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Primary Research Paper

Hydrological controls on the diatom assemblage of a seasonal arctic river: Boothia Peninsula, Nunavut, Canada

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Abstract

This study characterizes the melt season diatom assemblage of a middle arctic river with respect to hydrological conditions. In addition, the potential to identify species that show a strong affinity for the lotic environment provides an opportunity to interpret stratigraphic changes in these species in the lake sedimentary record in terms of past hydrological change. Understanding long-term hydrological variability is critical for assessing both current and future environmental change. Significantly higher relative abundances of *Achnanthes minutissima* Kützing, *Fragilaria capucina* var. *vaucheriae* (Kützing) Lange-Bertalot, *Diatoma tenuis* Agardh, *Cymbella arctica* (Lagerstedt) Schmidt, *C. minuta* Hilse ex. Rabenhorst, *C. silesiaca* Bleisch and *Encyonema fogedii* Krammer in the lotic environment throughout the 2001 growing season compared to the lacustrine sedimentary record suggest that these species characterize the Lord Lindsay River diatom assemblage. Comparison of seasonal abundances of these taxa to hydrological parameters including discharge, electrical conductivity, and water temperature reveal key information about the character of this community. The fact that the river diatom assemblage changes very little throughout the sampling period, despite major changes in hydrological conditions, suggests a degree of resilience and inherent structure in the community. However, a decrease in diatom biomass in response to rapid and dramatic changes in hydrological conditions following a major rainfall event suggests that a threshold tolerance may exist, with potentially important implications for interpreting stratigraphic changes in the paleoenvironmental record.

Introduction

Recent trends in global climate support the need for research aimed at understanding natural climate variability. Since historical climate records are geographically sparse and temporally limited, alternative means for understanding past climatic conditions are required. The continuous accumulation of sediment and entrained biological and chemical constituents in lakes over time can offer a detailed record of past environmental variability if the relationship between sedimentary components and environmental conditions are well understood. For example, fossil diatoms are frequently used in paleolimnological reconstructions because the seasonal sensitivities and ecological optima and tolerances of many taxa are well documented (Smol & Cumming, 2000). Additionally, diatoms respond rapidly to changing environmental conditions and are generally well-preserved in lake sediments due to the silica content of their cell walls (Smol & Cumming, 2000).

The ecological sensitivities and rapid response rates of diatoms may be particularly relevant for high-latitude flowing waters characterized by extreme changes in environmental conditions over relatively short periods of time (Irons & Oswood, 1992). Additionally, diatoms from remote locations without direct human impact are both the least well understood and potentially the most valuable for understanding the effects of climate change. Past changes in the physical and ecological environment may therefore be reflected in the lake sedimentary record through the transport and delivery of diatom remains from the river to the lake bottom. However, research aimed at characterizing lotic assemblages and their paleoenvironmental significance, particularly at high latitudes where climate change impacts are expected to occur first, is relatively sparse. Ludlam et al. (1996) examined habitat specificity patterns in lotic and littoral assemblages in a high arctic catchment and developed an index for the relative contribution of lotic diatoms in the sedimentary record. Based on their Lotic Index, they were able to infer historical changes in runoff, with important implications for understanding paleoclimatic conditions. Similarly, Antoniades & Douglas (2002) examined the lotic assemblages in high arctic rivers and streams and were able to qualitatively isolate species on the basis of both streamflow and temperature. Clearly, the information revealed by these investigations holds significant promise for improving understanding of current ecological conditions and past environmental change, and warrants further investigation into high latitude lotic diatom communities. Thus, the purpose of this study is to characterize the river diatom assemblage of a middle arctic river with respect to seasonal hydrological variability, with the future goal of enhancing interpretations of the lake sedimentary record.

Study site

The Lord Lindsay River flows into Sanagak Lake (70 °15′N, 94 °W) approximately 75 km north of Taloyoak (formerly Spence Bay) on the Boothia Peninsula, Nunavut, Canada (Fig. 1). The river drains a relatively large (1400 km^2) catchment of low relief (<350 m) hills and meadow lowlands typical of tundra terrain. The local geology is characterized by Paleozoic carbonates and Precambrian gneiss and granite, particularly in the upper catchment. Topographically, the area is dominated by glacial and periglacial features including extensive till, glaciofluvial deposits, ice-contact deposits and sub-glacial landforms (Dyke, 1984). The study site lies in the continuous permafrost zone with a maximum active layer of 1 m consisting of poorly developed regosolic turbic cryosols (Dyke, 1984). Climate records from Taloyoak (1984–1999) show a mean annual temperature of −14.8 °C, with January being the coldest month (−35 °C) and July the warmest (8.3 °C). Mean annual precipitation for this period is 176 mm, 103.5 mm of which falls as snow (Environment Canada, 1999).

