$ (Beyens and Meisterfeld, 2001). It is therefore no surprise that they are a more widely studied biological indicator in ombrotrophic peatlands than diatoms. Testate amoebae are highly sensitive to changes in the moisture regime. Although testate amoebae are best used to model and reconstruct past hydrological conditions (Charman et al., 2007; Payne et al., 2008, 2012; Booth, 2010), the responses of peatland water tables to climate, especially within ombrotrophic bogs are still poorly understood (e.g. Swindles et al., 2012). Mitchell et al. (2008) highlighted that, with a few exceptions, studies that have combined the results of testate amoebae with independent lines of evidence provided by other proxies are scarce. For instance, Gehrels et al. (2001) used a combination of foraminifera, testate amoebae and diatoms to reconstruct sea-level fluctuations in UK salt marshes, and found that a training set of all three biological indicators yielded more accurate reconstructions of tidal level than a training set with any single proxy.

The remains of thecamoebians that produce siliceous tests (as opposed to proteinaceous or calcareous thecameobians) are often used as an additional proxy that can be examined in combination with diatom analysis (Douglas and Smol, 2001). Typically, the use of testate amoebae in this way will provide supporting data based on, for example, a ratio of diatoms to siliceous testate amoebae plates (or a ratio of all siliceous indicators to testate amoebae plates). This ratio can be used as an independent line of evidence for tracking large aquatic or bryophytic changes such as a transition from a shallow, limnetic environment to a fen with the development of *Sphagnum* communities (Douglas and Smol, 1987), and the transition from a rich fen to a *Sphagnum*-dominated habitat within peatlands (Rühland et al., 2000).

Chrysophyte stomatocysts (Class Chrysophyceae and Synurophyceae), although a less commonly used proxy in peat studies than diatoms or testate amoebae, have been used to track a wide set of environmental conditions including past lakewater nutrient fluctuations (Smol, 1985), salinity (Cumming et al., 1993), and the extent of lake-ice cover related to climatic conditions (Smol, 1983; Zeeb and Smol, 1993; Lotter et al., 1997). Like protozoan plates, total cyst counts are often expressed relative to the total number of diatom frustules (Smol, 1985) or valves enumerated in a sample (C:D%) (Douglas and Smol, 2001), allowing for a rapid assessment of shifts between these two major algal groups. Although chrysophyte algae are more commonly associated with planktonic, slightly acidic and nutrient-poor conditions, periphytic taxa, associated with macrophytes and mosses have been observed in lakes and ponds at high latitudes (Douglas and Smol, 1995; Wilkinson et al., 1997; Zeeb and Smol, 2001). Studies have found that, in contrast to diatoms, chrysophyte stomatocysts are present and diverse in desiccated environments, such as the upper surface layer of peat bogs, which may be explained by their association with mosses and possibly the acidic and low nutrient conditions (Jasinski et al., 1998; Buczkó, 2006).

Fossil pollen and plant macrofossils preserved in lake and peat deposits are important for providing insights into regional and local vegetation changes over long time periods (Birks, 1993; Birks and Birks, 2006). These proxies represent different spatial scales with arboreal and shrub pollen often representing the vegetation covering the landscape at a broad scale, and hydrophytic pollen and spores reflecting localized macrophyte or bryophyte growth. Often the pollen and spores encountered help to distinguish the autogenic processes influencing ecosystem function (e.g. macrophyte establishment, hydroseral succession) versus climate or other allogenic (external) processes (e.g. biogeochemical cycle, soil development and associated changes in vegetation) (Birks et al., 2000). Fossil pollen analysis complements most paleolimnological and paleoecological studies utilizing diatoms because an understanding of catchment vegetation and its changes helps to validate interpretations or to evaluate alternative explanations for diatom changes.

The combined use of two paleoenvironmental indicators that are highly sensitive to chemical and moisture changes (i.e., diatoms and testate amoebae) has rarely been exploited (but see Beyens, 1985). The ecological responses of both diatoms and testate amoebae have the ability to provide valuable information on past peatland environments, peatland hydroseral succession and in some cases climate change. Each of these proxies represents a unique position within the peatland ecosystem and may be used to reconstruct different facets of the environment (Birks and Birks, 2006).

In this study, we use a multi-proxy paleoecological approach to track environmental change in three peat deposits in the Hudson Bay Lowlands to address the following questions: (1) Does the apparent sensitivity of diatom and testate amoebae assemblages, as well as ratios of diatom frustules to other siliceous indicators (i.e. chrysophyte stomatocysts and testate amoebae plates), to hydrological, chemical and associated bryophyte changes vary from proxy to proxy? (2) Is there synchrony (shared sensitivity) in observed changes among the various biological proxies, and what are the potential reasons for the similarity (or differences) in their responses? (3) How does the simultaneous analysis of these proxies in the same core improve our reconstruction and understanding of past peatland environments? and (4) What are the potential reasons for observed preservation differences among proxies? Based on multi-proxy data we will reconstruct the allogenic and autogenic changes in bog environments, considering potential drivers and implications for current climatic change impacts. As Birks and Birks (2006) highlight, deriving reliable and robust paleoenvironmental inferences from multiple proxies can be complex, but strengthens our overall understanding of past environmental change.

## 3.3 Study Area

The Hudson Bay Lowlands (HBL) cover ~373,700 km$^2$ and are the largest, unconfined cold peatlands in North America, and second in the world only to the West Siberian Plain (Far North Science Advisory Panel, 2010). The optimal regional climate for peatland development is maintained in part by the contribution of large-scale cold air masses that originate over Hudson Bay, along with land-sea breezes that impose cold air temperatures on the adjacent terrestrial environment with a sharp transition in zones of permafrost development inland from the Hudson Bay coast (Rouse, 1991; Gough and Leung, 2002). Even with abundant solar radiation and saturated surfaces, evaporation is actively suppressed by these cold temperatures, aiding in the maintenance of a water-saturated landscape that is optimal for peat growth and preservation (Rouse et al., 1987). Since peatland growth and development can be tied to climatic changes, especially ombrotrophic bogs, these ecosystems may provide a detailed record of environmental and climatic change over the Holocene. This is supported by new evidence that peatlands of the HBL have responded to climatic fluctuations over the last 2000 years, capturing periods that were warm and wet and periods of cool and dry conditions (Bunbury et al., 2012; Holmquist et al., 2014; O'Reilly et al., 2014).

Given the diversity of the types and the extent of permafrost and non-permafrost bogs and fens in the HBL, and with little monitoring of permafrost in the HBL of northern Ontario (Gough and Leung, 2002), it is difficult to predict changes to this landscape and its associated carbon budget with climatic warming. Although the influence of present climatic changes on HBL peatlands remains unclear, analysis of past environmental changes may provide important insights. Diatoms have been shown to respond more sensitively to chemical changes associated with peatland succession and therefore respond earlier than other peatland proxies (e.g. pollen and macrofossils; Rühland et al., 2000). To date, there have been no studies published on the use of diatoms in peatlands in the HBL of northern Ontario. Thus, there is considerable potential for these algae, used here in conjunction with testate amoebae and chrysopyhte cysts, to increase our understanding of present and historical peatland environments in the important and potentially climatically sensitive HBL peatlands.

## 3.4 Sample Collection and Site Description

Three peat cores, JBL2 (52°01'07"N, 90°07'53"W, 362 m.a.s.l.), JBL7 (54°23'43"N, 89°31'20"W, 150 m.a.s.l.), and VC04-06 (52°42'36"N, 84°10'48"W, 104 m.a.s.l.) were collected from *Sphagnum* bogs in northern Ontario, Canada (Figure 1). The chronologies from these cores and testate amoebae record from VC04-06 have been published previously (Bunbury et al., 2012; Holmquist et al., 2014), as well the testate amoebae records from the JBL cores are available in Holmquist (2013). In this study, siliceous microfossils (diatoms, chrysophyte stomatocysts, and the siliceous plates from testate amoebae (Douglas and Smol, 2001) were analyzed from these same cores, and comparisons were made to environmental interpretations from the previously published data on testate amoebae (Bunbury et al., 2012; Holmquist, 2013). Briefly, the three cores were retrieved from peatlands that did not contain permafrost between

2008 and 2009 using Jeglum (top ~ 100 cm of peat) and Russian peat corers (~100 cm to basal peat) (Bunbury et al., 2012; Holmquist et al., 2014). JBL2 (422 cm in depth) was collected from a bog hummock on an island within a larger poor-fen complex and contained grey silt at the base of the core. JBL7 (330 cm in depth) was collected from an ombrotrophic bog hummock, and contained marine clays at the base of the core (Holmquist et al., 2014). The VC04-06 peat core (319 cm in depth) consists of peat in the upper 304 cm and marine clay in the lower 15 cm and was collected from a hollow within a shrub bog with hummock-hollow microstructure in the Attawapiskat River basin (Bunbury et al., 2012). Further details can be found in Bunbury et al. (2012) and Holmquist et al. (2014).

The cores were collected from two terrestrial ecozones within Canada known as the Boreal Shield (JBL2) and the Hudson Plains ecozones (JBL7 and VC04-06, Figure 1) (Crins et al., 2009). The study region encompasses a number of environmental gradients including climate, permafrost, vegetation, as well as different bedrock geology. Steep south to north gradients in the degree of permafrost development characterize this region from sporadic in the boreal forest to discontinuous in the HBL that transitions into continuous permafrost in a narrow margin along the Hudson Bay coast. The geology of the three study sites differ with JBL7 and VC04-06 located on the sedimentary limestone basin of the HBL, and JBL2 situated on the granitic bedrock of the Canadian Shield.

The climate of the HBL is characterized by a humid, micro-thermal Arctic climate with relatively short, mild summers and long, cold winters (Martini, 2006). Across the HBL from south (southern James Bay region) to north (Churchill region), mean annual temperatures are -1°C and -5°C respectively, with mean daily winter minima reaching -27°C in the south and -30°C in the north (Martini, 2006; McKenney et al., 2010). July average temperatures range between 12 and 18°C from south to north across the HBL and mean daily maxima of 22°C in the south and 20°C in the north (Martini, 2006). West of the HBL, on the northern Boreal Shield where JBL2 was collected, temperatures are similar to those of the HBL with a mean annual temperature (1970-2000) of -1.7°C, annual average temperature maxima of 23°C and minima of -29°C; precipitation, however, is higher at 630 mm annually (~519 mm annual precipitation in central HBL) (McKenney et al., 2010).

## 3.5 Methods

### 3.5.1 Core chronologies

For JBL2 and JBL7, a total of 13 radiocarbon dates ($^{14}$C) dates were measured using accelerator mass spectrometry (AMS) $^{14}$C at Keck Laboratory (University of California Irvine). Dates were obtained on macrofossils and bulk peat (four bulk peat $^{14}$C dates in each core). For VC04-06, a total of six $^{14}$C dates were measured using AMS $^{14}$C at Beta Analytic (Miami, Florida) on macrofossils. Age-depth models were created using 'BACON 2.2', a flexible Bayesian age-depth modeling software (Blaauw and Christen, 2011) in R (R core development team, 2012). Conventional $^{14}$C ages were calibrated to 'calendar' years in BACON using the IntCal13 calibration dataset (Reimer et al., 2013). Dates are reported as calendar years before present (cal. BP) where 0 = AD 1950, therefore a start date of -58 BP for the surface of each JBL core and -59 BP for VC04-06. More detailed information on radioisotope dating used for these cores is provided in Bunbury et al. (2012) and in Holmquist et al. (2014).

### 3.5.2 Sample Preparation

*Diatoms, chrysophyte stomatocysts, and testate amoebae plates*. Diatom samples were prepared and examined every 2 cm for the full length of cores JBL2 and JBL7, and every 2-3 cm for VC04-06 for the upper 100 cm and every 5 cm from 100 cm to the base of the core. For each sub-sample, approximately 0.3 g of peat was treated with 10 mL of concentrated nitric acid [$HNO_3$] to digest the organic matrix using microwave digestion (Parr et al., 2004). The resulting slurries were allowed to settle for 24 hours, the supernatant was removed, and the sample was rinsed with deionized water until neutral pH. Given that diatoms were often in low numbers in these peat samples, slurries were concentrated by removing any excess water prior to being strewn onto coverslips and then mounted using Naphrax®. Diatoms were identified to the lowest taxonomic level possible using a number of taxonomic references including Krammer and Lange-Bertalot (1986-1991), Camburn and Charles (2000), and Kulikovskiy et al. (2010).

For each sample, we aimed to enumerate 400 diatom valves. In cases where diatoms were too scarce and species richness was low (< 10 species), a minimum of 200 valves were counted. Samples in which it was not practical to attain a count of 200 diatom valves were excluded from analyses and noted in the results. If diatom valves were broken, as was observed on occasion for some species (e.g. species of *Eunotia*), the tips of the valves were counted and later divided in half to calculate a species valve total.

Chrysophyte stomatocysts and testate amoebae plates were counted (but not identified) concurrently with the diatoms from the same prepared microscope slides. Due to the high number of cysts and protozoan plates relative to diatom valves present in many of the samples, these ratios were calculated when a minimum of 500 protozoan plates and at least 5 diatom valves were enumerated. If too few diatoms (< 200) were present in a sample, these other siliceous indicators were not enumerated.

*Testate amoebae*. In brief, processing and identification of testate amoebae followed protocols modified from Charman (2001) and Booth et al. (2010). For the JBL cores, samples were filtered through a 250 μm filter and then reverse-filtered through a 7 μm filter. For VC04-06, a 2 $cm^3$ sub-sample of peat was soaked overnight, boiled gently in distilled water and sieved, retaining the size fraction between 10 and 350 μm (Charman et al., 2000). At least 100 testate amoebae were identified from all samples and taxonomy followed Booth (2008) with reference to Charman et al. (2000). In some JBL core samples, if there were fewer than ~6000 tests per cubic centimeter, analyses were halted at 50 tests (Payne and Mitchell, 2009).

### 3.5.3 Data analyses

Diatom data for each core were expressed as percent relative abundance data and presented in biostratigraphic profiles using C2 (Juggins, 2003). Using the diatom data, biostratigraphic zones were established by cluster analysis using constrained incremental sum of squares (CONISS) (Grimm, 1987). A broken-stick model (Bennett, 1996) was also applied to the diatom data using the rioja package in R to determine the number of important zones (Juggins, 2009; R Development Core Team, 2012). All first order diatom zones are labeled using numbers. For clarity in data display, several diatoms were grouped in the stratigraphy. For example, in JBL2, *Eunotia praerupta*, *E. hexaglyphis*, and *E. circumborealis* were grouped as they share similar ecologies and similar trends were observed in their relative abundances. The *Hantzschia* complex (mainly *H. amphioxys, H. abundans*) were grouped as a complex because they showed similar trends in abundances and valves were often broken and difficult to distinguish when only tips of a valve were available. For the VC04-06 and JBL7 stratigraphies, all *Pinnularia* species with a few exceptions, e.g., *P. borealis*, were combined as 'Other *Pinnularia* spp.' because these species also showed similar trends. The 'benthic fragilarioid spp.' category was composed of small, benthic taxa: *Staurosirella pinnata, Staurosira construens,* and *Pseudostaurosira brevistriata*.

Testate amoebae data for each core were expressed as percent relative abundances. For the JBL cores (Holmquist, 2013) and VC04-06 (Bunbury et al., 2012), stratigraphic zones were defined using CONISS (Grimm, 1987) and the number of important zones was determined using the broken-stick method (Juggins, 2009). First order JBL2 and JBL7 testate amoebae zones were labeled with letters as opposed to numbers to distinguish from diatom zones. The ratio of testate amoebae plates and chrysophyte cysts to diatom valves was calculated for each interval and expressed as a percentage, TA:D% and C:D% respectively (Smol, 1985; Zeeb and Smol, 2001) using the formula C:D% = (# of cysts/(# of cysts + # of diatom valves))*100 (Cumming et al., 1993). To compare major trends among the main indicator groups (diatoms and testate amoebae) and to compare trends among cores, the data were summarized with principal components analysis (PCA) using both CANOCO version 4.5 (ter Braak and Šmilauer, 2002) and R (R core development team, 2012).

We also compare pollen profiles (both aquatic and terrestrial sources) from the HBL region to our siliceous microfossils and testate amoebae data to provide an independent line of evidence for large regional climatic changes. The closest pollen records with an adequate number of $^{14}$C dates to make comparisons to our study include the peat core records published in Glaser et al. (2004), and Dredge and Mott (2003). Two peat cores collected in the Albany River basin (~51°30'N, 83°31'W), termed the Albany River and Oldman cores are located ~130 km south of VC04-06 and ~500 km east of JBL2 and southeast of JBL7 (Glaser et al., 2004; Figure 1). Two pollen records from Dredge and Mott (2003) (Silcox 57°10'0"N, 94°14'2"W; Lost Moose 57°33'9"N, 94°19'0"W) are located in the Churchill region of the HBL, ~500-800 km north of our study sites (Figure 1). To make direct comparisons to the timing of changes reported in our study, we calibrated the $^{14}$C dates provided in these earlier studies using BACON and the IntCal13 calibration dataset (Blaauw and Christen, 2011; Reimer et al., 2013). Similarly, $^{14}$C dates for testate amoebae records published for peatlands located east of James Bay (500-1000 km from our study sites) have been likewise remodeled for easier comparison to our study (Loisel and Garneau, 2010; van Bellen et al., 2011). The remodeled dates were very similar to published calibrated $^{14}$C dates.

## 3.6 Results

### 3.6.1 JBL2

Radiocarbon dating estimated the basal age of JBL2 to be 6360 cal. BP. However, diatom valves were only well preserved in the upper 168 cm (1940 cal. BP), and therefore for this study we will limit our analysis to sections of the cores where diatoms are present. JBL2 represents the longest diatom record of the three cores, with a total of 66 diatom samples analyzed. There were a total of 107 diatom species observed, mainly from genera commonly associated with peat environments such as *Eunotia* and *Pinnularia*. Diatom assemblages underwent notable shifts throughout the 2000-year sequence, and CONISS identified three first-order diatom stratigraphic zones in JBL2 (Figure 2). Two additional significant second-order subzones are recognized within each primary Zone 1 and 3. Macrofossils underwent one major switch over the length of the diatom record between 670 and 500 cal. BP from herbaceous species to *Sphagnum* species (Figure 2; Holmquist, 2013).

Zone 1A (168 to 127 cm; 1940 to 1310 cal. BP) is marked by the dominance of the diatom *E. paludosa* (Figure 2). For a few intervals within Zone 1A, from 1680 to 1450 cal. BP, diatoms were found to be too scarce to count (Figure 2). Zone 1B (127 to 99 cm; 1310 to 820 cal. BP) is marked by a shift from *E. paludosa* to *E. monodon* dominating the assemblage with relative abundances greater than 60%. This zone marks increases by a variety of *Pinnularia* species including *P. streptoraphe*, *P. gibba*, and *P. microstauron*, which have relatively high optima with respect to alkalinity (Fallu et al., 2002; Freund et al., 2004). However, epiphytic and acidophilic diatoms such as *E. praerupta*, *E. hexaglyphis*, and *E. circumborealis*, appear during this period for the only time during the record. Benthic fragilarioid species are present in higher abundances in Zones 1A and 1B (maximum abundance of 25%, and mean of 4%). Zone 1C (99 to 86 cm; 820 to 580 cal. BP) is characterized by the replacement of *E. monodon* with *E. lapponica* to relative abundances greater than 40% (Figure 2). Increases in the percent relative abundances of acidobiontic species, *Kobayasiella subtilissima,* and acidophilic species, *Eunotia nymanniana,* (van Dam et al., 1994), occur during Zone 1C.

Zone 2 (86 to 60 cm; 580 to 270 cal. BP) is dominated by a small diatom species that was difficult to identify, but was similar in appearance to *Eolimna submuralis* (Figure 2). Within this zone there are small increases in aerophilic taxa including *Hantzschia amphioxys*, *Luticola mutica,* and *Pinnularia borealis*. Zone 3A (60 to 42 cm; 270 to 160 cal. BP) is distinguished by large increases in the relative abundances of *Caloneis bacillum*, *E. mucophila, E. nymanniana,* and *E. paludosa* morphotype 2 (*sensu lato* Hamilton and Siver, 2010) (Figure 2). In Zone 3B (42 to 30 cm; 170 to 95 cal. BP), some of the species that characterize Zone 3A persist but there is a notable increase in abundance of acidobiontic *E. paludosa,* with the co-occurrence but in lower abundance of acidobiontic *E. exigua* and *K. subtilissima* (Figure 2). Zone 3C (30 to 0 cm) marks the highest percent relative abundances of *E. paludosa* in the core sequence and is the dominant species at this time (> 95%). This taxon dominates the peatland environment from ~94 BP to the current modern peatland habitat sampled in 2008.

Testate amoebae plate abundances remain relatively high compared to diatom abundances until ~200 cal. BP, after which diatoms become more abundant (Figure 3). However, between 1000 and 580 cal. BP, the testate amoebae TA:D% decreases to ~65%. Chrysophyte cysts are abundant relative to diatoms at the beginning of the JBL2 record, and reach maximum abundances in Zone 1B. Cysts are absent at the transition from Zone 1B to Zone 1C, but increase again in Zone 2, followed by highly variable, low abundances in Zone 3. The testate amoebae PCA axis 1 (TA-PC1) and diatom PCA axis 1 (DI-PC1) account for 57% and 54% of the respective variation in species assemblages (Figure 3). In diatom Zone 1, trends in TA-PC1 differ from those of DI-PC1. However, in Zone 3 PCA sample score trajectories for both proxies are strikingly similar, showing a strong increasing trend.

The testate amoebae record spans from ~1050 cal. BP to modern times before which, testate amoebae were scarce (Holmquist, 2013). Testate amoebae Zone A (transition at 110 cm) spans from 1050 to 870 cal. BP with a dominance of *Amphitrema stenostoma-Amphitrema wrightianum* (Supplemental Figure 1). These proteinaceous species, as well as *Hyalosphenia* taxa are present during diatom Zone 1B, including over the brief period where diatom valves were too scarce to count. Within Zone B (transition at 101 cm) from 870 to 500 cal. BP these *Amphitrema* spp. decline from ~60% to ~40% mean relative abundance and are co-dominant with *Archerella flavum*. Zone C (transition at 80 cm) from 500 to 160 cal. BP is marked by the dominance of *A. flavum* and increases in *Difflugia pulex* and *Heleopera* spp. This zone overlaps with diatom Zone 2, when *Eolimna submuralis* (a diatom with uncertain modern ecological optima), becomes dominant. In Zone D (at 43 cm), from 160 cal. BP to present, testate amoebae transition occurs at the same time interval that the diatoms undergo a change (Zone 1C to 1B) (Figure 2; Supplemental Figure 1). Although only four testate amoebae intervals were analyzed for this zone, taxa inhabiting intermediate to wet ecological niches, *Hyalosphenia elegans* and *H. papilio* clearly increase in abundance.

### 3.6.2 JBL7

Radiocarbon dating estimated the basal age of peat in JBL7 to be 7680 cal. BP. Diatoms were present and well preserved in the upper 112 cm of the core, estimated age of ~1860 cal. BP, and the record contains 48 diatom samples. A total of 68 diatom species were found in JBL7, with similar genera dominating as were observed in JBL2, with the exception of *Pinnularia maior*, which was exclusive to this core. Similar to JBL2, diatom assemblages in JBL7 underwent notable shifts throughout the 2000-year sequence, and three main diatom stratigraphic zones were identified (Figure 4). However, there were fewer taxonomic turnovers in diatom assemblages than within JBL2, and only first-order zones were identified (Figure 4). Diatoms were scarce in only a few intervals in this core (87-91 cm; 715 to 925 cal. BP and 95-97 cm; 1100 to 1240 cal. BP). There was a switch from mixed *Sphagnum* and herbaceous macrofossils to solely *Sphagnum* macrofossils at ~2340 cal. BP.

Zone 1 (112 to 75 cm; 1860 to 460 cal. BP) is represented by relatively high abundances of *E. paludosa* (~32% mean abundance) and the presence (albeit in low relative abundances) of aerophilic taxa (*Hantzschia* complex, *Pinnularia borealis*, *Luticola mutica*) (Figure 4). In this zone, high abundances of a variety of moss epiphytes that have been found to prefer more nutrient-rich conditions occur, including *Pinnularia* species, *Nitzschia perminuta*, *Gomphonema* spp., and *Denticula kuetzingii* (Myers-Smith et al., 2007; Lim et al., 2008). Benthic fragilarioid spp. are also present in modest abundances (~5%). Similar in timing to JBL2 but for a longer duration, diatoms were absent from 1030 BP to 715 cal. BP. Peat accumulation in Zone 1 was higher than the other two zones resulting in greater temporal resolution during this zone, likely the result of the presence of faster growing moss species that characterize fen peats (Jasinski et al., 1998). Zone 2 (75 to 48 cm), from 460 to 210 cal. BP was characterized by similar dominant diatom species that were observed in JBL2 Zone 2 and Zones 3A-3B (Figures 2 and 4). For example relatively high abundances of *Eolimna submuralis, K. subtilissima, Pinnularia maior,* and *Eunotia mucophila,* dominate the assemblages for a brief period towards the close of this zone. Zone 3 (48 to 0 cm, 210 cal. BP to present) is distinguished by the replacement of almost all other taxa by *E. paludosa* (mean abundance 96%) with minor relative abundances of aerophilic taxa (~2%) (Figure 4).

Testate amoebae plates are more abundant than diatom valves in the early part of the record but begin to decline at the transition from Zone 1 to Zone 2, with highly variable abundances relative to diatoms in Zone 3 (Figure 3). Chrysophyte cysts are present in similar numbers to diatom valves in Zone 1 (C:D% ~ 45%), but are absent Zone 2. At the onset of Zone 3, the C:D ratio is high at 80% and gradually declines to 10% to the top of the core. Diatoms are the dominant siliceous microfossil in Zone 3 (Figure 3). The testate amoebae PCA axis 1 (TA-PC1) and diatom PCA axis 1 (DI-PC1) capture 52% and 80% of the variation in species assemblages, respectively (Figure 5). Both TA-PC1 and DI-PC1 are relatively stable in Zone 1, undergo changes in Zone 2, and stabilize again in Zone 3. Although, TA-PC1 scores in Zone 1 are similar to Zone 3, DI-PC1 scores are substantially different due to the dominance of *E. paludosa* in this zone (Figure 3).

Testate amoebae were present for the entire length of the record, and divided into five zones (three of which overlap with the diatom record): Zone A (330 cm) at the start of the record, Zone B (transition at 150 cm) at 2550 cal. BP, Zone C (98 cm) at 1280 cal. BP, Zone D (86 cm) at 660 cal. BP, and Zone E (58 cm) at 260 cal. BP (Holmquist, 2013), similar to the transition from diatom Zone 2 to 3 for this core. Zone A is largely represented by *Heleopera* taxa, *Hyalosphenia papilio*, and *Trigonopyxis* taxa (Supplemental Figure 2). In Zone B, *Heleopera* taxa decline and co-occur with *Archerella flavum*, *Amphitrema stenostoma-Amphitrema wrightianum,* and *Difflugia pulex*. In Zone C, the dominant testate amoeba taxon is *D. pulex* with minor occurrences of *Arcella catinus* and *A. vulgaris*. *Archerella flavum* peaks in dominance in Zone D, along with minor abundances of *D. pulex*. Zone E is characterized by increases in *Assulina* spp., *Hyalosphenia papilio*, *Nebela militaris*, *N. tincta*, *Phryganella acropodia*, and *Placocista spinosa*.

### 3.6.3 VC04-06

Unlike the three zones identified in JBL2 and JBL7, only two first-order diatom zones are recognized in VC04-06 (Figure 5). Radiocarbon dating estimated the basal age of VC04-06 to be 6700 cal. BP, with an acrotelm and catotelm boundary observed at a depth of 33 cm (based on bulk peat density and corresponding to 520 cal. BP; Bunbury et al., 2012). Diatoms were not present below 67 cm (~1200 cal. BP), making this the shortest diatom record of the three peat cores examined in this study. The diatom assemblage largely switches between one of predominantly aerophilic species to an almost complete dominance by *E. paludosa*, although there were many rare species with overall 94 diatom species identified in this core.

Diatom Zone 1 (70 to 40 cm; 1200 to 650 cal. BP) is characterized by the dominance of taxa that are often described as being aerophiles including the *Hantzschia* complex, *Luticola mutica,* and *Pinnularia borealis* (Johanson, 2010; Gaiser and Rühland, 2010). *Denticula kuetzingii*, reported to be a moss epiphyte and nutrient indicator (Lim et al., 2008), is also present, although in low relative abundances. The number of diatom species is highest in this zone including minor abundances of

*Pinnularia* spp., benthic fragilarioid spp., *Cyclotella* spp., *Aulacoseira* spp., *Epithemia* spp., *Gomphonema* spp., *Nitzschia* spp., and *Sellaphora pupula*.

At the beginning of diatom Zone 2 (40 to 0 cm, 650 cal. BP to present), similar to the shift that characterized the transition from Zone 2 to Zone 3 in JBL2 and JBL7, there is an increase of *Caloneis bacillum, E. mucophila*, and *E. nymanniana* that is immediately followed by an assemblage dominated by *E. paludosa* (Figure 5). With the exception of a few intervals where aerophilic diatom taxa are abundant, Zone 2 is almost exclusively represented by *E. paludosa* and aligns best with the assemblages of Zone 3 for the two JBL cores.

Testate amoebae plates relative to diatom valves were in high and stable abundances until the transition from diatom Zone 1 to Zone 2 where their abundances become more variable relative to the number of diatom valves (Figure 3). Chrysophyte cysts are absent in several intervals in Zone 1 but the C:D% gradually increases at the transition from Zone 1 to Zone 2, with the highest percentages of cysts found in the most recent part of the record. The testate amoeba PCA axis 1 (TA-PC1) and diatom PCA axis 1 (DI-PC1) capture 40% and 92% of the variation in species assemblages, respectively (Figure 3). Similar changes occur in both TA-PC1 and DI-PC1, with lower scores in Zone 1 and a switch to higher scores in diatom Zone 2.

Testate amoebae are present throughout the entire length of the core with the exception of the marine basal clays (Bunbury et al., 2012). From 1140 cal. BP, proteinaceous species represent the assemblage until 900 cal. BP when *Difflugia* spp. become dominant along with many siliceous species that secrete plates (e.g. *Nebela* taxa, *Heleopera* taxa) (Supplemental Figure 3). Four testate amoebae zones were identified, but only one testate amoebae zone occurs within the diatom record at ~900 cal. BP. During this zone from 900 cal. BP to present, *D. pulex* and *D. pristis* type are abundant. Bunbury et al. (2012) note changes in testate amoebae abundances around ~500 cal. BP similar to those in the JBL cores. Here *Arcella discoides*-type and *H. sphagni* are more abundant prior to ~500 cal. BP, and *Hyalosphenia papilio* more abundant thereafter and at the surface. At ~100 cal. BP *Hyalosphenia elegans*, *Nebela militaris* type, and *Assulina* spp. increase corresponding with a decline in *A. flavum*. Since the

VC04-06 testate amoebae record extends to the middle Holocene, these changes at ~500 cal. BP and ~100 cal. BP are not recognized as first order zone changes, but significant to note because they occur during the span of the diatom record.

## 3.7 Discussion

### 3.7.1 JBL2: Boreal Shield *Sphagnum* bog hummock core

It is unlikely that the hydrology of peatlands in Ontario's Boreal Shield ecoregion are influenced to the same extent by regional isostatic uplift as peatlands within the HBL (JBL7 and VC04-06). The Boreal Shield sites were not inundated by the Tyrrell Sea and they did not experience rates of uplift that were nearly as rapid as those experienced in the HBL, which is in considerably closer proximity to the centre of ice mass and to the margin of Hudson Bay. Rather, proxy changes within this core may be more closely linked to autogenic processes and past climatic changes. The length of the diatom record in this core occurs over a fen-bog transition between 670 and 500 cal. BP as determined from a macrofossil switch from herbaceous species to *Sphagnum* spp. Diatoms and testate amoebae track this peatland successional transition; it is also possible that diatoms are tracking microtopographic transitions that occur within the JBL2 bog over the past ~600 years.

The multiple proxies from JBL2 are consistent with Zone 1 being a period with a higher water table and more circum-neutral pH. In JBL2, all biological proxies are indicative of a fen peat environment, likely a rich fen, from ~1310 to ~810 cal. BP (Zone 1B), followed by poor fen conditions (Zone 1C). Epiphytic *Pinnularia* taxa are prevalent in Zone 1, and indicative of a rich fen environment, as they have been commonly reported to have relatively high alkalinity optima (Fallu et al., 2002; Freund et al., 2004). In a spatial survey of peat surface samples, epiphytic diatoms such as *Eunotia praerupta*, *E. hexaglyphis*, and *E. circumborealis* have been found to be indicative of rich fen conditions (Hargan et al., accepted), and in this core are only present during Zone 1B. *Eunotia praerupta* can thrive in shallow water and often tolerates a drier environment associated with living on moss, and *E. septentrionalis* is reported to be present in water with high mineral content indicating conditions associated with rich and poor fens (DeNicola, 2000; Fukumoto et al., 2012). As well, following the presence of these rich fen indicators, *Euntoia lapponica* is the dominant diatom species (Zone 1C), which has been found to grow in association with *Sphagnum* species representative of basin fens (Buczkó, 2006). Many of these diatom species are exclusive to the JBL2 stratigraphy and it is likely that this peatland was the most productive of the three peatland regions of this study over this time period.

Testate amoebae in the JBL2 peat core were first analyzed beginning at ~1050 cal. BP. Testate amoebae Zone 1 ends ~870 cal. BP and is approximately concurrent with the end of diatom Zone 1B. The dominance of *Amphitrema stenostoma-Amphitrema wrightianum* during this zone indicates high water tables and the possible presence of deep pools and hollows of standing water (Barber and Langdon, 2007; Swindles et al., 2009), consistent with diatom interpretations. From ~870 to ~500 cal. BP these *Amphitrema* spp. are co-dominant with *Archerella flavum,* a species indicative of moderate to wet conditions (Blundell and Barber, 2005). Chrysophyte stomatocysts are highly variable and absent within many samples during this zone, and it is likely that the shallow standing water is not an optimal environment for many chrysophyte taxa.

JBL2 proxy assemblages and changes in Zone 1 from ~1940 to ~580 cal. BP would suggest that variations in hydrology were important to the organisms living in this Boreal Shield peatland over this period, as inferred from substantial changes in dominant alkaline and mesotrophic peatland diatoms, and the dominance of testate amoebae indicative of high water tables. Climate may have also influenced the local hydrology of this peatland with potentially warmer temperatures and greater precipitation (Filion, 1984) supporting higher water tables.

The change in macrofossils and diatoms during the transition to Zone 2 is likely representative of the earliest microhabitat as the fen developed into a bog. In JBL2, this fen to bog transition may have been prompted from gradual peat accumulation in Zone 1 and subsequent disconnection from the water table and/or under fluctuating water table conditions (Hughes, 2000; Loisel and Garneau, 2010). At ~580 cal. BP until ~330 cal. BP, the dominance of *Eolimna* cf. *submuralis*, commonly found in shallow lakes, may be indicative of multiple peatland microhabitat types including bog hollows. At 275 cal. BP, increases in the diatom species *E. mucophila, Caloneis bacillum,* and *E. nymanniana,* indicate peat conditions have become substantially more acidic than in previous zones. *E. mucophila* has documented associations with *Sphagnum angustifolium*, which is often found in bog hollows and lower hummocks (Karlin and Bliss, 1984), and this species is recognized as a useful indicator of hollow peat habitats (Poulickova et al., 2004; Buczkó, 2006; Chen et al., 2012). *Caloneis bacillum* has been reported to be able to sustain large osmotic changes that enable it to withstand short periods of desiccation (Van de Vijver et al., 2003), and thus is also a good indicator of a drier environment. Collectively, the diatom assemblages of this zone suggest a more acidic, drier peat environment that is typical of the onset of bog development. The thecamoebae *Archerella flavum* and *Difflugia pulex* remain the dominant taxa over diatom Zone 2 (testate amoebae Zone C), suggesting conditions are still moderately wet, but do not provide any further indications of habitat type.

The JBL2 transition from Zone 1 to Zone 2 overlaps in time with the 'Little Ice Age' (LIA) occurring from 1400 to 1700 AD (Mann et al., 2009; Kaufman et al., 2009). Globally however, there is spatio-temporal variation in the timing and magnitude of this cooling event (Barlow, 2001). Nevertheless, in JBL2, all biological proxies undergo notable changes during the proposed LIA, including a macrofossil switch, the dominance of diatom *E. submuralis* to greater than 60% relative abundance, and disappearance of testate amoebae *A. stenostoma-A.wrightianum*, suggesting climatic conditions were drier here than within Zone 1, and may have contributed to the ombrotrophication of this peatland.

Many other testate amoebae records from the region reconstruct dry periods over 600-200 cal. BP and relate these to LIA cooling episodes (Loisel and Garneau, 2010; van Bellen et al., 2011). However, it is not clear whether conditions were cool and dry, or cool and humid. In northeastern Canada, cooling climatic conditions are associated with the intrusion of dry Arctic air masses (Carcaillet and Richard, 2000; Girardin et al., 2004), that are linked with a decrease in both annual precipitation and potential evaporation (Payette and Filion, 1993), and may result in contrasting effects on peatland water-tables. Although the biological proxies from JBL2 do not provide information on whether this period was cooler than before, they do suggest that conditions were drier and more acidic than Zone 1; however, *E. submuralis* requires some standing water to thrive (i.e. the peat environment was not completely disconnected from the water table). A cool and humid climate may trigger a switch from minerotrophic to ombrotrophic peatland status (Arlen-Pouliot and Bhiry, 2005) consistent with our multi-proxy inferences at this site at ~600 cal. BP. Although, the Dredge and Mott (2003) pollen records do record large vegetation changes around this time, they are located a substantial distance (~800 km) from JBL2 and within a different ecozone. More conclusive evidence for climatic changes at this time would be gained from expansion of regional pollen records, simultaneously with detailed macrofossil analysis (Birks and Birks, 2006). Currently, there is a large gap in Holocene pollen records from both Ontario's northern boreal region as well as within the HBL. Independent climate records reconstructed from lake or tree ring records would help tease apart the importance of autogenic and allogenic processes in prompting the JBL2 fen to bog transition.

Our proxy data are comparable to subarctic peatland work from Québec, that demonstrates climate cooling in the late Holocene, and associated freezing in peat can support the ombrotrophication of peatlands through water drawdown (Loisel and Garneau, 2010; van Bellen et al. 2011). Diatom assemblages suggest that at ~580 cal. BP a peatland formed in JBL2 and was most similar to either of the following modern habitats: (1) bog hollows, where the water table is at or near the surface in the spring, and below the surface for the drier times of the year; or (2) to flat/level bogs, where the water may remain at the surface throughout the summer (Riley, 2011). These habitat types (occurring at the transition from Zone 1 to Zone 2; ~580 cal. BP) could have subsequently formed through both the dry climatic conditions of the LIA, and through autogenic hydroseral succession. However, the lack of regional climatic reconstructions make it difficult to determine the contribution that climate has exerted on peatland development in the JBL2 region.

Following the fen to bog transition at ~580 cal. BP and the initial stages of bog development from ~580 to ~270 cal. BP, the JBL2 peatland continued to acidify with the establishment of bog *Sphagnum* species (Holmquist, 2013), and the prominence of several acidobiontic *Eunotia* taxa at ~270 cal. BP (diatom Zone 3). For example, the rise in *Eunotia exigua* during this bog stage is likely well suited to the highly acidic nature of *Sphagnum* bogs rather than the dry conditions that accompany this change in the chemical environment (DeNicola, 2000). In contrast, the almost complete dominance of *E. paludosa* from ~94 cal. BP to the present is undoubtedly due to this taxon's ability to secrete an external sheath enabling it to withstand periods of desiccation (Chen et al., 2012). In modern diatom surveys across peatland microhabitats, *E. paludosa* has been reported to be commonly associated with dry hummock tops and *Sphagnum fuscum* (Kingston, 1982; Poulíčková et al., 2004; Chen et al., 2012) suggesting that *E. paludosa* should be a good indicator of the dry conditions found in bog hummocks or ridges. Although bog hummocks have often been found to have higher nutrient concentrations than within hollows (Rietkerk et al., 2004; Eppinga et al., 2009), it is likely that diatom assemblages in this environment are restricted to taxa that are capable of surviving the extreme dryness of these microforms (e.g. *E. paludosa, L. mutica, P. borealis*).

As determined from bulk density, loss on ignition (LOI), and rates of carbon accumulation, the JBL2 acrotelm to catotelm boundary occurs at ~230 cal. BP (55 cm) (Holmquist et al., 2014). Following this, both diatoms and testate amoebae record assemblage changes at 160 cal. BP (42 cm). It could be expected that diatoms, as well as testate amoebae, may track this transition from wet, anaerobic peat (catotelm) to well-oxygenated and drier peat (acrotelm). However, it is difficult to untangle whether these diatom changes are tracking a change in microhabitat from hollow to hummock, or tracking when the peatland first started to develop a substantial acrotelm. More detailed macrofossil and microfossil analyses within this core including identifying *Sphagnum* macrofossils to the species level would help to untangle the timing of hummock establishment (e.g. Blundell and Barber, 2005; Birks and Birks, 2006; Loisel and Garneau, 2010). This would pinpoint whether diatoms are tracking microtopographic variations within this peatland, as inferred from the presence of hummock *Sphagnum* species (e.g. *S. fuscum*), or the catotelm-acrotelm boundary, as determined through the proxies mentioned above.

### 3.7.2 JBL7: Boreal Shield-HBL transition *Sphagnum* hummock peat core

In JBL7 a switch from mixed *Sphagnum* and herbaceous macrofossils to solely *Sphagnum* macrofossils occurs at ~2340 cal. BP (not shown in figure) indicative of the development of a more acidic, drier peat environment. Changes in diatom assemblage composition that occur throughout this ~2000-year record are likely tracking microtopographic variations that occur within this bog. For example, the diatom assemblages from ~1860 to ~460 cal. BP are indicative of highly variable water table depths, with intermittent wet periods including possible connections to mineral-rich ground water or flooding from surface water, which may be characteristic of changes in microtopographic variation within the bog. Variable hydrological conditions can be inferred from the presence of diatoms that are more closely associated with high mineral and nutrient concentrations including *Pinnularia maior, Denticula kuetzingii*, and benthic fragilarioid taxa (Pienitz et al., 1999; Fallu et al., 2002; Lim et al., 2008) suggesting periods of open water and/or a higher water table (Weilhoefer and Pan, 2006).

Within diatom Zone 1 from ~1860 to ~1200 cal. BP, *Archerella flavum* is the dominant testate amoeba taxon in JBL7, corroborating moderate to wet conditions (Blundell and Barber, 2005) indicated by diatom assemblages at the beginning of this zone. The switch in dominance ~1200 to ~600 cal. BP to *Difflugia pulex* may be indicative of fluctuating water tables (Loisel and Garneau 2010) where the species may be able to withstand periodic dry conditions (Charman et al., 2007; Booth, 2010) explaining its existence with taxa indicative of both wet and dry conditions. This ecological interpretation of *D. pulex* in the JBL7 core is consistent with fluctuations between diatoms indicative of varying moisture and nutrient conditions, as well as many intervals in which diatoms are absent. Additionally, diatoms and testate amoebae species (*Arcella catinus* and *A. vulgaris*; Zoltai and Vitt, 1995) that occur in this zone also suggest a more neutral pH which would be expected in peatlands with variable connections to ground water.

Zone 2, from ~460 to ~210 cal. BP, is dominated by diatom species that were found in JBL2 Zones 2 and 3A suggesting a bog hollow environment. These include *Eolimna submuralis*, *Eunotia mucophila, Caloneis bacillum,* and *E. nymanniana*. This diatom zone overlaps most closely with testate amoeba Zone D, when *Archerella flavum* again becomes the dominant taxon, indicating moderately wet conditions continue to persist. Similar to JBL2, the transition from Zone 1 to Zone 2 overlaps closely with the 'LIA', and cooler conditions may in part explain the diatom changes seen here. However, this interpretation is somewhat tenuous with the lack of regional records of Holocene climatic changes from northern Ontario.

The catotelm to acrotelm transition occurs at ~298 cal. BP (65 cm), following which there is a short-lived peak in *Eunotia mucophila, Eolimna submuralis* and *Pinnularia maior*. It is possible that, for this brief period, the acrotelm remained small enough to support diatom species commonly found living in modern hollow habitats of bogs. Once the acrotelm surpasses a critical depth, likely at ~210 cal. BP (Zone 2 to Zone 3 transition), the peat habitat was likely too dry and acidic for the survival of most diatom species and, similar to what was observed in JBL2, *Eunotia paludosa* becomes dominant. As suggested above, this diatom species may thrive due to its tolerance to either the dry conditions of the hummock top, and/or from the development of a substantial aerated acrotelm that may still be found within hollows. The presence of testate amoebae, *Nebela militaris* and *N. tincta,* is also a strong indication of an extremely dry habitat (Booth, 2002; Swindles et al., 2009). In addition, thecamoeba *Hyalosphenia papilio* clearly increases in abundance, and has been reported to be associated with *Sphagnum* species that colonize and establish some of the most acidic and driest bog environments (Booth, 2002; Loisel and Garneau, 2010).

### 3.7.3 VC04-06: Hudson Plains *Sphagnum* hollow peat core

Macrofossils and testate amoebae records from VC04-06 (Bunbury et al., 2012) indicate that the fen to bog transition occurred earliest (~4400 cal. BP) of the three peat records. This signifies that changes in diatom assemblages in VC04-06, like JBL7, occur only during a bog period of the peat record, and thus are likely tracking minor microhabitat and hydrological fluctuations occurring within a bog environment. In Zone 1, the occurrence of diatom species with differing life strategies including aerophiles, epiphytes, tychoplanktonic (e.g. *Aulacoseira* spp.) and benthic diatoms suggests a period of unstable hydrological conditions. Several species (e.g. *Gomphonema* spp., *Stauroneis* spp., *Nitzschia* *perminuta, Denticula kuetzingii*) indicate higher mineral and nutrient loads (Myers-Smith et al., 2007; Lim et al., 2008), which may be present along bog ridges/hummocks (Eppinga et al., 2009). However, the presence of many benthic diatom species within Zone 1 could also suggest that this zone may have had a higher water table and more closely resembled a hollow microhabitat with little to no acrotelm (i.e. there would be some standing water).

At the beginning of diatom Zone 1, high water tables are inferred from the dominance of testate amoeba *Archerella flavum*, along with an increase in *Sphagnum* spores in the pollen record at a regional lake (McAndrews et al., 1982), which suggest wet conditions either from an increase in precipitation and/or surface moisture conditions that supported the continued paludification of VC04-06 (Bunbury et al., 2012). At ~900 cal. BP, testate amoebae often reported in peatlands fluctuating between wet and dry conditions, including *Difflugia pulex*, *D. pristis* type, and *Arcella discoides* type (Loisel and Garneau, 2010), increase in abundance, corroborating the possibility of unstable hydrological conditions inferred by the diatom assemblages as also inferred during JBL7 Zone 1.

At 650 cal. BP, the diatom assemblages become dominated by *Eunotia paludosa*, the dominant taxon common in all three cores during a transition to dry, acidic conditions. Approximately 100 years prior to the onset of *E. paludosa* dominance, diatom taxa that would be expected in 'hollow' environments including *Caloneis bacillum, E. nymanniana*, and *E. mucophila,* make a brief appearance (albeit in low relative abundances). Although cluster analysis did not result in the establishment of a testate amoebae zone at ~650 cal. BP in core VC04-06, Bunbury et al. (2012) note that there are changes in testate amoeba abundances around ~500 cal. BP with *Arcella discoides* type and *H. sphagni* more abundant prior to ~500 cal. BP, and *Hyalosphenia papilio* more abundant thereafter. Once again, the timing of changes from Zone 1 to Zone 2 corresponds to the proposed LIA. However, these assemblage changes should be interpreted with caution as these changes also occur at the acrotelm-catotelm boundary within VC04-06.

The acrotelm-catotelm boundary was determined to be at ~520 cal. BP (33 cm) (Bunbury et al., 2012), the period when *E. paludosa* becomes the dominant diatom species. The brief appearance of the ‘hollow’ diatom species prior to the development of the acrotelm-catotelm boundary suggests they might be tracking hollow microhabitat conditions, and likely hollows with a small acrotelm. Given that the VC04-06 core was collected from a hollow (with a water table 33 cm below the vegetation surface), it is possible that the dominance of *E. paludosa* is tracking both: (1) the continued drying of the peat through peat accumulation and further separation from ground water, and (2) the development of a substantial acrotelm at this site. As diatoms require light to survive, it is unlikely that they are surviving and responding to the acrotelm-catotelm boundary 33 cm below the vegetation surface, but rather changes may have occurred when an acrotelm started to develop within the hollow, and slowly limited the survival of diatoms not adapted to particularly dry and acidic conditions.

### 3.7.4 Proxy abundance and preservation issues

Across the study cores, diatoms are absent prior to ~2000 cal. BP. Within these peatlands, open water and fen conditions are inferred at the base of these cores (Bunbury et al., 2012; Holmquist et al., 2014), conditions that should be optimal for the growth of diatoms as shown from modern calibration sets (e.g. Poulíčková et al., 2004; Kapetanović et al., 2011). Despite this, siliceous indicators including diatoms, cysts and plates were absent from these earlier peat intervals. The absence of siliceous indicators could be an indication that, over time the growth of these organisms has been severely limited by silica availability or that samples have been affected by post-burial dissolution of silica, which can occur in extremely organic-rich and anoxic environments (Bennett et al., 1991). In general, proteinaceous testate amoebae dominated when diatoms were scarce or absent and siliceous thecamoebians dominated when diatoms were plentiful in the peat cores. However, there are some exceptions, including the typically siliceous *Heleopera* taxa, which are found at the base of JBL7 when diatoms are absent as well as the occurrence of *Difflugia* species that dominated in VC04-06 beyond the length of the diatom record. Species of the genera *Heleopera* and *Difflugia* can produce tests composed of euglyphid body plates (i.e. autogenous), mineral elements (e.g. sand grains) or diatoms, and so their preservation in the absence of diatoms is not consistent with dissolution of diatom valves. Perhaps the mineral elements in addition to silica, and the ‘organic cement’ used to construct the test, may help to preserve these species over time and explain their presence in the absence of diatoms. This would make it unclear how transitions between dominant test-type should be interpreted, and whether there may be preferential preservation of particular testate amoebae species.

In JBL7, diatoms were too scarce to count from ~1000 to ~750 cal. BP and at ~1000 cal. BP in JBL2, but other siliceous proxies that occur within the peatland including cysts and testate amoebae are present, indicating that silica was likely in short supply. Again, siliceous *Difflugia* taxa are present and dominant in JBL7 over this time along with other siliceous indicators, so it is unlikely that diatom valves experienced dissolution. Given that proxies across JBL7 Zone 1 indicate hydrological conditions were wet and unstable, it is likely that these brief periods lacking abundant diatoms represent environmental conditions where water tables were low and silica flux to that peatland was reduced, limiting the proliferation of diatoms. Diatoms present an interesting challenge as a peat proxy and we need to better understand why they preserve well in some peat records, and are absent from others.

## 3.8 Conclusions

We used multiple proxies to examine environmental change over the past ~2000 years in three peat deposits from the Boreal Shield and Hudson Plains ecozones of northern Ontario. From these cores it is evident that the combined use of diatoms and testate amoebae to track peatland changes is complementary, as testate amoebae are directly sensitive to hydrological changes, while diatoms closely track the chemical conditions of a peatland which may also be influenced by changes in hydrology. Slight differences in the responses of these proxies to past environmental change may be linked to their ecology, with a greater number of testate amoebae adapted to both survive and flourish in the dry, acidic conditions of peatlands. Diatoms, likely due to their ability to track subtle pH changes, record greater microhabitat fluctuations both within the JBL2 fen phase, and the JBL2 and JBL7 bog phases. We propose that diatoms are tracking the microtopographic changes that occur within bogs (i.e. the hollow to hummock transition), which is particularly marked in the most recent parts of each core where the acidity and aridity conditions are especially severe for diatoms (*E. paludosa* almost completely dominates in all cores). The occurrence of diatoms with better known autecology (optima and tolerances for water chemistry and habitat preferences) additionally helped to improve our understanding of testate amoeba taxa with poorly understood autecology (e.g. *Difflugia pulex*). In general, the timing of many of the assemblage changes between proxies aligned closely (e.g. taxonomic changes occurring during the 'LIA'). However, where there are substantial differences (e.g. JBL7 ~1850 to 450 cal. BP), it may be due to preservation difficulties with diatoms, as well as not fully understanding the main driver of environmental change (e.g. allogenic vs. autogenic). Greater research on Holocene climatic change in northern Ontario is needed to help tease apart possible interactions between hydroseral succession, isostatic rebound, and climatic change in peatlands. This study corroborates the main points made by Birks and Birks (2006), namely that deriving reliable and robust paleoenvironmental inferences from multiple proxies can often be complex, but strengthens our overall understanding of past environmental change. Multiple proxy records collected from different sources in northern Ontario (e.g. peatlands, lakes, trees) will result in an improved understanding of the impacts of future climatic warming on northern peatlands.

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## 3.11 References

Arlen-Pouliot Y and Bhiry N (2005) Palaeoecology of a palsa and a filled thermokarst pond in a permafrost peatland, subarctic Québec, Canada. *The Holocene* 15: 408–419.

Barber KE and Langdon PG (2007) What drives the peat-based palaeoclimate record? A critical test using multi-proxy climate records from northern Britain. *Quaternary Science Reviews* 26: 3318–3327.

Barlow LK (2001) The time period A.D. 1400-1980 in central Greenland ice cores in relation to the north Atlantic sector. *Climate Change* 48: 101-119.

Beilman DW, MacDonald GM, Smith LC et al. (2009) Carbon accumulation in peatlands of West Siberia over the last 2000 years. *Global Biogeochemical Cycles* 23: GB1012.

Belya LR and Clymo RS (2001) Feedback control of the rate of peat formation. *Proceedings of the Royal Society of London Series B*: *Biological Sciences* 268: 1315-1321.

Bennett KD (1996) Determination of the number of zones in a biostratigraphical sequence. *The New Phytologist* 132: 155–170.

Bennett PC, Siegel DI, Hill BM et al. (1991) Fate of silicate minerals in a peat bog. *Geology* 19: 328-331.

Beyens L (1985) On the subboreal climate of the Belgian Campine as deduced from diatom and testate amoebae analyses. *Review of Palaeobotany and Palynology* 46: 9-31.

Beyens L and Meisterfeld R (2001) Protozoa: Testate Amoebae. In Smol JP, Birks HJB and Last WM (eds) *Tracking Environmental Change Using Lake Sediments, vol. 3: Terrestrial, Algal, and Siliceous Indicators*. Dordrecht: Kluwer, 121-154.

Birks HH, Battarbee RW, Birks HJB et al. (2000) The development of the aquatic ecosystem at Kråkenes Lake, western Norway, during the late-glacial and early-Holocene – a synthesis. *Journal of Paleolimnology* 23**:** 91–114.

Birks HH and Birks HJB (2006) Multi-proxy studies in palaeolimnology. *Vegetation History and Archaeobotany* 15: 235–251.

Birks HJB (1993) Quaternary palaeoecology and vegetation science current contributions and possible future developments. *Review of Palaeobotany and Palynology* 79: 153-177.

Blaauw M and Christen J (2011) Flexible paleoclimate age-depth models using an autoregressive gamma process. *Bayesian Analysis* 6: 457-474.

Blundell A and Barber K (2005) A 2800-year palaeoclimatic record from Tore Hill Moss, Strathspey, Scotland: the need for a multi-proxy approach to peat-based climate reconstructions. *Quaternary Science Reviews* 24: 1261–1277.

Booth RK (2002) Testate amoebae as paleoindicators of surface-moisture changes on Michigan peatlands: modern ecology and hydrological calibration. *Journal of Paleolimnology* 28: 329–348.

Booth RK (2008) Testate amoebae as proxies for mean annual water-table depth in *Sphagnum*-dominated peatlands of North America. *Journal of Quaternary Science* 23: 43-57.

Booth RK (2010) Testing the climate sensitivity of peat-based paleoclimate reconstructions in mid-continental North America. *Quaternary Science Reviews* 29: 720–731.

Booth RK, Lamentowicz M and Charman, DJ (2010). Preparation and analysis of testate amoebae in peatland paleoenvironmental studies. *Mires and Peat* 7(2): 1-7.

Brown K, Douglas MV and Smol JP (1994) Siliceous microfossils in a Holocene, High Arctic peat deposit (Nordvestø, northwestern Greenland). *Canadian Journal of Botany* 72: 208-216.

Bunbury J, Finkelstein SA and Bollmann J (2012) Holocene hydro-climatic change and effects on carbon accumulation inferred from a peat bog in the Attawapiskat River watershed, Hudson Bay Lowlands, Canada. *Quaternary Research* 78: 275-284.

Buzcho K (2006) Bryophytic diatoms from Hungary. In: Witkowski A (ed.) *Proceedings of the Eighteenth International Diatom Symposium, 2004*. Bristol: Biopress Limited, pp. 1–15.

Camburn KE and Charles DF (2000) *Diatoms of Low Alkalinity Lakes in the Northeastern United States*. Philadelphia, PA: Scientific Publications, The Academy of Natural Sciences of Philadelphia, 152 pp.

Campbell DR, Dutchie HC and Warner BG (1997) Post-glacial development of a kettle-hole peatland in southern Ontario. *Ecoscience* 4: 404-418.

Carcaillet C and Richard PJH (2000) Holocene changes in seasonal precipitation highlighted by fire incidence in eastern Canada. *Climate Dynamics* 16: 549–559.

Charman DJ (2001) Biostratigraphic and palaeoenvironmental applications of testate amoebae. *Quaternary Science Reviews* 20: 1753–1764.

Charman DJ (2002) *Peatlands and Environmental Change*. Chichester: John Wiley & Sons Ltd.

Charman DJ, Blundell A and Members A (2007) A new European testate amoebae transfer function for palaeohydrological reconstruction on ombrotrophic peatlands. *Journal of Quaternary Science* 22: 209-221.

Charman DJ, Hendon D and Woodland WA (2000) *The identification of testate amoebae (Protozoa:*

*Rhizopoda) in peats*. Technical Guide No. 9. London: Quaternary Research Association.

Chen X, Bu Z, Yang X et al. (2012) Epiphytic diatoms and their relation to moisture and moss composition in two montane mires, Northeast China. *Fundamental Applied Limnology* 181: 197–206.

Crins WJ, Gray PA, Uhlig PWC et al. (2009) *The Ecosystems of Ontario, part 1: Ecozones and Ecoregions*. Inventory, Monitoring and Assessment, SIB TER IMA TR- 01. Peterborough: Ontario Ministry of Natural Resources, 71pp.

Cumming BF, Wilson S and Smol JP (1993) Paleolimnological potential of chrysophyte cysts and scales and of sponge spicules as indicators of lake salinity. *International Journal of Salt Lake Research* 2: 87-92.

DeNicola DM (2000) A review of diatoms found in highly acidic environments. *Hydrobiologia* 433: 111-122.

Douglas SV and Smol JP (1987) Siliceous protozoan plates in lake sediments. *Hydrobiologia* 154: 13-23.

Douglas MSV and Smol JP (1995) Paleolimnological significance of observed distribution patterns of chrysophyte cysts in arctic pond environments. *Journal of Paleolimnology* 13: 79-83.

Douglas MSV and Smol JP (2001) Siliceous protozoan plates and scales. In Smol JP, Birks HJB, and Last WM (eds) *Tracking Environmental Change Using Lake Sediments, vol. 3: Terrestrial, Algal, and Siliceous Indicators*. Dordrecht: Kluwer, 265–280.

Dredge LA and Mott RJ (2003) Holocene Pollen Records and Peatland Development, Northeastern Manitoba. *Géographie physique et Quaternaire* 57: 7-19.

Eppinga MB, de Ruiter PC, Wassen MJ et al. (2009) Nutrients and hydrology indicate the driving mechanisms of peatland surface patterning. *The American Naturalist* 173: 803-818.

Fallu M-A, Allaire N and Pienitz R (2002) Distribution of freshwater diatoms in 64 Labrador (Canada) lakes: species–environment relationships along latitudinal gradients and reconstruction models for water colour and alkalinity. *Canadian Journal of Fisheries and Aquatic Science* 59: 329–349.

Far North Science Advisory Panel (2010) *Science for a Changing North: Report to the Ontario Ministry of Natural Resources*. Toronto: The Queen's Printer for Ontario.

Filion L (1984) A relationship between dunes, fire and climate recorded in the Holocene deposits of Quebec. *Nature* 309: 543-546.

Freund H, Gerdes G, Streif H et al. (2004) The indicative meaning of diatoms, pollen and botanical macrofossils for the reconstruction of palaeoenvironments and sea-level fluctuations along the coast of Lower Saxony; Germany. *Quaternary International* 112: 71–87.

Fukumoto Y, Kashima K, Orkhonselenge A et al. (2012) Holocene environmental changes in northern Mongolia inferred from diatom and pollen records of peat sediment. *Quaternary International* 254: 83-91.

Gaiser E and Rühland KM (2010) Diatoms as indicators of environmental change in wetlands and peatlands. In: Smol JP and Stoermer EF (eds) *The Diatoms: Applications for the Environmental and*

*Earth Sciences*. 2nd edition. Cambridge: Cambridge University Press, pp. 473-496.

Gehrels WR, Roe HM and Charman DJ (2001) Foraminifera, testate amoebae and diatoms as sea-level indicators in UK saltmarshes: a quantitative multiproxy approach. *Journal of Quaternary Science* 16: 201-220.

Girardin MP, Tardif C, Flannigan MD and Bergeron Y (2004) Multicentury reconstruction of the Canadian Drought Code from eastern Canada and its relationship with paleoclimatic indices of atmospheric circulation. *Climate Dynamics* 23: 99-115.

Glaser PH, Hansen BCS, Siegel DI et al. (2004) Rates, pathways and drivers for peatland development in the Hudson Bay Lowlands, northern Ontario, Canada. *Journal of Ecology* 92: 1036-1053.

Gough WA and Leung A (2002) Nature and fate of Hudson Bay permafrost. *Regional Environmental Change* 2: 177–184.

Grimm EC (1987) CONISS: A FORTRAN 77 program for stratigraphically constrained cluster analysis by the method of incremental sum of squares. *Computers & Geosciences* 13: 13–35.

Hamilton PB and Siver PA (2010) A morphological investigation of *Eunotia fennica* (Bacillariophyceae) from a freshwater acidic pond in Newfoundland, Canada. *Proceedings of the Academy of Natural Sciences of Philadelphia* 160: 89-98.

Hargan KE, Rühland KM, Paterson AM et al. The influence of water table depth and pH on the spatial distribution of diatom species in peatlands of the Boreal Shield and Hudson Plains, Canada. *Botany* accepted.

Holmquist JR (2013) *Holocene peatland carbon accumulation, ecology, and hydrology in the Canadian James Bay Lowlands*. PhD Thesis, University of California, Los Angeles.

Holmquist JR, MacDonald GM and Gallego-Sala A (2014) Peatland initiation, carbon accumulation, and 2 ka depth in the James Bay Lowland and adjacent regions. *Arctic, Antarctic, and Alpine Research* 46: 19-39.

Hughes PDM (2000) A reappraisal of the mechanisms leading to ombrotrophy in British raised mires. *Ecology Letters* 3: 7–9.

Jasinski JPP, Warner BG, Andreev AA et al. (1998) Holocene environmental history of a peatland in the Lena River valley, Siberia. *Canadian Journal of Earth Sciences* 35: 637-648.

Johansen JR (2010) Diatoms of aerial habitats. In: Smol JP and Stoermer EF (eds) *The Diatoms: Applications for the Environmental and Earth Sciences*. 2nd edition. Cambridge: Cambridge University Press, pp. 465-472.

Juggins S (2003) C2 user guide. Software for ecological and palaeoecological data analysis and visualisation. Newcastle upon Tyne. University of Newcastle, UK.

Juggins S (2009) Rioja: an R Package for the Analysis of Quaternary Science Data, Version 0.5-6.

Kapetanović T, Jahn R, Redžić S et al. (2011) Diatoms in a poor fen of Bijambare protected landscape, Bosnia and Herzegovina. *Nova Hedwigia* 93: 125-151.

Karlin EF and Bliss LC (1984) Variation in substrate chemistry along microtopographical and water-chemistry gradients in peatlands. *Canadian Journal of Botany* 62: 142-153.

Kaufman DS, Schneider DP, McKay NP et al. (2009) Recent warming reverses long term Arctic cooling. *Science* 325: 1236.

Kingston JC (1982) Association and distribution of common diatoms in surface samples from northern Minnesota peatlands. *Nova Hedwigia* 73: 333-346.

Korhola A (1990) Paleolimnology and hydroseral development of the Kotasuo bog, southern Finland, with special reference to the Cladocera. Annales Academie Scientiarum Fennicae A III 155, 40.

Krammer K and Lange-Bertalot H (1986–1991) Bacillariophyceae. In: Ettl H, Gerloff J, Heynig H and Mollenhauer D (eds) *Süßwasserflora von Mitteleuropa, vol. 2*. Stuttgart/Jena: Gustav Fischer Verlag, pp. 1-4.

Kulikovskiy MS, Lange-Bertalot H, Witkowski A et al. (2010) Diatom assemblages from *Sphagnum* bogs of the world. I. Nur bog in northern Mongolia. *Bibliotheca Diatomologica* 55: 1-326.

Lim DSS, Smol JP and Douglas MSV (2008) Recent environmental changes on Banks Island (N.W.T., Canadian Arctic) quantified using fossil diatom assemblages. *Journal of Paleolimnology* 40: 385-398.

Loisel J and Garneau M (2010) Late Holocene paleoecohydrology and carbon accumulation estimates from two boreal peat bogs in eastern Canada: Potential and limits of multi-proxy archives. *Palaeogeography, Palaeoclimatology, Palaeoecology* 291: 493–533.

Lotter AF, Birks HJB, Hofmann W et al. (1997) Modern diatom, cladocera, chironomid, and chrysophyte cyst assemblages as quantitative indicators for the reconstruction of past environmental conditions in the Alps. I. Climate. *Journal of Paleolimnology* 18: 395–420.

Mann ME, Zhang Z, Rutherford S et al. (2009) Global signatures and dynamical origins of the Little Ice Age and Medieval Climate Anomaly. *Science* 326: 1256.

Martini IP (2006) The cold-climate peatlands of the Hudson Bay Lowland, Canada: brief overview of recent work. In: Martini IP, Martinez Cortizas A and Chesworth W (eds) *Peatlands: Evolution and Records of Environmental and Climate Change*. Amsterdam: Elsevier, pp. 53–83.

McAndrews JH, Riley JL and Davis AM (1982) Vegetation history of the Hudson Bay Lowland: a postglacial pollen diagram from the Sutton Ridge. *Le Naturaliste Canadien* 109: 597–608.

McKenney DW, Pedlar JH, Lawrence K et al. (2010) *Current and projected future climatic conditions for ecoregions and selected natural heritage areas in Ontario*. Climate Change Research Report CCRR-16. Peterborough: Ontario Ministry of Natural Resources.

Mitchell EAD, Charman DJ and Warner BG (2008) Testate amoebae analysis in ecological and paleoecological studies of wetlands: past, present and future. *Biodiversity Conservation* 17: 2115-2137.

Myers-Smith IH, Harden JW, Wilmking M et al. (2007) Wetland succession in a permafrost collapse: interactions between fire and thermokarst. *Biogeosciences Discussion* 4: 4507–4538.

O'Reilly BC, Finkelstein SA and Bunbury J (2014) Pollen-derived paleovegetation reconstruction and long-term carbon accumulation at a fen site in the Attawapiskat River watershed, Hudson Bay Lowlands, Canada. *Arctic, Antarctic, and Alpine Research* 46: 6-18.

Parr JF, Taffs KH and Lane CM (2004) A microwave digestion techniques for the extraction of fossil diatoms from coastal lake and swamp sediments. *Journal of Paleolimnology* 31: 383-390.

Payette S and Filion L (1993) Holocene water-level fluctuations of a subarctic lake at the tree line in northern Quebec. *Boreas* 22: 7-14

Payne RJ, Charman DJ, Matthews S et al. (2008) Testate amoebae as palaeohydrological proxies in Surmene Agacbasi Yaylasi Peatland (Northeast Turkey). *Wetlands* 28: 311–323.

Payne RJ and Mitchell EAD (2009) How many is enough? Determining optimal count totals for ecological and palaeoecological studies of testate amoebae. *Journal of Paleolimnology* 42: 483-495.

Payne RJ, Telford RJ, Blackford JJ et al. (2012) Testing peatland testate amoeba transfer functions: Appropriate methods for clustered training-sets. *The Holocene* 22: 819-825.

Pienitz R, Smol JP and MacDonald GM (1999) Paleolimnological reconstruction of Holocene climatic trends from two boreal treeline lakes, Northwest Territories, Canada. *Arctic, Antarctic, and Alpine Research* 31: 82-93.

Poulíčková A, Hájková P, Křenková P et al. (2004) Distribution of diatoms and bryophytes on linear transects through spring fens. *Nova Hedwigia* 78: 411-424.

R Development Core Team (2012) R: a language and environment for statistical computing. Vienna: R Foundation for Statistical Computing, Available from http://www.R-project.org.

Reimer PJ, Bard E, Bayliss A et al. (2013) IntCal13 and Marine13 radiocarbon age calibration curves 0–50,000 years cal BP. *Radiocarbon* 55: 1869–1887.

Rietkerk M, Dekker SC, Wassen MJ et al. (2004) A putative mechanism for bog patterning. *American Naturalist* 163: 699–708.

Riley JL (2011) *Wetlands of the Hudson Bay Lowland: An Ontario Overview*. Toronto: Nature Conservancy of Canada.

Rouse WR (1991) Impacts of Hudson Bay on the Terrestrial Climate of the Hudson Bay Lowlands. *Arctic and Alpine Research* 23: 24-30.

Rouse WR, Hardill SG and Lafleur P (1987) The energy balance in the coastal environment of James Bay and Hudson Bay during the growing season. *Journal of Climatology* 7: 165-179.

Rühland KM, Phadtare NR, Pant RK et al. (2006) Accelerated melting of Himalayan snow and ice triggers pronounced changes in a valley peatland from northern India. *Geophysical Research Letters* 33: L15709.

Rühland KM, Smol JP, Jasinski JPP et al. (2000) Response of diatoms and other siliceous indicators to the developmental history of a peatland in the Tiksi Forest, Siberia, Russia. *Arctic, Antarctic, and Alpine Research* 32: 167-178.

Rydin H, Gunnarsson U and Sundbery S (2006) The Role of Sphagnum in Peatland Development and Persistence. In: Wieder RK and Vitt DH (eds) *Ecological Studies, vol. 188: Boreal Peatland Ecosystems*. Berlin: Springer-Verlag, pp. 1-19.

Smol JP (1983) Paleophycology of a high arctic lake near Cape Herschel, Ellesmere Island. *Canadian Journal of Botany* 61: 2195-2204.

Smol JP (1985) The ratio of diatom frustules to chrysophycean statospores: A useful paleolimnological index. *Hydrobiologia* 123: 199-208

Smol JP and Stoermer EF (2010) *The Diatoms: Applications for the Environmental and Earth Sciences*. 2nd Edition. Cambridge: Cambridge University Press.

Swindles GT, Charman DJ, Roe HM et al. (2009) Environmental controls on peatland testate amoebae (Protozoa: Rhizopoda) in the North of Ireland: Implications for Holocene palaeoclimate studies. *Journal of Paleolimnology* 42:123–140. doi:10.1007/s10933-008-9266-7

Swindles GT, Morris PJ, Baird AJ et al. (2012) Ecohydrological feedbacks confound peat-based climate reconstructions. *Geophysical Research Letters* 39: L11401.

Tarnocai C (2006) The effect of climate change on carbon in Canadian peatlands. *Global and Planetary Change* 53: 222–232.

ter Braak CJF and Šmilauer P (2002) CANOCO reference manual and CanoDraw for Windows user's guide: software for canonical community ordination, v.4.5. Ithaca, NY: Microcomputer Power.

Turetsky MR, Wieder RK, Vitt DH et al. (2007) The disappearance of relict permafrost in boreal north America: Effects on peatland carbon storage and fluxes. *Global Change Biology* 13: 1922-1934.

van Bellen S, Garneau M and Booth RK (2011) Holocene carbon accumulation rates from three ombrotrophic peatlands in boreal Quebec, Canada: Impact of climate-driven ecohydrological change. *The Holocene* 21: 1217-1231.

van Dam H, Mertens A and Sinkeldam J (1994) A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands. *Netherlands Journal of Aquatic Ecology* 28: 117-133.

Van de Vijver B, Van Kerckvoorde A and Beyens L (2003) Freshwater and terrestrial moss diatom assemblages of the Cambridge Bay area, Victoria Island (Nunavut, Canada). *Nova Hedwigia* 76: 225-243.

Vitt DH (2006) Functional Characteristics and Indicators of Boreal Peatlands. In: Wieder RK, and Vitt DH (eds) *Ecological Studies, vol. 188 Boreal Peatland Ecosystems*. Berlin: Springer-Verlag, pp.9-24.

Weilhoefer CL and Pan Y (2006) Diatom-based bioassessment in wetlands: how many samples do we need to characterize the diatom assemblage in a wetland adequately? *Wetlands* 26(3): 793-802.

Wilkinson A, Zeeb B, Smol JP et al. (1997) Chrysophyte stomatocyst assemblages associated with periphytic, high arctic pond environments. *Nordic Journal of Botany* 17: 95-112.

Zeeb BA and Smol JP (1993) Postglacial chrysophycean cyst record from Elk Lake, Minnesota *Geological Society of America Special Papers* 276: 239-250.

Zeeb BA and Smol JP (2001) Chrysophyte Scales and Cysts. In: Smol JP, Birks HJB, and Last WM (eds) *Tracking Environmental Change Using Lake Sediments. vol. 3: Terrestrial, Algal, and Siliceous Indicators*. Dordrecht: Kluwer, pp.203–224.

Zoltai SC and Vitt DH (1995) Canadian wetlands: Environmental gradients and classification. *Vegetation* 118: 131-137.