Flow in the Lord Lindsay River ceases from October to June, and hydrological investigations in the catchment during 2001 and 2002 revealed that over 80% of total annual runoff and over 90% of total annual sediment delivery occurs during the brief snowmelt peak in late June to early July. The river channel is large (maximum width 110 m; maximum depth 4 m) and relatively straight. Flow began on June 10 in 2001 and reached a maximum of 407 m^3 s^{-1} on July 1. Given the intensity of the Lord Lindsay River's peak flow, vegetation is largely confined to overhanging banks and marginal areas of the river channel.

Materials and methods

This study is based on diatom samples and hydrological data collected from the Lord Lindsay River between first flow in June and late season low flow in early August, 2001, and fossil diatoms from a surface sediment core collected from Sanagak Lake in spring, 2002. Surface sediments were collected from 59 m of water with a simple gravity corer (Boyle, 1995) suspended by a mechanical winch on the ice surface. Diatom samples were collected from both rock and moss substrates in the Lord Lindsay River approximately every three days from June 18 to August 1, 2001. For the rock samples, a minimum of three stones large enough to not be moved under normal hydrological conditions were brushed into a 20 ml

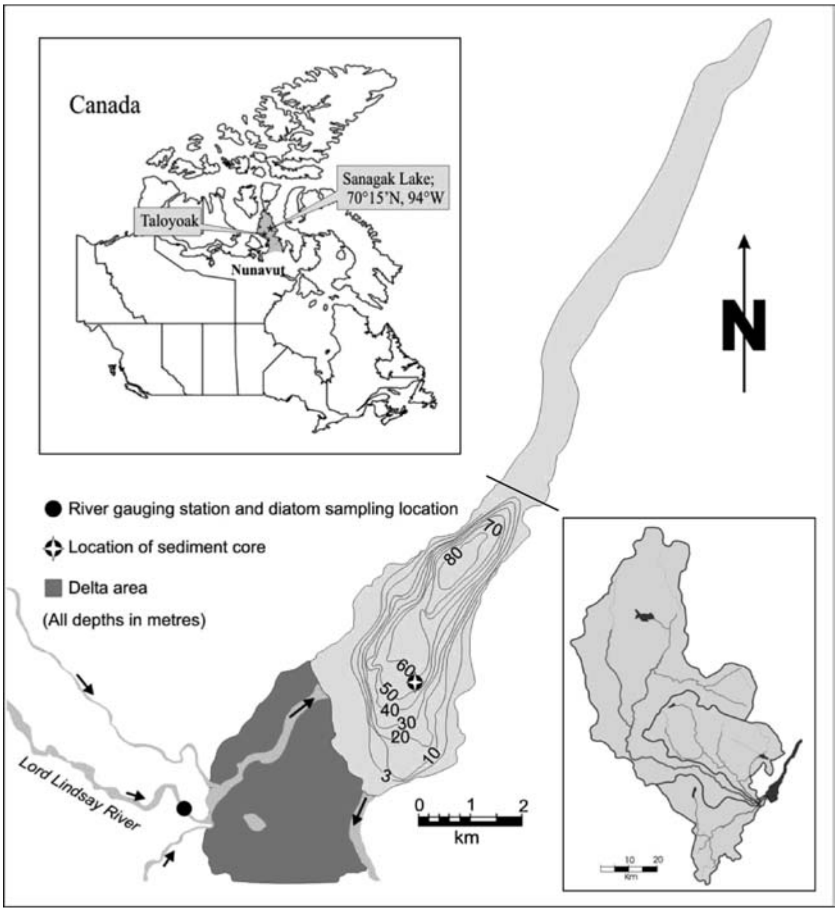

Figure 1. Inflow and outflow of the Lord Lindsay River to Sanagak Lake. Location of the river gauging station and collection site of the river diatom samples are shown. The location of the sediment core used in this analysis is also shown. Insets reveal the location of the study site and nearest community, Taloyoak, on the Boothia Peninsula (shaded) in Nunavut, and the size of the watershed feeding Sanagak Lake. Note that bathymetry is not available for the northeast arm of Sanagak Lake (i.e., beyond solid line).

scintillation vial using a toothbrush. Moss samples consisted of a small amount of moss collected by hand from several different spots within the same immediate area. Both rock and moss samples were collected near the river gauging station but sites were carefully selected close to the edge of the river channel where mosses were present and the effects of scouring were limited by lower water velocities. All diatom samples were preserved with one to two drops of Lugol's iodine solution. Diatom samples and sediment cores were kept cool prior to being transported back to the laboratory, and were kept dark and refrigerated at 4 °C in the laboratory prior to analyses in May 2003.