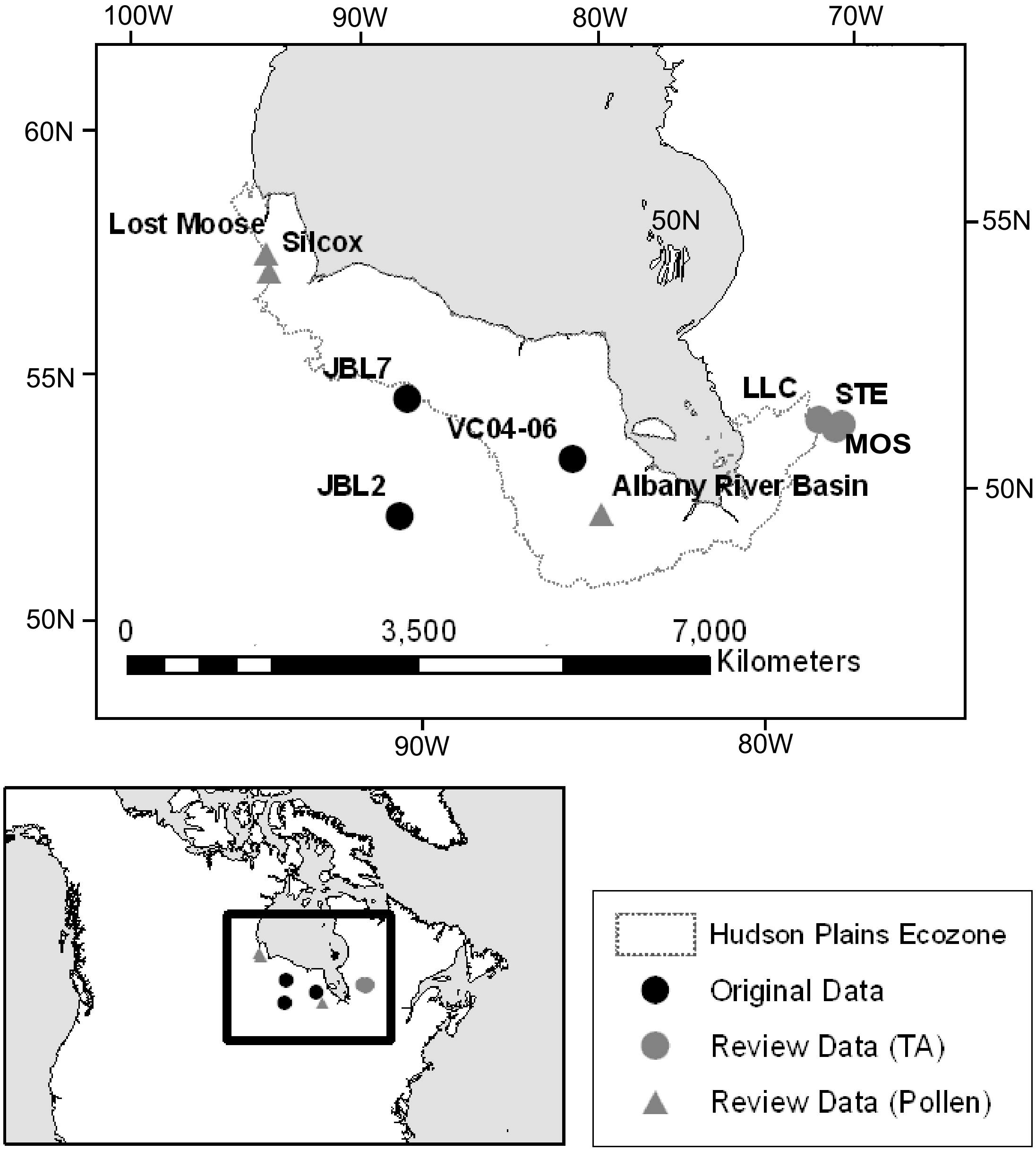


Figure 3-1 Location of the 3 study peatland cores from northern, Ontario, Canada, and other published regional peatland records for testate amoebae, macrofossils and pollen. The Hudson Bay Plains ecozone is delineated.

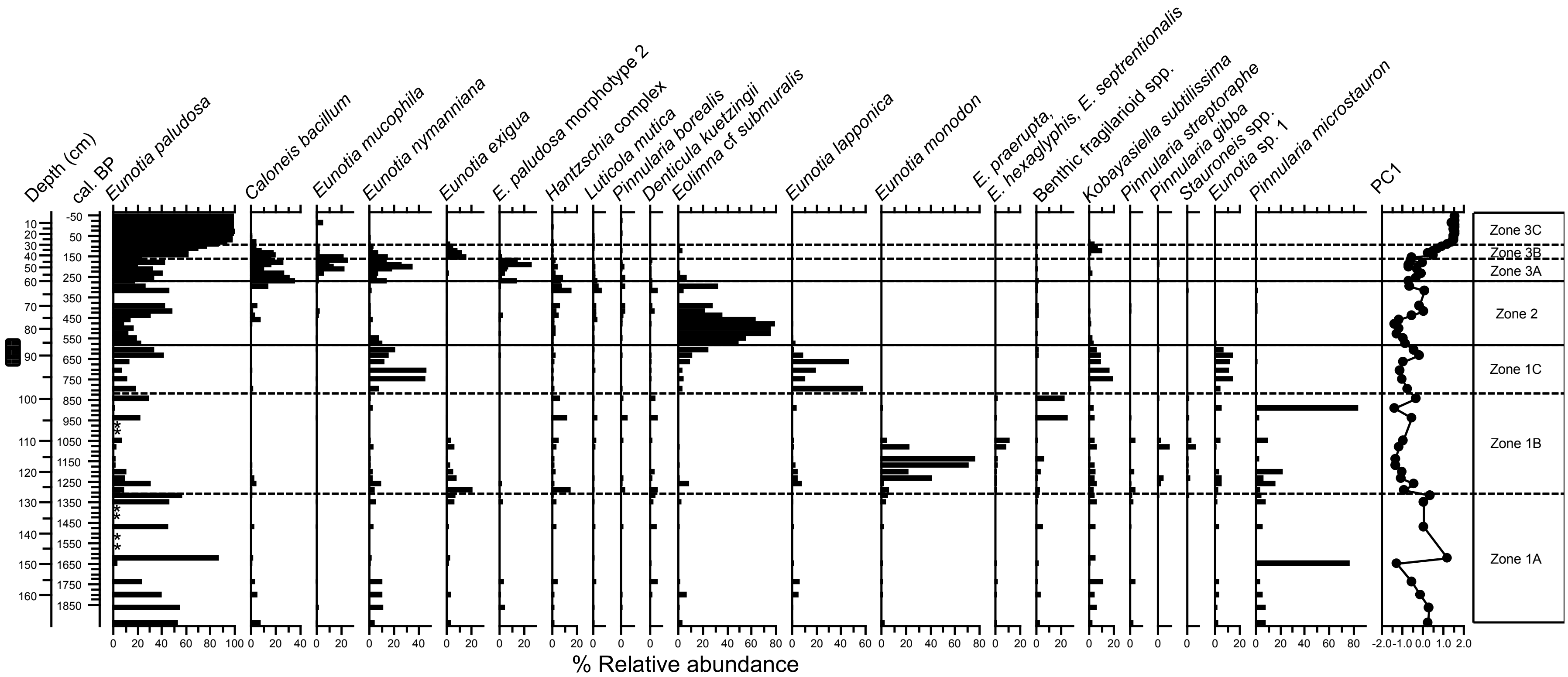


Figure 3-2 Stratigraphic diatom profiles showing changes in the relative abundances of the most common taxa in JBL2. Diatom principal component analysis axis 1 (PC1) sample scores are plotted. Three first-order zones are delineated by numbers and solid lines and second order zones by letters and dashed lines: Zone 1A (1940 to 1310 cal. BP), Zone 1B (1310 to 820 cal. BP), Zone 1C (820 to 580 cal. BP), Zone 2 (580 to 270 cal. BP), Zone 3A (270 to 160 cal. BP), Zone 3B (170 to 95 cal. BP), and Zone 3C (95 cal. BP to present). The checkered box on the left in the diagram highlights the period that macrofossils switched from herbaceous spp. to *Sphagnum* spp. from ~670 to 550 cal. BP. Asterisks denote individual samples that were excluded from analyses because diatoms were too scarce to count (< 200 valves). The corrected radiocarbon dates are represented in calendar years before present (cal. BP) and displayed on the left in the diagram.

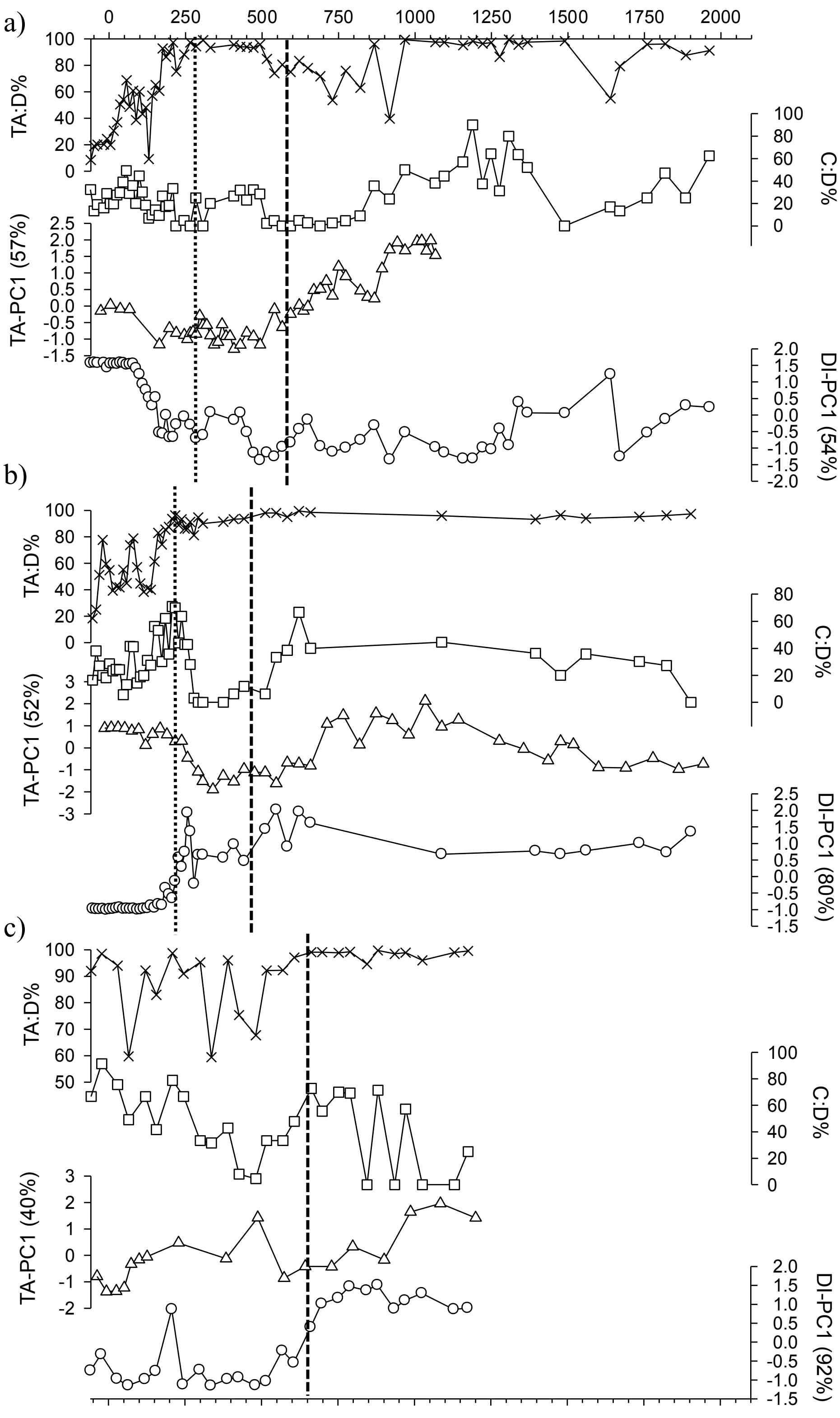

a)
b)
c)
TA:D%
C:D%
TA-PC1 (57%)
DI-PC1 (54%)
TA-PC1 (52%)
DI-PC1 (80%)
TA-PC1 (40%)
DI-PC1 (92%)
0
250
500
750
1000
1250
1500
1750
2000
cal. BP

Figure 3-3 Principal components analysis (PCA) for the first ordination axis of the diatom assemblage data (DI-PC1), testate amoeba assemblage data (TA-PC1), cysts to diatom percentage (C:D%) and testate amoebae plate to diatom percentage (TA:D%) are plotted for: (a) JBL2, (b) JBL7, and (c) VC04-06. First-order zones displayed are determined from diatom assemblage data, with long dashed lines representing the transition from Zone 1 to Zone 2, and the short dashed lines the transition from Zone 2 to Zone 3. The corrected radiocarbon dates are represented in calendar years before present (cal. BP) and displayed on the x-axis in the diagram.

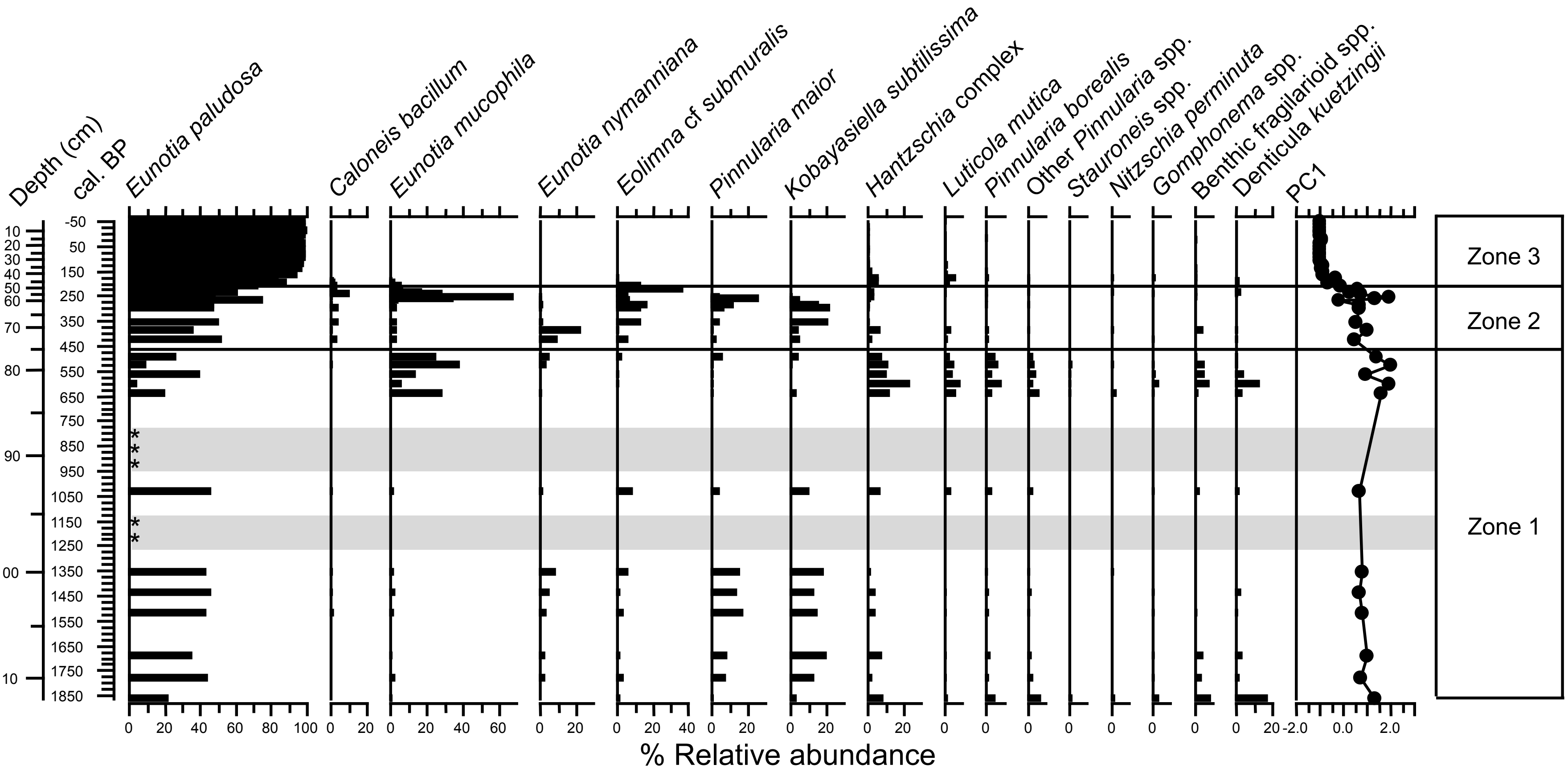


Figure 3-4 Stratigraphic diatom profiles showing changes in relative abundances of the most common taxa in JBL7. Diatom principal component analysis axis 1 (PC1) sample scores are plotted. Three first-order zones are delineated with solid lines: Zone 1 (1860 to 460 cal. BP), Zone 2 (460 to 210 cal. BP), and Zone 3 (210 cal. BP to present). Grey bars denote period in the core where diatoms were too scarce to count and asterisks are the individual samples that were excluded from analyses. The corrected radiocarbon dates are represented in calendar years before present (cal. BP) and displayed on the left in the diagram.

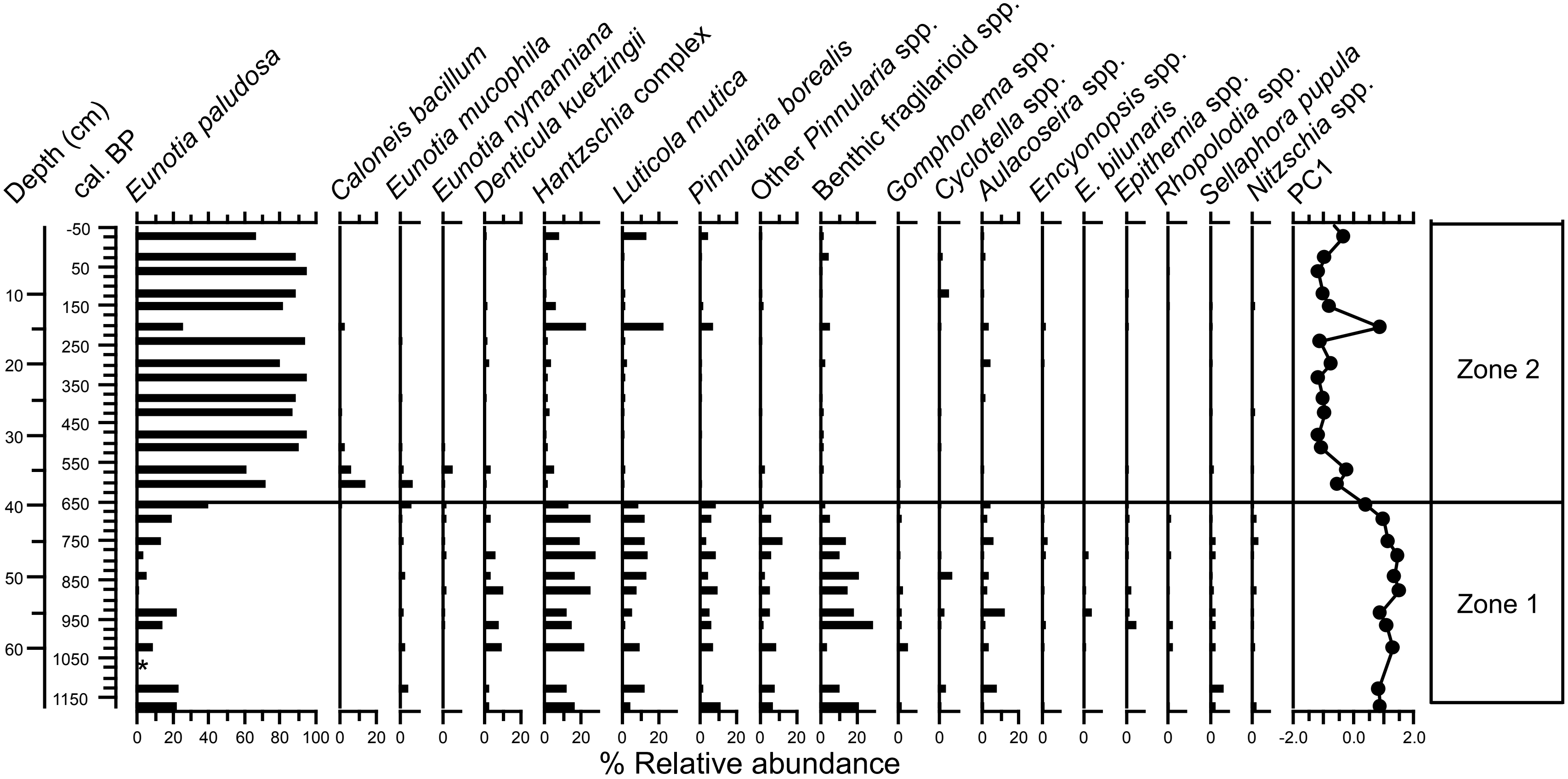
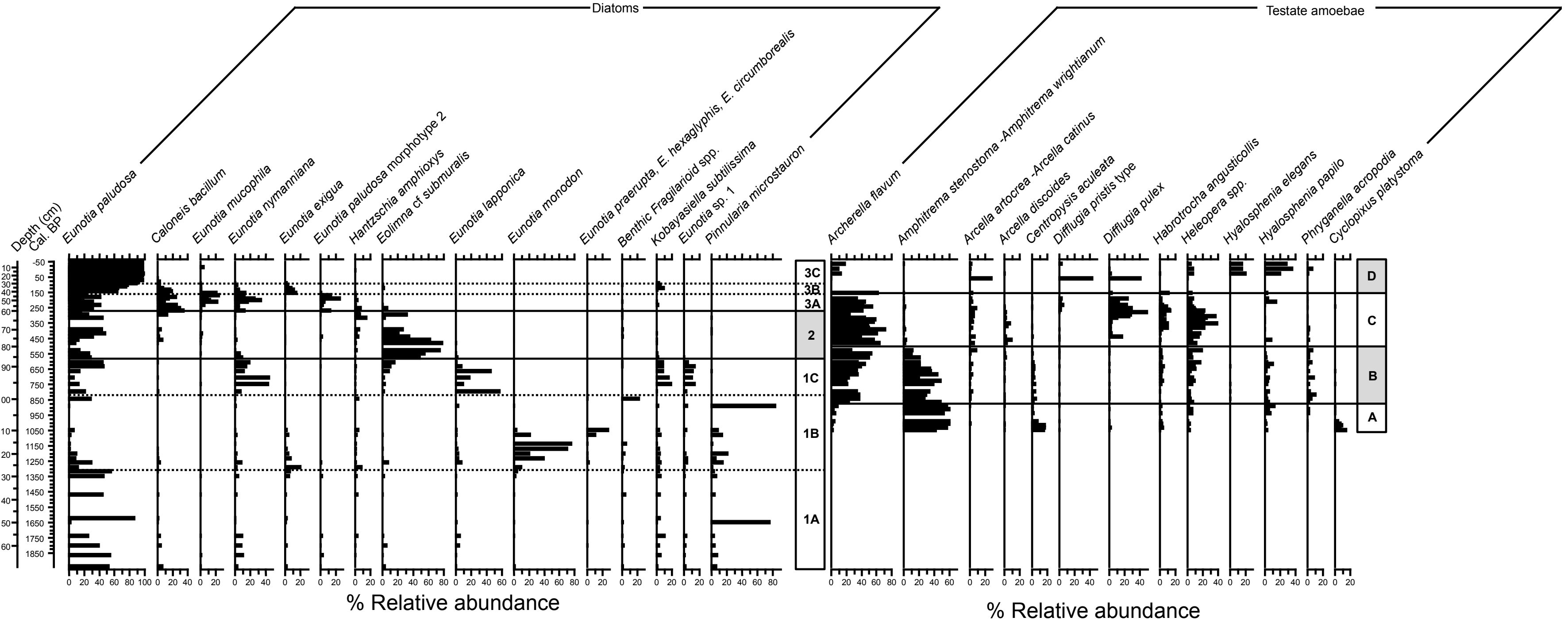
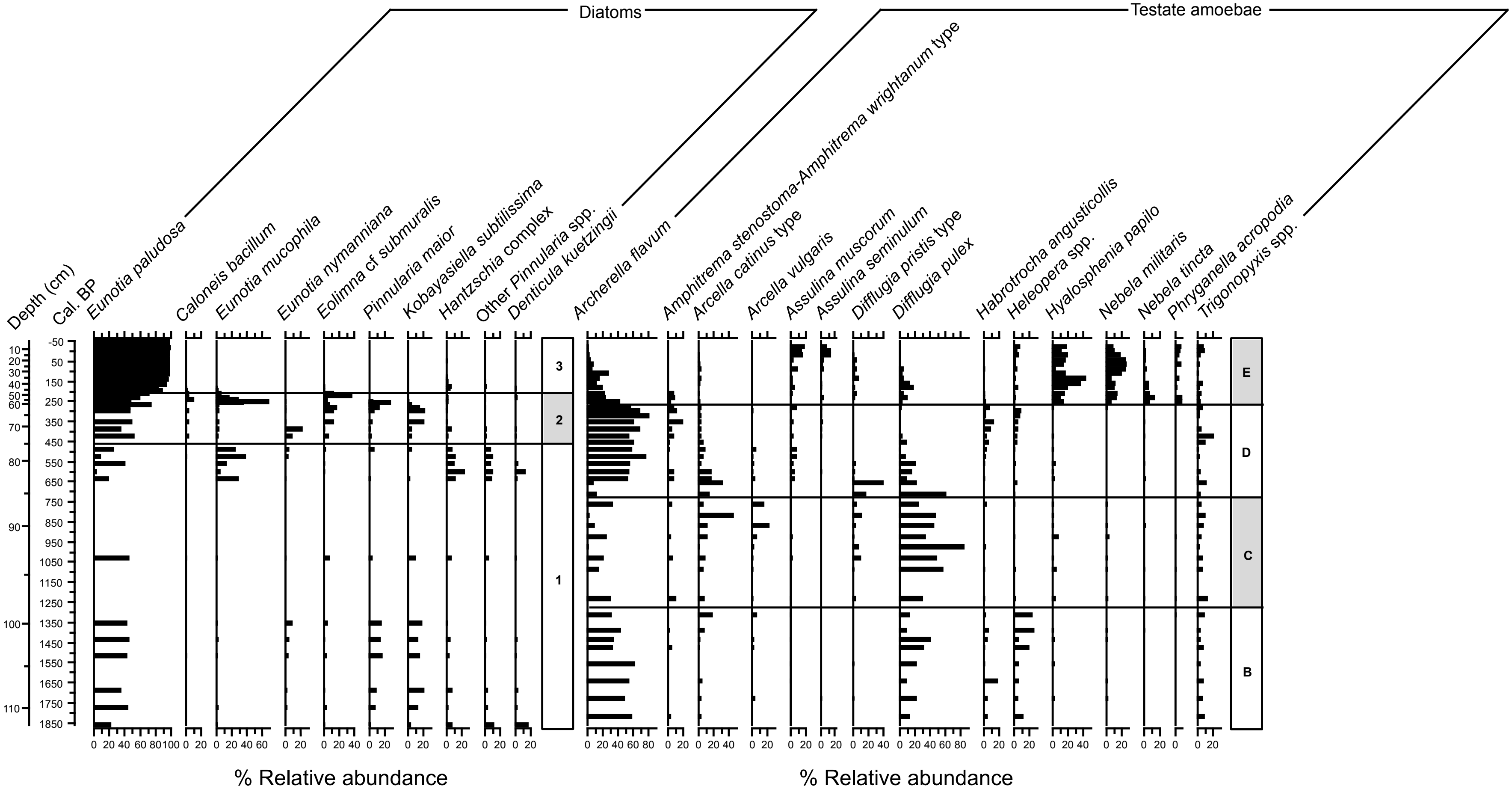


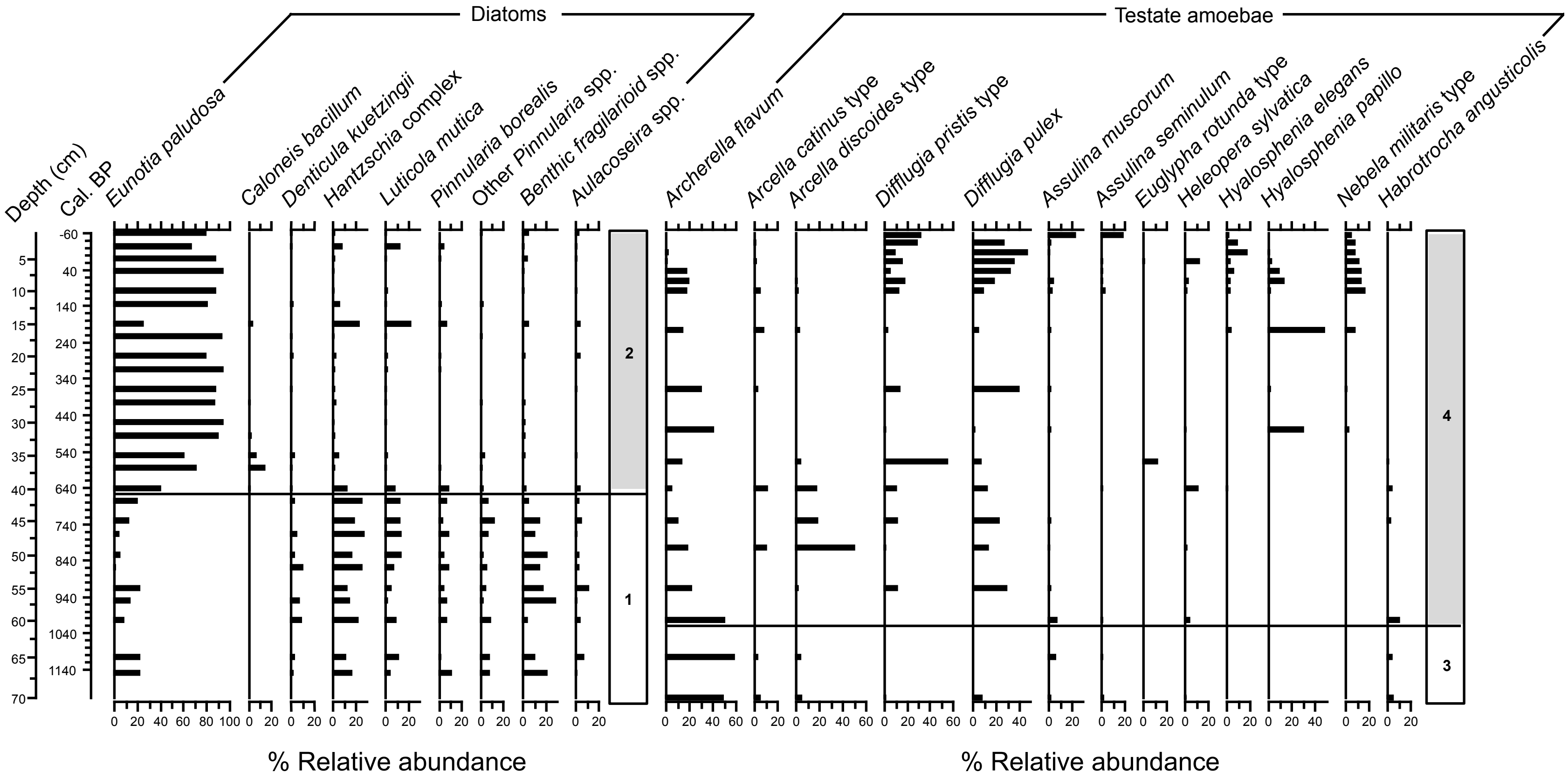
Figure 3-5 Stratigraphic diatom profiles showing changes in the relative abundances of the most common taxa in VC04-06. Diatom principal component analysis axis 1 (PC1) sample scores are plotted. Two first-order zones are identified: Zone 1 (1200 to 650 cal. BP) and Zone 2 (650 cal. BP to present). The asterisk denotes a sample that was excluded from analyses because diatoms were too scarce to count (< 200 valves).



Supplemental Figure 3-1 A stratigraphic profile for JBL2 showing changes in relative abundances of the diatom and testate amoeba taxa with maximum relative abundances greater than 10% in at least one interval. The corrected radiocarbon dates are represented in calendar years before present (cal. BP) and displayed on the left in the diagram.



Supplemental Figure 3-2 A stratigraphic profile for JBL7 showing changes in relative abundances of the diatom and testate amoeba taxa with maximum relative abundances greater than 10% in at least one interval. The corrected radiocarbon dates are represented in calendar years before present (cal. BP) and displayed on the left in the diagram.



Supplemental Figure 3-3 A stratigraphic profile for VC04-06 showing changes in relative abundances of the diatom and testate amoeba taxa with maximum relative abundances greater than 10% in at least one interval. The corrected radiocarbon dates are represented in calendar years before present (cal. BP) and displayed on the left in the diagram.

## Chapter 4

# Tracking the long-term responses of diatoms and Cladocera to climate warming across lakes of the Far North of Ontario, Canada

## 4.1 Abstract

The vast peatlands and lakes of the Far North of Ontario warrant greater scientific attention given their hydrological complexity and status as a significant carbon sink. Economic interest in this region is also growing due to the recent mineral discoveries (mainly chromite and nickel) known as the “Ring of Fire” (RoF). Mineral exploration and infrastructure planning are ongoing; however, environmental monitoring is only beginning. Detailed baseline ecological information is required to assess the impacts of future resource extraction within the context of multiple environmental stressors (including recent regional climate warming). Sedimentary chlorophyll-*a*, diatom and cladoceran assemblage composition from dated sediment cores were used to examine biotic responses to warming across multiple trophic levels over the past ~150 years. Study lakes were selected to cover the wide variation in lake type and setting across the RoF, with two deep lakes (~10 m) on the Boreal Shield and two shallow lakes (~2 m) in the Hudson Bay Lowlands (HBL). Over the past ~100 years, biotic assemblages within the study lakes have transitioned from dominance by littoral/benthic forms to greater abundances of pelagic Cladocera (an increase of ~34%) and planktonic diatom taxa (an increase of ~3-22%). Increased relative abundances of planktonic taxa are consistent with warming-induced changes in lake properties including longer ice-free periods and increased algal plankton production. The response of diatom assemblages in shallow HBL lakes to warming preceded the deep Boreal

Shield lakes by ~45-60 years, and substantial increases in aquatic production (~ 4 to 15 times higher than baseline conditions) was observed in the HBL lakes. These paleolimnological data provide important information that can help distinguish the potential ecological impacts related to resource development and extraction from changes linked to both natural variation and ongoing responses to regional warming.

**Key Words:** Paleolimnology; Ring of Fire; Ontario; Climate Change; Diatoms; Cladocera

## 4.2 Introduction

The Far North of Ontario (~50-57ºN, 79-94ºW; Figure 1), Canada, is a region of increasing ecological and economic significance. This region stores vast amounts of carbon (likely >35 Gt C; Far North Science Advisory Panel 2010) within the largest, continuous peatland in North America (and the second largest globally). Three of Canada's largest rivers cross the region and >10% of the landscape is covered by lakes and rivers representing a significant water resource (Cox 1978; Far North Science Advisory Panel 2010). The intrinsic value of this region stems from the substantial stores of carbon, the potential to act as a carbon sink in the future, and its abundant water resources, necessitating further research and collection of baseline ecological data.

Over the last decade in northern Ontario, mining exploration, land claims, development proposals, and future plans for mineral extraction have intensified with the discovery of extensive mineral deposits (e.g., chromite, gold, zinc, nickel, copper and platinum; Dyer and Burke 2012). Unpatented mining claims are particularly concentrated along the Attawapiskat River on the boundary between the Boreal Shield and Hudson Bay Lowlands (HBL), and this region of Ontario has become known as the "Ring of Fire" (RoF). The RoF is estimated to contain the fourth largest chromite deposit in the world (~220 tonnes; Hjartarson et al. 2014) and, therefore, the proposed mining and infrastructure development required to extract and transport these minerals is of great economic importance. Balancing future resource development and environmental conservation of the sensitive northern wetlands and lake ecosystems will require a detailed understanding of the regional ecology and ongoing natural processes and environmental changes. Prior to the onset of mining and development in the RoF, there is an opportunity to identify the impacts of recent warming on these northern environments and determine the baseline ecological conditions of the past ~150 years with the use of paleolimnological techniques.

The regional climate of the Far North of Ontario is primarily influenced by large-scale cold air masses that originate over Hudson Bay, along with land-sea breezes that impose cold air temperatures on the adjacent terrestrial environment (Martini 2006). Most of the Canadian Arctic began experiencing a pronounced warming trend beginning as early as the middle of the 19th century (Smol et al. 2005). In contrast, over the period of instrumental record, from 1960 to the mid-1990s, subarctic HBL continued to maintain stable and relatively cool conditions (Rouse 1991; Chapman and Walsh 1993; Gough et al. 2004; Macrae et al. 2014). The extent of the cooling influence of Hudson Bay inland is not precisely known; however, modeling has suggested that a significant maritime effect could extend up to ~650 km inland at a latitude of 54°N (Rouse 1991). Further south (at a latitude of 52°N), the RoF is situated ~300 km inland from Hudson Bay and here air temperature may not be as strongly influenced by the proximity of Hudson Bay, and continental effects are also important to the local climate (Crins et al. 2009). However, much of the RoF region resides within the most southern extent of permafrost in Canada supported in part by the cooling influence of Hudson Bay. This suggests that the coastal marine climate may in fact extend far inland and could have sheltered RoF lakes from the impacts of early 20th century warming.

The moderating effect of Hudson Bay sea ice has diminished substantially over the last ~20 years due to increases in land surface air temperatures, Hudson Bay sea surface temperatures, sea ice thickness and extent, and sea ice phenology (Gough et al. 2004; Hochheim and Barber 2010; 2014). A rapid, threshold response of lake and river ecosystems to warming temperatures has occurred including: a large-scale fish die-off event from abnormally warm conditions in the Sutton River in 2001(Gunn and Snucins 2010), evaporation and desiccation of lakes with low snowfall winters (Bouchard et al. 2013), and abrupt algal community shifts and increased primary production as a result of warming and shorter duration of lake ice cover (Rühland et al. 2013, 2014; Friel et al. 2014). Warmer air temperatures and longer ice-free seasons for Hudson Bay are projected to continue and accelerate (Gough et al. 2004; Gagnon and Gough 2005; McKenney et al. 2010; Hochheim et al. 2010), likely promoting further (and perhaps unexpected) aquatic changes in the Far North of Ontario.

Diatoms (Class Bacillariophytceae) are often used as bio-monitoring tools to track both direct and indirect anthropogenic impacts such as nutrient and mining pollution (e.g., Battarbee et al. 2010; Hall and Smol 2010; Greenaway et al. 2012). In lakes of the HBL, as well as across the globe, diatoms have been shown to respond to changes in limnological conditions linked to climate warming, including: a reduction in seasonal ice cover, a longer open water and growing season, and changes in the duration and strength of thermal stratification (Lotter and Bigler 2000; Smol and Cumming 2000; Rühland et al. 2008, 2013, 2014; Winder and Hunter 2008). A longer growing season has allowed many subarctic lakes in northern Ontario, which are typically ice-free for short time periods relative to lakes in more southern latitudes, to experience significant increases in primary production and develop more complex substrates for the growth of diatoms (Rühland et al. 2013; Friel et al. 2014).

Cladoceran subfossils are widely used invertebrate paleolimnological indicators that often respond to different ecological cues than diatoms, as Cladocera occupy a mid-trophic position and are major consumers of primary producers, benthic detritivores, and a source of food for planktivorous fish and invertebrate predators (Korhola and Rautio 2001; Korosi et al. 2010). Due to their intermediate position in aquatic food-webs, the Cladocera provide a critical link between upper and lower trophic levels, and have been utilized to examine changes in salinity (Bos et al. 1999), predation structure (Korosi et al. 2008), lake trophic level (Shumate et al. 2002) and understanding the biological impact of acidification (Korosi and Smol 2012a). Cladoceran communities are also strongly influenced and structured by ice cover (Catalan et al. 2002), and habitat changes and longer growing seasons may place pressure on larger bodied species (Brucet et al. 2010; Nevalainen et al. 2014; Adamczuk 2014). The species-environmental relationships of Cladocera, particularly littoral taxa, are not as well understood as those of diatoms. However, multi-proxy studies, such as this one, may provide insights into concurrent changes at multiple trophic levels, and improve interpretation of these relationships.

The response of aquatic biota to climate warming varies depending on a multitude of parameters including lake morphometry (Keatley et al. 2008; Lim et al. 2008), latitude (Smol et al. 2005; Rühland et al. 2008), altitude (Catalan et al. 2009; Lotter et al. 2012; Nevalainen et al. 2014), coastal or sea ice proximity (Paterson et al. 2003; Fallu et al. 2005; Bhiry et al. 2011), and the interaction of multiple environmental stressors within a warming world (Keller 2008; Quinlan et al. 2008; Smol 2010; Arseneau et al. 2011; Hawryshyn et al. 2012). Additionally, lakes within different climatic regions will often have different physical, chemical, and biological features, and thus may exhibit different ecological responses to climate change. Ultimately, aquatic biotic responses to climate warming are not uniform across the globe, and factors that influence differences in this response must first be disentangled at the local scale within the RoF.

The RoF study lakes are situated within an understudied region of Ontario, and thus the response aquatic biota to climate warming has yet to be described. As the RoF crosses a major physiographic boundary (capturing changes in geology), permafrost transitions, and includes lake catchments containing vast quantities of trapped water and carbon, the ecological response of lakes and aquatic biota within the RoF to climate change may be highly varied. In this paper, our objectives were to evaluate the response of diatom and cladoceran communities to recent environmental changes in lakes in the vicinity of the RoF, and to address the following questions: 1) Do the diatom and cladoceran communities of lakes located in the RoF infer physical changes in lake water column properties that are often induced from warmer air temperatures? 2) If so, when and how does the biota respond to recent climate change? 3) Do lakes from different physiographic regions exhibit similar biological responses to environmental and climate change? 4) Do deep and shallow lakes exhibit differences in biological response? 5) How does the timing of, and response to, climatic change recorded in lake sediments in the RoF region of northern Ontario compare to HBL lakes closer to Hudson Bay coast (e.g., Rühland et al. 2013), as well as to more southern, temperate lakes in Ontario (e.g., Labaj et al. 2014)?

## 4.3 Study sites

The four study lakes are located in the Far North of Ontario on the Boreal Shield (Eabamet and Attawapiskat lakes) and in the HBL (McFaulds and Symons lakes) (Figure 1). The study lakes are included in an area of ~10,000 km$^2$ (maximum distance ~185 km from Eabamet to McFaulds Lake). The Boreal Shield covers 46% of the Far North of Ontario and has an irregular topography that is underlain by Precambrian igneous and metamorphic rocks (Martini 2006; Far North Science Advisory Panel 2010; Keller et al. 2014). The predominantly flat HBL comprises 54% of the Far North and is underlain by sedimentary rocks of Paleozoic and Mesozoic age covered by loose glacial and marine deposits (Martini 2006; Far North Science Advisory Panel 2010). The surficial geology of the Boreal Shield in Canada is diverse, and includes morainal, organic, and glaciolacustrine deposits but in Ontario, a significant percentage of the region is characterized by exposed Precambrian bedrock (Crins et al. 2009).

### *Hudson Bay Lowland lakes*

McFaulds Lake (52°47'15.304" N, 86°3'10.384" W; Table 1) is located at the approximate center of the RoF (Figure 1). The lake is situated within the HBL, close to the transition zone between the HBL and the Boreal Shield. It is part of the Attawapiskat watershed and ~270 km from the Hudson Bay coast. McFaulds Lake (~6 km long and ~14 km in perimeter) is shallow (coring depth =2 m) and therefore is predominantly littoral habitat. Low relief organic peat deposits and bogs characterize the surrounding landscape (Riley 2011). Symons Lake (52°32'57.043" N, 86°9' 3.393" W; Table 1) is also located in the HBL, ~22 km to the south of McFaulds Lake (Figure 1), and thus shares similar geology and catchment characteristics. The lake is the smallest of the four study lakes (2.3 km long and 7 km in perimeter) and is the shallowest (coring depth=1.8 m). Both McFaulds and Symons lakes are situated within a region classified as having sporadic permafrost (Far North Science Advisory Panel 2010).

### *Boreal Shield lakes*

Eabamet Lake (51°31'11.661" N, 87°51'6.868" W) is located ~185 km to the SW of McFaulds Lake and is situated on the Boreal Shield (Figure 1). It is considerably larger (~30 km long and ~80 km in perimeter) and deeper (9.0 m coring depth) than McFaulds and Symons lakes, and the headwaters to Albany River. The lake is important to the community of Fort Hope and the Eabametoong First Nation, situated along its northern shoreline, because it provides a drinking water source as well as a cold-water fish for the community. As the lake is ~9 m deep (coring depth), it may thermally stratify at least periodically during the summer but thermal stratification could also be limited by the lake's large fetch and close connection to the Albany River. A water column temperature profile in mid July 2012 indicated that the lake was not stratified despite an air temperature of 24ºC. Attawapiskat Lake (52°11'40.711" N, 87°45'58.730" W), located ~40 km north of Eabamet Lake, is also a large (~ 18 km long and >100 km in perimeter) and deep (10.4 m at coring depth) lake located within the Boreal Shield physiographic region (Figure 1). Attawapiskat Lake is a widening of Attawapiskat River and the headwaters to Attawapiskat River, which flows through the center of the proposed RoF. This lake is distinguished by its irregular shape with many bays and islands. The Neskantaga First Nation community is situated on the shores of this lake and the Lansdowne House climate station (Environment Canada, http://climate.weather.gc.ca) is located at the community airport. Both Eabamet and Attawapiskat lakes are south of the permafrost zones of northern Ontario.

## 4.4 Methods

### 4.4.1 Water chemistry and sediment core collection

Sediment cores and water chemistry for the study lakes were collected in July 2012. Sediment cores were collected using either a Glew (1989) gravity corer (for Attawapiskat and Eabamet) or a modified Glew gravity push corer specifically developed for sampling shallow lakes (for Symons and McFaulds), and sectioned at 0.25 cm intervals using a Glew (1988) extruder. At each lake, efforts were made to sample within, or near, the deepest depositional basin of the lake determined from local knowledge for Eabamet Lake (from Xavier Sagutch, personal communication) or through visual identification from aerial surveys. Upon landing on each lake, several depth readings were taken to find the ideal coring location. At each lake, temperature and oxygen readings were taken every one-meter through the water column using an YSI model 58 meter. For water chemistry analyses, an integrated sample of the lake water column was collected from the Secchi depth to the surface, following standard Ontario Ministry of the Environment and Climate Change (MOECC) protocols (Ingram et al. 2013). All chemical analyses were performed at the MOECC Dorset Environmental Science Centre.

### 4.4.2 Radiometric dating

A chronology was determined for each core at PEARL using gamma spectrometry techniques to measure the activity of radioisotopes (e.g., $^{210}$Pb, $^{137}$Cs, $^{214}$Bi) (Schelske et al. 1994; Appleby 2001) using an EG&G Ortec germanium detector. Dates for each sample were determined using the constant rate of supply (CRS) model applied to the unsupported fraction of the $^{210}$Pb activity (Binford 1990; Schelske et al. 1994). Age versus depth models were produced for each lake using linear regression with a fixed y-intercept of 2012, the year the cores were collected.

### 4.4.3 Diatom preparation

Sediment samples were prepared for diatom analyses following standard procedures outlined in Battarbee et al. (2001). Briefly, ~0.5 g of wet sediment from every 0.25 cm interval was treated with a 1:1 molar ratio of concentrated sulphuric ($H_2SO_4$) and nitric ($HNO_3$) acids to digest the organic content of the sediment and isolate the siliceous material. The rinsed siliceous slurries were pipetted onto cover slips, dried, and mounted on glass microscope slides using

Naphrax®. A minimum of 400 diatom valves were counted for each sedimentary interval using a Leica DMRB light microscope fitted with differential interference contrast optics at 1000X magnification. Diatoms were identified to the lowest taxonomic level possible using a selection of taxonomic references (e.g., Krammer and Lange-Bertalot 1986–1991; Camburn and Charles 2000).

The prepared diatom samples contained an excess of siliciclastic material and very low concentrations of diatom valves below 5.5 cm in Eabamet Lake and below 4 cm in Attawapiskat Lake. To attain sufficient diatom counts for analysis, excess clastic material was removed and diatom valves were concentrated on the microscope slide by treating with a density gradient separation technique using the heavy liquid, sodium polytungstate (SPT) (Tapia and Harwood 2002) at a density of 2.3 g/cm$^3$.

### 4.4.4 Cladoceran preparation

The processing methods to isolate cladoceran subfossils from the sedimentary assemblage were adapted from Korhola and Rautio (2001). Approximately 1.0 g of wet sediment from each 0.25 cm interval was deflocculated in a 10% potassium hydroxide solution heated to 80°C, for ~20 minutes. Sediment slurries from each interval were then sieved using a 38-µm mesh. To aid identification, chitinous remains were stained with a safranin-glycerol solution, and a few drops of ethanol were added to the slurry to inhibit fungal growth. Identification of cladoceran subfossils was performed by following the guidelines established in Korosi and Smol (2012b,c), and as cladoceran taxa can leave behind multiple different subfossils (e.g., carapace, headshield, postabdomen), the subfossil type with the greatest frequency was used in establishing the number of individuals present for each taxon. A minimum of ~100 cladoceran individuals were identified from each interval to obtain a representative sample of the sedimentary assemblage (Kurek et al. 2010).

### 4.4.5 Chlorophyll-*a* analysis

The analyses of sedimentary chlorophyll-*a*, a proxy for overall aquatic primary production, largely followed the methods outlined in Michelutti et al. (2010). Freeze-dried sediment was sieved through a 125-µm screen onto weigh paper to equalize sediment grain size and the influence of water. Sediment filled vials were run through a spectrophotometer using Visible Near-Infrared Spectroscopy (NIRS) to infer chlorophyll-*a* concentration. As wave absorption and chlorophyll-*a* concentration are linearly correlated (Michelutti et al. 2010), the NIRS output of absorbance was used directly to calculate inferred chlorophyll-*a*. This was done by calculating the area under the 650-700 nm wavelength peak of a wavelength-absorbance plot (Wolfe et al. 2006). This technique is robust as the chlorophyll-*a* inferences are not affected by diagenetic processes or changes in chlorophyll-*a* sources (i.e., the inferences incorporate all algal production, including isomers and post-depositional degradation products) (Wolfe et al. 2006).

### 4.4.6 Statistical analyses

Mean annual air temperatures (MAAT) from ~1943 to 2011 (length of the instrumental record, missing data from 1989 to 1992 and 1994) were obtained from the Lansdowne House Climate Station (http://climate.weather.gc.ca). A 2-segment piecewise regression breakpoint analysis was used to determine the timing of greatest change in regional air temperature in the RoF of Ontario (Figure 2). To compare to temperature changes across the HBL, MAAT from Churchill, Manitoba were plotted with the Lansdowne House MAAT. Although, Churchill is located considerably north of the study lakes, the temperatures recorded at this climate station significantly correlate with air temperatures recorded at the Winisk Climate station, situated closer to the study lakes in the HBL (Rühland et al. 2013).

Species assemblage data from each core were expressed as percent relative abundances. For each proxy, biostratigraphic zones were identified by cluster analysis using constrained incremental sum of squares (CONISS) (Grimm 1987). A broken-stick model (Bennett 1996) was applied to both the diatom and cladoceran data using the rioja package in R to determine the number of important zones (Juggins 2009; R Development Core Team 2012). Diatom samples treated with SPT in Eabamet Lake where included in the CONISS analysis. A broken-stick model was also applied to the McFaulds and Symons sedimentary chlorophyll-*a* data to establish when the main change in primary production first occurs in these lakes. Due to a lack of a visual change in the sedimentary chlorophyll-a record throughout the Eabamet and Attawapiskat cores, break-point analysis was not undertaken.

For clarity in the data display, several diatoms were grouped for the stratigraphic figures. For example, the 'benthic fragilarioid spp.' category was composed of small, benthic taxa *Staurosirella pinnata* and *Staurosira construens* and their varieties; however, *Pseudostaurosira brevistriata* was excluded from this complex because it often showed different trajectories through time. We grouped members of *Bosmina* spp., as we could not reliably distinguish the headpore due to the large amount of inorganic material that persisted through the digestion process. However, we did not encounter any Eubosmina headshields.

The major patterns of variation in the diatom and cladoceran stratigraphical sequences were summarized using principal component analysis (PCA) using CANOCO version 4.5 for Windows (ter Braak and Šmilauer 2002). Diatom and cladoceran data were square-root transformed prior to analysis to equalize the variance among taxa. All four cores were plotted in the same ordination space to compare the magnitude of changes between cores. Diatom and cladoceran data were not compared in the same ordination space. Summarizing both the diatom and cladoceran data in this way enabled a graphical comparison of community compositional trajectories through time among the four dated sediment records. Additionally, the diatom PCA axis 1 and 2 scores for deeper Eabamet and Attawapiskat lakes were plotted in their own ordination space to better depict changes through time.

## 4.5 Results

### 4.5.1 McFaulds Lake

McFaulds Lake, located in the HBL, is shallow ($Z_{max}$= 2.0 m) and circum-neutral (pH = 7.4). Nutrient concentrations are elevated compared to the other study lakes (total phosphorus (TP) = 18.0 µg/L; total Kjeldahl nitrogen (TKN) = 509 mg/L); however, conductivity was the lowest relative to the other study lakes (Table 1). The radiometric profile shows a low initial activity of $^{210}$Pb at 0.25 cm which subsequently increases to ~1100 bq/kg at 3 cm, and then $^{210}$Pb activities exponentially decline with depth to ~5.25 cm (Figure S-1). Radioisotope $^{210}$Pb analysis and application of the CRS model identified a date of ~1850 at a depth of 5.25 cm. Sedimentary chlorophyll-*a* concentrations in McFaulds Lake were below the detection limit of 0.01 mg/g dry weight of sediment until ~1870, and it increased thereafter (Figure 3A). Breakpoint analysis identified an increase in inferred chlorophyll-*a* beginning at ~1870. The chlorophyll-*a* at 2012 is ~15 times higher than concentrations prior to ~1870, representing the most pronounced increase in primary production recorded in any of the study cores.

CONISS identified that the greatest change in the McFaulds Lake diatom assemblages occurred at ~1895 (4.5 cm, Figure 3A). Diatom Zone 1 is composed mainly of larger (> 40 µm) benthic diatom taxa including *Sellophora* complex, *Kobayasiella jaagii, Navicula reinhardtii*, *Neidium* spp., *Pinnularia* spp., and *Staruoneis* spp. These diatom assemblages are almost entirely replaced in the modern sediments by diatom assemblages dominated by a combination of diatoms with a variety of life-strategies including epipsammic (*Achnanthes sensu lato* complex), epilithic (fragilarioid taxa), epiphytic (*Brachysira neoexilis*) and planktonic (*Fragilaria tenera, Asterionella formosa*) taxa (Figure 3A). Of the diatom assemblages represented in Zone 1, only the *Sellophora* complex is present in low abundances in the modern sediments.

For cladocerans, CONISS identified two main zones within the stratigraphy, the first major split occurring in the mid-1990s (~2 cm), separating Zone 1 and Zone 2 and a secondary split within Zone 1 occurring in the early 1900's (4 cm; ~1920), yielding Zone 1a and 1b (Figure 3A). A total of 22 cladoceran taxa were recorded from the McFaulds Lake sediment core with *Bosmina* spp. and *Chydorus brevilabris* dominating the assemblages (Figure 3A). Early in the record, cladoceran Zone 1a represents an assemblage of composed almost entirely of *C. brevilabris* with ~83% relative abundance compared to *Bosmina* which accounts for ~10% of the relative abundance. The transition from Zone 1a to Zone 1b at ~1920 represents a substantial increase in *Bosmina* spp., and a concurrent decline in *C. brevilabris*. As well, both pelagic *Daphnia* spp. and littoral, acidophilous *Acantholeberis curvirostris* (Potts and Fryer 1979) appear for the first time in the sedimentary record and their presence continues to the top of the core. The transition from Cladocera Zone 1a to Zone 1b at 1920 lags the main diatom assemblage shift from Zone 1 to Zone 2 by ~25 years. Zone 2 represents a further increase in *Bosmina* spp. (from 10 to 40%) and a decline in *C. brevilabris* (from 83% to 35%) throughout the core.

### 4.5.2 Symons Lake

Symons Lake, located in the HBL, is most chemically similar to McFaulds Lake and is also shallow ($Z_{max}$= 1.8 m). The lake is circum-neutral (pH=7.6) and oligotrophic (TP = 11.2 µg/L; TKN=346 mg/L) (Table 1). The radiometric profile shows an exponential decline in $^{210}$Pb activities with a $^{210}$Pb date of ~1850 at a depth of 9 cm (Figure S-1). Breakpoint analysis identified the greatest change in primary production occurred ~1945 when chl-*a* concentrations increased above the detection limit (> 0.01 mg/g dry weight).

CONISS identified two main diatom zones, with the greatest change occurring at ~1975 (3 cm) establishing Zone 1 and Zone 2 (Figure 3B). There is a subsequent secondary split within each zone, at ~1940 (separating Zone 1a and 1b) and at ~1995 (splitting Zone 2a from Zone 2b). Common diatom taxa encountered in Symons Lake were epilithic fragilarioid species, largely from the genera *Staurosira* and *Staurosirella* (Figure 3B). These taxa contribute greater than 60% of the diatom assemblages in Zone 1. A subtle increase in *Achnanthes sensu lato* complex and *Nitzschia* taxa distinguish Zone 1a and Zone 1b. The transition from diatom Zone 1 to Zone 2 is marked by substantial increases in the relative abundances of many *Nitzschia* taxa (e.g., *N. palea, N. perminuta, N. dissipata*) and planktonic diatoms (e.g., *Fragilaria tenera, F. crotonensis, Asterionella formosa*). Planktonic taxa occurring in Symons Lake transition from a relative abundance of 0% at the end of the 19th century to an average of ~7% relative abundance within the 21st century (a subtle but notable change). The secondary split in Zone 2 is marked by the continued increase in planktonic taxa and *Nitzschia* spp., concurrent with a decline in benthic fragilarioid taxa.

Unlike the other study lakes, Symons Lake records very subtle cladoceran taxonomic changes (Figure 3B), and therefore CONISS and breakpoint analyses were not performed on this core. The sedimentary cladoceran assemblage of Symons Lake is dominated by *Bosmina* spp. for the past ~150 years fluctuating between 74% and 88% of the species relative abundance (Figure 3B). Over the period of the cladoceran record there are small changes in relative abundances of *Bosmina* spp., with an increase by ~4%, an increase in *Daphnia* spp. by ~5%, and decline in relative abundance of *C. brevilabris* by ~3%.

### 4.5.3 Eabamet Lake

The two Boreal Shield lakes are oligotrophic, with Eabamet Lake having the lowest nutrient and dissolved organic carbon (DOC) concentrations, but the highest specific conductivity of all the study lakes (Table 1). The radiometric profile for Eabamet Lake shows an exponential decline in $^{210}$Pb activities with a $^{210}$Pb date of ~1850 at a depth of 10 cm (Figure S-1). Inferred chlorophyll-*a* concentrations in Eabamet Lake were all below the detection limit of 0.01 mg/g dry weight, and so no trend was recorded.

CONISS identified a primary change in the diatom assemblages of Eabamet Lake at ~1995 (2.25 cm). Within Zone 1, there is a secondary split at ~1955 (~5 cm). In Zone 1a, below ~5 cm (~1955), the samples become increasingly difficult to count due to a high concentration of siliceous-clastic material. This made obtaining counts with greater than 400 diatom valves difficult. Treatment with SPT resulted in a more concentrated diatom sample with the removal of much of the clastic materials. This enabled an additional six intervals to be counted extending the diatom record from ~1940 to ~1880. Unlike the HBL lakes, planktonic diatoms dominate the diatom sedimentary record of deeper Eabamet Lake (Figure 3C). Planktonic *Asterionella formosa* and *Discostella stelligera*, gradually increase in relative abundance through time and peak at the top of the core (~2012) at ~24% and 7% relative abundance. Diatom Zone 1 is characterized by higher abundances (relative to Zone 2) of heavily silicified tychoplanktonic *Aulacoseira* spp. (mainly *A. ambigua, A. islandica,* and *A. subarctica*) and benthic fragilarioid species. Diatom

Zone 2 (~1995; 2.25 cm) is established by the marked decline in the relative abundance of these tychoplanktonic and benthic diatom species and increases in *A. formosa* and *D. stelligera*. In Zone 2, these planktonic diatoms are on average ~15% higher than in Diatom Zone 1, but from the assemblage at the bottom of Zone 1 to the assemblage at top of Zone 2 there is approximately ~22% increase in planktonic diatoms.

The cladoceran CONISS analysis of Eabamet Lake indicated the greatest change of the record occurred ~1960, represented by the transition from a *C. brevilabris* to *Bosmina* spp.-dominated assemblages. Although CONISS identified the primary split between Zone 1 and Zone 2 at ~1960, the onset of notable changes occurred ~30 years prior. There were a total of twenty observed cladoceran taxa throughout the length of the Eabamet core. Similar to McFaulds Lake, this assemblage was likewise dominated by *Bosmina* spp. and *Chydorus brevilabris* (Figure 3C). Apart from *Daphnia* spp. and *Alona affini*s, which were at times 10% and 2% of the species assemblage respectively, the remaining cladoceran taxa represented less than 2% of the species assemblage. Cladoceran Zone 1 consists of 48% *Chydorus brevilabris* and 40% *Bosmina* spp. in species relative abundances. In Zone 2, *Bosmina* spp. increases to 74% relative abundance and *C. brevilabris* decreases to 18% relative abundance.

### 4.5.4 Attawapiskat Lake

Oligotrophic (TP = 10.6 µg/L) Attawapiskat Lake had the highest DOC concentration (14.0 mg/L) of the study lakes, and not surprisingly the lowest Secchi depth of 1.5 m, which may indicate higher turbidity and/or colour from DOC. Although it is the deepest of the study lakes (coring depth = 10.4 m), it was not stratified on the day of sampling (Table 1). The radiometric profile for Attawapiskat Lake shows an exponential decline in $^{210}$Pb activities. This lake has the slowest sedimentation rate of the study lakes with a $^{210}$Pb date of ~1850 at a depth of 5 cm

(Figure S-1). Attawapiskat Lake primary production, inferred from sedimentary chlorophyll-*a* concentrations, is below detection throughout the sedimentary record, recording little change (Figure 3D).

For Attawapiskat Lake, below 4 cm (~1890) the concentration of clastic material increases, and it was not possible to obtain adequate diatom counts even after treatment with SPT. This yielded a short diatom record compared to the cladoceran profile, which extends back to ~1820. Although subtle, the main change in the diatom assemblage record, as identified by CONISS, occurs at ~1970 (2.75 cm), separating diatom Zone 1 and Zone 2. A planktonic assemblage of *Asterionella formosa, Discostella stelligera,* tychoplanktonic *Aulacoseira* spp. (largely *A. subarctica* and *A. ambigua*), and low abundances of *Stephanodiscus* spp. (largely *S. minutulus, S. niagarae*) were present throughout the sediment core of Attawapiskat Lake (Figure 3D). *Fragilaria capucina* was also present at modest relative abundances (i.e., ~10% mean abundance) through the sedimentary record. Subtle increases in the relative abundances of *A. formosa* and *D. stelligera* and a concurrent decline in the *Aulacoseira* complex occurs at the transition from Zone 1 to Zone 2, with an planktonic diatoms increasing by ~16% from the bottom assemblage of Zone 1 to the top assemblage of Zone 2.

CONISS identified one major transition in the cladoceran assemblages at ~1955 (3.25 cm) (Figure 3D). Cladoceran assemblages were co-dominated by pelagic species *Bosmina* spp. and *Daphnia longispina* complex at the start of Zone 1 (41% *Bosmina* spp. and 45% *D. longispina* mean abundance through Zone 1) (Figure 3D). Towards the close of Zone 1, at ~1955 (3.25 cm), *Bosmina* spp. becomes the dominant cladoceran taxon (73% abundance). The modern assemblage contains 84% *Bosmina* spp., and only 8% *D. longispina* complex. Compared to the other study lakes, *C. brevilabris* made up a smaller proportion of the species assemblage in

Attawapiskat Lake, fluctuating between 2.9% and 13% in species relative abundance over the length of the cladoceran record.

4.5.5 Ordination analyses

For all cores, principal component analysis (PCA) axes 1 and 2 accounted for 58% and 82% of the variation in diatom and cladoceran assemblage data, respectively (Figures 4 and 5). The diatom assemblages of Symons and McFaulds lakes are distinctly different than those of Eabamet and Attawapiskat lakes, demonstrated by their clear separation in ordination space along PCA axis 1 (Figure 4). The diatom assemblage trajectory through time is less variable (i.e. little separation along PCA axis 2) in the two deeper lakes (Eabamet and Attawapiskat lakes; Figure 4). The cladoceran assemblages of the study lakes differed considerably in the late 19th century (Figure 5); with dominance by either *Daphnia* spp. (Attawapiskat), *Chydorus brevilabris* (McFaulds) or a combination of *Bosmina* spp. and *Chydorus brevilabris* (Eabamet). However, since the early 20th century, the cladoceran assemblages have become increasing similar to Symons Lake, comprised almost entirely of generalist *Bosmina* (Figure 5).

## 4.6 Discussion

A common trend observed in both the diatoms and the cladocerans was an increase in the abundance of planktonic/pelagic biota relative to benthic and littoral taxa in all study lakes. However, there was a more distinct difference in the nature and timing of biological changes in the deeper, oligotrophic lakes of the Boreal Shield compared to the shallower, more nutrient-rich lakes of the HBL. In the deeper lakes, planktonic diatoms were present throughout the sedimentary records, but showed a distinct increase in relative abundance in the past few decades concurrent with declines in tychoplanktonic and benthic diatom taxa. In addition to an increase in planktonic diatom taxa in the two deeper lakes, there is a switch in the dominant planktonic Cladocera from the *Daphnia longispina* complex to more generalist *Bosmina* spp. In the two shallow HBL lakes, planktonic diatom taxa and pelagic Cladocera appear for the first time in the sedimentary record in the early 1900s (McFaulds) and in the 1970s (Symons) and increase in relative abundance to the present, concurrent with a decrease in benthic diatom taxa, and littoral Cladocera. Simultaneous with the arrival and rise in planktonic diatom and cladoceran taxa, there was a notable increase in sedimentary chlorophyll-*a* from previously low and stable concentrations.

Climate warming in the RoF region began in the mid-1970s, as apparent through substantially warmer mean annual temperatures recorded at the Lansdowne House Climate station on Attawapiskat Lake (Figure 2). Farther north, climate warming in subarctic HBL lagged this continental Boreal Shield region until the mid-1990s, when both regions show accelerated and synchronous increases in mean annual temperatures (Figure 2) (Rühland et al. 2013; Macrae et al. 2014). Many of the biotic assemblage changes across the four RoF lakes co-occur with these temperature increases, with an initial assemblage change during the 1950s to 1970s and a further pronunciation of this response in the 1990s (e.g., particularly Eabamet and Symons lakes).

Summer water chemistry measurements between the Boreal Shield and HBL study lakes were very similar with minimal differences in pH and dissolved organic carbon (DOC) across the four lakes. Greater differences in the nutrient concentrations occur between regions, with the highest total phosphorus (TP) concentrations measured in the HBL lakes. Regional surveys of lakes across the RoF have noted limnological differences in lakes, but, like our study, there was little difference between the limnology of lakes located on the Boreal Shield and in the HBL

(MacLeod 2014; Jeziorski et al. in review). Therefore, differences in the biological responses that we observed across the two physiographic regions are unlikely the result of limnological differences. Small distinctions in lake water chemistry (e.g., elevated nutrients in McFaulds Lake) would thus be due to variations in surficial cover (i.e. thick glacial till and peat deposits in catchments) rather than the underlying bedrock (MacLeod 2014; Jeziorski et al. in review). The similarity in water chemistry across the four RoF study lakes may be because the two shallow HBL lakes are located in the transition zone between the two physiographic regions (~50 km from the ecozone boundary). Typically, HBL lakes are more calcareous in nature (Paterson et al. 2014); however, there is no evidence of enhanced ionic content in the HBL study lakes, suggesting that these lakes are not in direct contact with glacial and marine soils that cover the HBL.

### 4.6.1 Biological community responses to warming

Across the RoF lakes, changes in the proportion of planktonic diatoms relative to benthic fragilarioid diatoms, heavily-silicified, tychoplanktonic *Aulacoseira* taxa, and large (>40 µm) benthic naviculoid *sensu lato* taxa is observed. Fragilarioid taxa are considered to be pioneering diatoms present in lakes with simple rock and sediment substrates (e.g., Michelutti et al. 2003; Smol and Douglas 2007) and with conditions that are generally unfavourable for the success of more diverse diatom assemblages, such as low-light from extended periods of ice-cover in cold environments (Lotter and Bigler 2000). This group of opportunistic species has broad chemical tolerances and can live in a wide variety of limnological conditions (e.g., low to high nutrients, circum-neutral to alkaline; Finkelstein and Gajewski 2008; Bennion et al. 2010). Thus, the dominance of benthic fragilarioid taxa in the early sediments of all four lakes may be due to a similarity in physical properties and resource availability as a result of, prolonged periods of ice-cover, short growing seasons and limited variety and availability of aquatic habitats.

Pennate planktonic diatoms (e.g., *Asterionella formosa*) across all the study lakes exhibit one of the biggest changes, increasing between ~3% and ~15% from ~1890 to ~2012. Additionally, the *Discostella stelligera* complex increases in relative abundance ~5% in the deep lakes from base of the record to the surface. This shift towards a higher abundance of planktonic diatoms in the recent sediments is consistent with enhanced thermal stratification and other climate related variables that may occur with increases in the length of the growing season from reductions in ice-cover (Rühland et al. 2008). For example, in lakes across the subarctic, increases in both centric and pennate planktonic diatoms have been linked to recent warming (e.g., Rautio et al. 2000; Smol et al. 2005; Solovieva et al. 2008; Rühland et al. 2013; Thienpont et al. 2013). In shallow, temperate lakes, *Asterionella* taxa have been reported to bloom in the spring (e.g., De Senerpont Domis et al. 2013). Due to their large surface area to volume ratios, these taxa have one of the lowest sinking velocities of all freshwater planktonic diatoms (Spaulding and Edlund 2009). Warmer winter and spring temperatures, a prolonged growing season, and increased lake thermal stability would favour the growth of planktonic diatoms.

Over the past four decades, warmer air temperatures, as recorded at the Lansdowne House climate station (Figure 2A), may have led to increases in the length of the growing season, opening up previously ice-covered pelagic habitat and potentially allowing greater time for planktonic taxa to bloom in these four study lakes. Increases in air temperatures begin in the mid-1970s, with an escalation in the 1990s until present (Figure 2C). Notably, planktonic taxa in deep Attawapiskat Lake increase from ~1973 to the present with a median planktonic increase by 12%. Interestingly, shallow Symons Lake also records the greatest change in diatom assemblage at this time (~1975) with the first appearance of planktonic taxa. This synchrony in timing of temperature changes and algal compositional changes suggests these substantially warmer annual temperatures may have triggered changes in the water column properties of lakes in the region, regardless of their depth, or their locations on or off the Boreal Shield. Additionally, during the 1990s the diatom assemblages of Eabamet and Symons lakes demonstrate a further expression of the initial response to climate seen in the 1970s. This includes a greater increase in both pelagic Cladoceran and planktonic diatoms, as well as a pronounced response in the Cladocera of McFaulds Lake.

### *Diatoms: increases in epiphytic Nitzschia taxa*

Both shallow HBL lakes track changes in littoral habitat, as well as increases in planktonic habitat availability. Given that these shallow lakes are ~2 m in depth and light penetrates to the bottom of each lake (see Secchi depths in Table 1), the lakes littoral habitat is important to the biotic assemblages, and therefore would be expected to respond to a longer and warmer open water period. Indeed, the epiphytic *Nitzschia* complex in Symons and McFaulds lake increases in relative abundance from ~1% in the 1800s to ~37% in McFaulds (with a step change at the turn of the twentieth century) and 8% in Symons by ca. 2012, in tandem with the arrival and increase in planktonic diatoms (Figure 3A-B). With warming, a reduction in the duration of ice-cover and a lengthened growing season allow mosses and aquatic macrophyte habitat to establish and/or expand, and thus epiphytic diatoms that grow attached to these substrates flourish (Douglas et al. 1994; Smol and Douglas 2007; Rühland et al. 2013). Additionally, enhanced nutrient export from the catchment related to climatic influences on weathering rates, precipitation, run-off, and terrestrial primary productivity (see Smol and Douglas 2007 and Adrian et al. 2009) may occur, increasing the relative abundances of diatom taxa commonly linked to higher nutrient influxes (e.g., *Nitzschia* spp.; Keatley et al. 2008, 2009; Stewart et al. 2014). Therefore, in the RoF lakes, not only is a change in ice-cover influencing the diatom and cladoceran assemblages, but many interrelated processes linked to climate change are likely promoting both littoral and pelagic habitat alterations. The development of these periphytic diatom assemblages are indicative of the expansion of aquatic plants and increased habitat availability, consistent with changes reported in lakes and ponds throughout the Canadian High Arctic (e.g., Antoniades et al. 2005; Smol et al. 2005), and in the European (Sorvari et al. 2002) and Canadian (Rühland et al. 2013) subarctic. Similar to the trends recorded in deeper subarctic HBL lakes near the Sutton River (Rühland et al. 2013), the first appearance of planktonic diatoms and increases in periphytic taxa in our two shallow HBL lakes, coincide with an exponential increase in chlorophyll-*a*.

### *Cladocera: shift from littoral to pelagic taxa*

Similar to the observed diatom assemblage changes, pelagic Cladocera taxa across the study lakes have increased in modern sediments at the expense of littoral taxa, with the change generally between two dominant taxa. This shift is likely in response to warmer water temperatures and increased pelagic habitat availability. The success of generalist, pelagic *Bosmina* spp. results in a reduction of the mainly generalist, littoral species *Chydorus brevilabris* in all lakes with the exception of Attawapiskat Lake. Attawapiskat Lake records a shift among pelagic species from *Daphnia longinspina* complex to *Bosmina* spp. Unlike our study, in a multi-proxy study in nearby HBL lakes situated closer to Hudson Bay, Rühland et al. (2014) reported that cladocerans in modern sediments are different than pre-industrial assemblages, albeit changes were minimal. However, they found that the most notable assemblage change among all indicator groups (diatoms, chironomids, cladocerans) was a decline in benthic/littoral taxa and an increase in planktonic/pelagic taxa in modern samples that was indicative of a warming-induced expansion of aquatic habitat with decreased ice cover (Rühland et al. 2014). The earlier onset of climate warming (ca. mid-1970s) in our RoF lakes that are situated farther inland from the climate moderating effects of Hudson Bay (which experienced warmer temperatures beginning mid-1990s) may have allotted greater time to capture a directional response in the cladoceran assemblage compared to the subtle cladoceran changes recorded in lakes studied by Rühland et al. (2014) that are situated closer to the Hudson Bay coast. The cladoceran changes from littoral to pelagic taxa that we observed in the RoF are similar in nature to cladoceran paleolimnological changes in a subarctic lake in the Northwest Territories, Canada (Deasley et al. 2012).