Diatom samples were prepared for analysis following the standard acid digestion and aspiration procedure for siliceous microfossils described by Wilson et al. (1996). Processed samples were mounted in two dilutions onto glass coverslips using a high refractive index (≥1.74) mounting medium (Naphrax®). Diatom valves were identified and enumerated using a Leica DMRB light microscope under a 100× oil immersion lens. Diatom taxonomy generally followed the floras of Krammer & Lange-Bertalot (1997–1999), Krammer (1997), Patrick & Reimer (1975) and Hustedt (1927–1966). For the river samples, a minimum of 300 diatom valves or two complete transects were counted per sample. Intervals that revealed fewer than 20 valves after two transects of the less dilute sample were deemed insufficiently concentrated to be reasonably counted and were thus excluded

Table 1. The number of diatom valves and slide transects counted for each rock, moss and combined rock and moss sample. The ratio of valves counted per transect (v:t) is also listed. A minimum of two complete transects were counted per sample, and those samples with final ratios of less than 10 valves per transect were deemed insufficiently concentrated to warrant further counting

Date	Rock			Moss			Combined rock and moss samples		
	# valves	# transects	v:t	# valves	# transects	v:t	# valves	# transects	v:t
Jn-18	0	2	0.0	9	2	4.5	9	4	2.3
Jn-23	0	2	0.0	0	2	0.0	0	4	0.0
Jn-26	3	2	1.5	0	2	0.0	3	4	0.8
Jn-29	12	2	6.0	0	3	0.0	12	5	2.4
Jy-02	0	2	0.0	0	2	0.0	0	4	0.0
Jy-05	11	2	5.5	13	2	6.5	24	4	6.0
Jy-08	8	2	4.0	342	4	85.5	350	6	58.3
Jy-11	188	6	31.3	339	1	339.0	527	7	75.3
Jy-15*	9	3	3.0	44	5	8.8	53	8	6.6
Jy-17	7	4	1.8	471	1	471.0	478	5	95.6
Jy-20	23	2	11.5	306	5	61.2	329	7	47.0
Jy-23	411	5	82.2	325	5	65.0	736	10	73.6
Jy-26	313	10	31.3	339	5	67.8	652	15	43.5
Jy-30	153	8	19.1	332	6	55.3	485	14	34.6
Ag-01	476	7	68.0	325	3	108.3	801	10	80.1

*first sample after major rain event on July 12–13.

from the analysis (Table 1). For the sediment samples, a minimum of 600 diatom valves per 0.5 cm interval to a depth of 15 cm were identified and enumerated.

Hydrological parameters used in this study are briefly summarized as follows. River discharge was gauged with a pressure transducer logged at 10 min intervals and manually rated with a Columbia current meter (±4%) throughout the season. River water temperatures were logged at 10 min intervals from June 18 to July 28 using an Onset Hobo logger and a high resolution external shielded thermister probe. Electrical conductivity was measured with a YSI 30M SCT meter a minimum of once daily from filtered (0.45 μm pore size cellulose acetate filters) water samples. Air temperature was logged at 15 min intervals with a shielded Onset Hobo Pro temperature logger.

Results

A total of 108 species corresponding to 24 genera were identified in the Lord Lindsay River diatom samples. While the number of species identified is approximately half that identified in the lake sedimentary record (209), 15 species found in the river samples have not been previously identified in Sanagak Lake's sedimentary record (Table 2).

Table 2. Species found in the river samples but not in the sedimentary record

Taxon and authority	Number of valves counted
Cyclotella stelligera Cleve & Grunow	16
Cyclotella michiganiana Skvortzow	3
Aulacoseira ambigua (Grunow) Simonsen	2
Aulacoseira distans (Ehrenberg) Simonsen	10
Aulacoseira perglabra (Oestrup) Haworth	7
Amphora kriegeri Krasske	2
Caloneis undosa Krammer	1
Diploneis modica Hustedt	1
Fragilaria zeilleri var. *elliptica* Gasse	2
Nitzschia cf. *linearis* (Agardh) W. Smith	1
Brachysira neolixis var. *capitata* Lange-Bertalot	1
Navicula irmengardis Lange-Bertalot	2
Pinnularia cf. *polyonca* (de Brébisson) W. Smith	1
Pinnularia hemiptera (Kützing) Rabenhorst	1
Tabellaria quadrasepta Knudson	2

The number of valves of each species counted is also listed.

However, for most of these species only one or two valves were counted in total, and therefore cannot be considered significant in terms of the overall assemblage. The exception to this is *Cyclotella stelligera,* which exhibits an overall relative abundance of 1% in the rock scrape samples (Table 3). Interestingly, of the 80 centric valves identified in the river samples, none were associated with the moss samples, despite the greater number of valves counted in the moss samples (2845) versus the rock samples (1614) (Table 1).

A total of 13 species identified in the combined moss and rock samples exhibited relative abundances of >1% and are thus considered common in this analysis (Table 4). Due to difficulties associated with differentiating *Nitzschia perminuta*, *N. paleacea* and *N. liebetruthii*, particularly in girdle view, these taxa have been grouped under the name of the most dominant species, *N. perminuta* complex in Table 4. Since *Cymbella arctica, C. silesiaca, C. minuta and Encyonema fogedii* display distinctly similar trends in relative abundance, they have been plotted together under the collective name *Cymbella* species in Figure 2.

To examine the relationship between the river diatom assemblage and that of the sedimentary record, the common species from both river substrates and the lake sediment record were compared. Based on significantly higher relative abundances in the river samples compared to the sedimentary record, *A. minutissima, F. capucina* var. *vaucheriae, D. tenuis*, *C. arctica*, *C. minuta*, *C. silesiaca*, and *E. fogedii* appear to best represent the river assemblage and are therefore selected for direct comparison with hydrological changes (Table 4). Thus, all subsequent mention of the river assemblage refers to the aforementioned species. To investigate the nature of the relationship between the river assemblage and hydrological conditions, trends in individual relative abundances of the river taxa were compared to river discharge, electrical conductivity, water temperature and air temperature throughout the 2001 growing season (Fig. 2).

The relative contribution of individual river taxa to the overall diatom assemblage remains relatively stable during the flow season, despite major hydrological changes. Most notably, river discharge ranges from zero in early June to over 400 $m^3 s^{-1}$ at peak flow in early July. Similarly, water temperature in the Lord Lindsay River ranged from less than 2 °C early in the season to over 20 °C in late July. Dramatic fluctuations in electrical conductivity, resulting from changes in the contribution of snow water to overall discharge, also characterized the hydrological season.

Although there is relatively little change in the proportional contribution of the river species during the growing season, it appears that significant diatom biomass initiates only after the peak

Table 3. Species and relative abundances of centric diatoms found in the rock samples. Note that not a single centric valve was found in the moss samples

Species and authority	Total # valves	Relative abundance (%)
Cyclotella stelligera Cleve & Grunow	16	1.0
Cyclotella radiosa Grunow	16	1.0
Cyclotella bodanica var. *lemmanica* (O. Müller ex Schröter)	13	0.8
Cyclotella atomus Hustedt	4	0.2
Cyclotella michiganiana Skvortzow	3	0.2
Cyclotella comensis Grunow	1	0.1
Aulacoseira alpigena (Grunow) Krammer	3	0.2
Aulacoseira italica (Ehrenberg) Simonsen	2	0.1
Aulacoseira ambigua (Grunow) Simonsen	2	0.1
Aulacoseira distans (Ehrenberg) Simonsen	10	0.6
Aulacoseira perglabra (Oestrup) Hawarth	7	0.4
Stephanodiscus minutulus (Kützing) Cleve & Möller	3	0.2
Centrics	80	5.0

Table 4. Relative abundances of all common (mean relative abundance > 1%) taxa in either the river (rock or moss) or sedimentary (lake) samples. Taxa that appear to be more strongly associated with the river environment (defined here as having a lake relative abundance less than 60% that of the combined river relative abundance) are in bold

Common taxa and authorities	Relative abundance (%)			
	Rock[a]	Moss[b]	Combined river[c]	Lake[d]
Achnanthes flexella (Kützing)	1.6	0.7	1.2	1.4
Achnanthes marginulata Grunow	0.7	1.5	1.1	3.1
***Achnanthes minutissima* Kützing**	**31.5**	**32.2**	**31.8**	**18.6**
Achnanthes petersenii Hustedt	1.0	2.6	1.8	1.1
Amphora inariensis Krammer	0.9	0.7	0.8	1.6
Asterionella formosa Hassall	0.4	0.0	0.2	1.4
Aulacoseira alpigena (Grunow) Krammer	0.2	0.0	0.1	5.5
Aulacoseira italica (Ehrenberg) Simonsen	0.1	0.0	0.1	2.6
Cocconeis placentula Ehrenberg	0.1	0.0	0.1	2.4
Cyclotella atomus Hustedt	0.3	0.0	0.1	1.5
Cyclotella radiosa Grunow	1.0	0.0	0.5	2.4
***Cymbella arctica* (Lagerstedt) Schmidt**	**3.4**	**2.6**	**3.0**	**1.4**
***Cymbella minuta* Hilse ex. Rabenhorst**	**1.5**	**1.3**	**1.4**	**0.2**
***Cymbella silesiaca* Bleisch**	**1.2**	**1.7**	**1.4**	**0.8**
***Diatoma tenuis* Agardh**	**4.0**	**4.9**	**4.4**	**0.8**
***Encyonema fogedii* Krammer**	**1.2**	**3.1**	**2.2**	**0.4**
***Fragilaria capucina* var. *vaucheriae* (Kützing) Lange-Bertalot**	**22.6**	**23.2**	**22.9**	**4.5**
Fragilaria construens Ehrenberg	2.3	5.5	3.9	6.9
Fragilaria pinnata Ehrenberg	2.3	3.7	3.0	4.0
Nitzschia alpina Hustedt	0.3	0.7	0.5	1.6
Nitzschia perminuta complex (Grunow)	7.4	4.5	5.9	5.9
Stephanodiscus niagarae Ehrenberg	0.0	0.0	0.0	1.9