### *Cladocera: Daphnia spp*.

The trend through time in the relative abundance of *Daphnia* spp. varies in direction across RoF lakes. For example, in shallow McFaulds Lake, pelagic *Daphnia* and *Bosmina* spp. increase in relative abundance coincident with a decline in littoral species that is likely a response to an increase in the availability in pelagic habitat. Here, a lengthened ice-free period has potentially allowed a pelagic cladoceran assemblage with both *Bosmina* spp. and *Daphnia* spp. to develop and flourish, which was previously inhibited by short growing seasons. However, in the deeper study lakes, there is a shift among pelagic taxa with *Daphnia* relative abundances decreasing in tandem with the success of *Bosmina* spp. One potential explanation for this trend is that *Daphnia* taxa are more vulnerable to size-selective predation by planktivorous fish than small-bodied *Bosmina*, and therefore a switch between these two pelagic species can occur in response to natural changes in fish densities or to fish stocking (Nevalainen et al. 2014). With a longer open water season on deep RoF lakes, predation pressure from planktivores may be enhanced, reducing the overall biomass of zooplankton communities (Jeppesen et al. 2014) and favouring smaller taxa (e.g., the pelagic taxa *Bosmina* spp.). This generally occurs because planktivorous fish tend to selectively consume the larger, more visible cladocerans (e.g., *Daphnia*) whereas smaller taxa (e.g., *Bosmina*) are a less effective source of food (Korosi et al. 2012). Additionally, communities located on the shores of Eabamet and Attawapiskat lakes have actively fished piscivore populations (e.g., whitefish) since the establishment of the community. As the communities and their fishing pressure have grown, predation pressure on planktivorous fish may have been lessened, increasing predation on large-bodied zooplankton.

### 4.6.2 Shallow, HBL lakes vs. deep, Shield lakes

*Deep lakes Eabamet and Attawapiskat:*

The timing of aquatic primary production and taxonomic shifts across the study lakes is spatially asynchronous, with the response in the shallow lakes predating the deep lakes by ~45 to 60 years. The two deep lakes, Eabamet and Attawapiskat lakes are large, long lakes with a large fetch, that have strong riverine connections as they form the headwaters to the Albany and Attawapiskat rivers, respectively. Although recent warming can lead to stronger and longer thermal stratification periods in deeper lakes (e.g., Smol and Douglas 2007; Winder and Hunter 2008; Hawryshyn et al. 2012), it is likely that the riverine nature and large fetch of Eabamet and Attawapiskat lakes have precluded these lakes from experiencing sustained periods of thermal stratification in the past. This may explain the more muted nature of the diatom responses relative to the shallower lakes from our study. If regional air temperatures continue to increase, vertical lake mixing will likely weaken and thermal stratification may become more frequent and prolonged potentially leading to a stronger biological response. This is similar to conclusions reached by Rühland et al. (2013), where Hawley Lake in the HBL, which formed from a deepening and widening of the Sutton River, exhibited modest biological changes through time compared to many other shallow lakes within the local vicinity, and may be due to only short periods of weak stratification within this lake. Increases in planktonic diatoms and pelagic Cladocera in Eabamet and Attawapiskat lakes may be indicative of warmer conditions and longer open-water periods for lakes in this region. Most likely, these lakes have been historically isothermal. Higher temperatures over the past decade may have resulted in the establishment of thermal stratification for the first time with short periods of stratification during warm periods in the summer and less frequent mixing than experienced in the past. As warming continues and exposure of the water column to sunlight lengthens, the frequency and duration of stratification events may be expected to increase, and thus the dominance of the planktonic diatom assemblage may expand with further reductions in the benthic and tychoplanktonic assemblage.

### *Shallow lakes McFaulds and Symons:*

The biota of shallow RoF lakes in the HBL show a more distinct as well as an earlier biological response than the two deeper lakes in the Boreal Shield. Both shallow lakes experience the first notable appearance of planktonic diatoms in the recent past although this occurs considerably earlier in McFaulds lake (~1895) than in Symons (~1973) (Figure 3A-B). Given that the location of these two shallow HBL lakes is closer to the Hudson Bay coast, it would be expected that the cooling effect of sea ice would have resulted in a later diatom response to regional warming than the two deeper lakes farther inland. The largest diatom shift ~1973 recorded in Symons Lake is similar in timing to the main diatom shift in Attawapiskat Lake, but is earlier than the greatest diatom change observed in Eabamet Lake (~1995). In the

High Arctic, an earlier and more sensitive response to warming occurs in ponds and shallow lakes than in deeper, perennially frozen lakes from this region (Michelutti et al. 2003; Smol et al. 2005). The muted response of diatoms in deep High Arctic lakes is linked to the maintenance of prolonged ice-cover year-round that limits the development of more complex benthic habitats and planktonic assemblages (Michelutti et al. 2003; Antoniades et al. 2005; Smol and Douglas 2007). Similar to High Arctic ponds, in Symons and McFaulds lakes, the water column may warm substantially over a shorter time period than the water column within the deep Eabamet and Attawapiskat, which requires greater thermal inertia to warm (Smol and Douglas 2007; Macrae et al. 2014). In lower latitude subarctic regions, deeper lakes tend to show a strong diatom response to warming as longer ice-free periods and increased thermal stability often results in a switch in life strategy to planktonic diatom assemblage (Rautio et al. 2000; Korhola et al. 2002; Sorvari et al. 2002; Rühland et al. 2003; Rühland and Smol 2005). In this study, both deep lakes and shallow lakes show a pronounced response to recent warming with the first appearance of planktonic taxa in the shallow lakes, and a notable increase in planktonic taxa in the deep lakes. However, due to large surface areas and shallow depths of lakes in the HBL, these lakes may be highly vulnerable and responsive to climatic and hydrological changes (White et al. 2014), whereas the deep RoF lakes may maintain their ice cover longer and are also strongly connected to rivers, which will effect thermal stability.

The diatom, cladoceran and chl-a trends from McFaulds Lake show the most striking changes of all four lakes with an almost complete species turnover in the diatom assemblages and a striking shift in the cladoceran assemblages. However, it is not entirely clear why this shallow lake records an earlier change in all proxies by ~30 to 50 years than the other three RoF lakes. The onset of chlorophyll-*a* increase in McFaulds Lake occurs ~1870 followed closely by diatom assemblage changes, consistent with the timing of biological response to climate warming recorded in many Arctic lakes (Smol et al. 2005; Rühland et al. 2008). The differences in timing of biological responses among our study lakes may be due to differences in lake morphometry, physical setting and differences in catchment-specific characteristics and processes that can lead to variation in the magnitude, nature and timing of response among our study lakes. For example, the two shallow HBL lakes show differences in timing of response and this could potentially be accounted for by the sporadic nature of permafrost in this region (i.e. not all lakes are surrounded by permafrost). It may be that changes in localized catchment processes triggered changes in the littoral and planktonic habitat of McFaulds Lake late in the 19th century that was not present in nearby Symons Lake. McFaulds Lake may have undergone large catchment-scale changes in localized, ice-rich permafrost as temperatures initially increased at the turn of the 20th century. The thawing of ground ice may release and mobilize inorganic nutrients, previously immobilized in permafrost soil horizons, which then stimulates biogeochemical processes in the receiving waters (Vincent et al. 2013). This scenario is consistent with the moderately elevated nutrient concentrations measured at McFaulds Lake (TP = 18 µg/L; TKN = 509 mg/L) relative to other lakes in the region (MacLeod 2014). This may have resulted in the development and/or increase in aquatic macrophytes and mosses and other littoral habitat alterations at McFaulds Lake leading to a diatom assemblage turnover from large benthic naviculoid taxa in the earlier sediment to epipsammic *Achnanthes sensu lato* species and epiphytic *Nitzschia* species, which have been found to respond to increases in nutrients in other Arctic regions (Keatley et al. 2009; Stewart et al. 2014).

## 4.7 Conclusions

A change in life strategy in the cladoceran assemblages from littoral to pelagic species, coinciding with benthic to planktonic diatom assemblage changes and increases in sedimentary-inferred primary production, are a strong indication of regional warming in lakes across the RoF. Each lake record tracks a change in aquatic habitat availability over the past 100 years, which may be linked to warmer air temperatures (recorded at Lansdowne House climate station on Attawapiskat Lake) and a subsequent reduction in ice cover and lengthened growing season. In Attawapiskat and Symons lakes, the timing of changes in the biological proxies in mid-1970s were similar to that found to be typical in many temperate lakes in the northern hemisphere (Rühland et al. 2008, 2010; Labaj et al. in press). Eabamet and Symons lakes also demonstrate a later response comparable to changes recorded in lakes located proximal to Hudson Bay, where warming occurred much later in the mid-1990s (Rühland et al. 2013; Friel et al. 2014). The early timing of biotic changes in shallow McFaulds Lake is most similar to shallow High Arctic lakes and ponds that first began detecting signs of climatic change in the mid-19th century (Smol et al. 2005). However, it is plausible that this lake has experienced local changes in hydrology including permafrost thawing and changes in connectivity to other water bodies potentially causing an expansion in lake size. Although substantial biotic changes occur in the deeper lakes on the Boreal Shield, these lakes respond later than that of the shallow lakes sampled in the HBL. Increases in aquatic primary production are pronounced through the sedimentary record of the shallow lakes and marginally precedes a response in the diatom assemblages; however, no change in primary production has yet to be detected in the deep lakes. It is likely that the shallow depths and large surface areas of the shallow lakes warm faster than the deep lakes promoting earlier shifts in aquatic biota (reviewed in Smol and Douglas 2007). Together with catchment-specific differences, such as potential permafrost located in close proximity to McFaulds Lake, local variation in lakes across the RoF yields differences in the timing of biotic responses to climatic change. An earlier response to climatic changes in the RoF shallow lakes highlights the sensitivity and utility of shallow ponds across the HBL for tracking environmental changes. This study demonstrates that lakes within a similar regional climate, and thus experiencing consistent changes in temperature, can vary significantly in their sensitivity and response to climatic change.

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## 4.9 References

Adamczuk, M. 2014. Niche separation by littoral-benthic Chydoridae (Cladocera, Crustacea) in a deep lake - potential drivers of their distribution and role in littoral-pelagic coupling. *Journal of Limnology* 73: 490-501.

Adrian, R., O'Reilly, C.M., Zagarese, H., Baines, S.B., Hessen, D.O., Keller, W., Livingstone, D.M., Sommaruga, R., Straile, D., Van Donk, E., Weyhenmeyer, G.A., and Winder, M. 2009. Lakes as sentinels of climate change. *Limnology and Oceanography* 54: 2283-2297.

Antoniades, D., Douglas, M.S.V., and Smol, J.P. 2005. Quantitative estimates of recent environmental changes in the Canadian High Arctic inferred from diatoms in lake and pond sediments. *Journal of Paleolimnology* 33: 349-360.

Appleby, P.G. 2001. Chronostratigraphic techniques in recent sediments. In Tracking environmental change using lake sediments. Vol. 1. Basin Analysis, coring, and chronological techniques. Edited by W.M. Last and J.P. Smol. Kluwer Academics

Publishers, Dordrecht, Netherlands. pp. 171-203.

Arseneau, K.M.A., Driscoll, C.T., Brager, L.M., Ross, K.A., and Cumming, B.F. 2011. Recent evidence of biological recovery from acidification in the Adirondacks (New York, USA): a multiproxy paleolimnological investigation of Big Moose Lake. *Canadian Journal of Fisheries and Aquatic Sciences* 68: 575-592. doi:10.1139/F2011-003

Battarbee, R.W., Charles, D.F., and Bigler, C., Cumming, B.F., and Renberg, I. 2010. Diatoms as indicators of surface-water acidity. In The Diatoms: Applications for the Environmental and Earth Sciences. Edited by J.P. Smol, and E.F. Stoermer. Cambridge University Press, New York. pp. 98-121.

Battarbee, R.W., Jones, V.J., Flower, R.J., Cameron, N.G., Bennion, H., Carvalho, L., and Juggins, S. 2001: Diatoms. In Tracking Environmental Change Using Lake Sediments: Terrestrial, Algal, and Siliceous Indicators, 3. Edited by Smol, J.P., Birks, H.J.B., and Last, W.M. Dordrecht: Kluwer Academic Publishers. pp. 155-202.

Bennett, K.D. 1996. Determination of the number of zones in a biostratigraphical sequence. *The New Phytologist* 132: 155-170.

Bennion, H., Sayer, C.D., Tibby, J., and Carrick, H.J. 2010. Diatoms as indicators of environmental change in shallow lakes. In The Diatoms: Applications for the Environmental and Earth Sciences. Edited by Smol, J.P., and Stoermer, E.F. 2010. 2nd edition. Cambridge, U.K.: Cambridge University Press. pp. 152-173.

Bhiry, N., Delwaide, A., Allard, M., Bégin, Y., Filion, L., Lavoie, M., Nozais, C., Payette, S., Pienitz, R., Saulnier-Talbot, É., and Vincent, W.F. 2011. Environmental change in the Great Whale River region, Hudson Bay: Five decades of multidisciplinary research by Centre d'études Nordiques (CEN). *Ecoscience* 18: 182-203. doi:10.2980/18-3-3469

Binford, M.W. 1990. Calculation and uncertainty analysis of $^{210}$Pb dates for PIRLA project lake sediment cores. *Journal of Paleolimnology* 3: 253-267.

Bos, D.G., and Pellatt, M.G. 2012. The water chemistry of shallow ponds around Wapusk National Park of Canada, Hudson Bay Lowlands. *Canadian Water Resources Journal* 37: 163-175.

Bouchard, F., Turner, K.W., MacDonald, L.A., Deakin, C., White, H., Farquharson, N., Medeiros, A.S., Wolfe, B.B., Hall, R.I., Pienitz, R., and Edwards, T.W.D. 2013. Vulnerability of shallow subarctic lakes to evaporate and desiccate when snowmelt runoff is low. *Geophysical Research Letters* 40: 6112-6117. doi:10.1002/2013GL058635

Brucet, S., Boix, D., Quintana, X.D., Jensen, E., Nathansen, L.W., Trochine, C., Meerhoff, M., Gascon, S., and Jeppesen, E. 2010. Factors influencing zooplankton size structure at contrasting temperatures in coastal shallow lakes: Implications for effects of climate change. *Limnology and Oceanography* 55: 1697-1711. doi:10.4319/lo.2010.55.4.1697

Camburn, K.E., and Charles, D.F. 2000. Diatoms of Low Alkalinity Lakes in the Northeastern United States. The Academy of Natural Sciences of Philadelphia. Philadelphia: Scientific Publications. 152 pp.

Catalan, J., Barbieri, G., Bartumeus, F., Bitusik, P., Botev, I., Brancelj, A., Cogalniceanu, D., Manca, M., Marchetto, A., Ognjanova-Rumenova, N., Pla, S., Rieradevall, M., Sorvari, S., Stefkova, E., Stuchlik, E., and Ventura, M. 2009. Ecological thresholds in European alpine lakes. *Freshwater Biology* 54: 2494-2517.

Catalan, J., Pla, S., Rieradevall, M., Felip, M., Ventura, M., Buchaca, T., Camarero, L., Brancelj, A., Appleby, P.G., Lami, A., Grytnes, J.A., Agust.-Panareda, A., and Thompson, R. 2002. Lake Redó ecosystem response to an increasing warming in the Pyrenees during the twentieth century. *Journal of Paleolimnology* 28: 129-145.

Chapman, W.L., and Walsh, J.E. 1993. Recent variations of sea ice and air temperature in high latitudes. *Bulletin American Meteorological Society* 74: 33-47.

Cox, E.T. 1978. Counts and measurements of Ontario lakes: watershed unit summaries based on maps of various scales by watershed unit by watershed unit. Ontario Ministry of National Research Rep. Toronto.

Crins, W.J., Gray, P.A., Uhlig, P.W.C., and Wester, M.C. 2009. The ecosystems of Ontario, Part 1: ecozones and ecoregions. Ministry of Natural Resources, Peterborough Ontario, Inventory, Monitoring and Assessment, SIB TER IMA TR- 01. 71 pp.

De Senerpont Domis, L.N., Elser, J.J., Gsell, A.S., Huszar, V.L.M., Ibelings, B.W., Jeppesen, E., Kosten, S., Mooij, W.M., Roland, F., Sommer, U., Van Donk, E., Winder, M., and Lürling, M. 2013. Plankton dynamics under different climatic conditions in space and time. *Freshwater Biology* 58: 463-482.

Deasley, K., Korosi, J.B., Thienpont, J.R., Kokelj, S.V., Pisaric, M.F.J. and Smol, J.P. 2012. Investigating the response of Cladocera to a major saltwater intrusion event in an Arctic lake from the outer Mackenzie Delta (NT, Canada). *Journal of Paleolimnology* 48: 287-296.

Douglas, M.S.V., Smol, J.P., and Blake Jr., W. 1994. Marked post-18th century environmental change in High-Arctic ecosystems. *Science* 266: 416-419.

Dyer, R.D. and Burke, H.E. 2012. Preliminary results from the McFaulds Lake ("Ring of Fire") area lake sediment geochemistry pilot study, northern Ontario. Ontario Geological Survey, Open File Report 6269.

Environment Canada, Lansdowne House A Climate Station http://climate.weather.gc.ca

Fallu, M.A., Pienitz, R., Walker, I.R., and Lavoie, M. 2005. Paleolimnology of a shrub-tundra lake and response of aquatic and terrestrial indicators to climatic change in arctic Quebec, Canada. *Palaeogeography, Palaeoclimatology, Palaeoecology* 215: 183-203. doi:10.1016/j.palaeo.2004.07.006

Far North Science Advisory Panel (Ont.). 2010. Science for a Changing Far North. The Report of the Far North Science Advisory Panel. Far North Branch, Ontario Ministry of Natural Resources.

Finkelstein, S.A., and Gajewski, K. 2008. Responses of Fragilarioid-dominated diatom assemblages in a small Arctic lake to Holocene climatic changes, Russell Island, Nunavut, Canada. *Journal of Paleolimnology* 40: 1079-1095. doi:10.1007/s10933-008-9215-5

Friel, C.E., Finkelstein, S.A., and Davis, A.M. 2014. Relative importance of hydrological and climatic controls on Holocene paleoenvironments inferred using diatom and pollen records from a lake in the central Hudson Bay Lowlands, Canada. *The Holocene* 24: 295-306. doi:10.1177/0959683613518587

Gagnon, A.S., and Gough, W.A. 2005. Trends in the dates of ice freeze-up and breakup over Hudson Bay, Canada. *Arctic* 58: 370-382.

Glew, J.R. 1988. A portable extruding device for close interval sectioning of unconsolidated core samples. *Journal of Paleolimnology* 1: 235-239.

Glew, J.R. 1989. A new trigger mechanism for sediment samplers. *Journal of Paleolimnology* 2: 241–243. doi:http://dx.doi.org/10.1007/BF00195474.

Gough, W.A., and Leung, A. 2002. Nature and fate of Hudson Bay permafrost. *Regional Environmental Change* 2: 177-184. doi:10.1007/s10113-002-0048-x

Gough, W.A., Cornwell, A.R., and Tsuji, L.J.S. 2004. Trends in seasonal sea ice duration in southwestern Hudson Bay. *Arctic* 57: 299-305.

Greenaway, C.M., Paterson, A.M., Keller, W., and Smol, J.P. 2012. Dramatic diatom species assemblage responses in lakes recovering from acidification and metal contamination near Wawa, Ontario, Canada: a paleolimnological perspective. *Canadian Journal of Fisheries and Aquatic Sciences* 69: 656-669. doi:10.1139/F2012-003

Grimm, E.C. 1987. CONISS: A FORTRAN 77 program for stratigraphically constrained cluster analysis by the method of incremental sum of squares. *Computers and Geosciences* 13: 13-35.

Gunn, J. and Snucins, E. 2010. Brook charr mortalities during extreme temperature events in Sutton River, Hudson Bay Lowlands, Canada. *Hydrobiologia* 650: 79-84

Hall, R.I., and Smol, J.P. 2010. Diatoms as indicators of lake eutrophication. In The Diatoms:

Applications for the Environmental and Earth Sciences. Edited by J.P. Smol and E.F. Stoermer. Cambridge University Press, New York. pp. 122-151.

Hawryshyn, J., Rühland, K.M., Quinlan, R., and Smol, J.P. 2012. Long-term water quality changes in a multiple stressor system: a diatom-based paleolimnological study of Lake Simcoe (Ontario, Canada). *Canadian Journal of Fisheries and Aquatic Sciences* 69: 24-40. doi:10.1139/F2011-134

Hjartarson, J., McGuinty, L., Boutilier, S., and Marjernikova, E. 2014. Beneath the Surface: Uncovering the Economic Potential of Ontario's Ring of Fire. Ontario Chamber of Commerce.

Hochheim, K.P. and Barber, D.G. 2010. Atmospheric forcing of sea ice in Hudson Bay during the fall period, 1980-2005. *Journal of Geophysical Research* 115: C05009. doi:10.1029/2009JC005334

Hochheim, K.P. and Barber, D.G. 2014. An update on the ice climatology of the Hudson Bay system. *Arctic, Antarctic, and Alpine Research* 46: 66-83.

Hochheim, K., Barber, D.G., and Lukovich, J.V. 2010. Changing Sea Ice Conditions in Hudson Bay, 1980–2005. In A Little Less Arctic. Edited by S.H. Ferguson, L.L. Loseto, and M.L. Mallory. Springer, Heidelberg, Germany. pp. 39-52.

Ingram, R.G., Girard, R.E., Paterson, A.M., Sutey, P., Evans, D., Xu, R., Rusak, J., Thomson, C., and Masters, C. 2013. Lake Sampling Methods. Dorset, Ontario: Ontario Ministry of the Environment, Dorset Environmental Science Centre, 93 pp.

Jeppesen, E., Meerhoff, M., Davidson, T.A., Trolle, D., Søndergaard, M., Lauridsen, T.L., Beklioğlu, M., Brucet, S., Volta, P., González-Bergonzoni, I. and Nielsen, A. 2014. Climate change impacts on lakes: an integrated ecological perspective base on a multi-faceted approach, with special focus on shallow lakes. *Journal of Limnology* 73: 84-107.

Jeziorski, A., Keller, B., Dyer, R.D., Paterson, A.M., and Smol, J.P. Differences among modern-day and historical cladoceran communities from the "Ring of Fire" lake region of northern Ontario: Identifying responses to climate warming. *Fundamental and Applied Limnology*, accepted.

Juggins, S. 2003. C2 user guide. Software for ecological and palaeoecological data analysis and visualisation. Newcastle upon Tyne. University of Newcastle, UK.

Juggins, S. 2009. Rioja: an R Package for the Analysis of Quaternary Science Data, Version 0.5-6.

Keatley, B.E., Douglas, M.S.V., and Smol, J.P. 2008. Prolonged Ice Cover Dampens Diatom Community Responses to Recent Climatic Change in High Arctic Lakes. *Arctic, Antarctic, and Alpine Research* 40: 364-372.

Keatley, B.E., Douglas, M.S.V., Blais, J.M., Mallory, M.L., and Smol, J.P. 2009. Impacts of seabird-derived nutrients on water quality and diatom assemblages from Cape Vera, Devon Island, Canadian High Arctic. *Hydrobiologia* 621: 191-205. doi:10.1007/s10750-008-9670-z

Korhola, A., and Rautio, M. 2001. 2. Cladocera and other branchiopod crustaceans. In: Smol JP, Birks HJB, Last WM (eds.) Tracking Environmental Change Using Lake Sediments. Volume 4: Zoological Indicators. Kluwer Academic Publishers, Dordrecht, The Netherlands, pp 4-41.

Korhola, A., Sorvari, S., Rautio, M., Appleby, P.G., Dearing, J.A., Hu, Y., Rose, N., Lami, A., and Cameron, N.G. 2002. A multi-proxy analysis of climate impacts on the recent development of subarctic Lake Saanajärvi in Finnish Lapland. *Journal of Paleolimnology* 28: 59-77.

Korosi, J.B., Paterson, A.M., DeSellas, A.M., and Smol, J.P. 2008. Linking mean body size of pelagic Cladocera to environmental variables in Precambrian Shield lakes: a paleolimnological approach. *Journal of Limnology* 67: 22-34.

Korosi, J.B., Paterson, A.M., DeSellas, A.M., and Smol, J.P. 2010. A comparison of pre-industrial and present-day changes in *Bosmina* and *Daphnia* size structure from soft-water Ontario lakes. *Canadian Journal of Fisheries and Aquatic Sciences* 67: 754-762.

Korosi, J.B., and Smol, J.P. 2012a. Examining the effects of climate change, acidic deposition, and copper sulphate poisoning on long-term changes in cladoceran assemblages. *Aquatic Sciences* 74: 781-792.

Korosi, J.B., and Smol, J.P. 2012b. An illustrated guide to the identification of cladoceran subfossils from lake sediments in northeastern North America: part 1—The Daphniidae, Leptodoridae, Bosminidae, Polyphemidae, Holopedidae, Sididae, and Macrothricidae. *Journal of Paleolimnology* 48: 571-586.

Korosi, J.B., and Smol, J.P. 2012c. An illustrated guide to the identification of cladoceran subfossils from lake sediments in northeastern North America: part 2—The Chydoridae. *Journal of Paleolimnology* 48: 587-622.

Korosi, J.B., Burke, S.M., Thienpont, J.R., and Smol, J.P. 2012. Anomalous rise in algal production linked to lakewater calcium decline through food web interactions. *Proceedings of the Royal Society B* 279: 1210-1217. doi:10.1098/rspb.2011.1411

Krammer, K., and Lange-Bertalot, H. 1986–1991. Bacillariophyceae. In *Süßwasserflora von Mitteleuropa,* Volume 2 (1–4). Edited by Ettl, H., Gerloff, J., Heynig, H., and Mollenhauer, D. Stuttgart/Jena: Gustav Fischer Verlag.

Kurek, J., Korosi, J.B., Jeziorski, A., and Smol, J.P. 2010. Establishing reliable minimum count sizes for cladoceran subfossils sampled from lake sediments. *Journal of Paleolimnology* 44: 603-612.

Labaj, A.L., Kurek, J., Jeziorski, A., and Smol, J.P. 2014. Elevated metal concentrations inhibit biological recovery of Cladocera in previously acidified boreal lakes. *Freshwater Biology* in press. doi:10.1111/fwb.12496

Lavery, J.M., Kurek, J., Rühland, K.M., Gillis, C.A., Pisaric, M.F.J., and Smol, J.P. 2014. Exploring the environmental context of recent *Didymosphenia geminata* proliferation in Gaspsie, Quebec, using paleolimnology. *Canadian Journal of Fisheries and Aquatic Sciences* 71: 1-11. dx.doi.org/10.1139/cjfas-2013-0442

Lim, D.S.S., Smol, J.P., and Douglas, M.S.V. 2008. Recent environmental changes on Banks Island (N.W.T., Canadian Arctic) quantified using fossil diatom assemblages. *Journal of Paleolimnology* 40: 385-398. doi:10.1007/s10933-007-9168-0

Lotter, A.F., and Bigler, C. 2000. Do diatoms in the Swiss Alps reflect the length of ice-cover? *Aquatic Sciences* 62: 125–141. doi:1015-1621/00/020125-17

MacLeod, J. 2014. Lakes in the Far North of Ontario: Regional Comparisons and Contrasts. MSc thesis, Laurentian University, Sudbury, Canada.

Macrae, M.L., Brown, L.C., Duguay, C.R., Parrott, J.A., and Petrone, R,M. 2014. Observed and projected climate change in the Churchill region of the Hudson Bay Lowlands and implications for pond sustainability. *Arctic, Antarctic, and Alpine Research* 46: 272-285.

Martini, I.P. 2006. The cold-climate peatlands of the Hudson Bay Lowland, Canada: brief overview of recent work. In Martini, I. P., Martinez Cortizas, A., and Chesworth, W. (eds.), Peatlands: Evolution and Records of Environmental and Climate Changes. Amsterdam: Elsevier, 53-84.

McKenney, D.W., Pedlar, J.H., Lawrence, K., Gray, P.A., Colombo, S.J., and Crins, W.J. 2010. Current and projected future climatic conditions for ecoregions and selected natural heritage areas in Ontario. Ontario Ministry of Natural Resources. Climate Change Research Report CCRR-16.

Michelutti, N., Blais, J.M., Cumming, B.F., Paterson, A.M., Rühland, K., Wolfe, A.P., and Smol, J.P. 2010. Do spectrally inferred determinations of chlorophyll a reflect trends in lake trophic status? *Journal of Paleolimnology* 43: 205-217. doi:10.1007/s10933-009-9325-8.

Michelutti, N., Douglas, M.S.V., and Smol, J.P. 2003. Diatom response to recent climatic change in a High Arctic lake (Char Lake, Cornwallis Island, Nunavut). *Global and Planetary Change* 38: 257-271.

Nevalainen, L., Ketola, M., Korosi, J.B., Manca, M., Kurmayer, R., Koinig, K.A., Psenner, R. and Luoto, T.P. 2014. Zooplankton (Cladocera) species turnover and long-term decline of *Daphnia* in two high mountain lakes in the Austrian Alps. *Hydrobiologia* 722: 75-91

Nevalainen, L., Luoto, T. P., Kultti, S. and Sarmaja-Korjonen, K. 2013. Spatio-temporal distribution of sedimentary Cladocera (Crustacea: Branchiopoda) in relation to climate. *Journal of Biogeography* 40: 1548-1559

Ontario Ministry of the Environment. 1983. Handbook of Analytical Methods for Environmental Samples. Vols. 1 and 2. Sudbury, Ontario: Laboratory Services Branch, Ontario Ministry of the Environment and Energy.

Paterson, A.M., Betts, A.A., Smol, J.P., and Zeeb, B.A. 2003. Diatom and chrysophyte algal response to longterm PCB contamination from a point-source in northern Labrador, Canada. *Water Air Soil Pollution* 145: 377-393. doi:10.1023/A:1023654105342

Paterson, A.M., Keller, W., Rühland, K.M., Jones, F.C., and Winter, J.G. 2014. An exploratory survey of summer water chemistry and plankton communities in lakes near the Sutton River, Hudson Bay Lowlands, Ontario, Canada. *Arctic, Antarctic, and Alpine Research* 46: 121-138.

Potts, W.T.W., and Fryer, G. 1979. The effects of pH and salt content on sodium balance in *Daphnia magna* and *Acantholeberis curvirostris* (Crustacea: Cladocera). *Journal of Comparative Physiology* B 129: 289-294.

R Development Core Team. 2012. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna. Available from http://www.R-project.org.

Rautio, M., Sorvari, S., and Korhola, A. 2000. Diatom and crustacean zooplankton communities, their seasonal variability and representation in the sediments of subarctic Lake Saanajärvi. *Journal of Limnology* 59: 81-96.

Rouse, W.R. 1991. Impacts of Hudson Bay on the terrestrial climate of the Hudson Bay Lowlands. *Arctic and Alpine Research* 23: 24-30.

Rühland, K.M., and Smol, J.P. 2005. Diatom shifts as evidence for recent subarctic warming in a remote tundra lake, NWT, Canada. *Palaeogeography, Palaeoclimatology, Palaeoecology* 226: 1-16.

Rühland, K.M., Hargan, K.E., Jeziorski, A., Paterson, A.M., Keller, W. and Smol, J.P. 2014. A multi-trophic exploratory survey of recent environmental change using lake sediments in the Hudson Bay Lowlands, Ontario, Canada. *Arctic, Antarctic, and Alpine Research* 46: 139-158.

Rühland, K.M., Paterson, A.M., and Smol, J.P. 2008. Hemisphericscale patterns of climate-related shifts in planktonic diatoms from North American and European lakes. *Global*

*Change Biolog*y 14: 2740-2754.

Rühland, K.M., Paterson, A.M., Keller, W., Michelutti, N. and Smol, J.P. 2013. Global warming triggers the loss of a key Arctic refugium. *Proceedings of the Royal Society B* 280: 20131887.

Rühland, K.M., Priesnitz, A., and Smol, J.P. 2003. Paleolimnological evidence form diatoms for recent environmental changes in 50 lakes across the Canadian Arctic treeline. *Arctic, Antarctic, and Alpine Research* 35: 110-123.

Schlueter, M.H., Merico, A., Reginatto, M., Boersma, M., Wiltshire, K.H., and Greve, W. 2010. Phenological shifts of three interacting zooplankton groups in relation to climate change. *Global Change Biology* 16: 3144-3153.

Shumate, B.C., Schelske, C.L., Crisman, T.L., and Kenney, W.F. 2002. Response of the cladoceran community to trophic state change in Lake Apopka, Florida. *Journal of Paleolimnology* 27: 71-77.

Smol, J.P. 2008. Pollution of lakes and rivers: a paleoenvironmental perspective. John Wiley & Sons.

Smol, J.P. 2010. The power of the past: using sediments to track the effects of multiple stressors on lake ecosystems. *Freshwater Biology* 55: 43-59.

Smol, J.P., and Cumming, B.F. 2000. Tracking long-term changes in climate using algal indicators in lake sediments. *Journal of Phycology* 36: 986-1011.

Smol, J.P., and Douglas, M.S.V. 2007. From controversy to consensus: making the case for recent climate change in the Arctic using lake sediments. *Frontiers in Ecology and the Environment* 5: 466-474.

Smol, J.P., and Stoermer, E.F. 2010. The Diatoms: Applications for the Environmental and Earth Sciences. 2nd edition. Cambridge, U.K.: Cambridge University Press.

Smol, J.P., Wolfe, A.P., Birks, H.J.B., Douglas, M.S.V., Jones, V.J., Korhola, A., Pienitz, R., Rühland, K.M., Sorvari, S., Antoniades, D., Brooks, S.J., Fallu, M.A., Hughes, M., Keatley, B.E., Laing, T. E., Michelutti, N., Nazarova, L., Nyman, M., Paterson, A.M., Perren, B., Quinlan, R., Rautio, M., Saulnier-Talbot, E., Siitonen, S., Solovieva, N., and Weckström, J. 2005. Climate-driven regime shifts in the biological communities of arctic lakes. *Proceedings of the National Academy of Science* 102: 4397-4402. doi:10.1073/pnas.0500245102.

Solovieva, N., Jones, V., Birks, J.H.B., Appleby, P. and Nazarova, L. 2008. Diatom responses to 20th century climate warming in lakes from the northern Urals, Russia. *Palaeogeography, Palaeoclimatology, Palaeoecology* 259: 96-106.

Sorvari, S., Korhola, A., and Thompson, R. 2002. Lake diatom response to recent Arctic warming in Finnish Lapland. *Global Change Biology* 8: 171-181.

Spaulding, S., and Edlund, M. 2009. Asterionella. In: Diatoms of the United States. Retrieved October 16, 2013, from http://westerndiatoms.colorado.edu/taxa/genus/Asterionella

Stewart, E.M., McIver, R., Michelutti, N., Douglas, M.S.V., and Smol, J.P. 2014. Assessing the efficacy of chironomid and diatom assemblages in tracking eutrophication in High Arctic sewage ponds. *Hydrobiologia* 721: 251-268. doi:10.1007/s10750-013-1667-6

Tapia, P.M., and Harwood, D.M. 2002. Upper Cretaceous diatom biostratigraphy of the Arctic Archipelago and northern continental margin, Canada. *Micropaleontology* 48: 303-342.

Tarnocai, C. 2006. The effect of climate change on carbon in Canadian peatlands. *Global and Planetary Change* 53: 222-232.

Thienpont, J.R., Rühland, K.M., Pisaric, M.F.J., Kokelj, S.V., Kimpe, L.E., Blais, J.M., and Smol, J.P. 2013. Biological responses to permafrost thaw slumping in Canadian Arctic lakes. *Freshwater Biology* 58: 337-353.

ter Braak, C.J.F., and Šmilauer, P. 2002. CANOCO Reference Manual and CanoDraw for Windows User's Guide: Software for Canonical Community Ordination. Version 4.5. Ithaca, New York: Microcomputer Power, 500 pp.

Vincent, W.F., Laurion, I., Pienitz, R., and Walter Anthony, K.M. 2013. Climate impacts on Arctic lake ecosystems. In Climatic Change and Global Warming of Inland Waters: Impacts and Mitigation for Ecosystems and Societies. Edited by Goldman, C.R., Kumagai, M., and Robarts, R.D. New York: John Wiley and Sons Ltd., 27-42.

White, J., Hall, R.I., Wolfe, B.B., Light, E.M., Macrae, M.L., and Fishback, L. 2014. Hydrological connectivity and basin morphometry influence seasonal water-chemistry variations in tundra ponds of the northwestern Hudson Bay Lowlands. *Arctic, Antarctic, and Alpine Research* 46(1): 218-235.

Winder, M., and Hunter, D.A. 2008. Temporal organization of phytoplankton communities linked to physical forcing. *Oecologia* 156: 179-192.

Wolfe, A.P., Vinebrooke, R.D., Michelutti, N., Rivard, B., and Das, B. 2006. Experimental calibration of lake-sediment spectral reflectance to chlorophyll a concentrations: methodology and paleolimnological validation. *Journal of Paleolimnology* 36: 91-100.

Table 4-1 Coordinates, physical variables, and water chemistry including calcium (Ca), total phosphorus (TP), total Kjeldahl nitrogen (TKN), dissolved organic carbon (DOC), and dissolved oxygen (DO) for the four study lakes.

| | McFaulds | Symons | Eabamet | Attawapiskat |
|---|---|---|---|---|
| Coordinates | 52°47'15.304"N<br>86°3'10.384"W | 52°32'57.043"N<br>86°9'53.393"W | 51°31'11.661"N<br>87°51'6.868"W | 52°11'40.711"N<br>87°45'58.730"W |
| Physiographic region | Lowlands | Lowlands | Shield | Shield |
| Coring depth (m) | 2.0 | 1.8 | 9.0 | 10.4 |
| Secchi depth (m) | 1.4 | 1.4 | 2.8 | 1.5 |
| pH | 7.4 | 7.6 | 7.8 | 7.7 |
| Ca (mg/L) | 7.2 | 9.0 | 14.0 | 12.8 |
| TP (μg/L) | 18.0 | 11.2 | 8.6 | 10.6 |
| TKN (mg/L) | 509 | 346 | 336 | 381 |
| DOC (mg/L) | 12.0 | 13.0 | 10.9 | 14.0 |
| Specific conductivity (μS/cm) | 46.2 | 61.8 | 96.4 | 87.6 |
| DO at Surface (mg/L) | 8.3 | 8.0 | 8.2 | 7.9 |
| DO at Bottom (mg/L) | 8.3 | 8.0 | 7.7 | 7.1 |

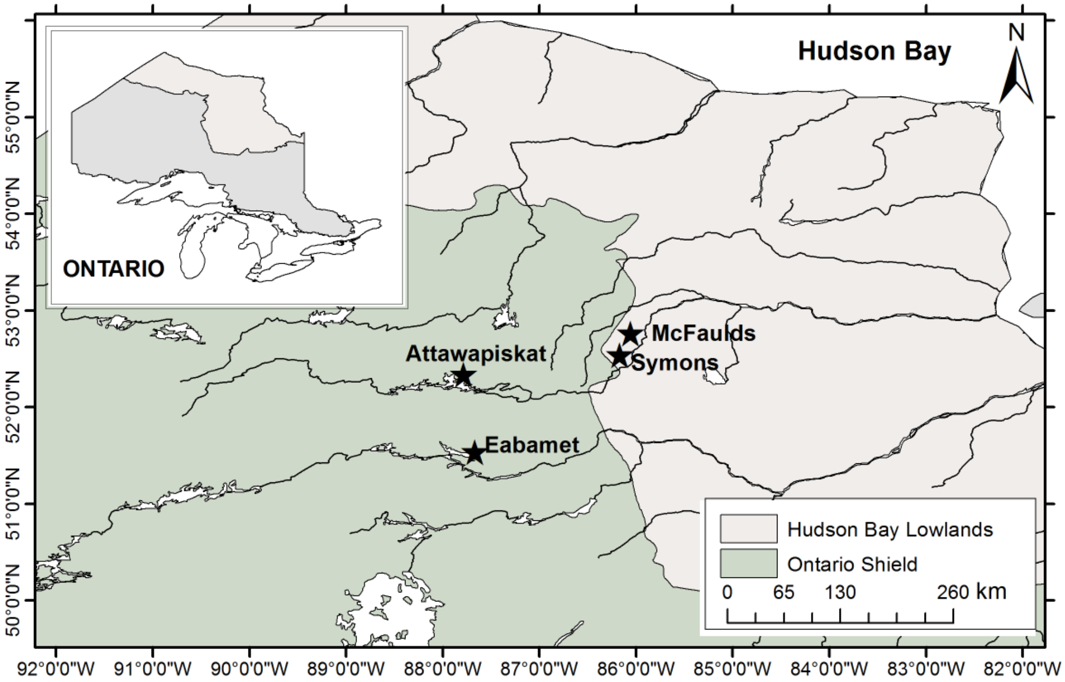


Figure 4-1 Location of the four study lakes in the Far North of Ontario, Canada, with the Hudson Bay Lowlands and Ontario Boreal Shield delineated.

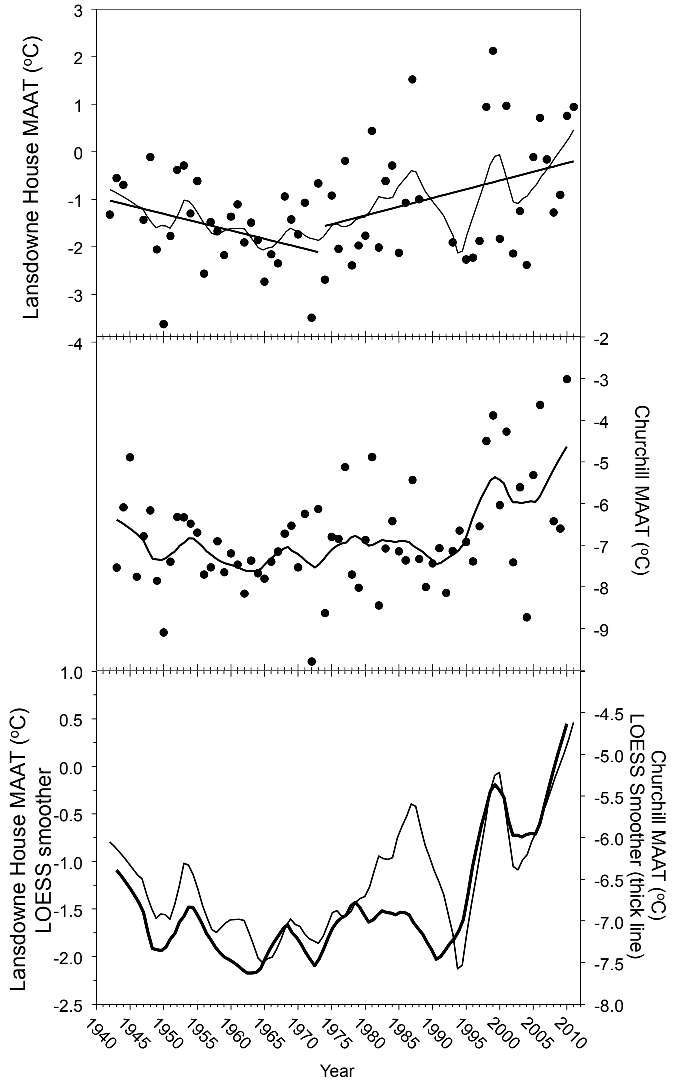


Figure 4-2 Mean annual air temperature (MAAT) (http://climate.weather.gc.ca) with a LOESS smoother (span=0.15; solid line) for: A) Lansdowne House climate station (located at Attawapiskat Lake) with break-point analysis identified at 1973 (two straight solid lines). This climate station is missing data from 1989 to 1992 and 1994. B) MAAT for Churchill, MB. C) LOESS smoothers from both A) and B) to highlight similarities and differences in temperature trends and trajectories.

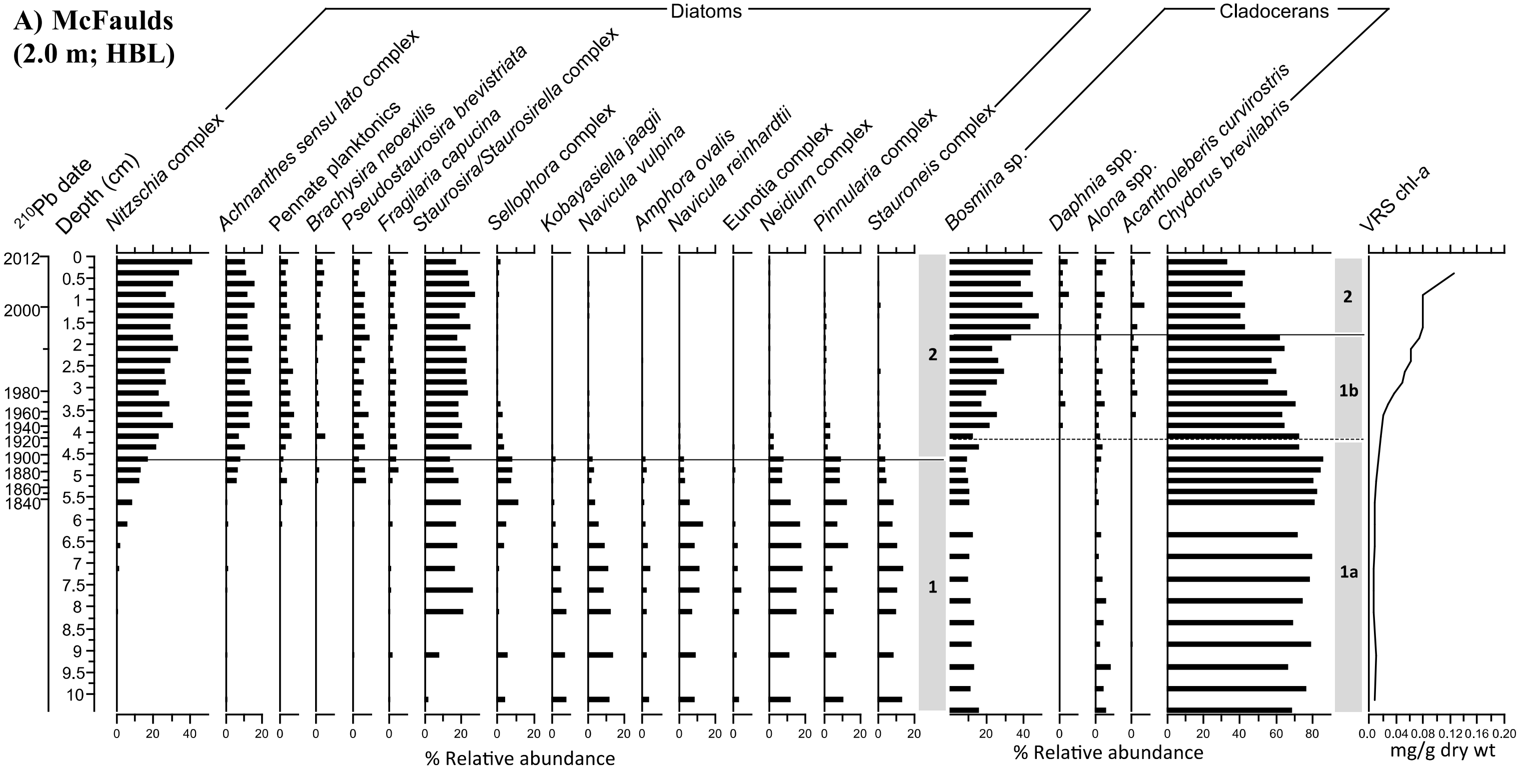


Figure 4-3 Combined diatom and cladoceran profiles, scaled by depth (with secondary axis of estimated $^{210}$Pb year), showing relative abundances of the most common taxa and species complexes for (A) McFaulds Lake, (B) Symons Lake, (C) Eabamet Lake, and (D) Attawapiskat Lake. Diatom and Cladocera results for the constrained incremental sum of squares (CONISS) are also shown (solid horizontal lines indicate the primary zonation identified by the broken stick model, dashed lines if present indicate secondary zonations). Sedimentary chlorophyll-*a* analysis is plotted to the right of the species profiles on the same y-axis (and approximately same scale for all cores).

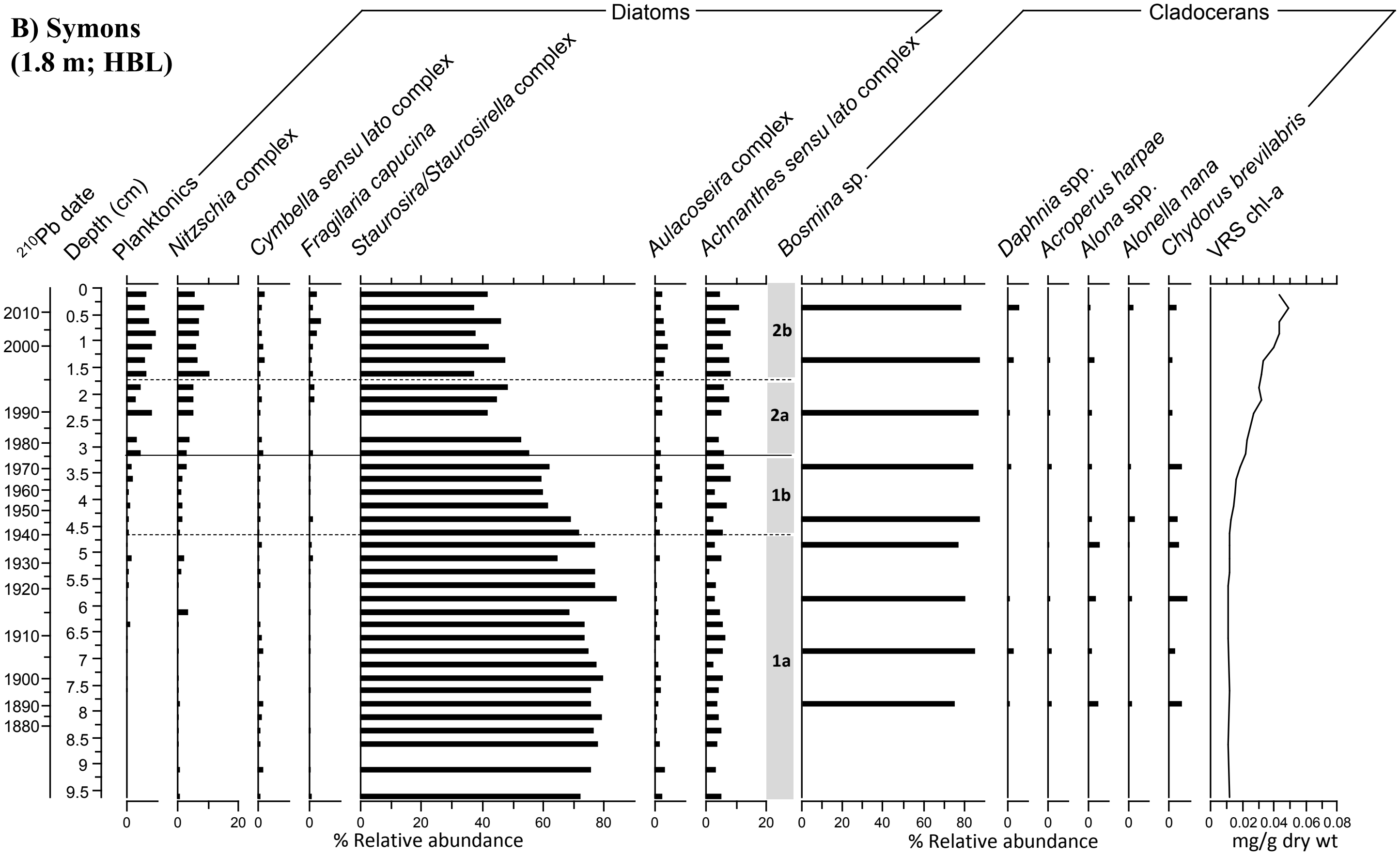
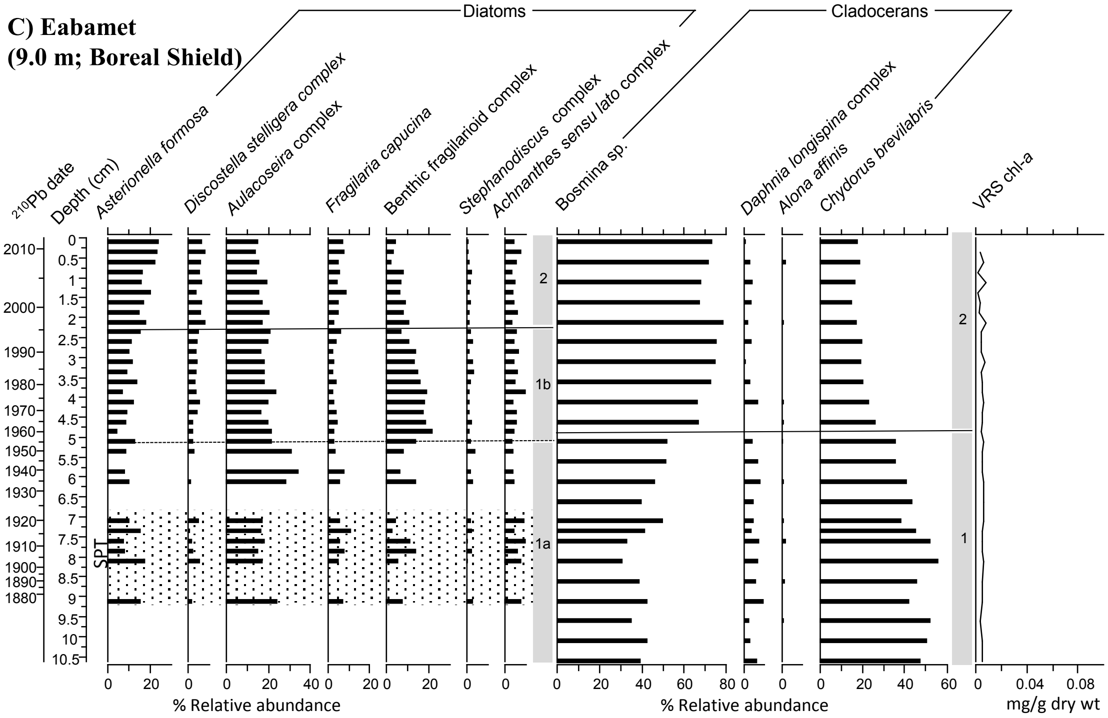
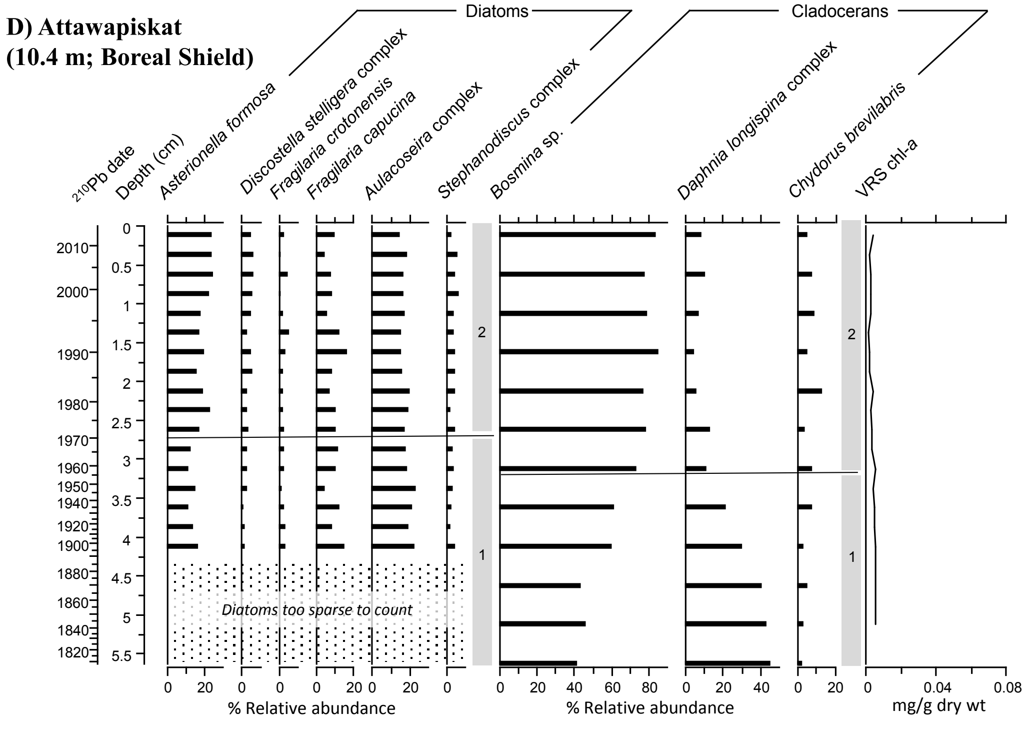


Figure 4-3 continued.



C) Eabamet
(9.0 m; Boreal Shield)



D) Attawapiskat
(10.4 m; Boreal Shield)

Figure 4-3 continued.

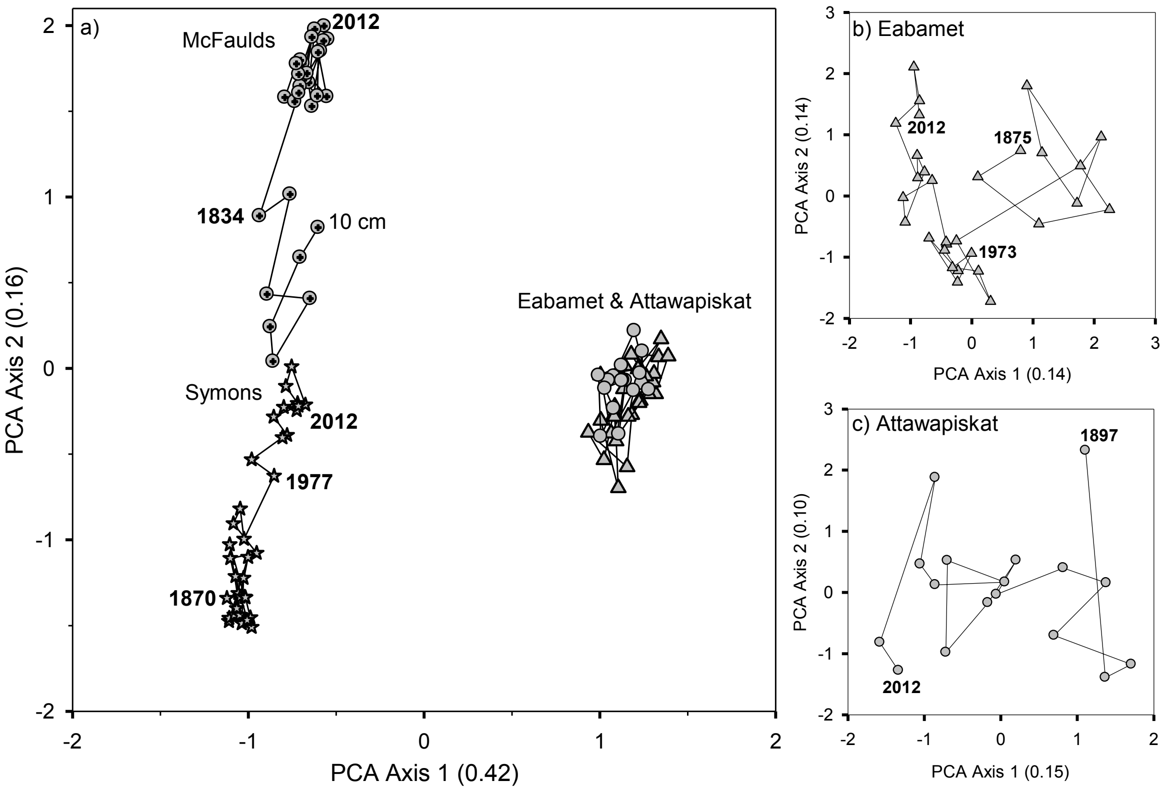


Figure 4-4 a) Principal component analysis (PCA) axis 1 and 2 sample scores of the sedimentary diatom assemblages from the four study lakes through time. Lines connect the sediment intervals in temporal sequence. Sample scores along PCA axis 1 depict differences in diatom assemblage composition among sites, and differences in assemblages through time are captured principally by axis 2. $^{210}$Pb estimated dates are denoted for the youngest, oldest and relevant sediment intervals from each study lake. Due to their tight clustering within the ordination space relative to the shallow sites, PCA ordination of sample scores for each deep, Boreal Shield site are depicted in b) Eabamet Lake, and c) Attawapiskat Lake.

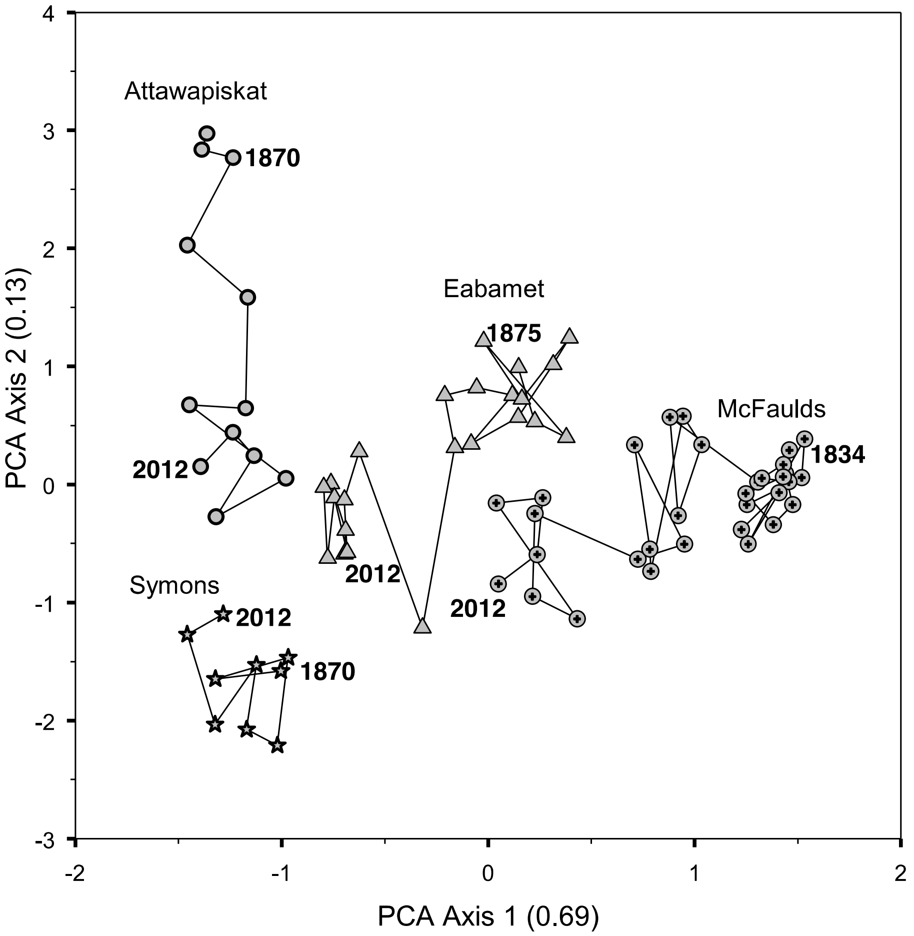
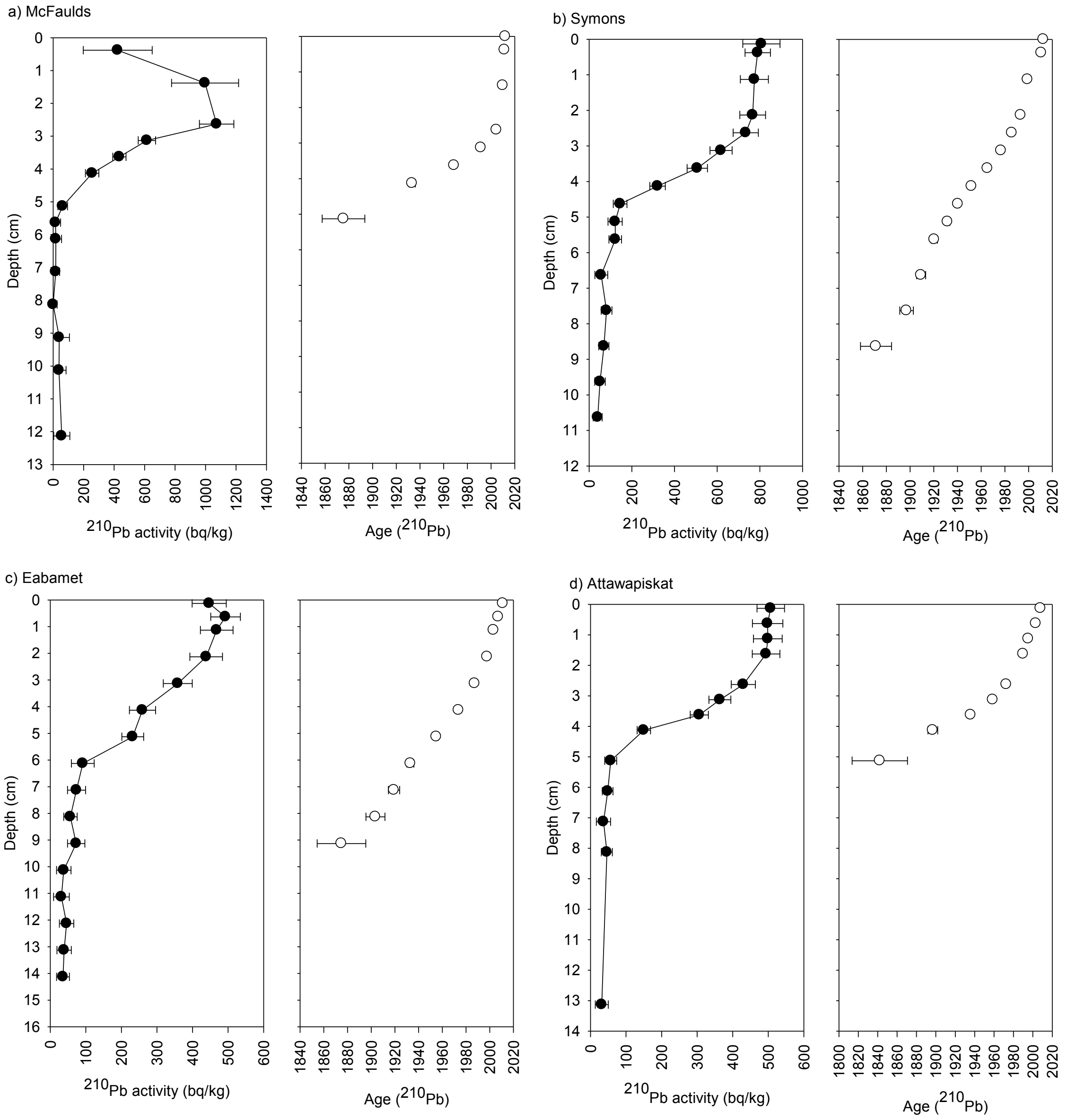


Figure 4-5 Principal component analysis (PCA) axis 1 and 2 sample scores of the sedimentary cladoceran assemblages from the four study lakes through time. Lines connect the sediment intervals in temporal sequence. Sample scores along PCA axis 1 depict differences in cladoceran assemblage composition among sites, and differences in assemblages through time are captured principally by axis 2. $^{210}$Pb estimated dates are denoted for the youngest, oldest and relevant sediment intervals from each study lake.



Supplemental Figure 4-1 $^{210}$Pb activities and estimated interval ages based on $^{210}$Pb and the constant rate of supply (CRS) model (Appleby 2001) for a) McFaulds, b) Symons, c) Eabamet, and d) Attawapiskat.

# Chapter 5

## General Discussion and Conclusions

Climatic and other forms of environmental change are having significant impacts on ecosystems at a global scale. It is imperative that we understand the nature of these changes, the drivers of change, and the long-term impacts and potential adaptations. In order to place climatic changes since the start of the 'Anthropocene' into perspective, and to determine the trajectories of current environmental changes, paleoecological data are required. These data can span the relatively recent past where monitoring records are lacking (e.g., within the last 100-200 years), thus establishing baseline conditions. Alternatively, these data can span considerably longer time periods, demonstrating the natural range of ecosystem variability and responses to climatic changes.

Long-term monitoring data, as well as paleoecological records, are lacking in the Far North of Ontario (~50-57ºN, 79-94ºW), a region of considerable ecological and economic significance. Covered by extensive peatland complexes that have accumulated vegetation (and carbon) since deglaciation ~6000 years ago, and with tens of thousands of lakes (Cox 1978), this region contains many potential paleoecological archives. Peat profiles, in particular, are effective archives of climatic changes with a high temporal resolution (often decadal scale, or finer). This is because of the close connection of ombrotrophic peatlands to the atmosphere (Aaby 1986), and because the growth rate of vegetation (and lack of decomposition) within peatlands is often substantially faster than the slow sedimentation rates in sub-Arctic lakes. However, given that peatlands act as an interface between terrestrial and aquatic ecosystems, finding reliable biotic proxies that are present with well-defined ecological optima is challenging.

The overall goal of this thesis was to determine ecological optima of paleolimnological proxies in the Far North of Ontario and to track environmental changes over the Holocene using diatoms archived in both peat and lake sediment deposits. In **Chapter 2**, the aim of the research was to determine if diatom assemblages are sensitive to the chemical and moisture gradients established by different peatland types and micro-habitats across the Boreal Shield and Hudson Bay Lowlands (HBL) of Ontario and Manitoba. Although understanding biological diversity across peatlands is important, my goal was ultimately to assess the potential for diatoms to be used as indicators of long-term environmental change in peatlands. Diatom-based calibration models are commonly applied to lake records to infer past environmental changes (Smol and Stoermer 2010), but rarely have diatoms been used in peatland cores. In the few cases where inference models have been applied to diatom peatland records, the inferences were based on lake calibration sets (Campbell et al. 1997; Kienel et al. 1999; Brugam and Swain 2000), as peatland diatom calibration sets do not yet exist. In Chapter 2, diatoms, collected from 93 northern surface peat samples, showed that assemblage compositional changes were associated with macro-vegetation type, pH and position relative to the water table. These results indicate that diatom assemblage composition was determined by both the broader peatland type (i.e., bog, rich and poor fens) and microhabitats within peatland formations (e.g., hummock, hollows). The diatom assemblages were primarily influenced by pH with bog and fen sites divided at a pH value of 5.5, and secondarily by the depth to the water table. Interestingly a pH value of 5.5 has been described previously for explaining the separation of brown mosses (higher pH) and *Sphagnum* spp. (lower pH) abundances (Gignac 1992), as well as for the separation of acidophilous taxa within diatom (Battarbee et al. 2010) and chrysophyte (Smol 1995) lake calibration sets. However, it is still not certain whether diatom assemblages in peatlands occur across a pH gradient or rather there is a threshold response with substantial differences between the assemblages of low pH values and circumneutral pH values. More sampling across peatlands is needed to tease this apart.

Acidic bog hollow and hummock microhabitats were species poor and dominated almost exclusively by one to two diatom species. The acidophilic and aerophilic diatom species recorded in hummocks and hollows were mainly associated with the narrow pH optima of the dominant *Sphagnum* species found in these habitats (e.g., Gignac and Vitt 1990; Riley 2011). However, diatom presence was probably most closely associated with pH and an ability to tolerate dry conditions, as opposed to attachment or a specific association to bryophyte species. Rich and poor fen samples, which were less acidic, supported more diverse diatom assemblages (>30 species) with diatom assemblages and bryophytes with a greater range in pH optima and tolerances. The diatom assemblages recorded in bogs and fens are similar to those found in peatlands around the world (e.g., Kingston 1982; Poulíčková et al. 2004; Chen et al. 2012), demonstrating that diatom species are very specialized to exist in these often harsh semi-aquatic environments, regardless of geographic setting.

The autecological data gathered from the calibration work completed in Chapter was then applied in downcore reconstructions in **Chapter 3**. Three northern Ontario bog peat cores were examined: one collected from a peatland on the Boreal Shield and two from peatlands within the HBL. Radiocarbon dating estimated the basal ages of the cores to be between 6360 and 7680 cal. BP. However, diatom valves were only present and well preserved over the past ~2000 years within each core, and therefore the study was limited to sections of the cores where diatoms were present. From ~2000 to ~600 cal. BP, changes in diatom composition recorded in all three cores likely reflected hydrosere succession within the peatland, including fluctuations in connectivity to the water table and pH changes. From ~600 cal. BP to the present, the synchronous timing of changes in diatoms and testate amoebae tracked drying conditions and subsequent microhabitat variations. Our proxy data are comparable with subarctic peatland work from Quebec, which demonstrated that climate cooling in the late Holocene and associated freezing can foster the ombrotrophication of peatlands through water drawdown (Loisel and Garneau 2010; van Bellen et al. 2011).

Apart from the work of Beyens (1985), this is only the second attempt to use both diatoms and testate amoebae to track past chemical and moisture conditions from the same peat record. Each of these proxies represents a different position within the peatland ecosystem and was used to reconstruct different facets of the environment (Birks and Birks 2006). A plausible interpretation of this multi-proxy study was that diatoms are tracking subtle changes in the stability of peat microforms, including bog hollows and hummocks, highlighting their sensitivity to small chemical changes, whereas testate amoebae are tracking the lowering of the peatland water table and subsequent drying of the peatland. It still remains unclear whether peatland diatoms and testate amoebae can capture recent environmental changes occurring during the 'Anthropocene', because the natural succession of peatlands often climaxes with a dry, ombrotrophic bog (Charman 2002; Glaser et al. 2004), where the living surface of vegetation is substantially elevated above the water table. With climate change, boreal peatlands are predicted to become drier and potentially be more susceptible to forest fires and burning (Tarnocai 2006), thus untangling the influence of peatland succession and current climate change in some northern regions may prove to be difficult through paleoecological studies. Therefore, lakes may be far better sentinels for capturing and incorporating the current impacts of climate warming than peatland archives (Williamson et al. 2009).

**Chapter 4** aimed to focus on the response of aquatic biota to climate change over the past ~150 years by examining lake sediment records. Economic interest in northern Ontario is growing due to the recent discovery of extensive mineral deposits (mainly chromite and nickel) termed the “Ring of Fire” (RoF). With environmental monitoring only beginning in the region, detailed baseline ecological data are required to determine the impacts of future resource extraction within the context of multiple environmental stressors (including recent climate warming). Across the four study lakes, biotic assemblages transitioned from a littoral/benthic-dominated assemblage to one with greater abundances of pelagic/planktonic taxa. This shift is consistent with longer ice-free conditions and/or enhanced thermal stratification. For example, in lakes across the subarctic, increases in both centric and pennate planktonic diatoms have been linked to recent warming (e.g., Rautio et al. 2000; Smol et al. 2005; Solovieva et al. 2008; Rühland et al. 2013; Thienpont et al. 2013). Comparable to the diatom assemblage changes we recorded, pelagic Cladocera taxa across the study lakes have increased in modern sediments at the expense of littoral taxa. Over the past four decades, warmer air temperatures, as recorded at the Lansdowne House climate station (center of RoF), may have led to increases in the length of the growing season, opening up previously ice-covered pelagic habitat and potentially allowing greater time for both diatom and Cladocera planktonic taxa to bloom in the four study lakes.