[a] Relative abundances based on the total number of valves counted in all rock samples.

[b] Relative abundances based on the total number of valves counted in all moss samples.

[c] Relative abundances based on the total number of valves counted in all rock and moss samples.

[d] Average relative abundance of all samples counted from the sediment core.

discharge period (Fig. 2). In particular, the rise to significant numbers of valves occurs first in the moss samples on July 8 and then in the rock samples on July 11 (Table 1). For the remainder of the season the river taxa appear relatively stable, with a slight increase and a slight decrease at the end of July for *A. minutissima* and *F. capucina* var. *vaucheriae*, respectively. However, all taxa are absent in the samples collected on July 15. This coincides with a rapid increase in discharge and electrical conductivity and simultaneous decrease in temperature resulting from a major rainfall event on July 12–13. Diatoms are similarly absent prior to peak flow when discharge and water temperature are low and conductivity and snowmelt contribution to discharge are relatively stable.

Discussion

Characterization of diatom assemblage

Of the 108 species and 24 genera observed in the Lord Lindsay River samples, only 13 species representing the five genera *Nitzschia, Fragilaria, Cymbella, Diatoms* and *Achnanthes* are considered common. Worth mention among the uncommon taxa, however, are the 12 centric species that appear in the rock samples but are entirely absent in the moss samples. Round et al. (1990) characterize the three centric diatom genera *Aulacoseira*, *Cyclotella* and *Stephanodiscus* as common freshwater planktonic genera, and all three are widespread in freshwaters of North America (Wehr & Sheath, 2003).