With a lack of both a diatom and testate amoebae response in northern Ontario peat cores (Chapter 3) over the past ~150 years, lake records provide detailed qualitative biological data capturing aquatic responses to warming through the ‘Anthropocene’. These biotic data provide baseline ecological information prior to the onset of regional climate warming in the ~1970s, as well as information on the natural variation of the ecosystem prior to impacts related to resource development. Together with catchment-specific differences, such as potential thaw of permafrost in the McFaulds Lake catchment (at the epicenter of the RoF), local variation in lakes across the

RoF yields differences in the timing of biotic responses to climatic change. An earlier response to climatic changes in the RoF shallow lakes highlights the sensitivity and utility of shallow ponds across the HBL for tracking environmental changes. Our paleolimnological data demonstrate that lakes within a similar regional climate, and thus experiencing consistent changes in temperature, can vary significantly in their sensitivity and response to climatic change, as would be expected because of differences in other limnological characteristics (reviewed in Smol and Douglas 2007).

Here, research completed in this thesis provides information on how ecosystems of the Far North of Ontario have responded to environmental changes over the past ~100 to 2000 years. By using novel approaches, this thesis has furthered our understanding of how diatoms may be used to track peatland environments in combination with other proxies such as testate amoebae and macrofossil analysis. Together, the use of multiple proxies provided a more holistic approach to interpreting past ecological succession and responses to climate within peatlands and lakes of northern Ontario. This research also emphasizes the importance of studying numerous types of systems to understand biotic responses to climatic change over different time scales.

## 5.1 Future Research

*Peatland diatom autecology:*

This thesis provides new evidence that diatoms are sensitive to chemical and moisture gradients across northern peatland environments and that diatoms can successfully be used to track peatland successional development through the Holocene. However, much work remains to be done to thoroughly understand the autecology of peatland diatoms and the significance of this proxy for inferring past peatland environments. There are numerous research avenues that can be explored to improve this paleoecological tool. To start simply, more peatland habitats in the HBL, especially fens (which where shown to have the greatest diatom diversity but were sampled substantially less in Chapter 2), need to be collected. This would expand the chemical and moisture gradients captured in this thesis, and potentially determine if fens, like bogs, contain microhabitats for diatoms. Although pH and depth to the water table (DWT) are likely the most important variables structuring the diatom assemblages of northern peatlands, alkalinity (specifically calcium) and nutrients become increasingly more important in fen habitats, and water chemistry analysis could yield important information on the presence (or absence) of many diatom taxa. Additionally, it would be interesting to include ‘depth of peat’ as a parameter within the calibration set, as the gradual accumulation of peat and decomposition processes influence the connection of the living vegetation with ground water and thus delivery of cations and nutrients. This measure may be equally important to DWT, as well as more seasonally stable than DWT, allowing another means of inferring contact with mineral-rich ground water.

*Multi-proxy approaches:*

Chapter 3 and 4 demonstrated the advantages of multi-proxy approaches in teasing apart ecosystem responses to environmental change. The diatom assemblages of both modern peat samples and historical peat records need to be paired with testate amoebae records and calibration models to develop the known ecological optima and tolerance of taxa for both proxies. This may additionally help to tease apart why diatoms are not always found in modern peatlands as well as throughout a peat core.

In general, more paleolimnological and paleoecological studies are needed in the Far North of Ontario, and in particular, complete Holocene records in northern Ontario are lacking. Independent records of regional climate change over the Holocene from lake sediment cores and tree rings would help separate the possible interactions between hydroseral succession, isostatic rebound, and climatic change in peatlands. Broadscale vegetational changes inferred from pollen records archived in lakes would help identify regional changes in climate. As well, temperature changes and associated aquatic ecosystem changes over the Holocene could be inferred from chironomids, an invertebrate proxy sensitive to water temperature, achieved in lake sediments. A complete chironomid record for the Holocene would further help identify periods when the climate may have changed (e.g., 'Little Ice Age') and promoted peatland successional responses (e.g., water table draw down and disconnection surface vegetation from groundwater).

To date, a complete Holocene diatom record for the HBL is missing. Obtaining intact Holocene records with diatoms preserved throughout the profile has proved problematic. Most lakes in the HBL region are shallow thermokarst-type features (<2 m in depth), and not ideal for Holocene sediment collection (i.e., greater possibility of disturbance and less sediment focusing). The best lakes in the lowlands for coring are situated in raised glacial moraine or Precambrian Shield rock outcrops (e.g., Sutton Ridges), and with substantially greater water depths. However, very little is known about these lakes. For example, the only core currently available with a Holocene diatom record from the lowlands has a hiatus in sediment accumulation from ~3650 to 200 cal. BP (Friel et al. 2014). This sediment hiatus may be the result of localized hydrological changes including a potential lowering of the groundwater table, the final decay and drainage of remnant kettle ice in the lake basin, thermokarst-driven drainage of the lake, and/or drainage following erosion of a sediment bar (Friel et al. 2014). During fieldwork for this PhD thesis, a piston core from North Raft Lake in the Sutton Ridges, HBL, was collected. Although this core has been radiocarbon dated and spans back to a marine phase (i.e., undulation by the Tyrell Sea), thus containing a complete Holocene record for the HBL, diatoms are completely missing from the record prior to ca. 1900 (see Rühland et al. 2013).

This thesis highlights the complexity of the Far North of Ontario (e.g., maritime and continental climates, permafrost, varied surficial geology, isostatic rebound). Chapter 3 suggests that it is very difficult to tease apart allogenic and autogenic signals of change in peatlands, especially given that development of peatlands in the HBL are largely driven by isostatic rebound (Glaser et al. 2004; Packalen et al. 2014). Chapter 4 shows that landscape complexity across the Far North of Ontario yields asynchronous timing in the responses of lake biota to climate warming over the past ~100 years. It is still necessary to obtain more paloecological records to show that large and accelerated biotic responses, though variable, are limited to the 'Anthropocene'. Complete records over the Holocene are needed to place biotic responses over the past ~100 years within a longer-term perspective. The relatively inaccessible nature of the HBL and the associated high cost of reaching lakes with the required equipment, has thus far limited such work in the HBL.

## 5.2 Literature Cited

Aaby, B. 1986. Palaeoecological studies of mires. In Handbook of Holocene Palaeoecology and Palaeohydrology. Edited by B.E. Berglund. John Wiley and Sons, New York, New York. pp. 145-164.

Battarbee, R.W., Jones, V.J., Flower, R.J., Cameron, N.G., Bennion, H., Carvalho, L., and Juggins, S. 2001: Diatoms. In Tracking Environmental Change Using Lake Sediments: Terrestrial, Algal, and Siliceous Indicators, 3. Edited by Smol, J.P., Birks, H.J.B., and Last, W.M. Dordrecht: Kluwer Academic Publishers, 155–202.

Beyens, L. 1985. On the subboreal climate of the Belgian Campine as deduced from diatom and testate amoebae analyses. *Review of Palaeobotany and Palynology* 46: 9-31.

Birks, H.H., and Birks, H.J.B. 2006. Multi-proxy studies in palaeolimnology. *Vegetation History and Archaeobotany* 15: 235–251.

Brugam, R.B., and Swain, P. 2000. Diatom indicators of peatland development at Pogonia Bog Pond, Minnesota, USA. *The Holocene* 10: 453-464.

Campbell, D.R., Dutchie, H.C., and Warner, B.G. 1997. Post-glacial development of a kettle-hole peatland in southern Ontario. *Ecoscience* 4: 404-418.

Charman, D.J. 2002. Peatlands and Environmental Change. John Wiley Sons Ltd., West Sussix, England.

Chen, X., Bu, Z., Yang, X., and Wang, S. 2012. Epiphytic diatoms and their relation to moisture and moss composition in two montane mires, Northeast China. *Fundamental and Applied Limnology* 181: 197–206.

Cox, E.T. 1978. Counts and measurements of Ontario lakes: watershed unit summaries based on maps of various scales by watershed unit by watershed unit. Ontario Ministry of National Research Rep. Toronto.

Friel, C.E., Finkelstein, S.A., and Davis, A.M. 2014. Relative importance of hydrological and climatic controls on Holocene paleoenvironments inferred using diatom and pollen records from a lake in the central Hudson Bay Lowlands, Canada. *The Holocene* 1: 1-12.

Gignac, L.D. 1992. Niche structure, resource partitioning, and species interactions of mire bryophytes relative to climatic and ecological gradients in western Canada. *Bryologist* 95: 406-418.

Gignac, L.D., and Vitt, D.H. 1990. Habitat limitations of *Sphagnum* along climatic, chemical, and physical gradients in mires of western Canada. *Bryologist* 93: 7-22.

Glaser, P.H., Hansen, B.C.S., Siegel, D.I., Reeve, A.S., and Morin, P.J. 2004. Rates, pathways and drivers for peatland development in the Hudson Bay Lowlands, northern Ontario, Canada. *Journal of Ecology* 92: 1036-1053.

Kienel, U., Siegert, C., and Hahne, J. 1999. Late Quaternary palaeoenvironmental reconstructions from a permafrost sequence (North Siberian Lowland, SE Taymyr Peninsula) - a multidisciplinary case study. *Boreas* 28: 181-193.

Kingston, J.C. 1982. Association and distribution of common diatoms in surface samples from northern Minnesota peatlands. *Nova Hedwigia* 73: 333-346.

Loisel, J., and Garneau, M. 2010. Late Holocene paleoecohydrology and carbon accumulation estimates from two boreal peat bogs in eastern Canada: Potential and limits of multi-proxy archives. *Palaeogeography, Palaeoclimatology, Palaeoecology* 291: 493–533.

Packalen, M.S., Finkelstein, S.A., and McLaughlin, J.W. 2014. Carbon storage and potential methane production in the Hudson Bay Lowlands since mid-Holocene peat initiation. *Nature Communications* 5: 4078.

Poulíèková, A., Hájková, P., Krenková, P., and Hájek, M. 2004. Distribution of diatoms and bryophytes on linear transects through spring fens. *Nova Hedwigia* 78: 411-424.

Rautio, M., Sorvari, S., and Korhola, A. 2000. Diatom and crustacean zooplankton communities, their seasonal variability and representation in the sediments of subarctic Lake Saanajärvi. *Journal of Limnology* 59: 81-96.

Riley, J. 2011. Wetlands of the Hudson Bay Lowlands: an Ontario overview. Nature Conservancy of Canada and the Ontario Ministry of Natural Resources.

Rühland, K.M., Paterson, A.M., Keller, W., Michelutti, N. and Smol, J.P. 2013. Global warming triggers the loss of a key Arctic refugium. *Proceedings of the Royal Society Series B* 280: 20131887.

Smol, J.P. 1995. Application of chrysophytes to problems in paleoecology. In Chrysophyte Algae: Ecology, phylogeny and development. Edited by Sandgren, C.D., Smol, J.P., and Kristiansen, J. Cambridge University Press, New York, pp. 303-329.

Smol, J.P., and Douglas, M.S.V. 2007. From controversy to consensus: making the case for recent climate change in the Arctic using lake sediments. *Frontiers in Ecology and the Environment* 5: 466-474.

Smol, J.P., and Stoermer, E.F. 2010. The Diatoms: Applications for the Environmental and Earth Sciences. Cambridge University Press, New York.

Smol, J.P., Wolfe, A.P., Birks, H.J.B., Douglas, M.S.V., Jones, V.J., Korhola, A., Pienitz, R., Rühland, K., Sorvari, S., Antoniades, D., Brooks, S.J., Fallu, M.A., Hughes, M., Keatley, B.E., Laing, T.E., Michelutti, N., Nazarova, L., Nyman, M., Paterson, A.M., Perren, B., Quinlan, R., Rautio, M., Saulnier-Talbot, E., Siitonen, S., Solovieva, N., and Weckström, J. 2005. Climate-driven regime shifts in the biological communities of arctic lakes. *Proceedings of the National Academy of Science* 102: 4397–4402.

Solovieva, N., Jones, V., Birks, J.H.B., Appleby, P. and Nazarova, L. 2008 Diatom responses to 20th century climate warming in lakes from the northern Urals, Russia. *Palaeogeography, Palaeoclimatology, Palaeoecology* 259: 96–106.

Tarnocai, C. 2006. The effect of climate change on carbon in Canadian peatlands. *Global and Planetary Change* 53: 222-232.

Thienpont, J.R., Rühland, K.M., Pisaric, M.F.J., Kokelj, S.V., Kimpe, L.E., Blais, J.M., and Smol, J.P. 2013. Biological responses to permafrost thaw slumping in Canadian Arctic lakes. *Freshwater Biology* 58: 337-353.

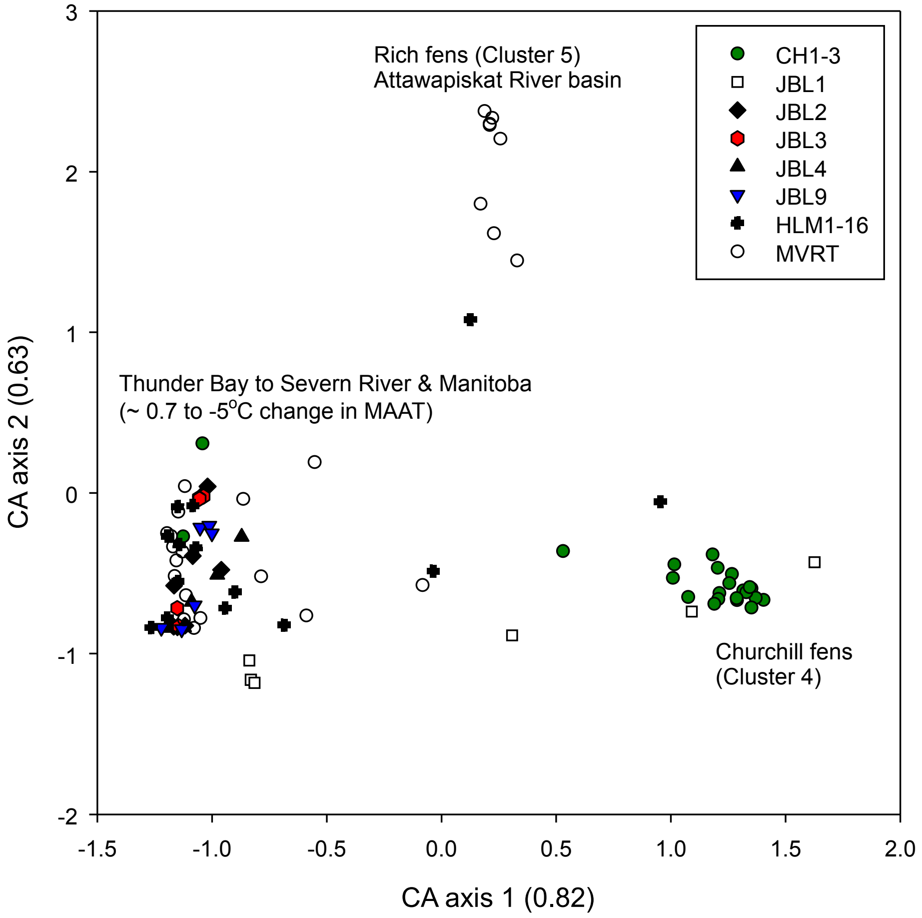
van Bellen, S., Garneau, M., and Booth, R.K. 2011. Holocene carbon accumulation rates from three ombrotrophic peatlands in boreal Quebec, Canada: Impact of climate-driven ecohydrological change. *The Holocene* 21: 1217-1231.

Williamson, C.E., Saros, J.E., Vincent, W.F., and Smol, J.P. 2009. Lakes and reservoirs as sentinels, integrators, and regulators of climate change. *Limnology and Oceanography* 54: 2273–2282.

# Appendix A

## Correspondance analysis (CA) of diatom assemblage data from modern peatlands

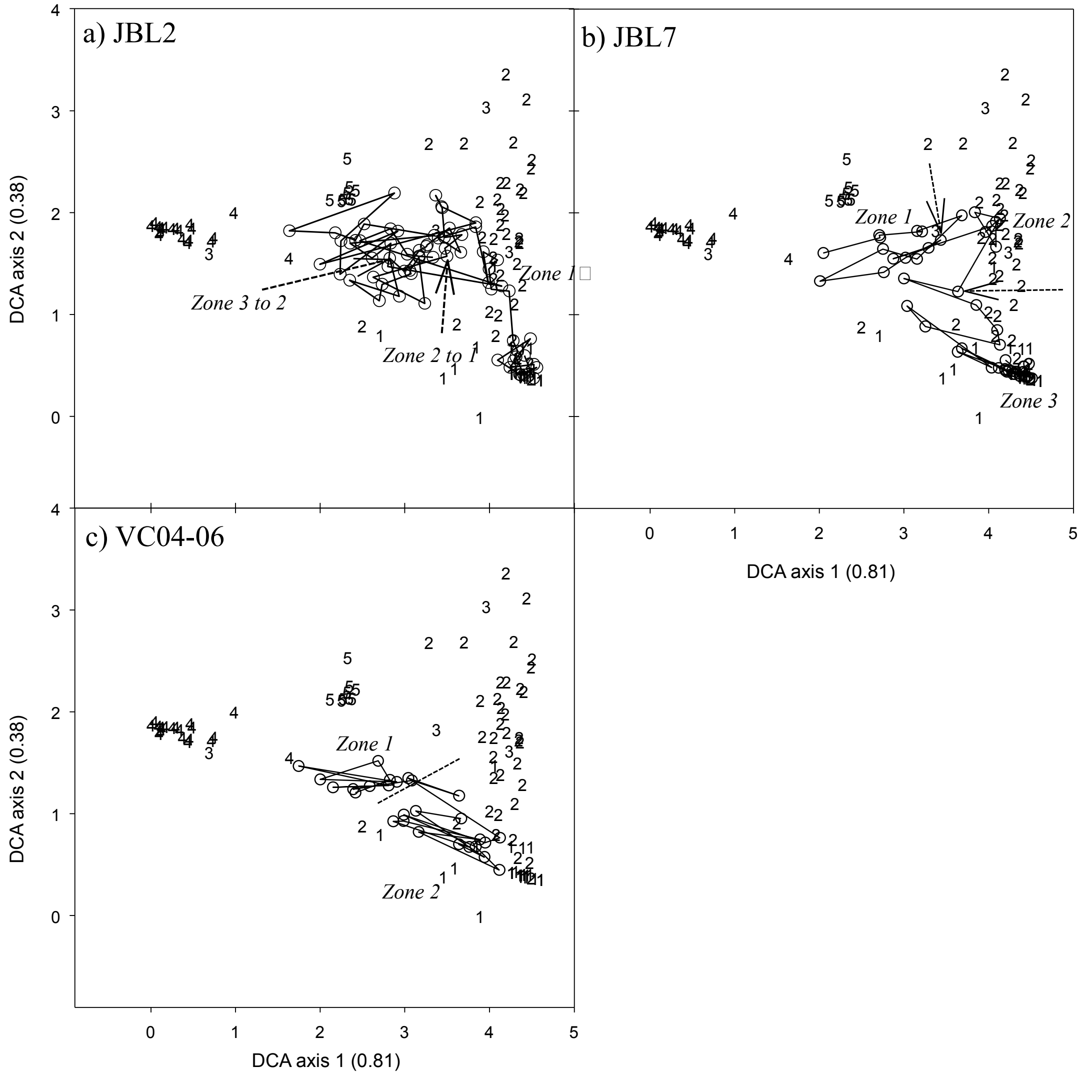
Correspondance analysis (CA) of diatom assemblage data from modern peatlands (Chapter 2) with site scores plotted and organized be geographic location (see map Figure 2-1). Specific clusters from the multivariate regression tree analysis are identified.



# Appendix B

## DCA of modern diatom assemblages from peatlands (Ch. 2) and diatom assemblages from peat cores (Ch. 3)

Detrended correspondence analysis (DCA) of the diatom species assemblages from modern peatlands (Chapter 2) with the site cores plotted based the multivariate regression tree (MRT; Figure 2-2). DCA axis 1 and 2 are plotted for each peat core interval examined in Chapter 3, and the primary zones identified in each peat core are labeled on the graphs.



# Appendix C

## Peat cores examined for the presence of diatoms (Chapter 3)

Peatland cores collected from across the northern Ontario Boreal Shield and the Hudson Bay Lowlands, which were examined for the presence and preservation of diatoms.

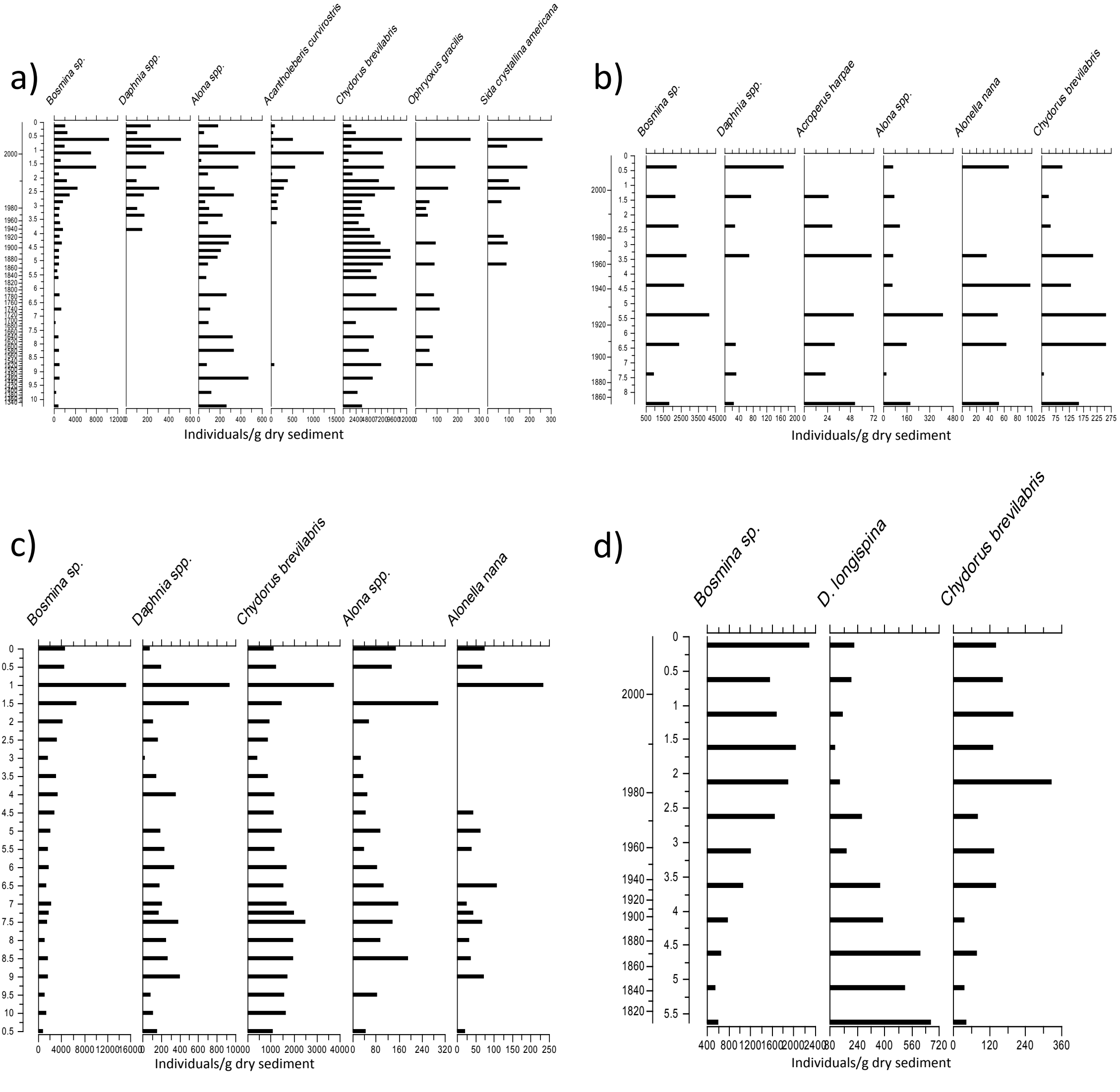
| **Core** | **Digested resolution** | **Presence of diatoms** | **Sub-sampling further?** |
|---|---|---|---|
| Attawapiskat Bog – VC04-06 | Every 2 cm | Top 70 cm (~1200 cal. BP) | **Chapter 3** |
| HL02 *Sphagnum* Bog, Hawley lake, HBL | Every 50 cm from 1 to 225 cm | None | n/a |
| HL04a, Hawley lake, HBL | 3 samples from 1 to 89 cm | None | n/a |
| HL03, Hawley lake, HBL | Every 50 cm from 1 to 265 cm | None | n/a |
| JBL1, *Sphagnum* bog, HBL | Every 50 cm | Top 50 cm (~500 cal. BP) | No |
| JBL2, *Sphagnum* bog | Every 50 cm | Top ~150 cm (~2000 cal. BP) | **Chapter 3** |
| JBL3, *Sphagnum* bog | Every 50 cm | Top ~100 cm, ~2000 ybp | No |
| JBL4, *Sphagnum* bog | Every 50 cm | Top ~150 cm with diatom hiatus at 100 cm (~3000 cal. BP) | No |
| JBL5, Permafrost plateau *Sphagnum* bog | Every 50 cm | No | n/a |

| | | | |
|---|---|---|---|
| JBL6, Permafrost *Sphagnum* bog | Every 50 cm | Top 100 cm, ~3000 cal. BP (basal core not collected) | No |
| JBL7, *Sphagnum* bog | Every 50 cm | Top ~200 cm, ~2000 cal. BP | **Chapter 3** |
| JBL8, *Sphagnum* bog in boreal ON | Every 50 cm | Top 100 cm, ~500 cal. BP | No |
| Attawapiskat fen | Every 50 cm | No | n/a |

# Appendix D

## Cladoceran concentration data (Chapter 4)

Stratigraphies of the domiant cladocera plotted in number of individuals per gram of dry sediment for a) McFaulds, b) Symons, c) Eabamet, and d) Attawapiskat.



# Appendix E

## E.1 Raw diatom counts for 93 surface peat samples (Chapter 2)

| | CH1-1 | CH1-2 | CH1-3 | CH1-4 | CH2-2 | CH2-7 | CH3-10 | CH3-11 | CH3-12 | CH3-13 | CH3-15 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Achnanthes spp. | | | | | 4 | 3 | | | | | |
| Achnanthes flexella | 1 | | | | 8 | | | 1 | | | |
| Achnanthes minutissima | 25 | 3 | 6 | 14 | 107 | 61 | 10 | 71 | 34 | 76 | 76 |
| Achnanthes nodosa | | | | | 2 | | | | | | |
| Achnanthes petersonii | | | | | 2 | | | 2 | | 7 | 2 |
| Achnanthes taeniata/linearis | | | | | | | | | | | |
| Amphora spp. | | | | | | | | | | | |
| Amphora libyca | | | | 2 | | | | | | | 1 |
| Amphora ovalis | 2 | 1 | | | | | | | | 1 | |
| Aulacoseira species | | 1 | | | | 1 | | | 2 | | |
| Aulacoseira ambigua | | | | | | | | | | | |
| Aulacoseira italica | | | | | | | | | | | |
| Aulacoseira pfaffiana | | | | | | | | | | | |
| Aulacoseira subarctica | | | | | | | | | | | 1 |
| Brachysira spp. | | | | | | | | | | | |
| Brachysira aponina | | | | | | | | | | | |
| Brachysira brebissoni | | | | | | | | | | | |
| Brachysira hofmanniae | | | | | | | | | | | |
| Brachysira serians | | | | | | | | | | | |
| Brachysira vitrea | 3 | | | | | | | | | | |
| Brachysira zellensis | | | | | 13 | 1 | | | | | 1 |
| Caloneis spp. | 4 | | | 6 | | | | | | | |
| Caloneis bacillum | | | | | | | | | | | |
| Caloneis molaris | | | | | | | 254 | | | | |
| Caloneis tenuis | 7 | | | 5 | 21 | 2 | 3 | | | | |
| Caloneis pulchra | | | | 7 | 2 | | | | | | |
| Caloneis undulata | | | | 9 | 16 | 2 | | | | | |
| Caloneis silicula | 1 | | | | 2 | | | | | | |
| Cocconeis spp. | 1 | 1 | | 1 | | | | | 1 | | |
| Cymbella spp. | 7 | 6 | 3 | | 3 | 5 | | 1 | 1 | 2 | 2 |
| Cymbella amphioxys | | | | | | | | | | 2 | |
| Cymbella angustata | 13 | | | | 4 | 9 | 3 | | | | 3 |
| Cymbella arctica | | | | | 7 | 1 | | | | 2 | |
| Cymbella aueri | | | | | | | | 26 | | 25 | |
| Cymbella austriaca | | | | | | 3 | | | | | |
| Cymbella cf caespitosa | | | | | | | | | | | |
| Cymbella cesatii | | | | | | | | | | | |
| Cymbella cistula | 4 | | 1 | 1 | 5 | 8 | | | 1 | | |
| Cymbella cuspidata | | | | | | | | | | | 3 |
| Cymbella cymbiformis | | | | | 1 | | | | | | |
| Cymbella descripta | 3 | | | 16 | 6 | 6 | 2 | | 3 | 5 | 7 |
| Cymbella elginensis | | | | | | | | | | | |
| Cymbella gracilis | | 2 | | 2 | | | | 2 | 1 | 2 | |
| Cymbella hybrida | | | | | | | 1 | | | | |
| Cymbella incerta | 3 | 2 | 4 | | 42 | 20 | 10 | | | | 19 |
| Cymbella lacustris | | | | | | | | | | 2 | |
| Cymbella lapponica | 11 | | 3 | | 3 | 2 | | | 3 | | 27 |
| Cymbella laterns | | | | | | | | 2 | | | 9 |
| Cymbella mesiana | | | | | 1 | | | | | | |
| Cymbella microcephala | | 2 | | 6 | 147 | 29 | 24 | 28 | 17 | 19 | 60 |
| Cymbella minuta | 9 | | | | | | 3 | 6 | 13 | 6 | 24 |
| Cymbella naviculacea | | | | | | | | | | | |
| Cymbella naviculiformis | 2 | | | | | | | | | | |
| Cymbella norvegica | | | | | 22 | 3 | 2 | | 4 | | |
| Cymbella obscura | | | | | | | | | | | |
| Cymbella paucistriata | | 23 | | | | | | | 6 | | |
| Cymbella silesiaca | 4 | 45 | 10 | 31 | 16 | 39 | 10 | 27 | | 25 | 10 |
| Cymbella subaequalis | 6 | 9 | | | 9 | 2 | 2 | | | 1 | 6 |

|  | CH1-1 | CH1-2 | CH1-3 | CH1-4 | CH2-2 | CH2-7 | CH3-10 | CH3-11 | CH3-12 | CH3-13 | CH3-15 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cymbella subarctica |  |  |  |  | 10 |  |  |  |  |  |  |
| Cymbella subcuspidata | 1 |  |  |  |  |  |  |  |  |  |  |
| Cymbella tynaii |  |  |  |  | 1 |  |  |  |  |  |  |
| Cyclotella spp. |  |  |  |  |  |  |  |  |  |  |  |
| Cyclotella bodanica |  |  |  |  |  |  |  |  |  |  |  |
| Cyclotella michiganiana | 1 |  |  |  |  |  |  |  |  |  | 1 |
| Cyclotella stelligera |  |  |  |  |  |  |  |  |  |  |  |
| Denticula kuetzingii | 59 | 15 | 29 |  | 23 | 36 | 38 | 17 | 9 | 7 | 81 |
| Diatoma species |  |  |  |  |  |  |  |  |  |  |  |
| Diatoma tenuis | 9 |  |  | 1 |  |  |  | 2 | 13 | 3 | 19 |
| Diploneis elliptica |  |  |  |  |  |  |  |  |  |  |  |
| Diploneis puella |  |  |  |  |  |  |  |  |  |  |  |
| Epithemia adnata |  |  |  | 82 | 17 | 12 | 48 | 1 |  |  |  |
| Eunotia spp. |  |  |  |  |  |  | 2 |  |  |  |  |
| Eunotia arcus |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia argus |  |  |  |  | 2 |  |  |  |  |  |  |
| Eunotia aculus |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia bilunaris | 1 |  |  | 3 | 8 | 4 |  |  |  |  |  |
| E. bilunaris v. mucophila |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia circumborealis |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia fennica |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia exigua |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia faba |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia fallax |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia flexuosa |  |  |  |  |  |  | 2 |  |  |  |  |
| Eunotia formica |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia glacialis |  |  |  |  |  |  |  | 7 |  | 3 |  |
| Eunotia glacialifalsa |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia hexaglyphis |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia implicata |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia incisa |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia lapponica |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia maior |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia monodon |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia naegelli |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia nymanniana |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia paludosa type 1 | 1 |  |  |  |  |  |  |  |  |  |  |
| Eunotia paludosa type 2 |  |  |  |  |  |  |  |  |  |  | 1 |
| Eunotia paludosa v. trinarcia |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia pectinalis |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia pirla |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia praerupta | 2 | 2 | 1 |  | 2 | 5 |  | 1 |  | 1 |  |
| Eunotia praerupta v. bidens |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia septentrionalis |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia serra |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia soleirolii |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia vanheurckii |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria spp. |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria brevistriata |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria biceps |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria capucina | 18 | 4 | 9 | 2 | 2 |  | 2 | 5 | 20 | 4 | 27 |
| F. capucina v. vaucheriae |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria construens |  |  |  |  |  |  |  |  | 2 |  | 4 |
| Fragilaria crotonensis |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria exigua |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria fasciculata | 1 |  | 2 |  |  |  |  |  |  |  |  |
| Fragilaria parasitica |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria pinnata | 2 |  |  |  |  |  |  |  |  |  |  |

|  | CH1-1 | CH1-2 | CH1-3 | CH1-4 | CH2-2 | CH2-7 | CH3-10 | CH3-11 | CH3-12 | CH3-13 | CH3-15 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Fragilaria tenera | 34 | 1 | 3 | 5 | 10 | 2 |  | 15 | 28 | 31 | 3 |
| Fragilaria ulna | 6 | 1 |  |  | 5 |  |  |  |  | 1 |  |
| Frustulia rhomboides | 1 |  |  |  |  |  |  |  |  |  |  |
| F. rhomboides v. saxonica |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema spp. |  |  |  |  |  |  | 4 |  |  | 3 |  |
| Gomphonema girdle | 6 | 4 |  |  | 6 | 17 |  |  |  |  |  |
| Gomphonema acuminatum |  | 1 |  | 214 | 14 | 18 |  |  | 1 |  |  |
| Gomphonema amoenum | 9 |  |  |  |  |  |  |  |  |  |  |
| Gomphonema angustatum |  |  |  |  |  | 1 |  |  | 7 | 3 | 1 |
| G. angustatum v. undulatum |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema angustum |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema bohemicum |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema clavatum |  |  |  |  |  |  |  |  |  |  | 2 |
| Gomphonema gracile |  |  |  |  | 3 | 53 | 2 |  | 12 | 8 |  |
| Gomphonema hebridense |  |  |  |  |  |  |  |  | 6 |  |  |
| Gomphonema intricatum |  |  |  |  |  |  |  |  |  | 1 |  |
| Gomphonema lagerheimii |  |  |  |  | 4 | 8 | 6 |  | 3 | 5 |  |
| Gomphonema longiceps |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema parvulum | 3 |  |  |  |  |  |  |  |  |  | 7 |
| Gomphonema subtile |  |  |  |  |  | 3 |  |  |  |  |  |
| Hantzchia amphioxys | 7 | 1 | 3 | 5 | 7 |  | 6 |  | 1 |  | 9 |
| Hantzschia elongata |  |  |  |  | 2 |  |  |  |  |  |  |
| Navicula spp. |  | 2 | 1 |  |  |  |  | 2 |  |  |  |
| Navicula cf angusta |  |  |  |  |  |  |  |  |  |  |  |
| Navicula brockmannii |  |  |  |  |  |  | 2 |  |  |  |  |
| Navicula bryophilia |  |  |  | 10 | 11 |  | 19 |  |  | 2 |  |
| Navicula cohnii |  |  |  |  |  |  |  |  |  |  |  |
| Navicula cryptocephala | 29 |  | 1 | 59 | 27 | 17 | 53 | 4 | 9 | 4 | 24 |
| Navicula cryptotenella |  |  |  | 7 |  | 2 | 9 |  |  |  | 2 |
| Navicula eidriginia |  |  |  |  | 3 |  |  |  |  |  |  |
| Navicula cf exilis |  |  |  |  |  |  |  |  |  |  |  |
| Navicula festiva |  |  |  |  |  |  |  |  |  |  |  |
| Navicula gallica | 2 |  |  |  | 2 |  |  |  |  |  |  |
| Navicula geoppertiana |  |  |  |  |  |  |  |  |  |  |  |
| Navicula jaegii |  |  | 1 |  |  |  | 24 |  |  |  |  |
| Navicula lancelolata |  |  |  |  | 7 | 1 |  |  |  |  |  |
| Navicula maceria |  |  |  |  |  |  |  |  |  |  |  |
| Navicula mediocris |  |  |  |  |  |  |  |  |  |  |  |
| Navicula mutica | 3 |  | 2 |  |  |  |  | 3 | 3 |  | 6 |
| Navicula muticopis |  |  |  |  |  |  |  |  |  |  |  |
| Navicula lapidosa |  |  |  |  |  |  |  |  |  |  |  |
| Navicula leptostriata |  |  |  |  |  |  |  |  |  |  |  |
| Navicula peregrina |  |  | 8 |  |  | 7 |  |  |  |  | 5 |
| Navicula pupula |  |  | 3 |  | 1 |  | 3 |  |  | 1 | 2 |
| Navicula pseudosubtillisima |  |  |  |  |  |  |  |  |  |  |  |
| Navicula radiosa | 4 | 3 |  |  | 36 | 4 | 8 | 1 |  |  | 6 |
| Navicula rhynchocephala |  |  |  |  |  | 5 | 1 |  |  |  |  |
| Navicula seminulum |  |  |  |  |  |  |  |  |  |  |  |
| Navicula suchlandtii |  |  |  |  |  |  |  |  |  |  |  |
| Navicula soehrensis |  |  |  |  |  |  |  |  |  |  |  |
| Navicula soehrensis v. hassica |  |  |  |  |  |  |  |  |  |  |  |
| N. soehrensis v. soehrensis |  |  |  |  |  |  |  |  |  |  |  |
| Navicula striolata |  |  |  | 20 | 5 |  |  |  |  |  |  |
| Navicula subtilissima | 1 |  |  |  |  |  |  |  | 1 |  |  |
| Navicula tuscula | 5 |  | 1 |  | 2 |  |  | 1 | 2 |  | 4 |
| Navicula tridentula |  |  |  |  |  |  |  |  |  |  |  |
| Navicula viridula | 7 |  |  |  | 2 |  |  | 3 | 8 | 2 | 12 |
| Navicula vulpina |  |  |  |  |  |  | 1 |  |  |  |  |

|  | CH1-1 | CH1-2 | CH1-3 | CH1-4 | CH2-2 | CH2-7 | CH3-10 | CH3-11 | CH3-12 | CH3-13 | CH3-15 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Neidium species | 1 |  |  |  |  | 1 |  | 2 |  |  |  |
| Neidium affine |  |  |  |  |  |  |  |  |  |  |  |
| Neidium dubium |  |  |  |  |  |  |  |  |  |  |  |
| Neidium temperei |  |  |  |  |  |  |  |  |  |  |  |
| Nitzschia sp. |  |  |  |  |  |  |  |  | 1 |  |  |
| Nitzschia acidoclinata |  |  |  |  |  |  |  |  |  |  |  |
| Nitzschia alpina | 4 |  |  |  |  |  | 3 |  |  |  | 6 |
| Nitzschia fonticola | 2 |  |  |  |  |  |  |  |  |  |  |
| Nitzschia frustulum | 2 |  |  | 66 | 43 |  |  | 7 |  | 12 | 1 |
| Nitzschia glacilis | 3 |  |  |  |  |  |  |  |  |  |  |
| Nitzschia hungarcia |  |  |  |  |  |  |  |  |  |  |  |
| Nitzschia intermedia | 5 | 3 | 1 |  |  |  |  | 5 |  | 18 | 1 |
| Nitzschia liebetruhii |  |  |  |  |  |  | 1 |  |  |  |  |
| Nitzschia linearis | 2 | 1 |  |  | 3 |  |  | 21 |  | 16 | 2 |
| Nitzschia peisonis |  |  |  |  |  |  |  |  |  |  | 1 |
| Nitzschia perminuta | 65 | 453 | 336 | 118 | 117 | 65 | 40 | 261 | 197 | 256 | 97 |
| Nitzschia sigmoidea |  |  |  | 1 | 3 |  |  |  |  |  |  |
| Pinnularia spp. | 2 |  | 1 |  |  |  |  |  |  |  |  |
| Pinnularia biceps |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia borealis | 2 | 1 | 2 |  |  | 1 | 1 | 1 | 1 |  | 3 |
| Pinnularia divergens |  |  |  | 2 |  |  |  |  |  |  |  |
| Pinnularia gibba |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia cf intermedia |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia interrupta |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia maior | 1 |  |  |  | 1 |  |  |  |  |  |  |
| Pinnularia microstauron |  |  |  |  |  |  |  |  |  |  |  |
| P. microstauron small type |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia rupestris | 1 |  |  |  |  |  |  |  |  |  |  |
| Pinnularis supcapitata |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia streptoraphe |  |  |  | 2 |  |  |  |  |  |  |  |
| Rhopolodia gibba |  |  |  | 32 | 20 |  | 6 |  |  |  | 1 |
| Stauroneis phoenicenteron | 9 | 3 | 3 | 1 | 4 |  |  |  | 2 | 1 | 10 |
| Stauroneis anceps | 1 |  |  |  |  |  |  |  |  |  |  |
| Stauroneis smithii |  |  |  |  |  |  |  |  |  |  |  |
| Stenopterobia spp. |  |  |  |  |  |  |  |  |  |  |  |
| Stenopterobia anceps |  |  |  |  |  |  |  |  |  |  |  |
| Stenopterobia delicatissima |  |  |  |  |  |  |  |  |  |  |  |
| Stephanodiscus niagrae |  |  |  |  |  |  |  |  |  |  |  |
| Stephanodiscus medius |  |  |  |  |  |  |  |  | 1 |  |  |
| Tabellaria spp. |  |  |  |  |  |  |  |  |  |  |  |
| Tabellaria fenestrata |  |  |  |  |  |  |  |  |  |  |  |
| Tabellaria flocculosa | 3 | 1 |  |  | 14 | 4 |  |  | 1 |  |  |
| Tabellaria flocculosa str. 3 |  |  |  |  |  |  |  |  |  |  |  |
| Tabellaria flocculosa srt. 4 |  |  |  |  |  |  |  |  |  |  |  |
| Tabellaria linearis |  |  |  |  |  |  |  |  |  |  |  |
| Tabellaria quadrisepta |  |  |  |  |  |  |  |  |  |  |  |
| Unknown spp. |  |  |  |  |  | 2 |  |  |  |  | 6 |

|  | CH3-17 | CH3-18 | CH3-21 | CH3-21 | CH3-22 | CH3-25 | CH3-28 | CH3-29 | CH3-30 | CH4-1 | CH4-3 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Achnanthes spp. | 4 | 2 | 4 | 22 | 19 | 2 |  | 9 | 2 |  |  |
| Achnanthes flexella |  |  |  |  |  |  |  |  |  |  |  |
| Achnanthes minutissima | 104 | 31 | 26 | 23 | 18 | 5 | 50 | 18 | 15 |  |  |
| Achnanthes nodosa |  |  |  |  |  |  |  |  |  |  |  |
| Achnanthes petersonii | 5 |  |  |  |  |  | 16 |  | 7 |  |  |
| Achnanthes taeniata/linearis |  |  |  |  |  |  |  |  |  |  |  |
| Amphora spp. |  | 1 |  |  |  |  |  |  |  |  |  |
| Amphora libyca |  |  |  |  |  |  |  |  |  |  |  |
| Amphora ovalis |  |  |  |  |  |  |  |  |  |  |  |
| Aulacoseira species |  |  |  |  |  |  | 1 |  |  |  |  |
| Aulacoseira ambigua |  |  |  |  |  |  |  |  |  |  |  |
| Aulacoseira italica |  |  |  |  |  |  |  |  |  |  |  |
| Aulacoseira pfaffiana |  |  |  |  |  |  |  |  |  |  |  |
| Aulacoseira subarctica |  |  |  |  |  |  |  |  |  |  |  |
| Brachysira spp. |  | 1 |  |  |  |  |  |  |  |  |  |
| Brachysira aponina |  |  |  |  |  |  |  |  |  |  |  |
| Brachysira brebissoni |  |  |  |  |  |  |  |  |  |  |  |
| Brachysira hofmanniae |  |  |  |  |  |  |  |  |  |  |  |
| Brachysira serians |  |  |  |  |  |  |  |  |  |  |  |
| Brachysira vitrea |  |  |  |  |  |  |  |  |  |  |  |
| Brachysira zellensis |  |  |  |  |  |  |  |  |  |  |  |
| Caloneis spp. |  |  |  |  |  |  |  |  |  |  |  |
| Caloneis bacillum |  |  |  |  |  |  |  |  |  |  |  |
| Caloneis molaris |  |  |  |  |  |  |  |  |  |  |  |
| Caloneis tenuis |  |  |  |  |  |  |  |  |  |  |  |
| Caloneis pulchra |  |  |  |  |  |  |  |  |  |  |  |
| Caloneis undulata |  |  |  |  |  |  |  |  |  |  |  |
| Caloneis silicula |  |  |  |  |  |  |  |  |  |  |  |
| Cocconeis spp. |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella spp. |  | 1 | 3 |  | 4 | 2 |  |  |  |  |  |
| Cymbella amphioxys |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella angustata |  |  |  |  |  | 2 |  |  |  |  |  |
| Cymbella arctica |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella aueri |  |  |  |  |  |  | 18 | 3 |  |  |  |
| Cymbella austriaca |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella cf caespitosa |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella cesatii |  | 3 |  |  |  |  |  |  |  |  |  |
| Cymbella cistula |  | 1 |  |  |  |  |  |  |  |  |  |
| Cymbella cuspidata |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella cymbiformis |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella descripta |  | 7 |  | 1 |  | 1 |  |  | 2 |  |  |
| Cymbella elginensis |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella gracilis |  |  |  |  |  |  |  | 3 | 6 |  |  |
| Cymbella hybrida |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella incerta |  |  | 2 | 3 | 2 | 2 |  |  |  |  |  |
| Cymbella lacustris |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella lapponica | 3 | 8 |  |  |  |  | 1 |  |  |  |  |
| Cymbella laterns | 3 |  | 1 |  |  |  | 1 |  | 2 |  |  |
| Cymbella mesiana |  |  |  |  |  |  | 1 |  |  |  |  |
| Cymbella microcephala | 33 | 50 | 12 | 9 | 3 | 8 | 14 | 9 | 11 |  |  |
| Cymbella minuta | 33 | 12 | 10 |  | 1 |  |  |  | 1 |  |  |
| Cymbella naviculacea |  |  | 2 |  |  |  |  |  |  |  |  |
| Cymbella naviculiformis |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella norvegica | 9 | 1 |  |  |  |  |  | 2 | 9 |  |  |
| Cymbella obscura |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella paucistriata | 29 |  |  | 1 |  |  |  |  |  |  |  |
| Cymbella silesiaca | 7 |  | 12 | 35 | 36 |  | 27 | 15 | 38 |  |  |
| Cymbella subaequalis |  |  |  |  |  |  |  |  |  |  |  |

|  | CH3-17 | CH3-18 | CH3-21 | CH3-21 | CH3-22 | CH3-25 | CH3-28 | CH3-29 | CH3-30 | CH4-1 | CH4-3 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cymbella subarctica |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella subcuspidata |  | 1 |  |  |  |  |  |  |  |  |  |
| Cymbella tynaii |  |  |  |  |  |  |  |  |  |  |  |
| Cyclotella spp. |  |  |  |  |  |  |  |  |  |  |  |
| Cyclotella bodanica |  |  |  |  |  |  |  |  |  |  |  |
| Cyclotella michiganiana |  |  |  |  |  |  |  |  |  |  |  |
| Cyclotella stelligera |  |  |  |  |  |  |  |  |  |  |  |
| Denticula kuetzingii | 15 | 43 | 7 | 1 |  | 15 | 4 | 2 | 3 |  |  |
| Diatoma species |  |  |  |  |  |  |  |  |  |  |  |
| Diatoma tenuis |  | 5 | 1 | 1 |  |  | 1 | 5 |  |  |  |
| Diploneis elliptica |  |  |  |  |  |  |  | 3 |  |  |  |
| Diploneis puella |  |  |  |  |  |  |  |  |  |  |  |
| Epithemia adnata |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia spp. |  |  |  |  |  |  |  | 1 |  |  |  |
| Eunotia arcus |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia argus |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia aculus |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia bilunaris |  |  |  |  |  |  | 1 | 1 |  |  |  |
| E. bilunaris v. mucophila |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia circumborealis |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia fennica |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia exigua |  |  |  |  |  |  |  |  |  | 60 | 21 |
| Eunotia faba |  |  |  |  | 1 |  |  |  |  |  |  |
| Eunotia fallax |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia flexuosa |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia formica | 1 |  |  |  |  |  |  |  |  |  |  |
| Eunotia glacialis |  |  |  |  |  |  | 4 | 1 |  |  |  |
| Eunotia glacialifalsa |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia hexaglyphis |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia implicata |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia incisa |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia lapponica |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia maior |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia monodon |  |  |  |  |  |  |  | 1 |  |  |  |
| Eunotia naegelli |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia nymanniana |  |  |  |  |  | 31 |  |  |  |  |  |
| Eunotia paludosa type 1 |  |  |  |  |  |  |  |  |  | 485 |  |
| Eunotia paludosa type 2 |  |  |  |  | 1 |  | 11 | 25 | 3 |  |  |
| Eunotia paludosa v. trinarcia |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia pectinalis | 1 | 1 |  |  |  |  |  |  |  |  |  |
| Eunotia pirla |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia praerupta |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia praerupta v. bidens |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia septentrionalis |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia serra |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia soleirolii |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia vanheurckii |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria spp. |  |  |  |  |  | 1 |  |  |  |  |  |
| Fragilaria brevistriata |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria biceps |  |  |  |  |  |  |  | 1 |  |  |  |
| Fragilaria capucina | 15 | 11 | 6 | 7 |  | 4 | 4 |  | 2 |  |  |
| F. capucina v. vaucheriae |  |  | 4 |  | 2 |  |  |  |  |  |  |
| Fragilaria construens |  | 2 |  |  | 2 | 11 |  |  |  |  |  |
| Fragilaria crotonensis |  |  |  |  |  |  |  |  | 8 |  |  |
| Fragilaria exigua |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria fasciculata |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria parasitica |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria pinnata |  | 3 |  |  |  | 1 |  |  |  |  |  |

|  | CH3-17 | CH3-18 | CH3-21 | CH3-21 | CH3-22 | CH3-25 | CH3-28 | CH3-29 | CH3-30 | CH4-1 | CH4-3 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Fragilaria tenera | 12 | 1 | 12 | 14 | 15 | 3 | 22 | 18 | 22 |  |  |
| Fragilaria ulna |  |  |  |  |  | 1 |  | 2 |  |  |  |
| Frustulia rhomboides |  |  |  |  |  |  |  |  |  |  |  |
| F. rhomboides v. saxonica |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema spp. |  | 1 |  |  |  |  |  |  |  |  |  |
| Gomphonema girdle |  |  |  | 25 | 22 |  | 2 | 16 | 9 |  |  |
| Gomphonema acuminatum |  |  |  |  | 2 |  |  | 2 | 1 |  |  |
| Gomphonema amoenum |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema angustatum | 13 |  |  | 9 | 2 |  |  | 12 |  |  |  |
| G. angustatum v. undulatum | 4 |  |  | 74 | 42 | 4 | 29 | 19 | 95 |  |  |
| Gomphonema angustum |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema bohemicum |  | 6 |  | 2 |  |  |  |  |  |  |  |
| Gomphonema clavatum |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema gracile | 6 |  | 10 | 9 | 30 | 5 | 23 | 24 | 42 |  |  |
| Gomphonema hebridense |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema intricatum |  |  |  |  | 1 |  |  |  | 3 |  |  |
| Gomphonema lagerheimii |  |  |  |  |  |  |  | 2 |  |  |  |
| Gomphonema longiceps |  |  |  |  |  |  |  |  | 3 |  |  |
| Gomphonema parvulum |  | 1 |  | 3 |  | 2 |  |  |  |  |  |
| Gomphonema subtile |  |  |  |  |  |  |  |  |  |  |  |
| Hantzchia amphioxys |  | 4 |  |  |  | 12 | 1 | 42 | 1 | 1 |  |
| Hantzschia elongata |  |  |  |  |  |  |  |  |  |  |  |
| Navicula spp. |  |  |  | 4 | 1 |  | 2 |  |  |  |  |
| Navicula cf angusta |  |  |  |  |  |  | 14 |  |  |  |  |
| Navicula brockmannii |  |  |  |  |  |  |  |  |  |  |  |
| Navicula bryophilia |  |  |  |  |  |  | 3 | 2 |  |  |  |
| Navicula cohnii |  |  |  |  |  |  |  |  |  |  |  |
| Navicula cryptocephala | 14 | 8 | 2 | 1 | 4 | 5 | 5 | 1 | 3 |  |  |
| Navicula cryptotenella |  |  |  |  | 3 |  |  |  | 3 |  |  |
| Navicula eidriginia |  |  |  |  |  | 2 |  |  |  |  |  |
| Navicula cf exilis |  |  |  |  |  |  |  |  |  |  |  |
| Navicula festiva |  |  |  |  |  |  |  |  |  |  |  |
| Navicula gallica |  | 2 |  |  |  |  |  |  |  |  |  |
| Navicula geoppertiana |  |  |  |  |  |  |  |  |  |  |  |
| Navicula jaegii |  |  |  |  |  |  |  |  |  |  |  |
| Navicula lancelolata |  |  |  |  |  |  |  |  |  |  |  |
| Navicula maceria |  |  |  |  |  |  |  |  |  |  |  |
| Navicula mediocris |  |  |  |  |  |  |  |  |  |  |  |
| Navicula mutica |  | 3 |  | 1 | 1 | 19 |  | 17 |  |  |  |
| Navicula muticopis |  |  |  |  |  |  |  |  |  |  |  |
| Navicula lapidosa |  | 2 |  |  |  |  |  |  |  |  |  |
| Navicula leptostriata |  |  | 2 |  |  |  |  |  |  |  |  |
| Navicula peregrina |  | 6 |  |  |  |  | 3 | 2 |  |  |  |
| Navicula pupula |  | 1 |  | 2 |  |  | 2 | 2 |  |  |  |
| Navicula pseudosubtillisima |  |  |  |  |  |  |  |  |  |  |  |
| Navicula radiosa | 2 |  | 1 |  |  | 3 |  | 5 | 2 |  |  |
| Navicula rhynchocephala |  |  |  |  |  |  |  |  |  |  |  |
| Navicula seminulum |  |  |  | 1 |  |  |  |  |  |  |  |
| Navicula suchlandtii |  | 2 |  |  |  |  |  |  |  |  |  |
| Navicula soehrensis |  |  |  |  |  |  |  |  |  |  |  |
| Navicula soehrensis v. hassica |  |  |  |  |  |  |  |  |  |  |  |
| N. soehrensis v. soehrensis |  |  |  |  |  |  |  |  |  |  |  |
| Navicula striolata |  |  |  |  |  |  |  |  |  |  |  |
| Navicula subtilissima |  |  |  |  |  |  |  | 3 |  | 197 | 395 |
| Navicula tuscula | 1 |  |  |  |  | 1 |  | 1 |  |  |  |
| Navicula tridentula |  |  |  |  |  |  |  |  |  |  |  |
| Navicula viridula |  | 4 | 3 |  | 3 | 2 |  |  |  |  |  |
| Navicula vulpina | 5 |  |  |  |  |  |  |  |  |  |  |

|  | CH3-17 | CH3-18 | CH3-21 | CH3-21 | CH3-22 | CH3-25 | CH3-28 | CH3-29 | CH3-30 | CH4-1 | CH4-3 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Neidium species |  |  |  |  |  |  |  |  |  |  |  |
| Neidium affine |  |  |  |  |  |  |  |  |  |  |  |
| Neidium dubium |  |  |  |  |  |  |  |  | 2 |  |  |
| Neidium temperei |  |  |  |  |  |  |  |  |  |  |  |
| Nitzschia sp. |  |  | 1 |  |  |  |  |  |  |  |  |
| Nitzschia acidoclinata |  |  |  |  |  |  |  |  |  |  |  |
| Nitzschia alpina |  | 4 |  |  |  |  |  |  |  |  |  |
| Nitzschia fonticola |  |  |  |  |  |  |  |  |  |  |  |
| Nitzschia frustulum |  |  |  |  |  | 1 |  | 2 | 5 |  |  |
| Nitzschia glacilis |  |  |  |  |  |  |  |  |  |  |  |
| Nitzschia hungarcia |  |  | 2 |  |  |  |  |  |  |  |  |
| Nitzschia intermedia |  |  |  |  |  |  | 1 | 9 | 10 |  |  |
| Nitzschia liebetruhii |  |  |  |  |  |  |  |  |  |  |  |
| Nitzschia linearis | 1 | 2 |  | 4 | 2 |  | 4 | 21 |  |  |  |
| Nitzschia peisonis |  |  |  |  |  |  |  |  |  |  |  |
| Nitzschia perminuta | 457 | 32 | 227 | 111 | 276 | 19 | 201 | 165 | 305 |  |  |
| Nitzschia sigmoidea |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia spp. |  |  | 2 | 2 | 1 | 2 |  | 4 |  |  |  |
| Pinnularia biceps |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia borealis |  | 1 |  |  |  | 5 | 2 | 9 |  |  |  |
| Pinnularia divergens |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia gibba |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia cf intermedia |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia interrupta |  | 1 |  |  |  |  |  |  |  |  |  |
| Pinnularia maior |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia microstauron |  |  |  |  |  | 2 |  | 1 |  |  |  |
| P. microstauron small type |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia rupestris |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularis supcapitata |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia streptoraphe |  |  |  |  |  |  |  |  |  |  |  |
| Rhopolodia gibba |  |  |  |  |  |  |  | 2 |  |  |  |
| Stauroneis phoenicenteron | 2 | 2 |  | 3 | 1 | 2 | 1 | 2 |  |  |  |
| Stauroneis anceps |  |  |  |  |  | 2 |  |  |  |  |  |
| Stauroneis smithii |  |  |  |  |  |  |  |  |  |  |  |
| Stenopterobia spp. |  |  |  |  |  |  |  |  |  |  |  |
| Stenopterobia anceps |  |  |  |  |  |  |  |  |  |  |  |
| Stenopterobia delicatissima |  |  |  |  |  |  |  |  |  |  |  |
| Stephanodiscus niagrae |  |  |  |  |  |  |  |  |  |  |  |
| Stephanodiscus medius |  |  |  | 1 |  |  |  |  |  |  |  |
| Tabellaria spp. |  |  |  |  |  |  |  |  |  |  |  |
| Tabellaria fenestrata |  |  |  |  |  |  |  |  |  |  |  |
| Tabellaria flocculosa |  |  |  |  |  |  |  |  |  |  |  |
| Tabellaria flocculosa str. 3 |  |  |  |  |  |  |  |  |  |  |  |
| Tabellaria flocculosa srt. 4 |  |  |  |  |  |  |  |  |  |  |  |
| Tabellaria linearis |  |  |  |  |  |  |  |  |  |  |  |
| Tabellaria quadrisepta |  |  |  |  |  |  |  |  |  |  |  |
| Unknown spp. |  | 6 | 2 | 2 |  | 3 |  | 2 |  |  |  |

|  | JBL1-1A | JBL1-1B | JBL1-1C | JBL1-2A | JBL1-2B | JBL1-2C | JBL2-1A | JBL2-1C | JBL2-2A | JBL2-2B |
|---|---|---|---|---|---|---|---|---|---|---|
| Achnanthes spp. |  |  |  |  |  |  |  |  |  |  |
| Achnanthes flexella |  |  |  |  |  |  |  |  |  |  |
| Achnanthes minutissima |  |  |  |  |  |  |  |  |  |  |
| Achnanthes nodosa |  |  |  |  |  |  |  |  |  |  |
| Achnanthes petersonii |  |  |  |  |  |  |  |  |  |  |
| Achnanthes taeniata/linearis |  |  |  |  |  |  |  |  |  |  |
| Amphora spp. |  |  |  |  |  |  |  |  |  |  |
| Amphora libyca |  |  |  |  |  |  |  |  |  |  |
| Amphora ovalis |  |  |  |  |  |  |  |  |  |  |
| Aulacoseira species |  |  |  |  |  |  |  |  |  |  |
| Aulacoseira ambigua |  |  |  |  |  |  |  |  |  |  |
| Aulacoseira italica |  |  |  |  |  |  |  |  |  |  |
| Aulacoseira pfaffiana |  |  |  |  |  |  |  |  |  |  |
| Aulacoseira subarctica |  |  |  |  |  |  |  |  |  |  |
| Brachysira spp. |  |  |  |  |  |  |  |  |  |  |
| Brachysira aponina |  |  |  |  |  |  |  |  |  |  |
| Brachysira brebissoni |  |  |  |  | 60 | 37 |  |  |  |  |
| Brachysira hofmanniae |  |  |  |  |  |  |  |  |  |  |
| Brachysira serians |  |  |  |  |  |  |  |  |  |  |
| Brachysira vitrea |  |  |  |  |  |  |  |  |  |  |
| Brachysira zellensis |  |  |  | 2 |  |  |  |  |  |  |
| Caloneis spp. |  |  |  |  |  |  | 1 |  |  |  |
| Caloneis bacillum |  |  |  |  |  |  |  |  |  |  |
| Caloneis molaris |  |  |  |  |  |  |  |  |  |  |
| Caloneis tenuis |  |  |  |  |  |  |  |  |  |  |
| Caloneis pulchra |  |  |  |  |  |  |  |  |  |  |
| Caloneis undulata |  |  |  |  |  |  |  |  |  |  |
| Caloneis silicula |  |  |  |  |  |  |  |  |  |  |
| Cocconeis spp. |  |  |  |  |  |  |  |  |  |  |
| Cymbella spp. |  |  |  |  |  |  |  |  |  |  |
| Cymbella amphioxys |  |  |  |  |  |  |  |  |  |  |
| Cymbella angustata |  |  |  |  |  |  |  |  |  |  |
| Cymbella arctica |  |  |  |  |  |  |  |  |  |  |
| Cymbella aueri |  |  |  |  |  |  |  |  |  |  |
| Cymbella austriaca |  |  |  |  |  |  |  |  |  |  |
| Cymbella cf caespitosa |  |  |  |  |  |  |  |  |  |  |
| Cymbella cesatii |  |  |  |  |  |  |  |  |  |  |
| Cymbella cistula |  |  |  |  |  |  |  |  |  |  |
| Cymbella cuspidata |  |  |  |  |  |  |  |  |  |  |
| Cymbella cymbiformis |  |  |  |  |  |  |  |  |  |  |
| Cymbella descripta |  |  |  |  |  |  |  |  |  |  |
| Cymbella elginensis |  |  |  |  |  |  |  |  |  |  |
| Cymbella gracilis |  |  |  |  | 2 |  |  |  |  |  |
| Cymbella hybrida |  |  |  |  |  |  |  |  |  |  |
| Cymbella incerta |  |  |  |  |  |  |  |  |  |  |
| Cymbella lacustris |  |  |  |  |  |  |  |  |  |  |
| Cymbella lapponica |  |  |  |  |  |  |  |  |  |  |
| Cymbella laterns |  |  |  |  |  |  |  |  |  |  |
| Cymbella mesiana |  |  |  |  |  |  |  |  |  |  |
| Cymbella microcephala |  |  |  |  |  |  |  |  |  |  |
| Cymbella minuta |  |  |  |  |  |  |  |  |  |  |
| Cymbella naviculacea |  |  |  |  |  |  |  |  |  |  |
| Cymbella naviculiformis |  |  |  |  |  |  |  |  |  |  |
| Cymbella norvegica |  |  |  |  | 4 |  |  |  |  |  |
| Cymbella obscura |  |  |  |  |  |  |  |  |  |  |
| Cymbella paucistriata |  |  |  |  |  |  |  |  |  |  |
| Cymbella silesiaca |  |  |  |  |  |  |  |  |  |  |
| Cymbella subaequalis |  |  |  |  |  |  |  |  |  |  |

|  | JBL1-1A | JBL1-1B | JBL1-1C | JBL1-2A | JBL1-2B | JBL1-2C | JBL2-1A | JBL2-1C | JBL2-2A | JBL2-2B |
|---|---|---|---|---|---|---|---|---|---|---|
| Cymbella subarctica |  |  |  |  |  |  |  |  |  |  |
| Cymbella subcuspidata |  |  |  |  |  |  |  |  |  |  |
| Cymbella tynaii |  |  |  |  |  |  |  |  |  |  |
| Cyclotella spp. |  |  |  |  |  |  |  |  |  |  |
| Cyclotella bodanica |  |  |  |  |  |  |  |  |  |  |
| Cyclotella michiganiana |  |  |  |  |  |  |  |  |  |  |
| Cyclotella stelligera |  |  | 2 |  |  |  |  |  |  |  |
| Denticula kuetzingii |  |  |  |  |  |  |  |  |  |  |
| Diatoma species |  |  |  |  |  |  |  |  |  |  |
| Diatoma tenuis |  |  |  |  |  |  |  |  |  |  |
| Diploneis elliptica |  |  |  |  |  |  |  |  |  |  |
| Diploneis puella |  |  |  |  |  |  |  |  |  |  |
| Epithemia adnata |  |  |  |  |  |  |  |  |  |  |
| Eunotia spp. |  |  |  |  |  |  |  |  |  |  |
| Eunotia arcus |  |  |  |  |  |  |  |  |  |  |
| Eunotia argus |  |  |  |  |  |  |  |  |  |  |
| Eunotia aculus |  |  |  |  |  |  |  |  |  |  |
| Eunotia bilunaris |  |  |  | 3 | 10 |  |  |  |  |  |
| E. bilunaris v. mucophila |  |  |  |  |  | 1 |  |  | 19 |  |
| Eunotia circumborealis |  |  |  |  |  |  |  |  |  |  |
| Eunotia fennica |  |  |  |  |  |  |  |  |  |  |
| Eunotia exigua |  |  |  | 11 | 42 | 39 |  |  | 30 |  |
| Eunotia faba |  |  |  |  |  |  |  |  |  |  |
| Eunotia fallax |  |  |  | 1 | 7 | 2 |  |  |  |  |
| Eunotia flexuosa |  |  |  | 1 | 5 | 2 |  |  |  |  |
| Eunotia formica |  |  |  |  |  |  |  |  |  |  |
| Eunotia glacialis |  |  |  |  |  |  |  |  |  |  |
| Eunotia glacialifalsa |  |  |  |  |  |  |  |  |  |  |
| Eunotia hexaglyphis |  |  |  |  |  |  |  |  |  |  |
| Eunotia implicata |  |  |  |  |  |  |  |  |  |  |
| Eunotia incisa |  |  |  |  |  |  |  |  |  |  |
| Eunotia lapponica |  |  |  |  | 2 | 4 |  |  |  |  |
| Eunotia maior |  |  |  |  |  |  |  |  |  |  |
| Eunotia monodon |  |  |  |  |  |  |  |  |  |  |
| Eunotia naegelli |  |  |  |  |  |  |  |  |  |  |
| Eunotia nymanniana |  |  |  |  | 10 | 1 |  |  | 10 |  |
| Eunotia paludosa type 1 | 310 | 500 | 396 | 333 | 14 | 39 | 373 | 504 | 558 | 480 |
| Eunotia paludosa type 2 |  |  |  |  |  |  |  |  | 11 |  |
| Eunotia paludosa v. trinarcia |  |  |  |  |  |  |  |  | 13 |  |
| Eunotia pectinalis |  |  |  |  |  |  |  |  |  |  |
| Eunotia pirla |  |  |  |  |  |  |  |  |  |  |
| Eunotia praerupta |  |  |  |  |  |  |  |  |  |  |
| Eunotia praerupta v. bidens |  |  |  |  |  |  |  |  |  |  |
| Eunotia septentrionalis |  |  |  | 3 | 17 |  |  |  |  |  |
| Eunotia serra |  |  |  |  |  |  |  |  |  |  |
| Eunotia soleirolii |  |  |  |  |  |  |  |  |  |  |
| Eunotia vanheurckii |  |  |  |  |  |  |  |  |  |  |
| Fragilaria spp. |  |  |  |  |  |  |  |  |  |  |
| Fragilaria brevistriata |  |  |  |  |  |  |  |  |  |  |
| Fragilaria biceps |  |  |  |  |  |  |  |  |  |  |
| Fragilaria capucina |  |  |  |  |  |  |  |  |  |  |
| F. capucina v. vaucheriae |  |  |  |  |  |  |  |  |  |  |
| Fragilaria construens | 3 |  |  |  |  |  |  |  |  |  |
| Fragilaria crotonensis |  |  |  |  |  |  |  |  |  |  |
| Fragilaria exigua |  |  |  |  |  |  |  |  |  |  |
| Fragilaria fasciculata |  |  |  |  |  |  |  |  |  |  |
| Fragilaria parasitica |  |  |  |  |  |  |  |  |  |  |
| Fragilaria pinnata |  |  |  |  |  |  |  |  |  |  |

|  | JBL1-1A | JBL1-1B | JBL1-1C | JBL1-2A | JBL1-2B | JBL1-2C | JBL2-1A | JBL2-1C | JBL2-2A | JBL2-2B |
|---|---|---|---|---|---|---|---|---|---|---|
| Fragilaria tenera |  |  | 1 |  |  |  |  |  |  |  |
| Fragilaria ulna |  |  |  |  |  |  |  |  |  |  |
| Frustulia rhomboides |  |  |  | 1 |  |  |  |  |  |  |
| F. rhomboides v. saxonica |  |  |  |  | 41 | 36 |  |  |  |  |
| Gomphonema spp. |  |  |  |  |  |  |  |  |  |  |
| Gomphonema girdle |  |  |  |  |  |  |  |  |  |  |
| Gomphonema acuminatum |  |  |  |  |  |  |  |  |  |  |
| Gomphonema amoenum |  |  |  |  |  |  |  |  |  |  |
| Gomphonema angustatum |  |  |  |  |  |  |  |  |  |  |
| G. angustatum v. undulatum |  |  |  |  |  |  |  |  |  |  |
| Gomphonema angustum |  | 1 |  |  |  |  |  |  |  |  |
| Gomphonema bohemicum |  |  |  |  |  |  |  |  |  |  |
| Gomphonema clavatum |  |  |  |  |  |  |  |  |  |  |
| Gomphonema gracile |  |  |  |  |  |  |  |  |  |  |
| Gomphonema hebridense |  |  |  |  |  |  |  |  |  |  |
| Gomphonema intricatum |  |  |  |  |  |  |  |  |  |  |
| Gomphonema lagerheimii |  |  |  |  |  |  |  |  |  |  |
| Gomphonema longiceps |  |  |  |  |  |  |  |  |  |  |
| Gomphonema parvulum |  |  |  |  |  |  |  |  |  |  |
| Gomphonema subtile |  |  |  |  |  |  |  |  |  |  |
| Hantzchia amphioxys |  |  | 2 |  |  |  |  | 1 | 2 | 3 |
| Hantzschia elongata |  |  |  |  |  |  |  |  |  |  |
| Navicula spp. |  |  |  |  |  |  |  |  |  |  |
| Navicula cf angusta |  |  |  |  |  |  |  |  |  |  |
| Navicula brockmannii |  |  |  |  |  |  |  |  |  |  |
| Navicula bryophilia |  |  |  |  |  |  |  |  |  |  |
| Navicula cohnii |  |  |  |  |  |  |  |  |  |  |
| Navicula cryptocephala |  |  |  |  |  |  |  |  |  |  |
| Navicula cryptotenella |  |  |  |  |  |  |  |  |  |  |
| Navicula eidriginia |  |  |  |  |  |  |  |  |  |  |
| Navicula cf exilis |  |  |  |  |  |  |  |  |  |  |
| Navicula festiva |  |  |  | 5 | 50 | 15 |  |  |  |  |
| Navicula gallica |  |  |  |  |  |  |  |  |  |  |
| Navicula geoppertiana |  |  |  |  |  |  |  |  |  |  |
| Navicula jaegii |  |  |  |  |  |  |  |  |  |  |
| Navicula lancelolata |  |  |  |  |  |  |  |  |  |  |
| Navicula maceria |  |  |  |  |  |  |  |  |  |  |
| Navicula mediocris |  |  |  |  | 46 | 4 |  |  |  |  |
| Navicula mutica |  |  | 1 |  |  |  | 2 | 2 |  | 1 |
| Navicula muticopis |  |  |  |  |  |  |  |  |  |  |
| Navicula lapidosa |  |  |  |  |  |  |  |  |  |  |
| Navicula leptostriata |  |  |  |  |  |  |  |  |  |  |
| Navicula peregrina |  |  |  |  |  |  |  |  |  |  |
| Navicula pupula |  |  |  |  |  |  |  |  |  |  |
| Navicula pseudosubtillisima |  |  |  |  |  |  |  |  |  |  |
| Navicula radiosa |  |  |  |  |  |  |  |  |  |  |
| Navicula rhynchocephala |  |  |  |  |  |  |  |  |  |  |
| Navicula seminulum |  |  |  |  |  |  |  |  |  |  |
| Navicula suchlandtii |  |  |  |  |  |  |  |  |  |  |
| Navicula soehrensis |  |  |  | 2 |  |  |  |  |  |  |
| Navicula soehrensis v. hassica |  |  |  |  |  |  |  |  |  |  |
| N. soehrensis v. soehrensis |  |  |  | 2 | 3 |  |  |  |  |  |
| Navicula striolata |  |  |  |  |  |  |  |  |  |  |
| Navicula subtilissima |  |  |  | 77 | 153 | 618 |  |  |  |  |
| Navicula tuscula |  |  |  |  |  |  |  |  |  |  |
| Navicula tridentula |  |  |  |  |  |  |  |  |  |  |
| Navicula viridula |  |  |  |  |  |  |  |  |  |  |
| Navicula vulpina |  |  |  |  |  |  |  |  |  |  |

|  | JBL1-1A | JBL1-1B | JBL1-1C | JBL1-2A | JBL1-2B | JBL1-2C | JBL2-1A | JBL2-1C | JBL2-2A | JBL2-2B |
|---|---|---|---|---|---|---|---|---|---|---|
| Neidium species |  |  |  |  |  |  |  |  |  |  |
| Neidium affine |  |  |  |  |  |  |  |  |  |  |
| Neidium dubium |  |  |  |  |  |  |  |  |  |  |
| Neidium temperei |  |  |  |  |  |  |  |  |  |  |
| Nitzschia sp. |  |  |  |  |  |  |  |  |  |  |
| Nitzschia acidoclinata |  |  |  |  |  |  |  |  |  |  |
| Nitzschia alpina |  |  |  |  |  |  |  |  |  |  |
| Nitzschia fonticola |  |  |  |  |  |  |  |  |  |  |
| Nitzschia frustulum |  |  |  |  |  |  |  |  |  |  |
| Nitzschia glacilis |  |  |  |  |  |  |  |  |  |  |
| Nitzschia hungarcia |  |  |  |  |  |  |  |  |  |  |
| Nitzschia intermedia |  |  |  |  |  |  |  |  |  |  |
| Nitzschia liebetruhii |  |  |  |  |  |  |  |  |  |  |
| Nitzschia linearis |  |  |  |  |  |  |  |  |  |  |
| Nitzschia peisonis |  |  |  |  |  |  |  |  |  |  |
| Nitzschia perminuta |  |  |  |  |  |  |  |  |  |  |
| Nitzschia sigmoidea |  |  |  |  |  |  |  |  |  |  |
| Pinnularia spp. |  |  |  |  |  |  |  |  |  |  |
| Pinnularia biceps |  |  |  |  |  |  |  |  |  |  |
| Pinnularia borealis |  |  |  |  |  |  |  |  | 1 |  |
| Pinnularia divergens |  |  |  |  |  |  |  |  |  |  |
| Pinnularia gibba |  |  |  |  | 4 | 19 |  |  |  |  |
| Pinnularia cf intermedia |  |  |  |  |  |  |  |  |  |  |
| Pinnularia interrupta |  |  |  |  |  |  |  |  |  |  |
| Pinnularia maior |  |  |  | 1 |  |  |  |  |  |  |
| Pinnularia microstauron |  |  |  |  |  | 4 |  |  |  |  |
| P. microstauron small type |  |  |  |  |  |  |  |  | 35 |  |
| Pinnularia rupestris |  |  |  |  | 1 |  |  |  |  |  |
| Pinnularis supcapitata |  |  |  |  |  |  |  |  |  |  |
| Pinnularia streptoraphe |  |  |  |  | 2 |  |  |  |  |  |
| Rhopolodia gibba |  |  |  |  |  |  |  |  |  |  |
| Stauroneis phoenicenteron |  |  |  |  |  |  |  |  |  |  |
| Stauroneis anceps |  |  |  |  |  |  |  |  |  |  |
| Stauroneis smithii |  |  |  |  |  |  |  |  |  |  |
| Stenopterobia spp. |  |  |  |  |  |  |  |  |  |  |
| Stenopterobia anceps |  |  |  |  | 1 | 3 |  |  |  |  |
| Stenopterobia delicatissima |  |  |  |  |  | 3 |  |  |  |  |
| Stephanodiscus niagrae |  |  |  |  |  |  |  |  |  |  |
| Stephanodiscus medius |  |  |  |  |  |  |  |  |  |  |
| Tabellaria spp. |  |  |  |  |  |  |  |  |  |  |
| Tabellaria fenestrata |  |  |  |  |  |  |  |  |  |  |
| Tabellaria flocculosa |  |  |  |  |  |  |  |  |  |  |
| Tabellaria flocculosa str. 3 |  |  |  |  |  |  |  |  |  |  |
| Tabellaria flocculosa srt. 4 |  |  |  |  |  |  |  |  |  |  |
| Tabellaria linearis |  |  |  |  |  |  |  |  |  |  |
| Tabellaria quadrisepta |  |  |  |  |  |  |  |  |  |  |
| Unknown spp. |  |  |  |  |  |  |  |  |  |  |

|  | JBL2-2C | JBL2-3A | JBL2-3B | JBL2-3C | JBL3-1A | JBL3-1C | JBL3-2A | JBL3-2B | JBL3-2C | JBL4-1A |
|---|---|---|---|---|---|---|---|---|---|---|
| Achnanthes spp. |  |  |  |  |  |  |  |  |  |  |
| Achnanthes flexella |  |  |  |  |  |  |  |  |  |  |
| Achnanthes minutissima |  |  |  |  |  |  |  |  |  |  |
| Achnanthes nodosa |  |  |  |  |  |  |  |  |  |  |
| Achnanthes petersonii |  |  |  |  |  |  |  |  |  |  |
| Achnanthes taeniata/linearis |  |  |  |  |  |  |  |  |  |  |
| Amphora spp. |  |  |  |  |  |  |  |  |  |  |
| Amphora libyca |  |  |  |  |  |  |  |  |  |  |
| Amphora ovalis |  |  |  |  |  |  |  |  |  |  |
| Aulacoseira species |  |  |  |  |  |  |  |  |  |  |
| Aulacoseira ambigua |  |  |  |  |  |  |  |  |  |  |
| Aulacoseira italica |  |  |  |  |  |  |  |  |  |  |
| Aulacoseira pfaffiana |  |  |  |  |  |  |  |  |  |  |
| Aulacoseira subarctica |  |  |  |  |  |  |  |  |  |  |
| Brachysira spp. |  |  |  |  |  |  |  |  |  |  |
| Brachysira aponina |  |  |  |  |  |  |  |  |  |  |
| Brachysira brebissoni |  |  |  |  |  |  |  |  |  |  |
| Brachysira hofmanniae |  |  |  |  |  |  |  |  |  |  |
| Brachysira serians |  |  |  |  |  |  |  |  |  |  |
| Brachysira vitrea |  |  |  |  |  |  |  |  |  |  |
| Brachysira zellensis |  |  |  |  |  |  |  |  |  |  |
| Caloneis spp. |  |  |  |  |  |  |  |  |  |  |
| Caloneis bacillum |  | 3 |  |  |  |  |  |  |  |  |
| Caloneis molaris |  |  |  |  |  |  |  |  |  |  |
| Caloneis tenuis |  |  |  |  |  |  |  |  |  |  |
| Caloneis pulchra |  |  |  |  |  |  |  |  |  |  |
| Caloneis undulata |  |  |  |  |  |  |  |  |  |  |
| Caloneis silicula |  |  |  |  |  |  |  |  |  |  |
| Cocconeis spp. |  |  |  |  |  |  |  |  |  |  |
| Cymbella spp. |  |  |  |  |  |  |  |  |  |  |
| Cymbella amphioxys |  |  |  |  |  |  |  |  |  |  |
| Cymbella angustata |  |  |  |  |  |  |  |  |  |  |
| Cymbella arctica |  |  |  |  |  |  |  |  |  |  |
| Cymbella aueri |  |  |  |  |  |  |  |  |  |  |
| Cymbella austriaca |  |  |  |  |  |  |  |  |  |  |
| Cymbella cf caespitosa |  |  |  |  |  |  |  |  |  |  |
| Cymbella cesatii |  |  |  |  |  |  |  |  |  |  |
| Cymbella cistula |  |  |  |  |  |  |  |  |  |  |
| Cymbella cuspidata |  |  |  |  |  |  |  |  |  |  |
| Cymbella cymbiformis |  |  |  |  |  |  |  |  |  |  |
| Cymbella descripta |  |  |  |  |  |  |  |  |  |  |
| Cymbella elginensis |  |  |  |  |  |  |  |  |  |  |
| Cymbella gracilis |  |  |  |  |  |  |  |  |  |  |
| Cymbella hybrida |  |  |  |  |  |  |  |  |  |  |
| Cymbella incerta |  |  |  |  |  |  |  |  |  |  |
| Cymbella lacustris |  |  |  |  |  |  |  |  |  |  |
| Cymbella lapponica |  |  |  |  |  |  |  |  |  |  |
| Cymbella laterns |  |  |  |  |  |  |  |  |  |  |
| Cymbella mesiana |  |  |  |  |  |  |  |  |  |  |
| Cymbella microcephala |  |  |  |  |  |  |  |  |  |  |
| Cymbella minuta |  |  |  |  |  |  |  |  |  |  |
| Cymbella naviculacea |  |  |  |  |  |  |  |  |  |  |
| Cymbella naviculiformis |  |  |  |  |  |  |  |  |  |  |
| Cymbella norvegica |  |  |  |  |  |  |  |  |  |  |
| Cymbella obscura |  |  |  |  |  |  |  |  |  |  |
| Cymbella paucistriata |  |  |  |  |  |  |  |  |  |  |
| Cymbella silesiaca |  |  |  |  |  |  |  |  |  |  |
| Cymbella subaequalis |  |  |  |  |  |  |  |  |  |  |

| | JBL2-2C | JBL2-3A | JBL2-3B | JBL2-3C | JBL3-1A | JBL3-1C | JBL3-2A | JBL3-2B | JBL3-2C | JBL4-1A |
|---|---|---|---|---|---|---|---|---|---|---|
| Cymbella subarctica | | | | | | | | | | |
| Cymbella subcuspidata | | | | | | | | | | |
| Cymbella tynaii | | | | | | | | | | |
| Cyclotella spp. | | | | | | | | | | |
| Cyclotella bodanica | | | | | | | | | | |
| Cyclotella michiganiana | | | | | | | | | | |
| Cyclotella stelligera | | | | | | | | | | |
| Denticula kuetzingii | | | | | | | | | | |
| Diatoma species | | | | | | | | | | |
| Diatoma tenuis | | | | | | | | | | |
| Diploneis elliptica | | | | | | | | | | |
| Diploneis puella | | | | | | | | | | |
| Epithemia adnata | | | | | | | | | | |
| Eunotia spp. | | | | | | | | 4 | | |
| Eunotia arcus | | | | | | | | | | |
| Eunotia argus | | | | | | | | | | |
| Eunotia aculus | | | | | | | | | | |
| Eunotia bilunaris | | | | | | | | | | |
| E. bilunaris v. mucophila | 8 | 33 | 1 | 12 | | | 13 | 25 | 61 | |
| Eunotia circumborealis | | | | | | | | | | |
| Eunotia fennica | | | | | | | | | | |
| Eunotia exigua | 18 | 3 | 1 | 3 | | | 2 | 10 | 5 | |
| Eunotia faba | | | | | | | | | | |
| Eunotia fallax | | | 4 | 17 | | | | | | |
| Eunotia flexuosa | | | | | | | | | | |
| Eunotia formica | | | | | | | | | | |
| Eunotia glacialis | | | | | | | | | | |
| Eunotia glacialifalsa | | | | | | | | | | |
| Eunotia hexaglyphis | | | | | | | | | | |
| Eunotia implicata | | | | | | | | | | |
| Eunotia incisa | | | | | | | | | | |
| Eunotia lapponica | 2 | 9 | 110 | 25 | | | | | | |
| Eunotia maior | | | | | | | | | | |
| Eunotia monodon | | | | | | | | | | |
| Eunotia naegelli | | | | | | | 1 | | | |
| Eunotia nymanniana | 3 | 2 | 3 | 10 | | | 79 | 24 | 9 | |
| Eunotia paludosa type 1 | 351 | 393 | 374 | 286 | 290 | 240 | 366 | 201 | 65 | 345 |
| Eunotia paludosa type 2 | | | 38 | 12 | | | | 5 | 2 | |
| Eunotia paludosa v. trinarcia | | 9 | 12 | 3 | | | 26 | 25 | 4 | |
| Eunotia pectinalis | | | | | | | | | | |
| Eunotia pirla | | | | | | | | | | |
| Eunotia praerupta | | | | | | | | | | |
| Eunotia praerupta v. bidens | | | | | | | | | | |
| Eunotia septentrionalis | | | | | | | | | | |
| Eunotia serra | | | | | | | | | | |
| Eunotia soleirolii | | | | | | | | | | |
| Eunotia vanheurckii | | | | | | | | | | |
| Fragilaria spp. | | 2 | | | | | | | | |
| Fragilaria brevistriata | | | | | | | | | | |
| Fragilaria biceps | | | | | | | | | | |
| Fragilaria capucina | | | | | | | | | | |
| F. capucina v. vaucheriae | | | | | | | | | | |
| Fragilaria construens | 2 | | | | 2 | | | | | |
| Fragilaria crotonensis | | | | | | | | | | |
| Fragilaria exigua | | | | | | | | | | |
| Fragilaria fasciculata | | | | | | | | | | |
| Fragilaria parasitica | | | | | | | | | | |
| Fragilaria pinnata | | | | | 1 | | | | | |

| | JBL2-2C | JBL2-3A | JBL2-3B | JBL2-3C | JBL3-1A | JBL3-1C | JBL3-2A | JBL3-2B | JBL3-2C | JBL4-1A |
|---|---|---|---|---|---|---|---|---|---|---|
| Fragilaria tenera | | | | | | | | | | |
| Fragilaria ulna | | | | | | | | | | |
| Frustulia rhomboides | | | | | | | | | | |
| F. rhomboides v. saxonica | | | | | | | | | | |
| Gomphonema spp. | | | | | | | | | | |
| Gomphonema girdle | | | | | | | | | | |
| Gomphonema acuminatum | | | | | | | | | | |
| Gomphonema amoenum | | | | | | | | | | |
| Gomphonema angustatum | | | | | | | | | | |
| G. angustatum v. undulatum | | | | | | | | | | |
| Gomphonema angustum | | | | | | | | | | |
| Gomphonema bohemicum | | | | | | | | | | |
| Gomphonema clavatum | | | | | | | | | | |
| Gomphonema gracile | | | | | | | | | | |
| Gomphonema hebridense | | | | | | | | | | |
| Gomphonema intricatum | | | | | | | | | | |
| Gomphonema lagerheimii | | | | | | | | | | |
| Gomphonema longiceps | | | | | | | | | | |
| Gomphonema parvulum | | | | | | | | | | |
| Gomphonema subtile | | | | | | | | | | |
| Hantzchia amphioxys | 2 | 15 | | | | | | | | 4 |
| Hantzschia elongata | | | | | | | | | | |
| Navicula spp. | | | | | | | | | | |
| Navicula cf angusta | | | | | | | | | | |
| Navicula brockmannii | | | | | | | | | | |
| Navicula bryophilia | | | | | | | | | | |
| Navicula cohnii | | | | | | | | | | |
| Navicula cryptocephala | | | | | | | | | | |
| Navicula cryptotenella | | | | | | | | | | |
| Navicula eidriginia | | | | | | | | | | |
| Navicula cf exilis | | | | | | | | | | |
| Navicula festiva | | | | | | | | | | |
| Navicula gallica | | | | | | | | | | |
| Navicula geoppertiana | | | | | | | | | | |
| Navicula jaegii | | | | | | | | | | |
| Navicula lancelolata | | | | | | | | | | |
| Navicula maceria | | | | | | | | | | |
| Navicula mediocris | | | | | | | | | | |
| Navicula mutica | | 18 | | | | 1 | 1 | | 1 | 1 |
| Navicula muticopis | | | | | | | | | | |
| Navicula lapidosa | | | | | | | | | | |
| Navicula leptostriata | | | | | | | | | | |
| Navicula peregrina | | | | | | | | | | |
| Navicula pupula | | | | | | | | | | |
| Navicula pseudosubtillisima | | | | | | | | | | |
| Navicula radiosa | | | | | | | | | | |
| Navicula rhynchocephala | | | | | | | | | | |
| Navicula seminulum | | | | | | | | | | |
| Navicula suchlandtii | | | | | | | | | | |
| Navicula soehrensis | | | | | | | | | | |
| Navicula soehrensis v. hassica | | | | | | | | | | |
| N. soehrensis v. soehrensis | | | | | | | | | | |
| Navicula striolata | | | | | | | | | | |
| Navicula subtilissima | | 36 | 161 | 86 | 2 | | 290 | 267 | 252 | |
| Navicula tuscula | | | | | | | | | | |
| Navicula tridentula | | | | | | | | | | |
| Navicula viridula | | | | | | | | | | |
| Navicula vulpina | | | | | | | | | | |

| | JBL2-2C | JBL2-3A | JBL2-3B | JBL2-3C | JBL3-1A | JBL3-1C | JBL3-2A | JBL3-2B | JBL3-2C | JBL4-1A |
|---|---|---|---|---|---|---|---|---|---|---|
| Neidium species | | | | | | | | | | |
| Neidium affine | | | | | | | | | | |
| Neidium dubium | | | | | | | | | | |
| Neidium temperei | | | | | | | | | | |
| Nitzschia sp. | | | | | | | | | | |
| Nitzschia acidoclinata | | | | | | | | | | |
| Nitzschia alpina | | | | | | | | | | |
| Nitzschia fonticola | | | | | | | | | | |
| Nitzschia frustulum | | | | | | | | | | |
| Nitzschia glacilis | | | | | | | | | | |
| Nitzschia hungarcia | | | | | | | | | | |
| Nitzschia intermedia | | | | | | | | | | |
| Nitzschia liebetruhii | | | | | | | | | | |
| Nitzschia linearis | | | | | | | | | | |
| Nitzschia peisonis | | | | | | | | | | |
| Nitzschia perminuta | | | | | | | | | | |
| Nitzschia sigmoidea | | | | | | | | | | |
| Pinnularia spp. | | | | | | | | | | |
| Pinnularia biceps | | | | | | | | | | |
| Pinnularia borealis | | 9 | | | | 1 | | | | |
| Pinnularia divergens | | | | | | | | | | |
| Pinnularia gibba | | | | | | | | | | |
| Pinnularia cf intermedia | | | | | | | | | | |
| Pinnularia interrupta | | | | | | | | | | |
| Pinnularia maior | | | | | | | | | | |
| Pinnularia microstauron | | | | 2 | | | | | | |
| P. microstauron small type | 127 | | | | | | | | | |
| Pinnularia rupestris | | | | | | | | | | |
| Pinnularis supcapitata | | | | 11 | 1 | | | | | |
| Pinnularia streptoraphe | | | | | | | | | | |
| Rhopolodia gibba | | 1 | | | | | | | | |
| Stauroneis phoenicenteron | | | | | | | | | | |
| Stauroneis anceps | | | | | | | | | | |
| Stauroneis smithii | | | | | | | | | | |
| Stenopterobia spp. | | | | | | | | | | |
| Stenopterobia anceps | | | | | | | | | | |
| Stenopterobia delicatissima | | | | | | | | | | |
| Stephanodiscus niagrae | | | | | | | | | | |
| Stephanodiscus medius | | | | | | | | | | |
| Tabellaria spp. | | | | | | | | | | |
| Tabellaria fenestrata | | | | | | | | | | |
| Tabellaria flocculosa | | | | | | | | | | |
| Tabellaria flocculosa str. 3 | | | | | | | | | | |
| Tabellaria flocculosa srt. 4 | | | | | | | | | | |
| Tabellaria linearis | | | | | | | | | | |
| Tabellaria quadrisepta | | | | | | | | | | |
| Unknown spp. | | | | | | | | | | |

|  | JBL4-1B | JBL4-1C | JBL4-2A | JBL4-2B | JBL4-2C | JBL9-1A | JBL9-1B | JBL9-1C | JBL9-2A | JBL9-2B |
|---|---|---|---|---|---|---|---|---|---|---|
| Achnanthes spp. |  |  |  |  |  |  |  |  |  |  |
| Achnanthes flexella |  |  |  |  |  |  |  |  |  |  |
| Achnanthes minutissima |  |  |  |  |  |  |  |  |  |  |
| Achnanthes nodosa |  |  |  |  |  |  |  |  |  |  |
| Achnanthes petersonii |  |  |  |  |  |  |  |  |  |  |
| Achnanthes taeniata/linearis |  |  |  |  |  |  |  |  |  |  |
| Amphora spp. |  |  |  |  |  |  |  |  |  |  |
| Amphora libyca |  |  |  |  |  |  |  |  |  |  |
| Amphora ovalis |  |  |  |  |  |  |  |  |  |  |
| Aulacoseira species |  |  |  |  | 1 |  |  |  |  |  |
| Aulacoseira ambigua |  |  |  |  |  |  |  |  |  |  |
| Aulacoseira italica |  |  |  |  |  |  | 2 |  |  |  |
| Aulacoseira pfaffiana | 11 |  |  |  |  |  |  |  |  |  |
| Aulacoseira subarctica | 3 |  |  |  |  |  |  |  |  |  |
| Brachysira spp. |  |  |  |  |  |  |  |  |  |  |
| Brachysira aponina |  |  |  |  |  |  |  |  |  |  |
| Brachysira brebissoni |  |  |  |  |  |  |  |  |  |  |
| Brachysira hofmanniae |  |  |  |  |  |  |  |  |  |  |
| Brachysira serians |  |  |  |  |  |  |  |  |  |  |
| Brachysira vitrea |  |  |  |  |  |  |  |  |  |  |
| Brachysira zellensis |  |  |  |  |  |  |  |  |  |  |
| Caloneis spp. |  |  |  |  |  |  |  |  |  |  |
| Caloneis bacillum |  |  |  |  |  |  |  |  |  |  |
| Caloneis molaris |  |  |  |  |  |  |  |  |  |  |
| Caloneis tenuis |  |  |  |  |  |  |  |  |  |  |
| Caloneis pulchra |  |  |  |  |  |  |  |  |  |  |
| Caloneis undulata |  |  |  |  |  |  |  |  |  |  |
| Caloneis silicula |  |  |  |  |  |  |  |  |  |  |
| Cocconeis spp. |  |  |  |  | 1 |  |  |  |  |  |
| Cymbella spp. |  |  |  |  |  |  |  |  |  |  |
| Cymbella amphioxys |  |  |  |  |  |  |  |  |  |  |
| Cymbella angustata |  |  |  |  |  |  |  |  |  |  |
| Cymbella arctica |  |  |  |  |  |  |  |  |  |  |
| Cymbella aueri |  |  |  |  |  |  |  |  |  |  |
| Cymbella austriaca |  |  |  |  |  |  |  |  |  |  |
| Cymbella cf caespitosa |  |  |  |  |  |  |  |  |  |  |
| Cymbella cesatii |  |  |  |  |  |  |  |  |  |  |
| Cymbella cistula |  |  |  |  |  |  |  |  |  |  |
| Cymbella cuspidata |  |  |  |  |  |  |  |  |  |  |
| Cymbella cymbiformis |  |  |  |  |  |  |  |  |  |  |
| Cymbella descripta |  |  |  |  |  |  |  |  |  |  |
| Cymbella elginensis |  |  |  |  |  |  |  |  |  |  |
| Cymbella gracilis |  |  |  |  |  |  |  |  |  |  |
| Cymbella hybrida |  |  |  |  |  |  |  |  |  |  |
| Cymbella incerta |  |  |  |  |  |  |  |  |  |  |
| Cymbella lacustris |  |  |  |  |  |  |  |  |  |  |
| Cymbella lapponica |  |  |  |  |  |  |  |  |  |  |
| Cymbella laterns |  |  |  |  |  |  |  |  |  |  |
| Cymbella mesiana |  |  |  |  |  |  |  |  |  |  |
| Cymbella microcephala |  |  |  |  |  |  |  |  |  |  |
| Cymbella minuta |  |  |  |  |  |  |  |  |  |  |
| Cymbella naviculacea |  |  |  |  |  |  |  |  |  |  |
| Cymbella naviculiformis |  |  |  |  |  |  |  |  |  |  |
| Cymbella norvegica |  |  |  |  |  |  |  |  |  |  |
| Cymbella obscura |  |  |  | 1 |  |  |  |  |  |  |
| Cymbella paucistriata |  |  |  |  |  |  |  |  |  |  |
| Cymbella silesiaca |  |  |  |  |  |  |  |  |  |  |
| Cymbella subaequalis |  |  |  |  |  |  |  |  |  |  |

| | JBL4-1B | JBL4-1C | JBL4-2A | JBL4-2B | JBL4-2C | JBL9-1A | JBL9-1B | JBL9-1C | JBL9-2A | JBL9-2B |
|---|---|---|---|---|---|---|---|---|---|---|
| Cymbella subarctica | | | | | | | | | | |
| Cymbella subcuspidata | | | | | | | | | | |
| Cymbella tynaii | | | | | | | | | | |
| Cyclotella spp. | | | | | | | | | | |
| Cyclotella bodanica | | | | | | | | | | |
| Cyclotella michiganiana | | | | | | | 1 | | | |
| Cyclotella stelligera | | | | | | | | | | |
| Denticula kuetzingii | | | | | | | | | | |
| Diatoma species | | | | | | | | | | |
| Diatoma tenuis | | | | | | | | | | |
| Diploneis elliptica | | | | | | | | | | |
| Diploneis puella | | | | | | | | | | |
| Epithemia adnata | | | | | | | | | | |
| Eunotia spp. | | | | | | | | | 12 | |
| Eunotia arcus | | | | | | | | | | |
| Eunotia argus | | | | | | | | | | |
| Eunotia aculus | | | | | | | | | | |
| Eunotia bilunaris | | | | | | | | | 4 | 27 |
| E. bilunaris v. mucophila | | | | | 331 | | | | 119 | 43 |
| Eunotia circumborealis | | | | | | | | | | |
| Eunotia fennica | | | | | | | | | | |
| Eunotia exigua | | | | 2 | | | 2 | | 20 | 15 |
| Eunotia faba | | | | | | | | | | |
| Eunotia fallax | | | | | | | | | | |
| Eunotia flexuosa | | | | | | | | | | |
| Eunotia formica | | | | | | | | | | |
| Eunotia glacialis | | | | | | | | | | |
| Eunotia glacialifalsa | | | | | | | | | | |
| Eunotia hexaglyphis | | | | | | | | | | |
| Eunotia implicata | | | | | | | | | | |
| Eunotia incisa | | | | | | | | | | |
| Eunotia lapponica | | | | 1 | | | | | | |
| Eunotia maior | | | | | | | | | | |
| Eunotia monodon | | | | | | | | | | |
| Eunotia naegelli | | | | | | | | | | |
| Eunotia nymanniana | | | | | | | | | | |
| Eunotia paludosa type 1 | 148 | 387 | 229 | 300 | 118 | 500 | 359 | 500 | 274 | 285 |
| Eunotia paludosa type 2 | | | | | | | | | 40 | 3 |
| Eunotia paludosa v. trinarcia | | | | | | | | | 16 | |
| Eunotia pectinalis | | | | | | | | | | |
| Eunotia pirla | | | | | | | | | | |
| Eunotia praerupta | | | | | | | | | | |
| Eunotia praerupta v. bidens | | | | | | | | | | |
| Eunotia septentrionalis | | | | | | | | | | |
| Eunotia serra | | | | | | | | | | |
| Eunotia soleirolii | | | | | | | | | | |
| Eunotia vanheurckii | | | | | | | | | | |
| Fragilaria spp. | | | | | | | | | | |
| Fragilaria brevistriata | | | | | | | | | | |
| Fragilaria biceps | | | | | | | | | | |
| Fragilaria capucina | | | | | | | | | | |
| F. capucina v. vaucheriae | | | | | | | | | | |
| Fragilaria construens | | | | | | | | | | |
| Fragilaria crotonensis | | | | | | | | | | |
| Fragilaria exigua | | | | | | | | | | |
| Fragilaria fasciculata | | | | | | | | | | |
| Fragilaria parasitica | | | | | 1 | | | | | |
| Fragilaria pinnata | | | | | | | | | | |

|  | JBL4-1B | JBL4-1C | JBL4-2A | JBL4-2B | JBL4-2C | JBL9-1A | JBL9-1B | JBL9-1C | JBL9-2A | JBL9-2B |
|---|---|---|---|---|---|---|---|---|---|---|
| Fragilaria tenera |  |  |  |  |  |  |  |  |  |  |
| Fragilaria ulna |  |  |  |  |  |  |  |  |  |  |
| Frustulia rhomboides | 1 |  |  |  | 1 |  |  |  |  |  |
| F. rhomboides v. saxonica |  |  |  |  |  |  |  |  |  |  |
| Gomphonema spp. |  |  |  |  |  |  |  |  |  |  |
| Gomphonema girdle |  |  |  |  |  |  |  |  |  |  |
| Gomphonema acuminatum |  |  |  |  |  |  |  |  |  |  |
| Gomphonema amoenum |  |  |  |  |  |  |  |  |  |  |
| Gomphonema angustatum |  |  |  |  |  |  |  |  |  |  |
| G. angustatum v. undulatum |  |  |  |  |  |  |  |  |  |  |
| Gomphonema angustum |  |  |  |  |  |  |  |  |  |  |
| Gomphonema bohemicum |  |  |  |  |  |  |  |  |  |  |
| Gomphonema clavatum |  |  |  |  |  |  |  |  |  |  |
| Gomphonema gracile |  |  |  |  |  |  |  |  |  |  |
| Gomphonema hebridense |  |  |  |  |  |  |  |  |  |  |
| Gomphonema intricatum |  |  |  |  |  |  |  |  |  |  |
| Gomphonema lagerheimii |  |  |  |  |  |  |  |  |  |  |
| Gomphonema longiceps |  |  |  |  |  |  |  |  |  |  |
| Gomphonema parvulum |  |  |  |  |  |  |  |  |  |  |
| Gomphonema subtile |  |  |  |  |  |  |  |  |  |  |
| Hantzchia amphioxys | 1 | 1 | 1 | 1 | 13 | 1 | 1 |  |  |  |
| Hantzschia elongata |  |  |  |  |  |  |  |  |  |  |
| Navicula spp. |  |  |  |  |  |  |  |  |  |  |
| Navicula cf angusta |  |  |  |  |  |  |  |  |  |  |
| Navicula brockmannii |  |  |  |  |  |  |  |  |  |  |
| Navicula bryophilia |  |  |  |  |  |  |  |  |  |  |
| Navicula cohnii |  |  |  |  |  |  |  |  |  |  |
| Navicula cryptocephala |  |  |  |  |  |  |  |  |  |  |
| Navicula cryptotenella |  |  |  |  |  |  |  |  |  |  |
| Navicula eidriginia |  |  |  |  |  |  |  |  |  |  |
| Navicula cf exilis |  |  |  |  |  |  |  |  |  |  |
| Navicula festiva |  |  |  |  |  |  |  |  |  |  |
| Navicula gallica |  |  |  |  | 1 |  |  |  |  |  |
| Navicula geoppertiana |  |  |  |  |  |  |  |  |  |  |
| Navicula jaegii |  |  |  |  |  |  |  |  |  |  |
| Navicula lancelolata |  |  |  |  |  |  |  |  |  |  |
| Navicula maceria |  |  |  |  | 2 |  |  |  |  |  |
| Navicula mediocris |  |  |  |  |  |  |  |  |  |  |
| Navicula mutica |  | 1 |  | 2 | 8 |  | 4 |  |  |  |
| Navicula muticopis |  |  |  |  |  |  |  |  |  |  |
| Navicula lapidosa |  |  |  |  |  |  |  |  |  |  |
| Navicula leptostriata |  |  |  |  |  |  |  |  |  |  |
| Navicula peregrina |  |  |  |  |  |  |  |  |  |  |
| Navicula pupula |  |  |  |  |  |  |  |  |  |  |
| Navicula pseudosubtillisima |  |  |  |  |  |  |  |  |  |  |
| Navicula radiosa |  |  |  |  |  |  |  |  |  |  |
| Navicula rhynchocephala |  |  |  |  |  |  |  |  |  |  |
| Navicula seminulum |  |  |  |  |  |  |  |  |  |  |
| Navicula suchlandtii |  |  |  |  |  |  |  |  |  |  |
| Navicula soehrensis |  |  |  |  |  |  |  |  |  |  |
| Navicula soehrensis v. hassica |  |  |  |  |  |  |  |  | 6 | 2 |
| N. soehrensis v. soehrensis |  |  |  |  |  |  |  |  |  |  |
| Navicula striolata |  |  |  |  |  |  |  |  |  |  |
| Navicula subtilissima |  |  |  | 1 | 1 |  | 2 |  |  | 9 |
| Navicula tuscula |  |  |  |  |  |  |  |  |  |  |
| Navicula tridentula |  |  |  |  |  |  |  |  |  |  |
| Navicula viridula |  |  |  |  |  |  |  |  |  |  |
| Navicula vulpina |  |  |  |  |  |  |  |  |  |  |

|  | JBL4-1B | JBL4-1C | JBL4-2A | JBL4-2B | JBL4-2C | JBL9-1A | JBL9-1B | JBL9-1C | JBL9-2A | JBL9-2B |
|---|---|---|---|---|---|---|---|---|---|---|
| Neidium species |  |  |  |  |  |  |  |  |  |  |
| Neidium affine | 1 |  |  |  |  |  |  |  |  |  |
| Neidium dubium |  |  |  |  |  |  |  |  |  |  |
| Neidium temperei |  |  |  |  |  |  |  |  |  |  |
| Nitzschia sp. |  |  |  |  |  |  |  |  |  |  |
| Nitzschia acidoclinata |  |  |  |  |  |  |  |  |  |  |
| Nitzschia alpina |  |  |  |  |  |  |  | 2 |  |  |
| Nitzschia fonticola |  |  |  |  |  |  |  |  |  |  |
| Nitzschia frustulum |  |  |  |  |  |  |  |  |  |  |
| Nitzschia glacilis |  |  |  |  |  |  |  |  |  |  |
| Nitzschia hungarcia |  |  |  |  |  |  |  |  |  |  |
| Nitzschia intermedia |  |  |  |  |  |  |  |  |  |  |
| Nitzschia liebetruhii |  |  |  |  |  |  |  |  |  |  |
| Nitzschia linearis |  |  |  |  |  |  |  |  |  |  |
| Nitzschia peisonis |  |  |  |  |  |  |  |  |  |  |
| Nitzschia perminuta |  |  |  |  |  |  |  |  |  |  |
| Nitzschia sigmoidea |  |  |  |  |  |  |  |  |  |  |
| Pinnularia spp. | 2 |  |  |  |  |  |  |  |  |  |
| Pinnularia biceps | 11 |  |  |  | 1 |  |  |  |  |  |
| Pinnularia borealis |  | 1 |  | 1 | 2 |  | 1 |  |  |  |
| Pinnularia divergens |  |  |  |  |  |  |  |  |  |  |
| Pinnularia gibba |  |  |  |  |  |  |  |  |  |  |
| Pinnularia cf intermedia |  |  |  |  |  |  |  |  |  |  |
| Pinnularia interrupta |  |  |  |  |  |  |  |  |  | 30 |
| Pinnularia maior |  |  |  |  |  |  |  |  |  |  |
| Pinnularia microstauron | 8 |  |  |  |  |  |  |  |  |  |
| P. microstauron small type |  |  |  |  |  |  |  |  |  |  |
| Pinnularia rupestris |  |  |  |  |  |  |  |  |  |  |
| Pinnularis supcapitata |  |  |  |  |  |  |  |  |  | 2 |
| Pinnularia streptoraphe |  |  |  |  |  |  |  |  |  |  |
| Rhopolodia gibba |  |  |  |  |  |  |  |  |  |  |
| Stauroneis phoenicenteron |  |  |  |  |  |  |  |  |  |  |
| Stauroneis anceps |  |  |  |  |  |  |  |  |  |  |
| Stauroneis smithii |  |  |  |  |  |  |  |  |  |  |
| Stenopterobia spp. |  |  |  |  |  |  |  |  |  |  |
| Stenopterobia anceps |  |  |  |  |  |  |  |  |  |  |
| Stenopterobia delicatissima |  |  |  |  |  |  |  |  |  |  |
| Stephanodiscus niagrae |  |  |  |  |  |  |  |  |  |  |
| Stephanodiscus medius |  |  |  |  |  |  |  |  |  |  |
| Tabellaria spp. |  |  |  |  |  |  |  |  |  |  |
| Tabellaria fenestrata |  |  |  |  |  |  |  |  |  |  |
| Tabellaria flocculosa |  |  |  |  |  |  |  |  |  |  |
| Tabellaria flocculosa str. 3 | 1 |  |  |  |  |  |  |  |  |  |
| Tabellaria flocculosa srt. 4 |  |  |  |  |  |  |  |  |  |  |
| Tabellaria linearis |  |  |  |  |  |  |  |  |  |  |
| Tabellaria quadrisepta |  |  |  |  |  |  |  |  |  |  |
| Unknown spp. |  |  |  |  | 3 |  |  |  |  |  |

|  | JBL9-2C | HLM01 | HLM02 | HLM03 | HLM04 | HLM05 | HLM06 | HLM07 | HLM08 | HLM09 | HLM10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Achnanthes spp. |  |  | 2 |  |  |  |  |  |  |  |  |
| Achnanthes flexella |  |  |  |  |  |  |  |  |  |  |  |
| Achnanthes minutissima |  |  |  |  |  |  |  |  |  |  |  |
| Achnanthes nodosa |  |  | 1 |  |  |  |  |  |  |  |  |
| Achnanthes petersonii |  |  |  |  |  |  |  |  |  |  |  |
| Achnanthes taeniata/linearis |  |  |  |  |  |  |  |  |  |  |  |
| Amphora spp. |  |  |  |  |  |  |  |  |  |  |  |
| Amphora libyca |  |  |  |  |  |  |  |  |  |  |  |
| Amphora ovalis |  |  |  |  |  |  |  |  |  |  |  |
| Aulacoseira species |  |  |  |  | 2 |  |  |  |  |  |  |
| Aulacoseira ambigua |  |  |  |  |  |  |  |  |  |  |  |
| Aulacoseira italica |  |  | 4 |  |  |  |  |  |  |  |  |
| Aulacoseira pfaffiana |  |  |  |  |  |  |  |  |  |  |  |
| Aulacoseira subarctica |  |  |  |  |  |  |  |  |  |  |  |
| Brachysira spp. |  |  |  |  |  |  |  |  |  |  |  |
| Brachysira aponina |  |  |  |  |  |  |  |  |  |  |  |
| Brachysira brebissoni |  |  | 1 |  |  |  |  |  |  |  |  |
| Brachysira hofmanniae |  |  |  |  |  |  |  |  |  |  |  |
| Brachysira serians |  |  |  |  |  |  |  |  |  |  |  |
| Brachysira vitrea |  |  |  |  |  |  |  |  |  |  |  |
| Brachysira zellensis |  |  |  | 75 |  |  |  |  |  |  |  |
| Caloneis spp. |  |  |  |  |  |  |  |  |  |  |  |
| Caloneis bacillum |  |  |  |  |  |  |  |  |  |  |  |
| Caloneis molaris |  |  | 2 |  |  |  |  |  |  |  |  |
| Caloneis tenuis |  |  |  |  |  |  |  |  |  |  |  |
| Caloneis pulchra |  |  |  |  |  |  |  |  |  |  |  |
| Caloneis undulata |  |  |  |  |  |  |  |  |  |  |  |
| Caloneis silicula |  |  |  |  |  |  |  |  |  |  |  |
| Cocconeis spp. |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella spp. |  |  | 1 |  |  |  |  |  |  |  |  |
| Cymbella amphioxys |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella angustata |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella arctica |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella aueri |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella austriaca |  |  |  | 2 |  |  |  |  |  |  |  |
| Cymbella cf caespitosa |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella cesatii |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella cistula |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella cuspidata |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella cymbiformis |  |  |  | 6 |  |  |  |  |  |  |  |
| Cymbella descripta |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella elginensis |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella gracilis |  |  |  | 100 |  |  |  |  |  |  |  |
| Cymbella hybrida |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella incerta |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella lacustris |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella lapponica |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella laterns |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella mesiana |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella microcephala |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella minuta |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella naviculacea |  |  |  | 74 |  |  |  |  |  |  |  |
| Cymbella naviculiformis |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella norvegica |  |  |  | 12 |  |  |  |  |  |  |  |
| Cymbella obscura |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella paucistriata |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella silesiaca |  |  |  | 23 |  |  |  |  |  |  |  |
| Cymbella subaequalis |  |  |  |  |  |  |  |  |  |  |  |

|  | JBL9-2C | HLM01 | HLM02 | HLM03 | HLM04 | HLM05 | HLM06 | HLM07 | HLM08 | HLM09 | HLM10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cymbella subarctica |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella subcuspidata |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella tynaii |  |  |  | 1 |  |  |  |  |  |  |  |
| Cyclotella spp. |  |  |  |  |  |  |  |  |  |  |  |
| Cyclotella bodanica |  |  |  |  |  |  |  |  |  |  |  |
| Cyclotella michiganiana |  |  |  |  |  |  |  |  |  |  |  |
| Cyclotella stelligera |  |  |  |  |  |  |  |  |  |  |  |
| Denticula kuetzingii |  |  |  |  | 2 |  |  |  |  |  |  |
| Diatoma species |  |  | 2 |  |  |  |  |  |  |  |  |
| Diatoma tenuis |  |  |  |  |  |  |  |  |  |  |  |
| Diploneis elliptica |  |  |  |  | 2 |  |  |  |  |  |  |
| Diploneis puella |  |  |  |  | 1 |  |  |  |  |  |  |
| Epithemia adnata |  |  |  |  | 1 |  |  |  |  |  |  |
| Eunotia spp. |  |  | 1 |  |  |  |  |  |  |  |  |
| Eunotia arcus |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia argus |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia aculus |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia bilunaris | 16 |  |  |  |  |  |  |  |  | 1 |  |
| E. bilunaris v. mucophila | 32 |  |  |  |  | 54 | 111 | 56 | 6 |  |  |
| Eunotia circumborealis |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia fennica |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia exigua | 8 |  |  | 1 |  |  | 1 |  |  |  |  |
| Eunotia faba |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia fallax |  |  |  |  |  |  |  |  |  | 2 |  |
| Eunotia flexuosa |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia formica |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia glacialis |  |  |  | 48 |  |  |  |  |  |  |  |
| Eunotia glacialifalsa |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia hexaglyphis |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia implicata |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia incisa |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia lapponica |  |  | 1 |  |  |  |  |  |  |  |  |
| Eunotia maior |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia monodon |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia naegelli |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia nymanniana |  |  |  | 3 |  |  |  |  |  |  |  |
| Eunotia paludosa type 1 | 338 | 400 |  |  | 354 | 316 | 194 | 217 | 58 |  |  |
| Eunotia paludosa type 2 | 1 |  |  | 6 |  |  |  | 2 |  |  |  |
| Eunotia paludosa v. trinarcia |  |  |  |  |  | 19 |  |  |  |  |  |
| Eunotia pectinalis |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia pirla |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia praerupta |  |  | 36 | 20 |  |  |  |  |  | 226 | 168 |
| Eunotia praerupta v. bidens |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia septentrionalis | 1 |  |  |  |  |  |  |  |  |  |  |
| Eunotia serra |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia soleirolii |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia vanheurckii |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria spp. |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria brevistriata |  |  |  |  | 3 |  |  |  |  |  |  |
| Fragilaria biceps |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria capucina |  |  |  |  |  |  |  |  |  |  |  |
| F. capucina v. vaucheriae |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria construens | 2 |  | 1 |  |  |  |  |  |  |  |  |
| Fragilaria crotonensis |  |  | 1 |  |  |  |  |  |  |  |  |
| Fragilaria exigua |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria fasciculata |  |  | 4 |  |  |  |  |  |  |  |  |
| Fragilaria parasitica |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria pinnata |  |  | 1 |  |  |  | 1 |  |  |  |  |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| Fragilaria tenera |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria ulna |  |  |  |  |  |  |  |  |  |  |  |
| Frustulia rhomboides |  |  |  |  |  |  |  |  |  |  |  |
| F. rhomboides v. saxonica |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema spp. |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema girdle |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema acuminatum |  |  | 3 |  |  |  |  |  |  |  |  |
| Gomphonema amoenum |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema angustatum |  |  |  |  |  |  |  |  |  |  |  |
| G. angustatum v. undulatum |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema angustum |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema bohemicum |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema clavatum |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema gracile |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema hebridense |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema intricatum |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema lagerheimii |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema longiceps |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema parvulum |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema subtile |  |  |  |  |  |  |  |  |  |  |  |
| Hantzchia amphioxys |  |  |  |  | 12 | 1 | 1 |  |  |  |  |
| Hantzschia elongata |  |  |  |  |  |  |  |  |  |  |  |
| Navicula spp. |  |  |  |  |  |  |  |  |  |  |  |
| Navicula cf angusta |  |  |  |  |  |  |  |  |  |  |  |
| Navicula brockmannii |  |  |  |  |  |  |  |  |  |  |  |
| Navicula bryophilia |  |  | 39 |  |  |  |  |  |  | 1 |  |
| Navicula cohnii |  |  |  |  |  |  |  |  |  |  |  |
| Navicula cryptocephala |  |  |  |  |  |  |  |  |  |  |  |
| Navicula cryptotenella |  |  |  |  |  |  |  |  |  |  |  |
| Navicula eidriginia |  |  |  |  |  |  |  |  |  |  |  |
| Navicula cf exilis |  |  |  |  |  |  |  |  |  |  |  |
| Navicula festiva |  |  |  |  |  |  |  |  |  |  |  |
| Navicula gallica |  |  |  |  |  |  |  |  |  |  |  |
| Navicula geoppertiana |  |  |  |  |  |  |  |  |  |  |  |
| Navicula jaegii |  |  |  |  |  |  |  |  |  |  |  |
| Navicula lancelolata |  |  |  |  |  |  |  |  |  |  |  |
| Navicula maceria |  |  |  |  |  |  |  |  |  |  |  |
| Navicula mediocris |  |  |  | 5 |  |  |  |  |  |  |  |
| Navicula mutica |  |  |  |  | 12 |  |  | 2 |  |  |  |
| Navicula muticopis |  |  |  |  | 2 |  |  |  |  |  |  |
| Navicula lapidosa |  |  |  |  |  |  |  |  |  |  |  |
| Navicula leptostriata |  |  |  |  |  |  |  |  |  |  |  |
| Navicula peregrina |  |  |  |  |  |  |  |  |  |  |  |
| Navicula pupula |  |  | 37 |  |  |  |  |  |  |  |  |
| Navicula pseudosubtillisima |  |  |  |  |  |  |  |  |  |  |  |
| Navicula radiosa |  |  | 1 |  |  |  |  |  |  |  |  |
| Navicula rhynchocephala |  |  |  |  |  |  |  |  |  |  |  |
| Navicula seminulum |  |  |  |  |  |  |  |  |  |  |  |
| Navicula suchlandtii |  |  | 3 |  |  |  |  |  |  |  |  |
| Navicula soehrensis |  |  |  | 7 |  |  |  |  |  |  |  |
| Navicula soehrensis v. hassica | 4 |  |  |  |  |  |  |  |  |  |  |
| N. soehrensis v. soehrensis |  |  |  |  |  |  |  |  |  |  |  |
| Navicula striolata |  |  |  |  |  |  |  |  |  |  |  |
| Navicula subtilissima | 3 |  |  | 360 |  | 92 | 136 | 5 | 476 |  |  |
| Navicula tuscula |  |  |  |  |  |  |  |  |  |  |  |
| Navicula tridentula |  |  |  |  |  |  |  |  |  |  |  |
| Navicula viridula |  |  |  |  |  |  |  |  |  |  |  |
| Navicula vulpina |  |  |  |  |  |  |  |  |  |  |  |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| Neidium species | | | | 1 | | | | | | 2 | |
| Neidium affine | | | | | | | | | | | |
| Neidium dubium | | | | | | | | | | | |
| Neidium temperei | | | | | | | | | | | |
| Nitzschia sp. | | | | | | | | | | | |
| Nitzschia acidoclinata | | | | | | | | | | | |
| Nitzschia alpina | | | | | | | | | | | |
| Nitzschia fonticola | | | | | | | | | | | |
| Nitzschia frustulum | | | | | | | | | | | |
| Nitzschia glacilis | | | 1 | | | | | | | | |
| Nitzschia hungarcia | | | | | | | | | | | |
| Nitzschia intermedia | | | | | | | | | | | |
| Nitzschia liebetruhii | | | | | | | | | | | |
| Nitzschia linearis | | | 1 | | | | | | | | |
| Nitzschia peisonis | | | | | | | | | | | |
| Nitzschia perminuta | | | | | | | | | | | |
| Nitzschia sigmoidea | | | | | | | | | | | |
| Pinnularia spp. | | | | | | | 1 | | | | |
| Pinnularia biceps | | | | | | | | | | | |
| Pinnularia borealis | | | | | 5 | | 1 | | | | |
| Pinnularia divergens | | | | | | | | | | | |
| Pinnularia gibba | | | | | | | | | | | |
| Pinnularia cf intermedia | | | 1 | | | | | | | 1 | |
| Pinnularia interrupta | 7 | | | | | | | | | | |
| Pinnularia maior | | | 10 | | | | | | | 2 | |
| Pinnularia microstauron | | | | 9 | | | 2 | | | | |
| P. microstauron small type | | | | | | | | | | | |
| Pinnularia rupestris | | | | | | | | | 65 | | |
| Pinnularis supcapitata | | | | | | | | | | | |
| Pinnularia streptoraphe | | | | 15 | | 3 | | | | | |
| Rhopolodia gibba | | | | | | | | | | | |
| Stauroneis phoenicenteron | | | | 1 | | | | | | | |
| Stauroneis anceps | | | | | 1 | | | | | | |
| Stauroneis smithii | | | | | | | | | | | |
| Stenopterobia spp. | | | | | | | | | | | |
| Stenopterobia anceps | | | | | | | | | | | |
| Stenopterobia delicatissima | | | | | | | | | | | |
| Stephanodiscus niagrae | | | | | | | | | | | |
| Stephanodiscus medius | | | | | | | | | | | |
| Tabellaria spp. | | | | | | | | | | | |
| Tabellaria fenestrata | | | | | | | | | | | |
| Tabellaria flocculosa | | | | | | | | | | | |
| Tabellaria flocculosa str. 3 | | | | | | | | | | | |
| Tabellaria flocculosa srt. 4 | | | | | | | | | | | |
| Tabellaria linearis | | | | | | | | | | | |
| Tabellaria quadrisepta | | | | | | | | | | | |
| Unknown spp. | | | 2 | 2 | | | | | | | |

|  | HLM11 | HLM12 | HLM14 | HLM15 | HLM16 | VD1 | VD2 | VD3 | VD4 | VD5 | VD8 | VD9 | VD11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Achnanthes spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Achnanthes flexella |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Achnanthes minutissima |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Achnanthes nodosa |  |  |  |  | 4 |  |  |  |  |  |  |  |  |
| Achnanthes petersonii |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Achnanthes taeniata/linearis |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Amphora spp. |  |  |  |  | 2 |  |  |  |  |  |  |  |  |
| Amphora libyca |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Amphora ovalis |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Aulacoseira species |  |  |  |  |  | 1 | 1 |  |  |  |  |  |  |
| Aulacoseira ambigua |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Aulacoseira italica |  | 4 |  |  |  |  |  |  |  |  |  |  |  |
| Aulacoseira pfaffiana |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Aulacoseira subarctica |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Brachysira spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Brachysira aponina |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Brachysira brebissoni |  |  |  |  |  |  |  |  | 57 |  |  |  |  |
| Brachysira hofmanniae |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Brachysira serians |  |  |  |  |  |  | 6 |  |  |  |  |  |  |
| Brachysira vitrea |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Brachysira zellensis |  |  |  |  |  | 1 | 14 | 119 |  |  |  |  |  |
| Caloneis spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Caloneis bacillum |  |  |  |  | 87 |  |  |  |  |  |  |  |  |
| Caloneis molaris |  |  |  |  | 1 |  |  |  |  |  |  |  |  |
| Caloneis tenuis |  |  |  |  |  |  |  | 5 | 15 |  |  |  |  |
| Caloneis pulchra |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Caloneis undulata |  |  |  |  |  |  | 5 |  | 4 |  |  |  |  |
| Caloneis silicula |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cocconeis spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella amphioxys |  |  |  |  | 1 |  |  |  |  |  |  |  |  |
| Cymbella angustata |  |  |  |  | 1 |  |  |  |  |  |  |  |  |
| Cymbella arctica |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella aueri |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella austriaca |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella cf caespitosa |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella cesatii |  |  |  |  | 15 |  |  |  |  |  |  |  |  |
| Cymbella cistula |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella cuspidata |  |  |  |  | 2 |  |  |  |  |  |  |  |  |
| Cymbella cymbiformis |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella descripta |  |  |  |  |  | 158 |  |  |  |  |  |  |  |
| Cymbella elginensis |  |  |  |  |  |  | 2 |  |  |  |  |  |  |
| Cymbella gracilis |  |  |  |  |  |  | 10 | 32 |  |  |  |  |  |
| Cymbella hybrida |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella incerta |  |  |  |  | 4 |  |  |  |  |  |  |  |  |
| Cymbella lacustris |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella lapponica |  |  |  |  | 27 |  |  |  |  |  |  |  |  |
| Cymbella laterns |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella mesiana |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella microcephala |  |  |  |  |  | 3 |  |  |  |  |  |  |  |
| Cymbella minuta |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella naviculacea |  |  |  |  | 102 |  |  |  |  |  |  |  |  |
| Cymbella naviculiformis |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella norvegica |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella obscura |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella paucistriata |  |  |  |  | 19 |  |  |  |  |  |  |  |  |
| Cymbella silesiaca |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella subaequalis |  |  |  |  |  |  |  |  |  |  |  |  |  |

|  | HLM11 | HLM12 | HLM14 | HLM15 | HLM16 | VD1 | VD2 | VD3 | VD4 | VD5 | VD8 | VD9 | VD11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cymbella subarctica |  |  |  |  | 2 |  |  |  |  |  |  |  |  |
| Cymbella subcuspidata |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella tynaii |  |  |  |  | 2 |  |  |  |  |  |  |  |  |
| Cyclotella spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cyclotella bodanica |  |  |  |  | 4 |  |  |  |  |  |  |  |  |
| Cyclotella michiganiana |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cyclotella stelligera |  |  |  |  |  |  |  |  |  |  | 1 |  |  |
| Denticula kuetzingii |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Diatoma species |  |  |  |  |  |  |  |  |  | 2 |  |  |  |
| Diatoma tenuis |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Diploneis elliptica |  |  |  |  |  |  |  |  | 1 |  |  |  |  |
| Diploneis puella |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Epithemia adnata |  |  |  |  | 10 |  |  |  |  |  |  |  |  |
| Eunotia spp. |  |  |  |  |  |  | 3 |  |  |  |  |  |  |
| Eunotia arcus |  |  |  |  |  |  | 5 | 32 | 1 |  |  |  |  |
| Eunotia argus |  |  |  |  |  |  | 2 | 6 | 41 |  |  |  |  |
| Eunotia aculus |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia bilunaris |  |  |  |  | 1 |  | 21 | 13 | 4 |  |  |  |  |
| E. bilunaris v. mucophila |  |  |  | 125 | 2 |  |  |  |  | 1 | 117 | 40 | 13 |
| Eunotia circumborealis |  |  |  |  | 2 |  |  |  |  |  |  |  |  |
| Eunotia fennica |  |  |  |  |  |  |  |  |  |  | 3 | 4 | 3 |
| Eunotia exigua |  |  |  |  |  |  |  |  | 5 |  |  |  |  |
| Eunotia faba |  |  |  |  | 2 |  |  |  | 8 |  |  |  |  |
| Eunotia fallax | 1 | 6 |  |  |  |  |  |  | 1 |  |  |  |  |
| Eunotia flexuosa |  |  |  |  |  |  | 6 | 3 | 9 |  | 3 |  |  |
| Eunotia formica | 239 | 5 |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia glacialis |  |  |  |  | 1 |  | 8 | 13 | 12 |  |  |  |  |
| Eunotia glacialifalsa |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia hexaglyphis |  |  |  |  |  |  |  |  | 9 |  |  |  |  |
| Eunotia implicata |  |  |  |  |  |  |  |  | 1 |  |  |  |  |
| Eunotia incisa |  |  |  |  |  |  |  |  | 46 |  |  |  |  |
| Eunotia lapponica |  |  |  |  | 12 |  |  |  |  |  |  |  |  |
| Eunotia maior |  |  |  |  |  |  |  |  | 10 |  |  |  |  |
| Eunotia monodon |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia naegelli |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia nymanniana |  |  |  | 2 |  |  |  |  | 19 |  |  |  |  |
| Eunotia paludosa type 1 |  |  | 254 | 112 |  | 122 |  |  |  | 404 | 317 | 224 |  |
| Eunotia paludosa type 2 |  |  |  | 13 |  |  | 8 |  | 5 |  |  |  |  |
| Eunotia paludosa v. trinarcia |  |  |  | 4 |  |  |  |  |  |  |  |  |  |
| Eunotia pectinalis |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia pirla | 9 |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia praerupta | 288 | 173 |  |  | 2 |  | 23 | 106 | 8 |  |  |  |  |
| Eunotia praerupta v. bidens |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia septentrionalis |  |  |  |  |  |  | 22 | 5 | 5 |  |  |  |  |
| Eunotia serra |  |  |  |  |  |  |  |  | 5 |  |  |  |  |
| Eunotia soleirolii |  |  |  |  |  |  |  | 4 |  |  |  |  |  |
| Eunotia vanheurckii |  |  |  |  | 45 |  |  |  |  |  |  |  |  |
| Fragilaria spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria brevistriata |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria biceps |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria capucina |  |  |  |  |  |  | 1 | 2 |  |  |  |  |  |
| F. capucina v. vaucheriae |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria construens |  |  |  |  |  |  |  |  |  | 1 |  |  |  |
| Fragilaria crotonensis |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria exigua |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria fasciculata |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria parasitica |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria pinnata |  | 1 |  |  |  |  | 1 |  |  | 6 | 6 |  |  |

|  | HLM11 | HLM12 | HLM14 | HLM15 | HLM16 | VD1 | VD2 | VD3 | VD4 | VD5 | VD8 | VD9 | VD11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fragilaria tenera |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria ulna |  |  |  |  |  |  | 56 | 19 | 5 |  |  |  |  |
| Frustulia rhomboides |  |  |  |  |  |  | 2 |  | 112 |  |  |  |  |
| F. rhomboides v. saxonica |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema spp. |  |  |  |  |  |  | 1 |  |  |  |  |  |  |
| Gomphonema girdle |  |  |  |  | 2 |  |  |  |  |  |  |  |  |
| Gomphonema acuminatum |  |  |  |  |  |  | 4 |  |  |  |  |  |  |
| Gomphonema amoenum |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema angustatum |  |  |  |  |  |  |  |  |  |  |  |  |  |
| G. angustatum v. undulatum |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema angustum |  |  |  |  | 4 |  |  |  |  |  |  |  |  |
| Gomphonema bohemicum |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema clavatum |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema gracile |  |  |  |  | 3 |  |  |  |  |  |  |  |  |
| Gomphonema hebridense |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema intricatum |  |  |  |  | 19 |  | 3 |  | 22 |  |  |  |  |
| Gomphonema lagerheimii |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema longiceps |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema parvulum |  |  |  |  | 2 |  | 3 | 3 | 4 |  |  |  |  |
| Gomphonema subtile |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Hantzchia amphioxys |  |  | 1 |  |  |  |  |  |  | 1 |  |  |  |
| Hantzschia elongata |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula cf angusta |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula brockmannii |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula bryophilia |  | 3 |  |  | 1 |  |  |  |  |  |  |  |  |
| Navicula cohnii |  |  |  |  |  |  |  | 1 | 7 |  | 1 |  |  |
| Navicula cryptocephala |  |  |  |  | 1 |  |  |  |  |  |  |  |  |
| Navicula cryptotenella |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula eidriginia |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula cf exilis |  |  |  |  | 7 |  | 6 |  |  |  |  |  |  |
| Navicula festiva |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula gallica |  |  |  |  | 49 | 12 | 10 |  | 3 |  |  |  |  |
| Navicula geoppertiana |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula jaegii |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula lancelolata |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula maceria |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula mediocris |  |  |  |  |  |  |  |  | 27 |  |  |  |  |
| Navicula mutica |  |  |  |  | 1 |  |  |  |  |  |  |  |  |
| Navicula muticopis |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula lapidosa |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula leptostriata |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula peregrina |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula pupula |  | 6 |  |  |  |  |  |  |  |  |  |  |  |
| Navicula pseudosubtillisima |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula radiosa |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula rhynchocephala |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula seminulum |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula suchlandtii |  |  |  |  | 3 |  |  |  |  |  |  |  |  |
| Navicula soehrensis |  |  |  |  |  |  |  |  | 12 |  |  |  |  |
| Navicula soehrensis v. hassica |  |  |  |  | 4 |  |  |  |  |  |  |  |  |
| N. soehrensis v. soehrensis |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula striolata |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula subtilissima |  |  | 1 | 409 |  |  | 21 | 23 | 2 |  | 62 | 305 | 440 |
| Navicula tuscula |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula tridentula |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula viridula |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula vulpina |  |  |  |  |  |  |  |  |  |  |  |  |  |

|  | HLM11 | HLM12 | HLM14 | HLM15 | HLM16 | VD1 | VD2 | VD3 | VD4 | VD5 | VD8 | VD9 | VD11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Neidium species | 131 | 1 |  |  | 2 |  |  |  |  |  |  |  |  |
| Neidium affine |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Neidium dubium |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Neidium temperei |  |  |  |  |  |  | 2 |  |  |  |  |  |  |
| Nitzschia sp. |  |  |  |  |  |  |  | 1 |  |  |  |  |  |
| Nitzschia acidoclinata |  |  |  |  |  |  | 2 |  |  |  |  |  |  |
| Nitzschia alpina |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Nitzschia fonticola |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Nitzschia frustulum |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Nitzschia glacilis |  |  |  |  |  |  | 1 |  |  |  |  |  |  |
| Nitzschia hungarcia |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Nitzschia intermedia |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Nitzschia liebetruhii |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Nitzschia linearis |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Nitzschia peisonis |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Nitzschia perminuta |  |  |  |  |  |  |  |  | 21 |  |  |  |  |
| Nitzschia sigmoidea |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia spp. |  |  |  |  |  | 1 |  | 11 |  |  |  |  |  |
| Pinnularia biceps |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia borealis |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia divergens |  |  |  |  |  |  |  |  | 5 |  |  |  |  |
| Pinnularia gibba |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia cf intermedia |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia interrupta |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia maior |  | 2 |  |  |  |  |  |  |  |  | 3 | 18 | 167 |
| Pinnularia microstauron |  |  |  |  |  |  |  | 3 |  |  |  |  |  |
| P. microstauron small type |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia rupestris |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularis supcapitata |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia streptoraphe |  |  |  |  |  |  |  |  | 12 |  |  |  |  |
| Rhopolodia gibba |  | 3 |  |  |  |  |  |  |  |  |  |  |  |
| Stauroneis phoenicenteron |  |  |  |  |  |  |  | 1 | 2 |  |  |  |  |
| Stauroneis anceps | 11 |  |  |  |  |  |  |  |  |  |  |  |  |
| Stauroneis smithii |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Stenopterobia spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Stenopterobia anceps |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Stenopterobia delicatissima |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Stephanodiscus niagrae |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Stephanodiscus medius |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Tabellaria spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Tabellaria fenestrata |  |  |  |  |  |  |  |  | 5 |  |  |  |  |
| Tabellaria flocculosa |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Tabellaria flocculosa str. 3 |  |  |  |  |  |  |  | 6 |  |  |  |  |  |
| Tabellaria flocculosa srt. 4 |  |  |  |  |  |  | 17 | 1 | 27 |  |  |  |  |
| Tabellaria linearis |  |  |  |  |  |  | 6 |  | 6 |  |  |  |  |
| Tabellaria quadrisepta |  |  |  |  |  |  |  | 1 |  |  |  |  |  |
| Unknown spp. |  |  |  |  |  | 1 |  |  |  | 3 | 3 |  |  |

| | VD12 | VD13 | VD14 | VD16 | VD17 | VD18 | VD20 | VD23 | VD24 | VD25 | VD26 | VD27 | VD28 | VD29 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Achnanthes spp. | | | | | | | | 3 | | | | | | |
| Achnanthes flexella | | | | | | | | | | | | | | |
| Achnanthes minutissima | | | | | | | | | | | | | | |
| Achnanthes nodosa | | | | | | | | | | | | | | |
| Achnanthes petersonii | | | | | | | | | | | | | | |
| Achnanthes taeniata/linearis | | | | | | | | | | | | | | 5 |
| Amphora spp. | | | | | | | | | | | | | | |
| Amphora libyca | | | | | | | | | | | | | | |
| Amphora ovalis | | | | | | | | | | | | | | |
| Aulacoseira species | | 3 | | 3 | | | | | | | | | | |
| Aulacoseira ambigua | | | | | | 2 | | | | | | | | |
| Aulacoseira italica | | | | | | | | | | | | | | |
| Aulacoseira pfaffiana | | | | | | | | | | | | | | |
| Aulacoseira subarctica | | | | | | 2 | | 2 | | | | | | |
| Brachysira spp. | | | | | | | 4 | | | | 1 | | 1 | |
| Brachysira aponina | | | | | | | | | 4 | | | | | |
| Brachysira brebissoni | | | | | | | | | 104 | 28 | 42 | | | 67 |
| Brachysira hofmanniae | | | | | | | | | | 2 | 7 | | | |
| Brachysira serians | | | | | | | | | | | | | | |
| Brachysira vitrea | | | | | | | | | | | | | | |
| Brachysira zellensis | | | | | | | | | | | | | | |
| Caloneis spp. | | | | | | | | | | | | | | |
| Caloneis bacillum | | | | | | | | | | | | | | |
| Caloneis molaris | | | | | | | | | | | | | | |
| Caloneis tenuis | | | | | | | | | 13 | 6 | | | | 5 |
| Caloneis pulchra | | | | | | | | | | | | | | |
| Caloneis undulata | | | | | | | | | | | | | | |
| Caloneis silicula | | | | | | | | | | | | | | |
| Cocconeis spp. | | | | | | | | | | | | | | |
| Cymbella spp. | | | | | | | | | | | | 1 | | |
| Cymbella amphioxys | | | | | | | | | | | | | | |
| Cymbella angustata | | | | | | | | | | | | | | |
| Cymbella arctica | | | | | | | | | | | | | | |
| Cymbella aueri | | | | | | | | | | | | | | |
| Cymbella austriaca | | | | | | | | | | | | | | |
| Cymbella cf caespitosa | | | | | | | | | | | | | | |
| Cymbella cesatii | | | | | | | | | | | | | | |
| Cymbella cistula | | | | | | | | | | | | | | |
| Cymbella cuspidata | | | | | | | | | | | | | | |
| Cymbella cymbiformis | | | | | | | | | | | | | | |
| Cymbella descripta | | 28 | | | | | | | | | | | | |
| Cymbella elginensis | | | | | | | | | | | | | | |
| Cymbella gracilis | | | | | | | 2 | | 48 | 16 | 25 | | | 25 |
| Cymbella hybrida | | | | | | | | | | | | | | |
| Cymbella incerta | | | | | | | | | | | | | | |
| Cymbella lacustris | | | | | | | | | | | | | | |
| Cymbella lapponica | | | | | | | | | | | | | | |
| Cymbella laterns | | | | | | | | | | | | | | |
| Cymbella mesiana | | | | | | | | | | | | | | |
| Cymbella microcephala | | 2 | | | | | | | | | | | | |
| Cymbella minuta | | | | | | | 6 | | 6 | 7 | 3 | | | |
| Cymbella naviculacea | | | | | | | | | | | | | | |
| Cymbella naviculiformis | | | | | | | | | | | | | | |
| Cymbella norvegica | | | | | | | | | | | | | | |
| Cymbella obscura | | | | | | | | | | | | | | |
| Cymbella paucistriata | | | | | | | | | | | | | | |
| Cymbella silesiaca | | | | | | | | | | | | | | |
| Cymbella subaequalis | | | | | | | | | | | | | | |

|  | VD12 | VD13 | VD14 | VD16 | VD17 | VD18 | VD20 | VD23 | VD24 | VD25 | VD26 | VD27 | VD28 | VD29 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cymbella subarctica |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella subcuspidata |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella tynaii |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cyclotella spp. |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  |
| Cyclotella bodanica | 1 |  |  |  |  |  |  |  |  |  |  |  | 1 |  |
| Cyclotella michiganiana |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cyclotella stelligera |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Denticula kuetzingii |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Diatoma species |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Diatoma tenuis |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Diploneis elliptica | 2 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Diploneis puella |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Epithemia adnata |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia spp. |  |  |  |  |  |  |  |  |  |  |  |  |  | 4 |
| Eunotia arcus |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia argus |  |  |  |  |  |  |  |  | 32 | 14 | 9 |  |  | 22 |
| Eunotia aculus |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 |
| Eunotia bilunaris |  |  |  |  | 8 | 3 | 99 |  | 8 | 7 | 11 |  |  | 3 |
| E. bilunaris v. mucophila |  |  | 9 |  |  | 78 |  | 13 |  |  |  |  | 73 |  |
| Eunotia circumborealis |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia fennica |  |  |  |  | 508 | 39 |  |  |  |  |  |  | 5 | 1 |
| Eunotia exigua |  |  |  |  |  | 1 |  |  |  | 2 | 1 |  |  |  |
| Eunotia faba |  |  |  |  |  |  |  |  | 1 | 7 | 1 |  |  | 5 |
| Eunotia fallax |  |  |  |  |  |  | 22 |  | 1 |  |  |  |  | 5 |
| Eunotia flexuosa |  |  |  |  |  |  | 11 |  | 11 |  | 9 |  |  | 9 |
| Eunotia formica |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia glacialis |  |  |  |  |  |  | 46 |  | 8 | 6 | 3 |  |  | 18 |
| Eunotia glacialifalsa |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia hexaglyphis |  |  |  |  |  |  | 1 |  | 13 | 5 | 1 |  |  | 8 |
| Eunotia implicata |  |  |  |  |  |  | 9 |  |  | 5 | 3 |  |  |  |
| Eunotia incisa |  |  |  |  |  |  | 1 |  | 57 | 19 | 31 |  |  | 47 |
| Eunotia lapponica |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia maior |  |  |  |  |  |  |  |  | 5 |  |  |  |  | 5 |
| Eunotia monodon |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia naegelli |  |  |  |  |  |  | 3 |  | 1 |  | 16 |  |  | 5 |
| Eunotia nymanniana |  |  |  |  |  |  | 3 |  | 21 | 25 | 22 |  |  | 35 |
| Eunotia paludosa type 1 | 245 | 225 | 500 | 215 | 34 | 437 |  | 380 |  |  |  | 513 | 217 |  |
| Eunotia paludosa type 2 |  |  |  |  |  |  | 64 |  | 20 | 20 | 31 |  |  | 15 |
| Eunotia paludosa v. trinarcia |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia pectinalis |  |  |  |  |  |  | 2 |  |  | 26 | 4 |  |  | 1 |
| Eunotia pirla |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia praerupta |  |  |  |  |  |  | 26 |  | 5 | 2 | 3 |  |  | 9 |
| Eunotia praerupta v. bidens |  |  |  |  |  |  | 16 |  |  |  |  |  |  |  |
| Eunotia septentrionalis |  |  |  |  |  |  | 89 |  | 6 | 27 | 22 |  |  | 13 |
| Eunotia serra |  |  |  |  |  |  |  |  | 19 | 7 | 5 |  |  | 4 |
| Eunotia soleirolii |  |  |  |  |  |  |  |  |  |  | 1 |  |  |  |
| Eunotia vanheurckii |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria spp. |  |  |  |  |  |  | 2 |  |  |  |  |  |  |  |
| Fragilaria brevistriata |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria biceps |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria capucina |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| F. capucina v. vaucheriae |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria construens | 1 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria crotonensis |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria exigua |  |  |  |  |  |  | 20 |  |  |  |  |  |  |  |
| Fragilaria fasciculata |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria parasitica |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria pinnata | 3 |  | 1 |  |  |  |  | 4 |  |  |  |  | 10 |  |

|  | VD12 | VD13 | VD14 | VD16 | VD17 | VD18 | VD20 | VD23 | VD24 | VD25 | VD26 | VD27 | VD28 | VD29 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fragilaria tenera |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria ulna | 1 |  |  |  |  |  | 19 |  | 6 | 5 | 4 |  |  | 1 |
| Frustulia rhomboides |  |  |  |  |  |  |  |  | 204 | 58 | 86 |  |  | 117 |
| F. rhomboides v. saxonica |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema spp. |  |  |  |  |  |  |  |  | 1 |  | 2 |  |  |  |
| Gomphonema girdle |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema acuminatum |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema amoenum |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema angustatum |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| G. angustatum v. undulatum |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema angustum |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema bohemicum |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema clavatum |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema gracile |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema hebridense |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema intricatum |  |  |  |  |  |  | 7 |  | 9 | 5 | 6 |  |  | 12 |
| Gomphonema lagerheimii |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema longiceps |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema parvulum |  |  |  |  |  |  | 1 |  | 13 | 12 | 9 |  |  | 9 |
| Gomphonema subtile |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Hantzchia amphioxys | 4 |  | 1 |  |  |  |  |  |  |  |  | 1 | 1 |  |
| Hantzschia elongata |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula cf angusta |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula brockmannii |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula bryophilia |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula cohnii | 4 |  |  | 4 |  |  |  |  |  |  |  |  |  |  |
| Navicula cryptocephala |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula cryptotenella |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula eidriginia |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula cf exilis |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula festiva |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula gallica |  | 2 |  |  |  |  |  |  | 3 | 15 |  |  |  | 3 |
| Navicula geoppertiana |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula jaegii |  |  |  |  |  |  |  |  |  | 2 |  |  |  | 6 |
| Navicula lancelolata |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula maceria |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula mediocris |  |  |  |  |  |  |  |  | 62 | 29 | 28 |  |  | 31 |
| Navicula mutica |  |  |  |  | 1 |  |  |  |  |  |  |  |  |  |
| Navicula muticopis |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula lapidosa |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula leptostriata |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula peregrina |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula pupula |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula pseudosubtillisima |  | 6 |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula radiosa |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula rhynchocephala |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula seminulum |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula suchlandtii |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula soehrensis |  |  |  |  |  |  |  |  | 1 | 4 | 9 |  |  | 7 |
| Navicula soehrensis v. hassica |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| N. soehrensis v. soehrensis |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula striolata |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula subtilissima |  |  | 206 |  | 190 | 120 | 8 | 5 | 40 | 5 | 22 |  | 19 | 22 |
| Navicula tuscula |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula tridentula |  |  |  |  |  |  |  |  |  | 4 |  |  |  | 2 |
| Navicula viridula |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula vulpina |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