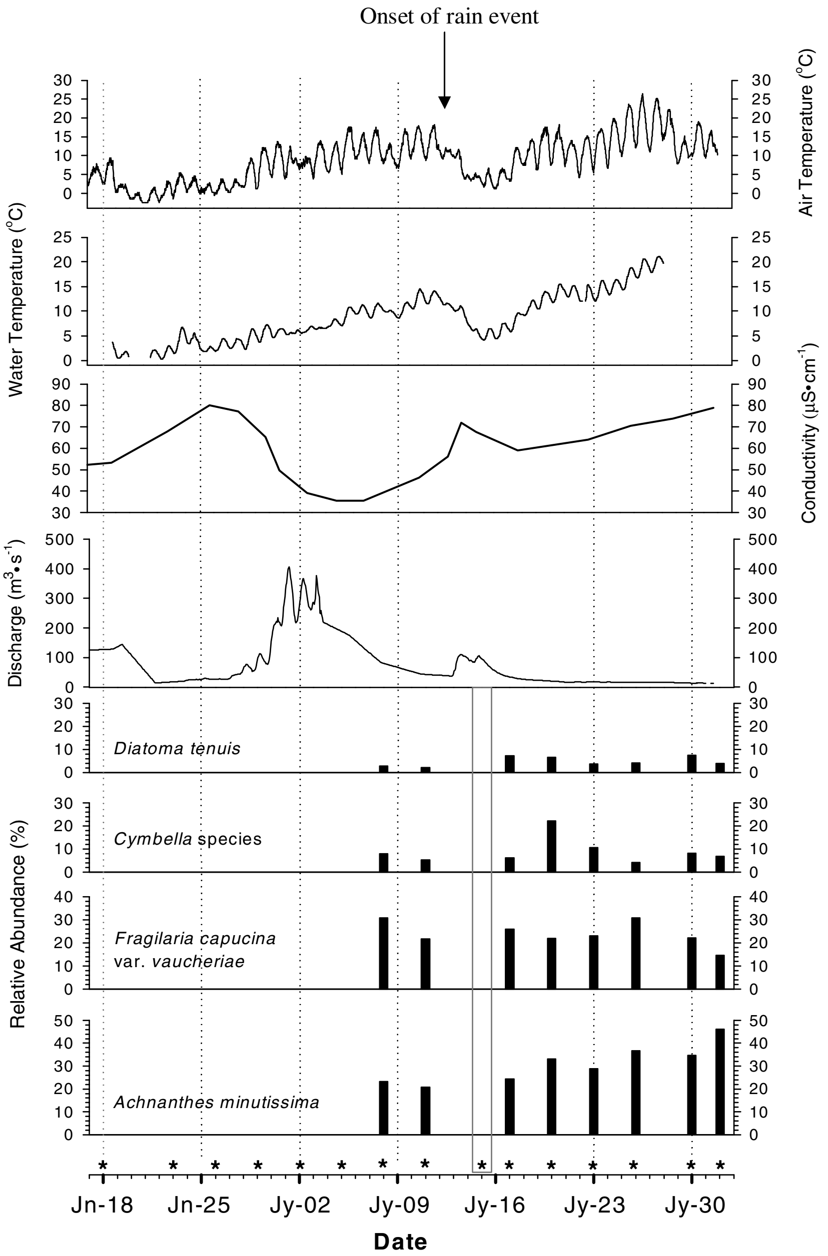

Figure 2. Changes in the relative abundance of river diatoms and concurrent trends in river discharge, conductivity, water temperature and air temperature during the 2001 growing season. Asterisks above the x-axis indicate diatom sampling dates. Samples showing no corresponding diatom abundances are those where fewer than 300 valves could be reasonably counted. The rectangle extending through the July 15 sample highlights the absence of diatoms following a major rain event beginning on July 12 (indicated with arrow).

However, their exclusivity to the rock substrates suggest that these taxa may be benthic in this environment, since planktonic or even tychoplanktonic species would likely collect on the river substrates in a more random manner. Similar observations were made in ponds on Bathurst Island, Nunavut where the taxon *Cyclotella pseudostelligera* was found exclusively on rock substrates and also deemed to be tychoplanktonic or benthic in that environment (Lim et al., 2001a).

Though a relatively high number of species were identified in the Lord Lindsay River samples, overall diversity and standing crop in the river community was low. Approximately half of the species identified in the lake were identified in the river, and the concentration of valves on the slides was generally very low. While it is difficult to attribute low concentrations of diatom valves on microscope slides to their actual biomass in that environment given the various biases introduced during sampling and slide preparation, similar trends in valve:transect ratios in rock and moss samples throughout the sampling period suggest that environmental conditions were at least partially responsible. In addition, while lotic environments can be very productive, reports of low diversity and diatom productivity are not uncommon in the literature and have been attributed to factors such as variability in flow rate and substrate instability (e.g., Douglas, 1958; Potapova, 1996).

Significantly higher relative abundances of *Achnanthes minutissima*, *Fragilaria capucina* var. *vaucheriae*, *Cymbella arctica*, *C. minuta*, *C. silesiaca*, *Encyonema fogedii* and *Diatoma tenuis* in the river samples compared to the lake sediments suggest that these taxa are rheophilic in this environment. The ability of *A. minutissima* to adhere closely and firmly to substrata may account for its competitiveness in flowing waters (Peterson & Stevenson, 1992; Wehr & Sheath, 2003), including those in northern Europe (Vilbaste & Truu, 2003) and across the Canadian Arctic (Moore, 1977; Moore, 1979; Hamilton et al., 1994; Ludlam et al., 1996; Antoniades & Douglas, 2002). However, Ludlam et al. (1996) noted that while *A. minutissima* was common in small stream and lake algal mat samples in a High Arctic catchment, it was rare in high energy stream samples, suggesting it is more representative of littoral environments. In Arctic freshwater environments, *A. minutissima* has been associated with the epilithon (Douglas & Smol, 1993), although strong affinities for the epiphyton (Moore, 1977; Lim et al., 2001a) or no appreciable affinity for a particular habitat (Antoniades & Douglas, 2002) have also been observed. Given the comparable relative abundances in rock and moss samples it appears that *A. minutissima* is equally competitive on both of these substrates in the Lord Lindsay River as well.

Like *A. minutissima*, similar relative abundances of *F. capucina* var. *vaucheriae* in rock and moss samples suggest it has no clear habitat preference in the Lord Lindsay River either. Both *A. minutissima* and *F. capucina* have been found to dominate epilithic stream communities in North America (Passy, 2001), yet were strongly associated with both moss and rock substrates in ponds on Bathurst Island, Nunavut (Lim et al., 2001a), much closer to the current study site. In Subantarctica, *F. capucina* was found to be common in streams and on moss substrates (Kawecka & Olech, 1993; Van de Vijver et al., 2004). In Europe, where this taxon was first identified, *F. capucina* var. *vaucheriae* is associated with a wide range of geographic and ecological conditions (Krammer & Lange-Bertalot, 1997–1999).