| | VD12 | VD13 | VD14 | VD16 | VD17 | VD18 | VD20 | VD23 | VD24 | VD25 | VD26 | VD27 | VD28 | VD29 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Neidium species | | | | | | | | | | | | | | |
| Neidium affine | | | | | | | | | | | | | | |
| Neidium dubium | | | | | | | | | | | | | | |
| Neidium temperei | | | | | | | | | | | | | | |
| Nitzschia sp. | | | | | | | | | | | 1 | | | |
| Nitzschia acidoclinata | | | | | | | | | | | | | | |
| Nitzschia alpina | | | | | | | | | | | | | | |
| Nitzschia fonticola | | | | | | | | | | | | | | |
| Nitzschia frustulum | | | | | | | | | | | | | | |
| Nitzschia glacilis | | | | | | | 3 | | | | | | | |
| Nitzschia hungarcia | | | | | | | | | | | | | | |
| Nitzschia intermedia | | | | | | | | | | | | | | |
| Nitzschia liebetruhii | | | | | | | | | | | | | | |
| Nitzschia linearis | | | | | | | | | | | | | | |
| Nitzschia peisonis | | | | | | | | | | | | | | |
| Nitzschia perminuta | | | | | | | 10 | | 45 | 48 | 39 | | | 45 |
| Nitzschia sigmoidea | | | | | | | | | | | | | | |
| Pinnularia spp. | | | | | | | | | | 1 | | | | |
| Pinnularia biceps | | | | | | | | | | | | | | |
| Pinnularia borealis | | | | | | | | | | | | 1 | | |
| Pinnularia divergens | | | | | | | | | | | 1 | | | 11 |
| Pinnularia gibba | | | | | | | | | | 2 | 1 | | | |
| Pinnularia cf intermedia | | | | | | | | | 4 | | | | | |
| Pinnularia interrupta | | 1 | | 2 | | | | | | 1 | | | 1 | |
| Pinnularia maior | | | | | 12 | 70 | 2 | | | | | | | |
| Pinnularia microstauron | | | | | | | 6 | | 5 | 1 | | | | |
| P. microstauron small type | | | | | | | | | | | | | | |
| Pinnularia rupestris | | | | | | | | | | | | | 8 | |
| Pinnularis supcapitata | | | | | | | | | | | | | | |
| Pinnularia streptoraphe | | | | | | | 2 | | 4 | 3 | 1 | | | 16 |
| Rhopolodia gibba | | | | | | | | | | | | | | |
| Stauroneis phoenicenteron | 1 | | | | | | 4 | 1 | 2 | | | | | 1 |
| Stauroneis anceps | | | | | | | | | | | | | | |
| Stauroneis smithii | | | | | | | | | | | | | | |
| Stenopterobia spp. | | | | | | | | | 1 | | 1 | | | |
| Stenopterobia anceps | | | | | | | | | | | | | | |
| Stenopterobia delicatissima | | | | | | | | | | | | | | |
| Stephanodiscus niagrae | | | | | | | | | | | | | 1 | |
| Stephanodiscus medius | | | | | | | | | | | | | | |
| Tabellaria spp. | | | | | | | | | | | | | | |
| Tabellaria fenestrata | | | | | | | 3 | | 23 | 16 | 10 | | | 1 |
| Tabellaria flocculosa | | | | | | | | | | | | | | |
| Tabellaria flocculosa str. 3 | 2 | | | | | | 4 | | | | 68 | | | |
| Tabellaria flocculosa srt. 4 | | | | | | | 157 | | 43 | 41 | | | | 31 |
| Tabellaria linearis | | | | | | | | | 37 | 71 | 140 | | | 10 |
| Tabellaria quadrisepta | | | | | | | | | | | | | | |
| Unknown spp. | 1 | | | | | | 3 | | 24 | 6 | 7 | 1 | | |

| | VD31 | VD32 | VD33 |
|---|---|---|---|
| Achnanthes spp. | | | |
| Achnanthes flexella | | | |
| Achnanthes minutissima | | | |
| Achnanthes nodosa | | | |
| Achnanthes petersonii | | | |
| Achnanthes taeniata/linearis | | | |
| Amphora spp. | | | |
| Amphora libyca | | 1 | |
| Amphora ovalis | | | |
| Aulacoseira species | | | 4 |
| Aulacoseira ambigua | | 1 | |
| Aulacoseira italica | | | |
| Aulacoseira pfaffiana | | | |
| Aulacoseira subarctica | | | 8 |
| Brachysira spp. | | | |
| Brachysira aponina | | | |
| Brachysira brebissoni | | | |
| Brachysira hofmanniae | | | |
| Brachysira serians | | | |
| Brachysira vitrea | | | |
| Brachysira zellensis | | | 7 |
| Caloneis spp. | | | |
| Caloneis bacillum | | | |
| Caloneis molaris | | | |
| Caloneis tenuis | | | |
| Caloneis pulchra | | | |
| Caloneis undulata | | | |
| Caloneis silicula | | | |
| Cocconeis spp. | | | |
| Cymbella spp. | | | |
| Cymbella amphioxys | | | |
| Cymbella angustata | | | |
| Cymbella arctica | | | |
| Cymbella aueri | | | |
| Cymbella austriaca | | | |
| Cymbella cf caespitosa | | | |
| Cymbella cesatii | | | |
| Cymbella cistula | | | |
| Cymbella cuspidata | | | |
| Cymbella cymbiformis | | | |
| Cymbella descripta | | | |
| Cymbella elginensis | | | |
| Cymbella gracilis | | | |
| Cymbella hybrida | | | |
| Cymbella incerta | | | |
| Cymbella lacustris | | | |
| Cymbella lapponica | | | |
| Cymbella laterns | | | |
| Cymbella mesiana | | | |
| Cymbella microcephala | | | |
| Cymbella minuta | | | |
| Cymbella naviculacea | | | |
| Cymbella naviculiformis | | | |
| Cymbella norvegica | | | |
| Cymbella obscura | | | |
| Cymbella paucistriata | | | |
| Cymbella silesiaca | | | |
| Cymbella subaequalis | | | |

| | VD31 | VD32 | VD33 |
|---|---|---|---|
| Cymbella subarctica | | | |
| Cymbella subcuspidata | | | |
| Cymbella tynaii | | | |
| Cyclotella spp. | | | |
| Cyclotella bodanica | | 2 | |
| Cyclotella michiganiana | | | |
| Cyclotella stelligera | | | |
| Denticula kuetzingii | | | |
| Diatoma species | | | |
| Diatoma tenuis | | | |
| Diploneis elliptica | | | |
| Diploneis puella | | | |
| Epithemia adnata | | | |
| Eunotia spp. | | | |
| Eunotia arcus | | | |
| Eunotia argus | | | |
| Eunotia aculus | | | |
| Eunotia bilunaris | 3 | | 2 |
| E. bilunaris v. mucophila | | 7 | 4 |
| Eunotia circumborealis | | | |
| Eunotia fennica | 204 | 1 | 3 |
| Eunotia exigua | | | 36 |
| Eunotia faba | | | |
| Eunotia fallax | | | |
| Eunotia flexuosa | | | |
| Eunotia formica | | | |
| Eunotia glacialis | | | |
| Eunotia glacialifalsa | | | |
| Eunotia hexaglyphis | | | |
| Eunotia implicata | | | |
| Eunotia incisa | | | |
| Eunotia lapponica | 16 | | |
| Eunotia maior | | | |
| Eunotia monodon | | | |
| Eunotia naegelli | | | |
| Eunotia nymanniana | | | |
| Eunotia paludosa type 1 | 273 | 80 | 74 |
| Eunotia paludosa type 2 | | | 5 |
| Eunotia paludosa v. trinarcia | | | |
| Eunotia pectinalis | | | |
| Eunotia pirla | | | |
| Eunotia praerupta | | | |
| Eunotia praerupta v. bidens | | | |
| Eunotia septentrionalis | | | |
| Eunotia serra | | | |
| Eunotia soleirolii | | | |
| Eunotia vanheurckii | | | |
| Fragilaria spp. | | 1 | |
| Fragilaria brevistriata | | | |
| Fragilaria biceps | | | |
| Fragilaria capucina | | | 1 |
| F. capucina v. vaucheriae | | | |
| Fragilaria construens | | 1 | 2 |
| Fragilaria crotonensis | | | |
| Fragilaria exigua | | | |
| Fragilaria fasciculata | | | |
| Fragilaria parasitica | | | |
| Fragilaria pinnata | | 1 | 14 |

| | VD31 | VD32 | VD33 |
|---|---|---|---|
| Fragilaria tenera | | | |
| Fragilaria ulna | | | 2 |
| Frustulia rhomboides | | | 1 |
| F. rhomboides v. saxonica | | | |
| Gomphonema spp. | | | |
| Gomphonema girdle | | | |
| Gomphonema acuminatum | | | |
| Gomphonema amoenum | | | |
| Gomphonema angustatum | | | |
| G. angustatum v. undulatum | | | |
| Gomphonema angustum | | | |
| Gomphonema bohemicum | | | |
| Gomphonema clavatum | | | |
| Gomphonema gracile | | | |
| Gomphonema hebridense | | | |
| Gomphonema intricatum | | | |
| Gomphonema lagerheimii | | | |
| Gomphonema longiceps | | | |
| Gomphonema parvulum | | | |
| Gomphonema subtile | | | |
| Hantzchia amphioxys | | 3 | 1 |
| Hantzschia elongata | | | |
| Navicula spp. | | | 3 |
| Navicula cf angusta | | | |
| Navicula brockmannii | | | |
| Navicula bryophilia | | | |
| Navicula cohnii | | 5 | |
| Navicula cryptocephala | | | |
| Navicula cryptotenella | | | |
| Navicula eidriginia | | | |
| Navicula cf exilis | | 2 | 3 |
| Navicula festiva | | | |
| Navicula gallica | | | |
| Navicula geoppertiana | | | |
| Navicula jaegii | | | |
| Navicula lancelolata | | | |
| Navicula maceria | | | |
| Navicula mediocris | | 1 | 2 |
| Navicula mutica | | | |
| Navicula muticopis | | | |
| Navicula lapidosa | | | |
| Navicula leptostriata | | | |
| Navicula peregrina | | | |
| Navicula pupula | | | |
| Navicula pseudosubtillisima | | | |
| Navicula radiosa | | | |
| Navicula rhynchocephala | | | |
| Navicula seminulum | | | |
| Navicula suchlandtii | | | |
| Navicula soehrensis | | | |
| Navicula soehrensis v. hassica | | | |
| N. soehrensis v. soehrensis | | | |
| Navicula striolata | | | |
| Navicula subtilissima | 168 | 255 | 44 |
| Navicula tuscula | | | |
| Navicula tridentula | | | |
| Navicula viridula | | | |
| Navicula vulpina | | | |

| | VD31 | VD32 | VD33 |
|---|---|---|---|
| Neidium species | | | |
| Neidium affine | | | |
| Neidium dubium | | | |
| Neidium temperei | | | |
| Nitzschia sp. | | | |
| Nitzschia acidoclinata | | | |
| Nitzschia alpina | | | |
| Nitzschia fonticola | | | |
| Nitzschia frustulum | | | |
| Nitzschia glacilis | | | |
| Nitzschia hungarcia | | | |
| Nitzschia intermedia | | | |
| Nitzschia liebetruhii | | | |
| Nitzschia linearis | | | |
| Nitzschia peisonis | | | |
| Nitzschia perminuta | | | |
| Nitzschia sigmoidea | | | |
| Pinnularia spp. | | | |
| Pinnularia biceps | | | |
| Pinnularia borealis | | 4 | 2 |
| Pinnularia divergens | | 1 | |
| Pinnularia gibba | | | |
| Pinnularia cf intermedia | | | |
| Pinnularia interrupta | | | |
| Pinnularia maior | | 3 | |
| Pinnularia microstauron | | | 2 |
| P. microstauron small type | | | |
| Pinnularia rupestris | 33 | | |
| Pinnularis supcapitata | | | |
| Pinnularia streptoraphe | | | |
| Rhopolodia gibba | | | |
| Stauroneis phoenicenteron | | | |
| Stauroneis anceps | | | |
| Stauroneis smithii | | | |
| Stenopterobia spp. | | | |
| Stenopterobia anceps | | | |
| Stenopterobia delicatissima | | | |
| Stephanodiscus niagrae | | | |
| Stephanodiscus medius | | | |
| Tabellaria spp. | | | |
| Tabellaria fenestrata | | | |
| Tabellaria flocculosa | | | |
| Tabellaria flocculosa str. 3 | | | |
| Tabellaria flocculosa srt. 4 | | 1 | 4 |
| Tabellaria linearis | | | |
| Tabellaria quadrisepta | | | |
| Unknown spp. | | 1 | 1 |

## E.2 JBL-2 raw diatom counts (Chapter 3)

| | 0 | 2 | 4 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 | 34 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Achnanthes spp. | | | | | | | | | | | | | | | | | |
| Achnanthes minutissima | | | | | | | | | | | | | | | | | |
| Achnanthes subatomoides | | | | | | | | | | | | | | | | | |
| Achnanthes cf acares | | | | | | | | | | | | | | | | | |
| Amphora spp. | | | | | | | | | | | | | | | | | |
| Amphora ovalis | | | | 1 | | | | | | | | | | | | | |
| Amphora pedicullus | | | | | | | | | | | | | | | | | |
| Aulacoseira spp. | | | | | | | | | | | | | | | | | |
| Aulacoseira ambigua | | | | | | | | | | | | | | | | | |
| Aulacoseira crenulata | | | | | | | | | | | | | | | | | |
| Aulacoseira granulata | | | | | | | | | | | | | | | | | |
| Aulacoseira italica | | | | | | | | | | | | | | | | | |
| Aulacoseira lirata | | | | | | | | | | | | | | | | | |
| Asterionella formosa | | | | | | | | | | | | | | | | | |
| Brachysira spp. | | | | | | | | | | | | | | 1 | | | |
| Caloneis spp. | | | | | | | | | | | | | | | | | |
| Caloneis bacillum | | | | | | | | | | | 2 | 4 | | 18 | 4 | 12 | 25 |
| Caloneis molaris | | | | | | | | | | | | | | | | | |
| Caloneis thermalis | | | | | | | | | | | | | | | | | |
| Cymbella spp. | | | | | | | | | | | | | | | | | |
| Cymbella cistula | | | | | | | | | | | | | | | | | |
| Cymbella gracilis | | | | | | | | | | | | | | | | | |
| Cymbella hebridica | | | | | | | | | | | | | | | | | |
| Cymbella minuta | | | | | | 1 | | | | | | | | | | | |
| Cymbella silsiaca | | | | | | | | | | | | | | | | | |
| Cymbella subaequalis | | | | | | | | | | | | | | | | | |
| Cyclotella spp. | | | | | | | | | | | | | | | | | |
| Cyclotella stelligera | | | | | | | | | | | | | | | | | |
| Denticula kuetzingii | | | | | | | | | | | | | | | | | 1 |
| Diploneis parma | | | | | | | | | | | | | | | | | |
| Epithemia adnata | | | | | | | | | | | | | | | | | |
| E. bilunaris v. biliunaris | | | | | | | | | | | | | | | | | |
| E. bilunaris v. mucophila | | | 2 | | 23 | | | | | | 1 | | 1 | | 6 | | 16 |
| E. bilunaris deformed | | | | | | | | | | | | | | | | | |
| E. circumborealis | | | | | | | | | | | | | | | | | |
| Eunotia exigua | 2 | | | | | | | | 1 | | 1 | | 1 | 2 | 17 | 15 | 32 |
| Eunotia fallax | | | | | | | | | | | | | | | | | |
| Eunotia flexuosa | | | | | | | | | | | | | | | | | |
| Eunotia formica | | | | | | | | | | | | | | | | | |
| Eunotia glacialis | | | | | | | | | | | | | | | | | |
| Eunotia hexaglyphis | | | | | | | | | | | | | | | | | |
| Eunotia implicata | | | | | | | | | | | | | | | | | |
| Eunotia incisa | | | | | | | | | | | | | | | | | |
| Eunotia lapponica | | | | | | | | | | | | | | | | | |
| Eunotia monodon | | | | | | | | | | | | | | | | | |
| Eunotia monodon deformed | | | | | | | | | | | | | | | | | |
| Eunotia nymanniana | | | | | | | | | | | | 2 | 1 | 1 | 5 | 13 | 16 |
| E. nymanniana deformed | | | | | | | | | | | | | | | | | |
| Eunotia paludosa | 389 | 449 | 412 | 337 | 427 | 300 | 402 | 459 | 365 | 405 | 403 | 400 | 441 | 400 | 526 | 250 | 425 |
| E. paludosa v. trinacria | | | | | 1 | | | 4 | | | 1 | | | | 18 | 5 | 43 |

| | 0 | 2 | 4 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 | 34 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E. paludosa v. type2 | | | | | | | | | | | | | | | | | |
| E. paludosa v. microcephala | | | | | | | | | | | | | | | | | |
| Eunotia pectionalis | | | | | | | | | | | | | | | | | |
| Eunotia praerupta | 1 | | | | | | | | | | | | | | | | |
| Eunotia septrentionalis | | | | | | | | | | | | | | | | | |
| Fragilaria spp. | | | | | | | | | | | | | | | | | |
| Fragilaria brevistrata | | | | | | | | | | | | | | | | 2 | |
| Fragilaria capucina | | | | | | | | | | | | | | | | | |
| Fragilaria construens | | | | | | | | | | | | | | | | | |
| Fragilaria constricta | | | | | | | | | | | | | | | | | |
| Fragilaria pinnata | | | | | | | | | | | | | | | | | |
| Fragilaria tenera | | | | | | | | | | | | | | | | | |
| Fragilaria ulna | | | | | | | | | | | | | | | | | |
| Fragilaria zeilleri | | | | | | | | | | | | | | | | | |
| Frustulia rhomboides | | | | | | | | | | | | | | | | | |
| Gomphonema spp. | | | | | | 2 | | | | | | | | | | | |
| Gomphonema acuminatum | | | | | | | | | | | | | | | | | |
| Gomphonema angustatum | | | | | | | | | | | | | | | | | |
| Gomphonema bohemicum | | | | | | | | | | | | | | | | | |
| Gomphonema gracile | | | | | | | | | | | | | | | | | |
| Gomphonema lagerhemeii | | | | | | | | | | | | | | | | | |
| Gomphonema parvulum | | | | | | | | | | | | | | | | | |
| Hantzschia abundans | | | | | | | | | | | | | | | | | |
| Hantzschia amphioxys | | 1 | 1 | | 1 | 1 | 4 | 1 | | 1 | 1 | 1 | 1 | 2 | 3 | 1 | 2 |
| Hantzschia elongata | | | | | | | | | | | | | | | | | |
| Navicula spp. | | | | | | | | | | | | | | | | | |
| Navicula cf submurlais | | | | | | | | | | | | | | | | 6 | |
| Navicula absoluta | | | | | | | | | | | | | | | | | |
| N. cf bergerii | | | | | | | | | | | | | | | | | |
| Navicula capitata | | | | | | | | | | | | | | | | | |
| Navicula cohnii | | | | | | | | | | | | | | | | | |
| Navicula cryptocephala | | | | | | | | | | | | | | | | | |
| Navicula cuspidata | | | | | | | | | | | | | | | | | |
| Navicula gallica | | | | | | | | | | | | | | | | | |
| Navicula elginensis | | | | | | | | | | | | | | | | | |
| Navicula minima | | | | | | | | | | | | | | | | | |
| Navicula mutica | | | | | 1 | | | 2 | | | 3 | | 3 | 2 | 1 | 3 | 8 |
| Navicula pupula | | | | | | | | | | | | | | | | | |
| Navicula soehensis | | | | | | | | | | | | | | | | | |
| Navicula subtilissima | | | | | | | | | | | | | | 2 | 25 | 19 | 40 |
| Navicula suecorum | | | | | | | | | | | | | | | | | |
| Navicula stormeii | | | | | | | | | | | | | | | | | |
| Neidium spp. | | | | | | | | | | | | | | | | | |
| Nitzschia spp. | | | | | | | | | | | | | | | | | |
| Nitzschia alpina | | | | | | | | | | | | 1 | | | | | |
| Nitzschia perminuta | | | | | | | | | | | | | | | | | |
| Pinnularia centres | | | | | | | | | | | | | | | | | |
| Pinnularia aestuarii | | | | | | | | | | | | | | | | | |
| Pinnularia borealis | | | | 2 | | | 1 | 1 | | 2 | 1 | | | | | | 2 |
| P. borealis v. rectangularis | | | | | | | | | | | | | | | | | |

| | 0 | 2 | 4 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 | 34 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pinnularia brevicostata | | | | | | | | | | | | | | | | | |
| Pinnularia gibba | | | | | | | | | | | | | | | | | |
| Pinnularia karelica | | | | | | | | | | | | | | | | | |
| Pinnularia macilenta | | | | | | | | | | | | | | | | | |
| Pinnularia microstauron | | | | | | | | | | | | | | | | | |
| Pinnularia rupestris | | | | | | | | | | | | | | | | | |
| Pinnularia supcapitata | | | | | | | | | | | | | | | | | |
| Pinnularia streptoraphe | | | | | | | | | | | | | | | | | |
| Rhopolodia spp. | | | | | | | | | | | | | | | | | |
| Rhopolodia gibba | | | | | | | | | | | | | | | | | |
| Stauroneis spp. | | | | | | | | | | | | | | | | | |
| Stephanodiscus spp. | | | | | | | | | | | | | | | | | |
| Suriella constricta | | | | | | | | | | | | | | | | | |
| Eunotia sp. 1 | | | | | | | | | | | | | | | | | |
| Tabellaria fenestrata | | | | | | | | | | | | | | | | | |
| Tabellaria flocculosa | | | | | | | | | | | | | | | | | |
| Tabellaria flocculosa str. 1 | | | | | | | | | | | | | | | | | |
| Tabellaria flocculosa str. 4 | | | | | | | | | | | | | | | | | |
| cf Diatomella p.855 KLB | | | | | | | | | | | | | | | | | |

|  | 36 | 38 | 40 | 42 | 44 | 46 | 48 | 50 | 52 | 56 | 58 | 60 | 62 | 64 | 70 | 72 | 74 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Achnanthes spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Achnanthes minutissima |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 2 |  |
| Achnanthes subatomoides |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Achnanthes cf acares |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Amphora spp. |  |  |  |  |  |  |  |  |  |  | 1 |  |  |  |  |  |  |
| Amphora ovalis |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Amphora pedicullus |  |  |  |  |  |  |  |  |  |  |  | 1 |  |  |  |  |  |
| Aulacoseira spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 2 | 5 | 1 |
| Aulacoseira ambigua |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 |
| Aulacoseira crenulata |  |  |  |  |  |  |  |  | 2 |  |  | 1 |  | 3 |  |  |  |
| Aulacoseira granulata |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Aulacoseira italica |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Aulacoseira lirata |  |  |  |  |  |  |  |  |  |  |  |  |  | 2 |  |  |  |
| Asterionella formosa |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Brachysira spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Caloneis spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Caloneis bacillum | 41 | 105 | 105 | 73 | 67 | 111 | 63 | 33 | 35 | 98 | 80 | 143 | 59 |  | 18 | 8 | 8 |
| Caloneis molaris |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Caloneis thermalis |  |  |  |  |  |  |  |  |  |  |  |  |  | 2 |  |  |  |
| Cymbella spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella cistula |  |  |  |  |  |  |  |  | 2 |  |  |  |  |  |  |  |  |
| Cymbella gracilis |  |  | 1 |  |  |  |  |  |  |  |  |  |  |  | 1 |  |  |
| Cymbella hebridica |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella minuta |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 2 |
| Cymbella silsiaca |  |  |  |  |  |  |  | 2 |  |  |  |  |  |  | 2 |  |  |
| Cymbella subaequalis |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cyclotella spp. |  |  |  |  |  |  |  | 2 |  |  |  |  | 3 |  | 1 |  |  |
| Cyclotella stelligera |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Denticula kuetzingii |  | 1 |  |  | 10 | 2 |  | 1 | 3 | 4 | 3 | 8 | 9 | 9 | 6 | 17 | 1 |
| Diploneis parma |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Epithemia adnata |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 3 |  |
| E. bilunaris v. biliunaris |  |  |  |  |  |  |  | 2 |  |  |  |  |  |  | 4.5 | 4 | 2 |
| E. bilunaris v. mucophila | 1 | 14 | 11 | 97 | 114 | 47 | 25 | 45 | 77 | 23 | 5.5 | 7.5 | 3.5 | 1 |  | 12 | 4.5 |
| E. bilunaris deformed |  |  |  | 2 | 3 |  |  |  |  |  |  | 3 |  |  |  |  |  |
| E. circumborealis |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia exigua | 40 | 67 | 25 | 71 | 2 | 5 | 4 | 1 |  | 5 |  |  |  | 1 | 1 | 1.5 | 2.5 |
| Eunotia fallax |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia flexuosa |  |  |  |  |  |  |  |  | 1 |  | 1 |  |  | 1 |  | 1 |  |
| Eunotia formica |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia glacialis |  |  |  |  |  |  |  | 1.5 |  |  |  |  | 1 |  |  |  |  |
| Eunotia hexaglyphis |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia implicata |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia incisa |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  |
| Eunotia lapponica |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  |
| Eunotia monodon |  |  |  |  |  |  |  | 1 |  |  |  |  |  |  |  |  |  |
| Eunotia monodon deformed |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia nymanniana | 6.5 | 38 | 36 | 67 | 63 | 33 | 103 | 111 | 61 | 25 | 16 | 56 | 4 | 2 | 3 | 3.5 | 2 |
| E. nymanniana deformed |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia paludosa | 280 | 297 | 326 | 104 | 99 | 181 | 76 | 64 | 109 | 149 | 86 | 70 | 110 | 69 | 155 | 216 | 71 |
| E. paludosa v. trinacria | 16 | 23 | 17 | 10 |  |  |  |  |  | 5.5 |  |  |  |  | 7 |  | 5 |

| | 36 | 38 | 40 | 42 | 44 | 46 | 48 | 50 | 52 | 56 | 58 | 60 | 62 | 64 | 70 | 72 | 74 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E. paludosa v. type2 | | 3 | | 8 | 66 | 37 | 103 | 22 | 21 | 16 | 5.5 | 58 | 4 | | | | 7 |
| E. paludosa v. microcephala | | | | | | | | | | | | | | | | | 1 |
| Eunotia pectionalis | | | | | | | | | | | | | | | | | |
| Eunotia praerupta | | | | | | | | | | | | 1 | | | | | |
| Eunotia septrentionalis | | | | | | | | | | | | | | | | | |
| Fragilaria spp. | | | | | | | | | | | | | | 1 | | | |
| Fragilaria brevistrata | | | | | | | | | 2 | | | | | | | 2 | 1 |
| Fragilaria capucina | | | | | | | | | | | | | | | 2 | 2 | |
| Fragilaria construens | | | | 2 | | | | | | | 1 | 4 | 2 | | | 1 | 4 |
| Fragilaria constricta | | | | | | | | | | | | | | | | | |
| Fragilaria pinnata | | | | | | | | | | | | | | | | | |
| Fragilaria tenera | | | | | | | | | | | | | | | | | |
| Fragilaria ulna | | | | | | | | | | | | | 1 | | 5 | 1 | |
| Fragilaria zeilleri | | | | | | | | | | | | 3 | | | | | |
| Frustulia rhomboides | | | | | | | | | | | | | | | | | |
| Gomphonema spp. | | | | | | | | | | 2 | | | | | 2 | 4 | 1 |
| Gomphonema acuminatum | | | | | | | | | | | | | | 2 | | | |
| Gomphonema angustatum | | | | | | | | | | | | 2 | 2 | | | | |
| Gomphonema bohemicum | | | | | | | | | | | | | | | | | |
| Gomphonema gracile | | | | | | | | | 2 | 1 | | | | 1 | | | |
| Gomphonema lagerhemeii | | | | | | | | | | | | | | | | | |
| Gomphonema parvulum | | | | | 2 | | | | | | 1 | | 2 | | | | |
| Hantzschia abundans | | | | | | | | | | | | | 2 | | | | |
| Hantzschia amphioxys | 2 | 2 | 1 | 4 | 10 | 4 | 6 | 13 | 4 | 7 | 20 | 25 | 30 | 23 | 21 | 14 | 13 |
| Hantzschia elongata | | | | | | | | | 1 | 1 | 2 | 2 | | 1 | 2 | 2 | |
| Navicula spp. | | | | | | | | | | 2 | | | | | | | 5 |
| Navicula cf submurlais | 14 | | | | | | | | | 5 | 19 | | 136 | 7 | 102 | 95 | 83 |
| Navicula absoluta | | | | | | | | | | | | | | | | | |
| N. cf bergerii | | | | | | | | | | | | | | | | | |
| Navicula capitata | | | | | | | | 1 | | | | | | | | | |
| Navicula cohnii | | | | | | | | | | | | | 8 | | | | |
| Navicula cryptocephala | | | | | | | | | | | | 1 | | 1 | | 2 | |
| Navicula cuspidata | | | | | | | | | | | | | | | 2 | | 1 |
| Navicula gallica | | | | | | | | | | | | | | | | | |
| Navicula elginensis | | | | | | | | | | | | | | | | | |
| Navicula minima | | | | | | | | | | | | | | | | | |
| Navicula mutica | | 1 | 2 | 1 | 4 | | 4 | 6 | 4 | 7 | 5 | 13 | 19 | 11 | 10 | 13 | 6 |
| Navicula pupula | | | | | 1 | 1 | | | | 1 | | 2 | 1 | 3 | 4 | 1 | |
| Navicula soehensis | | | | | | | | | | | | | | | | | |
| Navicula subtilissima | 49 | 11 | | | | | 1 | | 4 | 10 | | | 1 | | | 3 | 1 |
| Navicula suecorum | | | | | | | | | | | | 2 | 1 | | | | |
| Navicula stormeii | | | | | | | | | | | | | | | | | |
| Neidium spp. | | | | | | | | | | | | | | 2 | | | |
| Nitzschia spp. | | | | | 1 | | | | | | | | | | | | |
| Nitzschia alpina | | | | | | | | | | | | | | | | | |
| Nitzschia perminuta | | | | | | | | | | 2 | 1 | | 2 | 4 | 1 | 6 | 3 |
| Pinnularia centres | | | | | | | | | 1 | | | | | | | 2 | |
| Pinnularia aestuarii | | | | | | | | | | | | | | | | | 1 |
| Pinnularia borealis | 2 | | 2 | 1 | | 4 | 2 | 7 | 4 | | 9 | 4 | | | 12 | 15 | 3 |
| P. borealis v. rectangularis | | | | | | | | | | | | | 13 | | | | |

|  | 36 | 38 | 40 | 42 | 44 | 46 | 48 | 50 | 52 | 56 | 58 | 60 | 62 | 64 | 70 | 72 | 74 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pinnularia brevicostata |  |  |  |  |  |  |  |  |  |  |  |  | 2 | 4 |  |  |  |
| Pinnularia gibba |  |  |  | 1 |  | 2 | 2 |  |  |  | 1 | 2 |  |  |  |  |  |
| Pinnularia karelica |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia macilenta |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia microstauron |  |  |  |  |  |  |  |  |  |  |  |  |  | 2 | 3 | 5 | 1 |
| Pinnularia rupestris |  |  |  |  |  |  |  |  |  |  | 1 |  |  |  |  |  | 1 |
| Pinnularia supcapitata |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia streptoraphe |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 2 | 3 |  |
| Rhopolodia spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Rhopolodia gibba |  |  |  |  |  |  |  |  |  |  | 1 |  |  | 3 |  |  |  |
| Stauroneis spp. |  |  |  |  |  |  |  | 1 |  |  |  |  |  | 1 |  | 1 | 1 |
| Stephanodiscus spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Suriella constricta |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia sp. 1 |  |  |  |  |  |  |  |  | 1 |  |  |  |  |  |  |  |  |
| Tabellaria fenestrata |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Tabellaria flocculosa |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Tabellaria flocculosa str. 1 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 2 | 1 |
| Tabellaria flocculosa str. 4 |  |  |  |  |  |  |  |  | 1 |  |  |  |  |  |  |  | 1 |
| cf Diatomella p.855 KLB |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

|  | 76 | 78 | 80 | 82 | 84 | 86 | 88 | 90 | 92 | 94 | 96 | 98 | 100 | 102 | 104 | 110 | 112 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Achnanthes spp. | 2 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Achnanthes minutissima |  |  |  |  |  |  |  |  |  |  |  |  | 4 |  | 2 |  |  |
| Achnanthes subatomoides |  |  |  |  |  |  |  |  |  |  |  |  | 4 |  |  |  |  |
| Achnanthes cf acares |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  |  |  |  |
| Amphora spp. |  |  | 1 |  |  |  |  |  |  |  |  |  |  |  |  | 2 |  |
| Amphora ovalis |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  |  |  |  |
| Amphora pedicullus |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Aulacoseira spp. |  |  | 1 |  |  |  |  |  |  |  |  | 1 |  |  | 4 | 3 |  |
| Aulacoseira ambigua |  |  |  |  |  |  |  |  |  |  |  |  | 3 |  |  |  |  |
| Aulacoseira crenulata |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  |  |  |  |
| Aulacoseira granulata |  |  |  |  |  |  |  |  |  |  | 1 |  |  |  |  |  |  |
| Aulacoseira italica |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  |  |  |  |
| Aulacoseira lirata |  |  |  |  |  |  |  |  |  |  |  |  | 2 |  |  |  |  |
| Asterionella formosa |  |  |  |  |  |  |  |  |  |  |  | 2 |  |  |  |  |  |
| Brachysira spp. |  | 2 |  |  |  |  |  |  |  |  |  | 1 |  |  |  |  |  |
| Caloneis spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 2 | 1 |  |
| Caloneis bacillum | 21 | 3 |  |  |  | 1 |  |  | 1 | 2 |  | 4 |  |  |  |  |  |
| Caloneis molaris |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  |  |  |
| Caloneis thermalis |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 4 |  |
| Cymbella cistula |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella gracilis |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella hebridica |  |  |  |  | 1 |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella minuta |  | 1 |  |  |  |  | 1 |  |  |  |  |  |  |  | 4 |  |  |
| Cymbella silsiaca |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella subaequalis |  |  |  |  |  |  |  |  |  |  |  |  | 7 | 2 |  |  |  |
| Cyclotella spp. |  |  |  |  |  |  |  |  |  |  |  | 1 |  |  |  |  |  |
| Cyclotella stelligera |  |  |  |  |  |  |  |  |  |  |  |  | 2 |  |  |  |  |
| Denticula kuetzingii | 1 | 2 |  | 1 |  |  |  | 3 | 3 | 2 | 2 |  | 6 |  | 13 | 9 |  |
| Diploneis parma |  |  |  | 1 |  |  |  |  |  | 1 |  |  | 2 |  |  |  |  |
| Epithemia adnata |  |  | 1 | 1 |  |  |  |  |  | 2 |  | 2 | 1 | 1 | 1 | 2 |  |
| E. bilunaris v. biliunaris |  |  |  |  | 1 |  |  |  |  |  |  |  |  | 9 | 2.5 | 1 |  |
| E. bilunaris v. mucophila | 2.5 | 3 | 1 | 1 | 5 | 1.5 | 1 |  |  |  | 1.5 | 1 |  |  | 2 |  |  |
| E. bilunaris deformed |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| E. circumborealis |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 78 | 2 |
| Eunotia exigua | 2 | 1.5 | 1 | 2 |  |  | 1 | 1.5 | 1 | 1 | 2 | 1 |  |  | 1 | 16 | 14 |
| Eunotia fallax |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  |  |  |
| Eunotia flexuosa |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  | 1 | 1 |
| Eunotia formica |  |  |  |  |  |  |  |  |  |  |  |  | 4 |  | 1 |  |  |
| Eunotia glacialis |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1.5 | 4 | 1 |
| Eunotia hexaglyphis |  |  |  |  |  |  |  |  |  |  |  |  | 1 | 1 |  | 43 | 12 |
| Eunotia implicata |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 |
| Eunotia incisa |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia lapponica |  | 2.5 |  | 1 | 4 | 12 | 2.5 | 25 | 150 | 59 | 30 | 121 |  | 16 |  | 6.5 | 4 |
| Eunotia monodon |  |  |  |  |  |  |  |  |  |  |  |  |  | 3 |  | 19 | 55 |
| Eunotia monodon deformed |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia nymanniana | 7.5 | 2 | 3.5 | 3 | 31 | 41 | 30 | 44 | 40 | 143 | 125 | 17 | 1 | 10 |  | 5.5 | 7.5 |
| E. nymanniana deformed |  |  |  |  |  |  |  |  |  |  | 1 |  |  |  |  |  |  |
| Eunotia paludosa | 39 | 26 | 67 | 55 | 76 | 87 | 47 | 114 | 43 | 22 | 32 | 39 | 42 | 4.5 | 45 | 32 | 7 |
| E. paludosa v. trinacria |  | 1 | 2 | 14 | 32 | 27 | 9 | 14 | 6 | 3 | 6 | 8 | 1 | 1 |  |  |  |

|  | 76 | 78 | 80 | 82 | 84 | 86 | 88 | 90 | 92 | 94 | 96 | 98 | 100 | 102 | 104 | 110 | 112 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E. paludosa v. type2 | 3 |  |  | 2 |  |  |  | 1.5 |  | 1 |  |  |  |  |  |  |  |
| E. paludosa v. microcephala |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia pectionalis |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 |
| Eunotia praerupta |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  | 1 | 5 | 8 |
| Eunotia septrentionalis |  |  |  |  |  |  |  | 1 |  |  |  |  |  |  |  |  | 1 |
| Fragilaria spp. |  |  |  | 1 |  |  |  |  |  | 1 |  |  |  |  |  |  |  |
| Fragilaria brevistrata |  |  |  | 1 |  |  |  |  |  |  | 1 |  |  |  | 1 |  |  |
| Fragilaria capucina |  |  |  |  |  |  |  |  |  |  |  |  | 19 |  | 10 |  |  |
| Fragilaria construens | 1 |  |  |  | 1 |  | 2 | 4 |  |  |  |  | 9 |  | 35 | 2 |  |
| Fragilaria constricta |  |  |  |  |  |  |  |  |  |  |  |  | 4 |  |  |  |  |
| Fragilaria pinnata |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria tenera |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 3 |  |  |
| Fragilaria ulna |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  | 3 |  |  |
| Fragilaria zeilleri |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Frustulia rhomboides | 4 | 1 |  |  |  |  |  |  |  |  |  |  | 3 |  |  |  |  |
| Gomphonema spp. |  |  | 2 |  |  |  |  |  |  | 1 |  |  |  |  | 2 | 3 |  |
| Gomphonema acuminatum |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema angustatum |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema bohemicum |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema gracile |  |  |  |  |  | 1 |  |  | 1 |  |  |  |  |  |  | 28 |  |
| Gomphonema lagerhemeii |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema parvulum |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Hantzschia abundans |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Hantzschia amphioxys | 4 | 6 | 12 | 10 | 2 | 3 | 1 | 6 | 5 | 4 | 3 | 3 | 8 | 1 | 20 | 23 | 9 |
| Hantzschia elongata |  |  |  | 3 |  |  |  | 1 |  |  |  |  |  |  | 4 |  |  |
| Navicula spp. |  |  |  |  | 2 |  |  |  |  |  | 1 |  | 1 |  |  |  |  |
| Navicula cf submurlais | 176 | 227 | 302 | 338 | 220 | 186 | 34 | 31 | 30 | 10 | 13 | 7 |  |  |  | 1 | 3 |
| Navicula absoluta |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  |  |  |  |
| N. cf bergerii |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula capitata |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula cohnii |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula cryptocephala | 2 | 1 |  | 1 |  |  |  |  |  |  |  |  | 1 |  |  |  |  |
| Navicula cuspidata |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula gallica |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula elginensis |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  |  |  |  |
| Navicula minima |  |  |  |  |  |  |  |  |  |  |  |  | 3 |  |  |  | 2 |
| Navicula mutica | 10 | 1 | 4 |  | 5 | 2 | 1 |  | 2 | 5 | 1 |  | 1 |  | 7 | 11 | 4 |
| Navicula pupula |  | 1 | 1 | 3 |  | 1 |  |  | 1 |  |  |  | 5 | 1 | 3 | 3 |  |
| Navicula soehensis |  |  |  |  |  |  |  |  |  |  |  |  | 4 |  |  |  |  |
| Navicula subtilissima | 3 | 4 | 1 |  | 9 | 13 | 9 | 27 | 31 | 51 | 54 | 3 |  | 14 | 9 | 19 | 15 |
| Navicula suecorum |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula stormeii |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  |  |  |  |
| Neidium spp. |  |  |  |  |  |  |  |  |  | 1 |  |  | 1 |  | 5 |  |  |
| Nitzschia spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Nitzschia alpina |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Nitzschia perminuta |  |  |  | 3 |  | 1 |  | 1 | 5 |  |  |  |  |  |  | 5 |  |
| Pinnularia centres | 1 |  |  | 3 | 1 | 2 |  |  |  |  | 3 | 1 | 2 |  |  | 19 | 16 |
| Pinnularia aestuarii |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia borealis | 3 | 3 | 1 |  | 3 | 1 |  | 3 | 1 | 1 | 1 | 1 | 2 |  | 10 | 6 |  |
| P. borealis v. rectangularis |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

|  | 76 | 78 | 80 | 82 | 84 | 86 | 88 | 90 | 92 | 94 | 96 | 98 | 100 | 102 | 104 | 110 | 112 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pinnularia brevicostata |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia gibba |  |  |  |  |  |  | 1 |  |  |  |  |  | 1 |  |  | 11 | 23 |
| Pinnularia karelica |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 2 |  |  |
| Pinnularia macilenta |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia microstauron |  |  |  |  |  |  |  |  | 2 |  |  |  |  | 352 | 5 | 41 |  |
| Pinnularia rupestris |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 37 |
| Pinnularia supcapitata |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 3 |  |  |
| Pinnularia streptoraphe |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 2 | 20 |  |
| Rhopolodia spp. |  |  |  | 1 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Rhopolodia gibba |  |  |  | 1 | 2 |  |  |  |  |  | 1 |  |  |  | 1 | 4 |  |
| Stauroneis spp. |  | 1 |  |  |  |  |  |  |  |  |  |  | 3 | 1 | 4 | 17 | 18 |
| Stephanodiscus spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  |  |
| Suriella constricta |  |  |  |  |  |  |  |  |  |  |  |  | 3 |  |  |  |  |
| Eunotia sp. 1 |  |  |  | 1 | 1 | 4 | 10 | 41 | 40 | 35 | 41 | 9 |  | 21 |  | 18 | 2 |
| Tabellaria fenestrata |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Tabellaria flocculosa |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  |
| Tabellaria flocculosa str. 1 |  |  |  |  |  |  |  |  |  |  |  | 1 | 1 |  |  |  |  |
| Tabellaria flocculosa str. 4 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| cf Diatomella p.855 KLB |  |  |  | 3 |  | 1 |  |  |  |  |  |  |  |  |  |  |  |

|  | 116 | 118 | 120 | 122 | 124 | 126 | 128 | 130 | 138 | 148 | 150 | 156 | 160 | 164 | 168 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Achnanthes spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Achnanthes minutissima |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Achnanthes subatomoides |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Achnanthes cf acares |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Amphora spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Amphora ovalis |  |  |  |  |  |  |  |  |  |  | 1 |  |  |  |  |
| Amphora pedicullus |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Aulacoseira spp. |  | 1 | 1 |  | 1 |  | 4 | 1 | 5 |  |  |  | 3 | 1 |  |
| Aulacoseira ambigua |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Aulacoseira crenulata | 5 |  |  | 1 |  |  |  |  |  | 1 | 2 |  |  |  |  |
| Aulacoseira granulata |  |  |  |  |  |  |  |  |  |  | 2 |  |  |  |  |
| Aulacoseira italica |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Aulacoseira lirata |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Asterionella formosa |  |  |  | 1 |  |  |  |  |  |  |  |  |  |  |  |
| Brachysira spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Caloneis spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Caloneis bacillum |  | 2 | 2 | 4 | 14 | 1 | 2 |  | 4 | 7 | 2 | 4 | 12 |  | 10 |
| Caloneis molaris |  |  |  |  |  |  |  | 2 |  |  |  |  |  |  |  |
| Caloneis thermalis |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella spp. |  |  | 1 |  |  |  | 1 |  |  |  |  | 1 | 1 |  |  |
| Cymbella cistula |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella gracilis |  |  |  |  |  | 3 |  |  |  |  |  |  |  |  |  |
| Cymbella hebridica |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella minuta |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella silsiaca |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella subaequalis |  |  |  |  |  |  |  |  |  |  | 3 |  |  |  |  |
| Cyclotella spp. |  |  | 1 |  |  |  |  | 1 | 1 |  |  |  | 1 |  |  |
| Cyclotella stelligera |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Denticula kuetzingii |  |  | 7 | 3 |  | 5 | 9 | 6 | 9 |  | 3 | 7 | 4 | 1 |  |
| Diploneis parma | 1 |  |  |  | 1 |  |  |  |  |  |  |  |  |  |  |
| Epithemia adnata | 5 |  |  | 1 | 1 | 3 | 2 | 2 | 2 |  | 1 | 1 | 1 |  | 1 |
| E. bilunaris v. biliunaris |  | 1 |  | 5 | 2 | 1 |  | 1 | 2 |  | 6 |  |  |  | 1 |
| E. bilunaris v. mucophila |  |  |  |  |  |  |  | 2 | 1 | 1.5 |  | 1 |  | 4.5 | 1.5 |
| E. bilunaris deformed |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| E. circumborealis |  |  |  |  | 9 |  |  |  |  |  |  |  |  |  |  |
| Eunotia exigua | 2.5 | 5 | 9 | 14 | 4 | 18 | 14 | 15 | 3.5 | 10 | 5 |  | 8 |  | 4.5 |
| Eunotia fallax |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia flexuosa | 1 |  | 1 |  |  |  |  | 1 |  |  |  |  |  |  |  |
| Eunotia formica |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia glacialis |  |  | 2 |  |  |  | 2 | 1 | 1 |  |  |  |  | 2 |  |
| Eunotia hexaglyphis | 3 |  | 2 | 1 | 3 |  |  |  |  |  | 2 |  | 1 |  |  |
| Eunotia implicata |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia incisa |  |  |  | 1 |  |  |  | 1 |  |  |  |  |  |  |  |
| Eunotia lapponica | 1.5 | 5.5 | 7.5 | 7 | 29 |  |  | 2.5 | 3.5 |  | 4.5 | 6 | 12 | 2 | 1 |
| Eunotia monodon | 208 | 135 | 40 | 71 | 5 | 5 | 9.5 | 8 | 2.5 |  | 1.5 | 1 | 1 | 1 | 3 |
| Eunotia monodon deformed | 1 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia nymanniana | 2.5 | 1 | 5 | 4.5 | 33 | 3.5 |  | 13 | 5.5 | 5 | 2.5 | 11 | 23 | 29 | 6 |
| E. nymanniana deformed |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia paludosa | 5.5 | 3.5 | 19 | 16 | 110 | 7.5 | 111 | 103 | 73 | 309 | 8.5 | 25 | 90 | 132 | 68 |
| E. paludosa v. trinacria |  |  |  |  |  |  |  |  | 1 |  |  | 2 | 1 | 1 |  |

|  | 116 | 118 | 120 | 122 | 124 | 126 | 128 | 130 | 138 | 148 | 150 | 156 | 160 | 164 | 168 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E. paludosa v. type2 |  |  |  |  | 6 |  | 1 | 6 |  | 1 |  | 3.5 | 2 | 12 |  |
| E. paludosa v. microcephala |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia pectionalis |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia praerupta | 1 | 1 |  |  |  |  |  |  |  |  | 1.5 |  | 1 |  |  |
| Eunotia septrentionalis |  | 2 |  | 1 |  | 1 |  |  |  |  |  | 2 |  |  | 1 |
| Fragilaria spp. |  |  |  | 1 |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria brevistrata |  |  | 2 |  |  | 2 |  |  |  |  |  |  |  |  |  |
| Fragilaria capucina | 17 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria construens |  |  | 3 |  |  |  |  |  | 8 |  | 6 |  | 6 |  |  |
| Fragilaria constricta |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria pinnata |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 2 |
| Fragilaria tenera |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria ulna |  |  | 2 |  | 1 |  | 4 | 1 |  |  |  | 1 | 2 |  | 1 |
| Fragilaria zeilleri |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Frustulia rhomboides |  |  |  |  |  |  |  |  | 1 |  |  |  |  | 1 |  |
| Gomphonema spp. |  |  |  | 2 | 1 | 2 | 2 | 1 | 2 |  |  |  | 3 | 2 | 1 |
| Gomphonema acuminatum |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema angustatum |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema bohemicum |  |  |  |  |  |  |  |  |  |  | 1 |  |  |  |  |
| Gomphonema gracile | 1 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema lagerhemeii |  |  | 4 |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema parvulum |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Hantzschia abundans |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Hantzschia amphioxys | 1 | 4 | 4.5 |  | 7.5 | 9 | 2 | 6 | 6 | 1 |  | 4.5 | 3 | 3.5 | 2.5 |
| Hantzschia elongata | 4.5 |  |  |  |  | 3 |  | 2 |  |  |  |  |  |  |  |
| Navicula spp. |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  |  |
| Navicula cf submurlais |  | 2 |  | 1 | 30 |  |  | 6 | 2 |  | 1 | 2 | 15 | 3 | 5 |
| Navicula absoluta |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| N. cf bergerii |  |  |  |  | 3 |  |  |  |  |  |  |  |  |  |  |
| Navicula capitata |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula cohnii |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula cryptocephala |  |  |  |  |  |  |  |  |  |  | 1 |  |  |  |  |
| Navicula cuspidata |  |  | 1 |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula gallica |  |  |  |  |  |  |  | 1 |  |  |  |  |  |  |  |
| Navicula elginensis |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula minima |  |  | 2 |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula mutica |  |  |  | 1 | 1 | 1 |  | 3 | 3 | 2 |  | 3 | 1 | 2 | 1 |
| Navicula pupula |  |  | 1 |  |  |  | 1 |  | 6 |  |  |  |  | 2 |  |
| Navicula soehensis |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula subtilissima | 3 | 8 | 10 | 7 | 22 | 3 | 9 | 13 | 9 | 18 | 3 | 12 | 9 | 14 | 3 |
| Navicula suecorum |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula stormeii |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Neidium spp. | 1 | 2 | 7 | 2 |  | 1 | 2 | 3 | 3 |  |  | 3 |  |  |  |
| Nitzschia spp. | 1 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Nitzschia alpina |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Nitzschia perminuta | 1 | 2 |  |  |  | 1 | 2 |  |  |  | 1 |  | 1 | 2 |  |
| Pinnularia centres |  | 14 |  | 4 |  |  | 3 |  |  |  |  |  |  |  |  |
| Pinnularia aestuarii |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia borealis |  |  |  | 3 | 2 | 3 |  |  | 3 |  |  |  | 1 | 2 |  |
| P. borealis v. rectangularis |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

|  | 116 | 118 | 120 | 122 | 124 | 126 | 128 | 130 | 138 | 148 | 150 | 156 | 160 | 164 | 168 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pinnularia brevicostata |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia gibba |  |  |  | 7 | 9 |  | 2 |  |  |  |  |  |  |  |  |
| Pinnularia karelica | 3 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia macilenta |  |  |  |  |  |  |  |  |  |  | 2 |  |  |  |  |
| Pinnularia microstauron | 6 |  | 40 | 10 | 55 | 3 | 8 | 17 | 8 |  | 210 | 4 | 12 | 20 | 10 |
| Pinnularia rupestris |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia supcapitata |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia streptoraphe |  |  | 6 |  | 2 | 4 | 3 | 6 | 1 |  | 1 | 5 |  |  | 3 |
| Rhopolodia spp. |  |  |  |  |  | 1.5 |  |  |  |  |  |  |  |  |  |
| Rhopolodia gibba |  |  | 3 | 1 |  |  | 1 |  | 1 |  | 2 | 1 |  | 1 |  |
| Stauroneis spp. | 2 | 1 | 1 | 5 |  |  | 3 |  |  |  |  |  |  | 1 |  |
| Stephanodiscus spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Suriella constricta |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia sp. 1 |  |  | 6 | 9 | 19 | 2 | 2 | 4 | 5 |  |  | 4 | 8 | 4 | 3.5 |
| Tabellaria fenestrata |  | 1 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Tabellaria flocculosa |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Tabellaria flocculosa str. 1 |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  |  |
| Tabellaria flocculosa str. 4 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| cf Diatomella p.855 KLB |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

## E.3 JBL-7 raw diatom counts (Chapter 3)

| | 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 | 17 | 19 | 21 | 23 | 25 | 27 | 29 | 31 | 33 | 35 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Achnanthes spp. | 1 | | | | | | | | | | | | | | | | | |
| Achnanthes minutissima | | | | | | | | | | | | | | | | | | |
| Amphora spp. | | | | | | | | | | | | | | | | | | |
| Amphora ovalis | | | | | | | | | | | | | | | | | | |
| Aulacoseira spp. | | | | | | | | | | | | | | | | | | |
| Aulacoseira crenulata | | | | | | | | | | | | | | | | | | |
| Asterionella formosa | | | | | | | | | | | | | | | | | | |
| Caloneis spp. | | | | | | | | | | | | | | | | | | |
| Caloneis bacillum | | | | | | | | | | | | | | | | | | |
| Caloneis silicula | | | | | | | | | | | | | | | | | | |
| Coccenenis spp. | | | | 2 | | | | | | | | | | | | | | |
| Cymbella spp. | | | | | | | | | | | | | | | | | | |
| Cymbella gracilis | | | | | | | | | | | | | | | | | | |
| Cymbella microcephala | | | | | | 1 | | | | | | | | | | | | |
| Cymbella minuta | | | | | | | | | | | | | | | | | | |
| Cymbella proxima | | | | | | | | | | | | | | | | | | |
| Cymbella silsiaca | | | | | | | | | | | | | | | | | | |
| Cyclotella spp. | | | | | | | | | | | | | | | | | | |
| Denticula kuetzingii | | | | | | | | 1 | | | 1 | | | | | | | 1 |
| Diploneis parma | | | | | | | | | | | | | | | | | | |
| Epithemia adnata | | | | | | | | | | | | | | | | | | |
| E. bilunaris v. biliunaris | | | | | | | | | | | | | | | | | | |
| E. bilunaris v. mucophila | | | | | | | | | | 1 | | | | 1.5 | | | | |
| Eunotia exigua | 1 | | | | | | | | | | | | | | | | | |
| Euntoia flexuosa | | | | | | | | | | | | | | | | | | |
| Eunotia glacialis | | | | | | | | | | | | | | | | | | |
| Eunotia incisa | | | | | | | | | | | | | | | | | | |
| Eunotia lapponica | | | | | | | | | | | | | | | | | | |
| Eunotia monodon | | | | | | | | | | | | | | | | | | |
| Eunotia nymanniana | | | | | | | | | | | | | | | | | | |
| Eunotia paludosa | 320 | 268 | 349 | 393 | 323 | 347 | 374 | 365 | 375 | 346 | 396 | 303 | 383 | 364 | 335 | 370 | 310 | 361 |
| E. paludosa v. trinacria | | | 1 | | | | | | | | | | | | | | | |
| E. paludosa v. type 2 | | | 1.5 | | | | | | | | | | | | | | | |
| Eunotia praerupta | | | | | | | | | | | | | | | | | | |
| Eunotia septrentionalis | | | | | | | | | | | | | | | | | | |
| Fragilaria spp. | | | | | | | | | | | | | | | | | | 1 |
| Fragilaria brevistrata | | | | | | | | | | | | | | | | | | |
| Fragilaria capucina | | | | | | | | | | | | | | | | | | |
| Fragilaria construens | 2 | | | | | | | | 5 | | | | | | | | 1 | |
| Fragilaria ulna | | | | | | | | | | | | | | | | | | |
| Frustulia rhomboides | | | | | | | | | | | | | | | | | | |
| Gomphonema spp. | | | | | | | | | | | | | | | | | | |
| Gomphonema gracile | | | | | | | | | | | | | | | | | | 1 |
| Gomphonema parvulum | | | | | | | | | | | | | | | | | | |
| Hantzschia amphioxys | 1 | | | 2 | 1 | 2 | 1 | 2 | | 1 | 3 | 2 | 2 | | | 2 | 2 | 4 |
| Hantzschia elongata | | | | | | | | | | | | | | | | | | |
| Navicula spp. | | | | | | | | | | | | | | | | | | |
| Navicula cf submuralis | | | | | | | | | | | | | 1 | | | | | |
| Navicula atomus | | | | 1 | | 1 | | | | | | | | | | | | |
| Navicula cryptocephala | | | | | | | | | | | | | | | | | | |

| | 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 | 17 | 19 | 21 | 23 | 25 | 27 | 29 | 31 | 33 | 35 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Navicula cuspidata | | | | | | | | | | | | | | | | | | |
| Navicula elginensis | | | | | | | | | | | | | | | | | | |
| Navicula minima | | | | | | | | | | | | | | | | | | |
| Navicula mutica | | 3 | 1 | | | | 4 | 2 | 3 | 2 | 2 | 1 | 2 | | 3 | 3 | 2 | 7 |
| Navicula nivalis | | | | | | | | | | | | | | | | | | |
| Navicula pupula | | | | | | | | | | | | | | | | | | |
| Navicula subtilissima | | | | | | | | | | | | | | | | | | |
| Navicula tuscula | | | | | | | | | | | | | | | | | | |
| Neidium spp. | | | | | | | | | | | | | | | | | | 2 |
| Nitzschia spp. | | | | | | | | | | | | | | | | | | |
| Nitzschia perminuta | | | | | | | | | | | | | | | | | | |
| Pinnularia centres | | | | | | | | | | | | | | 1 | | | | |
| Pinnularia borealis | | | | | | | | 2 | 1 | | | | 1 | | | 1 | 1 | 1 |
| Pinnularia brevicostata | | | | | | | | | | | | | | | | | | |
| Pinnularia gibba | | | | | | | | | | | | | | | | | | |
| Pinnularia cf maior | | | | | | | | | | | | | | | | | | |
| Pinnularia microstauron | | | | | | | | | | | | 1 | | | | | | |
| Pinnularia schroederii | | | | | | | | | | | | | | | | | | |
| Pinnularia supcapitata | | | | | | | | | | | | | | | | | | |
| Pinnularia streptoraphe | | | | | | | | | | | | | | | | | | |
| Rhopolodia spp. | | | | | | | | | | | | | | | | | | |
| Rhopolodia gibba | | | | | | | | | | | | | | | | | | |
| Stauroneis spp. | | | | | | | | | 1 | | | | | | | | | |
| Stephanodiscus spp. | | | | | | | | | | | | | | | | | | |
| Eunotia sp. 1 | | | | | | | | | | | | | | | | | | |
| Tabellaria flocculosa str. 1 | | | | | | | | | | | | | | | | | | |

|  | 37 | 39 | 41 | 43 | 45 | 47 | 49 | 51 | 53 | 55 | 57 | 59 | 61 | 63 | 65 | 69 | 71 | 73 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Achnanthes spp. |  |  |  |  |  |  |  |  |  | 2 |  |  |  |  |  |  |  |  |
| Achnanthes minutissima |  | 2 |  | 2 |  |  |  |  |  |  |  | 2 |  |  |  |  |  |  |
| Amphora spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  |
| Amphora ovalis |  |  |  |  |  |  |  |  | 1 |  |  | 1 |  |  |  |  |  |  |
| Aulacoseira spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  | 2 |  |
| Aulacoseira crenulata |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Asterionella formosa |  |  | 1 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Caloneis spp. |  |  |  |  | 2 |  |  |  |  |  |  | 1 |  |  |  |  | 1 | 1 |
| Caloneis bacillum |  |  |  |  | 3 | 4 | 10 | 13 | 10 | 37 | 3 |  |  | 2 | 19 | 19 | 3 | 14 |
| Caloneis silicula |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Coccenenis spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella spp. |  | 2 |  |  |  |  |  |  |  |  | 1 |  |  |  |  |  |  | 1 |
| Cymbella gracilis |  |  |  | 1 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella microcephala |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella minuta |  |  |  | 1 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella proxima |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella silsiaca |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cyclotella spp. |  |  | 2 |  |  |  |  |  |  | 1 |  |  |  |  |  |  | 1 |  |
| Denticula kuetzingii |  |  |  |  | 4 |  |  | 3 | 7 | 2 |  |  | 1 |  | 1 |  | 3 | 4 |
| Diploneis parma |  |  |  | 1 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Epithemia adnata |  |  |  |  |  |  |  |  | 3 |  |  |  |  |  |  |  | 2 | 1 |
| E. bilunaris v. biliunaris |  |  |  |  | 1 | 1 |  |  |  |  |  |  |  |  |  |  |  |  |
| E. bilunaris v. mucophila |  |  |  | 1 | 1.5 | 4 | 18 | 31 | 48 | 103 | 207 | 146 | 16 | 9 | 16 | 15 | 9 | 12 |
| Eunotia exigua |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Euntoia flexuosa |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia glacialis |  |  |  |  |  |  |  | 1 |  |  |  |  |  |  |  |  |  |  |
| Eunotia incisa |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia lapponica |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia monodon |  |  |  |  |  |  |  |  | 2.5 |  |  |  |  |  |  |  |  |  |
| Eunotia nymanniana |  |  |  | 1 |  |  |  |  | 1 |  | 2 |  | 2 | 5.5 | 4 | 8 | 53 | 35 |
| Eunotia paludosa | 331 | 228 | 300 | 319 | 188 | 152 | 214 | 219 | 167 | 176 | 60 | 130 | 302 | 190 | 224 | 222 | 84 | 192 |
| E. paludosa v. trinacria |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| E. paludosa v. type 2 |  |  |  |  |  |  |  |  |  |  |  | 6 | 7 |  |  |  | 9 | 26 |
| Eunotia praerupta |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia septrentionalis |  |  |  |  |  |  |  |  |  |  |  |  | 2 |  |  |  |  |  |
| Fragilaria spp. |  |  |  | 2 |  |  |  |  |  |  |  | 1 |  |  |  |  |  |  |
| Fragilaria brevistrata |  |  |  |  |  |  |  | 1 |  |  |  |  |  |  | 2 |  |  |  |
| Fragilaria capucina |  |  |  |  | 1 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria construens | 2 |  | 2 |  |  |  |  |  |  |  | 3 |  |  |  |  |  | 9 |  |
| Fragilaria ulna |  |  |  |  |  | 1 |  |  | 2 |  |  |  |  |  |  | 1 | 1 |  |
| Frustulia rhomboides |  |  |  | 1 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema spp. |  |  |  | 6 |  |  |  | 1 |  | 2 |  | 1 |  |  |  | 2 | 1 |  |
| Gomphonema gracile |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema parvulum |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 2 |
| Hantzschia amphioxys | 3 | 6 | 5 | 24 | 12 | 3 | 6 | 1 | 7 | 6 | 10 | 6 | 1 | 4 | 4 | 5 | 15 | 10 |
| Hantzschia elongata |  |  |  | 2 | 1 |  |  |  | 2 |  |  |  |  |  |  |  | 2 |  |
| Navicula spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula cf submuralis |  |  |  | 3 |  | 2 | 39 | 165 | 12 | 21 |  | 5 | 30 | 67 | 62 | 59 | 3 | 22 |
| Navicula atomus |  |  |  | 1 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula cryptocephala |  |  |  |  |  |  | 1 |  |  |  |  |  |  |  |  |  | 2 | 1 |

| | 37 | 39 | 41 | 43 | 45 | 47 | 49 | 51 | 53 | 55 | 57 | 59 | 61 | 63 | 65 | 69 | 71 | 73 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Navicula cuspidata | | | | | | | | | | | | | | | | | | |
| Navicula elginensis | | | | | | | | | | | | | | | | | | |
| Navicula minima | | | | | | | | | | | | | | 1 | | | | |
| Navicula mutica | 2 | 1 | 5 | 24 | 3 | 4 | 4 | | 1 | 3 | | 1 | | 1 | | | 8 | 5 |
| Navicula nivalis | | | | 3 | | | | | | | | | | | | | 1 | |
| Navicula pupula | | | | 1 | 1 | | | | 2 | 2 | | | | | 2 | | | 1 |
| Navicula subtilissima | | | | | | | | | | | 3 | | 22 | 63 | 104 | 93 | 11 | 19 |
| Navicula tuscula | | | | | | | | | | | | | | | | | | |
| Neidium spp. | | | | | | | | | | | | | | | | | | |
| Nitzschia spp. | | | | | | | | 1 | | | | | | | | | | |
| Nitzschia perminuta | | | | 3 | | | | | 3 | | | | | | | | 2 | |
| Pinnularia centres | | | | 1 | | | | | | 1 | | | | | | | 2 | |
| Pinnularia borealis | | 2 | 1 | 7 | 1 | | | | 2 | 3 | | 2 | | 2 | | | 4 | 7 |
| Pinnularia brevicostata | | | | | | | | | | | | | | | | | | |
| Pinnularia gibba | | | | 3 | | | | 1 | 1 | | | | | | | | | |
| Pinnularia cf maior | | | | | | | | | | | 14 | 111 | 18 | 51 | 32 | 18 | 2 | 11 |
| Pinnularia microstauron | 1 | 1 | | | 2 | | | | 1 | | | | | 2 | | | | |
| Pinnularia schroederii | | | | | | | 1 | | | | | | | | | | | |
| Pinnularia supcapitata | | | | | | | | | | | | | | | | | 1 | 1 |
| Pinnularia streptoraphe | | | | 1 | 1 | | | | | | | | | | | | | |
| Rhopolodia spp. | | | | | | | | | 1 | | | | | 2 | | | | |
| Rhopolodia gibba | | | | | | | | | | | | | | | | | 1 | 1 |
| Stauroneis spp. | | | | | 1 | | 1 | | | | | | | | | | | 1 |
| Stephanodiscus spp. | | | | | | | | | | | | | | | | | | |
| Eunotia sp. 1 | | | | | | | | | | | | | | | | | | |
| Tabellaria flocculosa str. 1 | | | | | | | | 1 | | | | | | | | | | |

|  | 77 | 79 | 81 | 83 | 85 | 93 | 100 | 102 | 104 | 108 | 110 | 112 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Achnanthes spp. |  |  |  |  |  |  |  |  |  |  |  |  |
| Achnanthes minutissima |  |  |  |  |  |  |  |  |  |  |  |  |
| Amphora spp. |  |  |  |  |  |  |  |  |  |  |  |  |
| Amphora ovalis |  |  | 1 |  |  |  |  |  |  |  | 4 |  |
| Aulacoseira spp. | 1 | 3 |  | 3 |  | 2 |  | 1 | 2 | 1 | 1 | 1 |
| Aulacoseira crenulata |  |  |  |  | 3 |  |  |  |  |  |  |  |
| Asterionella formosa |  |  |  |  |  |  |  |  |  |  |  |  |
| Caloneis spp. |  |  |  | 5 | 1 |  | 1 |  |  |  |  | 2 |
| Caloneis bacillum |  | 2 |  |  |  | 3 | 2 | 2 | 6 |  |  |  |
| Caloneis silicula |  |  |  |  |  |  | 1 |  |  |  |  |  |
| Coccenenis spp. |  |  |  |  |  |  |  | 2 |  |  |  |  |
| Cymbella spp. | 1 |  | 1 | 1 |  |  |  |  |  | 1 |  |  |
| Cymbella gracilis |  |  |  |  |  |  |  |  |  |  |  | 1 |
| Cymbella microcephala |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella minuta |  |  |  | 2 | 2 |  |  |  |  | 2 | 1 | 2 |
| Cymbella proxima |  |  |  |  |  |  |  |  |  | 1 |  | 1 |
| Cymbella silsiaca |  |  |  |  |  |  |  |  |  | 4 |  |  |
| Cyclotella spp. |  | 3 |  |  |  |  |  |  | 1 |  |  |  |
| Denticula kuetzingii | 1 | 1 | 8 | 23 | 5 | 5 | 1 | 9 | 5 | 12 | 6 | 24 |
| Diploneis parma |  |  |  |  |  |  |  |  |  |  |  |  |
| Epithemia adnata |  | 1 | 5 | 3 | 1 | 2 |  |  | 2 | 1 | 2 | 2 |
| E. bilunaris v. biliunaris | 1 |  | 2 | 3 | 2 |  |  | 1 |  |  | 1 |  |
| E. bilunaris v. mucophila | 39 | 62 | 27 | 10 | 46 | 5 | 5 | 7.5 | 6 | 2 | 7.5 | 1 |
| Eunotia exigua |  |  |  |  |  |  |  |  |  |  |  | 1 |
| Euntoia flexuosa |  | 1 | 1 |  |  |  |  |  |  | 2 | 1 |  |
| Eunotia glacialis |  |  | 1 |  |  |  |  |  |  | 3.5 |  |  |
| Eunotia incisa |  |  |  |  |  |  |  |  |  |  |  | 1 |
| Eunotia lapponica |  |  |  |  |  |  |  |  |  |  | 2 |  |
| Eunotia monodon |  |  | 1 |  |  |  |  |  |  |  | 1 |  |
| Eunotia nymanniana | 7.5 | 5.5 |  |  | 1.5 | 4.5 | 32 | 16 | 14 | 9 | 8.5 |  |
| Eunotia paludosa | 40 | 15 | 78 | 7 | 32 | 119 | 149 | 148 | 167 | 112 | 129 | 31 |
| E. paludosa v. trinacria |  |  |  |  |  |  |  |  |  |  |  |  |
| E. paludosa v. type 2 | 12 | 4 |  |  |  |  |  |  |  |  |  |  |
| Eunotia praerupta |  |  |  |  |  |  |  |  | 2 |  | 2 | 2 |
| Eunotia septrentionalis |  |  |  |  |  |  |  |  |  |  |  | 1 |
| Fragilaria spp. |  |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria brevistrata |  |  |  | 4 |  |  |  |  |  |  | 1 |  |
| Fragilaria capucina |  | 3 |  | 8 | 2 |  |  |  |  | 4 | 7 | 10 |
| Fragilaria construens |  | 6 | 3 |  | 1 |  |  |  | 2 | 5 |  |  |
| Fragilaria ulna | 1 |  | 8 | 2 |  | 6 |  | 1 | 1 | 4 | 2 | 3 |
| Frustulia rhomboides |  |  |  |  |  |  |  |  | 1 |  |  |  |
| Gomphonema spp. |  | 1 | 4 | 2 |  | 3 |  |  | 2 | 2 | 2 |  |
| Gomphonema gracile |  |  |  | 4 |  |  |  |  |  |  |  | 5 |
| Gomphonema parvulum |  |  |  |  | 2 |  |  | 4 |  |  |  |  |
| Hantzschia amphioxys | 12 | 19 | 20 | 40 | 17 | 18 | 6 | 13 | 15 | 22 | 7 | 10 |
| Hantzschia elongata |  |  |  | 2 | 2 | 1 |  | 3 | 1 | 4 | 2 | 2 |
| Navicula spp. |  |  |  | 1 |  |  |  |  |  |  |  |  |
| Navicula cf submuralis | 4 |  | 2 | 2 |  | 22 | 20 | 5 | 14 | 5 | 11 | 2 |
| Navicula atomus |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula cryptocephala |  |  |  |  |  |  |  |  |  |  |  |  |

| | 77 | 79 | 81 | 83 | 85 | 93 | 100 | 102 | 104 | 108 | 110 | 112 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Navicula cuspidata | | | 1 | 2 | | | | | | | 1 | |
| Navicula elginensis | | | | | | | | | | 3 | | |
| Navicula minima | | | | | | | | | | | | 1 |
| Navicula mutica | 4 | 8 | 9 | 15 | 10 | 9 | 1 | 3 | 3 | 3 | 2 | 2 |
| Navicula nivalis | | | | | | | | | | | | |
| Navicula pupula | 2 | | | 5 | 1 | 4 | | 3 | 6 | 6 | 3 | 5 |
| Navicula subtilissima | 7 | 1 | | | 5 | 28 | 63 | 42 | 60 | 65 | 39 | 5 |
| Navicula tuscula | | | | | | | | | | | 3 | |
| Neidium spp. | | | | | | | | | | | | |
| Nitzschia spp. | | | 3 | 4 | | | | | | | 3 | |
| Nitzschia perminuta | | 2 | | | 4 | | 3 | 1 | | | | 3 |
| Pinnularia centres | | | | 2 | 1 | | | | | | | |
| Pinnularia borealis | 8 | 11 | 7 | 15 | 5 | 8 | 2 | 4 | 5 | 7 | 5 | 7 |
| Pinnularia brevicostata | | | | | | | | | | | | 3 |
| Pinnularia gibba | | | 1 | 1 | 2 | | | | | | | |
| Pinnularia cf maior | 9 | 1 | 1 | 1 | 2 | 11 | 53 | 45 | 67 | 27 | 23 | 1 |
| Pinnularia microstauron | 1 | 4 | 4 | | 5 | 1 | 2 | 4 | 1 | 2 | 7 | 2 |
| Pinnularia schroederii | | | | | | | | | | | | |
| Pinnularia supcapitata | 2 | | | | | 5 | | | | | | |
| Pinnularia streptoraphe | 1 | 2 | 3 | 1 | 2 | 1 | | 1 | 1 | 4 | 1 | 5 |
| Rhopolodia spp. | | | | | | | | | | | | |
| Rhopolodia gibba | | 1 | 1 | 2 | 1 | 1 | | 4.5 | 3 | 2 | 5 | 2 |
| Stauroneis spp. | | 3 | 2 | 2 | 2 | 1 | 1 | | | 1 | 1 | 2 |
| Stephanodiscus spp. | | 1 | | | 1 | | | | 1 | 1 | | |
| Eunotia sp. 1 | | | | | | | | | | | 1 | |
| Tabellaria flocculosa str. 1 | | | | | | | | | 1 | | | |

## E.4 VC04-06 raw diatom counts (Chapter 3)

| | 0 | 2 | 5 | 7 | 10 | 12 | 15 | 17 | 20 | 22 | 25 | 27 | 30 | 32 | 35 | 37 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Achnanthes spp. | | | | | | | | | | | | | | | | | 2 |
| Achnanthes lanceolata | | | | | | | | | | | | | | | | | |
| Amphora spp. | | | | | | | | | | | | | | | | | |
| Amphora inariensis | | | | | | | | | | | | | | | | | |
| Amphora libyca | | | | | | | 1 | | | | | | | | | | |
| Aulacoseira spp. | | | | | | | | | | | | | | | | | |
| Aulacoseira ambigua | | 2 | | | | | | | | | | | | | | | 2 |
| Aulacoseira crenulata | | | | | | | | | | | | | | | | | |
| Aulacoseira granulata | | 2 | | | | | 1 | | | | | | | | | | |
| Aulacoseira islandica | | | | | | | 2 | | | | | | | | | | |
| Aulacoseira subarctica | 6 | | 5 | | 2 | | 5 | | 5 | | 3 | | | | 4 | | 12 |
| Brachysira zellensis | | | | | | | | | | | | | | | | | |
| Caloneis spp. | | | | | | | | | | | | | | | | | |
| Caloneis bacillum | | | | | | | 6 | | | | | 2 | | 6 | 20 | 60 | 3 |
| Caloneis molaris/tenuis | | | | | | | 1 | | | | | 2 | | | | | |
| Coccenenis spp. | | | | | | | | | | | | | | | | | |
| Cocconeis placentula | | 3 | | 1 | | | | | | | | | | 1 | | | |
| Cymbella spp. | | | | | | | | | 1 | | | 1 | | | | | 2 |
| Cymbella gracilis | | | | | | | | | | | | | | | | | 1 |
| Cymbella norvegica | | | | | | | | | | | | | | | | | |
| Cymbella proxima | | | | | | | | | | | | | | | | | |
| Cymbella silsiaca | | | | | | | 3 | | | | | | | | | | |
| Cyclotella spp. | 2 | | 6 | | 10 | | 1 | | | | | 2 | | | | | |
| Cyclotella bodanica | | | | | | | | | | | | | | | 1 | | 3 |
| Cyclotella stelligera | | | | | | | 1 | | | | | | | 2 | | | |
| Denticula kuetzingii | 1 | 2 | | 1 | | 4 | | 2 | 3 | | 2 | 1 | | | 11 | 3 | 2 |
| Diatoma spp. | | | | | | | | | 1 | | | | | | | | |
| Diploneis spp. | | | | | 1 | | 1 | | | | | | | | | | |
| Diploneis elliptica | | | | | | | | | | | | | | | | | |
| Diploneis parma | | | | | | | | | | | | | | | | | |
| Epithemia spp. | | | | | 1 | | 1 | | | | | | | | 2 | | 4 |
| Epithemia adnata | | 1 | | | | | | | | | | | | | | | |
| E. bilunaris v. biliunaris | | 1 | | 1 | | | | | | | | | | | | | |
| E. bilunaris v. mucophila | 2 | | | | | | | 1 | | | 1 | | | 2 | 6 | 30 | 18 |
| Eunotia eruca | | | | | | | | | | | | | | | | | 1 |
| Eunotia exigua | | 2 | | | | | | | | | | | | | | | |
| Eunotia flexuosa | | | | | | | | | | | | | | | | 1 | |
| Eunotia glacialis | | | | | | | | | | | | 1 | | | | | |
| Eunotia incisa | | | | | | | | | | | | | | | | | |
| Eunotia lapponica | | 1 | | | | | 1 | | | | | | | | | | 1 |
| Eunotia maior | | | | | | | | | | | | | | 1 | | | |
| Eunotia nymanniana | 2 | 1 | | | | | | | | | | | | 3 | 16 | 4 | 7 |
| Eunotia paludosa | 148 | 253 | 305 | 300 | 192 | 177 | 54 | 139 | 96 | 331 | 180 | 243 | 350 | 218 | 194 | 307 | 131 |
| Eunotia praerupta | | | | 1 | | | | | | | | | | | | | |
| Eunotia septrentionalis | | 1 | | | | | | | | | | | | | | | |
| Fragilaria brevistrata | 8 | 1 | | | | | | | | | | | | | | 1 | 1 |
| F. brevistrata/capucina | | 1 | | 4 | | | | | | | | 3 | | | | | |
| Fragilaria construens | | 3 | | | | | 2 | | | | | 2 | | 4 | | | |
| Fragilaria exigua | | | | | | | | | | | | | | | | | |
| Fragilaria elliptica | | | | | | | | | | | | | | | | | |

| | 0 | 2 | 5 | 7 | 10 | 12 | 15 | 17 | 20 | 22 | 25 | 27 | 30 | 32 | 35 | 37 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fragilaria fasciculata | | | | | | | 2 | | | | | | | | | | |
| Fragilaria lapponica | | | 11 | | 1 | | | | | | | | | | | | |
| Fragilaria parasitica | | | | | | | | | | | | | | | 1 | | |
| Fragilaria pinnata | | | 4 | | 1 | | 5 | | 2 | | 1 | | 7 | | 3 | | 8 |
| Fragilaria ulna | 1 | 1 | | | | | 2 | | 1 | | | | | | 2 | | |
| Frustulia rhomboides | | | | | | | | | | | | | | | | | |
| Gomphonema spp. | | | | | | | | | | | | | | | | | 4 |
| Gomphonema gracile | | | | | | | | | | | | | | | | 2 | |
| Gomphonema intricatum | | | | | | | | | | | | | | | | | |
| Gomphonema lagerhemeii | | | | | | | | | | | | | | | | | |
| Gomphonema parvulum | | | | | | | | | | | | | | | | | |
| Gomphonema truncatum | | | | | | | | | | | | | | | | | |
| Hantzschia amphioxys | 3 | 30 | 6 | 4 | 2 | 12 | 48 | 2 | 4 | 7 | 4 | 8 | 3 | 4 | 18 | 7 | 42 |
| Hantzschia elongata | | 1 | | | | 2 | | | | | | | | | | | |
| Navicula spp. | | | | | | | | | | | | | 3 | | 1 | | |
| N. cf bergerii | | | | | | | | | | | | | | | | | |
| Navicula capitata | | | | | | | | | | | | | | | | | |
| Navicula cryptocephala | | 2 | | | | 2 | | | | | | | | | | | |
| Navicula cuspidata | | | | | | | | 1 | | | | | | | | | |
| Navicula gallica | | 1 | | | | | | | | | | | | | | | |
| Navicula elginensis | | | | | | | | | | | | | | | | | |
| Navicula cf lapidosa | | | | | | | 4 | | | | | | | | | | |
| Navicula mutica | 2 | 50 | 3 | | 4 | 3 | 47 | 2 | 3 | 6 | 3 | 2 | 3 | | 6 | 5 | 29 |
| Navicula nivalis | | | | | | | | | | | | | | | | | |
| Navicula pupula | | | | | | 1 | 1 | | 1 | | | 3 | | | 5 | | 1 |
| Navicula pseudoventralis | | | | | | | | | | | | | | | | | 1 |
| Navicula subminuscula | | | 3 | | | | | | | | | | | | | | |
| Navicula subtillisima | 4 | | | | | | 1 | | | | | 1 | 1 | | 10 | | 5 |
| Navicula tuscula | | | | | | | | | | | | | | | | | |
| Navicula vulpina | | | | | | | | | | | | | | | | | |
| Neidium spp. | | | | | | | | | | | | | | | | | |
| Nitzschia alpina | | | | | | | | | | | | | | | 2 | | 1 |
| Nitzschia frustulum | | | | | | | | | | | | | | | | | |
| Nitzschia gracilis | | | | | | | | | | | | | | | | | |
| Nitzschia perminuta | | | | | | 4 | | | | | | 4 | | | 2 | | 2 |
| Pinnularia centres | | | | | | | | | | | | | | | 4 | | |
| Pinnularia borealis | 1 | 15 | 3 | 1 | | 4 | 15 | | 1 | 3 | 1 | 1 | 2 | | | 3 | 19 |
| P. borealis v. rectangularis | | | | | | | | | | | | | | | | | 10 |
| Pinnularia gibba | 2 | | | | | | | | | | | | | | 1 | | |
| Pinnularia karelica | | | | | | | | | | | | | | | | | |
| Pinnularia cf maior | | | | | | | | | | | | | | | | 3 | |
| Pinnularia microstauron | | 1 | | | | 4 | | | | | | 2 | | | 3 | 1 | 5 |
| Pinnularia pulchra | | | | 1 | | | | | | | | | | | | | |
| Pinnularia streptoraphe | | 1 | | | 1 | | | 1 | | | | 1 | | | 1 | | 2 |
| Rhopolodia spp. | | | | | | | | | | | | | | | 1 | | |
| Rhopolodia gibba | | 1 | | 1 | | 1 | | | | | | | | | | 1 | |
| Rhopolodia operculata | | | | 1 | | | | | | | | | | | | | |
| Stauroneis spp. | | 3 | | 1 | | 3 | | | | 1 | | | | | | | |
| Stauroneis phoenicenteron | | | | | | | | | | | | | | | 2 | | |
| Stauroneis anceps | | | | | | | | | | | | | | | | | |

| | 0 | 2 | 5 | 7 | 10 | 12 | 15 | 17 | 20 | 22 | 25 | 27 | 30 | 32 | 35 | 37 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stephanodiscus spp. | 1 | | | | | | | | | | | | | | | | |
| Stephanodiscus niagrae | | | | | | | | | | | | | | | | | 1 |
| Stephanodiscus medius | | | | | | 1 | 2 | | | | | | | | 1 | | 2 |
| Stephanodiscus minutulus | | | | | | | | | | | | | | | | | |
| Tabellaria flocculosa | | | | | 2 | | 1 | | 1 | | | | | | 1 | | 4 |
| Unknown spp. | 2 | | | | | | | | 1 | | 8 | | 1 | | | | 1 |

|  | 42 | 45 | 47 | 50 | 52 | 55 | 57 | 60 | 65 | 67 |
|---|---|---|---|---|---|---|---|---|---|---|
| Achnanthes spp. | 1 |  | 1 |  |  |  |  |  |  |  |
| Achnanthes lanceolata |  |  | 2 |  |  |  |  |  |  |  |
| Amphora spp. |  |  |  | 2 |  |  | 3 |  | 2 |  |
| Amphora inariensis | 1 |  |  |  |  |  |  |  |  |  |
| Amphora libyca |  |  |  |  |  |  |  |  |  |  |
| Aulacoseira spp. |  |  | 3 |  | 7 | 2 |  |  | 1 | 2 |
| Aulacoseira ambigua |  |  |  |  | 2 |  |  |  |  |  |
| Aulacoseira crenulata | 5 |  |  |  |  |  |  |  |  |  |
| Aulacoseira granulata | 4 |  |  |  | 2 |  |  |  | 2 |  |
| Aulacoseira islandica |  |  |  |  |  | 4 |  |  |  |  |
| Aulacoseira subarctica |  | 9 |  | 3 |  | 11 | 2 | 4 | 2 |  |
| Brachysira zellensis |  | 1 |  |  |  |  |  |  |  |  |
| Caloneis spp. |  | 1 |  |  |  | 1 | 1 |  |  | 1 |
| Caloneis bacillum | 1 |  |  |  |  |  |  |  |  |  |
| Caloneis molaris/tenuis | 2 |  |  |  | 4 |  |  |  |  |  |
| Coccenenis spp. |  |  |  |  |  |  |  | 1 |  |  |
| Cocconeis placentula | 1 |  | 1 |  |  |  |  |  |  |  |
| Cymbella spp. |  | 1 | 5 |  | 2 |  |  | 1 |  | 2 |
| Cymbella gracilis |  |  |  |  |  |  |  |  |  |  |
| Cymbella norvegica | 2 |  |  |  |  |  |  |  |  |  |
| Cymbella proxima | 1 |  |  |  | 1 |  |  |  |  |  |
| Cymbella silsiaca |  | 3 |  |  | 1 |  | 2 |  |  |  |
| Cyclotella spp. |  |  | 1 |  | 1 |  |  |  |  | 1 |
| Cyclotella bodanica |  |  | 1 | 6 |  | 3 | 1 |  | 2 | 1 |
| Cyclotella stelligera | 1 |  |  |  |  |  |  |  |  |  |
| Denticula kuetzingii | 11 |  | 15 | 3 | 39 |  | 11 | 10 | 2 | 6.5 |
| Diatoma spp. |  |  |  |  |  |  |  |  |  |  |
| Diploneis spp. |  |  |  |  |  |  |  |  |  |  |
| Diploneis elliptica |  |  |  | 2 |  |  |  |  |  |  |
| Diploneis parma |  |  |  |  |  |  |  |  |  | 1 |
| Epithemia spp. |  | 2 |  |  |  | 2 | 1 |  |  |  |
| Epithemia adnata | 5 |  | 3 |  | 10 |  | 7 |  |  | 1 |
| E. bilunaris v. biliunaris | 1 |  | 7 |  | 5 | 7 |  | 1 |  | 1 |
| E. bilunaris v. mucophila | 2 | 2 |  | 2 |  | 2 |  | 3 | 3 | 1 |
| Eunotia eruca |  |  |  |  |  |  |  |  | 1 |  |
| Eunotia exigua |  |  | 1 |  |  |  |  |  |  |  |
| Eunotia flexuosa | 2 |  |  |  |  |  |  |  |  |  |
| Eunotia glacialis | 4 |  |  |  | 3 |  | 1 |  |  | 2.5 |
| Eunotia incisa | 1 |  | 1 |  | 1 | 1 |  |  |  |  |
| Eunotia lapponica |  | 3 |  | 1 |  |  |  | 2 |  |  |
| Eunotia maior |  |  |  |  |  |  |  |  |  |  |
| Eunotia nymanniana | 7 | 1 | 5 |  | 8 | 1 | 1 |  |  |  |
| Eunotia paludosa | 64 | 21 | 10 | 5 | 4 | 31 | 21 | 9 | 15 | 61 |
| Eunotia praerupta |  |  |  |  | 2 |  |  |  |  |  |
| Eunotia septrentionalis |  |  |  |  |  |  |  |  |  |  |
| Fragilaria brevistrata | 8 |  | 4 |  | 2 |  | 1 |  |  | 7 |
| F. brevistrata/capucina |  |  | 5 |  | 40 | 1 | 10 |  |  |  |
| Fragilaria construens | 7 |  | 11 | 1 | 12 | 2 | 28 |  |  | 52 |
| Fragilaria exigua |  |  |  |  |  |  | 3 |  | 2 |  |
| Fragilaria elliptica |  |  |  |  |  |  |  | 1 |  |  |

|  | 42 | 45 | 47 | 50 | 52 | 55 | 57 | 60 | 65 | 67 |
|---|---|---|---|---|---|---|---|---|---|---|
| Fragilaria fasciculata |  |  |  |  |  |  |  |  |  |  |
| Fragilaria lapponica |  |  |  |  |  |  |  |  |  |  |
| Fragilaria parasitica |  | 2 |  |  |  |  |  |  |  |  |
| Fragilaria pinnata | 2 | 17 | 3 | 17 |  | 21 | 1 | 1 | 4 |  |
| Fragilaria ulna | 1 | 4 | 5 | 1 | 2 | 2 |  | 2 | 1 |  |
| Frustulia rhomboides |  |  |  |  | 2 |  |  |  |  | 1 |
| Gomphonema spp. | 4 |  | 1 |  |  | 1 | 1 | 2 |  | 2 |
| Gomphonema gracile | 1 |  | 1 |  | 3 |  |  |  |  |  |
| Gomphonema intricatum |  |  |  |  |  | 1 |  | 1 |  |  |
| Gomphonema lagerhemeii |  |  |  |  | 3 |  |  |  |  |  |
| Gomphonema parvulum |  |  |  |  | 1 |  |  | 3 |  | 2 |
| Gomphonema truncatum |  |  |  |  | 4 |  | 2 |  |  |  |
| Hantzschia amphioxys | 79 | 31 | 71 | 15 | 89 | 18 | 21 | 23 | 8 | 43 |
| Hantzschia elongata | 3 |  | 3 |  | 8 |  | 2 |  |  | 3 |
| Navicula spp. |  |  |  |  |  | 2 |  |  | 1 |  |
| N. cf bergerii |  |  |  |  | 2 |  |  |  |  |  |
| Navicula capitata |  |  |  |  | 1 |  |  |  |  |  |
| Navicula cryptocephala |  |  | 1 |  | 1 |  |  |  |  |  |
| Navicula cuspidata |  |  |  |  | 1 |  |  |  |  | 1 |
| Navicula gallica | 1 |  | 1 |  |  |  |  |  |  |  |
| Navicula elginensis |  |  | 3 |  | 6 |  | 1 |  |  |  |
| Navicula cf lapidosa |  |  |  |  |  |  |  |  |  |  |
| Navicula mutica | 41 | 20 | 37 | 12 | 29 | 5 | 3 | 10 | 8 | 12 |
| Navicula nivalis |  |  |  |  |  | 2 |  |  |  |  |
| Navicula pupula | 3 | 5 | 7 | 1 | 7 | 4 | 4 | 3 | 5 | 8 |
| Navicula pseudoventralis |  | 1 |  |  |  |  |  |  |  |  |
| Navicula subminuscula |  |  |  |  |  |  |  |  |  |  |
| Navicula subtillisima |  |  |  |  |  | 1 |  |  | 1 |  |
| Navicula tuscula |  |  |  |  | 3 |  |  |  |  |  |
| Navicula vulpina |  |  |  |  |  |  |  |  |  | 1 |
| Neidium spp. |  |  |  |  |  |  | 1 |  |  | 1 |
| Nitzschia alpina |  |  |  |  |  | 1 |  | 1 |  |  |
| Nitzschia frustulum |  | 4 |  |  |  |  |  |  |  |  |
| Nitzschia gracilis |  |  |  |  |  |  |  | 1 |  |  |
| Nitzschia perminuta | 9 | 2 | 3 |  | 11 |  | 1 |  |  | 7 |
| Pinnularia centres |  | 7 |  |  |  |  |  |  | 2 | 1 |
| Pinnularia borealis | 20 | 5 | 24 | 4 | 35 | 7 | 9 | 7 | 1 | 30 |
| P. borealis v. rectangularis |  |  |  |  |  |  |  |  |  |  |
| Pinnularia gibba |  |  |  |  | 1 | 4 |  | 5 | 1 | 4 |
| Pinnularia karelica |  |  |  |  |  |  |  |  |  | 2 |
| Pinnularia cf maior |  |  |  |  |  |  |  | 4 |  |  |
| Pinnularia microstauron | 16 | 9 | 14 |  | 6 | 3 |  |  | 2 | 4 |
| Pinnularia pulchra |  |  |  |  |  |  |  |  |  |  |
| Pinnularia streptoraphe | 5 | 3 | 3 | 2 | 13 |  | 3 |  |  | 9 |
| Rhopolodia spp. |  |  |  |  |  |  |  | 3 |  |  |
| Rhopolodia gibba | 1 |  | 4 |  | 2 |  | 3.5 |  |  | 3 |
| Rhopolodia operculata | 4 |  | 1 |  |  |  |  |  |  |  |
| Stauroneis spp. | 2 |  | 5 |  | 1 |  | 1 |  |  |  |
| Stauroneis phoenicenteron |  | 2 |  | 1 |  |  |  |  |  |  |
| Stauroneis anceps |  | 1 |  |  |  |  |  |  |  |  |

|  | 42 | 45 | 47 | 50 | 52 | 55 | 57 | 60 | 65 | 67 |
|---|---|---|---|---|---|---|---|---|---|---|
| Stephanodiscus spp. |  |  |  |  |  |  |  |  |  |  |
| Stephanodiscus niagrae |  |  |  |  |  |  |  |  |  |  |
| Stephanodiscus medius |  |  |  |  |  |  |  | 1 |  |  |
| Stephanodiscus minutulus |  |  |  | 1 |  |  |  | 2 |  |  |
| Tabellaria flocculosa |  | 1 |  | 2 |  | 1 | 1 |  |  | 1 |
| Unknown spp. |  | 1 |  | 8 |  | 1 |  | 3 |  |  |

## E.5 McFaulds Lake raw diatom counts (Chapter 4)

| | 0.00 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 | 2.50 | 2.75 | 3.00 | 3.25 | 3.50 | 3.75 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Achnanthes spp. | | | | | | | | | | | | | | | | |
| Achnanthes carissima | | | | | | | | | | | | | | | | |
| Achnanthes childanos | 3 | | 2 | | 4 | 2 | | 2 | 1 | 2 | 2 | | | 2 | | 1 |
| Achnathes didymo | | | | | | | | | | | | | | 2 | | 2 |
| Achnanthes exigua | | | 4 | 2 | | 2 | 1 | 2 | | | 2 | | | 4 | | |
| Achnanthes flexella | 2 | 3 | | | 3 | | | | 3 | 2 | | 2 | 3 | | | 2 |
| Achnanthes impexiformis | | | | | | | | | | | | | | | | 2 |
| Achnanthes lacus-vulcani | | | | | | | | | | | | | | | | |
| Achnanthes lanceolata | | | | | 2 | | | | | | | | | | | |
| Achnanthes levanderi | | | 3 | | | 1 | | | | | | | 6 | | 6 | |
| Achnanthes linearis | | 1 | | 2 | 6 | 2 | | | | | 2 | | | | | 2 |
| Achnanthes marginulata | | | | | | | | | | | | | | | | |
| Achnanthes minutissima | 36 | 32 | 42 | 28 | 35 | 37 | 38 | 38 | 72 | 48 | 42 | 30 | 38 | 44 | 38 | 37 |
| Achnanthes nodosa | | | | | | | | | | | | 2 | | | | |
| Achnanthes saccula | 21 | 25 | 43 | 38 | 51 | 20 | 28 | 37 | 12 | 19 | 34 | 30 | 30 | 33 | 18 | 35 |
| Achnanthes subatomoides | | | | | | | 2 | 2 | 2 | 4 | 4 | 2 | 1 | | | 3 |
| Amphipleura spp. | | | | | | | | | | | | | | | | |
| Amphipleura rutilans | | | | | 2 | | | | | | | | | | | |
| Amphora inariensis | | | | | | | | | | | | | | | 4 | |
| Amphora ovalis | | | | | | | | | | 2 | 1 | | | 4 | | |
| Asterionella formosa | 6 | 6 | 8 | 7 | 3 | 7 | 6 | 6 | 3 | 9 | 4 | 5 | 12 | 12 | 7 | 2 |
| Aulacoseira spp. | | | | | | | | | | | | | | | | |
| Aulacoseira ambigua | | 2 | | | 1 | | | 2 | | 1 | 1 | | | 5 | 3 | 1 |
| Aulacoseira subarctica | | | | | | | | | | | | | | | | |
| Aulacoseira valida | | | | | | | | | | | 1 | | | | | |
| Brachysira spp. | | | | | | | | | | | | | | | | |
| Brachysira neoexilis | 22 | 24 | 21 | 16 | 11 | 14 | 10 | 22 | 4 | 7 | 4 | 8 | 7 | 9 | 8 | 9 |
| Caloneis spp. | | | 1 | 1 | | 1 | 1 | 4 | 2 | | | | | 2 | | |
| Caloneis silicula | | | | | | | | | | | | | | | | |
| Cocconeis placentula | | | | | | | | | | | | | | | | |
| Cyclotella bodanica v. lemmanica | | 1 | | 3 | 1 | | | | | 3 | | 1 | 1 | | | 2 |
| Cyclotella stelligera | | | | | | | | | 2 | | | | | | | |
| Cymbella spp. | | | | | | | | | | | | | | | | |
| Cymbella amphicephala | 1 | 1 | | | | | | | | | | | | | | |
| Cymbella cuspidata | | | | | | | | | | | | | | 2 | | |
| Cymbella descripta | 3 | 4 | 4 | 1 | 2 | 4 | | 11 | | 4 | 2 | 2 | 3 | 4 | 3 | |
| Cymbella gracilis | | | | | | | | | | | | | | | | 2 |
| Cymbella hebridica | 2 | | | | | 2 | | | | 1 | | | 3 | | | 1 |
| Cymbella incerta | | 6 | 4 | 5 | | 2 | 6 | 2 | | | 4 | 2 | 1 | 3 | 1 | 2 |
| Cymbella minuta | | | | | | | | | | | | | | | | |
| Cymbella silesiaca | | | | | | | | | | 4 | | 2 | | | | |
| Denticula kuet. | | | | | | | | | | | | | | | | |
| Diploneis spp. | | | | | | | | | | | | | | | | |
| Diploneis marginestriata | | | | | | | | | 1 | | 1 | | | | | |
| Diploneis parma | | | | | | | | | | | | | | | | |
| Epithemia adnata | | | | | | | | | | | | | | | | |
| Eunotia spp. | | | 1 | | | | | | | | | | | | | |
| Eunotia argus | | | | | | | | | | | | | | | | 1 |
| Eunotia circumborealis | | | | | | | | | | | | | | | | |
| Eunotia incisa | | | | | | | | | | | 1 | | | | | |

|  | 0.00 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 | 2.50 | 2.75 | 3.00 | 3.25 | 3.50 | 3.75 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Eunotia monodon |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia praerupta |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia rhomboidea |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria brevistriata | 22 | 17 | 16 | 38 | 31 | 30 | 26 | 46 | 19 | 33 | 19 | 30 | 28 | 22 | 44 | 17 |
| F. brevistriata v. papillosa |  |  |  |  | 4 | 4 | 10 | 10 | 9 | 2 |  | 2 |  |  |  | 2 |
| Fragilaria capucina | 15 | 20 | 22 | 20 | 15 | 18 | 24 | 15 | 12 | 15 | 23 | 21 | 20 | 23 | 15 | 20 |
| F. construens v. construens | 23 | 44 | 50 | 45 | 54 | 9 | 19 | 42 | 4 | 40 | 20 | 32 | 19 | 25 | 15 | 6 |
| F. construens v. venter | 57 | 52 | 46 | 74 | 53 | 61 | 61 | 37 | 61 | 45 | 62 | 58 | 63 | 38 | 43 | 65 |
| Fragilaria crotonensis | 8 | 5 |  | 5 | 6 | 12 | 15 | 8 | 4 | 9 | 33 | 13 | 12 | 2 | 14 | 18 |
| Fragilaria leptostauron | 7 | 9 | 21 | 13 | 15 | 9 | 24 | 2 | 25 | 20 | 15 | 15 | 32 | 7 | 7 | 17 |
| F. pinnata v. pinnata | 7 | 17 | 20 | 27 | 10 | 19 | 34 | 28 | 37 | 19 | 26 | 25 | 23 | 30 | 28 | 26 |
| Fragilaria tenera | 10 | 5 | 14 | 9 | 15 | 8 | 10 | 8 | 16 | 8 | 4 | 9 | 10 | 16 | 17 | 9 |
| F. virescins v. exigua |  |  |  |  |  |  |  |  | 1 |  |  |  |  |  |  |  |
| Frustulia rhomboides |  |  |  |  |  |  |  | 1 |  |  |  |  |  |  |  |  |
| Gomphonema parvulum |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 2 |  |
| Hantzchia amphioxys |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula absoluta |  |  |  |  |  |  |  |  | 2 |  |  |  |  | 2 | 2 |  |
| Navicula cocconeiformis |  |  |  |  |  |  | 2 |  |  |  |  | 1 |  |  |  |  |
| Navicula cuspidata |  |  |  |  |  | 2 |  |  |  |  |  |  |  | 1 |  |  |
| Navicula cryptocephala | 17 | 6 | 7 | 15 | 14 | 16 | 7 | 21 | 8 | 11 | 11 | 21 | 13 | 11 | 4 | 13 |
| Navicula disjuncta | 2 | 1 |  |  |  |  | 2 | 1 |  |  |  | 2 | 2 | 2 | 3 |  |
| Navicula elginensis | 2 | 2 | 1 |  |  | 2 |  |  | 1 |  |  | 1 | 2 | 5 | 2 | 2 |
| Navicula jaagii |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  |  |
| Navicula kuelbsii |  |  | 4 | 7 | 4 | 5 | 8 | 8 | 8 | 4 | 12 | 21 | 7 | 6 | 11 | 3 |
| Navicula laevissima |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula leptostriata | 5 | 6 |  | 3 | 6 | 8 | 2 | 8 | 5 | 4 | 1 | 8 | 9 | 12 | 1 | 5 |
| Navicula mediocris |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula minima | 4 | 12 | 6 | 13 | 4 | 4 | 4 | 9 | 8 | 8 | 11 | 9 |  | 6 | 7 | 7 |
| Navicula mimima small |  | 2 | 4 | 3 | 2 | 2 | 6 | 6 |  | 2 | 2 | 4 |  | 10 |  | 4 |
| Navicula mutica |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula pupula | 9 | 4 | 3 | 8 | 5 | 4 | 2 | 4 | 5 |  | 2 | 3 |  | 9 | 12 | 3 |
| Navicula pseudoscutiformis |  |  |  |  |  | 2 |  |  |  |  |  |  | 2 | 1 | 2 | 2 |
| Navicula pseudoventralis |  | 1 |  |  |  |  |  |  |  | 2 |  |  | 2 | 2 |  |  |
| Navicula radiosa | 3 | 1 |  | 1 |  |  |  |  |  |  |  |  | 3 |  |  |  |
| Navicula rhynchocephala |  |  | 2 |  |  |  |  |  |  |  |  |  |  |  |  | 2 |
| Navicula reinhardtii | 1 |  |  |  | 1 |  |  |  | 1 | 1 |  |  |  |  |  | 4 |
| Navicula salinarium |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  |
| Navicula schadei |  |  |  |  |  |  |  |  |  |  |  | 2 |  |  |  |  |
| Navicula seminulum | 3 | 2 |  | 2 | 6 | 3 | 5 | 4 | 13 | 6 | 6 | 9 | 20 | 2 | 2 | 5 |
| Navicula soehrensis | 2 | 2 |  | 2 |  | 2 | 1 | 1 |  |  |  |  |  |  | 1 |  |
| Navicula submuralis | 2 | 3 | 2 | 8 | 4 |  |  | 2 | 3 | 2 |  | 2 | 11 |  | 2 | 2 |
| Navicula subrotundata | 3 |  | 1 |  |  | 6 |  |  |  | 4 | 5 | 2 | 6 |  | 7 | 1 |
| Navicula subtilissima |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula tuscula |  |  |  |  |  |  |  |  |  |  | 1 |  |  |  |  |  |
| Navicula variostriata |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  | 7 |  |
| Navicula ventralis |  |  |  |  |  |  |  |  |  |  |  |  | 2 |  | 2 |  |
| Navicula viridula |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 2 |  |
| Navicula vitabunda |  |  |  |  |  |  |  |  |  |  |  |  | 4 |  |  | 2 |
| Navicula vitiosa | 11 | 3 | 9 | 5 | 10 | 7 | 14 | 10 | 12 | 13 | 25 | 11 | 11 | 5 | 4 | 7 |
| Navicula vulpina |  | 1 | 2 | 3 | 2 | 3 |  | 1 |  |  |  |  | 2 | 4 | 2 | 1 |

|  | 0.00 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 | 2.50 | 2.75 | 3.00 | 3.25 | 3.50 | 3.75 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Neidium spp. (Centres) | 1 |  |  |  |  |  |  |  |  | 1 |  | 1 | 2 | 1 | 1 | 1 |
| Neidium amplicatum | 1 | 2 | 2 | 1 |  | 2 | 3 |  | 2 |  |  | 2 | 2 |  | 6 | 2 |
| Neidium hitchcockii |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 2 |
| Neidium iridis |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  | 1 |  |
| Neidium septrentionale |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Nitzschia dissipata | 4 | 1 | 1 | 3 | 2 | 4 | 1 | 3 | 4 | 2 | 5 | 4 | 4 | 8 |  | 8 |
| Nitzschia frustulum |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Nitzschia glacilis | 13 | 13 | 19 | 14 | 6 | 12 | 8 | 13 | 10 | 15 | 11 | 14 | 5 | 19 | 6 | 6 |
| Nitzschia incognita | 21 | 20 | 23 | 23 | 26 | 26 | 29 | 27 | 32 | 23 | 28 | 24 | 24 | 24 | 29 | 17 |
| Nitzschia intermedia |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Nitzschia palea | 7 | 12 | 9 | 10 | 14 | 8 | 4 | 7 | 10 | 11 | 11 | 12 | 15 | 9 | 14 | 8 |
| Nitzschia perminuta | 181 | 119 | 118 | 98 | 134 | 107 | 120 | 128 | 134 | 106 | 85 | 95 | 79 | 94 | 72 | 130 |
| Nitzschia pura |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Nitzschia recta | 3 | 6 |  | 3 | 4 | 2 |  | 7 | 1 |  | 3 |  | 4 |  | 3 | 3 |
| Pinnularia spp. |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  |  |
| Pinnularia borealis |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia gibba | 1 |  |  |  |  | 2 |  |  |  |  |  |  |  |  |  |  |
| Pinnularia interrupta |  |  | 1 | 1 | 4 | 1 | 6 | 2 | 4 | 7 | 2 | 2 |  | 1 | 5 | 9 |
| Pinnularia cf karelica |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia microstauron |  |  |  | 2 |  | 3 | 1 |  |  |  |  |  | 2 |  |  | 4 |
| Pinnularia nodosa |  |  |  |  |  |  |  |  |  |  |  | 1 |  |  |  |  |
| Pinnularia rupestris |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia viridis |  |  |  |  |  |  |  | 1 | 2 | 1 |  |  |  |  |  | 4 |
| Stauroneis spp. (Centres) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Stauroneis acuta |  |  |  |  |  |  |  |  | 1 |  |  |  |  |  |  |  |
| Stauroneis anceps |  |  |  |  | 2 |  | 1 |  |  |  | 1 | 1 |  |  |  | 2 |
| Stauroneis lauenburginana |  |  | 1 |  | 2 | 1 |  |  |  |  |  |  | 2 |  |  |  |
| Stauroneis noblis v. gracilis |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Stauroneis phoenicenteron |  | 1 | 2 |  | 3 | 2 |  | 1 | 1 | 1 | 3 |  | 2 | 2 | 4 | 6 |
| Stauroneis prominula |  |  |  |  |  |  |  |  |  |  |  | 2 |  |  |  |  |
| Stauroneis smithii |  |  |  |  |  |  |  |  |  |  | 2 |  |  |  |  |  |
| Stenopterobia spp. |  |  |  | 1 |  |  |  |  |  |  | 1 |  |  |  |  | 1 |
| Suriella spp. |  |  | 1 |  |  | 1 |  |  |  |  |  |  | 2 |  | 1 |  |
| Suriella constricta |  |  |  |  |  |  |  |  | 3 |  |  |  |  |  |  |  |
| Tabellaria fenestrata | 1 | 1 |  |  |  |  |  |  |  | 2 | 1 |  |  | 1 |  |  |
| Tabellaria flocculosa | 6 | 7 | 2 | 4 | 5 | 8 | 3 | 8 | 8 | 11 | 7 | 6 | 7 | 8 | 2 | 4 |
| Tabellaria flocculosa str. 4 |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  | 2 | 4 |
| Tabellaria quadrisepta | 2 |  | 8 |  |  |  | 3 |  |  |  | 2 | 1 | 3 |  | 1 |  |
| CYSTS | 10 | 7 | 5 | 12 | 17 | 16 | 12 | 25 | 22 | 13 | 18 | 19 | 30 | 13 | 16 | 21 |
| PHYTOLITHS |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  |
| SCALES |  |  |  |  |  |  |  |  | 1 |  | 1 |  |  |  | 1 |  |
| PLATES |  |  |  | 1 |  |  |  |  |  |  |  | 1 |  |  |  |  |

|  | 4.00 | 4.25 | 4.50 | 4.75 | 5.00 | 5.50 | 6.00 | 6.50 | 7.00 | 7.50 | 8.00 | 9.00 | 10.00 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Achnanthes spp. | 2 |  |  |  |  |  |  |  |  |  |  |  |  |
| Achnanthes carissima | 2 |  |  |  |  |  |  |  |  |  |  |  |  |
| Achnanthes childanos |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Achnathes didymo |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Achnanthes exigua |  |  |  |  |  |  |  |  |  |  | 4 |  |  |
| Achnanthes flexella |  |  |  |  |  |  | 1 |  |  |  | 3 | 4 | 1 |
| Achnanthes impexiformis |  |  |  |  | 1 |  |  |  |  |  |  |  |  |
| Achnanthes lacus-vulcani |  |  |  |  |  |  |  |  | 2 |  |  |  |  |
| Achnanthes lanceolata |  |  | 1 |  |  |  |  |  |  |  |  |  |  |
| Achnanthes levanderi |  |  | 2 |  |  |  |  |  |  |  |  |  |  |
| Achnanthes linearis | 2 | 1 |  |  |  |  |  |  |  |  |  |  |  |
| Achnanthes marginulata |  |  |  |  | 4 |  |  |  |  |  |  |  |  |
| Achnanthes minutissima | 16 | 34 | 24 | 15 | 14 |  | 5 |  | 4 |  |  |  | 2 |
| Achnanthes nodosa |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Achnanthes saccula | 19 | 21 | 14 | 4 | 16 | 2 |  |  |  | 2 |  | 2 |  |
| Achnanthes subatomoides |  |  |  |  | 2 |  |  |  |  |  |  |  |  |
| Amphipleura spp. |  |  | 1 |  |  |  |  |  |  |  |  |  |  |
| Amphipleura rutilans |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Amphora inariensis |  |  |  |  |  |  |  |  | 1 |  | 4 |  |  |
| Amphora ovalis |  |  | 9 | 8 | 7 | 6 | 7 | 12 | 16 | 7 | 12 | 11 | 16 |
| Asterionella formosa | 4 | 2 | 1 | 2 | 6 |  | 1 |  |  |  |  |  |  |
| Aulacoseira spp. |  |  |  | 3 |  | 2 | 1 | 1 | 2 | 3 | 3 | 1 | 1 |
| Aulacoseira ambigua |  |  |  | 1 | 1 |  |  |  |  |  |  |  |  |
| Aulacoseira subarctica |  |  | 1 |  |  |  |  |  | 1 |  |  |  |  |
| Aulacoseira valida |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Brachysira spp. |  |  |  |  |  |  |  |  |  |  | 1 |  |  |
| Brachysira neoexilis | 27 | 3 | 3 | 6 | 8 | 1 | 2 |  |  |  |  |  |  |
| Caloneis spp. | 2 |  |  |  |  |  |  | 2 |  |  |  |  |  |
| Caloneis silicula |  |  |  |  |  |  |  |  | 2 |  | 1 |  |  |
| Cocconeis placentula |  |  |  |  |  |  |  |  |  |  |  |  | 1 |
| Cyclotella bodanica v. lemmanica | 1 | 1 |  | 1 |  |  |  |  |  |  |  |  |  |
| Cyclotella stelligera |  | 1 | 1 |  |  |  |  |  |  |  |  |  |  |
| Cymbella spp. |  |  |  |  |  |  |  |  | 1 |  |  |  |  |
| Cymbella amphicephala |  |  |  |  |  |  |  | 2 | 1 | 1 | 4 |  |  |
| Cymbella cuspidata |  |  |  | 1 |  |  | 3 |  |  |  |  |  | 1 |
| Cymbella descripta | 2 | 4 |  | 2 |  |  |  |  |  |  |  |  |  |
| Cymbella gracilis |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella hebridica |  |  | 4 | 2 |  | 2 | 2 |  |  |  |  | 21 | 17 |
| Cymbella incerta |  | 8 | 4 | 2 |  |  | 2 | 4 |  | 1 | 2 | 12 | 8 |
| Cymbella minuta |  | 2 |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella silesiaca |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Denticula kuet. |  |  |  |  | 2 |  |  |  |  |  | 1 |  |  |
| Diploneis spp. |  |  |  |  |  |  |  | 1 |  |  |  |  |  |
| Diploneis marginestriata |  |  | 2 |  |  | 2 |  |  |  |  |  |  |  |
| Diploneis parma |  |  |  |  |  |  |  |  |  |  | 1 |  |  |
| Epithemia adnata |  |  |  |  |  |  |  |  |  |  |  | 1 |  |
| Eunotia spp. |  |  | 1 |  |  |  |  |  |  |  |  |  |  |
| Eunotia argus |  | 1 |  | 2 |  |  | 5 | 1 |  |  |  |  | 1 |
| Eunotia circumborealis |  |  |  |  |  |  |  | 4 | 1 | 2 | 2 | 1 |  |
| Eunotia incisa |  |  | 1 |  |  | 1 | 1 | 3 | 3 | 1 | 1 |  |  |

|  | 4.00 | 4.25 | 4.50 | 4.75 | 5.00 | 5.50 | 6.00 | 6.50 | 7.00 | 7.50 | 8.00 | 9.00 | 10.00 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Eunotia monodon |  |  |  |  |  | 1 |  |  |  |  |  |  |  |
| Eunotia praerupta |  | 1 | 1 | 1 | 3 |  | 1 | 5 | 8 | 10 | 11 | 3 | 8 |
| Eunotia rhomboidea |  |  |  |  |  |  |  |  |  |  | 2 | 4 | 6 |
| Fragilaria brevistriata | 28 | 28 | 18 | 20 | 31 |  | 3 |  |  |  | 1 | 2 | 1 |
| F. brevistriata v. papillosa |  | 8 |  |  | 4 |  |  |  |  |  |  |  |  |
| Fragilaria capucina | 18 | 25 | 20 | 15 | 11 | 4 | 9 |  | 4 | 3 | 2 | 7 | 4 |
| F. construens v. construens | 4 | 35 | 13 | 13 | 28 | 23 | 4 | 3 | 3 | 3 | 9 | 2 |  |
| F. construens v. venter | 29 | 58 | 40 | 25 | 26 | 46 | 18 | 32 | 61 | 60 | 70 | 28 | 9 |
| Fragilaria crotonensis | 12 | 8 | 4 |  | 5 | 4 | 1 |  |  |  |  |  |  |
| Fragilaria leptostauron | 20 | 15 | 3 | 6 | 12 |  |  |  |  |  |  |  |  |
| F. pinnata v. pinnata | 37 | 33 | 16 | 4 | 26 | 10 | 47 | 31 |  | 11 | 18 | 2 |  |
| Fragilaria tenera | 16 | 8 | 5 | 2 | 9 | 2 | 4 |  |  |  |  |  |  |
| F. virescins v. exigua |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Frustulia rhomboides |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema parvulum |  |  |  |  |  |  |  | 1 |  |  | 1 | 2 |  |
| Hantzchia amphioxys |  |  |  |  |  | 1 |  | 2 |  |  | 2 |  |  |
| Navicula absoluta |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula cocconeiformis |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula cuspidata | 1 |  |  | 1 |  | 4 | 1 |  |  |  |  |  |  |
| Navicula cryptocephala | 6 | 16 | 5 | 6 | 9 |  | 1 | 1 | 4 | 4 | 15 | 16 | 24 |
| Navicula disjuncta | 2 | 10 | 19 | 6 | 17 | 16 | 1 | 1 |  |  |  |  |  |
| Navicula elginensis |  | 2 | 6 | 2 | 9 | 14 | 6 | 1 | 2 |  | 2 | 4 | 1 |
| Navicula jaagii |  | 2 | 11 | 2 | 4 | 5 | 8 | 12 | 18 | 14 | 36 | 30 | 34 |
| Navicula kuelbsii | 12 |  | 10 | 4 | 2 | 2 | 2 |  |  |  |  |  |  |
| Navicula laevissima | 2 |  | 3 |  | 13 |  |  |  |  |  |  |  |  |
| Navicula leptostriata | 15 | 9 |  |  | 3 |  |  |  |  |  |  |  |  |
| Navicula mediocris | 2 |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula minima | 4 | 2 | 2 |  | 2 |  |  |  |  |  |  |  |  |
| Navicula mimima small | 2 | 2 | 2 |  |  |  |  |  |  |  |  |  |  |
| Navicula mutica |  | 2 |  |  |  |  |  |  |  |  |  |  | 2 |
| Navicula pupula | 13 | 10 | 23 | 19 | 8 | 31 | 20 | 13 | 6 | 1 | 5 | 23 | 18 |
| Navicula pseudoscutiformis |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula pseudoventralis | 4 |  | 2 |  | 1 | 7 |  |  |  |  |  |  |  |
| Navicula radiosa | 3 |  | 2 |  |  |  | 1 | 3 |  |  | 1 | 11 |  |
| Navicula rhynchocephala |  |  |  |  |  |  |  |  |  |  |  |  | 4 |
| Navicula reinhardtii | 3 | 5 | 15 | 7 | 15 | 24 | 53 | 31 | 43 | 31 | 32 | 40 | 38 |
| Navicula salinarium |  |  | 3 |  | 1 |  |  |  |  |  |  |  |  |
| Navicula schadei |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula seminulum | 8 | 4 | 6 |  |  | 2 |  |  |  |  |  |  |  |
| Navicula soehrensis |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula submuralis | 1 |  |  |  |  |  | 1 |  |  |  |  |  |  |
| Navicula subrotundata |  |  | 4 |  |  |  |  |  |  |  |  |  |  |
| Navicula subtilissima |  |  |  |  | 1 |  |  |  |  |  |  |  |  |
| Navicula tuscula |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula variostriata |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula ventralis |  | 2 |  |  |  |  |  |  |  |  |  |  |  |
| Navicula viridula |  |  |  |  |  |  |  |  |  |  |  |  | 1 |
| Navicula vitabunda |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula vitiosa | 10 | 11 |  | 2 |  |  |  |  |  |  |  |  |  |
| Navicula vulpina | 3 | 3 | 13 | 10 | 10 | 15 | 25 | 35 | 43 | 24 | 57 | 57 | 50 |

| | 4.00 | 4.25 | 4.50 | 4.75 | 5.00 | 5.50 | 6.00 | 6.50 | 7.00 | 7.50 | 8.00 | 9.00 | 10.00 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Neidium spp. (Centres) | | 4 | 16 | 10 | | 27 | 56 | 50 | 71 | 38 | 68 | 39 | |
| Neidium amplicatum | 12 | 11 | 26 | 11 | 35 | 16 | 8 | 12 | 1 | 5 | 1 | 6 | 41 |
| Neidium hitchcockii | | | | | | | | 5 | | | | 1 | 4 |
| Neidium iridis | | | | | | | 1 | | | | | | 5 |
| Neidium septrentionale | | | | | | 5 | 3 | | | | | | |
| Nitzschia dissipata | 3 | | | | 3 | | 1 | | | | | | |
| Nitzschia frustulum | | | | | | | 2 | | | | | | |
| Nitzschia glacilis | 7 | 13 | 6 | 3 | 8 | | 2 | | 3 | | | | |
| Nitzschia incognita | 17 | 23 | 13 | | 6 | 7 | 9 | 2 | | | 2 | | |
| Nitzschia intermedia | | | | | | | 1 | | | | | | |
| Nitzschia palea | 3 | 6 | 18 | 7 | 9 | | | | | | | | |
| Nitzschia perminuta | 78 | 72 | 50 | 29 | 34 | 27 | 11 | 4 | 2 | | 2 | | |
| Nitzschia pura | | | | | | | 2 | | | | | | |
| Nitzschia recta | 4 | 2 | 1 | | 1 | | 1 | 2 | | | | | |
| Pinnularia spp. | 3 | | | 1 | 1 | 2 | 3 | 13 | 14 | 9 | 6 | | 1 |
| Pinnularia borealis | | | | | | | | | | | | 1 | |
| Pinnularia gibba | | | | | | | | 3 | 1 | | 1 | 6 | 6 |
| Pinnularia interrupta | 13 | 8 | 38 | 12 | 33 | 31 | 8 | 11 | | 5 | 8 | 10 | 18 |
| Pinnularia cf karelica | | | | | 3 | | | | | | | | |
| Pinnularia microstauron | 1 | 2 | 5 | 7 | 3 | 15 | 6 | 8 | | 1 | | | 2 |
| Pinnularia nodosa | 1 | | | | 3 | 1 | 1 | | | | | 1 | 1 |
| Pinnularia rupestris | | | | | | | | | | | | | 1 |
| Pinnularia viridis | | 2 | 4 | 6 | 5 | 3 | 11 | 15 | 3 | 6 | 9 | 13 | 19 |
| Stauroneis spp. (Centres) | | | 3 | | | 13 | 15 | 21 | 22 | 19 | 12 | 8 | |
| Stauroneis acuta | | | | | | | | | | | | | |
| Stauroneis anceps | | 2 | 5 | 2 | 5 | 4 | 4 | 1 | 4 | | 1 | 3 | 11 |
| Stauroneis lauenburginana | 1 | 3 | 2 | 2 | 4 | 11 | | 2 | | | | | |
| Stauroneis noblis v. gracilis | | 5 | | | | | | | | | | | |
| Stauroneis phoenicenteron | 4 | 2 | 10 | 8 | 9 | 7 | 14 | 15 | 28 | 10 | 32 | 24 | 45 |
| Stauroneis prominula | | | | | | | | | | | | | |
| Stauroneis smithii | | | | | 5 | | | | | | | | |
| Stenopterobia spp. | 2 | | | | | | | | | | | | |
| Suriella spp. | | | | | | | | | | | | | |
| Suriella constricta | | | 2 | | 3 | | | | | | | | |
| Tabellaria fenestrata | | 2 | | | | | | | | | | | |
| Tabellaria flocculosa | 9 | 3 | 4 | 5 | 6 | 5 | 2 | 1 | 4 | 4 | 7 | 19 | 24 |
| Tabellaria flocculosa str. 4 | | | | | | | | 1 | | | 1 | | 1 |
| Tabellaria quadrisepta | | | | 1 | | | | | | | | | |
| CYSTS | 31 | 39 | 99 | 60 | 79 | 193 | 190 | 276 | 259 | 227 | 300 | 201 | 229 |
| PHYTOLITHS | | | | | | 5 | 2 | 2 | | 1 | | 2 | |
| SCALES | | | 2 | | | | 1 | | | | | | |
| PLATES | 1 | | 1 | 1 | | | 1 | | | | | | |

## E.6 Symons Lake raw diatom counts (Chapter 4)

| | 0.00 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 | 2.75 | 3.00 | 3.25 | 3.50 | 3.75 | 4.00 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Achnanthes acares | | | | | 2 | | 6 | | | | | | | 2 | | |
| Achnanthes altaica | 2 | 2 | | 5 | 2 | 2 | 2 | | 2 | 2 | 2 | 4 | | | 4 | |
| Achnanthes carissima | 2 | | 4 | | 2 | | | 1 | | | | | | | | |
| Achnanthes childanos | | 2 | | | | | 1 | 2 | | 1 | | | 2 | | | 2 |
| Achnanthes clevei | | | | 2 | 2 | | | 1 | 2 | | | 1 | | | | 1 |
| Achnanthes curtissima | | | | | | | | | | | | 2 | | | | |
| Achnanthes exigua | 3 | 16 | 4 | 6 | 8 | 10 | 8 | 4 | 11 | 3 | 2 | 10 | 12 | 14 | 5 | 21 |
| Achnanthes flexella | | | | | | | 1 | | | | | | | | | |
| Achnanthes impexiformis | 5 | 5 | 4 | 3 | | 7 | 9 | 7 | 2 | 6 | | 3 | | 5 | | 4 |
| Achnanthes lacus-vulcani | | | | | | | | | | 2 | | | | 2 | | |
| Achnanthes lanceolata | | | | 1 | | 1 | | | 2 | | | | | | | |
| Achnanthes laevis | | 4 | | 3 | | 2 | | | 2 | | | | | | | |
| Achnanthes levanderi | 2 | | | | 2 | | | | 3 | | 1 | 4 | 2 | | | 1 |
| Achnanthes linearis | | 3 | | | | | | | | | | | | | | |
| Achnanthes marginulata | | | | | | | | | | | | | | | | 2 |
| Achnanthes minutissima | 1 | 4 | 4 | 2 | | 6 | | 10 | 6 | 10 | 12 | 8 | | 10 | 4 | |
| A. minutissima v. inconspicua | | | | | | | | | | | | | | | | 5 |
| Achnanthes oestruptii | | | | | | | 1 | | | | | | | | | |
| Achnanthes petersonii | | | | | | | | | | | | | | | | |
| Achnanthes pusilla | | | | | | | 2 | | 1 | | | | | | | |
| Achnanthes saccula | 9 | 20 | 14 | 16 | 11 | 8 | 13 | 2 | 8 | 4 | 2 | 5 | 4 | 3 | 2 | 6 |
| Achnanthes subatomoides | 2 | 4 | 6 | 7 | 2 | 1 | | 4 | 2 | | 5 | 6 | 7 | 6 | 1 | 2 |
| Achnanthes ventralis | | | | | | 2 | | | | | | | | | | |
| Actinella brasilensis | | | | | | | | | | | | | | | | |
| Amphora aequlis | | | | | | | | | | | | 2 | | | | |
| Amphora inariensis | | 2 | | 1 | 2 | | | 1 | | 2 | | | 4 | 3 | 3 | |
| Amphora ovalis | 2 | 4 | | 5 | 2 | 2 | 4 | 1 | 3 | 5 | 5 | 3 | 3 | | 1 | 1 |
| Amphora pediculus | | | | | | | | | | | | | | | | 3 |
| Asterionella ralfsii | 1 | 4 | 3 | 9 | 5 | 9 | 6 | 9 | 4 | 7 | 3 | 4 | 3 | 3 | 2 | |
| Asterionella formosa | 9 | 9 | 6 | 12 | 8 | 6 | 19 | 6 | 5 | 13 | 8 | 11 | 1 | 2 | 2 | 2 |
| Aulacoseira spp. | | | | | | | | | | | | | | | | |
| Aulacoseira ambigua | 9 | 10 | 11 | 17 | 18 | 16 | 15 | 9 | 14 | 12 | 7 | 7 | 7 | 5 | 5 | 11 |
| Aulacoseira lirata | | | | | | | | | | | | | | | 1 | |
| Aulacoseira subarctica | | | | | 2 | | | | | | 2 | | | | | |
| Aulacoseira valida | 4 | 2 | 5 | 1 | 4 | | | | | 1 | | 8 | | 9 | | 4 |
| Brachysira spp. | 2 | | | | | | | | | | | | | | | |
| Brachysira brebessoni | | | | | | | | | | | | | | 1 | | |
| Caloneis spp. | | | | | | 1 | 1 | | | | | | | | | |
| Caloneis bacillum | 5 | 4 | | 2 | | | | 1 | 5 | 2 | 1 | | | | | |
| Caloneis silicula | | | | | | | | | | | | | | | | 8 |
| Cocconeis disculus | | | | | | | | | | | | | | | | 1 |
| Cocconeis placentula | | | | | | | | 1 | | 1 | | | | | 1 | |
| Cyclotella bodanica v. lemmanica | | | | | 1 | | | | | | | 1 | | 1 | | 3 |
| Cyclotella stelligera | | | | | | | | | 1 | | 1 | | 1 | | | |
| Cymbella spp. | | | | | | | | | 4 | | | | | | | |
| Cymbella amphicephala | 3 | 4 | 1 | 2 | 2 | 2 | 2 | 3 | 2 | 2 | 6 | 4 | 2 | | 2 | 4 |
| Cymbella cesatii | | 1 | | | | | | | | | | | | | | |
| Cymbella cuspidata | | | | | | | | | | | | | | | | |
| Cymbella descripta | | | | 2 | | | | | | | | | | | | |
| Cymbella gracilis | | | | | | | | | | | | | | | | |

|  | 0.00 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 | 2.75 | 3.00 | 3.25 | 3.50 | 3.75 | 4.00 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cymbella hebridica | 3 | 3 | 2 |  | 1 | 7 | 2 |  |  | 3 |  |  | 2 | 5 | 1 |  |
| Cymbella hybrida |  |  |  |  |  |  |  |  |  |  |  | 2 |  |  |  |  |
| Cymbella incerta |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella minuta | 4 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cymbella silesiaca |  |  | 2 | 4 | 7 | 1 |  | 2 |  |  | 2 | 5 |  |  |  |  |
| Denticula kuet. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 2 |
| Diploneis elliptica |  |  |  |  |  |  |  |  |  |  |  | 1 |  |  |  |  |
| Diploneis finnica |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Diploneis marginestriata |  |  |  |  |  |  |  |  |  |  | 4 | 2 | 1 | 2 | 1 | 3 |
| Diploneis oculata | 4 | 3 |  | 3 |  | 2 | 3 | 4 | 5 |  |  |  |  |  |  |  |
| Diploneis parma | 1 |  |  |  |  | 1 | 1 |  | 1 |  |  |  | 1 |  |  |  |
| Epithemia adnata |  |  |  |  |  |  | 2 |  |  | 1 |  |  |  |  |  |  |
| Eunotia spp. |  |  | 1 |  |  |  | 2 |  |  |  |  |  |  |  |  |  |
| Eunotia argus |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia bilunaris |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eunotia incisa |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Fragilaria brevistriata | 35 | 36 | 66 | 36 | 53 | 32 | 34 | 23 | 38 | 15 | 13 | 25 | 23 | 18 | 28 | 9 |
| F. brevistriata v. papillosa | 6 | 2 |  |  | 2 | 4 | 5 | 3 | 9 | 2 | 3 | 4 |  |  |  | 4 |
| Fragilaria capucina | 14 | 6 | 20 | 14 | 8 | 4 | 7 | 8 | 9 | 3 |  | 10 | 2 | 2 | 3 | 1 |
| F. construens v. binodis |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 3 |
| F. construens v. construens |  | 11 | 8 |  | 12 | 12 |  | 9 | 1 |  | 6 | 5 |  | 2 | 3 | 6 |
| F. construens v. venter | 100 | 114 | 125 | 115 | 115 | 137 | 102 | 135 | 124 | 130 | 184 | 242 | 218 | 178 | 218 | 225 |
| Fragilaria crotonensis | 12 | 8 | 14 | 18 | 17 | 13 | 3 | 4 |  | 21 | 5 | 17 | 2 | 4 |  | 3 |
| Fragilaria leptostauron |  |  |  |  |  |  |  |  |  |  |  | 1 |  |  |  |  |
| Fragilaria parasitica | 2 |  |  |  |  | 2 |  | 4 | 1 | 2 |  | 4 |  |  |  |  |
| F. pinnata v. pinnata | 70 | 39 | 47 | 50 | 45 | 40 | 49 | 72 | 58 | 73 | 86 | 93 | 38 | 100 | 50 | 132 |
| Fragilaria tenera | 12 | 11 | 17 | 12 | 14 | 2 | 4 | 6 | 6 | 2 | 3 |  | 1 |  | 1 |  |
| Gomphonema spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema gracile |  |  |  | 2 |  |  |  |  |  |  |  |  |  |  |  |  |
| Gomphonema parvulum | 2 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gyrosigma acuminatum | 7 | 4 | 1 |  | 3 | 4 | 5 | 2 | 2 | 6 | 4 | 7 | 8 | 3 | 6 | 7 |
| Hantzchia amphioxys |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula absoluta | 4 | 11 | 2 | 10 | 4 | 3 | 10 | 4 | 2 | 2 | 4 | 3 | 4 | 3 |  | 2 |
| Navicula agretis |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula capitata |  | 4 | 5 | 3 | 3 | 2 |  |  | 2 | 2 | 1 |  |  | 2 |  |  |
| Navicula cocconeiformis | 3 |  |  |  |  |  | 7 | 2 | 4 | 4 |  | 2 |  | 3 | 1 | 5 |
| Navicula cuspidata |  |  | 1 |  |  |  |  |  |  |  |  |  |  |  |  | 1 |
| Navicula cryptocephala | 19 | 11 | 12 | 17 | 8 | 14 | 9 | 18 | 16 | 13 | 16 | 7 | 2 | 5 | 4 |  |
| Navicula detenta | 5 | 2 | 3 | 7 | 8 | 6 | 1 |  | 2 | 3 | 1 | 2 |  | 1 | 2 |  |
| Navicula digitulus |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula disjuncta | 4 |  | 1 | 6 | 3 | 5 |  | 3 | 7 | 2 |  | 2 | 3 | 3 | 5 | 1 |
| Navicula elginensis | 4 | 3 | 5 | 5 | 4 |  | 4 | 3 | 4 | 2 | 3 | 6 | 5 | 4 | 5 | 8 |
| Navicula festiva |  |  | 1 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula gastrum |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 |
| Navicula harderii |  | 2 | 10 | 6 |  |  | 4 | 3 | 8 | 4 | 6 |  |  |  |  |  |
| Navicula helensis |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 |
| Navicula ignota |  |  |  |  |  |  |  |  |  |  |  | 1 |  |  | 2 |  |
| Navicula jaagii |  |  |  |  |  | 2 | 1 |  |  |  |  |  |  | 1 |  |  |
| Navicula jaernerfeltii |  |  | 2 |  |  |  |  |  |  |  |  |  |  |  |  | 2 |
| Navicula kuelbsii | 29 | 33 | 19 | 37 | 34 | 28 | 8 | 22 | 17 | 34 | 28 | 30 | 16 | 27 | 27 | 33 |

|  | 0.00 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 | 2.75 | 3.00 | 3.25 | 3.50 | 3.75 | 4.00 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Navicula laevissima |  |  |  |  |  |  |  |  |  |  |  | 1 |  |  |  |  |
| Navicula leptostriata |  |  | 2 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula medioconvexa |  |  |  |  |  |  |  |  | 2 |  |  |  |  |  |  |  |
| Navicula minima | 11 | 16 | 9 | 7 | 6 | 4 | 14 | 6 | 12 | 12 | 12 | 13 | 5 | 3 | 4 | 17 |
| Navicula mimima small |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 2 |
| Navicula minuscula |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 2 |  |
| Navicula monoculatva |  |  |  |  |  |  |  |  |  | 2 |  |  |  |  |  |  |
| Navicula pupula | 8 | 8 | 5 | 4 | 7 | 2 | 6 | 13 | 8 | 3 | 15 | 3 | 3 | 6 | 3 | 5 |
| Navicula pseudoscutiformis |  |  |  |  |  | 2 |  |  |  |  |  | 2 |  |  |  |  |
| Navicula pseudoventralis | 8 | 4 | 2 |  | 2 |  | 1 | 4 | 2 | 2 | 7 | 2 | 2 | 3 | 2 | 6 |
| Navicula radiosa |  |  |  |  | 1 |  |  |  |  |  |  | 1 |  |  |  |  |
| Navicula rhynchocephala | 4 | 2 | 3 | 5 | 7 | 4 | 4 | 6 | 4 |  | 2 | 1 |  |  |  |  |
| Navicula reinhardtii | 1 |  | 1 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula salinarium |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula saxophila |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula schadei |  |  |  |  |  |  | 2 | 2 |  |  |  |  |  | 1 |  |  |
| Navicula schmassmannii |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Navicula seminulum | 11 | 6 | 6 | 5 | 12 | 2 | 6 | 7 | 7 | 9 | 12 | 5 | 4 | 6 | 18 | 2 |
| Navicula subminiscula |  |  | 4 |  | 2 |  | 2 |  |  |  |  |  | 2 |  |  |  |
| Navicula submuralis | 2 | 6 |  |  | 5 |  | 4 | 5 | 17 | 12 |  | 16 | 7 | 4 | 12 | 5 |
| Navicula subrotundata | 11 | 10 | 8 | 8 | 2 | 4 | 8 | 6 | 7 | 9 | 3 |  |  | 4 |  | 4 |
| Navicula subtilissima |  |  | 1 |  |  |  |  | 1 |  | 2 |  |  | 2 |  |  |  |
| Navicula tridentula |  |  |  | 2 |  | 4 |  |  |  |  |  |  |  |  |  |  |
| Navicula ventralis | 2 | 2 |  |  |  |  | 2 |  | 2 | 2 |  |  |  |  |  |  |
| Navicula vitabunda |  | 3 |  | 2 |  | 3 | 4 | 8 | 4 | 6 |  | 5 | 2 |  |  | 2 |
| Navicula vitiosa |  | 14 | 8 | 8 | 14 | 2 | 13 | 10 | 6 | 8 | 14 | 4 | 13 | 6 | 28 | 5 |
| Navicula vulpina | 1 |  |  |  |  |  |  |  |  | 1 |  | 1 | 3 | 3 | 4 |  |
| Neidium spp. (Centres) |  |  |  |  |  |  |  |  |  |  |  | 3 |  |  |  |  |
| Neidium amplicatum | 1 |  |  | 1 |  | 1 | 1 | 1 |  | 2 | 4 | 3 | 3 |  | 2 | 1 |
| Neidium hitchcockii |  |  |  |  |  |  |  |  | 1 |  | 2 |  |  |  |  | 2 |
| Neidium iridis |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  |
| Nitzschia alpina |  |  |  |  |  |  |  |  | 2 |  |  |  |  |  |  |  |
| Nitzschia dissipata | 2 | 8 |  | 4 | 4 | 2 |  | 1 |  | 2 |  | 1 | 1 | 3 |  |  |
| Nitzschia glacilis | 9 | 7 | 4 | 6 | 1 | 7 | 6 | 4 | 2 | 1 |  | 2 | 1 |  | 1 | 2 |
| Nitzschia intermedia |  |  | 1 | 3 | 2 |  |  |  |  |  |  | 2 |  |  |  |  |
| Nitzschia palea | 13 | 14 | 16 | 12 | 12 | 8 | 24 | 10 | 10 | 13 | 8 | 2 |  |  |  | 2 |
| Nitzschia perminuta | 5 | 12 | 12 | 9 | 14 | 9 | 14 | 11 | 10 | 12 | 14 | 9 | 11 | 6 | 5 | 3 |
| Nitzschia recta | 1 | 6 | 4 | 5 | 1 | 6 | 9 | 1 | 4 | 1 | 1 | 4 | 1 |  |  | 3 |
| Pinnularia spp. |  |  | 2 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia gibba |  |  |  |  |  |  |  |  |  | 1 |  | 1 |  |  |  |  |
| Pinnularia interrupta | 4 | 1 | 6 | 2 | 8 | 10 | 5 | 9 | 11 | 12 | 19 | 10 | 4 | 9 | 10 | 5 |
| Pinnularia maior |  |  |  |  |  |  |  |  |  |  |  | 2 |  |  |  | 3 |
| Pinnularia microstauron |  | 4 |  |  |  |  | 4 | 2 | 2 | 3 | 2 | 4 | 2 | 2 | 2 | 2 |
| Pinnularia nodosa |  |  |  |  |  |  |  |  |  |  |  | 3 |  |  | 1 |  |
| Pinnularia streptoraphe |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Pinnularia viridis |  |  |  | 2 |  |  | 2 |  |  | 2 | 1 |  | 2 |  |  |  |
| Rhisolsenia spine |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Rhisolsenia cysts |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Stauroneis spp. (Centres) |  |  |  |  |  |  |  |  |  |  |  | 1 |  |  |  |  |
| Stauroneis anceps |  |  |  |  | 4 | 1 |  |  |  | 5 |  | 3 | 5 |  | 1 | 5 |

|  | 0.00 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 | 2.75 | 3.00 | 3.25 | 3.50 | 3.75 | 4.00 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stauroneis lauenburginana | 2 |  |  |  | 3 | 1 | 3 | 2 |  |  | 3 | 2 |  |  |  |  |
| Stauroneis noblis v. gracilis | 1 |  |  |  |  | 1 |  | 1 | 1 | 1 | 2 | 2 |  | 1 |  |  |
| Stauroneis phoenicenteron |  |  | 1 | 1 | 1 |  |  |  |  | 3 | 2 | 1 | 2 | 5 | 3 | 2 |
| Stauroneis smithii |  | 2 | 3 |  | 1 |  | 2 | 1 | 1 | 1 | 2 |  |  | 2 | 5 | 1 |
| Stenopterobia spp. |  |  | 1 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Suriella spp. | 4 | 2 | 3 |  | 7 | 1 | 4 | 4 |  |  |  |  |  | 2 |  |  |
| Suriella constricta |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 |
| Tabellaria flocculosa | 7 | 8 | 3 | 5 | 3 | 6 | 13 | 4 | 4 | 3 | 2 | 8 |  | 5 | 4 | 3 |
| Tabellaria flocculosa st. 4 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| CYSTS | 8 | 11 | 6 | 10 | 13 | 6 | 7 | 14 | 10 |  | 9 | 15 | 14 | 14 | 6 | 12 |
| PHYTOLITHS |  |  |  |  | 1 |  |  | 1 |  |  |  |  | 1 |  | 0 | 1 |
| SCALES |  |  | 1 | 1 | 1 |  |  | 1 |  |  |  |  | 0 |  | 0 |  |
| PLATES |  |  |  |  |  |  |  |  |  |  |  |  | 0 |  | 0 |  |

| | 4.25 | 4.50 | 4.75 | 5.00 | 5.25 | 5.50 | 5.75 | 6.00 | 6.25 | 6.50 | 6.75 | 7.00 | 7.25 | 7.50 | 7.75 | 8.00 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Achnanthes acares | | | | | | | | | | 2 | | | | | | |
| Achnanthes altaica | | 3 | 1 | | 1 | | | 2 | | | 2 | 2 | 4 | 4 | 5 | |
| Achnanthes carissima | | | | 2 | | | | | | | | | | | | |
| Achnanthes childanos | | | 1 | | | | 1 | | | | | 2 | | 2 | | |
| Achnanthes clevei | | | | | | | | | | | | | | | | |
| Achnanthes curtissima | | | | | | | | | | | | | | | | |
| Achnanthes exigua | 8 | 18 | 8 | 22 | 4 | 10 | 11 | 11 | 7 | 13 | 9 | | 12 | 9 | 8 | 8 |
| Achnanthes flexella | | | | | | 2 | | 1 | | 2 | | 4 | 1 | | | |
| Achnanthes impexiformis | | | | 1 | | | | | | 2 | | | | 1 | 2 | 1 |
| Achnanthes lacus-vulcani | | | | | | | | | | | | | | | | |
| Achnanthes lanceolata | | 2 | | | 2 | 1 | | 2 | | 5 | 4 | | | | | 4 |
| Achnanthes laevis | | | | | | | | | | | | | | | | |
| Achnanthes levanderi | | 2 | | 1 | | 2 | | 3 | | | | | | | 2 | |
| Achnanthes linearis | | | | | | | | | | | | | | | | |
| Achnanthes marginulata | | | | | | | | | | | | | | | | |
| Achnanthes minutissima | | | | | | 2 | 2 | | 4 | 4 | 8 | | 4 | | | 7 |
| A. minutissima v. inconspicua | | 2 | | | | | | | | | | | | | | |
| Achnanthes oestruptii | | 1 | | | | | | | | | | | | | | |
| Achnanthes petersonii | | 2 | | | | | | | | | | | | | | |
| Achnanthes pusilla | | | | | | | | | | | | | | | | |
| Achnanthes saccula | 4 | | 2 | | | 1 | | 2 | 4 | 5 | | 4 | 6 | 2 | | 2 |
| Achnanthes subatomoides | | 4 | 2 | | | 2 | | 2 | 8 | | 6 | 2 | 2 | | 2 | |
| Achnanthes ventralis | | | | | | | | | | | | | | | | |
| Actinella brasilensis | | | | | | | | | | | | | | | | |
| Amphora aequlis | | | | | | | | | | | | | | | | |
| Amphora inariensis | 2 | | 8 | 4 | 6 | 7 | 1 | 4 | 1 | | 3 | | 3 | 3 | 5 | 3 |
| Amphora ovalis | 1 | 1 | | | 2 | 2 | 1 | 4 | 2 | | 3 | 4 | 3 | 2 | 1 | |
| Amphora pediculus | | 6 | | | | | | | | | | | | | | |
| Asterionella ralfsii | 3 | | | 2 | | | | | | | | | | | | |
| Asterionella formosa | 1 | | | 1 | 2 | 2 | 2 | | 2 | 2 | 2 | | 2 | | | |
| Aulacoseira spp. | | | | | | | | | | | | | | | | |
| Aulacoseira ambigua | 4 | 4 | 1 | 7 | | | 3 | 3 | 4 | 9 | 3 | 7 | 11 | 10 | 6 | 3 |
| Aulacoseira lirata | | | | | | | | | | | | | | | | |
| Aulacoseira subarctica | | | | | 2 | 4 | 1 | 3 | | | | | | | | 1 |
| Aulacoseira valida | | 6 | | 2 | | | | | | | | | | | | |
| Brachysira spp. | | | | | | | | | | | | | | | | |
| Brachysira brebessoni | | | | | | | | | | | | | | | | |
| Caloneis spp. | | | | | | | | | | | 1 | | | | | |
| Caloneis bacillum | | | | 2 | | | | 2 | | | | | | | | |
| Caloneis silicula | | 3 | | | 2 | | | | | | | | | | 2 | |
| Cocconeis disculus | | | | | | | | | | | | | | | | |
| Cocconeis placentula | | | | | | | | 1 | 2 | | | | | | | |
| Cyclotella bodanica v. lemmanica | | 2 | | | | | | | | | | | | | | |
| Cyclotella stelligera | | | | | | | | | | | | | | | | |
| Cymbella spp. | | | | | | | | | | | | | | | | |
| Cymbella amphicephala | 3 | | 5 | | 4 | 4 | 1 | | 1 | 4 | 8 | 2 | 3 | | 5 | 7 |
| Cymbella cesatii | | | | | | | | | | | | | | | | |
| Cymbella cuspidata | | | | | | | | | | | | | | | | |
| Cymbella descripta | | | | | | | | | | | | | | | | |
| Cymbella gracilis | | | | 1 | | | | | | | | | | | | |