Cymbella species are common in lentic environments; however, some taxa do show a clear affinity for stream environments (Patrick & Reimer, 1975; Pfister, 1992; Douglas & Smol, 1993; Tang et al., 2002). Of the *Cymbella* taxa common in the Lord Lindsay River, other studies from the Canadian Arctic identify *C. arctica* as a dominant species in lotic environments on Victoria Island, Nunavut (Van de Vijver et al., 2003), whereas *C. minuta* was common in acidic ponds on Ellesmere Island (Douglas and Smol, 1993). *C. minuta* and *C. selisiaca* are considered cosmopolitan and eurytopic in both North American and European freshwaters (Patrick and Reimer, 1975; Krammer and Lange-Bertalot, 1997–1999), whereas *C. arctica* is generally restricted to high-latitude environments (Krammer, 2002). Krammer (1997) first documented the taxon *E. fogedii* in moss samples from the shore of a large pond in Spitsbergen. Subsequently, *E. fogedii* has been found on moss substrates in alkaline but not in acidic waters of the Canadian High Arctic (Antoniades et al., 2004; Antoniades et al., in press). With respect to habitat, it appears *C. arctica* is more successful on rock substrates in the Lord Lindsay River, whereas *C. minuta* and *C. silesiaca* exhibit no preference. Consistent with previous reports, *E. fogedii* demonstrates a clear preference for the moss substrate, with a moss relative abundance over twice that of the rock samples.

According to Krammer & Lange-Bertalot (1997–1999) *D. tenuis* is a common epiphyte and planktonic species in lakes and rivers worldwide, especially those with average to high conductivities. However, the occurrence of *D. tenuis* in lotic environments appears to be far less common than that of *A. minutissima, F. capucina* or the *Cymbella* species. For example, *D. tenuis* was dominant in freshwaters on Victoria Island but unlike *C. arctica,* was only found in standing water bodies (Van de Vijver et al., 2003). In addition, *D. tenuis* was strongly associated with both rock and moss substrates in ponds and lakes on Bathurst Island in the Canadian High Arctic (Lim et al., 2001a). However, Potapova (1996) did observe *D. tenuis* in rivers in Northeast Siberia and noted higher abundances in more ion-rich environments. Moreover, *D. tenuis, A. minutissima* and *C. arctica* were all associated with high rates of change in total nitrogen and temperature gradients in ponds on Bathurst Island (Lim et al., 2001b). Perhaps the high abundance of these taxa in the Lord Lindsay River may similarly reflect seasonal changes in nutrient concentrations and/or water temperature.

Ludlam et al. (1996) hypothesized that the often eurytopic nature of lotic assemblages may be a function of variable flow regimes that favor species relatively indifferent to such changes. In support of this hypothesis, Aboal et al. (1996) noted that while *A. minutissima* dominated high-energy flow environments in Mediterranean streams, it was replaced by *Amphora pediculus* in streams with a more constant flow regime. Certainly, the extremely seasonal hydrological regime of the Lord Lindsay River may be characterized as variable. However, given that samples were collected from marginal areas of the river where the effects of rapidly changing flow conditions would be significantly buffered, it is unlikely that variable flow alone can account for this particular assemblage. Hence, other sources of hydrologic variability, including water temperature, conductivity and nutrient concentrations are a more likely explanation for the eurytopic assemblage in the Lord Lindsay River.

Trends in abundance and hydrology

All river taxa first appear in significant abundances on July 8. In other studies, *A. minutissima* has dominated the early successional assemblage of both middle and high latitude streams (e.g., Moore, 1977; Stevenson et al., 1991; Peterson & Stevenson, 1992; Eulin & Le Cohu, 1998). While it is unclear whether the *Cymbella* species and *D. tenuis* are also early colonizers, it appears that the sudden proliferation of the river species in the July 8 sample likely reflects the onset of the diatom growing season in this environment.

The Lord Lindsay River assemblage exhibits little indication of a seasonal succession in species abundance and composition during the sampling period. However, this pattern may not be unusual for high latitude lotic environments characterized by a relatively short growing season (Moore, 1979). Potapova (1996) found that more mature successional stages were only achieved after relatively stable flow conditions, suggesting that the highly dynamic nature of such an extreme environment may also be a significant factor limiting diatom species succession in this system. While it is not known how the Lord Lindsay River assemblage evolved after August 1, it appears that the dynamic nature of this environment at least partially explains the low standing crop in the early to mid-season and during a major rain event in mid-July. Moreover, data collected after August 1 (not included here) indicate a consistent decline in air and water temperatures suggesting that the majority of the growing season has likely been captured in the river samples presented here.

While little variation in relative abundances of river taxa occurs during the hydrological season, closer inspection of the selected river taxa compared to trends in the hydrological parameters reveals that these species do reflect major changes in hydrological conditions. The fact that significant diatom standing crop only occurs after the period of peak discharge suggests that flow rate may exert a considerable influence on diatom biomass. A possible mechanism to explain this may be that increased turbidity due to heightened levels of discharge introduces light as a limiting factor for cell growth. However, a maximum suspended sediment concentration of $\sim$15 mg l^{-1} in the Lord Lindsay River suggests that turbidity is not appreciable in this environment. Alternatively, high rates of flow may restrict immigration onto the substrates and any colonized cells may be quickly scoured away (Biggs & Thomsen, 1995; Peterson et al., 2001). This may explain the apparent suppression in biomass among the rock compared to the moss samples, since it is unlikely that scouring would affect moss and rock samples equally (Table 1). Moreover, the three dimensional structure of the vegetation would likely afford diatom cells greater protection from shear stress.

Current velocity has been well documented as a critical factor in determining diatom community composition, complexity and biomass in lotic systems (Wendker, 1992; Potapova, 1996; Passy, 2001; Antoniades & Douglas, 2002). However, in this case it appears that flow rate alone can not explain diatom biomass, since few frustules were found in samples collected during both high (e.g., July 2, July 15) and low (e.g., June 26, June 29) flow periods. Moreover, diatom samples were collected from marginal areas not subjected to major changes in flow velocity. However, the sudden increase in discharge due to a rain event beginning July 12 is also accompanied by a rapid decline in water temperature characterized by reduced diurnal variation, and a sudden increase in conductivity due to a major decrease in the overall contribution of snowmelt to discharge. The fact that diatoms are abundant when conductivity is both low (after peak flow) and high (late season), suggests conductivity cannot explain the presence or absence of diatoms in this system. The rapid rebound to pre-rain abundances by July 17 suggests that there was sufficient time for diatoms to become established before the peak flow period, although the migration of cells from the sediment or other more sheltered areas may have contributed to the quick recovery following the rain event. However, the moderated flow conditions of the sampling location and the relative absence of diatoms during low and high flow periods do suggest that low water temperatures (< 5 °C) may be exerting a critical influence on river diatom abundance in this system. This hypothesis is consistent with findings from other Arctic lotic (Moore, 1977; Antoniades & Douglas, 2002) and lentic (Joynt & Wolfe, 2001; Lim et al., 2001b) environments where temperature was also identified as an important factor in controlling these assemblages. Additional data on seasonal changes in water chemistry may shed further light on the extent to which the early season suppression of diatoms is a reflection of low nutrient concentrations, but the lack of diatoms in the July 15 sample, despite a likely pulse of nutrients due to the rain event, suggests that in this case nutrients are not the only limiting factor in seasonal diatom abundances.

Conclusion

This study is the first of its kind detailing the river diatom response to seasonal hydrological variability in this region and at the large arctic watershed scale. The purpose of this study was to characterize the seasonal dynamics of diatoms in the Lord Lindsay River with respect to changing hydrological conditions with the future goal of augmenting paleoenvironmental interpretations with more detailed ecological knowledge of the sedimentary diatom assemblage. For example, identifying a distinct river assemblage of *Achnanthes minutissima, Fragilaria capucina* var. *vaucheriae, Cymbella arctica, C. minuta, C. silesiaca, Encyonema fogedii* and *Diatoma tenuis* presents an opportunity to infer past hydrological variability based on changes in the abundances of these taxa in sediment cores.

The eurytopic diatom assemblage reflects the highly variable hydrological conditions in the Lord Lindsay River throughout the melt season. The relative contribution of the river taxa to the assemblage remains relatively stable throughout the sampling period; however, diatom standing crop was suppressed during the early season and after a major rainfall event, likely due to low and/or rapidly declining water temperatures. The fact that the diatom assemblage only responded to rapid and dramatic hydrological change suggests that a threshold tolerance exists. The complete recovery of the river assemblage within two days after the rainfall event attests to their ability to rapidly colonize substrates and demonstrates an inherent structure and resilience in this assemblage. The combination of these factors suggests that changes in the relative contribution of the river assemblage in the lake sedimentary record is likely a reflection of persistent rather than ephemeral changes in hydrological conditions. Understanding long-term hydrological variability is critical for assessing the current and future responses of high latitudes to environmental change.

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