| | 4.25 | 4.50 | 4.75 | 5.00 | 5.25 | 5.50 | 5.75 | 6.00 | 6.25 | 6.50 | 6.75 | 7.00 | 7.25 | 7.50 | 7.75 | 8.00 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cymbella hebridica | | | | | | | | | 2 | | | | 1 | | 3 | |
| Cymbella hybrida | | | | | | | | | | | | | | | | |
| Cymbella incerta | | 2 | | | | | | | | | | | | | | |
| Cymbella minuta | | | | | | | | | | | | | | | | |
| Cymbella silesiaca | | | | 2 | | | | | | 2 | | | | | | |
| Denticula kuet. | | | | | | | | | | | | | | | | |
| Diploneis elliptica | | | | | | | | | | | | | | | | |
| Diploneis finnica | | 1 | | | | 1 | | | | | | | | | | |
| Diploneis marginestriata | 2 | | 1 | | | 1 | 2 | 1 | 2 | | 4 | 3 | 1 | 10 | 6 | 2 |
| Diploneis oculata | | | | | | | | | | | | | | | | |
| Diploneis parma | | | | | 1 | | | | 1 | 1 | 1 | 2 | 2 | 2 | | |
| Epithemia adnata | | | | | | | | | | | | | | | | |
| Eunotia spp. | | | | | | | | | | | | | | | | |
| Eunotia argus | | | | 2 | | | | | | | | | | | | |
| Eunotia bilunaris | | | | | | | | | | | | | | | | |
| Eunotia incisa | | | | | | | | | | | | | | | | |
| Fragilaria brevistriata | 9 | 7 | 24 | 10 | 12 | 18 | 13 | 16 | 3 | 12 | 9 | 10 | 14 | 9 | 10 | 5 |
| F. brevistriata v. papillosa | | | | | | | | | | | | | | | | |
| Fragilaria capucina | 6 | | 3 | 7 | 2 | 3 | | 2 | | 2 | 2 | 1 | | 2 | | 1 |
| F. construens v. binodis | | 1 | | | | | | | | | | | | | | |
| F. construens v. construens | 4 | | | | | 2 | 3 | 4 | 2 | | | | 4 | 1 | 4 | |
| F. construens v. venter | 223 | 263 | 293 | 181 | 316 | 215 | 315 | 215 | 257 | 200 | 321 | 261 | 341 | 245 | 315 | 330 |
| Fragilaria crotonensis | | 2 | 2 | 3 | | 2 | 1 | | 4 | | | | | | | |
| Fragilaria leptostauron | | | | | | | | | | | | | | | | |
| Fragilaria parasitica | 1 | | | | | | | | | | | | | | | |
| F. pinnata v. pinnata | 78 | 161 | 31 | 125 | 29 | 181 | 58 | 100 | 42 | 159 | 41 | 120 | 37 | 68 | 23 | 54 |
| Fragilaria tenera | | | | 2 | 2 | | | | | | | | | 1 | | |
| Gomphonema spp. | | | | | | | | | 1 | | | | | | | |
| Gomphonema gracile | | | | | | | | | | | | | | | | |
| Gomphonema parvulum | | | | | | | | | | | 1 | | | | | |
| Gyrosigma acuminatum | 3 | 1 | 1 | 2 | | 2 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | | | 1 |
| Hantzchia amphioxys | | | | | | | | | 1 | | | | | | | |
| Navicula absoluta | 2 | 2 | | 1 | | 2 | | 3 | | | | | | | | |
| Navicula agretis | 1 | | | | | | | | | | | | | | | |
| Navicula capitata | | | | | | | | | | | | | | 2 | | |
| Navicula cocconeiformis | | | 2 | | | 2 | | | | | 1 | | | 2 | | |
| Navicula cuspidata | | | | | | | | | | | | | | | | |
| Navicula cryptocephala | | 3 | | | | 1 | 1 | | | | 2 | | | | 2 | |
| Navicula detenta | 2 | | 2 | 2 | 2 | 1 | 1 | | | 2 | | 3 | 2 | 1 | | 1 |
| Navicula digitulus | | | | 1 | | | | | | | 1 | | | | | |
| Navicula disjuncta | | | | 1 | | | | 2 | | | | 3 | | 2 | | 3 |
| Navicula elginensis | 3 | 6 | 1 | 4 | 4 | 8 | 3 | 6 | 5 | 8 | | 5 | 3 | 3 | 8 | 2 |
| Navicula festiva | | | | | | | | | | | | | | | | |
| Navicula gastrum | | 2 | | | | | | | | | | | | | | |
| Navicula harderii | | | | 2 | | | | | | | | | | | | |
| Navicula helensis | | 2 | | | | | | | | 1 | | | | | | |
| Navicula ignota | | | | | | | | | | | | | 2 | | | 2 |
| Navicula jaagii | | | | | | | | | | | | | | | | |
| Navicula jaernerfeltii | 2 | 2 | 2 | | 3 | | | | | | | | | | 2 | |
| Navicula kuelbsii | 16 | 20 | 8 | 6 | 7 | 15 | 6 | 18 | 9 | 14 | 6 | 10 | 6 | 10 | 2 | 16 |

| | 4.25 | 4.50 | 4.75 | 5.00 | 5.25 | 5.50 | 5.75 | 6.00 | 6.25 | 6.50 | 6.75 | 7.00 | 7.25 | 7.50 | 7.75 | 8.00 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Navicula laevissima | | | 2 | | | | | | | | | | | | | |
| Navicula leptostriata | | | | | | | | | | | | | | | | |
| Navicula medioconvexa | | | | | | | | | | | | | | | | |
| Navicula minima | 7 | 5 | | 4 | | | | 10 | 2 | 3 | | 10 | | | 6 | |
| Navicula mimima small | | | | | | | | | | | | | | | | |
| Navicula minuscula | | | | 2 | | | | | | | | | | | | |
| Navicula monoculatva | | | | | | | | | | | | | | | | |
| Navicula pupula | 10 | 9 | 3 | 8 | 2 | 1 | | 3 | 5 | 2 | | 4 | | 5 | 2 | 1 |
| Navicula pseudoscutiformis | | 2 | | | | | | | | | | | | | | |
| Navicula pseudoventralis | | | 4 | 4 | 6 | | | 2 | | | | 2 | | 7 | | 2 |
| Navicula radiosa | 2 | | | | | | | | | | | | | | | |
| Navicula rhynchocephala | | | | | | | | | | 1 | | | | | | |
| Navicula reinhardtii | | | | | | | | | | 1 | | | | 1 | | |
| Navicula salinarium | 2 | | | | | | | | | | | | | | | |
| Navicula saxophila | | | | | | | | | | | | | | | | |
| Navicula schadei | | | | | | | | | | | | 1 | | | | |
| Navicula schmassmannii | | | | | | | | | | | | | | | | |
| Navicula seminulum | 4 | 4 | 10 | 1 | 3 | 3 | 4 | | 8 | 13 | 4 | 3 | | 2 | 4 | |
| Navicula subminiscula | | | | | | | | | | | | | | | | |
| Navicula submuralis | 6 | 5 | | 6 | | 7 | 1 | 4 | 6 | 5 | 5 | 6 | 2 | 1 | 4 | 2 |
| Navicula subrotundata | | 2 | | 12 | | | | 1 | | 2 | | 2 | | | | |
| Navicula subtilissima | | | | | | | | | | | | | | | | |
| Navicula tridentula | | | | | | | | | | | | | | | | |
| Navicula ventralis | | | 2 | | | | | | | | | | 2 | | | |
| Navicula vitabunda | | | 1 | | | 2 | | | | | | | | | | 2 |
| Navicula vitiosa | 20 | 4 | 16 | 15 | 20 | 15 | 19 | 18 | 17 | 14 | 30 | 20 | 23 | 14 | 13 | 13 |
| Navicula vulpina | | 1 | 3 | 1 | | | | 1 | | | 2 | | | | 4 | 4 |
| Neidium spp. (Centres) | | | | | | | | | | | | | | | | |
| Neidium amplicatum | 3 | 1 | 2 | 1 | 3 | 1 | | | | 1 | 2 | 2 | | | | 1 |
| Neidium hitchcockii | | | | | | | | | | | | | | | | |
| Neidium iridis | | | | | | | | | | | | | 1 | | | |
| Nitzschia alpina | | | | | | | | | | | 1 | | | | 2 | |
| Nitzschia dissipata | | | | | | | | | | | | 1 | | | 2 | |
| Nitzschia glacilis | | 1 | | 1 | | | | 2 | | | | | | | | |
| Nitzschia intermedia | | | | | | | | | | | | | | | | |
| Nitzschia palea | 2 | 2 | | 5 | | | | 2 | | | | | 2 | | | 1 |
| Nitzschia perminuta | 6 | 2 | | 4 | 7 | 2 | 1 | 12 | 2 | | 1 | | | 2 | 1 | 2 |
| Nitzschia recta | | | | | | | | 1 | | | | | 1 | | | |
| Pinnularia spp. | | | | | | | | | | | | | | | | |
| Pinnularia gibba | | | | | | | | | | | | | | | | |
| Pinnularia interrupta | 10 | 5 | 3 | 10 | 5 | 3 | 7 | 10 | 4 | 6 | 4 | 3 | | | 3 | 2 |
| Pinnularia maior | | 3 | | | | 1 | | | | | | | | | | |
| Pinnularia microstauron | 1 | 6 | 1 | 2 | 3 | 1 | | | 1 | | 1 | | | 1 | 2 | 1 |
| Pinnularia nodosa | | | | | | | | | | | | | | | | |
| Pinnularia streptoraphe | | | | 2 | | | | 1 | | | | | | | | |
| Pinnularia viridis | | | | | 4 | | | | | | | | | | 1 | |
| Rhisolsenia spine | | 1 | | | | | | | | | | | | | | |
| Rhisolsenia cysts | 1 | 1 | | 1 | | | | | | | | | | | | |
| Stauroneis spp. (Centres) | | | | | | | | | | | | | | | | |
| Stauroneis anceps | 1 | 7 | | | | 1 | | | 1 | | 4 | | | | | 3 |

|  | 4.25 | 4.50 | 4.75 | 5.00 | 5.25 | 5.50 | 5.75 | 6.00 | 6.25 | 6.50 | 6.75 | 7.00 | 7.25 | 7.50 | 7.75 | 8.00 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stauroneis lauenburginana |  |  |  | 3 |  |  |  | 1 |  | 1 |  | 1 |  |  |  |  |
| Stauroneis noblis v. gracilis |  |  |  | 2 |  | 2 |  |  |  | 1 |  |  |  |  |  |  |
| Stauroneis phoenicenteron | 1 | 3 | 5 | 5 | 4 | 3 | 1 | 7 |  | 1 | 1 |  |  |  | 4 |  |
| Stauroneis smithii |  | 3 | 1 | 1 | 2 |  |  | 3 | 1 | 3 | 1 | 1 |  | 1 | 3 |  |
| Stenopterobia spp. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Suriella spp. |  |  |  |  |  |  |  |  |  |  |  | 1 |  |  |  | 2 |
| Suriella constricta |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Tabellaria flocculosa | 1 | 1 |  | 1 |  | 3 | 1 | 1 |  | 1 |  | 1 | 1 | 1 | 1 |  |
| Tabellaria flocculosa st. 4 |  |  |  |  |  | 1 |  |  |  |  |  |  |  |  |  |  |
| CYSTS | 14 | 10 | 3 | 13 | 6 | 14 | 5 | 5 | 6 | 7 | 6 | 7 | 6 | 6 | 5 | 8 |
| PHYTOLITHS | 1 |  | 0 |  | 0 | 1 | 0 |  | 0 |  | 0 |  | 0 | 1 | 0 | 0 |
| SCALES | 0 | 1 | 0 |  | 0 |  | 0 |  | 0 |  | 0 |  | 0 |  | 0 | 0 |
| PLATES | 0 |  | 0 |  | 0 |  | 0 |  | 0 |  | 0 |  | 0 |  | 0 | 0 |

|  | 8.25 | 8.50 | 8.75 | 9.00 | 9.25 | 9.50 |
|---|---|---|---|---|---|---|
| Achnanthes acares |  | 2 |  |  |  |  |
| Achnanthes altaica | 2 | 2 |  | 4 |  | 4 |
| Achnanthes carissima |  |  |  |  |  |  |
| Achnanthes childanos |  |  |  |  |  | 3 |
| Achnanthes clevei |  |  |  |  |  |  |
| Achnanthes curtissima |  |  |  |  |  |  |
| Achnanthes exigua | 9 | 14 |  | 6 |  | 4 |
| Achnanthes flexella |  |  |  |  |  |  |
| Achnanthes impexiformis |  |  |  |  |  |  |
| Achnanthes lacus-vulcani |  |  |  |  |  |  |
| Achnanthes lanceolata |  |  |  |  |  |  |
| Achnanthes laevis |  |  |  |  |  | 2 |
| Achnanthes levanderi | 2 |  |  |  |  |  |
| Achnanthes linearis |  |  |  |  |  |  |
| Achnanthes marginulata |  |  |  |  |  |  |
| Achnanthes minutissima |  | 2 |  |  |  | 2 |
| A. minutissima v. inconspicua |  |  |  |  |  |  |
| Achnanthes oestruptii |  |  |  |  |  | 1 |
| Achnanthes petersonii |  |  |  |  |  |  |
| Achnanthes pusilla |  |  |  |  |  |  |
| Achnanthes saccula | 6 |  |  | 2 |  | 8 |
| Achnanthes subatomoides | 8 |  |  | 4 |  | 3 |
| Achnanthes ventralis |  |  |  |  |  |  |
| Actinella brasilensis | 2 |  |  |  |  |  |
| Amphora aequlis |  |  |  |  |  |  |
| Amphora inariensis | 4 | 1 |  | 4 |  | 5 |
| Amphora ovalis | 4 | 1 |  | 4 |  | 4 |
| Amphora pediculus |  |  |  |  |  |  |
| Asterionella ralfsii |  |  |  |  |  |  |
| Asterionella formosa |  |  |  |  |  |  |
| Aulacoseira spp. |  |  |  | 1 |  |  |
| Aulacoseira ambigua | 5 | 8 |  | 11 |  | 14 |
| Aulacoseira lirata |  |  |  |  |  |  |
| Aulacoseira subarctica |  |  |  | 5 |  |  |
| Aulacoseira valida |  | 2 |  |  |  |  |
| Brachysira spp. |  |  |  |  |  |  |
| Brachysira brebessoni |  |  |  |  |  |  |
| Caloneis spp. |  |  |  |  |  |  |
| Caloneis bacillum |  |  |  |  |  |  |
| Caloneis silicula |  |  |  |  |  |  |
| Cocconeis disculus |  |  |  |  |  |  |
| Cocconeis placentula |  |  |  |  |  |  |
| Cyclotella bodanica v. lemmanica |  |  |  |  |  |  |
| Cyclotella stelligera |  |  |  |  |  |  |
| Cymbella spp. |  |  |  |  |  |  |
| Cymbella amphicephala | 4 |  |  | 5 |  | 4 |
| Cymbella cesatii |  |  |  |  |  |  |
| Cymbella cuspidata |  | 3 |  |  |  |  |
| Cymbella descripta |  |  |  |  |  |  |
| Cymbella gracilis |  |  |  |  |  |  |

|  | 8.25 | 8.50 | 8.75 | 9.00 | 9.25 | 9.50 |
|---|---|---|---|---|---|---|
| Cymbella hebridica |  | 1 |  | 2 |  |  |
| Cymbella hybrida |  |  |  |  |  |  |
| Cymbella incerta |  |  |  | 2 |  |  |
| Cymbella minuta |  |  |  |  |  |  |
| Cymbella silesiaca |  |  |  |  |  |  |
| Denticula kuet. |  |  |  |  |  |  |
| Diploneis elliptica |  |  |  |  |  |  |
| Diploneis finnica |  |  |  |  |  |  |
| Diploneis marginestriata | 3 | 5 |  |  |  | 1 |
| Diploneis oculata |  |  |  |  |  |  |
| Diploneis parma |  |  |  | 1 |  | 1 |
| Epithemia adnata |  |  |  |  |  |  |
| Eunotia spp. |  | 1 |  |  |  |  |
| Eunotia argus |  |  |  |  |  |  |
| Eunotia bilunaris |  | 1 |  |  |  |  |
| Eunotia incisa | 1 | 2 |  |  |  |  |
| Fragilaria brevistriata | 6 | 15 |  | 6 |  | 24 |
| F. brevistriata v. papillosa |  | 2 |  |  |  | 2 |
| Fragilaria capucina | 2 |  |  | 3 |  | 5 |
| F. construens v. binodis |  |  |  |  |  |  |
| F. construens v. construens | 4 | 4 |  |  |  |  |
| F. construens v. venter | 343 | 313 |  | 311 |  | 243 |
| Fragilaria crotonensis |  |  |  |  |  |  |
| Fragilaria leptostauron |  |  |  |  |  |  |
| Fragilaria parasitica |  |  |  |  |  |  |
| F. pinnata v. pinnata | 30 | 74 |  | 32 |  | 91 |
| Fragilaria tenera |  |  |  |  |  |  |
| Gomphonema spp. |  |  |  |  |  |  |
| Gomphonema gracile |  |  |  |  |  |  |
| Gomphonema parvulum |  |  |  |  |  |  |
| Gyrosigma acuminatum | 1 |  |  |  |  | 2 |
| Hantzchia amphioxys |  |  |  |  |  |  |
| Navicula absoluta |  |  |  |  |  | 2 |
| Navicula agretis |  |  |  |  |  |  |
| Navicula capitata |  | 1 |  |  |  |  |
| Navicula cocconeiformis |  |  |  | 1 |  |  |
| Navicula cuspidata |  |  |  |  |  |  |
| Navicula cryptocephala | 2 | 1 |  |  |  | 1 |
| Navicula detenta | 1 | 4 |  | 1 |  | 1 |
| Navicula digitulus |  |  |  |  |  |  |
| Navicula disjuncta |  |  |  | 1 |  |  |
| Navicula elginensis |  | 4 |  | 4 |  | 7 |
| Navicula festiva |  |  |  |  |  |  |
| Navicula gastrum |  |  |  |  |  |  |
| Navicula harderii |  | 2 |  |  |  |  |
| Navicula helensis |  |  |  |  |  |  |
| Navicula ignota |  |  |  |  |  |  |
| Navicula jaagii |  |  |  |  |  |  |
| Navicula jaernerfeltii |  |  |  |  |  |  |
| Navicula kuelbsii | 4 | 4 |  | 14 |  | 15 |

|  | 8.25 | 8.50 | 8.75 | 9.00 | 9.25 | 9.50 |
|---|---|---|---|---|---|---|
| Navicula laevissima |  |  |  |  |  |  |
| Navicula leptostriata |  |  |  |  |  |  |
| Navicula medioconvexa |  |  |  |  |  |  |
| Navicula minima |  |  |  |  |  | 6 |
| Navicula mimima small |  |  |  |  |  |  |
| Navicula minuscula |  |  |  |  |  |  |
| Navicula monoculatva |  |  |  |  |  |  |
| Navicula pupula | 2 | 10 |  |  |  | 4 |
| Navicula pseudoscutiformis |  |  |  |  |  |  |
| Navicula pseudoventralis | 6 |  |  |  |  |  |
| Navicula radiosa |  |  |  |  |  |  |
| Navicula rhynchocephala |  |  |  |  |  |  |
| Navicula reinhardtii |  |  |  |  |  |  |
| Navicula salinarium |  |  |  |  |  |  |
| Navicula saxophila |  |  |  |  |  |  |
| Navicula schadei |  |  |  |  |  |  |
| Navicula schmassmannii | 2 |  |  |  |  |  |
| Navicula seminulum | 2 |  |  | 6 |  | 2 |
| Navicula subminiscula |  |  |  |  |  |  |
| Navicula submuralis | 12 | 2 |  | 2 |  | 5 |
| Navicula subrotundata |  |  |  |  |  | 2 |
| Navicula subtilissima |  |  |  |  |  |  |
| Navicula tridentula |  |  |  |  |  |  |
| Navicula ventralis |  | 1 |  |  |  | 4 |
| Navicula vitabunda |  |  |  |  |  | 4 |
| Navicula vitiosa | 17 | 13 |  | 12 |  | 12 |
| Navicula vulpina | 1 | 3 |  | 2 |  |  |
| Neidium spp. (Centres) |  |  |  |  |  |  |
| Neidium amplicatum | 2 |  |  |  |  | 2 |
| Neidium hitchcockii |  |  |  |  |  |  |
| Neidium iridis |  |  |  |  |  |  |
| Nitzschia alpina |  |  |  |  |  |  |
| Nitzschia dissipata |  |  |  |  |  |  |
| Nitzschia glacilis |  |  |  |  |  |  |
| Nitzschia intermedia |  |  |  |  |  |  |
| Nitzschia palea |  |  |  | 1 |  |  |
| Nitzschia perminuta | 2 | 2 |  | 4 |  | 5 |
| Nitzschia recta |  |  |  |  |  |  |
| Pinnularia spp. |  |  |  |  |  |  |
| Pinnularia gibba |  |  |  | 1 |  |  |
| Pinnularia interrupta | 4 | 7 |  | 4 |  | 2 |
| Pinnularia maior |  | 1 |  |  |  |  |
| Pinnularia microstauron | 1 |  |  |  |  |  |
| Pinnularia nodosa | 1 |  |  |  |  |  |
| Pinnularia streptoraphe |  |  |  |  |  |  |
| Pinnularia viridis |  | 2 |  |  |  |  |
| Rhisolsenia spine |  |  |  |  |  |  |
| Rhisolsenia cysts |  |  |  |  |  |  |
| Stauroneis spp. (Centres) |  |  |  |  |  |  |
| Stauroneis anceps |  | 1 |  | 1 |  |  |

|  | 8.25 | 8.50 | 8.75 | 9.00 | 9.25 | 9.50 |
|---|---|---|---|---|---|---|
| Stauroneis lauenburginana |  | 2 |  |  |  |  |
| Stauroneis noblis v. gracilis |  | 1 |  | 2 |  |  |
| Stauroneis phoenicenteron | 2 | 2 |  | 2 |  |  |
| Stauroneis smithii | 1 | 3 |  |  |  | 1 |
| Stenopterobia spp. |  |  |  |  |  |  |
| Suriella spp. |  | 1 |  |  |  | 1 |
| Suriella constricta |  |  |  |  |  |  |
| Tabellaria flocculosa |  | 2 |  |  |  |  |
| Tabellaria flocculosa st. 4 |  |  |  |  |  |  |
| CYSTS | 8 | 6 |  | 9 |  | 10 |
| PHYTOLITHS | 0 |  |  | 0 |  |  |
| SCALES | 0 |  |  | 0 |  |  |
| PLATES | 0 |  |  | 0 |  |  |

## E.7 Eabamet Lake raw diatom counts (Chapter 4)

| | 0.00 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 | 2.50 | 2.75 | 3.00 | 3.25 | 3.50 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Achnanthes spp. | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Achnanthes acares | 0.4 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0.1 | 0.6 | 0 | 0 | 0 | 0 | 0 |
| Achnanthes biovetii | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Achnanthes calcar | 0 | 0 | 0 | 0 | 0.3 | 0.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Achnanthes childanos | 0 | 0 | 0 | 0 | 0.2 | 0.2 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0.4 |
| Achnanthes clevei | 1 | 1.7 | 1.2 | 1 | 0.6 | 0 | 1.5 | 0.8 | 0.9 | 0.9 | 1.8 | 1.2 | 2 | 1.5 | 0.2 |
| Achnanthes curtissima | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0.3 | 0 | 0.7 | 1.3 |
| Achnanthes exigua | 0 | 0.4 | 0.3 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0.2 | 0 | 0.8 | 0.4 | 0 | 0.4 |
| Achnanthes flexella | 0.4 | 0 | 0.1 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0.2 | 0 | 0.2 | 0.4 | 0 |
| Achnanthes impexiformis | 0 | 0 | 0 | 0 | 0.3 | 0.3 | 0 | 0 | 0 | 0.2 | 0.4 | 0 | 0 | 0 | 0 |
| Achnanthes lacus-vulcani | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 |
| Achnanthes lanceolata | 0.8 | 0 | 2.1 | 0.8 | 0.6 | 0.5 | 1.1 | 1.4 | 0.4 | 1.1 | 0.5 | 1.3 | 0 | 2 | 0.2 |
| Achnanthes laevis | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 |
| Achnanthes levanderi | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.4 | 0 | 0 | 0.4 | 0.5 | 1.2 | 0 | 0 |
| Achnanthes linearis | 0 | 0 | 0 | 0 | 0.3 | 0 | 0.1 | 0.3 | 0 | 0.3 | 0 | 0 | 0 | 0.6 | 0 |
| Achnanthes marginulata | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Achnanthes minutissima | 1.7 | 1.7 | 0.3 | 1.3 | 0.6 | 1.2 | 1 | 1.9 | 1.2 | 1.4 | 1.3 | 1.7 | 0 | 0 | 2.1 |
| Achnanthes obligua | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Achnanthes oestruptii | 0 | 0 | 0 | 0 | 0.3 | 0.2 | 0.1 | 0 | 0.3 | 0 | 0 | 0.2 | 0 | 0 | 0 |
| Achnanthes peragalli | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Achnanthes ricula | 0.4 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0.4 | 0 | 0 |
| Achnanthes rossi | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Achnanthes saccula | 0 | 0 | 1.2 | 0.6 | 0.3 | 0.3 | 0.1 | 0.3 | 0 | 0.6 | 0 | 0 | 0 | 0.4 | 0 |
| Achnanthes scotia | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Achnanthes subatomoides | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.4 | 0 | 0 |
| Achnanthes suchlandtii | 0.4 | 3.2 | 0.6 | 0.2 | 0.6 | 0.6 | 0.4 | 1 | 0.5 | 0.5 | 0.2 | 0.7 | 0.5 | 0.9 | 0.4 |
| Amphipleura kriegeriana | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Amphipleura pellueida | 0 | 0 | 0 | 0 | 0.2 | 0.5 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0.2 | 0.2 |
| Amphipleura rutilans | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Amphora forgidena | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.4 | 0 | 0 | 0 | 0 |
| Amphora libyca | 0 | 0 | 0.6 | 0.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Amphora inariensis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Amphora ovalis | 0 | 0 | 0.3 | 0 | 0 | 0.3 | 0.4 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 |
| Amphora pediculus | 0 | 0 | 0 | 0 | 0.9 | 0.8 | 0.7 | 1.4 | 1.2 | 1.4 | 0.7 | 0.3 | 1.4 | 0.7 | 0.4 |
| Asterionella formosa | 24 | 24 | 23 | 17 | 16 | 20 | 17 | 15 | 19 | 16 | 11 | 10 | 12 | 9.5 | 14 |
| Aulacoseira ambigua | 4.4 | 8.2 | 4.5 | 5 | 6.9 | 3.2 | 4.8 | 4.2 | 5.5 | 6.5 | 4.5 | 3.4 | 4.4 | 4.6 | 5 |
| Aulacoseira granulata | 1.1 | 1.9 | 1.9 | 3.5 | 2 | 1.1 | 2.1 | 3 | 2.1 | 2.4 | 2.7 | 2.7 | 3.7 | 3.1 | 2.3 |
| Aulacoseira granulata v. skinny | 1.1 | 0.2 | 1 | 1.7 | 1.9 | 2 | 1.5 | 1.5 | 1.3 | 1.6 | 2.2 | 0.8 | 0.7 | 1.3 | 1.5 |
| Aulacoseira islandica | 5.5 | 2.6 | 4.8 | 4.6 | 3.6 | 5.2 | 4.3 | 5.6 | 3.9 | 2.8 | 2.2 | 3.2 | 4.1 | 4 | 3.8 |
| Aulacoseira subarctica | 3.1 | 1.3 | 4 | 0 | 5.2 | 4.8 | 5.1 | 6.2 | 5.1 | 7.9 | 9 | 6.9 | 5.9 | 5.9 | 6.1 |
| Aulacoseira valida | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Brachysira spp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Brachysira neoexilis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Brachysira vitrea | 0 | 0 | 0 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Caloneis spp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Caloneis bacillum | 0 | 0.4 | 0.1 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0.3 | 0.2 | 0.2 | 0.8 |
| Caloneis silsiaca | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cocconeis spp. | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cocconeis disculus | 1.1 | 0.6 | 0.9 | 0.6 | 0.6 | 0.5 | 1 | 1.5 | 1.2 | 0.8 | 2.2 | 1.3 | 2.5 | 2.6 | 1.7 |
| Cocconeis placentula | 0 | 0 | 0.1 | 0 | 0 | 0.3 | 0.3 | 0.3 | 0 | 0.9 | 0.4 | 0.5 | 0.4 | 0 | 0.2 |

|  | 0.00 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 | 2.50 | 2.75 | 3.00 | 3.25 | 3.50 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cyclostephanos damasii | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 |
| Cyclostephanos tholiformis | 0 | 1.5 | 0.9 | 1.2 | 2.2 | 0.6 | 0.6 | 0.6 | 1.6 | 0.5 | 0.7 | 0.7 | 1.1 | 0.9 | 0.8 |
| Cyclotella bodanica v. lemmanica | 1 | 0.9 | 2.4 | 1 | 1.1 | 1.4 | 1.9 | 1.8 | 1.7 | 1.4 | 0.4 | 1.9 | 2 | 0.7 | 2.1 |
| Cyclotella distinguenda | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cyclotella meneghiniana | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cyclotella michiganiana | 2.3 | 2.2 | 2.1 | 2.7 | 2 | 2.4 | 2.5 | 1.1 | 2.2 | 1.6 | 1.4 | 1.5 | 1.8 | 2.8 | 1.9 |
| Cyclotella ocellata | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0.2 | 0 | 0.6 | 0.2 |
| Cyclotella stelligera | 7.1 | 8.2 | 6.4 | 5.8 | 7.1 | 4.2 | 6.9 | 6.5 | 8.2 | 5.5 | 4.5 | 4.4 | 5 | 4 | 3.6 |
| Cyclotella striata | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0.2 | 0 | 0 |
| Cymbella spp. | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cymbella affinis | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cymbella amphicephala | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cymbella budayana | 0 | 0 | 0 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0.6 | 0 | 0 | 0 | 0 | 0 |
| Cymbella cesatii | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 |
| Cymbella cistula | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cymbella cuspidata | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cymbella descripta | 0.2 | 0 | 0 | 0 | 0.3 | 0.3 | 0.4 | 1.1 | 0.1 | 0.2 | 0.4 | 0.2 | 0.2 | 0.4 | 0.2 |
| Cymbella gracilis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cymbella hebridica | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cymbella helvetica | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0.6 |
| Cymbella hybrida | 0 | 0.9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cymbella incerta | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 |
| Cymbella microcephala | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 |
| Cymbella minuta | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 |
| Cymbella silesiaca | 0 | 1.3 | 0.6 | 0.6 | 0.3 | 0 | 0.8 | 0 | 0 | 0 | 0.5 | 1 | 0.2 | 0 | 0.2 |
| Cymbella sinuata | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.6 | 0 |
| Denticula kuet. | 0 | 0 | 0.3 | 0.4 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0.3 | 0.4 | 0 | 0 |
| Diploneis spp. | 0 | 0 | 0.4 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Diploneis marginestriata | 0 | 0 | 0 | 0 | 0.2 | 0.3 | 0.1 | 0.3 | 0.3 | 0 | 1.3 | 0 | 0.5 | 0.6 | 0.4 |
| Diploneis parma | 0.4 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0.4 | 0.2 | 0.2 |
| Epithemia spp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Epithemia adnata | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Eunotia spp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Eunotia bilunaris | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 |
| Eunotia paludosa | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fragilaria brevistriata | 1 | 0 | 0 | 0.4 | 0.3 | 1.1 | 1 | 1 | 1.2 | 0.9 | 2.3 | 2.9 | 0.4 | 2.2 | 1.7 |
| F. brevistriata v. papillosa | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fragilaria capucina | 7.8 | 7.8 | 5.5 | 6 | 4.9 | 8.5 | 5.5 | 2 | 3.1 | 6.6 | 4.1 | 2.4 | 2.7 | 2.6 | 4.4 |
| F. capucina v. mesolepta | 0 | 0 | 0 | 0 | 0 | 0.5 | 0 | 3.3 | 0 | 0 | 0 | 0.3 | 0.5 | 0 | 0 |
| F. capucina v. rumpens | 0 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| F. construens v. binodis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.6 | 0 | 0 | 0 | 0 | 0 | 1.1 | 1.5 |
| F. construens v. construens | 0.2 | 0 | 0.9 | 3.5 | 1.6 | 0 | 0.3 | 1.3 | 0 | 0.5 | 0.5 | 2.5 | 1.1 | 0.7 | 0.4 |
| F. construens v. venter | 3.1 | 3.2 | 1 | 4.2 | 4.4 | 4.7 | 8 | 4.8 | 8.1 | 4.6 | 6.6 | 7.9 | 9.6 | 7.2 | 11 |
| Fragilaria crotonensis | 2.9 | 7.1 | 6.9 | 7.7 | 3.9 | 9.2 | 4.3 | 6.5 | 5.6 | 5.5 | 5.2 | 8.3 | 3.9 | 6.2 | 3.8 |
| Fragilaria cyclopum | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fragilaria leptostauron | 0 | 0 | 0 | 0 | 0.8 | 0.6 | 0.1 | 0.6 | 0.8 | 0.6 | 0.9 | 0.3 | 1.1 | 0.9 | 1 |
| Fragilaria parasitica | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0.8 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fragilaria pinnata | 0.6 | 0.4 | 0.7 | 0.4 | 0.3 | 0.3 | 0 | 0 | 0.3 | 0.6 | 0.5 | 0.5 | 1.8 | 3.3 | 1.3 |
| Fragilaria tenera | 1.7 | 1.1 | 0.9 | 2.5 | 3.1 | 1.1 | 0.4 | 1 | 1.4 | 0.8 | 1.6 | 0.8 | 0.4 | 2.2 | 2.1 |
| Fragilaria ulna | 0.6 | 0 | 0.1 | 0.2 | 0.6 | 0 | 0.4 | 0.1 | 0.1 | 0.2 | 0.5 | 0.3 | 0.5 | 0.2 | 1.5 |

| | 0.00 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 | 2.50 | 2.75 | 3.00 | 3.25 | 3.50 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F. virescins v. exigua | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gomphonema spp. | 0 | 0.4 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gomphonema acuminatum | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gomphonema clavatum | 0 | 0 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gomphonema gracile | 0 | 0 | 0.1 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 1.1 | 0 | 0 | 0 | 0 |
| Gomphonema grovei | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.2 |
| Gomphonema parvulum | 0.6 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.1 | 0 |
| Hantzchia amphioxys | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula absoluta | 0 | 0 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula agretis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula bryophilia | 0 | 0 | 0 | 0.2 | 0.3 | 0 | 0 | 0.5 | 0 | 0.3 | 0 | 0.2 | 0 | 0 | 0.4 |
| Navicula capitata | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0.4 | 0.3 | 0 | 0.2 | 0.4 |
| Navicula capaitoradiata | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 |
| Navicula cocconeiformis | 0.4 | 0 | 0 | 0 | 0 | 0 | 0.8 | 0.1 | 0.3 | 0.2 | 0 | 0 | 0.2 | 0 | 0.4 |
| Navicula cuspidata | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.2 | 0 |
| Navicula cryptocephala | 0.6 | 0.4 | 0.6 | 0.8 | 0.8 | 0.9 | 0.4 | 0.3 | 0.5 | 1.1 | 2.2 | 0.5 | 1.2 | 0.9 | 0.2 |
| Navicula cryptotenella | 0 | 0 | 0.3 | 0 | 0.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula detenta | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula disjuncta | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0.2 |
| Navicula elginensis | 0 | 0 | 0.3 | 0.2 | 0.3 | 0.2 | 0 | 0 | 0 | 0.3 | 0.7 | 0 | 0 | 0 | 0 |
| Navicula expecta | 0 | 0 | 0 | 0.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula festiva | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula helensis | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula ignota | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula indifferns | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula jaernerfeltii | 0 | 0 | 0.1 | 0 | 0.2 | 0.2 | 0.1 | 0.4 | 0 | 0.2 | 0.2 | 0.3 | 0.4 | 0.7 | 0.6 |
| Navicula kuelbsii | 0 | 0 | 0 | 0.4 | 0.3 | 0 | 0.3 | 0 | 0.8 | 0 | 0.4 | 0 | 0.4 | 0.2 | 0 |
| Navicula lacustris | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 |
| Navicula medioconvexa | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula menisculus | 0 | 0 | 0 | 0 | 0 | 0 | 0.4 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 |
| Navicula minima | 0.2 | 0 | 0 | 0.4 | 0 | 0 | 0.6 | 0.1 | 0 | 0.3 | 0.2 | 0 | 0 | 0.6 | 0.4 |
| Navicula minuscula | 0 | 0 | 0.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0.4 | 0 | 0 |
| Navicula mutica | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula pupula | 0.4 | 0.4 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0.3 | 0.2 | 0 | 0 | 0.2 | 0 |
| Navicula pseudoscutiformis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula pseudoventralis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula radiosa | 0 | 0 | 0.3 | 0.2 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0.4 | 1.2 | 0 | 0 | 0 |
| Navicula rhynchocephala | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula reinhardtii | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula salinarium | 0 | 0 | 0.3 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.4 |
| Navicula schadei | 0 | 0 | 0 | 0 | 0.9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula scutilloides | 0.2 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0.5 | 0 | 0.2 | 0 | 0.2 | 0.2 | 0.4 | 0 |
| Navicula scutiformis | 0 | 0.4 | 0 | 0.2 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.2 |
| Navicula seminulum | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula subminiscula | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.4 | 0.2 | 0 |
| Navicula submuralis | 0.6 | 1.1 | 2.4 | 2.9 | 3 | 1.4 | 2.2 | 2.5 | 3 | 1.7 | 3.2 | 5.2 | 5.1 | 4.8 | 2.7 |
| Navicula subplacentula | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula or Achnan subsalsa | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula tuscula | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula tridentula | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.4 |

|  | 0.00 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 | 2.50 | 2.75 | 3.00 | 3.25 | 3.50 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Navicula tripunctata | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula vitabunda | 0 | 0 | 0 | 0.4 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 |
| Navicula vulpina | 0.2 | 0 | 0 | 0.2 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0.2 | 0.3 | 0 | 0 | 0.2 |
| Neidium spp. (Centres) | 0 | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0.4 | 0.2 | 0 |
| Nitzschia spp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nitzschia acuminata | 0 | 0 | 0 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nitzschia alpina | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nitzschia disspata | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nitzschia glacilis | 3.2 | 0.9 | 0.9 | 2.7 | 2 | 1.7 | 1.8 | 2.7 | 2 | 2.2 | 2 | 2 | 1.6 | 1.3 | 1.9 |
| Nitzschia palea | 0 | 1.1 | 0.9 | 0.2 | 0.9 | 0 | 0.6 | 0 | 0.5 | 0 | 0 | 0 | 0 | 0.2 | 0 |
| Nitzschia peisonis | 0.2 | 0 | 0 | 0 | 0.2 | 0.5 | 0.3 | 0.1 | 0.1 | 0 | 0 | 0.2 | 0.2 | 0 | 0 |
| Nitzschia perminuta | 0.4 | 0 | 0.1 | 0 | 0 | 0 | 0.7 | 0.3 | 0.8 | 0.2 | 2.2 | 0.8 | 0.9 | 0.6 | 0.4 |
| Nitzschia recta | 0.6 | 1.1 | 0.9 | 1 | 0.3 | 0.8 | 1 | 0.6 | 0.5 | 0.8 | 0.9 | 0.7 | 0.4 | 0.2 | 0.2 |
| Pinnularia spp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0.4 |
| Pleurosigma | 0.2 | 0.6 | 0 | 0.8 | 0.2 | 0.6 | 0.7 | 0.4 | 0.4 | 0.8 | 0.9 | 0.5 | 0 | 1.1 | 0 |
| Rhopolodia spp. | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Rhopolodia gibba | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0.2 | 0 | 0 |
| Rhisoselina spines | 2.7 | 0 | 0.1 | 0.2 | 0.5 | 0.5 | 1.4 | 0.9 | 1.2 | 0.5 | 1.3 | 1.7 | 0.5 | 0.6 | 0.2 |
| Rhisolsenia cysts | 0.4 | 0.4 | 0.1 | 0 | 0 | 0.6 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0.2 |
| Stauroneis spp. (Centres) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Stauroneis anceps | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Stephanodiscus minutulus | 0.2 | 0.2 | 0.4 | 0.8 | 0.2 | 0.3 | 0.6 | 0.5 | 0.7 | 0.6 | 0.4 | 0.2 | 0.7 | 1.1 | 0.2 |
| Stephanodiscus medius | 0.2 | 0.4 | 0.4 | 1 | 1.6 | 0.9 | 1.1 | 0.5 | 0.8 | 0.9 | 1.6 | 0.7 | 1.2 | 1.8 | 0.8 |
| Stephanodiscus niagrae | 0.6 | 0.2 | 0.7 | 1.2 | 0.6 | 0.5 | 0.3 | 0.8 | 0.4 | 0.3 | 1.1 | 0.7 | 1.2 | 0.6 | 1 |
| Suriella spp. | 0.4 | 0 | 0.7 | 0.8 | 0.5 | 0.9 | 0.4 | 0.8 | 0.7 | 0.5 | 0.5 | 0.3 | 0.5 | 0 | 0 |
| Suriella constricta | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 | 0.1 | 0 | 0.5 | 0.5 | 0 | 0.2 | 0 |
| Suriella cf gracilis | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tabellaria fenestrata | 0 | 0 | 0.1 | 0.2 | 0.2 | 0.8 | 0.1 | 0.3 | 0 | 0.2 | 0.2 | 0.3 | 0.2 | 0 | 0 |
| Tabellaria flocculosa str. 1 | 0.4 | 0.4 | 0 | 0 | 0.3 | 0.3 | 0.3 | 0 | 0 | 0 | 0.2 | 0.3 | 0.7 | 0 | 0 |
| Tabellaria flocculosa str. 3 | 0.8 | 0.2 | 0.6 | 0.2 | 0.8 | 0.3 | 1 | 0.5 | 1.3 | 0.3 | 1.4 | 1 | 1.1 | 0.7 | 1 |
| Tabellaria flocculosa str. 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tabellaria quadriseptata | 12 | 9.5 | 10 | 10 | 6.4 | 9.1 | 8.4 | 6.6 | 7.3 | 9.6 | 5.9 | 7.6 | 6.9 | 6.4 | 6.7 |
| CYSTS | 41 | 40 | 38 | 29 | 43 | 52 | 64 | 53 | 53 | 41 | 58 | 58 | 52 | 52 | 30 |
| PHYTOLITHS | 1 | 0 | 0 | 0 | 1 | 0 | 4 | 1 | 1 | 1 | 0 | 4 | 1 | 4 | 4 |
| SCALES | 19 | 12 | 22 | 12 | 23 | 18 | 20 | 20 | 12 | 16 | 8 | 4 | 6 | 6 | 3 |
| PLATES | 0 | 0 | 0 | 10 | 12 | 2 | 3 | 0 | 1 | 0 | 1 | 1 | 2 | 2 | 1 |

|  | 3.75 | 4.00 | 4.25 | 4.50 | 4.75 | 5.00 | 5.25 | 5.75 | 6.00 | 7.00 | 7.25 | 7.50 | 7.75 | 8.00 | 9.00 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Achnanthes spp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Achnanthes acares | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 |
| Achnanthes biovetii | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Achnanthes calcar | 0 | 0 | 0.2 | 0.9 | 0.2 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Achnanthes childanos | 0 | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Achnanthes clevei | 1.3 | 1 | 0 | 1.1 | 1.1 | 1.2 | 0.3 | 1.6 | 1.5 | 1.2 | 0 | 2 | 0.8 | 3.2 | 1.2 |
| Achnanthes curtissima | 0.3 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Achnanthes exigua | 0.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.9 | 0 | 0 | 0.3 | 0 | 0.3 |
| Achnanthes flexella | 0.3 | 0 | 0 | 0.2 | 0 | 0.5 | 0.5 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 |
| Achnanthes impexiformis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Achnanthes lacus-vulcani | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 | 0.3 | 0 | 0 | 0 |
| Achnanthes lanceolata | 1.8 | 1.8 | 2.2 | 2.2 | 1.4 | 1.2 | 1.6 | 2.1 | 1.2 | 2.5 | 1.9 | 2 | 2.4 | 2.9 | 2.7 |
| Achnanthes laevis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Achnanthes levanderi | 0.1 | 0.2 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Achnanthes linearis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.6 | 0 |
| Achnanthes marginulata | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.6 | 0 | 0 | 0 | 0 | 0 |
| Achnanthes minutissima | 3.1 | 0.2 | 2.6 | 1.1 | 1.6 | 0 | 0.5 | 0 | 1.8 | 1.5 | 0.8 | 0 | 2.1 | 1.3 | 1.5 |
| Achnanthes obligua | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Achnanthes oestruptii | 0.3 | 0 | 0 | 0 | 0 | 0 | 0.5 | 0.5 | 0 | 0 | 0.5 | 4.1 | 0 | 0 | 0.3 |
| Achnanthes peragalli | 0 | 0 | 0.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Achnanthes ricula | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 |
| Achnanthes rossi | 0 | 0 | 0 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Achnanthes saccula | 0.8 | 0.2 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | 0.6 | 0 | 0 | 0 | 0 | 0.6 |
| Achnanthes scotia | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Achnanthes subatomoides | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.6 |
| Achnanthes suchlandtii | 1 | 0.6 | 0 | 0 | 0 | 0.5 | 0 | 0 | 0 | 1.5 | 0.5 | 1.4 | 1.1 | 0 | 0.9 |
| Amphipleura kriegeriana | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Amphipleura pellueida | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.6 | 0 | 0 | 0 | 0 | 0 | 0 |
| Amphipleura rutilans | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Amphora forgidena | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Amphora libyca | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Amphora inariensis | 0 | 1 | 0 | 0 | 0 | 0 | 0.5 | 0.8 | 1.5 | 1.5 | 0.3 | 1.4 | 0.5 | 0.3 | 0.9 |
| Amphora ovalis | 0 | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 0 | 0.6 | 0 | 0.3 | 0 | 0 | 0 |
| Amphora pediculus | 2.5 | 0.6 | 1.5 | 0.7 | 2 | 1.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Asterionella formosa | 7.6 | 13 | 9.3 | 8.9 | 5 | 13 | 9.1 | 8.4 | 11 | 11 | 16 | 8.1 | 8.4 | 18 | 16 |
| Aulacoseira ambigua | 5.6 | 5 | 3 | 2.4 | 4.5 | 6.3 | 10 | 12 | 7.5 | 6.7 | 4.9 | 5.7 | 5.3 | 2.9 | 7.4 |
| Aulacoseira granulata | 3.5 | 2.4 | 2.2 | 3 | 4.3 | 2.1 | 5.1 | 6.8 | 6.3 | 1.5 | 3.3 | 1.7 | 2.1 | 1.3 | 2.4 |
| Aulacoseira granulata v. skinny | 2.8 | 1.6 | 2.2 | 1.7 | 0.2 | 1.9 | 0 | 0 | 0 | 0 | 0 | 0 | 1.1 | 4.8 | 2.7 |
| Aulacoseira islandica | 3.5 | 4.8 | 3.7 | 5 | 3.6 | 2.5 | 2.9 | 5 | 3.9 | 4.3 | 4.6 | 5.7 | 3.7 | 3.2 | 8.3 |
| Aulacoseira subarctica | 8.8 | 6.6 | 6.1 | 8.3 | 9 | 9.3 | 13 | 10 | 11 | 4.9 | 3.8 | 5.4 | 3.4 | 5.7 | 4.1 |
| Aulacoseira valida | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 |
| Brachysira spp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 |
| Brachysira neoexilis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 0 |
| Brachysira vitrea | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Caloneis spp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 |
| Caloneis bacillum | 0 | 0.2 | 0.2 | 0 | 0 | 0.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Caloneis silsiaca | 0 | 0 | 0 | 0 | 0 | 0 | 1.9 | 0.3 | 0 | 1.8 | 0 | 0 | 0 | 0.6 | 0.9 |
| Cocconeis spp. | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cocconeis disculus | 1.5 | 2.4 | 1.1 | 3 | 2.5 | 2.1 | 0 | 0.3 | 0.6 | 2.8 | 1.6 | 5.7 | 2.4 | 3.2 | 0.6 |
| Cocconeis placentula | 0 | 0 | 0.4 | 0 | 0 | 0 | 0 | 0.3 | 0 | 1.8 | 0 | 0 | 0 | 0 | 0 |

| | 3.75 | 4.00 | 4.25 | 4.50 | 4.75 | 5.00 | 5.25 | 5.75 | 6.00 | 7.00 | 7.25 | 7.50 | 7.75 | 8.00 | 9.00 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cyclostephanos damasii | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cyclostephanos tholiformis | 0.8 | 1 | 0.6 | 0.9 | 0.9 | 0.7 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0.3 | 0.3 | 0 |
| Cyclotella bodanica v. lemmanica | 0.7 | 2.4 | 1.7 | 0.7 | 0.9 | 0.7 | 1.6 | 1.6 | 0.3 | 0.6 | 0.5 | 0.7 | 0.5 | 0 | 1.2 |
| Cyclotella distinguenda | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cyclotella meneghiniana | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cyclotella michiganiana | 2.2 | 0.4 | 1.3 | 2.4 | 1.6 | 0.9 | 5.4 | 2.9 | 2.1 | 1.8 | 3.8 | 0.7 | 0.8 | 1 | 2.1 |
| Cyclotella ocellata | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 |
| Cyclotella stelligera | 4.1 | 5.8 | 5 | 2.6 | 2.7 | 2.8 | 2.9 | 0.3 | 1.5 | 5.2 | 0.8 | 2.4 | 2.9 | 6 | 2.1 |
| Cyclotella striata | 0.4 | 0 | 0 | 1.3 | 0.2 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 |
| Cymbella spp. | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 |
| Cymbella affinis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cymbella amphicephala | 0 | 0 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cymbella budayana | 0.1 | 0.4 | 0 | 0 | 0.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cymbella cesatii | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cymbella cistula | 0 | 0 | 0 | 0.4 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.6 | 0 |
| Cymbella cuspidata | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | 1.1 | 0 | 0 | 0 | 0 |
| Cymbella descripta | 0.3 | 0.8 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0.5 | 0 | 0 |
| Cymbella gracilis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 |
| Cymbella hebridica | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cymbella helvetica | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cymbella hybrida | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cymbella incerta | 0 | 0 | 0 | 0 | 0 | 0 | 0.8 | 0.5 | 0 | 0 | 0 | 0.3 | 1.1 | 0 | 0.3 |
| Cymbella microcephala | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.9 | 0 | 0 | 1.3 | 0 | 0 |
| Cymbella minuta | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cymbella silesiaca | 0 | 0 | 0.4 | 0.4 | 0.5 | 0 | 1.1 | 1.6 | 0.9 | 0 | 1.9 | 0 | 0 | 0 | 0 |
| Cymbella sinuata | 0 | 0 | 0 | 0 | 0.5 | 0 | 0.5 | 0 | 0.9 | 0 | 0 | 0.7 | 1.3 | 0.3 | 0 |
| Denticula kuet. | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0.3 |
| Diploneis spp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Diploneis marginestriata | 0.1 | 0.4 | 0.4 | 0.4 | 0 | 0.2 | 0 | 0 | 0.3 | 0.9 | 0 | 0 | 0.5 | 0 | 0 |
| Diploneis parma | 0.3 | 0.4 | 0 | 0 | 0.7 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0.3 | 0.3 | 0 |
| Epithemia spp. | 0 | 0 | 0 | 0 | 0.2 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Epithemia adnata | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 |
| Eunotia spp. | 0.1 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Eunotia bilunaris | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 |
| Eunotia paludosa | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fragilaria brevistriata | 2.4 | 0.6 | 1.1 | 1.5 | 1.1 | 0 | 1.1 | 1.3 | 1.5 | 1.2 | 0 | 0.7 | 2.4 | 0.6 | 1.2 |
| F. brevistriata v. papillosa | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fragilaria capucina | 2.5 | 3.2 | 4.5 | 4.8 | 3.2 | 3.5 | 3.8 | 7.9 | 6 | 6.1 | 11 | 6.1 | 8.2 | 5.4 | 7.7 |
| F. capucina v. mesolepta | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| F. capucina v. rumpens | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| F. construens v. binodis | 0 | 0 | 0.6 | 0 | 1.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| F. construens v. construens | 0.8 | 0 | 1.5 | 0.9 | 2.7 | 0.5 | 0.5 | 0 | 3.9 | 0 | 0.3 | 0 | 2.4 | 0 | 0 |
| F. construens v. venter | 12 | 13 | 8.4 | 14 | 14 | 11 | 4.6 | 4.2 | 5.4 | 2.1 | 2.4 | 3.4 | 5.5 | 3.5 | 4.1 |
| Fragilaria crotonensis | 3.4 | 8 | 9.7 | 7.8 | 3.8 | 8.3 | 4 | 5.2 | 1.5 | 3.1 | 4.6 | 4.4 | 5.8 | 2.2 | 3.5 |
| Fragilaria cyclopum | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fragilaria leptostauron | 1.7 | 1.8 | 3.7 | 0.9 | 0 | 0.9 | 1.6 | 1 | 0.9 | 1.2 | 0.5 | 4.1 | 1.3 | 1 | 0.6 |
| Fragilaria parasitica | 0 | 0 | 0 | 0 | 0.9 | 0 | 0 | 0 | 1.2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fragilaria pinnata | 2.2 | 2.6 | 2.4 | 1.7 | 1.8 | 1.4 | 0.8 | 0 | 1.2 | 0 | 0 | 3.4 | 2.9 | 0.6 | 1.8 |
| Fragilaria tenera | 1.4 | 1 | 1.5 | 0.7 | 0.5 | 1.2 | 0.3 | 1 | 0.9 | 0.6 | 1.9 | 0 | 0.8 | 1 | 0.6 |
| Fragilaria ulna | 0.1 | 0.2 | 1.1 | 0.2 | 0.2 | 0.2 | 0 | 0.3 | 0.3 | 0.6 | 0.3 | 0 | 0 | 0 | 0.3 |

| | 3.75 | 4.00 | 4.25 | 4.50 | 4.75 | 5.00 | 5.25 | 5.75 | 6.00 | 7.00 | 7.25 | 7.50 | 7.75 | 8.00 | 9.00 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F. virescins v. exigua | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 |
| Gomphonema spp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0.3 |
| Gomphonema acuminatum | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gomphonema clavatum | 0 | 0 | 0.4 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gomphonema gracile | 0 | 0 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gomphonema grovei | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gomphonema parvulum | 0.4 | 0 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 |
| Hantzchia amphioxys | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0.5 | 0 | 0 | 0 | 0 |
| Navicula absoluta | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula agretis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0.5 | 0 | 0 |
| Navicula bryophilia | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 |
| Navicula capitata | 0 | 0 | 0 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula capaitoradiata | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula cocconeiformis | 0.1 | 0 | 0 | 0 | 0 | 1.2 | 0 | 0 | 0.3 | 0.6 | 0 | 0 | 0.8 | 0.6 | 1.2 |
| Navicula cuspidata | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 |
| Navicula cryptocephala | 0.1 | 0 | 1.5 | 0.4 | 1.1 | 1.4 | 0.5 | 0 | 0 | 0.3 | 0.5 | 1.4 | 1.8 | 1 | 1.5 |
| Navicula cryptotenella | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula detenta | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0.6 | 0 |
| Navicula disjuncta | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula elginensis | 0 | 0 | 0 | 0.2 | 0 | 0.2 | 0.5 | 0.3 | 0 | 0.3 | 0 | 0 | 0.3 | 0 | 0 |
| Navicula expecta | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula festiva | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula helensis | 0 | 0.2 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.6 | 0 |
| Navicula ignota | 0 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | 0 | 0.6 | 0 | 0 | 0 | 0 | 0 |
| Navicula indifferns | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula jaernerfeltii | 0.3 | 0.4 | 0.4 | 0.4 | 0 | 0 | 0.3 | 0.3 | 0.6 | 1.8 | 0 | 1.4 | 0.8 | 0 | 0 |
| Navicula kuelbsii | 0 | 0.2 | 0.2 | 0.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula lacustris | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula medioconvexa | 0.4 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula menisculus | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula minima | 0 | 0.4 | 0 | 0.7 | 0.5 | 0.5 | 0 | 0 | 0 | 0.6 | 0 | 0 | 0.5 | 1.9 | 0.6 |
| Navicula minuscula | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula mutica | 0 | 0 | 0 | 0 | 0 | 0.7 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 |
| Navicula pupula | 0.3 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | 0 | 0.6 | 0 | 1.4 | 0.8 | 0.3 | 0 |
| Navicula pseudoscutiformis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula pseudoventralis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.6 | 0 | 0 | 0 | 0 | 0 |
| Navicula radiosa | 0 | 0 | 0.9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.7 | 0 | 0 | 0 |
| Navicula rhynchocephala | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula reinhardtii | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0.6 | 0 |
| Navicula salinarium | 0 | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0.7 | 0.3 | 0 | 0 |
| Navicula schadei | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula scutilloides | 0 | 0.2 | 0.4 | 0.9 | 0.5 | 0 | 0 | 0 | 0.3 | 0.3 | 0.8 | 1.4 | 1.8 | 0.6 | 1.2 |
| Navicula scutiformis | 0 | 0.2 | 0 | 0 | 0 | 0 | 0.5 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula seminulum | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula subminiscula | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 |
| Navicula submuralis | 2.5 | 2.2 | 2.4 | 2 | 5 | 3.2 | 1.9 | 0.3 | 3 | 4.9 | 1.9 | 7.1 | 3.4 | 5.4 | 2.7 |
| Navicula subplacentula | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula or Achnan subsalsa | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula tuscula | 0 | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0.6 |
| Navicula tridentula | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | 3.75 | 4.00 | 4.25 | 4.50 | 4.75 | 5.00 | 5.25 | 5.75 | 6.00 | 7.00 | 7.25 | 7.50 | 7.75 | 8.00 | 9.00 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Navicula tripunctata | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula vitabunda | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.2 | 0 | 0 | 0 | 0 | 0 |
| Navicula vulpina | 0 | 0 | 0.2 | 0 | 0.5 | 0.2 | 0.3 | 1.6 | 0 | 0 | 0 | 0.7 | 1.3 | 0 | 0.6 |
| Neidium spp. (Centres) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 |
| Nitzschia spp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 |
| Nitzschia acuminata | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nitzschia alpina | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nitzschia disspata | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.3 | 0.6 |
| Nitzschia glacilis | 1.4 | 0.4 | 0.2 | 0.2 | 1.6 | 0.9 | 0.8 | 0.5 | 0.6 | 0.6 | 0.3 | 0.3 | 0.5 | 1 | 1.2 |
| Nitzschia palea | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0.5 | 0 | 0 | 0 | 0.3 |
| Nitzschia peisonis | 0.1 | 0 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nitzschia perminuta | 0.4 | 0 | 0 | 0 | 0.9 | 0 | 0 | 0.5 | 0 | 0.9 | 0.8 | 0 | 0 | 1 | 0 |
| Nitzschia recta | 0.6 | 1.2 | 1.5 | 0.2 | 0.7 | 0.7 | 0.8 | 0.5 | 0.9 | 1.2 | 2.7 | 0 | 0.8 | 1.3 | 0.6 |
| Pinnularia spp. | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0.3 | 0.3 | 0.3 | 0.5 | 0 | 0.3 | 0 | 0 |
| Pleurosigma | 0.7 | 1 | 0.4 | 1.1 | 0.7 | 1.2 | 0.8 | 0.5 | 1.2 | 0.6 | 0.3 | 2.7 | 0.8 | 1 | 0.6 |
| Rhopolodia spp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Rhopolodia gibba | 0 | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 |
| Rhisoselina spines | 0.6 | 0.8 | 0.4 | 0 | 0.5 | 0.5 | 0 | 0 | 0 | 0.9 | 1.1 | 0.7 | 0.3 | 1.6 | 0.6 |
| Rhisolsenia cysts | 0.1 | 0 | 0.2 | 0.9 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Stauroneis spp. (Centres) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Stauroneis anceps | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Stephanodiscus minutulus | 0.4 | 0.2 | 0 | 0.9 | 0.2 | 0.5 | 1.1 | 0 | 0 | 0 | 0 | 0 | 0.5 | 0.3 | 2.1 |
| Stephanodiscus medius | 0.8 | 0.6 | 0.6 | 1.1 | 0.9 | 0.7 | 2.4 | 0.5 | 1.5 | 1.2 | 1.6 | 0.3 | 1.8 | 0 | 0.3 |
| Stephanodiscus niagrae | 0.6 | 1 | 0.9 | 0.4 | 0.7 | 0.9 | 0.5 | 1.6 | 1.5 | 0.9 | 0.8 | 0 | 0.5 | 0 | 0.9 |
| Suriella spp. | 0.1 | 0.2 | 0.4 | 0.4 | 0.7 | 0.5 | 0 | 0.5 | 0.6 | 0.3 | 0 | 0 | 0 | 0 | 0 |
| Suriella constricta | 0.3 | 0.2 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0.7 | 0 | 0 | 0 |
| Suriella cf gracilis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tabellaria fenestrata | 0.4 | 0 | 0 | 0.2 | 0.5 | 0 | 0.3 | 0.5 | 0.9 | 0.3 | 0.3 | 0 | 0.3 | 0 | 0.3 |
| Tabellaria flocculosa str. 1 | 0.1 | 1.4 | 0.2 | 0.2 | 0.7 | 0.2 | 1.1 | 2.1 | 2.1 | 1.5 | 1.6 | 1.7 | 0.8 | 1.3 | 1.5 |
| Tabellaria flocculosa str. 3 | 0.8 | 1.2 | 1.9 | 0.9 | 2.5 | 0.7 | 1.3 | 1 | 1.5 | 3.1 | 1.4 | 1 | 1.1 | 0.6 | 1.5 |
| Tabellaria flocculosa str. 4 | 0 | 0 | 0.2 | 0.2 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tabellaria quadriseptata | 6.3 | 3.8 | 5 | 5.9 | 6.3 | 7.4 | 8.3 | 10 | 7.5 | 4 | 13 | 5.4 | 5.8 | 7.9 | 4.1 |
| CYSTS | 68 | 42 | 44 | 57 | 48 | 35 | 63 | 26 | 50 | 90 | 76 | 90 | 129 | 81 | 66 |
| PHYTOLITHS | 0 | 0 | 4 | 5 | 4 | 3 | 4 | 0 | 0 | 8 | 4 | 7 | 11 | 4 | 3 |
| SCALES | 7 | 7 | 5 | 0 | 5 | 5 | 2 | 1 | 1 | 12 | 2 | 1 | 2 | 21 | 5 |
| PLATES | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## E.8 Attawapiskat Lake raw diatom counts (Chapter 4)

| | 0.00 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.50 | 2.75 | 3.00 | 3.25 | 3.50 | 3.75 | 4.00 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Achnanthes acares | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| Achnanthes altaica | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| Achnanthes childanos | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 3 | 2 | 5 | 0 | 1 | 0 | 0 | 0 | 0 |
| Achnanthes clevei | 4 | 7 | 4 | 13 | 4 | 2 | 2 | 5 | 5 | 3 | 3 | 4 | 2 | 8 | 5 | 1 |
| Achnanthes curtissima | 0 | 2 | 2 | 1 | 6 | 3 | 2 | 3 | 0 | 2 | 2 | 4 | 0 | 4 | 0 | 1 |
| Achnanthes exigua | 0 | 0 | 2 | 3 | 3 | 1 | 0 | 2 | 0 | 2 | 0 | 2 | 0 | 2 | 2 | 0 |
| Achnanthes flexella | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 1 |
| Achnanthes impexiformis | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Achnanthes lacus-vulcani | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Achnanthes lanceolata | 4 | 11 | 1 | 7 | 2 | 9 | 7 | 6 | 9 | 5 | 7 | 10 | 8 | 11 | 8 | 3 |
| Achnanthes laevis | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 0 |
| Achnanthes levanderi | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Achnanthes linearis | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 3 | 3 | 2 | 4 | 0 | 0 | 2 |
| Achnanthes minutissima | 10 | 9 | 9 | 15 | 18 | 6 | 4 | 12 | 10 | 15 | 14 | 12 | 11 | 8 | 8 | 4 |
| Achnanthes oestruptii | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 2 |
| Achnanthes peragalli | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 |
| Achnanthes ricula | 2 | 2 | 2 | 0 | 1 | 3 | 0 | 0 | 0 | 0 | 2 | 1 | 2 | 0 | 0 | 0 |
| Achnanthes saccula | 0 | 2 | 0 | 0 | 2 | 0 | 2 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| Achnanthes subatomoides | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 1 |
| Achnanthes suchlandtii | 1 | 2 | 2 | 2 | 1 | 3 | 0 | 2 | 0 | 0 | 2 | 2 | 0 | 1 | 0 | 0 |
| Amphipleura pellueida | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 2 |
| Amphora forgidena | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Amphora ovalis | 1 | 0 | 1 | 2 | 1 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| Amphora pediculus | 8 | 2 | 0 | 2 | 0 | 2 | 0 | 3 | 8 | 0 | 7 | 7 | 2 | 0 | 5 | 0 |
| Asterionella formosa | 137 | 122 | 106 | 124 | 102 | 86 | 96 | 79 | 88 | 78 | 71 | 51 | 76 | 50 | 60 | 46 |
| Aulacoseira ambigua | 40 | 36 | 24 | 36 | 35 | 31 | 35 | 34 | 42 | 30 | 47 | 37 | 55 | 35 | 45 | 22 |
| Aulacoseira granulata | 6 | 4 | 2 | 6 | 5 | 5 | 5 | 8 | 9 | 4 | 6 | 6 | 12 | 4 | 7 | 4 |
| Aulacoseira granulata v. skinny | 2 | 2 | 1 | 3 | 2 | 3 | 3 | 4 | 3 | 3 | 3 | 4 | 3 | 4 | 2 | 1 |
| Aulacoseira islandica | 4 | 13 | 17 | 15 | 13 | 9 | 10 | 10 | 14 | 17 | 19 | 10 | 20 | 16 | 11 | 13 |
| Aulacoseira subarctica | 32 | 39 | 29 | 34 | 44 | 29 | 22 | 26 | 24 | 25 | 28 | 26 | 26 | 37 | 18 | 22 |
| Brachysira spp. | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Brachysira neoexilis | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Caloneis spp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| Caloneis bacillum | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 2 | 2 | 0 | 0 |
| Cocconeis disculus | 4 | 3 | 4 | 6 | 7 | 6 | 5 | 3 | 4 | 6 | 10 | 6 | 7 | 7 | 8 | 2 |
| Cocconeis placentula | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 |
| Cyclostephanos tholiformis | 5 | 3 | 2 | 3 | 7 | 5 | 5 | 4 | 6 | 4 | 6 | 3 | 6 | 3 | 2 | 2 |
| Cyclotella bodanica v. lemmanica | 2 | 3 | 1 | 0 | 4 | 2 | 4 | 4 | 3 | 0 | 3 | 4 | 4 | 4 | 3 | 0 |
| Cyclotella michiganiana | 3 | 2 | 7 | 8 | 11 | 6 | 7 | 7 | 4 | 2 | 7 | 5 | 6 | 5 | 6 | 1 |
| Cyclotella ocellata | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| Cyclotella stelligera | 29 | 31 | 28 | 32 | 29 | 15 | 25 | 29 | 15 | 16 | 16 | 13 | 16 | 5 | 8 | 5 |
| Cyclotella striata | 2 | 1 | 1 | 3 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 2 | 2 | 1 | 0 | 1 |
| Cymbella spp. | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cymbella cistula | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 4 | 1 | 0 | 0 | 0 | 2 | 0 | 0 |
| Cymbella descripta | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| Cymbella helvetica | 0 | 0 | 4 | 1 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cymbella incerta | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| Cymbella lapponica | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| Cymbella microcephala | 0 | 2 | 2 | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| Cymbella minuta | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 |

|  | 0.00 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.50 | 2.75 | 3.00 | 3.25 | 3.50 | 3.75 | 4.00 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cymbella puella | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cymbella proxima | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 |
| Cymbella silesiaca | 7 | 4 | 0 | 0 | 0 | 0 | 2 | 4 | 4 | 1 | 4 | 0 | 0 | 0 | 0 | 0 |
| Cymbella sinuata | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Denticula kuet. | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Diatoma tenuis | 7 | 1 | 1 | 0 | 4 | 4 | 4 | 0 | 2 | 2 | 3 | 1 | 0 | 2 | 1 | 0 |
| Diploneis marginestriata | 2 | 2 | 1 | 5 | 3 | 1 | 2 | 0 | 1 | 2 | 4 | 3 | 2 | 2 | 3 | 4 |
| Diploneis parma | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 2 |
| Epithemia adnata | 0 | 2 | 0 | 0 | 1 | 1 | 0 | 3 | 0 | 1 | 1 | 1 | 2 | 0 | 2 | 0 |
| Eunotia spp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| Eunotia incisa | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fragilaria brevistriata | 6 | 0 | 1 | 3 | 2 | 2 | 1 | 0 | 0 | 0 | 2 | 5 | 0 | 0 | 8 | 0 |
| Fragilaria capucina | 58 | 22 | 34 | 49 | 35 | 62 | 81 | 44 | 35 | 48 | 69 | 46 | 23 | 55 | 37 | 42 |
| F. construens v. binodis | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| F. construens v. construens | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 3 | 4 | 0 | 6 | 5 | 1 |
| F. construens v. venter | 7 | 25 | 24 | 27 | 31 | 14 | 27 | 51 | 29 | 26 | 44 | 35 | 46 | 42 | 25 | 15 |
| Fragilaria crotonensis | 14 | 5 | 19 | 5 | 12 | 28 | 17 | 10 | 9 | 12 | 14 | 11 | 7 | 13 | 13 | 9 |
| Fragilaria cyclopum | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 |
| Fragilaria leptostauron | 2 | 1 | 0 | 0 | 1 | 3 | 2 | 0 | 3 | 2 | 0 | 2 | 1 | 4 | 2 | 0 |
| Fragilaria nitzschoides | 1 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 2 | 2 | 0 |
| Fragilaria pinnata | 12 | 2 | 0 | 3 | 8 | 5 | 1 | 6 | 6 | 12 | 3 | 5 | 4 | 9 | 13 | 2 |
| Fragilaria tenera | 20 | 11 | 15 | 9 | 21 | 21 | 20 | 24 | 11 | 13 | 17 | 9 | 11 | 4 | 10 | 5 |
| Fragilaria ulna | 1 | 1 | 2 | 3 | 2 | 6 | 5 | 0 | 1 | 2 | 2 | 1 | 1 | 0 | 2 | 0 |
| Frustulia rhomboides | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gomphonema spp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 |
| Gomphonema acuminatum | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 |
| Gomphonema clavatum | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 2 | 1 | 0 | 0 | 0 | 0 |
| Gomphonema gracile | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| Gomphonema parvulum | 4 | 4 | 0 | 2 | 3 | 0 | 3 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gomphonema subtile | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| Navicula bryophilia | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula capitata | 2 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| Navicula clemensis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 |
| Navicula cocconeiformis | 0 | 0 | 2 | 1 | 1 | 0 | 0 | 0 | 4 | 0 | 0 | 2 | 0 | 0 | 4 | 2 |
| Navicula cryptocephala | 1 | 10 | 5 | 10 | 3 | 7 | 2 | 7 | 1 | 8 | 6 | 2 | 8 | 5 | 9 | 3 |
| Navicula detenta | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula digitulus | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula disjuncta | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula elginensis | 3 | 1 | 0 | 1 | 2 | 0 | 0 | 2 | 0 | 4 | 0 | 0 | 0 | 2 | 2 | 0 |
| Navicula festiva | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| Navicula helensis | 0 | 1 | 3 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 |
| Navicula ignota | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 2 | 0 | 0 | 0 | 0 |
| Navicula indifferns | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 |
| Navicula jaernerfeltii | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 1 | 0 |
| Navicula kuelbsii | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 2 | 1 | 0 | 0 | 1 | 2 | 0 | 0 |
| Navicula leptostriata | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 2 | 0 |
| Navicula medioconvexa | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula minima | 4 | 4 | 2 | 0 | 7 | 2 | 0 | 2 | 1 | 3 | 5 | 4 | 0 | 0 | 2 | 3 |
| Navicula mutica | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula pupula | 1 | 0 | 0 | 1 | 4 | 0 | 1 | 1 | 0 | 2 | 0 | 0 | 5 | 0 | 0 | 0 |

|  | 0.00 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.50 | 2.75 | 3.00 | 3.25 | 3.50 | 3.75 | 4.00 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Navicula pseudoscutiformis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 4 | 3 | 0 |
| Navicula pseudoventralis | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula pygmaea | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| Navicula radiosa | 3 | 2 | 3 | 0 | 0 | 0 | 3 | 2 | 0 | 1 | 0 | 0 | 2 | 3 | 2 | 0 |
| Navicula salinarium | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 4 | 0 | 0 | 0 |
| Navicula scutilloides | 2 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| Navicula scutiformis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 |
| Navicula seminulum | 0 | 0 | 0 | 0 | 2 | 4 | 0 | 2 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 |
| Navicula subminiscula | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| Navicula submuralis | 11 | 10 | 7 | 7 | 7 | 5 | 4 | 6 | 6 | 9 | 16 | 8 | 17 | 14 | 7 | 4 |
| Navicula subplacentula | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| Navicula subtilissima | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| Navicula trivalis | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula utermoehlii | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula ventralis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula vitabunda | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula vulpina | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 1 |
| Nitzschia glacilis | 23 | 9 | 4 | 9 | 8 | 15 | 1 | 8 | 7 | 7 | 7 | 3 | 6 | 3 | 3 | 3 |
| Nitzschia palea | 0 | 2 | 0 | 6 | 4 | 4 | 0 | 0 | 4 | 4 | 2 | 0 | 0 | 4 | 2 | 0 |
| Nitzschia peisonis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| Nitzschia perminuta | 1 | 2 | 6 | 3 | 1 | 4 | 0 | 0 | 6 | 2 | 5 | 6 | 7 | 0 | 2 | 6 |
| Nitzschia recta | 5 | 2 | 4 | 7 | 13 | 5 | 6 | 7 | 8 | 7 | 10 | 3 | 8 | 4 | 4 | 1 |
| Pinnularia spp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 1 |
| Pleurosigma spp. | 2 | 2 | 1 | 2 | 1 | 2 | 1 | 4 | 2 | 2 | 4 | 4 | 3 | 5 | 2 | 1 |
| Rhisoselina spines | 4 | 2 | 0 | 2 | 3 | 1 | 1 | 2 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| Rhisolsenia cysts | 2 | 4 | 0 | 2 | 4 | 1 | 2 | 4 | 2 | 5 | 2 | 5 | 1 | 1 | 1 | 1 |
| Stephanodiscus minutulus | 6 | 22 | 13 | 29 | 16 | 12 | 16 | 13 | 15 | 7 | 12 | 5 | 2 | 6 | 4 | 6 |
| Stephanodiscus medius | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| Stephanodiscus niagrae | 8 | 7 | 7 | 8 | 6 | 9 | 7 | 7 | 6 | 12 | 8 | 12 | 15 | 7 | 5 | 7 |
| Suriella spp. | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Suriella constricta | 6 | 2 | 0 | 3 | 2 | 3 | 0 | 2 | 1 | 0 | 0 | 0 | 3 | 1 | 0 | 0 |
| Tabellaria flocculosa str. 1 | 0 | 1 | 1 | 2 | 2 | 0 | 2 | 2 | 2 | 2 | 4 | 4 | 2 | 1 | 0 | 0 |
| Tabellaria flocculosa str. 3 | 21 | 17 | 16 | 16 | 18 | 26 | 20 | 22 | 19 | 13 | 28 | 26 | 27 | 14 | 21 | 13 |
| Tabellaria flocculosa str. 4 | 1 | 1 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tabellaria quadriseptata | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CYSTS | 17 | 44 | 52 | 51 | 42 | 38 | 26 | 34 | 41 | 37 | 42 | 45 | 54 | 58 | 37 | 13 |
| PHYTOLITHS | 5 | 3 | 3 | 7 | 6 | 9 | 3 | 8 | 8 | 1 | 6 | 8 | 10 | 13 | 15 | 6 |
| SCALES | 12 | 7 | 5 | 3 | 6 | 1 | 4 | 6 | 4 | 1 | 2 | 0 | 2 | 3 | 1 | 0 |
| PLATES | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |