Assessing Thule Inuit Impacts on High Arctic Lakes and Ponds:

A Paleolimnological Approach

by

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Abstract

Until recently it has been widely believed that significant anthropogenic influences on the environment began in Canada following the onset of European colonization. However, our paleolimnological data indicate that centuries prior to European settlement, ponds on Ellesmere and Bathurst Island were impacted by Thule Inuit whalers, whose activities altered nutrient levels in nearby ponds. Two Thule Inuit whaling sites were selected based on input from several archeologists, to ensure good coverage of the Thule geographic range and proximity to freshwater ponds.

Multiple independent paleolimnological proxies have been used to analyze a pond from Ellesmere Island, showing taxonomic shifts in diatoms assemblages coinciding with 1.5 - 2‰ shifts in δ^{15}N, during the period of Thule occupation (ca. 1000 – 1670 AD). Increases in the relative abundance of *Amphora ovalis*, indicate nutrient concentrations above average for the High Arctic. Elevated levels of nitrogen and phosphorus were observed in the pond indicating the continuing influence of nutrient inputs centuries after the abandonment of the camp.

Meanwhile, on Bathurst Island, the orientation of the Deblicquy site, such that the large majority of the Thule nutrient inputs are focused towards one of our two study ponds, provided us with the opportunity to compare two ponds that are essentially identical with the exception of the degree of Thule influence. In our “impacted” site, a marked increase in *Stephanodiscus minutulus*, coincides with a 2‰ shift in δ^{15}N. While our *a priori* determined control site shows no major changes in geochemistry or algal composition.

Previous research on Bathurst Island used water chemistry and surface sediment diatoms to construct a diatom-inferred total nitrogen model for Bathurst Island. However, this study was limited by excluding unbuffered, low pH sites which characterize the western half of Bathurst Island. By expanding the previous Bathurst Island dataset to include western sites, we have been able to construct a diatom-inferred pH model which will prove invaluable in future climate research in this region.

Together, these three studies serve to highlight the sensitivity of freshwater ecosystems to relatively minor anthropogenic disturbances and represent some of the earliest known anthropogenic impacts on North American aquatic ecosystems.

Candidate's contribution to thesis

K. Hadley undertook all the diatom analyses. This included lab and microscopic work, as well as data entry and interpretation. In addition, K. Hadley completed two field seasons in the High Arctic, collecting much of the material described in this thesis. The only exception being the core from E-Knud, which was taken by one of my co-supervisor's (M. Douglas). I did however also sample the present-day limnology of this site. The isotope analyses were performed by the G.G. Hatch Stable Isotope Laboratory and the mercury analyses were performed in the lab of Dr. Jules Blais (University of Ottawa). Water chemistry data in Chapter 4 was partially from Lim et al. (2001); I collected the water samples that supplemented this survey.

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CHAPTER 1

General Introduction and Literature Review

Environmental Research in the Arctic

Recent environmental change driven by anthropogenic impacts has been observed throughout a wide range of ecosystems. However, nowhere has the impact of climate-driven change been more pronounced than in polar environments such as the circumpolar Arctic (ACIA 2004). Heightened sensitivity of Arctic ecosystems to changes in nutrients, temperature and pH provides an excellent opportunity to study the impacts of anthropogenic stressors. Despite recent improvements in the amount of baseline limnological data available, the Arctic has remained amongst the least studied regions on the globe. Since the mid-1980's a significant commitment of time and resources has led to an increase in the amount of long-term limnological data available across the High Arctic (e.g. Pienitz et al. 2004). As a result, our understanding of Arctic systems within specific pond (e.g. Douglas et al. 2004a) and lake systems (e.g. Michelutti et al. 2003), regionally (e.g. Lim et al. 2001) and across the entire circumpolar Arctic (e.g. Smol et al. 2005) has improved significantly.

Until recently, human influences on lakes and ponds in Arctic systems were assumed to have been non-existent until the arrival of Europeans. However, Douglas et al. (2004a) demonstrated this is not the case, and showed that Thule Inuit whalers altered the limnological and ecological characteristics of a pond ecosystem on Somerset Island from ~1200-1600 AD. Furthermore, they showed that limnological characteristics of this pond are presently very different from undisturbed sites, even though the Thule whalers abandoned the site ~400 years ago. To date, only the Douglas et al. (2004a) study on

Somerset Island has been published. The research of this thesis further explores the effects of past Inuit activities on High Arctic ecosystems, as well it assesses the ecological responses of these sites to recent warming.

Diatoms as Indicators of Environmental Change

Lack of long-term environmental data, especially in poorly-monitored Arctic systems, poses a problem in assessing environmental change. Without a better understanding of background conditions or the trajectories of past environmental changes, it is impossible to put recent environmental changes into perspective (Smol 2002). Paleolimnological techniques may be used to reconstruct past environments and estimate the range of natural variability of a system, thereby allowing anthropogenic influences to be quantified relative to natural environmental variability. By using a variety of physical, chemical and biological indicators archived in the sediment record, paleolimnologists can reconstruct past environmental conditions well beyond the scope of the historical record.

Algal indicators, especially diatoms, are being used increasingly as early indicators of change due to a variety of natural and anthropogenic changes (Stoermer and Smol 1999). Silica, which is used by diatoms to form cell walls or frustules, is highly resistant to chemical and physical degradation, so that diatoms are often well preserved in sediments. Diatoms account for over 50% of the primary production in many freshwater ecosystems and are found in virtually every aquatic environment, both freshwater and marine. Mann and Droop (1996) estimate that approximately 200 000 species of diatoms exist globally, many of which are constrained to ecosystems that satisfy specific environmental optima and tolerances for a variety of variables (Birks 1998). Salinity, nutrient concentrations, pH and habitat changes are amongst the environmental variables to which diatoms are most sensitive (Stoermer and Smol 1999). Quantifiable species-specific responses to these environmental conditions make diatoms the most powerful proxy indicator available to paleolimnologists (Stoermer and Smol 1999).

Diatoms have been used increasingly in the past several decades to assist researchers in studying the impacts of numerous stressors such as acidification (Battarbee et al. 1999), eutrophication (Douglas and Smol 2000), atmospheric pollution (Wolfe et al. 2003) and anthropogenic climate warming (Smol et al. 2005; Rühland et al. 2003) on aquatic ecosystems. Their usefulness in polar regions as paleolimnological indicators has also recently been reviewed by Douglas et al. (2004b).

Bowhead Whales (Balaena mysticetus) and Thule Inuit Culture

The Classic Thule culture (1000 AD – 1350 AD) is distinguished from the earlier Dorset culture (800 BC – 1000 AD) by increased winter sedentism and an increasingly material culture (Maxwell 1985; McCartney 1980; Coltrain et al. 2004). In an environment devoid of trees, Thule Inuit relied on whale bones as a primary source of building material as well as for sled runners and small tools during their expansion into the Canadian Arctic from Alaska (Whitridge 2002). Thule wintering dwellings were traditionally constructed from sod, stone and whale bone (Dawson 2001), and they have been widely studied, described and dated for decades across the Arctic (e.g. Mathiassen 1927; Taylor and McGhee 1981; Park 1997; Dawson 2001; Friesen 2004). The largest Thule winter sites are located where access to whales is available early in the season (i.e.

Hazard Inlet and Cresswell Bay, Somerset Island), with some settlements as large as 60 semi-subterranean houses (Savelle and McCartney 1999).

Thule Inuit hunted large bowhead whales using umiaks, which were large open skin boats manned by a crew of 7 or 8 people, and inflated seal skin floats which were attached to harpoon lines providing drag to fatigue the whale (Whitridge 2002). Once the tired whale surfaced, lances were used to pierce vital organs and the dead whale was towed to shore and flensed (Whitridge 2002). Whale carcasses were used for a variety of purposes including the construction of Thule over-winter settlements.

Paleolimnology and Thule Inuit Whaling

In July of 1995, a joint team of researchers from the University of Toronto and the Paleoecological Environmental Assessment and Research Lab (PEARL) at Queen's University working on Somerset Island cored a pond near an abandoned overwintering Thule settlement (Douglas et al. 2004). Upon analysis of the sediment archive, they found that abrupt shifts in diatom assemblages and $\delta^{15}N$ (~ 3 ‰) coincided with archeological evidence for Thule occupation (Douglas et al. 2004). Douglas et al. found that nutrient enrichment, attributable to Thule whaling practices, resulted in alteration of the pond ecosystem by enhanced moss growth, as well as other limnological changes. Increases in moss within the pond were likely related to a shift in diatom assemblage from dominantly the benthic diatom *Fragilaria pinnata*, to the moss epiphyte *Pinnularia balfouriana* at ca. 1200 AD. In general, the relative abundance of *P. balfouriana* was high for the duration of Thule occupation and then returned to pre-disturbance, benthic dominated conditions with the abandonment of the site at ca. 1600 AD. Nitrogen isotopes continued to remain high relative to pre-Thule conditions in modern sediments. This was attributed to increased nutrient input from the remaining bones at the site, both within and surrounding the pond (Douglas et al. 2004). Overall the Douglas et al. study demonstrated that this pond ecosystem, at the boundary between the Mid and High Arctic ecozones, was altered prior to European settlement. However, this study represented only one pond, at one Thule settlement, and at a relatively low latitude compared with the majority of Thule settlements in the Canadian Arctic. While providing a solid foundation from which to begin, it also raised many questions that require future research. The primary focus of this MSc project was to investigate the impact of Thule Inuit settlements and whaling practices on two of freshwater Arctic pond systems on Bathurst Island and Ellesmere Island, using primarily diatom microfossils and nitrogen stable isotope geochemistry from the sediment record (Chapters 2 and 3). In addition to assessing past Thule impacts, this study also expands the baseline modern limnological data available for Bathurst Island (Lim et al. 2001), provides a functional calibration set for our Thule ponds and examines the recent sediments from our cores for evidence of recent climate change (Chapter 4).

References

ACIA, 2004. Impacts of a warming Arctic. Cambridge University Press, Cambridge, UK.

Battarbee, R.W., Charles, D.F., Dixit, S.S., and Renberg, I., 1999. Diatoms as indicators of surface water acidity, in Stoermer, E.F. and Smol, J.P. (eds.), The Diatoms: Applications for the Environmental and Earth Sciences: Cambridge, UK, Cambridge University Press, Ltd: 85–127.

Birks, H.J.B. 1998. Numerical tools in paleolimnology – progress, potentialities, and problems. Journal of Paleolimnology 20: 307-332.

Coltrain, J.B., Hayes, M.G. and O'Rourke, D.H. 2004. Sealing, whaling and caribou: the skeletal isotope chemistry of Eastern Arctic foragers. Journal of Archaeological Science 31: 39 – 57.

Dawson, P.C. 2001. Interpreting variability in Thule Inuit architecture: A case study from the Canadian High Arctic. American Antiquity 66: 453-470.

Douglas, M.S.V. and Smol, J.P. 2000. Eutrophication and recovery in the High Arctic: Meretta Lake (Cornwallis Island, Nunavut, Canada) revisited. Hydrobiologia 431: 193-204.

Douglas M.S.V., Smol J.P., Savelle J.M. and Blais J.M., 2004a. Prehistoric Inuit whalers affected freshwater ecosystems. Proceedings in the National Academy of Sciences USA 101: 1613–1617.

Douglas, M.S.V., Hamilton, P.B., Pienitz, R. and Smol, J.P. 2004b. Algal indicators of environmental change in arctic and antarctic lakes and ponds. . In: Pienitz, R., Douglas, M.S.V. and Smol, J.P. (eds.), Long-term Environemental Change in Arctic and Antarctic Lakes. Developments in Paleoenvironmental Research. Volume 8. Dordrecht, The Netherlands, Springer, p. 117 – 159.

Friesen, T. Max 2004. Contemporaneity of Dorset and Thule cultures in the North American Arctic: New radiocarbon dates from Victoria Island, Nunvut. Current Anthropology 45: 685-691.

Lim, D.S.S., Douglas, M., Smol, J.P., and Lean, D. 2001. Physical and chemical limnological characteristics of 38 lakes and ponds on Bathurst Island, Nunavut, Canadian High Arctic. International Review of Hydrobiology 86: 1-22.

Mann, D.G. and Droop, S.J.M. 1996. Biodiversity, biogeography and conservation of diatoms. Hydrobiologia 336: 19-32.

Mathiassen, T. 1927. Archaeology of the Central Eskimos: the Thule culture and its position within the Eskimo culture. Report on the Fifth Thule Expedition 1921-1924. Gyldendalske Boghandel, Nordisk Forlag, Copenhagen.

Maxwell, M.S. 1985. Prehistory of the Eastern Arctic. Academic Press, Orlando

McCartney, A.P. 1980. The nature of Thule Eskimo whale use. Arctic 33: 517-541.

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

Park, R.W. 1997. Thule winter site demography in the High Arctic. American Antiquity 62: 273-284.

Pienitz, R., Douglas, M.S.V. and Smol, J.P. 2004. Paleolimnological research in Polar Regions: An Introduction. In Long-term environmental change in Arctic and Antarctic lakes. Springer, Netherlands. 1-17.

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

Savelle, J.M. and McCartney, A.P. 1999. Thule Eskimo bowhead whale interception strategies. World Archaeology 30: 437-451.

Smol, J.P. 2002. Key Issues in Environmental Change: Pollution of Lakes and Rivers – A Paleoenvironmental Perspective. Bradley, R.S., Roberts, N. and Williams, M.A.J. (eds.) New York, NY, USA.

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, É., 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 Sciences 102: 4397-4402.

Stoermer, E.F. and Smol, J.P. (eds). 1999. The Diatoms: Applications for the Environmental and Earth Sciences. Cambridge University Press. Cambridge.

Taylor, W.E. Jr. and McGhee, R. 1981. De Blicquy, a Thule Culture Site on Bathurst Island, N.W.T, Canada. Archaeological Survey of Canada, Mercury Series 102. National Museum of Man. Ottawa, On, Canada.

Whitridge, P. 2002. Social and ritual determinants of whale bone transport at a classic Thule winter site in the Canadian Arctic. International Journal of Osteoarchaeology 12: 65-75.

Wolfe A.P., Van Gorp, A.C. and Baron J.S. 2003. Recent ecological and biogeochemical changes in alpine lakes of Rocky Mountain National Park (Colorado, USA): a response to anthropogenic nitrogen deposition. Geobiology 1: 153–168.

CHAPTER 2

Impacts of marine-derived nutrients from ancient Thule whaling activities on diatom species and water chemistry at the Deblicquy site, Bathurst Island, Nunavut, High Arctic Canada

Kristopher R. Hadley

Abstract

Until recently, major anthropogenic impacts of freshwater ecosystems have largely been believed to be non-existent in North America prior to European colonization. However, based on paleolimnological and archeological data, Thule Inuit living in small, nomadic communities were altering pond ecology centuries earlier as a result of whaling activities. The geography of the Deblicquy site on Bathurst Island provides an interesting and rare opportunity for a comparative paleolimnological study of long-term human impacts on polar limnology. Because our two ponds are nearly identical in size and in geological and climatic setting, we were able to compare the two ponds with the main distinguishing feature being the degree of Thule influence. Using paleolimnological approaches, we recorded striking changes in diatom species assemblages, spectrally-inferred primary production, and nutrient geochemistry indicating eutrophication in one pond on Bathurst Island. Input of marine-derived nutrients from bowhead whale carcasses used by the Thule for both sustenance and the construction of winter settlements resulted in an increase in the eutrophic diatom taxon *Stephanodiscus minutulus*, whereas no comparable changes were recorded in the nearby control pond for the duration of the sedimentary record. Atypical modern water chemistry, in the form of elevated nitrogen and phosphorus, in the affected ponds indicates that the impact of Thule whalers at this site is still present today, three centuries after the site was abandoned.

Introduction

Thule Inuit culture represents one of the earliest instances of anthropogenic impacts on aquatic ecosystems in North America. Recently, Douglas et al. (2004a) recorded major diatom species changes in a paleolimnological investigation in a freshwater pond near an abandoned Thule site on Somerset Island, Arctic Canada. Douglas et al. (2004a) showed that the onset of Thule occupation resulted in unprecedented ecosystem changes, and other limnological changes, attributable to nutrients released from slaughtered whale carcasses. Nutrient levels continue to remain high at this site, even ~400 years after the Thule abandoned the region. Although the Douglas et al. (2004a) study unequivocally showed the Thule impacted the water quality of a freshwater pond, it was limited to a single site near the southernmost range of the Thule people, and thus the influence of the Thule on other freshwater site throughout the Arctic remained unexplored. Here, we examine two ponds near the geographical centre of the Thule range, a location known as the "Deblicquy site" on Bathurst Island, Nunavut (Figure 1) (Taylor and McGhee 1981; Le Mouel and Le Mouel 2002). The two ponds located at the Deblicquy site are ideal to study the impacts of Thule whaling practices on freshwater ponds, as only one of these sites received significant inputs of nutrients from whale carcasses (Figures 2 and 3). We know this from the location of Thule whalebone houses and the surrounding topography, which determines the direction of nutrient inputs from the catchment to the pond (Taylor and McGhee 1981). In essence, we are able to compare two ponds of similar size, in similar geologic and climatic settings, with the only variable distinguishing the two ponds being the degree of Thule influence. Paleolimnology presents an interesting opportunity to study long-term environmental changes, allowing us to investigate changes in multiple, independent environmental proxies to aid in our reconstruction of past environments. For example, paleolimnological techniques allow past environments to be reconstructed and anthropogenic influences to be quantified relative to natural variability (Smol 2002).

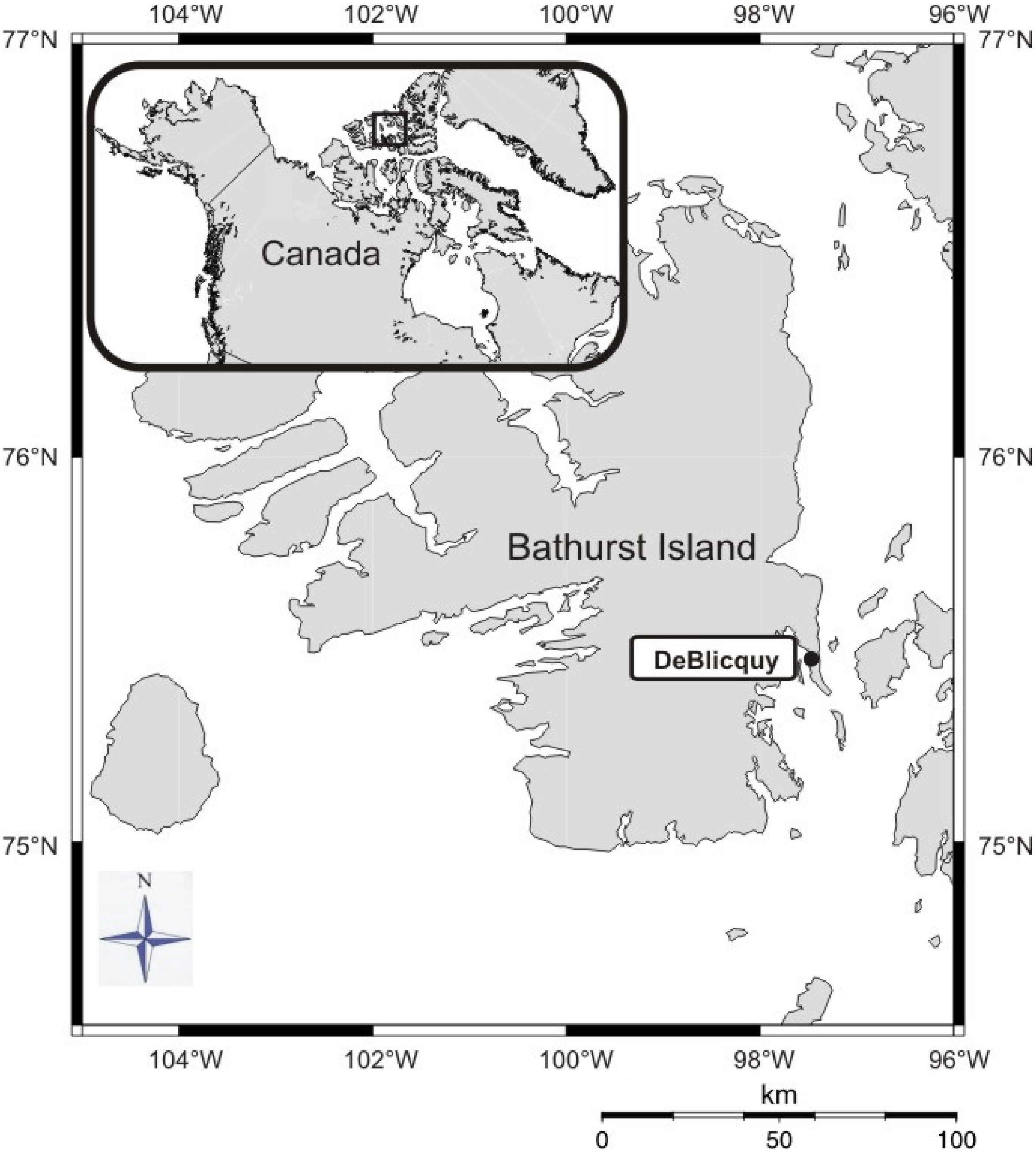

Figure 2.1. Map of Bathurst Island showing the approximate location of the Deblicquy Site.

By using a variety of physical, chemical and biological indicators archived in the sediment record, paleolimnologists can reconstruct past environmental conditions well beyond the scope of the historical record. These techniques are particularly important in

Arctic environments where we seldom have limnological data collected for more then one year (if at all), and long-term monitoring data are therefore completely lacking.

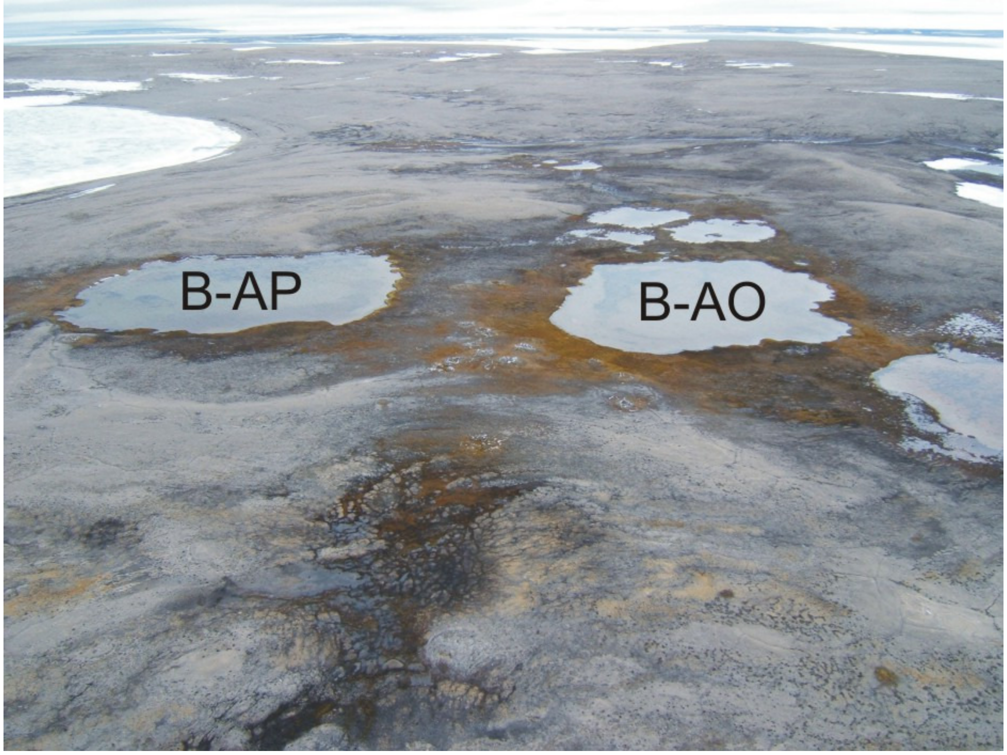

Figure 2.2. Aerial Photo of the Deblicquy site, showing both study sites (B-AO and B-AP) and the relative moss cover surrounding the two ponds. See Figure 3 for scale.

Numerous paleolimnological indicators such as chironomids, diatom and chrysophyte algae and zooplankton are useful in reconstructing past environments (Smol 2002). However, algal indicators, especially diatoms, are being used increasingly as early indicators of change due to a variety of natural and anthropogenic stressors (Stoermer and Smol 1999) because of their sensitivity to environmental variables such as temperature, pH, salinity and nutrient concentration (e.g. nitrogen and phosphorus). Quantifiable species-specific responses to these environmental conditions make diatoms the most powerful proxy available to paleolimnologists (Stoermer and Smol 1999).

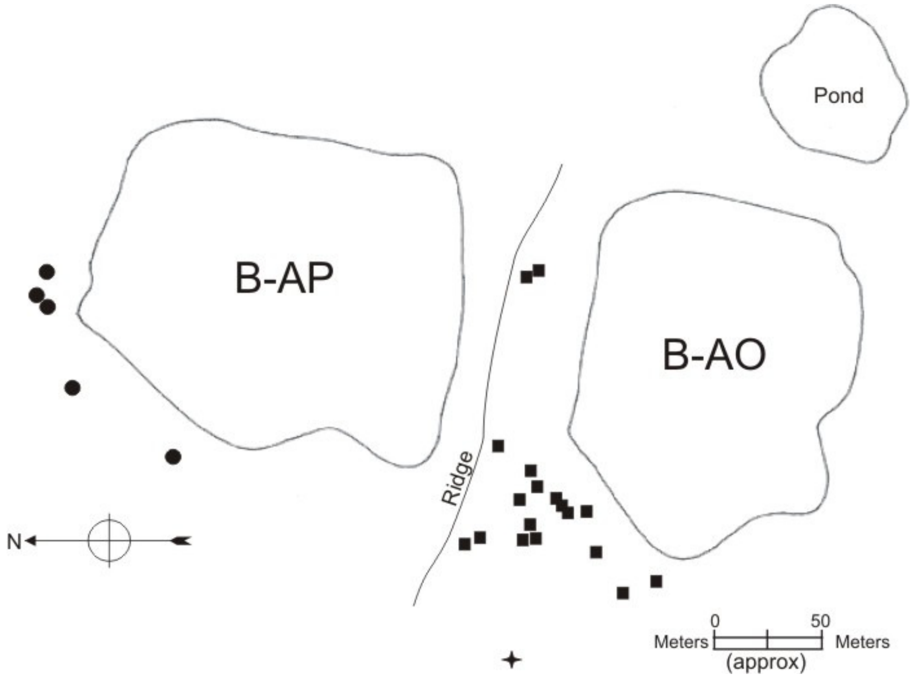

Figure 2.3. Schematic representation of the Deblicquy Thule site from directly above. Individual houses have been indicated and coded based upon which pond they drain into. Squares = B-AO, Circles = B-AP and Star = neither. (Modified from Taylor and McGhee 1981)

Diatoms have been used increasingly in the past several decades to assist researchers in studying the impacts of numerous stressors such as acidification (Battarbee et al. 1999), eutrophication (Douglas and Smol 2000), atmospheric pollution (Wolfe et al. 2003) and anthropogenic climate warming (Rühland et al. 2003; Smol et al. 2005) on aquatic ecosystems. Their usefulness in polar regions as paleolimnological indicators has recently been reviewed by Douglas et al. (2004b).

In addition to morphololgical indicators such as diatoms, sediment geochemistry is being increasingly used by paleolimnologists to track marine-derived nutrients in freshwater systems. Using $\delta^{15}N$ from sediment cores, researchers have been able to track nutrient inputs into freshwater ecosystems from birds (Blais et al. 2005), whales (Douglas et al. 2004) and sockeye salmon (Finney et al. 2002; Gregory-Eaves et al. 2003). In addition, spectrally-inferred chlorophyll *a* has been used in the past as a proxy for whole-lake primary production changes, and closely reflects changes recorded in other proxies for productivity such as total organic carbon (TOC) and biogenic silica ($BSiO_2$) (Michelutti et al. 2005).

Thule culture and occupation of the study region

Thule Inuit migrated across the Arctic tundra from Alaska to Greenland arriving at the Deblicquy site ca. 13th or 14th century, bringing with them unprecedented whaling technologies (Taylor and McGhee 1981; McGhee 2000). Whaling occurred primarily during ice break up as the whales entered the eastern Arctic in early summer moving to their maximum western extent by mid-September (Savelle and McCartney 1999). Whaling parties, in multiple boats each consisting of a six- to nine-man crew, composed of a helmsman, a harpooner and numerous paddlers, hunted bowhead whales using a combination of harpoons, seal skin floats (to fatigue the whale and force it to surface) and a lance (Whitridge 2002). Groups of as many as eight boat crews would then tow the whale ashore where it would be flensed and divided according to social hierarchy (Whitridge 2002). Following about 1400 – 1500 AD, the Thule culture began to decline and a transition to the historic Inuit occurred, who were more dependent on sealing (McCartney 1980; Whitridge 2002). This change in subsistence strategy is supported by research on the changing style of Thule winter dwellings (Schledermann 1976) and has been shown to coincide with the onset of the Little Ice Age and the resultant changes in distribution of fauna (McCartney 1977; Moore et al. 2001; Schledermann 1976).

The Classic Thule culture (1000 AD – 1350 AD) is distinguished from the earlier Dorset culture (800 BC – 1000 AD) by increased winter sedentism and an increasingly material culture (Maxwell 1985; McCartney 1980; Coltrain et al. 2004). In an environment devoid of trees, Thule Inuit relied on whale bones as a primary source of building material, as well as for sled runners and small tools, during their expansion into the Canadian Arctic from Alaska (Whitridge 2002). These structures were traditionally constructed from sod, stone and whale bone (Dawson 2001), and have been widely studied, described and dated for decades across the Arctic (e.g. Mathiassen 1927; Taylor and McGhee 1981; Park 1997; Dawson 2001; Friesen 2004). The largest Thule winter sites were located where access to whales was available early in the season (i.e. Hazard Inlet and Cresswell Bay, Somerset Island) and therefore supported some settlements as large as 60 semi-subterranean houses (Savelle and McCartney 1999).

Site Description

The Deblicquy site (75° 29' N, 97° 29' W) is located on an un-named point on the southern coast of Bathurst Island (Figure 1). It is approximately 22 m above sea level, 0.25 km away from the ocean, and is surrounded largely by grey limestone gravel (Taylor and McGhee 1981). The area is strewn with small- to medium-sized shallow melt-water ponds, which characterize much of Bathurst Island. Typically, ponds and lakes on Bathurst Island are oligotrophic, alkaline, and dilute (Lim et al. 2001). However, several of the Lim et al. (2001) ponds have higher than average nutrient concentrations, as a result of the influence of muskox and Peary caribou, resulting in average nutrient concentrations that are slightly higher then is typical in the large majority of other High Arctic lakes and ponds.

The Deblicquy site on eastern Bathurst Island was studied extensively during the 1960's by Taylor and McGhee (1981) who identified 24 semi-subterranean Thule whale bone houses that are directly adjacent to two small (~90 m diameter) and shallow (~50 cm maximum depth) ponds, which we refer to as B-AO and B-AP, continuing the naming scheme of Lim et al. (2001) (Figure 1). The majority of these houses are situated such that the bulk of the nutrient input is directed toward B-AO, which is also reflected by greater moss growth around this pond (Figure 2). This allows us to compare sites where other factors, such as climate change are similar, to assess the impact of nutrients from Thule whaling. Modern water chemistry of both B-AO and B-AP show elevated levels of nitrogen, phosphorus and dissolved organic carbon (DOC) relative to other lakes and ponds on Bathurst Island (Lim et al. 2001) and elsewhere in the Canadian Arctic (e.g. Michelutti et al. 2002; Keatley et al. 2007).

Methods

Sediment collection and geochronology

Short sediment cores were collected from the deepest portion of each pond (Z_{max} = ~40 cm) by wading out and pushing a 3 inch (7.6 cm) diameter core tube into the sediment. Cores were sectioned on site at 0.5 cm resolution using a Glew (1988) vertical extruder, and the sediment sections were stored in Whirlpak® bags and kept cool and dark until return to the laboratory.

As with sediments dated from our Ellesmere Island core (Chapter 3), low ^{210}Pb activity measured by both alpha and gamma spectrometry proved ineffective for dating the sediment (Appendix 1 and 2) and therefore sediment further downcore was submitted to INSTAAR (University of Colorado, Boulder CO) for ^{14}C humic-acid analysis. At the time of writing, the geochronology is still being investigated. For the purpose of this thesis, dates presented on diatom stratigraphies, which mark the beginning and ending of the Thule period, are approximations based on the changes seen in the $\delta^{15}N$ in the sediment record (Figure 6) and archeological evidence of when Thule occupied this region (Taylor and McGhee 1981), as discussed below.

The Thule Inuit period at this site has been well established by ^{14}C dating during past archeological expeditions. Excavation of several of the 24 houses during the 1970's, and the subsequent dating of artifacts associated with these sites, have led researchers to conclude that Thule Inuit occupation of this site took place between the 14th and 16th century (Taylor and McGhee 1981). Based upon the presence of marine diatom fragments in the bottom sections of the core (discussed below), we can assume that we have obtained a near-complete record of the ponds history since emergence from the ocean.

Diatoms

For diatom analysis, ~0.3 g of wet sediments were digested with nitric acid using a CEM MarsX microwave digester (Parr et al. 2004), rinsed with deionized water until a neutral pH was achieved and permanently mounted on slides using Naphrax®. Diatoms were then enumerated at 1000X under oil immersion using a Leica DMR2 microscope with differential interference contrast (DIC). A minimum of 300 - 400 diatom valves were counted for each interval and identified using standard taxonomic sources (Krammer and Lange-Bertalot 1986–1991; Cumming et al. 1995; Lake of the Woods Diatom Workshop

2006, pg. 14) except in a few cases where, due to extremely low diatom concentrations in older sediments, diatom enumeration stopped once a minimum of 200 diatom valves was reached.

Stable isotopes

Sediments were analyzed for $\delta^{15}N$ at 1-cm intervals from 0.0 - 3.0 cm and 7.0 - 8.5 cm and at 0.5 cm intervals from 3.0 - 7.0 cm. Measurements were taken at the G.G. Hatch Stable Isotope Laboratory using a Vario EL III (Elementar, Germany) + Conflo II + DeltaPlus XP IRMS (ThermoFinnigan, Germany) with analytical precision (2 sigma) of ±0.2 ‰. Freeze-dried sediment was weighed into tin capsules and flash combusted at 1800 ^{o}C in an elemental analyzer (EA) or elemental combustion system (ECS). The resultant gases were carried via helium through the EA for purification and separation into N_2 and CO_2 and then into an isotope ratio mass spectrometer (IRMS) for isotope analysis via a Conflo interface. Data were normalized using internal standards previously calibrated with International standards IAEA-CH-6, IAEA-NBS22, IAEA-N1, IAEA-N2, USGS-40, USGS-41.

Spectrally inferred chlorophyll a

Sediment used for spectral analysis was first freeze-dried and sieved through a <125 µm mesh. Using the Foss NIRSystem 500, measurements of absorption in the 400 nm – 1100 nm range were taken and Chl *a* concentrations were inferred based on the algorithm developed in Michelutti et al. (2005).

Water Chemistry

Water samples were collected approximately 1 m from shore and stored using Nalgene® plastic bottles and 125ml glass bottles. Samples were measured in the field for conductivity using a YSI model 33 conductivity meter. Multiple field measurements of pH and temperature were made using 2-point calibrated Hanna pHep pH meters and handheld thermometers. Analysis of major ions, nutrients and metals were performed at the National Water Research Institute (NWRI), following the same protocols used in our labs previous Arctic surveys (Environment Canada, 1994).

Analysis for major cations (Ca^{2+}, Mg^{2+}, K^+, Na^+), major anions (Cl^-, SO_4^{2-}) and for a variety of minor ions (e.g. barium (Ba), lithium (Li) and strontium (Sr)) was performed by NWRI. Water samples were also sent to NWRI for nutrients including phosphorus (total phosphorus unfiltered (TPU), total phosphorus filtered (TPF) and soluble reactive phosphorus (SRPF)), nitrogen (nitrate (NO_3), nitrate-nitrite (NO_3-NO_2), ammonia (NH_3), total Kjeldahl nitrogen (TKN) and particulate organic nitrogen (PON)), carbon (dissolved inorganic carbon (DIC), dissolved organic carbon (DOC) and particulate organic carbon (POC)) as well as dissolved silica (SiO_2) and chlorophyll *a* (both corrected (Chla-C) and uncorrected (Chla-UC) for phaeophytin). Metals analyses were performed including aluminum (Al), beryllium (Be), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), molybdenum (Mo), nickel (Ni), silver (Ag), vanadium (V) and zinc (Zn).

Results and Discussion

Modern Limnology

Both of our study ponds had elevated levels of nutrients (nitrogen and phosphorus) and dissolved organic carbon (DOC) (Table 1), a finding consistent with the modern limnology of the Savelle site on Somerset Island examined by Douglas et al. (2004a). Pond B-AO, the most highly influenced site, had 0.777 mg/L total nitrogen (TN) and 0.015 mg/L total phosphorus (TP), while pond B-AP had 0.721 mg/L total nitrogen and 0.014 mg/L total phosphorus. The values are higher than mean concentrations for TN (0.577 mg/L) and TP (0.013 mg/L) recorded in ponds elsewhere on Bathurst Island (Lim et al. 2001). DOC levels in both ponds were slightly elevated compared to the mean for Bathurst Island sites (Table 1). High nutrient concentrations (TN and TP) in the modern water chemistry of these ponds indicates that the alteration of these ecosystems has persisted for almost four centuries after the last estimated occupation of the site (Table 1).

Table 2.1. Summary of the key modern limnological variables from the Bathurst Island ponds (B-AO and B-AP), the Savelle Site on Somerset Island and other lakes/ponds elsewhere on Bathurst Island. Dissolved organic carbon (DOC), dissolved inorganic carbon (DIC), specific conductivity (Cond), total nitrogen (TN), total phosphorus unfiltered (TPU), total phosphorus filtered (TPF), total Kjeldahl nitrogen (TKN), particulate organic nitrogen (PON), particulate organic carbon (POC), chlorophyll *a* unfiltered (Chl *a* U). Bathurst Island Average from Lim et al. (2001). Savelle Site data from Douglas and Smol, unpublished data.

	DOC mg/L	**DIC** mg/L	**pH**	**Cond** µs/cm	**TN** mg/L	**TPU** mg/L	**TPF** mg/L	**TKN** mg/L
B-AO	6.3	10.4	8.1	85	0.777	0.015	0.006	0.485
B-AP	4.7	10.7	7.8	81	0.721	0.014	0.004	0.410
Bathurst Average	4.1	19.1	8.3	160	0.577	0.012	0.006	0.334
Savelle Site (1994)	3.9	18.9	7.7	190	0.585	0.017	0.008	0.295
Savelle Site (1995)	5.7	25.8	8.4	165	0.696	0.008	0.004	0.417

	POC mg/L	**PON** mg/L	**Ca** mg/L	**Chl *a* (U)** µg/L	**Na** mg/L	**SiO_2** mg/L	**Mg** mg/L	**Cl** mg/L
B-AO	0.657	0.071	11.3	1.1	6.39	0.12	5.09	12.8
B-AP	0.838	0.072	10.9	1.1	5.02	0.17	5.04	9.42
Bathurst Average	0.574	0.038	30.8	0.8	3.10	0.79	5.6	5.60
Savelle Site (1994)	0.249	0.037	26.2	0.9	2.60	0.88	6.9	6.08
Savelle Site (1995)	0.550	0.048	32.8	1.8	3.20	1.68	9.4	7.86

Paleolimnological proxies

Prior to Thule occupation, both our ponds showed similar levels of aquatic production, diatom species composition and nutrient geochemistry (Figures 4, 5 and 6). Paleolimnological data observed in the earliest portion of both cores are consistent with pre-disturbance, oligotrophic, High Arctic pond ecosystems recorded in many other studies (e.g. Michelutti et al. 2000; Rühland et al. 2003). The pre-Thule diatom assemblages in both B-AO (Figure 4) and B-AP (Figure 5) are dominated by taxa such as *Fragilaria* species, *Nitzschia* species, *Achnanthes minutissima* and *Navicula vulpina,* typical of what has been recorded in pre-Anthropocene High Arctic lakes and ponds (Michelutti et al. 2000; Rühland et al. 2003; Smol et al. 2005). While relative abundances of these common taxa vary between the two ponds, their species composition is virtually identical. During this period both sites also have low chlorophyll *a* concentrations and nutrient profiles (Figure 6).

At the 6.5 cm level of pond, B-AO, a site *a priori* identified as being most impacted by Thule occupation, a marked change in diatom composition, sediment geochemistry and whole lake productivity begins (Figure 4). Contemporaneous shifts recorded in multiple proxies indicate that nutrient inputs from Thule whaling and other activities (e.g. seal hunting, defecation) altered numerous limnological properties (Figure 4) due to the number of sites in its catchment (Figure 3). In contrast, B-AP, which received considerably less Thule nutrients, recorded only minor changes in diatom assemblages and sediment geochemistry (Figure 5).

Pond B-AO, which received the majority of the Thule nutrient enrichment, showed marked changes in diatom species assemblages (Figure 4), specifically an increase in relative abundance of planktonic, eutrophic taxon *Stephanodiscus minutulus* (Brugam, 1979), a diatom which has seldom been observed in the High Arctic. Although rare in Arctic ponds, *S. minutulus* has been widely observed and well described at southern latitudes in North America (e.g. Hall et al. 1997; Reavie et al. 2000) and Europe (e.g. Lotter 1998; Alefs and Muller 1999), where it flourishes in environments with elevated concentrations of nitrogen and phosphorus. The increased relative abundance of *S. minutulus* in B-AO strongly suggests a period of enhanced nutrient input into the system. Concurrent with the changes in the diatom assemblages in pond B-AO, our core showed altered nitrogen concentration and isotopic composition (Figure 6). Both % N and $\delta^{15}N$ begin to increase at 6.5 - 7.0 cm, the same time we recorded an increase in the key eutrophic taxon *S. minutulus* (Figure 4). A $\delta^{15}N$ increase of 2 ‰ similar to what was observed by Douglas et al. (2004a) in their Thule pond on Somerset Island was observed in pond B-AO at 6.5 cm.

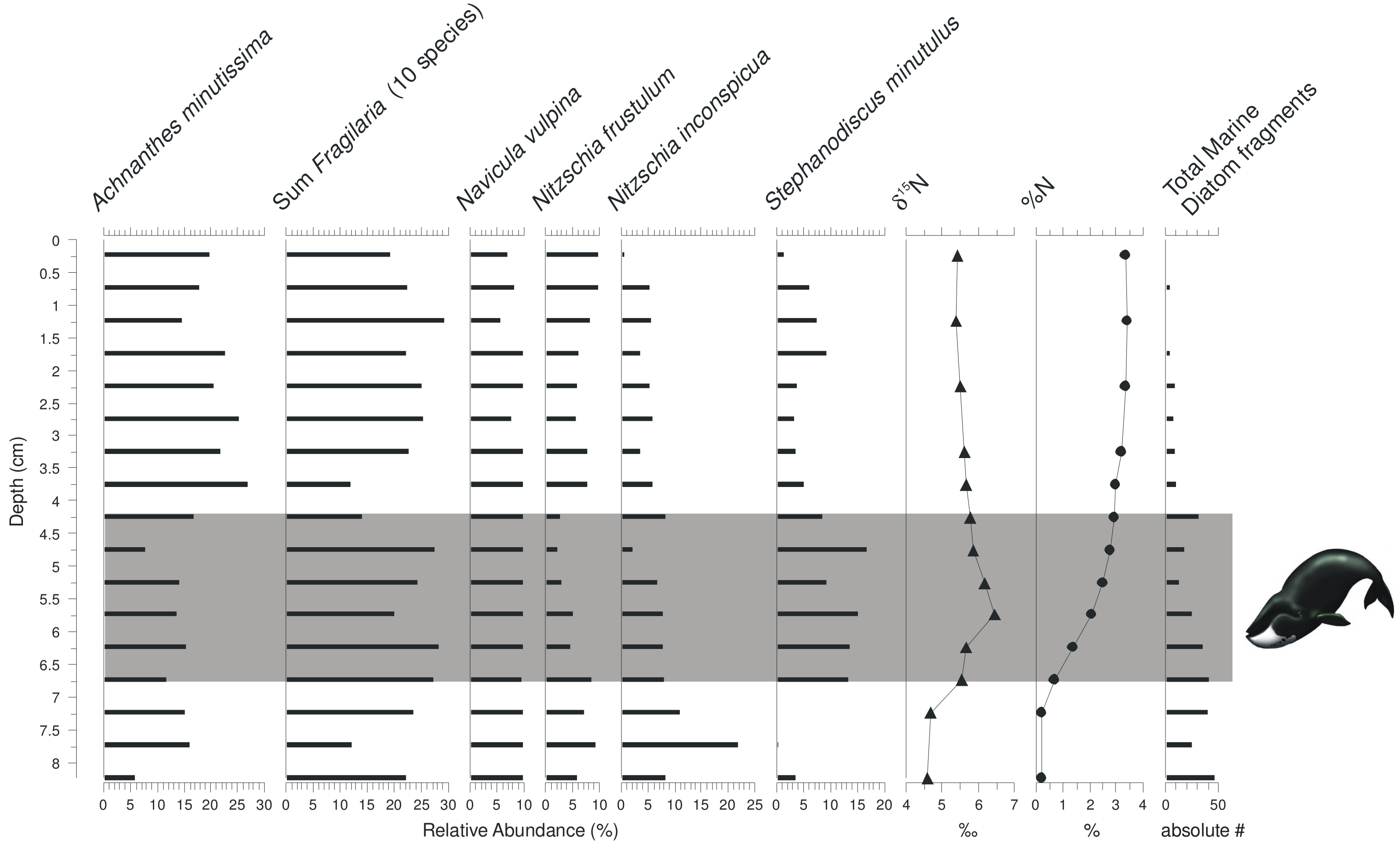

Figure 2.4. Stratigraphic profile of the dominant diatom taxa from pond B-AO and corresponding concentrations of $\delta^{15}N$ and %N. Shaded area represents the estimated Thule period based on $\delta^{15}N$ changes. Several (10) small benthic fragilarioid taxa were grouped into a single profile for simplicity. Marine diatom fragments are plotted as absolute numbers counted.

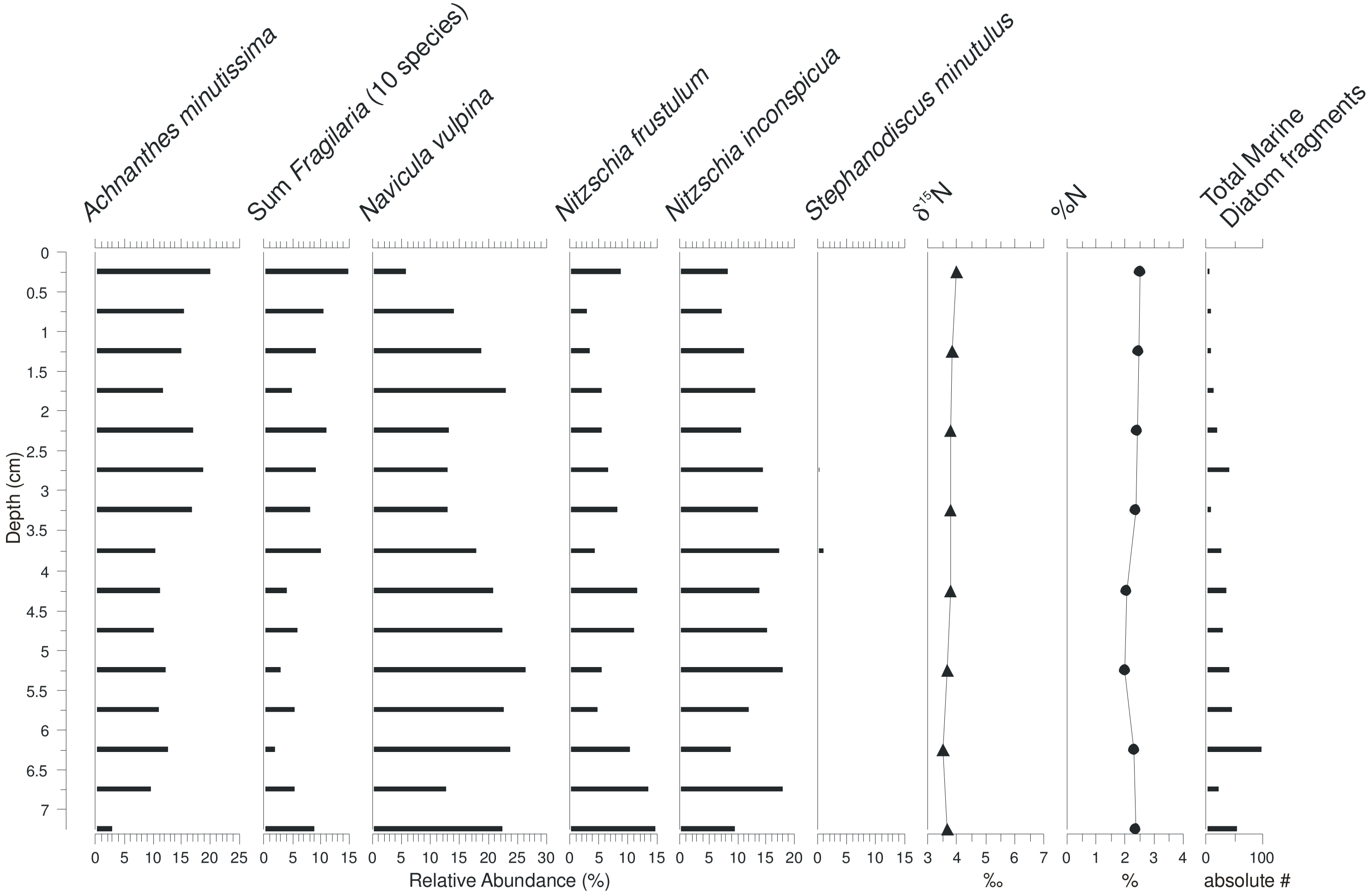

Figure 2.5. Stratigraphic profile of the dominant diatom taxa from pond B-AP and corresponding concentrations of δ^{15}N and %N. Several (10) small benthic fragilarioid taxa were grouped into a single profile for simplicity. Marine diatom fragments are plotted as absolute numbers counted.

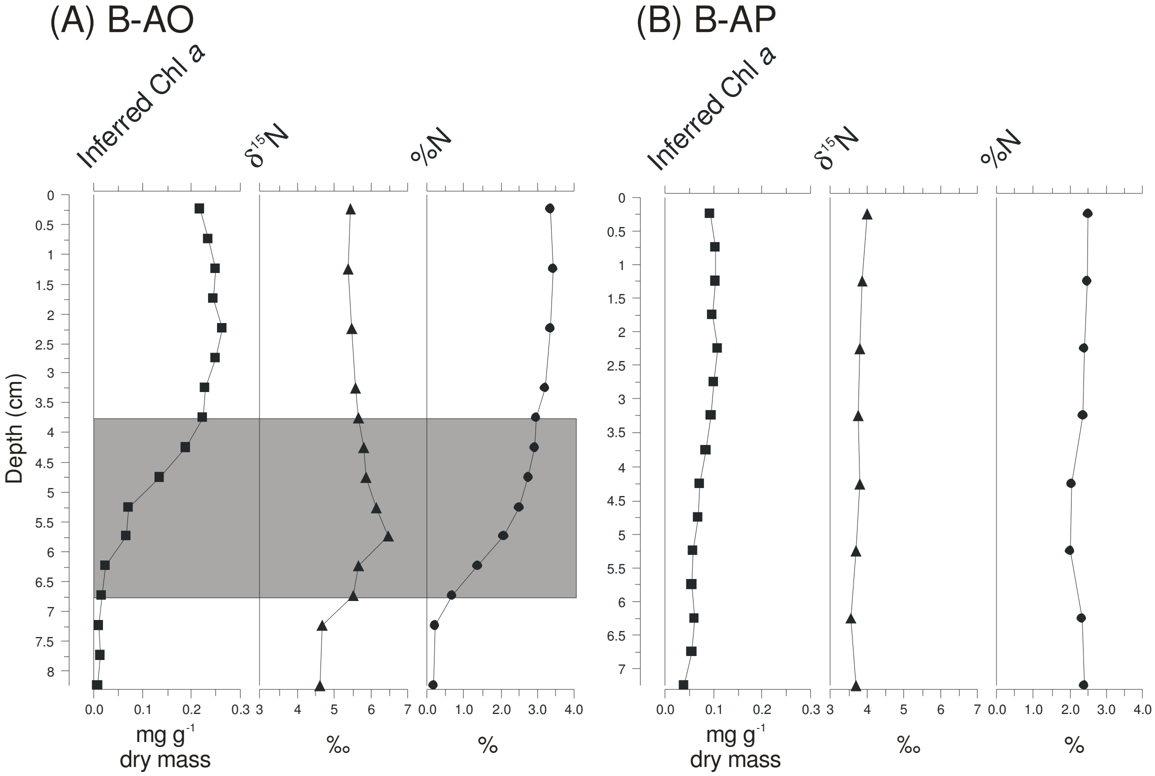

Figure 2.6. Sedimentary profiles of spectrally inferred Chl *a*, δ^{15}N and %N data for Deblicquy site ponds B-AO (left) and B-AP (right). Shaded area on B-AO profile indicates the period of Thule occupation at the site.

A marked decline in *S. minutulus* relative abundance at 4.0 cm in B-AO may indicate the end of the active Thule whaling period (Figure 4), which archaeologists estimate ca. 1500 AD (Taylor and McGhee 1981). *S. minutulus* relative abundances no longer constitute a major (>5% relative abundance) portion of the diatom assemblage for the rest of the core.

A striking and unprecedented increase in inferred Chl *a* concentration (Figure 6) occurs in B-AO at 6.0 cm, concurrently with the changes in both diatom species assemblage (Figure 5) and nitrogen stable isotope geochemistry (Figure 6), further indicating a significant increase in primary production. The timing of this change, prior to significant climatic warming, further suggests that the Thule Inuit settlements are the primary cause of limnological changes observed at this site.

In stark contrast to what was recorded in B-AO, our less impacted pond, B-AP, showed no major changes in geochemistry, nitrogen isotopes, or chlorophyll *a* concentration, and only some slight variations in diatom relative abundances, but no new taxa, as in B-AO (Figures 5 and 6).

Diatom assemblage changes, specifically the rise in the planktonic taxon *S. minutulus* recorded in B-AO, are more ecologically striking than those observed in the Savelle site on Somerset Island (Douglas et al. 2004a). Douglas et al. (2004a) attributed an increase in *Pinnularia balfouriana* during the period of Thule occupation on Somerset Island to enhanced moss growth resulting from increased nutrient concentrations. Altered diatom species assemblages as a result of cultural eutrophication have been previously documented on several occasions (Douglas and Smol 2000; Douglas et al. 2004); however, because of the shallow waters, cold temperatures, long periods of ice cover, and short growing season inherent in the Canadian High Arctic, these diatom species assemblage shifts have typically been limited to benthic taxa.

While both B-AO and Savelle Pond are both approximately the same depth (~30 – 50 cm), B-AO (120 m by 90 m) is considerably smaller than Savelle Pond (500 m by 150 m); however, the number of houses at the Deblicquy site is larger than the Savelle site (24 houses vs. 11 houses). Therefore, it is possible a greater input of nutrients occurred at the Deblicquy pond (B-AO), and this may be partially responsible for the increase in eutrophic planktonic taxa. However, given the modern limnological conditions (Table 1) and the observed shift in $\delta^{15}N$ at both the Savelle and the Deblicquy site being equal (~2 ‰), it is unlikely that the amount of nutrients alone can account for this change. *S. minutulus* has been observed to be highly successful in conditions of low Si:P ratios (Kilham & Kilham 1978; Lotter 1998), and was an excellent competitor for silicate, but a poor competitor for phosphate (Tilman et al. 1982). Based on the modern water chemistry data, the Si:P ratio in B-AO is very low (8:1) compared to Savelle pond (128:1) (Table 1). Furthermore, in these atypical Arctic sites where anthropogenic nutrient inputs via Thule whaling have likely lessened both N and P limitation, the next most limiting nutrient would be Si and a competitive taxon such as *S. minutulus* would be at an advantage.

Although there are some differences in the site-specific responses to nutrient enrichment between our sites and previous studies, there is no doubt that Thule Inuit whalers impacted the limnological properties of Bathurst Island ponds and that these impacts are still being experienced today.

Conclusions

Concurrent changes in multiple paleolimnological and geochemical proxies suggest that nutrient loading of marine origin associated with the Thule whalers has resulted in marked limnological changes in pond B-AO. Stable isotopes of nitrogen ($\delta^{15}N$) appears to be an equally useful tool in tracking marine-derived nutrients at Thule sites as it was in previous studies on sockeye salmon (Gregory-Eaves et al. 2003) and northern fulmars (Blais et al. 2005). The distribution of the whalebone houses at the Deblicquy site provides us with a unique opportunity to directly compare two ponds free of many confounding factors that often complicate limnological studies. The influence of the Thule whalers supports the conclusions of Douglas et al. (2004a) for Somerset Island, and the modern nutrient water chemistry at B-AO is more consistent with values seen in sewage ponds (Douglas and Smol 2000), than with the hundreds of documented oligotrophic lakes and ponds studied across the Arctic. Together these two studies, and similar studies on ancient cultural eutrophication (Ekdahl et al. 2007), serve to highlight the sensitivity of freshwater ecosystems to relatively minor anthropogenic disturbances and represent some of the earliest known anthropogenic impacts on North American ponds which have long been believed to be undisturbed prior to European settlement. Possibly more remarkable and concerning given the increasing magnitude of 21st century anthropogenic impacts in the Arctic, is that the influence of small communities of Thule whalers is still evident today, some three centuries after these sites were abandoned.

References

Alefs, J. and Müller, J. 1999. Differences in the eutrophication dynamics of Ammersee and Starnberger See (Southern Germany), reflected by the diatom succession in varve-dated sediments. Journal of Paleolimnology 21: 395–407.

Battarbee, R.W., Charles, D.F., Dixit, S.S., and Renberg, I., 1999. Diatoms as indicators of surface water acidity, in Stoermer, E.F., and Smol, J.P., eds., The Diatoms: Applications for the Environmental and Earth Sciences: Cambridge, UK, Cambridge University Press, Ltd., p. 85–127.

Blais J.M., Kimpe L.E., McMahon D., Keatley B.E., Mallory M.L., Douglas M.S.V. and Smol J.P. 2005. Arctic seabirds transport marine-derived contaminants. Science 309: 445.

Brugam, R.B. 1979. A re-evaluation of the Araphidineae/Centrales index as an indicator of lake trophic status. Freshwater Biology 9: 451–60.

Coltrain, J.B., Hayes, M.G. and O'Rourke, D.H. 2004. Sealing, whaling and caribou: the skeletal isotope chemistry of Eastern Arctic foragers. Journal of Archaeological Science 31: 39 – 57.

Cumming, B.F., Wilson, S.E., Hall, R.I. and Smol, J.P. 1995. Diatoms from British Columbia (Canada) lakes and their relationship to salinity, nutrients and other limnological variables. In: Lange-Bertalot H (eds.) Bibliotheca Diatomologica, Band 31, Gebruder Borntraeger, Berlin, Germany.

Dawson, P.C. 2001. Interpreting variability in Thule Inuit architecture: A case study from the Canadian High Arctic. American Antiquity 66: 453-470.

Douglas, M.S.V. and Smol, J.P. 2000. Eutrophication and recovery in the High Arctic: Meretta Lake (Cornwallis Island, Nunavut, Canada) revisited. Hydrobiologia 431: 193-204.

Douglas, M.S.V., Smol, J.P., Savelle, J.M. and Blais, J.M. 2004a. Prehistoric Inuit whalers affected Arctic freshwater ecosystems. Proceedings in the National Academy of Sciences of the United States of America 101: 1613-1617.

Douglas, M.S.V., Hamilton, P.B., Pienitz, R. and Smol, J.P. 2004b. Algal indicators of environmental change in arctic and antarctic lakes and ponds. In: Pienitz, R., Douglas, M.S.V. and Smol, J.P. (eds.), Long-term Environemental Change in Arctic and Antarctic Lakes. Developments in Paleoenvironmental Research. Volume 8. Dordrecht, The Netherlands, Springer, p. 117 – 159.

Ekdahl, E.J., Teranes, J.L., Wittkop, C.A., Stoermer, E.F., Reavie, E.D. and Smol, J.P. 2007. Diatom assemblage response to Iroquoian and Euro-Canadian eutrophication of Crawford Lake, Ontario, Canada. Journal of Paleolimnology 37: 233-246.

Finney B.P., Gregory-Eaves I., Douglas M.S.V. and Smol J.P. 2002. Fisheries productivity in the northeast Pacific over the past 2,200 years. Nature 416: 729-733.

Friesen, T. Max. 2004. Contemporaneity of Dorset and Thule cultures in the North American Arctic: New radiocarbon dates from Victoria Island, Nunvut. Current Anthropology 45: 685-691.

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

Gregory-Eaves. I., Smol, J.P., Douglas, M.S.V., and Finney, B.P. 2003. Diatoms and sockeye salmon (Oncorhynchus nerka) population dynamics: Reconstructions of salmon-derived nutrients over the past 2,200 years in two lakes from Kodiak Island, Alaska. Journal of Paleolimnology 30: 35–53.

Hall, R.I., Leavitt, P.R., Smol, J.P. and Zirnhelt, N. 1997. Comparison of diatoms, fossil pigments and historical records as measures of lake eutrophication. Freshwater Biology 38: 401-417.

Hobson, K.A. and Schell, D.M. 1998. Stable carbon and nitrogen isotope patterns in baleen from eastern Arctic bowhead whales (*Balaena mysticetus*). Canadian Journal of Fisheries and Aquatic Sciences 55: 2601-2607.

Keatley, B., Douglas, M.S.V., and Smol, J.P. 2007. Physical and chemical limnological characteristics of lakes and ponds across environmental gradients on Melville Island, Nunavut/N.W.T., High Arctic Canada. Archiv für Hydrobiologie 168: 355–376.

Kilham, S.S., and Kilham, P. 1978. Natural community bioassays: predictions of results based on nutrient physiology and competition. Verh. int. Ver. Limnol. 20: 68–74.

Krammer, K., and Lange-Bertalot, H. 1986–1991. Bacillariophyceae.In Ettl, H., J. Gerloff, H. Heynig & D.Mollenhauer (eds.), Subwasserfloa von Mitteleuropa, Band 2(2–4). Gustav Fischer Verlag, Stuttgart/Jena.

Le Mouel, J.F. and Le Mouel, M. 2002. Aspects of Early Thule culture as seen in the architecture of a site on Victoria Island, Amundsen Gulf area. Arctic 55: 167-189.

Lim, D.S.S., Douglas, M.S.V., Smol, J.P. and Lean, D.R.S. 2001. Physical and chemical limnological characteristics of 38 lakes and ponds on Bathurst Island, Nunavut, Canadian High Arctic. International Review of Hydrobiology 86: 1-22.

Lotter, A.F. 1998. The recent eutrophication of Baldeggersee (Switzerland) as assessed by fossil diatom assemblages. The Holocene 8: 395-405.

Mathiassen, T. 1927. Archaeology of the Central Eskimos: the Thule culture and its position within the Eskimo culture. Report on the Fifth Thule Expedition 1921-1924 4(2). Gyldendalske Boghandel, Nordisk Forlag, Copenhagen.

Maxwell, M.S. 1985. Prehistory of the Eastern Arctic, Academic Press, Orlando.

McCartney, A.P. 1977. Thule Eskimo prehistory along the Northwestern Hudson Bay. National Museum of Man Mercury Series, Archaeological Survey of Canada Paper No. 70, Ottawa.

McCartney, A.P. 1980. The nature of Thule Eskimo whale use. Arctic 33: 517-541.

McGhee, R. 2000. Radiocarbon dating and the timing of the Thule migration. In: Appelt, M., Berglund, J., and Gulløv, H.C. eds. Identities and cultural contacts in the Arctic. Copenhagen: Danish National Museum and Danish Polar Center. 181– 191.

Michelutti, N., Laing, T.E. and Smol, J.P. 2000. Diatom assessment of past environmental changes in lakes located near the Noril'sk (Siberia) smelters. Water, Air, and Soil Pollution 125: 231–241.

Michelutti, N., Douglas, M.S.V., Lean, D.R.S. and Smol, J.P. 2002. Physical and chemical limnology of 34 ultra-oligotrophic lakes and ponds near Wynniatt Bay, Victoria, Arctic Canada. Hydrobiologia 482: 1-13.

Michelutti, N., Wolfe, A.P., Vinebrooke, R.D. and Rivard, B. 2005. Recent primary production increases in arctic lakes. Geophysical Research Letters 32: L19715, doi:10.1029/2005GL023693.

Moore, J.J., Hughen, K.A., Miller, G.H. and Overpeck, J.T. 2001. Little Ice Age recorded in summer temperature reconstruction from varved sediments of Donard Lake, Baffin Island, Canada. Journal of Paleolimnology 25: 503 – 517.

Park, R.W. 1997. Thule winter site demography in the High Arctic. American Antiquity 62: 273-284.

Parr, J.F., Taffs, K.H. and Lane, C.M. 2004. A microwave digestion technique for the extraction of fossil diatoms from coastal lake and swamp sediments. Journal of Paleolimnology 31: 383-390.

Rautio, M. and Vincent, W.F. 2006. Benthic and pelagic food resources for zooplanktonin shallow high-latitude lakes and ponds. Freshwater Biology 51, 1038–1052.

Ramstack, J.M., Fritz, S.C., and Engstrom, D.R. 2004. Twentieth century water quality trends in Minnesota lakes compared with presettlement variability. Canadian Journal of Fisheries and Aquatic Sciences 61: 561–576.

Reavie, E.D., Smol, J.P., Sharpe, I.D., Westenhofer, L.A. and Roberts, A.M. 2000. Paleolimnological analyses of cultural eutrophication patterns in British Columbia lakes Canadian Journal of Botany 78: 873–888.

Rühland, K., Priesnitz, A. and Smol, J.P. 2003. Evidence for recent environmental changes in 50 lakes across the Canadian arctic treeline. Arctic, Antarctic and Alpine Research 35: 110-123.

Savelle, J.M., and McCartney, A.P. 1999. Thule Eskimo bowhead whale interception strategies. World Archaeology 30: 437-451.

Schindler, D.W. 2006 Recent advances in the understanding and management of eutrophication. Limnology and Oceanography 51: 356–363.

Smol, J.P. 2002. Pollution of Lakes and Rivers – A Paleoenvironmental Perspective. Arnold publishers, New York, NY, USA.

Stoermer, E.F. and Smol, J.P. [Editors]. 1999. The Diatoms: Applications for the Environmental and Earth Sciences. Cambridge University Press. Cambridge.

Taylor, W.E. Jr. and McGhee, R. 1981. De Blicquy, a Thule Culture Site on Bathurst Island, N.W.T, Canada. Archaeological Survey of Canada, Mercury Series 102. National Museum of Man. Ottawa, On, Canada.

Tilman, D., Kilham, S.S., Kilham, P. 1982. Phytoplankton community ecology: The role of limiting nutrients. Annual Review of Ecology and Systematics 13: 349-372.

Whitridge, P. 2002. Social and ritual determinants of whale bone transport at a classic Thule winter site in the Canadian Arctic. International Journal of Osteoarchaeology 12: 65-75.

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.

Wolfe, A.P., Miller, G.H., Olsen, C.A., Forman, S.L., Doran, P.T. and Holmgren, S.U. 2004. Geochronology of high latitude lake sediments. In Long-term environmental change in Arctic and Antarctic lakes. Springer, Netherlands: 19-52.

CHAPTER 3

Ancient cultural eutrophication caused by Thule Inuit whalers and recent climate warming impacts on a pond at the Eskimobyen site, Ellesmere Island, Nunavut, High Arctic Canada

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Abstract

Cultural eutrophication is one of many environmental stressors that continue to be of increasing concern as human population continues to grow. However, until recently the impact of ancient human populations, on freshwater Arctic ponds was thought to be insignificant. Based on paleolimnological and archeological data, we have shown that Thule Inuit living in small, nomadic communities were altering pond ecology as a result of their whaling activities, centuries before industrialization. Striking changes in diatom species assemblages, spectrally inferred primary production, mercury concentrations and nutrient geochemistry indicate eutrophication in a pond on Knud Peninsula, Ellesmere Island. Input of marine derived nutrients from bowhead whale carcasses used by the Thule for both sustenance and the construction of winter settlements could be linked to an increase in *Amphora ovalis*, which coincides with marked increases in mercury concentration and a ~2 ‰ increase in $\delta^{15}N$. In addition, we also record a change in the more recent sediments, specifically increases in diatom taxa *Craticula halophila* and *Achnanthidium minutissimum*, which we attribute to recent climate warming. Persistently elevated nitrogen and phosphorus levels in these ponds, as a result of whale bones remaining in the pond and surrounding catchment, indicate that the impact of Thule whalers at this site is still present today, three centuries after the sites were abandoned.

Introduction

Paleolimnological investigation allows us to study long-term ecological change and thereby reconstruct past environments using multiple, independent environmental proxies. For example, by using physical, chemical and biological indicators to reconstruct past environments beyond the historical record, anthropogenic influences may be quantified relative to natural variability (Smol 2002). Paleo-techniques are particularly important in the Arctic where we seldom have basic limnological data collected for more then one year (if at all) and are therefore completely lacking long-term monitoring data. Biological remains from organisms such as chironomids, diatom and chrysophyte algae and cladocerans, are useful in reconstructing past environmental conditions. However, algal subfossils, especially diatoms, are commonly used as environmental indicators because of their sensitivity to key environmental variables such as pH, salinity, nutrient concentrations (e.g. nitrogen and phosphorus) and climate-related factors (Stoermer and Smol 1999).

Because of their wide distribution and good preservation, diatoms make an ideal paleolimnological indicator and are being used to assist researchers in studying the impacts of numerous stressors such as acidification (e.g. Battarbee et al. 1999), eutrophication (e.g. Douglas and Smol 2000), atmospheric pollution (e.g. Wolfe et al. 2003) and anthropogenic climate warming (e.g. Rühland et al. 2003; Smol et al. 2005) on aquatic ecosystems. Their usefulness as paleolimnological indicators in polar regions, where many other indicators are not present, has recently been reviewed by Douglas et al. (2004b).

Stable isotope geochemistry is being used increasingly by paleolimnologists to track marine-derived nutrients in freshwater systems. For example, researchers have been able to track marine-derived nutrient inputs from birds (Blais et al. 2005), whales (Douglas et al. 2004) and sockeye salmon (Finney et al. 2002; Gregory-Eaves et al. 2003), using $\delta^{15}N$ from sediment cores. In addition, by measuring downcore spectrallyinferring chlorophyll *a*, estimates of whole-lake primary production changes have been shown to closely reflect shifts recorded in other chemical proxies for productivity such as total organic carbon (TOC) and biogenic silica ($BSiO_2$) (Michelutti et al. 2005).

Recently, Douglas et al. (2004a) and Hadley (Chapter 2) have recorded major changes in sedimentary profiles from freshwater ponds near abandoned Thule sites on Somerset and Bathurst islands, respectively. Douglas et al. (2004a) showed that unprecedented ecosystem changes and other limnological shifts have occured, attributable to nutrients released from whale carcasses and other activities of the Thule Inuit. In both studies, nutrient levels continue to remain elevated to the present day, some four centuries after the Thule abandoned the region. Although the Douglas et al. (2004a) study unequivocally showed the Thule impacted the water quality of freshwater ecosystems, it was limited to a single site near the southernmost range of the Thule people, and thus the influence of similar activities on other freshwater sites throughout the Arctic remains unexplored. The Bathurst Island study (Chapter 2) offered a rare opportunity to compare an "impact" and a "control" site where confounding factors such as geology and climate are relatively constant. Here, we further explore the influence of Thule whalers on aquatic ecology by examining a pond (E-Knud) near the northern-most extent of the Thule geographical range, a location known the Eskimobyen site on Ellesmere Island, Nunavut (Figure 1) (Taylor and McGhee 1981; Le Mouel and Le Mouel 2002). In contrast to what has been observed at other sites on Somerset Island (Douglas et al. 2004a) and Bathurst Island (Chapter 2), diatoms in E-Knud pond indicate responses to multiple environmental stressors, first to the onset of Thule whaling and then to reduced water levels, presumably brought about by post-1850 climate warming.

Thule culture and occupation of the Knud Peninsula region

Thule Inuit migration across the Arctic tundra is estimated to have occurred beginning ca. 1000 AD, with the first occupation of the Eskimobyen site being ca.12th or 13th century AD (McCullough 1989; Schledermann and McCullough 2003). Thule whalers brought with them unprecedented whaling technologies, including umiaks, seal skin floats and harpoons with toggling heads (McCullough 1989; Schledermann and McCullough 2003). Whaling season began during ice break up as the whales entered the eastern Arctic in early summer, moving to their maximum western extent by mid-September (Savelle and McCartney 1999). Multiple whaling parties consisting of umiaks, each crewed by six to nine men, hunted bowhead whales using harpoons, seal skin floats (to fatigue the whale and force it to surface) and a lance (Whitridge 2002). Whale kills were towed ashore, flensed and divided according to social hierarchy (Whitridge 2002). Decline in whaling tradition began to ca. 1400 – 1500 AD, as Thule culture began to rely more on sealing (McCartney 1980; Whitridge 2002). Change in Thule subsistence strategy was reflected in the changing style of Thule winter dwellings (Schledermann 1976) and is hypothesized to be the result of cooling climate related to the onset of the Little Ice Age and the resultant changes in distribution of ice-cover and fauna (McCartney 1977; Moore et al. 2001; Schledermann 1976).

Because the Arctic is devoid of trees, the Thule Inuit relied on whale bones as a primary source of building material, as well as for small tools and cultural artifacts, as they expanded into the Canadian Arctic from Alaska (Whitridge 2002). Thule Inuit whalebone houses were traditionally constructed from sod, stone, whale bone and seal skins (Dawson 2001), and have been widely studied by archeologists (e.g. Mathiassen 1927; Taylor and McGhee 1981; Park 1997; Dawson 2001; Friesen 2004). The largest Thule overwintering sites are located where access to whales is available early in the season (i.e. Hazard Inlet and Cresswell Bay, Somerset Island) (Savelle and McCartney 1999).

Site Description

The Eskimobyen site (79^{o} 07′ N, 76^{o} 45′ W) is located on Knud Peninsula on the eastern coast of Ellesmere Island (Figure 1). Geology of the region is comprised of Precambian rocks composed of gneiss, granite, pegmatite and crystalline limestone (Christie 1967). Typically, ponds and lakes in the region are oligotrophic, alkaline and dilute (Douglas and Smol 2004). Recently, this region of the Arctic has been highlighted due to the dramatic reduction in the water levels of many ponds, which researchers have attributed to increased evaporation due to warming climate (Smol and Douglas 2007).

The Eskimobyen site was first documented by Otto Sverdrup during his 1898/99 exploration of the region (Sverdrup 1904) and later excavated and studied by Schledermann and McCullough (2003), who identified 27 semi-subterranean Thule whale bone houses that are directly adjacent to a single, small (~70 x 35 m) and shallow (~1 m max depth) pond, which we refer to as E-Knud (Figures 1 and 2). Only about half of the houses at this site drain directly into the pond; however, given the highly oligotrophic nature of the region, this still represents a significant input of nutrients to the system. Exposed sediment, mosses and grasses around the pond indicate a modern water level significantly lower than in past decades (Figure 2).

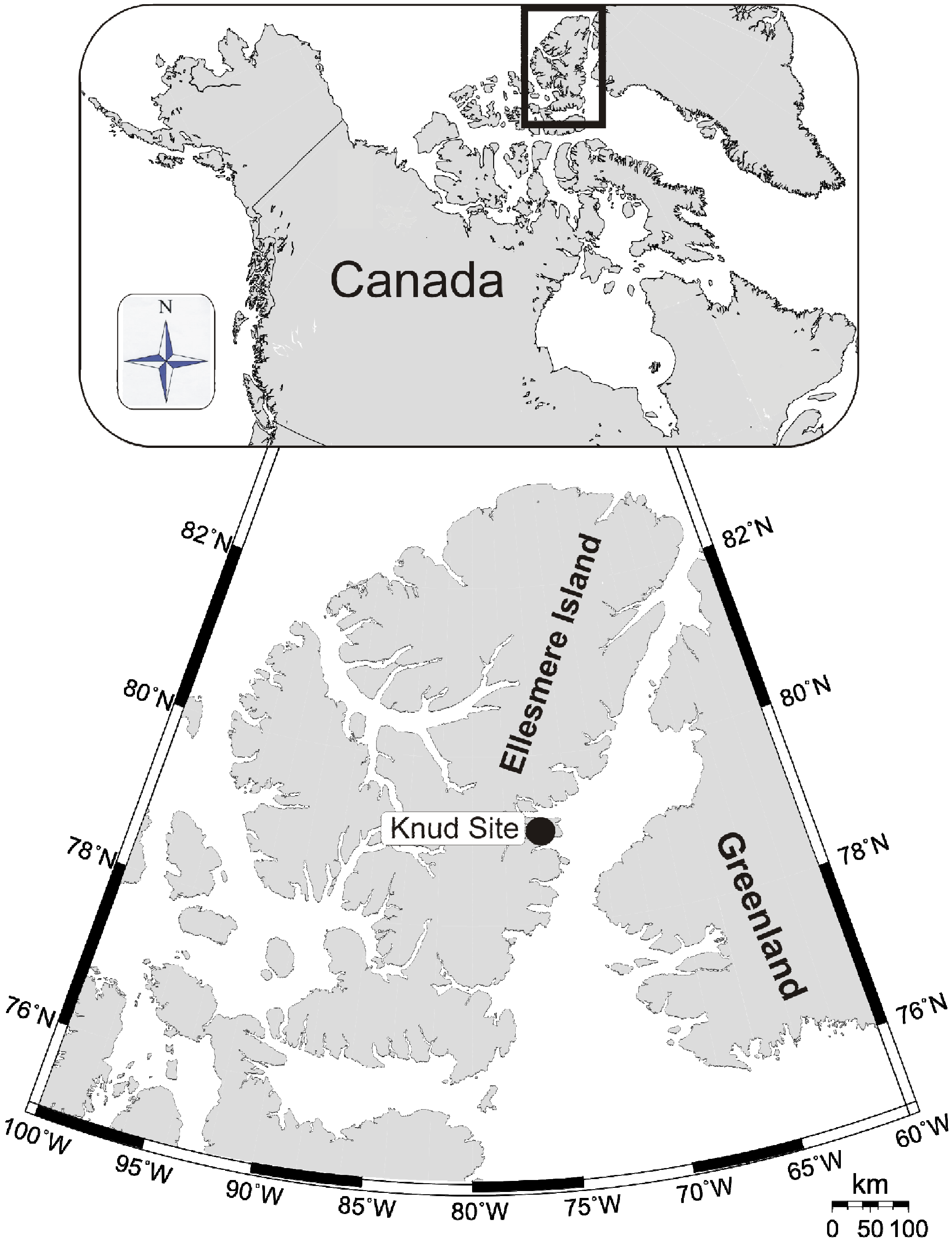


Figure 3.1. Map of Bathurst Island showing the location of the Eskimobyen Site.

Table 1 summarizes the elevated levels of nitrogen, phosphorus and DOC observed in E-Knud pond relative to other ponds studied on Ellesmere Island (Douglas M.S.V and Smol J.P. unpublished data).

Table 3.1. Summary of the key modern limnological variables from the Ellesmere Island Thule site (E-Knud) in comparison to other lakes and ponds elsewhere on Ellesmere Island. Dissolved organic carbon (DOC), dissolved inorganic carbon (DIC), specific conductivity (Cond), total nitrogen (TN), total phosphorus unfiltered (TPU), total phosphorus filtered (TPF), total Kjeldahl nitrogen (TKN), particulate organic nitrogen (PON), particulate organic carbon (POC), chlorophyll *a* unfiltered (Chl a U). Cape Herschel averages from Douglas and Smol, unpublished data.

	DOC	**DIC**	**pH**	**Cond**	**TN****	**TPU**	**TPF**	**TKN**
	mg/L	mg/L		µs/cm	mg/L	mg/L	mg/L	mg/L
E-Knud (2004)	10.3	16.8	9.76	207	1.104	0.032	0.011	0.988
E-Knud (2006)	11.1	18.2	9.87	210	1.081	0.042	0.088	0.965
Cape Herschel mean	5.9	16.0	8.66	170	0.575	0.011	0.060	0.525
	POC	**PON**	**Ca**	**Chl *a* (U)**	**Na**	**SiO_2**	**Mg**	**Cl**
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
E-Knud (2004)	0.763	0.111	22.3	1.6	19.7	1.17	11.2	39.8
E-Knud (2006)	3.580	0.297	21.8	4.7	18.1	0.54	9.75	34.2
Cape Herschel mean	0.530	0.046	16.5	1.1	13.1	1.22	8.23	24.3

**** TN = TKN +NO_3NO_2 + PON**

Figure 3.2. Photo of the Eskimobyen site, showing study site (E-Knud) and the relative drop in water level illustrated by exposed sediment and mosses.

Methods

Sediment collection and geochronology

A short (15.5 cm) sediment core was collected from the deepest portion of E-Knud pond (Z_{max} = ~1 m) using a 3″ (7.6 cm) diameter Glew (2001) corer and sectioned on site at 0.5 cm resolution using a Glew (1988) vertical extruder. The sediment sections were stored in Whirlpak® bags and kept cool and dark until return to the laboratory.

Due to low ^{210}Pb activity, characteristic of many high latitude regions (Wolfe et al. 2004), both gamma and alpha spectrometry proved ineffective for dating the sediment (Appendix A) and therefore sediment further downcore was submitted to INSTAAR (University of Colorado, Boulder CO) for ^{14}C humic acid analysis. At the time of writing, the geochronology is still being investigated. For the purpose of this thesis, dates presented on the diatom stratigraphies, which mark the beginning and ending of the Thule period, are approximations based on the changes seen in the δ^{15}N and mercury concentrations in the sediment record (Figure 3) and on archeological evidence of when Thule occupied this region (Schledermann and McCullough 2003), as described later in the chapter.

The Thule Inuit period at this site has been estimated by radiocarbon dating during past archeological expeditions. Excavation at Eskimobyen has led archaeologists to conclude that several occupations of the site have occurred between the 12th and 17th century AD (McCullough 1989; Schledermann and McCullough 2003). Presence of marine diatom fragments in the bottom sections of the core (as discussed below), indicates that we have obtained a near-complete record of the pond's history.

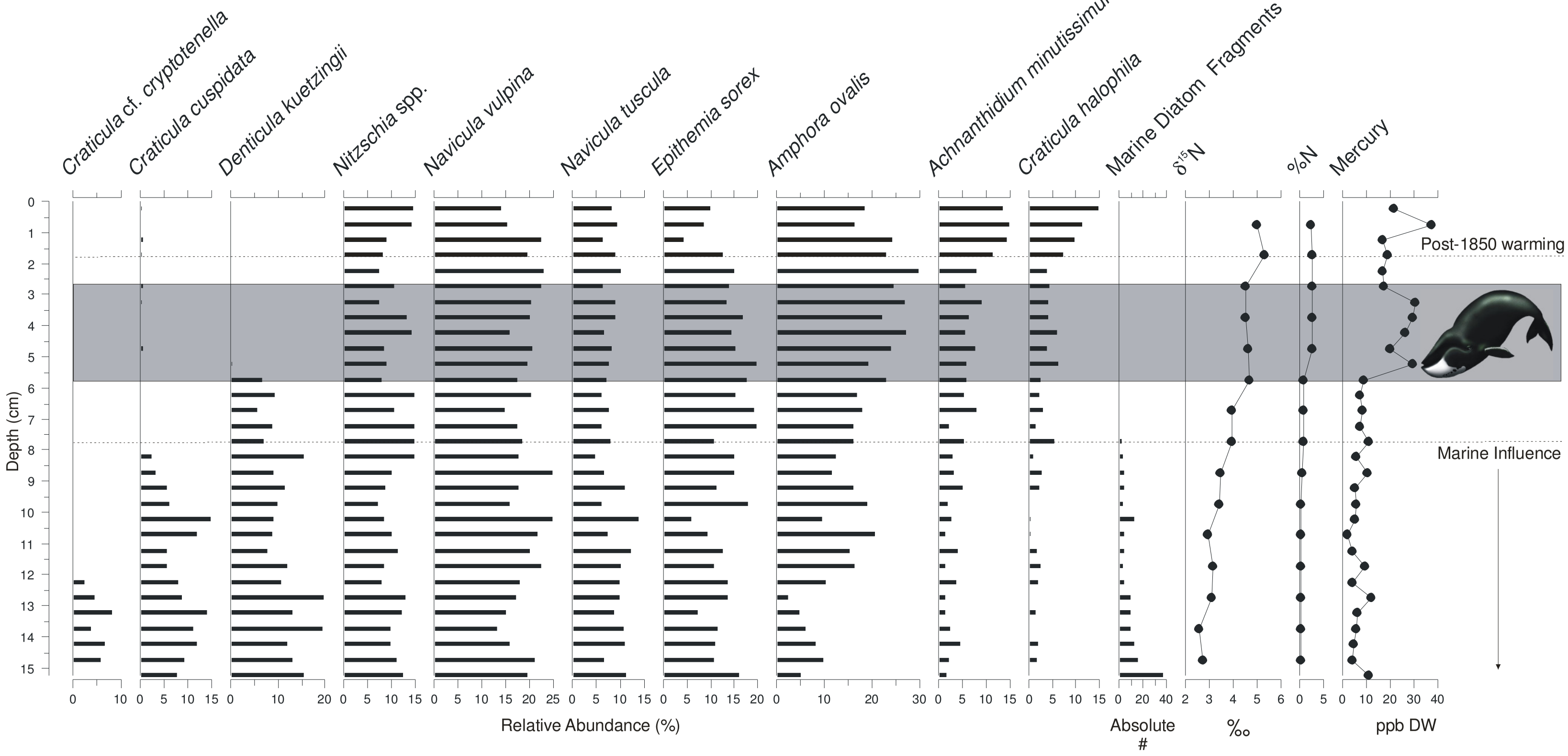


Figure 3.3. Stratigraphic profile of the dominant diatom taxa from pond E-Knud and corresponding co ncentrations of δ^{15}N, %N and mercury concentration. Shaded area represents the estimated Thule period based on δ^{15}N and mercury changes. Marine diatom fragments are plotted as absolute numbers counted.

Diatoms

Approximately 0.3 g of wet sediments were digested in 99% nitric acid using a CEM MarsX microwave digester (Parr et al. 2004), rinsed with deionized water until a neutral pH was achieved. Four dilutions of diatom slurry were permanently mounted on slides using Naphrax®. Diatoms were enumerated at 1000X magnification, under oil immersion using a Leica DMR2 microscope with differential interference contrast (DIC). Between 300 - 400 diatoms valves were counted for each interval and identified using standard freshwater floras (Krammer and Lange-Bertalot 1986-1991; Cumming et al. 1995). As a result of extremely low diatom concentrations in several sediment intervals, diatom enumeration was stopped after a minimum of 200 diatoms valves was reached.

Stable isotopes

Sediments were analyzed for $\delta^{15}N$ at 1-cm intervals for the entire length of the 15.5 cm core. Measurements were performed at the G.G. Hatch Stable Isotope Laboratory, Ottawa, Canada., using a Vario EL III (Elementar, Germany) + Conflo II + DeltaPlus XP IRMS (ThermoFinnigan, Germany) with analytical precision (2 sigma) of ±0.2‰. Freeze-dried sediment was weighed into tin capsules and combusted at 1800^{o}C in an elemental analyzer (EA) or elemental combustion system (ECS). The resultant gases were carried through the EA for purification and separation into N_2 and CO_2 and analyzed in an isotope ratio mass spectrometer (IRMS) via a Conflo interface. Data gathered were normalized using internal standards that had been previously calibrated with international standards IAEA-CH-6, IAEA-NBS22, IAEA-N1, IAEA-N2, USGS-40, USGS-41.

Spectrally inferred Chlorophyll a

Sediment used for spectral analysis was first freeze-dried and sieved through a <125 µm mesh. Measurements of absorption in the 400 nm - 1100 nm range were taken, using a Foss NIRSystem 500 and Chl *a* concentrations were inferred, based on the methods discussed in Michelutti et al. (2005) and Wolfe et al. (2006).

Water Chemistry

Water samples were collected approximately 1 m from shore and stored using Nalgene® plastic bottles and 125ml glass bottles. Samples were measured in the field for conductivity using a YSI model 33 conductivity meter. Multiple field measurements of pH and temperature were made using three 2-point calibrated Hanna pHep pH meters and handheld thermometers. Analysis of major ions, nutrients and metals were performed at the National Water Research Institute (NWRI), following the same protocols used in our labs previous Arctic surveys (Environment Canada, 1994).

Water samples were analyzed by NWRI for major cations (Ca^{2+}, Mg^{2+}, K^+, Na^+), major anions (Cl^-, SO_4^{2-}) and for a variety of minor ions (e.g. barium (Ba), lithium (Li) and strontium (Sr)). Nutrients measured include phosphorus (total phosphorus unfiltered (TPU), total phosphorus filtered (TPF) and soluble reactive phosphorus (SRPF)), nitrogen (nitrate (NO_3), nitrate-nitrite (NO_3-NO_2), ammonia (NH_3), total Kjeldahl nitrogen (TKN) and particulate organic nitrogen (PON)), carbon (dissolved inorganic carbon (DIC), dissolved organic carbon (DOC) and particulate organic carbon (POC)) as well as dissolved silica (SiO_2) and chlorophyll *a* (both corrected (Chla-C) and uncorrected (Chla-

UC) for phaeophytin). Metals analyzed included aluminum (Al), beryllium (Be), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), molybdenum (Mo), nickel (Ni), silver (Ag), vanadium (V) and zinc (Zn).

Results and Discussion

Modern Limnology

Multi-year water chemistry data from E-Knud pond showed elevated levels of nutrients (nitrogen and phosphorus) and dissolved organic carbon (DOC) relative to the regional average (Table 1), a finding consistent with the modern limnology of the Thule site on Somerset Island (Douglas et al. 2004a) and with both ponds studied at the Deblicquy site on Bathurst Island (Chapter 2). In the first sampling year (2004), pond E-Knud, which is the most nutrient-rich Thule site studied to date, had 1.11 mg/L total nitrogen (TN) and 0.032 mg/L unfiltered total phosphorus (TPU), values that are significantly higher than mean concentrations for TN (0.520 mg/L) and TPU (0.011 mg/L) recorded elsewhere on Ellesmere Island (Douglas M.S.V. and Smol J.P. unpublished data). DOC levels in E-Knud pond were also slightly elevated in 2004 compared to the mean Cape Herschel on Ellesmere Island (Table 1). Values for all major nutrients were observed to be higher when we resampled the pond in 2006, most likely due to continued nutrient input from bones still in the catchment and a significant reduction in the ponds size attributable to increased evaporation brought on by climate warming.

Paleolimnological proxies

Although it has been difficult to establish a chronology for this sediment core, dates are available from previous research undertaken by archeologists, and therefore the active

Thule period at this site has been well established. Based on excavation of approximately twelve whalebone houses at the site, archeologists estimate that the site was subject to multiple occupations beginning in the Thule Ruin Island phase (ca. 1100 - 1200 AD) and ending in the late 17th century (ca. 1670 AD) (Schledermann and McCullough 2003). A marked color change observed in the our sediment core from light gray clay-rich sediment to a reddish-brown organic deposit at 5.5 cm coincides with significant diatom, mercury and inferred chl *a* changes (discussed in detail below), which we attribute to the onset of active Thule whaling (ca. 1100 - 1200 AD) at the site (Figure 3). Mercury levels remain relatively high in the sediments until approximately 2.5 cm at which point a marked decrease is observed (Figure 3) marking the end of the active whaling period (ca. 1670 AD)

The diatom species assemblage between 8 and 15.5 cm, which we believe to be prior to the arrival of the Thule, appears to be influenced by marine input during isostatic uplift from the ocean. Marine fragments detected in this section of the core gradually decline in younger sediment intervals (Figure 3), indicating reduced marine input as isostatic uplift increased the ponds elevation. This is supported in the diatom record by taxa such as *Craticula* cf. *cryptotenella* and *Craticula cuspidata*, which are both associated with salinities greater than those found in most Arctic ponds (Roberts et al. 2004; Cumming et al. 1995).

Although not as striking ecologically as changes seen in other Thule sites (e.g. Chapter 2), diatom species in E-Knud pond appear to be responding to increased nutrient inputs from Thule whalers. For example, increases in *Amphora ovalis* beginning at ~5.5 cm coincided with shifts in δ^{15}N,, %N and a marked increase in mercury concentration

(Figure 3), which we would expect to see associated with input from marine mammals such as seal and bowhead whales where mercury would be both highly biomagnified and bioaccumulated (Wagemann et al. 1996; Julshamn et al. 1987). *A. ovalis* has been shown to have relatively high optima for key nutrients such as phosphorus (Bennion 1994) and therefore would be expected to thrive during a period of nutrient enrichment.

In the most recent sediments (~2 cm), we observed a secondary diatom response likely unrelated directly to the Thule period. Increases in the relative abundance of taxa *Achnanthidium minutissimum* and *Craticula halophila* were observed in the most recent sediments, coinciding with a secondary peak in mercury concentration (Figure 3). *A. minutissimum* has previously been associated with a longer growing season due to warmer temperature in other Arctic sites (Keatley et al. 2006; Antoniades et al. 2005). While *C. halophila*, a common saline taxon found more frequently in southern regions, has often been associated with droughts and fluctuating precipitation/evaporation dynamics driven by climate warming (Pienitz et al. 2000; McGowan et al. 2003). The latter is likely to be the principal factor in this pond, as water levels clearly appear to be lower in recent years (Figure 2). Increased mercury concentration during this same period, followed by a sharp decline (Figure 3), likely represents atmospheric anthropogenic inputs during industrialization and the subsequent reductions resulting from the creation of numerous emission reduction acts in North America.

The oldest sediments below ~5.5 cm depth had the lowest δ^{15}N and %N values recorded in the core (Figure 4). While δ^{15}N values are slightly higher in this region than observed in other fresh water ponds, this was probably the result of marine influence. Immediately following deglaciation, prior to isostatic emergence (Blake 1992) the pond would have been much closer to the sea and therefore subject to the influence of the ocean (Figures 3 and 4). At 5.5 cm, coinciding with the previously described shift in diatom species abundance of *A. ovalis*, increases in both δ^{15}N and %N were observed marking the beginning of the Thule occupation at this site (ca. 1100 – 1200 AD). At the onset of Thule whaling, δ^{15}N values increased to ~5 ‰ and remained stable until 2.5 cm when we estimate the Thule period ended, based on a significant decline in mercury concentration and other indicators (Figure 4). Similar to what was observed on Somerset Island (Douglas et al. 2004), nutrients (both δ^{15}N and %N) in E-Knud pond remained high even after the abandonment of the site (ca. 1670 AD), likely as a result of the influence of whalebones observed both in and around the water which would be a continued supply of nutrients. The small increase in δ^{15}N in the post-Thule period (Figure 4) was likely the result of this continued nutrient leeching from bones within the catchment.

As with previous research on Bathurst Island (Chapter 2), inferred chl *a* measurements appear to track anthropogenic inputs of nutrients during the Thule whaling period. Inferred chl *a* remained relatively low and constant for the entire core prior to ~6 cm, after which a gradual increase coincided with the increases in diatom taxon, *Amphora ovalis*, as well as increased mercury concentration and the highest δ^{15}N recorded to date (Figures 3 and 4). This apparent increase in primary production provides further evidence of limnological changes attributable to an increase in nitrogen and phosphorus input into the pond.

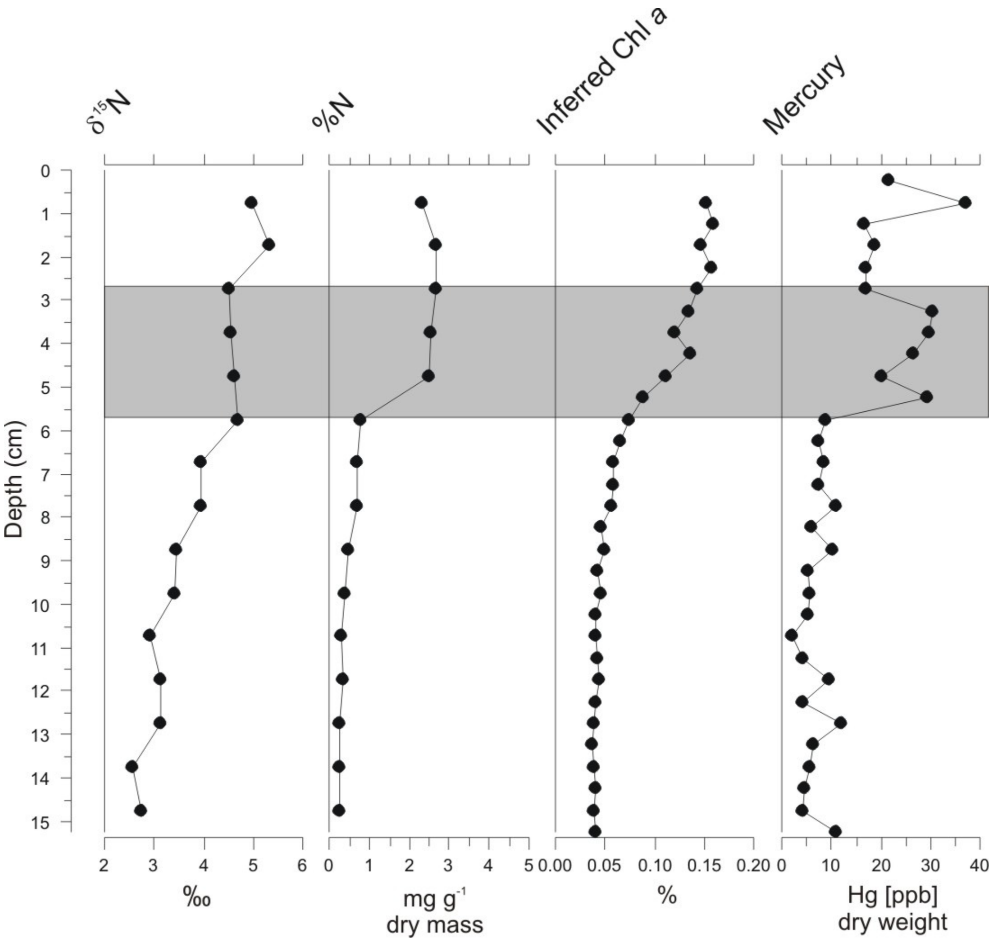


Figure 3.4. Sedimentary profiles of spectrally inferred Chl *a*, δ^{15}N, %N and mercury concentration data for Eskimobyen site pond E-Knud.

Conclusions

Concurrent changes in multiple paleolimnological and geochemical proxies suggest that nutrient loading of marine origin associated with the Thule whalers has resulted in marked limnological changes in pond E-Knud. Diatom species, δ^{15}N, %N, mercury concentration and inferred chl *a* all indicate shifts in limnological characteristics consistent with nutrient enrichment from Thule whalers. The Eskimobyen site on Knud Peninsula, the Deblicquy site on Bathurst Island (Chapter 2) and the Savelle site on Somerset Island (Douglas et al. 2004a), provide evidence that Thule whalers influenced the limnology of ponds across the Arctic. Modern nutrient water chemistry at these three sites is more consistent with values documented in Arctic sewage ponds (Douglas and Smol 2000), than with the hundreds of documented oligotrophic lakes and ponds studied across the Arctic. Together, these three studies, and similar studies on ancient cultural eutrophication (e.g. Ekdahl et al. 2007), serve to highlight the sensitivity of previously undisturbed freshwater ecosystems to relatively minor anthropogenic disturbances and represent some of the earliest known anthropogenic impacts on North American aquatic ecosystems. Possibly more remarkable, is that the influence of small communities of Thule whalers is still evident today, some three centuries after these sites were abandoned.

Future Work

Although we are confident, based on the shifts observed in multiple proxies, that the changes documented here are the result of the Thule Inuit, we are continuing to explore every possible option to help further develop our core chronology. Sediments have recently been sent for humic acid radiocarbon analysis from three intervals where we see significant limnological changes. It is our hope that these dates, combined with knowledge of sedimentation rate from other similar sights in the Arctic, will provide a more robust chronology and a better reconstruction of past limnological changes.

References

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.

Battarbee, R.W., Charles, D.F., Dixit, S.S., and Renberg, I., 1999. Diatoms as indicators of surface water acidity, in Stoermer, E.F., and Smol, J.P., eds., The Diatoms: Applications for the environmental and earth sciences: Cambridge, UK, Cambridge University Press, Ltd. 85–127.

Bennion, H. 1994. A diatom-phosphorus transfer function for shallow eutrophic ponds in Southeast England. Hydrobiologia, 275/276: 391 – 410.

Blais, J.M., Kimpe, L.E., McMahon, D., Keatley, B.E., Mallory, M.L., Douglas, M.S.V. and Smol, J.P. 2005. Arctic Seabirds Transport Marine-Derived Contaminants. Science 309: 445.

Christie, R.L. 1967. Geology Bache Peninsula, Ellesmere Island, District of Franklin. Geological Survey of Canada Memoir 347.

Coltrain, J.B., Hayes, M.G. and O'Rourke, D.H. 2004. Sealing, whaling and caribou: the skeletal isotope chemistry of Eastern Arctic foragers. Journal of Archaeological Science 31: 39 – 57.

Cumming, B.F., Wilson, S.E., Hall, R.I. and Smol, J.P. 1995. Diatoms from British Columbia (Canada) lakes and their relationship to salinity, nutrients and other limnological variables. In: Lange-Bertalot H (eds.) Bibliotheca Diatomologica, Band 31, Gebruder Borntraeger, Berlin, Germany.

Dawson, P.C. 2001. Interpreting variability in Thule Inuit architecture: A case study from the Canadian High Arctic. American Antiquity 66: 453-470.

Douglas, M.S.V. and Smol, J.P. 2000. Eutrophication and recovery in the High Arctic: Meretta Lake (Cornwallis Island, Nunavut, Canada) revisited. Hydrobiologia 431: 193-204.

Douglas, M.S.V., Smol, J.P., Savelle, J.M. and Blais, J.M. 2004a. Prehistoric Inuit whalers affected Arctic freshwater ecosystems. Proceedings in the National Academy of Sciences of the United States of America 101: 1613-1617.

Douglas, M.S.V., Hamilton, P.B., Pienitz, R. and Smol, J.P. 2004b. Algal indicators of environmental change in arctic and antarctic lakes and ponds. . In: Pienitz, R., Douglas, M.S.V. and Smol, J.P. (eds.), Long-term Environemental Change in Arctic and Antarctic Lakes. Developments in Paleoenvironmental Research. Volume 8. Dordrecht, The Netherlands, Springer, p. 117 – 159.

Ekdahl, E.J., Teranes, J.L., Wittkop, C.A., Stoermer, E.F., Reavie, E.D. and Smol, J.P. 2007. Diatom assemblage response to Iroquoian and Euro-Canadian eutrophication of Crawford Lake, Ontario, Canada. Journal of Paleolimnology 37: 233-246.

Environment Canada. 1994. Manual of analytical methods – National Laboratory of Environmental Testing, Canadian Centre for Inland Waters. Burlington, Canada.

Finney, B.P., Gregory-Eaves, I., Douglas, M.S.V. and Smol, J.P. 2002. Fisheries productivity in the northeast Pacific over the past 2,200 years. Nature 416: 729-733.

Friesen, T. Max. 2004. Contemporaneity of Dorset and Thule cultures in the North American Arctic: New radiocarbon dates from Victoria Island, Nunvut. Current Anthropology 45: 685-691.

Glew, J. 2001. Sediment Core Collection and Extrusion. In: Last W.M. and Smol, J.P. (eds.) Tracking Environmental Change Using Lake Sediments. Volume 1: Basin Analysis, Coring, and Chronological Techniques. Kluwer Academic Publishers, Dordrecht, The Netherlands.

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

Gregory-Eaves, I., Smol, J.P., Douglas, M.S.V. and Finney, B.P. 2003. Diatoms and sockeye salmon (Oncorhynchus nerka) population dynamics: Reconstructions of salmon-derived nutrients over the past 2,200 years in two lakes from Kodiak Island, Alaska. Journal of Paleolimnology 30: 35–53.

Julshamn, K., Andersen, A., Ringdale, O. & Mørkøre, J. 1987. Trace elements intake in the Faeroe Islands I: Element levels in edible parts of pilot whales (*Globicephalus meleanus*). Science of the Total Environment 65: 53–62.

Keatley, B.E., Douglas, M.S.V. and Smol, J.P. 2007. Physical and chemical limnological characteristics of lakes and ponds across environmental gradients on Melville Island, Nunavut/N.W.T., High Arctic Canada. Archiv für Hydrobiologie 168: 355–376.

Keatley, B.E., Douglas, M.S.V. & Smol, J.P. 2006. Early-20th century environmental changes inferred using subfossil diatoms from a small pond on Melville Island, N.W.T., Canadian high Arctic. Hydrobiologia 553: 15–26.

Krammer, K. and Lange-Bertalot, H. 1986–1991. Bacillariophyceae.In Ettl, H., J. Gerloff, H. Heynig & D.Mollenhauer (eds.), Subwasserfloa von Mitteleuropa, Band 2(2–4). Gustav Fischer Verlag, Stuttgart/Jena.

Le Mouel, J.F. and Le Mouel, M. 2002. Aspects of Early Thule culture as seen in the architecture of a site on Victoria Island, Amundsen Gulf area. Arctic 55: 167-189.

Mathiassen, T. 1927. Archaeology of the Central Eskimos: the Thule culture and its position within the Eskimo culture. Report on the Fifth Thule Expedition 1921-1924. Gyldendalske Boghandel, Nordisk Forlag, Copenhagen, Denmark.

Maxwell, M.S. 1985. Prehistory of the Eastern Arctic. Academic Press, Orlando, Fl. USA.

McCartney, A.P. 1977. Thule Eskimo Prehistory along the Northwestern Hudson Bay. National Museum of Man Mercury Series, Archaeological Survey of Canada Paper No. 70, Ottawa, ON, Canada.

McCartney, A.P. 1980. The nature of Thule Eskimo whale use. Arctic 33: 517-541.

McCullough, K.M. 1989. The Ruin Islanders: Early Thule culture pioneers in the Eastern High Arctic. Archaeological Survey of Canada Mercury Series Paper No.141, Canadian Museum of Civilization, Ottawa, ON, Canada.

McGhee, R. 2000. Radiocarbon dating and the timing of the Thule migration. In: Appelt, M., Berglund, J., and Gulløv, H.C., (eds). Identities and cultural contacts in the Arctic. Copenhagen:Danish National Museum and Danish Polar Center: 181– 191.

McGowan, S., Ryves, D.B. and Anderson, N.J. 2003. Holocene records of effective precipitation in West Greenland. The Holocene 13: 239 – 249.

Michelutti, N., Laing, T.E. and Smol, J.P. 2000. Diatom assessment of past environmental changes in lakes located near the Noril'sk (Siberia) smelters. Water, Air, and Soil Pollution 125: 231–241.

Michelutti, N., Douglas, M.S.V., Lean, D.R.S. and Smol, J.P. 2002. Physical and chemical limnology of 34 ultra-oligotrophic lakes and ponds near Wynniatt Bay, Victoria, Arctic Canada. Hydrobiologia 482: 1-13.

Michelutti, N., Wolfe, A.P., Vinebrooke, R.D. and Rivard, B. 2005. Recent primary production increases in arctic lakes. Geophysical Research Letters 32: L19715, doi:10.1029/2005GL023693.

Moore, J.J., Hughen, K.A., Miller, G.H. and Overpeck, J.T. 2001. Little Ice Age recorded in summer temperature reconstruction from varved sediments of Donard Lake, Baffin Island, Canada. Journal of Paleolimnology 25: 503 - 517.

Park, R.W. 1997. Thule winter site demography in the High Arctic. American Antiquity 62: 273-284.

Parr, J.F., Taffs, K.H. and Lane, C.M. 2004. A microwave digestion technique for the extraction of fossil diatoms from coastal lake and swamp sediments. Journal of Paleolimnology 31: 383-390.

Pienitz, R., Smol, J.P., Last, W.M., Leavitt, P.R. and Cumming, B.F. 2000. Multi-proxy Holocene palaeoclimatic record from a saline lake in the Canadian Subarctic. The Holocene 10: 673–686.

Reavie, E.D., Smol, J.P., Sharpe, I.D., Westenhofer, L.A. and Roberts, A.M. 2000. Paleolimnological analyses of cultural eutrophication patterns in British Columbia lakes Canadian Journal of Botany 78: 873 - 888.

Rühland, K., Priesnitz, A. and Smol, J.P. 2003. Evidence for recent environmental changes in 50 lakes across the Canadian arctic treeline. Arctic, Antarctic and Alpine Research 35: 110-123.

Savelle, J.M., and McCartney, A.P. 1999. Thule Eskimo bowhead whale interception strategies. World Archaeology 30: 437-451.

Schindler, D.W. 2006. Recent advances in the understanding and management of eutrophication. Limnology and Oceanography 51: 356–363.

Schledermann, P. and McCullough, K.M. 2003. Late Thule Culture developments on the central East Coast of Ellesmere Island. Copenhagen: Danish Polar Center, Denmark.

Schledermann, P. 1976. The Effect of Climatic/Ecological Changes on the Style of Thule Culture Winter Dwellings. Arctic and Alpine Research 8: 37-47.

Schuster,P.F., Krabbenhoft, D.P., Naftz, D.L., Cecil, L.D., Olson, M.L., Dewild, J.F., Susong, D.D., Green, J.R., and Abbott, M.L. 2002. Atmospheric mercury deposition during the last 270 Years: A glacial ice core record of natural and anthropogenic sources. Environmental Science and Technology 36: 2303-2310.

Smol, J.P. 2002. Pollution of Lakes and Rivers – A Paleoenvironmental Perspective. Arnold publishers, New York, NY, USA.

Smol, J.P. and Douglas, M.S.V. 2007. Crossing the final ecological threshold in high Arctic ponds. Proceedings in the National Academy of Sciences 30: 12395–12397

Stoermer, E.F. and Smol, J.P. [Editors]. 1999. The Diatoms: Applications for the Environmental and Earth Sciences. Cambridge University Press. Cambridge, UK.

Sverdrup, O. 1904. New Land: Four years in the Arctic regions. Longman, Green, and Co., London, UK.

Taylor, W.E. Jr. and McGhee, R. 1981. De Blicquy, a Thule Culture Site on Bathurst Island, N.W.T, Canada. Archaeological Survey of Canada, Mercury Series 102: National Museum of Man, Ottawa, ON, Canada.

Wagemann, R., Innes, S. & Richard, P.R. 1996. Overview and regional and temporal differences of heavy metals in Arctic whales and ringed seals in the Canadian Arctic. Science of the Total Environment 186: 41–66.

Whitridge, P. 2002. Social and ritual determinants of whale bone transport at a classic Thule winter site in the Canadian Arctic. International Journal of Osteoarchaeology 12: 65-75.

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.

Wolfe, A.P., Miller, G.H., Olsen, C.A., Forman, S.L., Doran, P.T. and Holmgren, S.U. 2004. Geochronology of high latitude lake sediments. In Long-term environmental change in Arctic and Antarctic lakes. Springer, Netherlands: 19-52.

Wolfe, A.P., Van Gorp, A.C., Baron, J.S. 2003. Recent ecological and biogeochemical changes in alpine lakes of Rocky Mountain National Park (Colorado, USA): a response to anthropogenic nitrogen deposition. Geobiology 1: 153–168.

CHAPTER 4

Physical and chemical limnological characteristics of lakes and ponds across two environmental gradients and development of a pH inference model for Bathurst Island, Nunavut, High Arctic Canada

Kristopher R. Hadley

Abstract

Physical and chemical limnological data were collected from nine ponds on western Bathurst Island and combined with a dataset collected previously from the eastern part of the island. The addition of these nine ponds expanded the pH gradient of the Bathurst Island dataset, allowing for the construction of a diatom-inferred weighted average pH model. Based on a canonical correspondence analysis with forward selection, pH, dissolved organic carbon (DOC), water temperature, specific conductivity, calcium and particulate organic carbon (POC) explained significant ($p \leq 0.05$) amounts of variation in the diatom data, together explaining 27.3% of the variation in the species data along the first four ordination axes. Canonical axis 1 was primarily influenced by pH, while axis 2 was most influenced by DOC. Weighted averaging diatom-inferred pH models were developed for lakewater pH ($r^2_{boot} = 0.63$, root-mean-squared-error of prediction = 0.298). The ability to reconstruct pH in a sensitive area such as the Canadian Arctic will potentially be a valuable tool for future paleolimnological studies in the region.

Introduction

Heightened sensitivity of the Arctic environment to climatic change provides an excellent opportunity to study the limnological impacts of warming on otherwise relatively undisturbed lakes and ponds. While the majority of the sites studied in the High Arctic have shown some form of response to climate change (e.g. Smol et al. 2005), not all of these sites are responding in a similar manner. For example, previous research on alpine and Arctic lakes has shown that poorly buffered waterbodies may be particularly susceptible to pH changes driven by late-Holocene climate change (e.g. Michelutti et al. 2006; Wolfe 2002; Koinig et al. 1998; Schmidt et al. 2004). As long-term monitoring data are not available, paleolimnological proxies, such as diatoms (e.g. Stoermer and Smol 1999), present us with a means with which to monitor changes in, and in some cases to reconstruct past environments of an ecosystem, thus providing information about the natural variability of a system prior to the modern instrumental record. Since the mid-1980's a significant commitment of time and resources has been dedicated to research aimed at improving the amount of limnological data available across the High Arctic (e.g. Pienitz et al. 2004). As a result, our understanding of Arctic systems within specific pond (Douglas et al. 2004) and lake systems (e.g. Michelutti et al. 2003), and in some cases on regional scales (e.g. Lim et al. 2001) and across the entire circumpolar Arctic (e.g. Smol et al. 2005), has significantly improved. For example, over the last decade, the requirement for a more complete baseline limnological dataset from the High Arctic and the need for more long-term research projects has resulted in regional surveys of Alaska (Gregory Eaves et al. 2000), eastern Bathurst Island (Lim et al. 2001), Axel Heiberg Island (Michelutti et al. 2002a), Victoria Island (Michelutti et al. 2002b), Ellef Ringnes Island (Antoniades et al. 2003), Banks Island (Lim et al. 2005) and Melville Island (Keatley et al. 2007), as well as a long-term monitoring project at Cape Herschel, Ellesmere Island (Smol and Douglas 2007). As the database of regional limnological conditions in the Arctic has expanded, our understanding of the principal environmental gradients driving limnological change and our ability to elucidate anthropogenic impacts at high latitudes has increased.

Bathurst Island presents an interesting and as yet unexplored opportunity to explore the impact of pH and buffering capacity on the susceptibility of High Arctic pond ecosystems to anthropogenic climatic forcing. Underlying geology dominated by carbonate bedrock on the eastern half of Bathurst Island has resulted in highly buffered lakes and ponds, whose pH measurements generally are restricted within a tight range of about 8.1 – 8.6 (Lim et al. 2001). Diatoms communities within these ponds have been shown to be related to a total nitrogen gradient; however, Lim et al. (2001) noted that their study failed to capture the pH gradient as it was restricted to lakes and ponds on eastern Bathurst.

Previous limnological research on Bathurst Island by Lim et al. (2001) was likewise restricted to eastern Bathurst Island, where researchers collected physical and chemical limnological data on 29 lakes (> 2m deep) and ponds (< 2m deep) on Bathurst island providing extensive coverage of the eastern half of the island; however, baseline limnological characteristics remain unexplored on the western half of the island. The carbonate-dominated geology formations described on Eastern Bathurst Island (Kerr 1974) are not a dominant feature of the western half of the island, and therefore we expected to see a reduced buffering capacity and more variable pH range. The western half of Bathurst is comprised of quartz sandstone, siltstone and shale with the only minor limestone deposits (Kerr 1974).

This study expanded the coverage of limnological sampling on Bathurst Island to provide a more comprehensive overview of its modern limnology, expand the pH gradient of the Bathurst Island dataset, and in the process attempt to identify sites that may be most responsive to climatic forcing by changes in lakewater pH and related variables (e.g. Wolfe 2002; Michelutti et al. 2006; Michelutti et al. 2007). To expand the pH gradient on Bathurst Island, we have added nine new sites that are located on previously unstudied western region of Bathurst Island and associated western flanking islands.

Site description

Bathurst Island (75^{o} 42′ N, 97^{o} 21′ W) is located at the geographic center of the Canadian High Arctic, is home to the Polar Bear Pass National Wildlife area, and supports a highly diverse wildlife population atypical of the Canadian Arctic Islands (Figure 1). Geology of the island is primarily composed of Ordovician to Late Devonian shale, sandstones, limestone and dolomites; however the distribution of these rock types varies across the island (Kerr 1974; Lim et al. 2001, Figure 1). The western half of Bathurst is comprised of Griper Bay, Helca Bay and Bird Fiord formations, which are primarily quartz sandstone, siltstone and shale with the only limestone being in the Bird Fiord formation (Kerr 1974). In comparison, eastern Bathurst geology is much more diverse and carbonate-rich than the west. Eids and Bathurst Island formations in the north-east; Disappointment Bay, Stuart Bay and Cape Phillips formations in the east and the Blue Fiord formation in the south-east all contain significant carbonate components thus leading to a stark geological contrast between eastern and western Bathurst Island.

Mean annual temperature of Bathurst Island is approximately -15.0 ^{o}C, which is typical for the High Arctic, with summer months (June – August) on average around 5^{o}C but getting as warm as 14 – 18 ^{o}C (Lim et al. 2001).

Vegetation on Bathurst Island is lush and highly diverse relative to other high Arctic sites particularly in low-lying sedge meadow areas (Henry 1998). Common species in these areas consist of a diverse assemblage of sedges (e.g. *Carex aquatilis stans*, *Eriophorum angustifolium*, *Carex membranacea*) as well as various other plants (e.g. *Saxifraga* *oppositifolia*), grasses (e.g. *Dupontia fisheri*) and shrubs (e.g. *Salix arctica*) (Henry 1998).

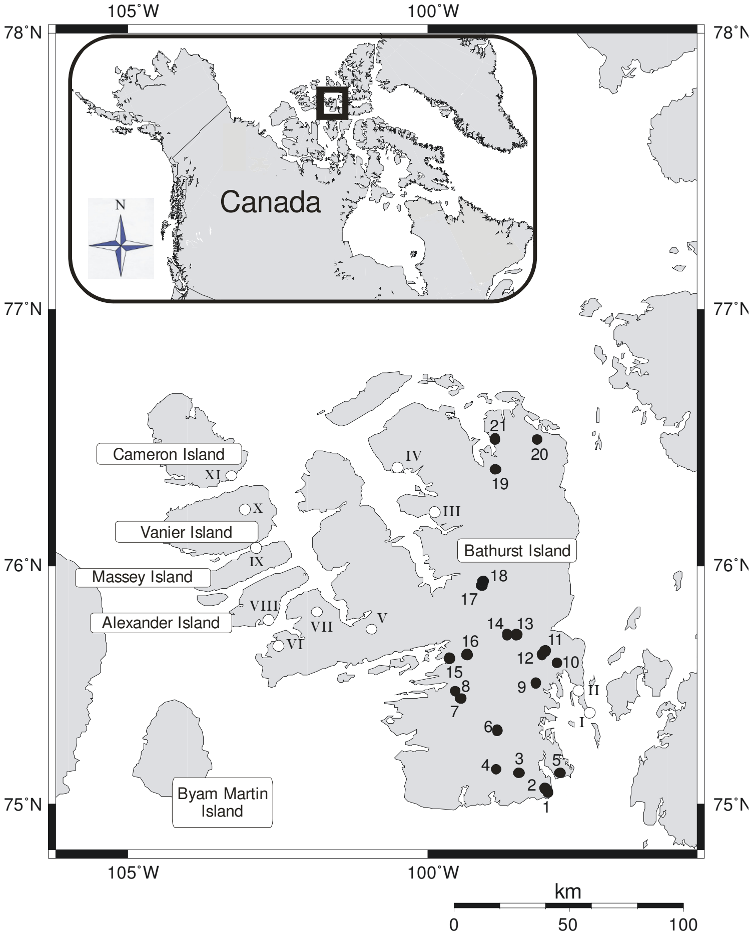


Figure 4.1. Map of Bathurst Island showing the study sites from both 2005 (Roman numerals) and 1994 (numbers). Numbers on the map correspond to 1994 sites as follows: BC = 1; BD, BE = 2; BF = 3; BO = 4; BM, BN = 5; BP, BQ, BR = 6; BG = 7; BH = 8; BS, BT = 9; BAD = 10; BV, BW BX = 11; BU = 12; BY = 13; BZ = 14; BI, BJ = 15; BK, BL = 16; BAA, BAB = 17; BAC = 18; BAE, BAF, BAG, BAH, BAI = 19; BAM, BAN = 20; BAJ, BAK, BAL = 21 and for 2005 sites: BAQ = I; BAO, BAP = II; BAZ = III; BAY = IV; BAS = V; BAT = VI; BAR = VII; BAU = VIII; BAV = IX; BAW = X; BAX = XI.

Materials and methods

Previous limnological research on Bathurst Island consisted of a survey by Lim et al. (2001) of water chemistry and related surface sediment diatom assemblages from 29 sites on eastern Bathurst Island, nine lakes (> 2 m depth) and 20 ponds (< 2 m depth) (full diatom and environmental data available in Appendices). To these sites, we have added nine new ponds sampled on July 9th 2005 by helicopter survey from previously unrepresented regions on the western portion of the Bathurst Island chain (Figure 1). This includes sites from western Bathurst Island as well as sites from Alexander Island, Massey Island, Vanier Island and Cameron Island. Due to logistical difficulties and poor weather conditions, we were unable to obtain additional sites. Nonetheless, the addition of these new ponds significantly increases the geographic range of sampling sites from this island. The sampling protocols used in our previous limnological surveys (e.g. Lim et al. 2001; Michelutti et al. 2002a; Lim et al. 2005; Keatley et al. 2007) were closely followed for this study in order to allow for the best possible comparisons of both inter- and intra-island variability.

Sediment Samples

The nine ponds were all shallow (< 50 cm depth) and therefore sediment was collected by hand sampling the top 1 cm of sediment into 15 ml plastic scintillation vials. Surface sediments were collected from near the center of each pond whenever possible, however, in some cases, collection from closer to shore was necessary where the pond bottom was covered by rocks or moss near the center.

Diatoms

For diatom analysis, ~0.3 g of wet sediments were digested with nitric acid using a CEM MarsX microwave digester (Parr et al. 2004), rinsed with deionized water until a neutral pH was achieved and permanently mounted on slides using Naphrax®. Diatoms were then enumerated at 1000X under oil immersion using a Leica DMR2 microscope with differential interference contrast (DIC). A minimum of 300 - 400 diatoms valves were counted for each sample and identified using standard taxonomic sources (Krammer & Lange-Bertalot, 1986–1991; Cumming et al. 1995, Camburn et al. 1984-1986).

Water Chemistry

Water samples were collected and stored using Nalgene® plastic bottles and 125 ml glass bottles. Samples were measured in the field for conductivity using a YSI model 33 conductivity meter. Field measurements of pH were done using 2-point calibrated Hanna pHep pH meters, and temperature was measured using three handheld thermometers. All other chemical (nutrient, major ion, etc.) analyses were performed at the National Water Research Institute (NWRI), following the same protocols used previous Arctic surveys (Environment Canada 1994).

Water samples were analyzed by NWRI for both major cations (Ca^{2+}, Mg^{2+}, K^+, Na^+) and major anions (Cl^-, SO_4^{2-}), as well as for a variety of minor ions including barium (Ba), lithium (Li) and strontium (Sr). Important nutrients measured include phosphorus (total phosphorus unfiltered (TPU), total phosphorus filtered (TPF) and soluble reactive phosphorus (SRPF)), nitrogen (nitrate (NO_3), nitrate-nitrite (NO_3-NO_2), ammonia (NH_3), total Kjeldahl nitrogen (TKN) and particulate organic nitrogen (PON)), carbon (dissolved inorganic carbon (DIC), dissolved organic carbon (DOC) and particulate organic carbon (POC)) as well as dissolved silica (SiO_2) and chlorophyll *a* (both corrected (Chla-C) and uncorrected (Chla-UC) for phaeophytin). Metals including aluminum (Al), beryllium (Be), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), molybdenum (Mo), nickel (Ni), silver (Ag), vanadium (V) and zinc (Zn) were also measured.

Statistical Analysis

Water chemistry variables that were below the detection limit in greater than 50% of the sites were eliminated from further statistical analysis. In cases where only a few sites had values below the detection limit, a value of half the detection limit was used as an estimate to allow the sites to be included in the statistical analysis. In this study, one value was lost entirely due to a broken bottle during shipment (TPF for pond B-AV) and was therefore replaced with an average value of all the other sites (Table 1). CALIBRATE version 1.01 (Juggins and ter Braak 1992) was used to assess the normality of all limnological variables and any variables that were not normally distributed were either transformed to a normal distribution, or eliminated from analysis. Variables eliminated during these procedures include NO_3-NO_2, Chl *a* corrected, Cd, Co, Cu, Cr, Pb, Be, V and NO_2, thus leaving 30 environmental variables to be included in our analysis. We used a Pearson correlation with Bonferroni-adjusted probabilities (Table 2), run in Systat v. 11.0, to assess and eliminate highly correlated environmental variables prior to Principal components analysis (PCA). PCAs were run using the transformed environmental and diatom species data in Canaco v. 4.5 (ter Braak and Šmilauer 2002) to determine the main directions of variation in the environmental data, as well as to determine any potential outliers with respect to both diatom species assemblages and environmental variables (Figure 2).

Table 4.1. Summary of all 30 environmental variables for western Bathurst Island sites that were included in statistical analysis and model development. A complete table of all water chemistry variables measured can be found in Appendix.

Site **ID**	**Ca** **mg/L**	**Mg** **mg/L**	**Na** **mg/L**	**K** **mg/L**	**SO4** **mg/L**	**Cl** **mg/L**	**Al** **mg/L**	**Ba** **mg/L**	**Fe** **mg/L**	**Li** **mg/L**	**Mn** **mg/L**
B-AR	0.8	0.3	0.4	0.3	0.4	0.58	0.26	0.0038	0.321	0.0003	0.0052
B-AS	0.2	0.1	0.4	0.1	0.5	0.71	0.04	0.0030	0.066	*0.0001*	0.0068
B-AT	0.4	0.4	0.9	0.2	0.5	1.68	0.08	0.0015	0.099	0.0002	0.0019
B-AU	10.9	15.8	104.0	9.3	4.8	184.00	0.04	0.0113	0.077	0.0031	0.0071
B-AV	6.3	2.3	6.6	0.5	0.8	11.80	0.16	0.0017	0.245	0.0005	0.0014
B-AW	0.3	0.3	0.4	0.2	0.4	0.65	0.18	0.0013	0.298	0.0002	0.0048
B-AX	9.6	5.4	15.9	1.0	0.6	32.10	0.01	0.0062	0.124	0.0021	0.0031
B-AY	23.9	5.8	5.9	1.1	3.5	7.33	0.13	0.1220	0.527	0.0025	0.0143
B-AZ	1.6	0.5	0.3	0.2	0.4	0.55	0.17	0.0027	0.301	0.0004	0.0046
Mean	**6.0**	**3.4**	**15.0**	**1.4**	**1.3**	**26.60**	**0.12**	**0.0170**	**0.229**	**0.001**	**0.0055**
Max	**23.9**	**15.8**	**104.0**	**9.3**	**4.8**	**184.00**	**0.26**	**0.1220**	**0.527**	**0.003**	**0.0143**
Min	**0.2**	**0.1**	**0.3**	**0.1**	**0.4**	**0.55**	**0.01**	**0.0013**	**0.066**	**0.000**	**0.0014**
Std	**7.9**	**5.2**	**33.8**	**3.0**	**1.6**	**59.91**	**0.08**	**0.0395**	**0.152**	**0.001**	**0.0039**

Italics denote values that were below detection limit

	Mo µg/L	Ni µg/L	Sr mg/L	Zn µg/L	SiO2 mg/L	DOC mg/L	DIC mg/L	POC* µg/L	SRPF µg/L	TPU µg/L	TPF µg/L
B-AR	*0.0025*	0.67	0.0019	1.54	0.67	4.5	1.5	560.4	1.1	9.3	5.5
B-AS	*0.0025*	0.17	0.0012	0.47	0.19	1.6	0.6	713.4	*0.1*	6.8	1.1
B-AT	*0.0025*	0.31	0.0020	0.52	0.05	1.9	1.1	494.0	*0.1*	11.7	1.6
B-AU	0.0910	0.31	0.0973	0.43	0.15	4.4	14.2	485.8	0.7	10.2	6.1
B-AV	0.0270	0.68	0.0245	0.89	0.33	8.2	5.3	544.1	0.4	6.5	**3.8**
B-AW	0.0050	0.57	0.0015	1.37	0.21	2.4	1	505.0	*0.1*	9.1	3.2
B-AX	0.0790	0.41	0.0419	0.48	0.27	6.5	8.7	658.0	0.5	9.0	5.0
B-AY	1.1900	1.35	0.0633	3.60	0.07	15.1	18.8	1,679.3	1.0	26.9	7.7
B-AZ	0.0050	0.55	0.0023	0.96	0.17	3.4	1.9	629.3	*0.1*	9.7	2.9
Mean	**0.156**	**0.558**	**0.0262**	**1.140**	**0.23**	**5.3**	**5.9**	**696.6**	**0.5**	**11.0**	**4.1**
Max	**1.190**	**1.350**	**0.0973**	**3.600**	**0.67**	**15.1**	**18.8**	**1679.3**	**1.1**	**26.9**	**7.7**
Min	**0.003**	**0.170**	**0.0012**	**0.430**	**0.05**	**1.6**	**0.6**	**485.8**	**0.1**	**6.5**	**1.1**
Std	**0.389**	**0.345**	**0.0348**	**1.008**	**0.19**	**4.3**	**6.7**	**376.8**	**0.4**	**6.2**	**2.2**

Italics denote values that were below detection limit
POC Sqrt X-formed
Bold - broken bottle

	NO_2	NO_3-NO_2	NH_3	TKN	PON	TN	ChlaU	Temp	pH	Cond
	mg/L	**mg/L**	**mg/L**	**mg/L**	**µg/L**	**µg/L**	**µg/L**	°C		**µs/cm**
B-AR	0.003	0.007	0.007	0.139	9.0	388.83	1.00	6.0	7.0	10.0
B-AS	0.003	0.013	0.021	0.059	51.0	306.90	2.00	6.0	6.9	5.0
B-AT	0.002	0.016	0.010	0.060	13.0	273.95	1.50	1.5	6.8	10.0
B-AU	0.002	0.008	0.019	0.425	13.0	672.92	*0.05*	9.0	8.3	510.0
B-AV	0.002	0.008	0.014	0.315	17.0	586.25	*0.05*	9.5	7.8	60.0
B-AW	0.001	0.006	0.007	0.059	16.0	264.90	0.90	9.0	7.3	11.0
B-AX	0.002	0.007	0.011	0.383	41.0	666.87	0.50	7.5	8.1	125.0
B-AY	0.003	0.008	0.027	0.970	281.0	1273.89	7.00	13.0	8.4	135.0
B-AZ	0.002	0.009	0.008	0.103	45.0	374.94	1.40	2.0	7.3	13.0
Mean	**0.002**	**0.009**	**0.014**	**0.279**	**54.0**	**534.38**	**1.6**	**7.1**	**7.5**	**97.7**
Max	**0.003**	**0.016**	**0.027**	**0.970**	**281.0**	**1273.89**	**7.0**	**13.0**	**8.4**	**510.0**
Min	**0.001**	**0.006**	**0.007**	**0.059**	**9.0**	**264.90**	**0.1**	**1.5**	**6.8**	**5.0**
Std	**0.001**	**0.003**	**0.007**	**0.297**	**86.6**	**321.15**	**2.1**	**3.7**	**0.6**	**162.9**

Italics denote values that were below detection limit

	Elev m asl	PON : POP	POC : ChlaU	TN : TPU	Lake (L) or Pond (P)	Lat °N	Long °W
B-AR	152	2	560	42	P	75 47.953	101 50.300
B-AS	122	9	357	45	P	75 44.249	100 55.285
B-AT	122	1	329	23	P	75 40.130	102 29.006
B-AU	3	3	4720	66	P	75 46.360	102 38.733
B-AV	15	6	5920	90	P	76 04.127	102 50.749
B-AW	137	3	561	29	P	76 12.861	103 01.865
B-AX	30	10	1316	74	P	76 21.316	103 16.055
B-AY	61	15	240	47	P	76 22.868	100 29.540
B-AZ	183	7	449	39	P	76 12.483	99 52.542
Mean	**92**	**6**	**1606**	**51**	**N/A**	**N/A**	**N/A**
Max	**183**	**15**	**5920**	**90**	**N/A**	**N/A**	**N/A**
Min	**3**	**1**	**240**	**23**	**N/A**	**N/A**	**N/A**
Std	**65**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**

Table 4.2. Summary of all 30 environmental variables from Eastern Bathurst Island sites that were included in statistical analysis and model development. A complete table of all water chemistry variables measured can be found in Appendix.

Site ID	**Ca mg/L**	**Mg mg/L**	**Na mg/L**	**K mg/L**	**SO4 mg/L**	**Cl mg/L**	**Al mg/L**	**Ba mg/L**	**Fe mg/L**	**Li mg/L**	**Mn mg/L**
BC	36.6	8.0	4.6	0.6	4.9	8.50	*0.005*	0.0667	0.012	0.001	0.0013
BD	43.2	18.9	3.9	0.6	2.1	7.14	*0.005*	0.0746	0.239	0.004	0.0081
BE	43.9	14.8	6.1	0.5	3.9	12.90	*0.005*	0.0851	0.243	0.003	0.0044
BF	9.2	4.1	0.7	*0.1*	0.6	1.16	*0.005*	0.0047	0.015	0.001	0.0007
BG	24.7	1.7	1.1	0.4	4.6	1.79	0.020	0.0159	0.048	0.002	0.0031
BH	19.4	2.4	1.4	0.5	6.7	1.48	*0.005*	0.0068	0.018	0.002	0.0019
BI	35.9	5.7	6.0	0.9	8.1	9.48	*0.005*	0.0672	0.026	0.004	0.0051
BJ	35.1	6.8	5.7	1.3	6.8	10.00	*0.005*	0.0567	0.038	0.004	0.0059
BK	53.3	10.5	6.2	1.3	15.8	10.50	0.940	0.1190	2.420	0.008	0.0797
BL	29.9	2.8	1.9	0.4	5.8	3.31	0.020	0.0261	0.060	0.002	0.0042
BM	29.1	4.5	3.6	0.5	3.6	5.41	*0.005*	0.0855	0.053	0.002	0.0038
BN	28.8	4.7	3.2	0.5	4.8	5.63	0.020	0.0736	0.064	0.002	0.0035
BO	27.1	2.6	0.8	*0.1*	1.4	1.46	*0.005*	0.0057	0.008	0.001	0.0016
BP	33.0	4.4	1.3	0.2	1.7	2.38	0.010	0.0177	0.052	0.002	0.0107
BQ	28.9	4.2	1.2	0.2	2.2	2.54	0.010	0.0162	0.021	0.002	0.0010
BR	29.1	4.0	1.0	*0.1*	0.8	1.89	*0.005*	0.0090	0.031	0.001	0.0009
BS	34.5	0.9	1.1	0.2	1.0	2.26	*0.005*	0.0156	0.011	0.002	0.0009
BT	25.6	2.1	0.9	*0.1*	0.8	1.82	*0.005*	0.0133	0.034	0.002	0.0005
BU	21.9	8.2	6.3	0.3	3.8	10.70	0.190	0.0657	1.280	0.002	0.0107
BV	23.1	8.4	6.5	0.2	6.9	10.10	0.020	0.0437	0.361	0.002	0.0037
BW	26.9	8.9	5.2	0.3	2.4	9.85	0.040	0.0441	0.249	0.001	0.0035
BX	26.4	7.4	6.5	0.3	3.7	10.20	*0.005*	0.0514	0.103	0.002	0.0018
BY	24.2	6.2	6.4	0.5	3.5	15.20	0.100	0.1070	0.382	0.002	0.0064
BZ	33.8	8.6	7.9	0.9	5.0	19.10	0.290	0.1750	0.774	0.004	0.0107

Italics denote values that were below detection limit

Site **ID**	**Ca** **mg/L**	**Mg** **mg/L**	**Na** **mg/L**	**K** **mg/L**	**SO4** **mg/L**	**Cl** **mg/L**	**Al** **mg/L**	**Ba** **mg/L**	**Fe** **mg/L**	**Li** **mg/L**	**Mn** **mg/L**
BAA	30.1	3.2	0.9	0.2	5.2	2.19	*0.005*	0.0326	0.017	0.001	0.0009
BAB	37.6	4.8	1.1	0.3	10.4	2.28	*0.005*	0.0351	0.017	0.002	*0.0003*
BAC	41.8	5.2	1.5	0.4	18.6	2.83	0.010	0.1310	0.040	0.001	0.0017
BAD	19.9	5.2	2.9	0.5	2.5	4.66	0.090	0.0196	1.410	0.002	0.0174
BAE	32.0	2.9	1.5	0.2	7.0	2.87	*0.005*	0.0391	0.029	0.001	0.0017
BAF	26.2	3.1	1.4	0.3	7.8	2.49	*0.005*	0.0294	0.046	0.002	0.0009
BAG	28.3	2.6	1.5	0.2	7.0	2.88	*0.005*	0.0337	0.042	*0.001*	0.0007
BAH	33.8	6.1	1.6	0.3	16.2	1.97	0.040	0.0249	0.066	0.003	0.0014
BAI	38.0	6.9	1.8	0.4	22.0	2.83	*0.005*	0.0318	0.043	0.002	0.0008
BAJ	43.7	7.8	3.2	0.9	18.7	4.46	*0.005*	0.1610	0.139	0.003	0.0043
BAK	15.7	2.1	1.1	0.2	2.8	1.40	*0.005*	0.0561	0.096	0.002	0.0033
BAL	36.7	5.7	2.5	0.5	13.6	3.48	*0.005*	0.1210	0.079	0.001	0.0021
BAM	28.6	2.7	3.3	0.3	2.4	8.53	0.010	0.0876	0.035	0.001	0.0017
BAN	33.1	3.9	2.8	0.3	3.6	5.24	0.010	0.0563	0.140	0.001	0.0017
B-AO	11.3	5.1	6.4	0.3	0.4	12.80	0.014	0.0360	0.137	*0.000*	0.0021
B-AP	10.9	5.0	5.0	0.4	0.5	9.42	0.025	0.0564	0.158	0.000	0.0027
B-AQ	15.1	6.2	14.1	0.6	1.8	33.00	0.004	0.0599	0.011	0.000	0.0005
PB-1	17.4	3.9	2.3	0.6	1.6	3.73	0.069	0.0784	0.072	0.001	0.0055
PB-2	32.7	7.1	2.7	1.0	0.3	4.26	0.003	0.1960	0.041	0.001	0.0012
PB-3	15.6	3.3	1.4	0.0	2.2	1.34	0.003	0.0571	0.016	0.000	0.0002
PB-4	19.3	2.5	1.4	0.6	0.6	2.48	0.071	0.1280	0.144	0.001	0.0037
Mean	**28.7**	**5.5**	**3.3**	**0.4**	**5.5**	**6.22**	**0.047**	**0.0604**	**0.207**	**0.002**	**0.0051**
Max	**53.3**	**18.9**	**14.1**	**1.3**	**22.0**	**33.00**	**0.940**	**0.1960**	**2.420**	**0.008**	**0.0797**
Min	**9.2**	**0.9**	**0.7**	**0.0**	**0.3**	**1.16**	**0.003**	**0.0047**	**0.008**	**0.000**	**0.0002**
Std	**9.6**	**3.4**	**2.7**	**0.3**	**5.4**	**5.95**	**0.146**	**0.0464**	**0.447**	**0.001**	**0.0119**
Whole Island											
Mean	**24.9**	**5.1**	**5.3**	**0.6**	**4.8**	**9.62**	**0.059**	**0.0532**	**0.211**	**0.002**	**0.0052**
Max	**53.3**	**18.9**	**104.0**	**9.3**	**22.0**	**184.00**	**0.940**	**0.1960**	**2.420**	**0.008**	**0.0797**
Min	**0.2**	**0.1**	**0.3**	**0.0**	**0.3**	**0.55**	**0.003**	**0.0013**	**0.008**	**0.000**	**0.0002**
Std	**12.6**	**3.7**	**14.0**	**1.2**	**5.2**	**25.10**	**0.139**	**0.0478**	**0.411**	**0.001**	**0.0109**

Italics denote values that were below detection limit

	Mo	Ni	Sr	Zn	SiO2	DOC	DIC	POC*	SRPF	TPU	TPF
	µg/L	µg/L	mg/L	µg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L
BC	0.0010	*0.001*	0.0769	0.005	0.15	3.3	26.2	347.9	1.1	7.2	5.9
BD	0.0010	*0.001*	0.0588	0.002	4.68	11.2	39.9	679.7	1.6	14.0	10.0
BE	0.0010	*0.001*	0.0689	0.001	3.36	10.7	35.8	695.7	0.9	11.6	10.0
BF	*0.0005*	*0.001*	0.0052	0.007	0.18	2.5	9.3	392.4	1.4	17.5	3.8
BG	0.0020	0.002	0.0967	0.002	0.23	1.5	14.3	357.8	1.0	5.5	4.3
BH	0.0010	*0.001*	0.0816	0.001	0.15	1.7	11.8	286.4	1.4	3.3	3.6
BI	*0.0005*	*0.001*	0.1520	0.003	1.40	2.7	23.6	462.6	1.1	7.1	5.4
BJ	0.0010	0.002	0.1790	0.008	0.40	5.8	23.7	473.3	1.0	7.0	5.4
BK	0.0010	0.007	0.4260	0.014	2.12	5.8	29.2	1100.0	1.1	64.0	8.8
BL	*0.0005*	0.004	0.1390	0.005	0.55	2.7	17.9	421.9	3.1	4.7	7.7
BM	*0.0005*	0.004	0.0628	0.015	0.13	2.6	19.2	450.6	1.2	7.9	2.8
BN	0.0010	*0.001*	0.0558	0.006	0.49	1.9	18.9	366.1	0.9	4.8	3.1
BO	*0.0005*	0.002	0.0644	0.002	0.25	1.8	17.1	363.3	0.9	4.3	3.0
BP	0.0010	0.003	0.0302	0.003	0.05	6.7	20.9	608.3	1.2	15.1	8.6
BQ	0.0020	0.003	0.0313	0.041	0.18	5.1	18.9	488.9	0.9	8.3	6.9
BR	0.0030	*0.001*	0.0409	0.007	0.06	5.9	20.1	705.0	1.8	17.3	11.5
BS	*0.0005*	0.002	0.0230	0.007	0.54	1.9	19.6	342.1	1.5	3.2	6.3
BT	*0.0005*	*0.001*	0.0213	0.002	0.44	1.7	15.8	389.9	1.1	3.7	3.9
BU	0.0010	0.009	0.0317	0.006	0.85	6.2	18.8	1334.2	1.4	38.2	9.4
BV	0.0010	*0.001*	0.0268	0.001	0.91	6.5	18.8	925.7	1.5	14.0	6.9
BW	0.0010	*0.001*	0.0281	0.001	0.14	10.9	21.7	527.3	1.4	8.7	6.5
BX	0.0010	*0.001*	0.0346	0.001	0.62	4.9	19.7	595.8	4.3	9.8	5.6
BY	0.0020	0.002	0.0607	0.008	0.34	3.2	16.2	707.1	2.7	21.8	7.6
BZ	0.0020	0.003	0.0954	0.004	0.50	3.7	22.1	1195.8	2.3	45.4	9.0

Italics denote values that were below detection limit

	Mo µg/L	Ni µg/L	Sr mg/L	Zn µg/L	SiO2 mg/L	DOC mg/L	DIC mg/L	POC* µg/L	SRPF µg/L	TPU µg/L	TPF µg/L
BAA	*0.0005*	*0.001*	0.3600	*0.001*	0.67	1.1	17.9	375.5	1.4	4.9	4.0
BAB	0.0010	*0.001*	0.5300	0.001	2.58	2.1	22.6	403.7	1.4	6.5	4.0
BAC	0.0020	0.005	0.1280	0.003	0.86	3.8	22.5	503.0	1.8	4.0	10.5
BAD	*0.0005*	*0.001*	0.0225	0.029	2.08	5.1	15.1	833.1	1.4	28.0	11.5
BAE	0.0010	*0.001*	0.2510	*0.001*	0.21	1.8	18.3	469.0	1.4	4.8	4.3
BAF	0.0010	*0.001*	0.1700	0.001	0.48	2.4	15.2	516.7	1.4	5.7	4.2
BAG	*0.0005*	*0.001*	0.2150	0.002	0.15	1.6	15.9	447.2	1.4	5.8	5.4
BAH	*0.0005*	*0.001*	0.2830	0.001	0.55	3.2	19.7	473.3	1.4	15.1	4.4
BAI	0.0010	*0.001*	0.3510	0.004	0.89	3.8	21.2	586.5	1.4	7.6	4.5
BAJ	0.0030	0.003	0.1530	0.017	1.12	6.9	26.6	640.3	1.4	16.0	8.8
BAK	0.0010	0.004	0.0351	0.004	0.15	2.2	10.1	515.8	1.4	9.7	4.3
BAL	0.0030	0.003	0.1060	0.005	0.66	4.8	22.2	630.9	1.4	9.6	4.6
BAM	0.0010	0.003	0.0408	0.005	0.20	1.8	16.4	474.3	1.4	7.3	1.7
BAN	*0.0005*	0.004	0.0320	0.002	0.76	2.7	20.2	725.3	1.4	12.3	3.6
B-AO	0.0003	0.000	0.0166	0.001	0.12	6.3	10.4	810.6	0.4	15.4	5.9
B-AP	0.0002	0.000	0.0150	0.001	0.17	4.7	10.7	915.4	0.4	14.8	3.8
B-AQ	0.0002	0.000	0.0402	0.002	0.29	1.9	11.5	515.8	0.7	4.0	1.6
PB-1	0.0006	0.001	0.0395	0.001	0.65	4	13.6	695.0	0.5	7.3	3.2
PB-2	0.0008	0.001	0.0765	0.000	0.27	8.4	25.2	652.7	0.8	8.6	4.2
PB-3	0.0003	0.001	0.0244	0.001	0.52	4.3	11.7	464.8	0.5	3.7	2.3
PB-4	0.0009	0.001	0.0524	0.001	0.09	2.8	13.6	697.9	0.7	18.1	3.0
Mean	**0.001**	**0.002**	**0.1074**	**0.005**	**0.72**	**4.1**	**19.1**	**590.3**	**1.4**	**12.3**	**5.7**
Max	**0.003**	**0.009**	**0.5300**	**0.041**	**4.68**	**11.2**	**39.9**	**1334.2**	**4.3**	**64.0**	**11.5**
Min	**0.000**	**0.000**	**0.0052**	**0.000**	**0.05**	**1.1**	**9.3**	**286.4**	**0.4**	**3.2**	**1.6**
Std	**0.001**	**0.002**	**0.1187**	**0.008**	**0.92**	**2.6**	**6.2**	**229.8**	**0.7**	**11.7**	**2.7**
Whole Island											
Mean	**0.027**	**0.095**	**0.0939**	**0.194**	**0.64**	**4.3**	**16.9**	**608.0**	**1.2**	**12.1**	**5.4**
Max	**1.190**	**1.350**	**0.5300**	**3.600**	**4.68**	**15.1**	**39.9**	**1679.3**	**4.3**	**64.0**	**11.5**
Min	**0.000**	**0.000**	**0.0012**	**0.000**	**0.05**	**1.1**	**0.6**	**286.4**	**0.1**	**3.2**	**1.1**
Std	**0.162**	**0.248**	**0.1132**	**0.579**	**0.86**	**2.9**	**8.0**	**258.6**	**0.7**	**11.0**	**2.6**

Italics denote values that were below detection limit

	NO_2 mg/L	**NO_3-NO_2 mg/L**	**NH_3 mg/L**	**TKN mg/L**	**PON µg/L**	**TN µg/L**	**ChlaU µg/L**	**Temp °C**	**pH**	**Cond µs/cm**
BC	0.001	0.010	*0.0025*	0.158	13.0	420.49	0.2	11.0	8.2	211.0
BD	0.001	*0.005*	0.0060	0.898	39.0	991.63	0.9	19.5	8.4	282.0
BE	0.001	*0.005*	0.0200	0.948	42.0	1020.65	0.5	19.5	8.3	276.0
BF	0.001	*0.005*	*0.0025*	0.099	9.0	328.64	0.9	16.5	8.3	69.0
BG	0.001	*0.005*	*0.0025*	0.123	7.0	362.71	0.4	4.0	8.1	111.0
BH	0.001	*0.005*	*0.0025*	0.065	8.0	267.95	*0.1*	10.0	8.0	109.0
BI	0.001	*0.005*	*0.0025*	0.149	30.0	421.01	*0.1*	7.0	8.2	213.0
BJ	0.001	*0.005*	0.0060	0.473	22.0	714.75	1.3	18.0	8.4	211.0
BK	0.001	*0.005*	*0.0025*	0.389	117.0	745.70	0.1	16.0	8.1	266.0
BL	0.002	*0.005*	0.0050	0.106	19.0	349.58	*0.1*	7.0	8.1	153.0
BM	0.001	*0.005*	0.0050	0.206	19.0	477.87	*0.1*	3.5	8.2	139.0
BN	0.001	*0.005*	*0.0025*	0.164	11.0	420.97	*0.1*	5.0	8.1	131.0
BO	0.001	*0.005*	*0.0025*	0.085	14.0	310.55	*0.1*	2.5	8.1	115.0
BP	0.001	*0.005*	0.0130	0.681	44.0	874.23	*0.1*	9.0	8.3	137.0
BQ	0.001	*0.005*	0.0170	0.483	20.0	719.98	1.3	10.0	8.3	131.0
BR	0.002	*0.005*	0.0110	0.504	54.0	768.93	0.4	8.5	8.3	131.0
BS	0.001	*0.005*	*0.0025*	0.056	11.0	252.64	0.8	6.0	8.2	121.0
BT	0.002	*0.005*	*0.0025*	0.075	18.0	296.86	0.7	6.0	8.2	112.0
BU	0.001	*0.005*	0.0050	0.543	196.0	937.89	3.4	7.5	8.1	152.0
BV	0.002	*0.005*	0.0070	0.627	92.0	888.83	0.8	9.0	8.2	160.0
BW	*0.001*	*0.005*	0.0170	1.080	26.0	1070.23	0.2	13.0	8.3	176.0
BX	*0.001*	0.019	*0.0025*	0.517	45.0	783.03	0.8	9.5	8.3	168.0
BY	*0.001*	*0.005*	*0.0025*	0.212	52.0	517.43	0.7	7.5	8.3	159.0
BZ	0.001	*0.005*	*0.0025*	0.258	134.0	646.94	1.6	7.0	8.2	215.0

Italics denote values that were below detection limit

	NO_2 mg/L	NO_3-NO_2 mg/L	NH_3 mg/L	TKN mg/L	PON µg/L	TN µg/L	ChlaU µg/L	Temp °C	pH	Cond µs/cm
BAA	0.001	0.124	0.010	0.085	12.0	427.55	1.6	3.0	8.2	140.0
BAB	0.001	0.014	0.006	0.137	10.0	394.14	0.8	9.0	8.4	182.0
BAC	0.001	*0.005*	0.006	0.339	18.0	605.24	1.1	8.0	8.3	200.0
BAD	0.001	*0.005*	0.005	0.450	72.0	747.82	2.0	9.0	8.3	128.0
BAE	*0.001*	*0.005*	0.013	0.107	23.0	355.11	1.3	4.0	8.3	140.0
BAF	0.001	*0.005*	0.007	0.169	23.0	439.10	1.6	8.0	8.4	120.0
BAG	0.001	*0.005*	0.005	0.094	21.0	332.59	1.7	8.0	8.4	135.0
BAH	0.001	*0.005*	0.011	0.317	13.0	581.03	1.6	9.0	8.5	110.0
BAI	0.002	*0.005*	0.009	0.324	31.0	605.21	2.5	10.5	8.5	196.0
BAJ	0.003	*0.005*	0.035	0.752	43.0	915.18	1.6	12.0	8.6	216.0
BAK	0.001	*0.005*	0.007	0.144	30.0	414.47	*0.1*	5.0	8.3	88.0
BAL	0.003	*0.005*	0.007	0.488	40.0	743.57	0.8	12.0	8.5	173.0
BAM	0.001	*0.005*	0.005	0.129	16.0	380.17	*0.1*	5.0	8.3	149.0
BAN	0.002	*0.005*	0.006	0.264	54.0	572.81	0.3	8.0	8.5	169.0
B-AO	0.003	0.010	0.006	0.485	71.0	777.42	1.1	7.0	8.1	85.0
B-AP	0.003	0.009	0.008	0.410	72.0	721.31	1.1	7.0	7.8	81.0
B-AQ	0.003	0.012	0.009	0.111	5.0	350.17	*0.1*	7.5	8.0	132.0
PB-1	0.001	0.007	0.008	0.297	32.0	583.98	1.5	7.5	7.9	92.0
PB-2	0.001	0.006	0.009	0.679	29.0	859.01	0.6	11.0	8.5	152.0
PB-3	0.001	*0.003*	0.005	0.223	*1.0*	475.73	0.8	11.0	8.1	69.0
PB-4	0.002	0.007	0.006	0.252	33.0	542.00	0.9	7.0	8.1	81.0
Mean	**0.001**	**0.009**	**0.007**	**0.337**	**37.6**	**586.96**	**0.9**	**8.9**	**8.2**	**150.8**
Max	**0.003**	**0.124**	**0.035**	**1.080**	**196.0**	**1070.23**	**3.4**	**19.5**	**8.6**	**282.0**
Min	**0.001**	**0.003**	**0.003**	**0.056**	**1.0**	**252.64**	**0.1**	**2.5**	**7.8**	**69.0**
Std	**0.001**	**0.018**	**0.006**	**0.258**	**37.3**	**228.48**	**0.7**	**4.0**	**0.2**	**52.3**
Whole Island										
Mean	**0.001**	**0.009**	**0.0084**	**0.327**	**40.31**	**578.2**	**1.0**	**8.6**	**8.1**	**141.9**
Max	**0.003**	**0.124**	**0.0350**	**1.080**	**281.00**	**1273.9**	**7.0**	**19.5**	**8.6**	**510.0**
Min	**0.001**	**0.003**	**0.0025**	**0.056**	**1.00**	**252.6**	**0.1**	**1.5**	**6.8**	**5.0**
Std	**0.001**	**0.016**	**0.0066**	**0.262**	**48.23**	**243.5**	**1.1**	**4.0**	**0.4**	**81.7**

Italics denote values that were below detection limit

	Elev m asl	PON : POP	POC : ChlaU	TN : TPU	Lake (L) or Pond (P)	Lat °N	Long °W
BC	91	10	1739	58	L	75 03.74	97 59.74
BD	30	10	755	70	P	75 04.63	98 02.96
BE	30	26	1391	88	P	75 04.63	98 02.96
BF	21	1	436	18	P	75 08.25	98 28.94
BG	21	6	894	65	L	75 27.43	99 26.67
BH	122	27	1640	80	L	75 27.16	99 32.12
BI	0	18	4280	59	P	75 37.64	99 38.30
BJ	0	14	364	101	P	75 37.64	99 38.30
BK	91	2	11000	12	L	75 78.63	99 20.20
BL	91	6	3560	73	L	75 78.63	99 20.20
BM	0	4	4060	60	L	75 08.26	97 47.42
BN	0	6	2680	87	L	75 08.26	97 47.42
BO	152	11	2640	71	L	75 09.40	98 51.29
BP	335	7	7400	58	P	75 19.02	98 50.58
BQ	335	14	376	86	P	75 19.02	98 50.58
BR	335	9	1762	44	P	75 19.02	98 50.58
BS	61	4	428	77	L	75 31.42	98 11.90
BT	61	90	557	79	P	75 31.42	98 11.90
BU	30	7	392	24	P	75 38.79	98 05.65
BV	152	13	1157	63	P	75 39.14	98 02.59
BW	152	12	2636	122	P	75 39.14	98 02.59
BX	152	11	745	80	P	75 39.14	98 02.59
BY	0	4	1010	24	L	75 43.29	98 31.03
BZ	0	4	747	14	L	75 43.25	98 40.68

	Elev m asl	PON : POP	POC : ChlaU	TN : TPU	Lake (L) or Pond (P)	Lat °N	Long °W
BAA	183	13	235	87	L	75 55.43	99 05.53
BAB	183	4	505	61	P	75 55.43	99 05.53
BAC	122	3	457	150	P	75 56.66	99 04.76
BAD	0	3	417	27	P	75 36.01	97 50.99
BAE	61	46	361	73	L	76 23.18	98 52.05
BAF	61	15	323	76	L	76 23.18	98 52.05
BAG	61	53	263	56	P	76 23.18	98 52.05
BAH	61	1	296	38	P	76 23.18	98 52.05
BAI	61	10	235	79	P	76 23.18	98 52.05
BAJ	122	6	400	57	L	76 39.52	98 52.82
BAK	122	6	5320	42	P	76 39.52	98 52.82
BAL	122	8	789	77	P	76 39.52	98 52.82
BAM	61	3	4500	51	P	76 30.14	98 10.05
BAN	61	6	2418	46	P	76 30.14	98 10.05
B-AO	22	7	737	50	P	75 29.047	97 28.150
B-AP	23	7	832	49	P	75 29.073	97 28.138
B-AQ	0	2	5320	88	P	75 23.288	97 17.269
PB-1	N/A	8	463	80	P	75 43.336	98 30.546
PB-2	N/A	7	1088	100	P	75 43.355	98 31.281
PB-3	N/A	1	581	129	P	75 43.252	98 29.166
PB-4	N/A	2	775	30	P	75 44.005	98 28.500
Mean	**88**	**13**	**1755**	**64**	**N/A**	**N/A**	**N/A**
Max	**335**	**90**	**11000**	**150**	**N/A**	**N/A**	**N/A**
Min	**0**	**1**	**235**	**12**	**N/A**	**N/A**	**N/A**
Std	**89**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
Whole Island							
Mean	**88**	**11**	**1730**	**63**	**N/A**	**N/A**	**N/A**
Max	**335**	**90**	**11000**	**150**	**N/A**	**N/A**	**N/A**
Min	**0**	**1**	**220**	**12**	**N/A**	**N/A**	**N/A**
Std	**85**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**

Table 4.3. Pearson correlation matrix with Bonferroni-adjusted probabilities.
Significantly correlated variables are indicated in italics (*p<0.01*) or bold (**p<0.05**).

Ca	1.00												
Mg	*0.57*	1.00											
Na	0.18	0.76	1.00										
K	0.23	*0.61*	0.79	1.00									
SO_4	*0.77*	0.50	0.27	0.41	1.00								
Cl	0.19	*0.74*	*0.99*	0.74	0.22	1.00							
Al	-0.36	-0.11	0.08	0.21	-0.23	0.06	1.00						
Ba	*0.67*	*0.59*	0.45	0.43	*0.62*	0.45	-0.05	1.00					
Fe	-0.10	0.25	0.27	0.29	-0.06	0.24	*0.78*	0.26	1.00				
Li	*0.64*	*0.59*	0.40	**0.55**	**0.55**	0.36	0.15	0.47	0.31	1.00			
Mn	0.04	0.27	0.30	0.45	0.04	0.25	*0.64*	0.29	0.76	0.52	1.00		
Mo	*0.64*	0.25	-0.07	-0.02	**0.53**	-0.07	-0.28	0.51	-0.09	0.28	-0.05	1.00	
Ni	**0.54**	0.18	0.01	0.08	0.47	0.00	0.10	0.51	0.20	0.45	0.32	**0.52**	1.00
Sr	*0.79*	**0.54**	0.36	0.41	*0.86*	0.35	-0.36	**0.52**	-0.21	*0.57*	-0.10	0.46	0.35
Zn	0.34	0.14	0.00	0.09	0.20	-0.01	0.03	0.28	0.11	0.34	0.23	0.50	0.51
SiO_2	0.52	0.43	0.14	0.22	0.45	0.14	-0.02	0.36	0.26	0.48	0.14	0.17	0.23
DOC	0.16	*0.59*	0.47	0.37	0.00	0.42	0.28	0.28	*0.58*	0.32	0.47	0.10	0.08
DIC	*0.93*	*0.77*	0.35	0.32	*0.65*	0.35	-0.34	*0.67*	0.00	0.65	0.13	**0.55**	0.43
SRPF	*0.59*	0.39	0.17	0.06	**0.55**	0.16	-0.27	0.46	-0.05	0.34	-0.06	*0.58*	0.46
NH_3	-0.15	0.08	0.09	0.10	-0.05	0.07	0.05	-0.07	0.14	-0.17	0.05	-0.08	-0.22
TKN	0.37	*0.75*	**0.56**	0.41	0.26	**0.52**	0.09	0.46	0.49	0.38	0.39	0.29	0.19
TPU	0.07	0.41	0.30	0.24	0.01	0.27	*0.59*	0.34	0.77	0.42	*0.65*	0.14	0.28
TPF	0.48	**0.56**	0.26	0.25	0.26	0.26	0.15	0.38	0.44	0.46	0.44	0.49	0.38
ChlaU	-0.05	-0.05	-0.24	-0.19	-0.02	-0.23	0.16	0.05	0.27	-0.11	-0.03	0.12	-0.13
POC	0.02	0.32	0.34	0.23	0.00	0.31	**0.56**	0.42	*0.75*	0.29	*0.60*	0.04	0.24
PON	0.14	0.34	0.29	0.13	0.05	0.27	0.39	0.42	*0.72*	0.32	*0.60*	0.15	0.28
Temp	0.41	*0.65*	0.32	0.35	0.26	0.28	-0.07	0.31	0.22	0.51	0.24	0.19	0.08
pH	*0.74*	*0.64*	0.39	0.27	*0.66*	0.38	-0.49	**0.54**	-0.16	0.45	-0.15	*0.58*	0.37
Cond	*0.74*	*0.86*	*0.69*	*0.64*	*0.68*	*0.69*	-0.28	*0.59*	-0.02	*0.64*	0.13	0.40	0.33
Elev.	-0.02	-0.27	-0.49	-0.46	-0.09	-0.50	-0.09	-0.32	-0.14	-0.24	-0.24	0.07	0.04
	Ca	**Mg**	**Na**	**K**	**SO_4**	**Cl**	**Al**	**Ba**	**Fe**	**Li**	**Mn**	**Mo**	**Ni**

1.00																
0.13	1.00															
0.37	0.13	1.00														
-0.01	0.16	0.15	1.00													
0.69	0.28	**0.54**	0.37	1.00												
0.54	0.24	0.33	0.06	**0.55**	1.00											
-0.09	-0.09	-0.17	0.43	-0.08	-0.35	1.00										
0.25	0.22	0.22	*0.91*	**0.55**	0.23	0.41	1.00									
-0.07	0.30	0.11	*0.57*	0.17	0.08	0.09	**0.55**	1.00								
0.26	0.40	0.35	*0.64*	*0.58*	0.46	0.08	*0.65*	**0.52**	1.00							
-0.12	0.02	0.15	0.18	-0.04	-0.04	0.24	0.16	0.30	0.21	1.00						
-0.06	0.11	0.08	*0.60*	0.12	0.01	0.22	**0.54**	*0.79*	0.45	0.41	1.00					
-0.01	0.16	0.11	*0.61*	0.23	0.10	0.19	*0.60*	*0.75*	**0.52**	0.38	0.89	1.00				
0.22	0.20	0.39	*0.64*	*0.58*	0.19	0.15	*0.60*	0.34	0.47	0.13	0.23	0.23	1.00			
0.78	0.31	0.28	0.22	*0.73*	*0.65*	-0.07	0.48	0.07	0.40	-0.05	0.03	0.14	0.40	1.00		
0.76	0.20	0.40	0.31	*0.82*	**0.53**	-0.04	**0.53**	0.14	0.50	-0.21	0.09	0.15	0.46	*0.78*	1.00	
-0.14	-0.22	-0.17	0.03	-0.09	-0.05	0.31	-0.03	-0.12	-0.01	0.16	-0.08	-0.02	-0.03	-0.13	-0.23	1.00
Sr	**Zn**	**SiO_2**	**DOC**	**DIC**	**SRPF**	**NH_3**	**TKN**	**TPU**	**TPF**	**ChlaU**	**POC**	**PON**	**Temp**	**pH**	**Cond**	**Elev.**

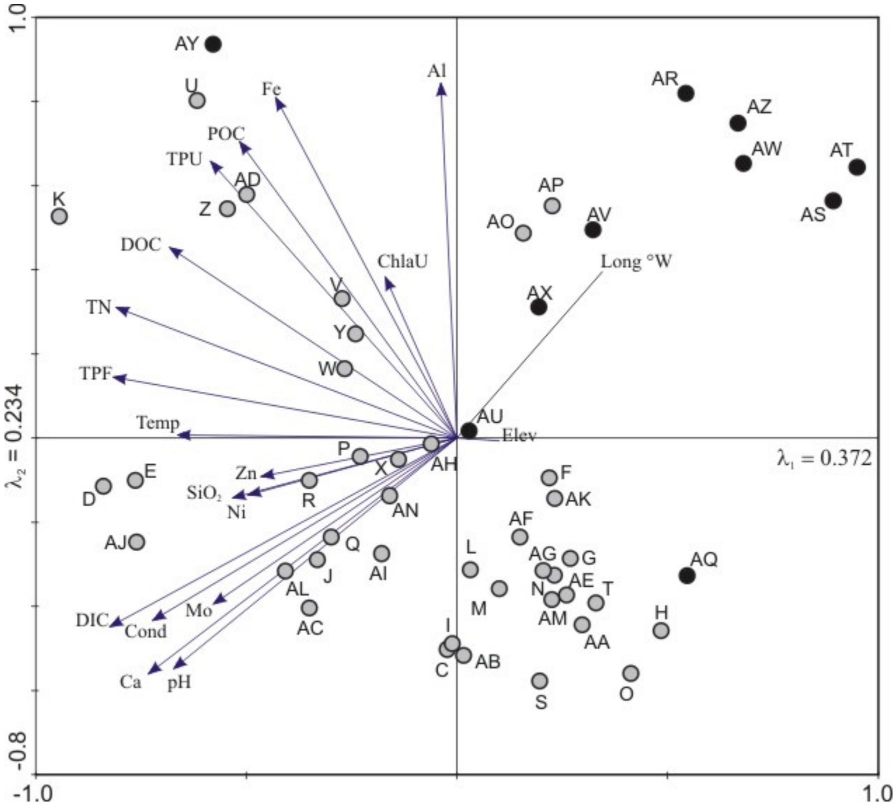


Figure 4.2. Principal components analysis (PCA) biplot of environmental variables (arrows) and sampling sites (circles). Sampling sites are separated into eastern Bathurst Island (grey) and western Bathurst Island (black) sites. Environmental variables that were run and plotted passively are indicated by thin lines.

Confidence intervals were calculated for both diatom species and environmental data using site scores from PCA analysis, and sites were considered to be outliers if outside the 95% confidence intervals in both the diatom species and environmental datasets. Detrended correspondence analysis was used to determine the gradient length for the individual datasets (east and west) and for the combined whole island dataset. Those environmental variables that significantly explained the variability in the diatom data were determined using a canonical correspondence analysis (CCA) with forward selection and Monte Carlo permutation tests (499 unrestricted permutations) (Figure 3). These variables were then run in a series of individually-constrained detrended canonical correspondence analyses (DCCA) to determine whether unimodal or linear reconstruction techniques would be appropriate.

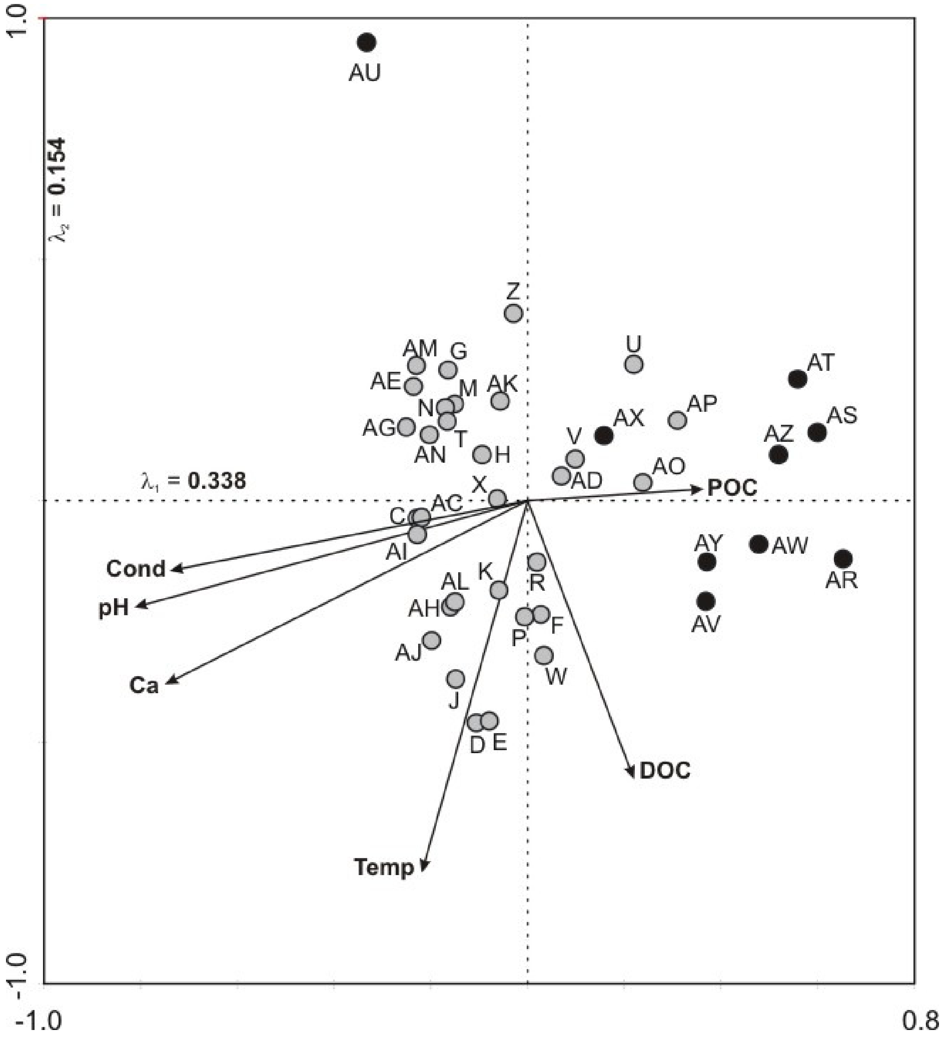


Figure 4.3. Canonical correspondence analysis (CCA) biplot showing six forward-selected environmental variables (arrows) and study sites (circles). Sites are split into western Bathurst Island (black) and eastern Bathurst Island (grey).

A diatom-based pH model was constructed using weighted averaging (WA) and weighted averaging with tolerance downweighting (WA_{tol}) with classical and inverse deshrinking using C^2 version 1.3 (Juggins 2003) following the procedures outlined in detail by Michelutti et al. (2006). Models were constructed using 72 diatom taxa, whose abundance was at least 1% in one of our sites (Table 3). Species data were square root transformed to reduce the impact of dominant taxa and when necessary, environmental variables were transformed to normal distributions using either square root, log (x) or log (x+1) transformation. The models were validated using bootstrapping and evaluated based upon bootstrapped coefficient of determination (r^2_{boot}) and root mean squared error of prediction (RMSEP).

Results and Discussion

Physical variables

Although there is more vertical relief on the western half of Bathurst Island, the ponds we sampled still only represent a small elevation gradient, similar to the Lim et al. (2001) survey from on the eastern half of the island. The elevation of the ponds ranged from 3 m asl to 183 m asl, whereas water temperature ranged between 1.5 – 13.0 ^{o}C (Table 1). As with the eastern half of the island (Lim et al. 2001), the Pearson's correlation matrix (Table 2) showed no significant relationship between elevation and temperature.

pH, specific conductivity and major ions

Contrary to what was found on the eastern half of Bathurst, sites on the western portion of the island show considerably more variability in the range of pH measurements. A very tight pH gradient (8.0 – 8.6), attributable to calcium-rich geological deposits and the resultant high buffering capacity of the lakes and ponds, on the eastern half of Bathurst was not observed in the western sites, where pH varied from 6.8 to 8.4, with 66% of the sites falling outside the pH range observed by Lim et al. (2001).

Table 4.4. List of diatom taxa included in pH model development listing number of occurrences, maximum abundance, Hill's N2 and WA optima for pH.

Species name	No. of occurrences	Maximum Abundance (%)	Hill's N2	pH WA optimum
Achnanthes childanos	19	4.75	17.2	8.3
Achnanthes hostii	2	8.78	1.7	7.0
Achnanthes flexella	25	21.05	18.8	8.3
Achnanthes kryophila	10	7.84	8.0	8.2
Achnanthes laevis	14	3.61	12.5	8.3
Achnanthes lanceolata	1	8.22	1.0	8.1
Achnanthes marginulata	21	9.09	16.5	7.9
Achnanthes minutissima	36	48.87	28.4	8.1
Achnanthes oestrupii	8	14.85	4.9	8.2
Achnanthes petersenii	10	15.50	6.6	7.5
Achnanthes sp. 2	13	4.80	11.4	7.9
Achnanthes sp. 1	7	3.27	6.1	8.3
Achnanthes subatomoides	8	5.57	6.8	8.2
Achnanthes ventralis	13	6.96	11.0	8.2
Amphora auqualis	11	2.05	10.5	8.3
Amphora inariensis	11	8.09	8.9	8.3
Amphora libyca	10	4.02	8.9	8.3
Amphora veneta	4	3.33	3.9	8.3
Brachysira cf. *procera*	1	9.04	1.0	6.9
Caloneis cf. *silicula*	5	10.29	3.8	8.3
Caloneis schumanniana	13	3.77	12.0	8.3
Caloneis sp. 1	15	3.19	13.6	8.4
Cymbella angustata	24	15.72	18.6	8.3
Cymbella arctica	31	11.01	26.9	8.2
Cymbella cf. *arctica*	12	19.94	8.3	8.4
Cymbella cesatii	19	4.79	16.9	8.3
Cymbella designate	20	9.80	16.4	8.3
Cymbella lateens	24	4.38	20.8	8.2
Cymbella microcephala	21	16.04	14.6	8.3
Cymbella minuta	24	31.82	17.4	8.1
Cymbella silesiaca	24	9.09	19.4	8.1
Cymbella similes	15	2.93	13.3	8.3
Cymbella subaequealis	5	5.66	3.9	8.3
Cymbella tumidula	13	9.15	8.7	8.3
Denticula elegans	11	22.19	7.6	8.4
Denticula kuetzingii	17	37.94	12.6	8.3

Species name	No. of occurrences	Maximum Abundance (%)	Hill's N2	pH WA optimum
Diadesmis sp. 1	15	23.44	11.0	8.3
Diatoma moniliformis	8	6.56	6.7	8.2
Diatoma oculata	16	4.43	14.5	8.3
Diatoma tenuis	3	5.01	2.3	8.0
Eunotia arcus	9	6.83	7.8	8.4
Fragilaria cf. construens	7	7.29	5.7	8.2
Fragilaria capucina var. *capucina*	30	32.91	21.6	8.0
Fragilaria capucina var. *gracilis*	2	5.14	1.4	7.8
Fragilaria capucina var. *vaucheriae*	8	20.35	6.0	7.6
Fragilaria pinnata	18	92.82	11.7	8.3
Frustulia rhomboides var. *crassinervia*	1	23.67	1.0	6.9
Navicula cf. *bacilllum*	2	1.68	2.0	8.3
Navicula bryophila	9	4.40	7.8	8.3
Navicula cf. *gallica*	8	48.65	4.5	7.5
Navicula cryptocephala	15	7.03	11.7	8.0
Navicula crypototenella	5	6.90	4.3	7.5
Navicula jaernefeltii	5	5.00	3.9	8.1
Navicula pseudoscutiformis	10	13.44	6.8	8.2
Navicula pupula var. *pupula*	5	1.86	4.2	8.0
Navicula salinarum	11	2.39	10.0	8.3
Navicula soehrensis	7	5.38	5.6	8.4
Navicula sp. 2	5	2.61	4.7	8.3
Navicula vulpina	21	10.96	16.2	8.2
Neidium umiatense	7	9.09	5.5	8.2
Nitzschia alpina	14	9.09	12.1	8.2
Nitzschia frustulum	35	36.90	26.8	8.0
Nitzschia inconspicua	19	20.72	12.9	8.0
Nitzschia palea	17	4.10	14.6	8.1
Nitzschia perminuta	35	26.05	27.3	8.1
Nitzschia perminuta T1	23	15.09	18.8	8.3
Pinnularia balfouriana	16	58.50	12.2	8.3
Pinnularia digerntissima	5	1.68	4.5	7.7
Pinnularia interupta	2	3.72	1.8	7.0
Pinnularia subrostrata	13	9.09	9.8	8.2

Species name	No. of occurrences	Maximum Abundance (%)	Hill's N2	pH WA optimum
Stauroneis anceps	9	1.71	8.7	8.4
Tabellaria flocculosa strain IV	3	12.06	2.8	7.1

Lack of extensive carbonate-bearing bedrock, described by Kerr (1974), has resulted in weakened buffering capacity of sites on western Bathurst Island, where a reduction in $CaCO_3$ input has left these sites more susceptible to climate-driven pH changes similar to those observed in other High Arctic studies (e.g. Wolfe et al. 2002; Michelutti et al. 2006).

Specific conductivity of the western sites was much lower then that observed by Lim et al. (2001). One exception was pond B-AU, an outlier site that, based on elevated Na and Cl concentrations, and relatively low elevation, is likely marine influenced, and had a specific conductivity of 510 µS/cm (Table 1). The mean specific conductivity of the western Bathurst sites was still significantly lower then the eastern half of the island (97.7 µS/cm compared to 150.8 µS/cm). The weak negative correlation (-0.32) noted between elevation and specific conductivity recorded for the eastern Bathurst Island dataset (Lim et al. 2001) weakens further (-0.23) when sites from the west are included in the statistical analysis, while a strong positive correlation between pH and specific conductivity is now evident (0.78, $p = 0.01$), possibly an indication that conductivity is more the result of terrestrial weathering of calcareous bedrock and evaporite deposits than marine influence in this dataset (Table 2).

Calcium levels in the western sites are greatly reduced (0.2 – 23.9 mg/L, mean = 6.0 mg/L) compared with those observed from the eastern sites (9.2 – 43.9 mg/L, mean = 30.8) (Table 1) and in other High Arctic regions (e.g. Antoniades et al. 2003; Lim et al. 2005; Keatley et al. 2007). Lack of significant carbonate deposits on western Bathurst explains the reduced Ca^{2+} concentrations in the ponds. An increase in the correlation between Ca^{2+} and pH from 0.26 (Lim et al. 2001) to 0.736 (Table 2) in the entire dataset further demonstrates the importance of calcium concentrations in the east vs. the west pH gradient.

As with eastern Bathurst Island, both Na^+ and Cl^- concentrations displayed strong negative correlation to the sites proximal to the ocean, as measured by elevation ($Na^+ = -0.49$ and $Cl^- = -0.50$). Mean Na^+ and Cl^- concentrations for the western ponds is greatly elevated due primarily to one outlier (B-AU), which is being heavily impacted by its proximity to the ocean (Table 1). When this site was removed from our analyses, the Na^+ mean for the western sites drops from 15.0 mg/L to 3.4 mg/L and Cl^- from 26.6 mg/L to 6.16 mg/L, which is similar to what was recorded by Lim et al. (2001) (means of 3.3 mg/L and 6.22 mg/L respectively). Furthermore, by removing pond B-AU from the analyses, the major ions follow the same $Ca^{2+} > Mg^{2+} > Na^+ > K^+$ sequence observed on the eastern half of Bathurst Island, as well as studies on many other High Arctic islands (e.g. Douglas and Smol 1994; Rühland and Smol 1998). Relative concentrations of the major anions in the western ponds were, on average, $Cl^- > DIC > SO_4^{2-}$, and do not follow the same pattern recorded in the eastern sites. Low DIC concentrations observed on western Bathurst are likely related to reduced terrestrial input from limestone deposits similar to what was noted with the calcium concentrations. Several of the western ponds (e.g. B-AU, B-AY) were near the sea, which would account for the relatively high concentrations of both Cl^- and SO_4^{2-} in these ponds compared to the rest of the western sites.

Variability in K^+ concentrations has previously been attributed to varying abundances of vascular plants in catchments, with those sites that have the highest plant cover showing proportionally higher K^+ concentration (Prentki et al. 1980; Lim et al. 2001). This is supported by our data, with the highest K concentrations (e.g. 1.0 and 1.1 mg/L) occurring in sites with the highest plant growth (B-AX and B-AY, respectively) (Table 1).

Nutrients

In general, both major nutrients (nitrogen and phosphorus) are found in similar concentrations in our sites on western Bathurst to what was reported by Lim et al. (2001) (Table 1). Sites on Bathurst Island generally follow the pattern found elsewhere in the Arctic (e.g. Keatley et al. 2007) whereby ponds surrounded by dense vegetation (i.e. ponds in the low-lying sedge dominated wet meadows) containing relatively elevated concentrations of nitrogen, phosphorus, carbon and, in many cases, chlorophyll *a*. The link between nutrient levels and vegetation is likely amplified on Bathurst Island, because these regions also support relatively diverse and abundant wildlife, leading to further nutrient enrichment in these sites from droppings. As with the eastern half of the island, TKN is the most variable (0.059 – 0.970 mg/L, mean = 0.279 mg/L) and typical of oligotrophic Arctic ponds. Without exception, NO_2, NO_3-NO_2 and NH_3 were all near or below detection, on western Bathurst similar to what was described by Lim et al. (2001).

Like nitrogen, phosphorus variables did not differ greatly between the eastern and western sites. TPU and TPF values ranged between 6.5 - 26.9 μg/L and 1.1 - 7.7 μg/L, with means of 11.3 μg/L and 4.1 μg/L respectively. SRPF is lower on the western half of Bathurst, with all 9 ponds having values (0.1 – 1.1 μg/L, mean = 0.5 μg/L) below the mean value of 1.4 μg/L found in the eastern sites (Lim et al. 2001).

Of the nine western ponds sampled, seven have PON : POP ratios <10:1 indicating a higher probability that they are more nitrogen, not phosphorus, limited (Schanz and Juon, 1983). The remaining two sites had N : P ratios between 10 : 1 and 20 : 1 and therefore may be either N or P limited, however none of our sites had N : P > 20 : 1 making them clearly P-limited. TN : TPU ratios for the western sites (23 : 1 - 90 : 1, mean = 51 : 1) fell within the range of variability seen on eastern Bathurst (Lim et al. 2001).

Carbon

Dissolved organic carbon (DOC) values across Bathurst Island measured slightly higher (1.1 – 15.1 mg/L, mean = 4.3 mg/L) than what is commonly reported in many high Arctic environments (e.g. Michelutti et al. 2002a; Antoniades et al. 2003). Elevated DOC is probably related to the abundance of vegetation on some parts of the island, such as Polar Bear Pass. No significant differences were found in average DOC values between east and west Bathurst Island.

Dissolved inorganic carbon (DIC) values vary greatly across Bathurst Island following a similar pattern to what was described above with respect to calcium concentration. DIC on the western portion were significantly lower (0.6 – 18.8 μg/L) than those observed on eastern sites (9.3 – 39.9 μg/L) and in other Arctic sites (e.g. Michelutti et al. 2002a; Lim et al. 2005; Keatley et al. 2007). As with calcium, this is likely the result of the lack of carbonate deposits on the western portion of the island.

Chlorophyll a

As is common in most Arctic studies, corrected Chl *a* measurements were below the detection limit in nearly all sites, and therefore only uncorrected Chl *a* values will be discussed. Chl *a* values ranged between below detection (0.1 μg/L) to a maximum of 7.0 μg/L, with a mean of 1.6 μg/L. B-AY, the pond with the highest Chl *a* concentration, is a small, shallow pond surrounded by dense vegetation and a small herd of muskox present near the pond at the time of sampling. Scats were also recorded in the catchment. Similar outlier sites with atypical Chl *a* levels have been mainly documented from Banks Island (Lim et al. 2005) and Melville Island (Keatley et al. 2007), where increased nutrients were also linked to higher concentrations of vegetation and/or wildlife activity.

Diatom flora

The majority of the diatom taxa found in the western ponds are similar to those recorded from eastern Bathurst Island (Lim et al. 2001). Taxa such as *Achnanthes minutissima*, *Cymbella arctica*, *Fragilaria capucina*, *Navicula vulpina*, *Nitzschia perminuta* and *N. frustulum* account for a majority of the diatom species assemblages on both sides of the island (full taxa list in Appendix 3) and are also typical of many high Arctic environments (Antoniades et al. 2004). However, in certain sites, diatom assemblages on Bathurst Island appear to differ along two ecological gradients. On eastern Bathurst Island, sites associated with high nutrients have shown diatom species response with increased abundances of taxa such as *Denticula elegans* and *Denticula kuetzingii* (Lim et al. 2001). On western Bathurst Island, acidiphilous to circumneutral taxa, such as *Brachysira* cf. *procera*, *Frustulia rhomboides* var. *crassinervia* and *Tabellaria flocculosa* strain IV, are found exclusively in the most acidic ponds. Clearly there are two significant ecological gradients on Bathurst Island, with highly-buffered eastern sites influenced primarily by nutrient availability, while variability in underlying bedrock has resulted in poorly-buffered ponds on western Bathurst Island which are more responsive to pH changes (Figure 2).

Ordinations of diatom and environmental data

No sites were identified as outliers in both the Bathurst Island diatom and environmental datasets on either axis 1 or axis 2 of the PCA. DCA analysis revealed that the addition of the 9 western sites expanded the gradient length of the species Axis 1 scores from 2.0 to 3.0 s.d.; therefore unimodal ordination methods are appropriate (ter Braak and Šmilauer 2002). Based on the CCA with forward selection, the environmental variables pH, DOC, temperature, specific conductivity, calcium and POC explained significant ($p \leq 0.05$) amounts of variation in the diatom data, explaining 27.3% of the variation in the species data along the first four ordination axes. Both PCA and CCA analyses show the importance of the pH gradient in the variability between eastern (grey) and western (black) sites (Figures 2 and 3), with the majority of the western sites plotting in the top right quadrant (low pH and low nutrients). The CCA biplot (Figure 3) identifies pH is the primary gradient represented by axis 1, with temperature and DOC (correlated with other nutrients; i.e. nitrogen and phosphorus) primarily influencing axis 2.

Of the 6 measured environmental variables identified as significant during the forward selection of the first CCA analysis, pH by far accounted for the most of the variance explained (21.3%) and therefore was judged to be an appropriate candidate for inference model development. When analyzed as a single constraining variable in the DCCA, pH had a gradient length of 2.3 (i.e. > 2 s.d.) indicating that a unimodal model would likely be the best approach. Multiple WA models were constructed, both with and without tolerance downweighting, and using both classical and inverse deshrinking. All models were found to be very similar when compared based upon r^2_{boot} and RMSEP criteria, and therefore we have chosen to demonstrate only one model ($WA_{(cla)}$) that had a slightly higher r^2_{boot} compared to the other three models (Figure 4). This is consistent with previous limnological studies that have shown $WA_{(cla)}$ to be the most robust inference model for diatom-based reconstruction in the Canadian Arctic (e.g. Rühland and Smol 2002; Antoniades et al. 2004; Michelutti et al. 2006). Weighted average pH reconstruction on Bathurst Island showed similar strength ($r^2_{boot} = 0.63$, RMSEP = 0.298) to constructions from other studies in the High Arctic (Wolfe 2002; Antoniades et al. 2004).

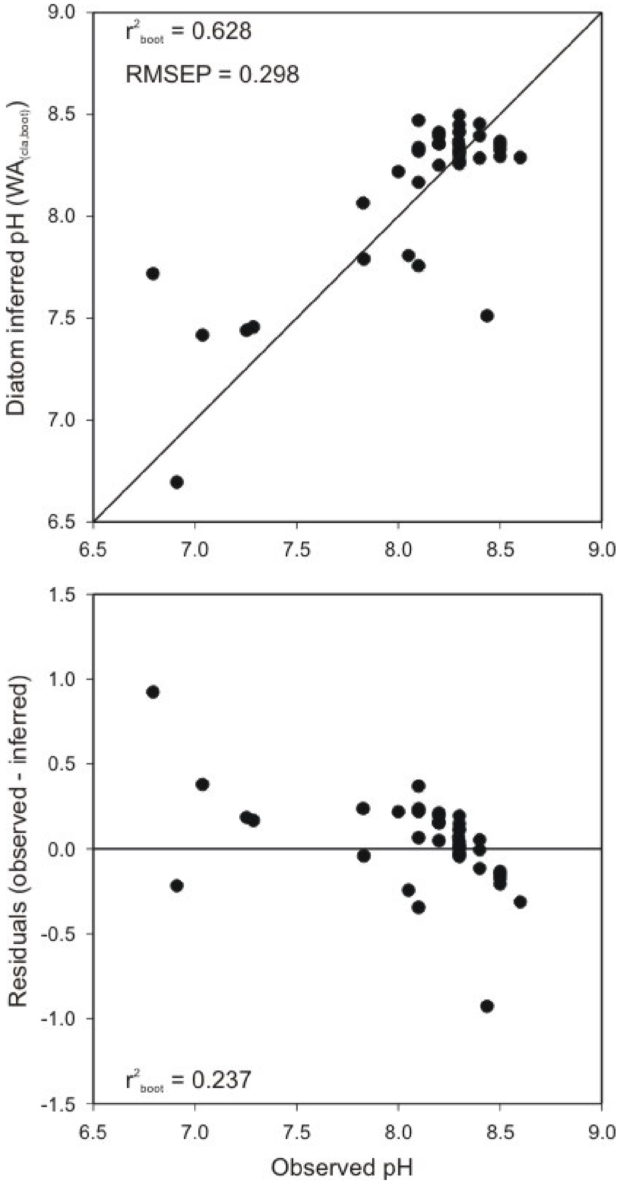


Figure 4.4. Diatom-inferred versus observed pH and the corresponding residuals for $WA_{(cla,boot)}$ model.

Conclusions

Major differences in the pH, specific conductivity and major ions, related to underlying geology, were recorded when we compared ponds from western to eastern Bathurst Island. Perhaps the most striking limnological differences were those noted for calcium and DIC concentrations on western Bathurst Island, which were significantly lower than those commonly recorded from western Bathurst Island, as well as from many other Arctic sites. Measurements of pH also clearly track the differences in geology from the eastern (high pH) and western parts (low pH) of the island. Diatom responses to pH have been well established in other Arctic regions (e.g. Douglas and Smol 1999; Antoniades et al. 2004). Not surprisingly, similar relationships were noted on Bathurst Island, and therefore we attempted to construct a diatom-based pH inference model using the combined Bathurst Island diatom dataset. By expanding the previous survey to include poorly buffered sites on the western half of Bathurst Island, and thereby expanding the pH gradient from 0.5 to 2.0 pH units, we were able to construct a reasonably strong pH model for the Bathurst Island dataset, which had similar robustness to those developed for other Arctic regions (e.g., Antoniades et al. 2004; Michelutti et al. 2006). Although we acknowledge the relatively small number of low pH sites in this study, cross-validation of the inference model appears promising, and further expanding the number of low pH sites would likely only serve to strengthen the model. Given the increased sensitivity of Arctic environments to climatic change, and previous findings suggesting a first order relationship between climate and pH (e.g. Wolfe 2002, Michelutti et al. 2006; Michelutti et al. 2007), such diatom-inferred pH models may be useful in future paleolimnological studies in this region.

References

Antoniades, D., Douglas, M.S.V., and Smol, J.P. 2003. The physical and chemical limnology of 24 ponds and one lake from Isachsen, Ellef Ringnes Island, Canadian High Arctic. Int. J. Hydrobiology 88: 519-539.

Antoniades, D., Douglas, M.S.V., and Smol, J.P. 2004. Diatom species–environment relationships and inference models from Isachsen, Ellef Ringnes Island, Canadian High Arctic. Hydrobiologia 529: 1 - 18.

Camburn, K. E., J. C. Kingston & D. F. Charles, Ed. 1984–1986. PIRLA Diatom Iconograph. PIRLA Unpublished Report Series 3, Indiana University, Bloomington, IN, U.S.A.

Cumming B.F., Wilson S.E., Hall R.I. and Smol J.P. 1995. Diatoms from British Columbia (Canada) lakes and their relationship to salinity, nutrients and other limnological variables. In: Lange-Bertalot H (eds.) Bibliotheca Diatomologica, Band 31, Gebruder Borntraeger, Berlin

Douglas, M.S.V. and Smol, J.P. 1994. Limnology of high arctic ponds (Cape Herschel, Ellesmere Island, N.W.T.). Arch. Hydrobiologie 131: 401-434.

Douglas, M.S.V. & J.P. Smol, 1999. Freshwater diatoms as indicators of environmental change in the High Arctic. In Stoermer, E. F. & J. P. Smol, (eds), The Diatoms: Applications for the Environmental and Earth Sciences. Cambridge University Press, Cambridge: 227–244.

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

Douglas, M.S.V., Smol, J.P., Savelle, J.M. and Blais, J.M., 2004. Prehistoric Inuit whalers affected freshwater ecosystems. Proceedings in the National Academy of Sciences USA 101: 1613–1617

Gregory-Eaves, I., Smol, J.P., Finney, B., Lean, D. and Edwards, M. 2000. Characteristics and variation in lakes along a north-south transect in Alaska. Archive Hydrobiologie 147: 193-223.

Hodgson, D.A. 1989. Quaternary geology of the Queen Elizabeth Islands. – In: Fulton, R.G. (Ed.). Quaternary geology of Canada and Greenland. – Canadian Government Publishing Centre, Ottawa, Ontario, Canada, p. 443 – 451.

Henry, G.H.R. 1998. Environmental influences on the structure of sedge meadows in the Canadian High Arctic. Plant Ecology 134: 119–129.

Juggin, S. 2003. C^2 user guide. Software for ecological and paleoecological data analysis and visualization. University of Newcastle, New Castle upon Tyne, UK.

Juggins, S. and ter Braak, C.J.F. 1992. Calibrate – a program for species-environment calibration by [weighted averaging] partial least squares regression. – University College, London.

Keatley, B., Douglas, M.S.V. and Smol, J.P. 2007. Physical and chemical limnological characteristics of lakes and ponds across environmental gradients on Melville Island, Nunavut/N.W.T., High Arctic Canada. Archiv für Hydrobiologie 168: 355 - 376.

Kerr, J.W. 1974. Bathurst Island Group and Byam Martin Island, District of Franklin. Geological Survey of Canada, "A" Series Map, 1350A

Koinig, K.A., Schmidt, R., Sammaruga-Wögrath, S., Tessadri, R., Psenner, R., 1998. Climate change as the primary cause for pH shifts in a high arctic lake. Water Air and Soil Pollution 104, 167–180.

Krammer, K. and Lange-Bertalot H. 1986–1991. Bacillariophyceae.In Ettl, H., J. Gerloff, H. Heynig & D.Mollenhauer (eds.), Subwasserfloa von Mitteleuropa, Band 2(2–4). Gustav Fischer Verlag, Stuttgart/Jena.

Lim, D.S.S., Douglas, M.S.V., Smol, J.P. 2001. Diatoms and their relationship to environmental variables from lakes and ponds on Bathurst Island, Nunavut, Canadian High Arctic. Hydrobiologia 450: 215-230.

Lim, D.S.S., Douglas, M.S.V., and Smol, J.P. 2005. Limnology of 46 lakes and ponds on Banks Island, N.W.T., Canadian Arctic Archipelago. Hydrobiologia 545: 11-32

Michelutti, N., Douglas, M.S.V., Muir, D., Wang, X., and Smol, J.P. 2002a. Limnological characteristics of 38 lakes and ponds on Axel Heiberg Island, High Arctic Canada. International Revue of Hydrobiology 87: 385-399.

Michelutti, N., Douglas, M.S.V., Lean, D.R.S., and Smol, J.P. 2002b. Physical and chemical limnology of 34 ultra-oligotrophic lakes and ponds near Wynniatt Bay, Victoria Island, Arctic Canada. Hydrobiologia 482: 1-13.

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

Michelutti, N., Douglas, M.S.V., Wolfe, A.P. and Smol, J.P. 2006. Heightened sensitivity of a poorly buffered high arctic lake to late-Holocene climatic change. Quaternary Research 65: 421–430.

Michelutti, N., Smol, J.P. and Douglas, M.S.V. 2006b. Ecological characteristics of modern diatom assemblages from Axel Heiberg Island (High Arctic Canada) and their application to paleolimnological inference models. Canadian Journal of Botany 84: 1695–1713.

Parr, J.F., Taffs, K.H. and Lane, C.M. 2004. A microwave digestion technique for the extraction of fossil diatoms from coastal lake and swamp sediments. Journal of Paleolimnology 31: 383-390.

Pienitz, R., Douglas, M.S.V. and Smol, J.P. 2004. Paleolimnological research in Polar Regions: An Introduction. In Long-term environmental change in Arctic and Antarctic lakes. Springer, Netherlands. 1-17.

Prentki, R.T., Miller, M.C., Barsdate, R.J., Kelly, J. and Coyne, P. 1980. Chemistry. – In: Hobbie J.E. (eds.). Limnology of Tundra Ponds, Barrow Alaska. Dowden, Hutchinson and Ross, Inc., Stroudsburg, 76 – 178.

Rühland, K. and Smol, J.P. 1998. Limnological characteristics of 70 lakes spanning arctic treeline from Coronation Gulf to Great Slave Lake in the central Northwest Territories, Canada. International Revue of Hydrobiology 83: 183-203.

Rühland, K., Smol, J.P., Muir, D., and Wang, X. 2003. Limnological characteristics of 56 lakes in the central Canadian arctic treeline region. Journal of Limnology 69: 2-27.

Schanz, F. and Juon, H. 1983. Two different methods of evaluating nutrient limitations of periphyton bioassays, using water from the River Rhine and eight of its tributaries. Hydrobiologia 102: 187 – 195.

Schmidt, R., Kamenik, C., Kaiblinger, C. and Hetzel, M. 2004. Tracking Holocene environmental changes in an alpine lake sediment core: application of regional diatom calibration, geochemistry, and pollen. Journal of Paleolimnology 32: 177–196.

Smol, J.P. 2005. Tracking long-term environmental changes in arctic lakes and ponds: A paleolimnological perspective. Arctic 58: 227-229.

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, É, 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 Sciences 102: 4397-4402.

Stoermer, E.F. and Smol, J.P. [Eds.]. 1999. The Diatoms: Applications for the Environmental and Earth Sciences. Cambridge University Press. Cambridge, UK.

Tedrow, J.C.F and Walton, G.F. 1977. Rendzina Formation on Bathurst Island. Journal of Soil Science 28: 519-525.

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). Microcomputer Power (Ithaca NY, USA), 500 pp.

Wolfe, A.P., 2002. Climate modulates the acidity of arctic lakes on millennial time scales. Geology 30, 215–218.

CHAPTER 5

General Discussion and Conclusions

The susceptibility and heightened sensitivity of Arctic systems to relatively minor environmental perturbations makes them ideal reference ecosystems for environmental research. Recent studies, such as Smol and Douglas (2007), where several ponds on Ellesmere Island have completely dried in recent years, underscore the severity of the changes occurring in the Arctic and serve as a warning for potential future scenarios in more highly populated southern latitudes. A growing database of limnological and paleolimnological information collected in the High Arctic over the past several decades continues to show unprecedented limnological changes in a large majority of lakes and ponds, confirming that climate impacts are being expressed not only locally but throughout the circumpolar Arctic (Smol et al. 2005). However, other long-term impacts can also be studied using lake and pond sediments.

Cultural eutrophication

The primary research goal of this thesis was to expand upon the work of Douglas et al. (2004) by using paleolimnological techniques to investigate the impacts of Thule whalers at several sites in the High Arctic. The information provided in this thesis from two Thule whaling sites (Chapter 2 and 3), showing marked changes in multiple paleolimnological proxies, support the findings of Douglas et al (2004). Our comparison study of two ponds on Bathurst Island (Chapter 2), where factors such as geology and climate were controlled, strengthens the argument that Thule whaling activities were responsible for the biological and geochemical changes observed in the paleolimnological record. The study of the Eskimobyen site on Ellesmere Island further expands our coverage of the Thule distribution to include one of their most northern camps (Chapter 3). Together these studies significantly expand the latitudinal gradient of Thule sites studied and highlight the sensitivity of the often dilute, oligotrophic lakes and ponds to even minor nutrient enrichment. Given that in all cases we record persistently altered environments, where nutrient concentrations remain elevated three or four centuries after the last known occupation of the sites, it is clear that the recovery potential of these sites is limited as long as whale debris is still present in the ponds and catchments.

Recent climate warming

Chapter 3 provides an interesting evaluation of the impacts of multiple stressors on an Arctic ecosystem. In addition to the prehistoric Thule Inuit nutrient enrichment discussed previously, we also record the impacts of presumably evaporative water loss driven by climate warming. An ongoing survey of ponds on Cape Herschel has shown the severity of recent climate warming and its impact on freshwater ponds (Smol and Douglas 2007). Smol and Douglas (2007) have observed the unprecedented complete desiccation of over a dozen ponds at Cape Herschel on Ellesmere Island (~85 km from the Eskimobyen site) due to enhanced evaporation driven by recent climate warming. The E-Knud site on nearby Knud Peninsula appears to be in the early stage of a similar transformation. Water levels in E-Knud pond were visibly reduced, indicating that the phenomena described by Smol and Douglas may be of increasing concern throughout the Arctic rather than a regional response. This change in water level was expressed in biological indicators within the pond. Specifically an increase in relative abundance of brackish diatom taxon, *Craticula halophila*, is observed in response to increased salt concentration as water level declines.

Baseline limnological data

In a region characterized by thousands of small lakes and ponds, the lack of basic limnological data throughout the Arctic represents an important gap in our knowledge of these ecosystems. In most cases, no limnological information is available due to the logistical difficulties associated with establishing Arctic monitoring programs. However, a concerted effort has been put forth in the past decade to expand the amount of limnological information available in the Arctic. This thesis contributes to that database by expanding the previous work completed on Bathurst Island (Lim et al. 2001) to include lakes and ponds on the western half of the island (Chapter 4). With the addition of these new sites the influence of the previously established nutrient (TN) gradient become less significant as the pH gradient dominates the diatom species assemblages, thus allowing for the construction of a moderately robust diatom-inferred pH model. In addition to the construction of a pH model for Bathurst Island, this study also identifies western Bathurst Island as a region of interest in studying Holocene climate change, given the increased sensitivity of poorly buffered systems to minor changes in pH driven by climate.

References

Douglas, M.S.V., Smol, J.P., Savelle, J.M. and Blais, J.M. 2004. Prehistoric Inuit whalers affected Arctic freshwater ecosystems. Proceedings in the National Academy of Sciences of the United States of America 101: 1613-1617.

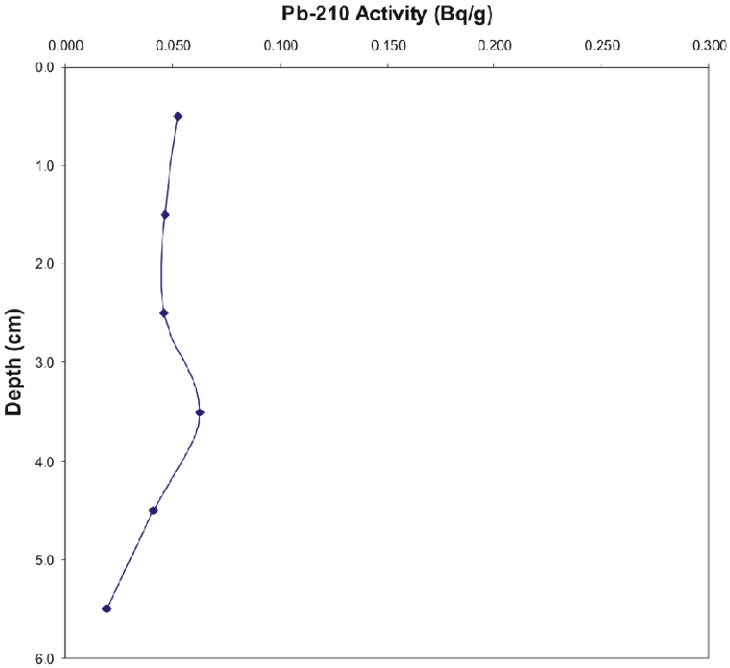
Lim, D.S.S., Douglas, M.S.V., Smol, J.P., and Lean, D. 2001. Physical and chemical limnological characteristics of 38 lakes and ponds on Bathurst Island, Nunavut, Canadian High Arctic. International Review of Hydrobiology 86: 1-22.

Smol, J.P. and Douglas M.S.V. 2007. Crossing the final ecological threshold in high Arctic ponds. Proceedings in the National Academy of Sciences 104: 12395–12397.

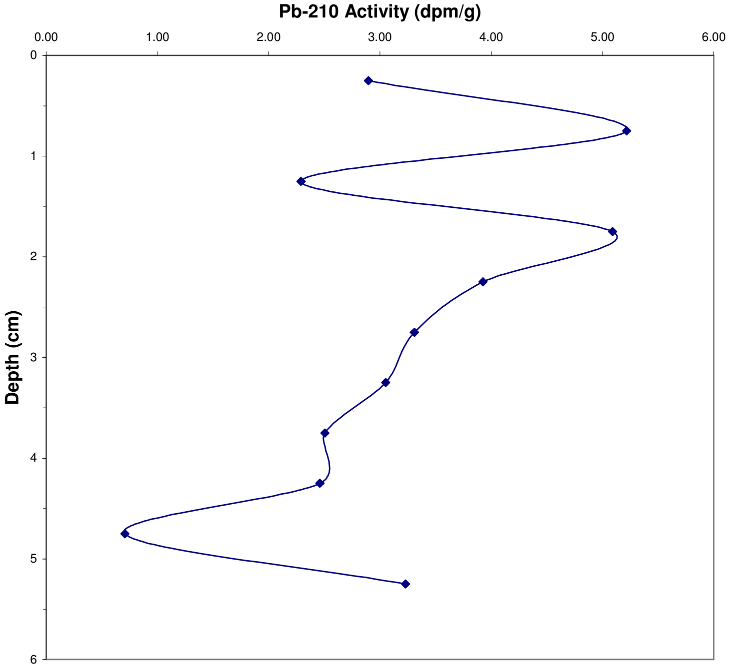
Smol, J.P., Wolfe, A.P., Birks, H.J.B., Douglas, M.S.V., Jones, V.J, Korhola, A., Pienitz, R., Rühland, K., Sorvari, S., Antoniades, D., Brooks, S.J., Fallu, M-A., Hughes, M., Keatley, B.E., Laing, T.E., Michelutti, N., Nazarova, L., Nyman, M., Paterson, A.M., Perren, B., Quinlan, R., Rautio, M., Saulnier-Talbot, É, 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 Sciences 102: 4397-4402.

Appendix 1.

Geochronology of Ellesmere Island



Ellesmere Island (E-Knud pond) Alpha spectrometry profile



Ellesmere Island (E-Knud pond) Gamma spectroscopy profile

Table of raw data from gamma counting on E-Knud core

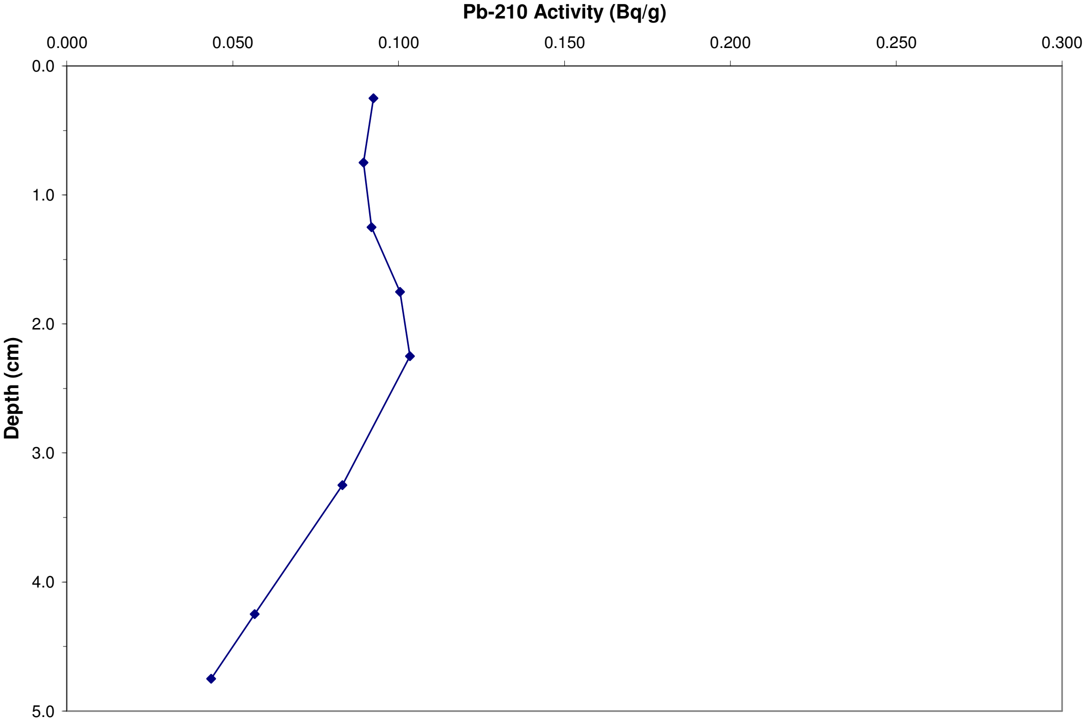
Coring Date:		18/7/2004					bkgnd cpm for 210Pb	bkgnd cpm for 214Bi	bkgnd cpm for 137Cs	bkg err. (cpm) 210Pb	bkg err. (cpm) 214Bi	bkg err. (cpm) 137Cs				
		Avg (Queen's Detector)				Det.1=	0.00	0.02	0.00	0.00	0.00	0.00				
Sample Descrip.	**Int. Mdpt**	**Date Counted**	**Live time (sec)**	**ROI (1-1)**	**ROI (1-2)**	**ROI (1-3)**	**ROI (1-4)**	**ROI (1-5)**	**ROI (1-6)**	**ROI (1-7)**	**ROI (1-8)**	**ROI (1-9)**	210Pb counts> Com.bk	214Bi counts> Com.bk	137Cs counts > Com.bk	210Pb cpm
E-Knud (203-MD-04)																
Coring date		7/18/2004														
0.0 - 0.5	0.25	1/30/2006	80000	266	594	250	85	243	77	55	229	67	78	81	107	0.06
0.5 - 1.0	0.75	8/5/2005	80000	254	608	213	84	202	82	55	227	67	141	36	105	0.11
1.0 - 1.5	1.25	8/7/2005	80000	255	586	254	91	227	63	60	271	72	77	73	139	0.06
1.5 - 2.0	1.75	8/8/2005	80000	237	632	235	90	212	78	66	272	94	160	44	112	0.12
2.0 - 2.5	2.25	8/9/2005	80000	264	650	260	87	207	90	61	265	88	126	30	116	0.09
2.5 - 3.0	2.75	8/13/2005	80000	265	605	253	80	230	82	62	264	84	87	68	118	0.07
3.0 - 3.5	3.25	8/10/2005	80000	272	612	240	90	211	88	59	312	75	100	33	178	0.08
3.5 - 4.0	3.75	10/13/2005	80000	252	554	242	90	171	79	67	247	84	60	2	96	0.05
4.0 - 4.5	4.25	8/11/2005	80000	247	568	241	98	211	87	65	242	80	80	26	97	0.06
4.5 - 5.0	4.75	1/24/2006	80000	293	611	289	109	262	98	75	330	60	29	55	195	0.02
5.0 - 5.5	5.25	8/12/2005	80000	262	620	221	84	254	90	66	249	88	137	80	95	0.10

Coring Date
Weight/height
ROI counts

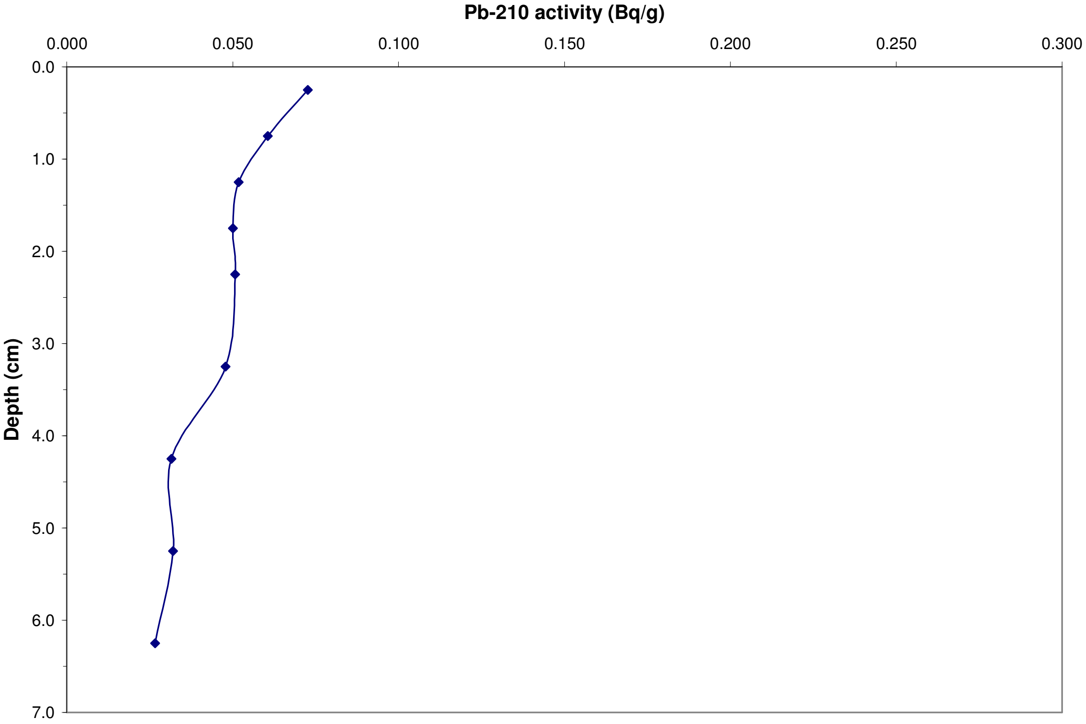
										cumulative error(net cnts+bkgnd)			Coring Date:	18/7/2004		
137Cs cpm	210Pb error 1 std. dev. cpm	214Bi error 1 std. dev. cpm	137Cs error 1 std. dev. cpm	Sample Descript.	**Wt. (g)**	**Ht. (mm)**	210Pb ht. adjstd cpm/g	214Bi ht. adjstd cpm/g	137Cs ht. adjstd cpm/g	210Pb error 1 std. dev. cpm/g	214Bi error 1 std. dev. cpm/g	137Cs error 1 std. dev. cpm/g	Sample Description	Date Counted	Live Count Time (s)	210Pb counts> Com.bk
0.08	0.01	0.01	0.01	0.0 - 0.5	0.5454	16.3	0.07	0.00	0.12	0.007751	0.000519	0.011531	0.0 - 0.5	30/01/2006	80,000.00	78.00
0.08	0.01	0.00	0.01	0.5 - 1.0	0.5570	17.17	0.17	(0.00)	0.12	0.014101	0.000821	0.011273	0.5 - 1.0	05/08/2005	80,000.00	141.00
0.10	0.01	0.01	0.01	1.0 - 1.5	0.7044	18.35	0.05	(0.00)	0.12	0.006124	0.000447	0.01054	1.0 - 1.5	07/08/2005	80,000.00	77.00
0.08	0.01	0.00	0.01	1.5 - 2.0	0.6771	20.04	0.16	0.00	0.10	0.012777	0.000569	0.009911	1.5 - 2.0	08/08/2005	80,000.00	160.00
0.09	0.01	0.00	0.01	2.0 - 2.5	0.6916	20.16	0.10	(0.05)	0.11	0.009033	0.008366	0.009907	2.0 - 2.5	09/08/2005	80,000.00	126.00
0.09	0.01	0.01	0.01	2.5 - 3.0	0.5545	19.36	0.11	0.03	0.13	0.012056	0.00406	0.012368	2.5 - 3.0	13/08/2005	80,000.00	87.00
0.13	0.01	0.00	0.01	3.0 - 3.5	0.6843	17.85	0.08	(0.04)	0.16	0.00756	0.007371	0.012336	3.0 - 3.5	10/08/2005	80,000.00	100.00
0.07	0.01	0.00	0.01	3.5 - 4.0	0.5672	17.72	0.11	(0.05)	0.10	0.014541	0.034384	0.010585	3.5 - 4.0	13/10/2005	80,000.00	60.00
0.07	0.01	0.00	0.01	4.0 - 4.5	0.6727	17.39	0.11	(0.02)	0.09	0.012598	0.003435	0.008946	4.0 - 4.5	11/08/2005	80,000.00	80.00
0.15	0.00	0.01	0.01	4.5 - 5.0	0.8580	19.59	0.05	0.01	0.15	0.00998	0.001157	0.010522	4.5 - 5.0	24/01/2006	80,000.00	29.00
0.07	0.01	0.01	0.01	5.0 - 5.5	0.9123	19.02	0.12	0.03	0.06	0.010616	0.002936	0.006632	5.0 - 5.5	12/08/2005	80,000.00	137.00

			cumulative error x correction factors								
corrected for efficiency & density **210Pb (dpm/g)**	**214Bi (dpm/g)**	corrected for sampling date **137Cs (dpm/g)**	210Pb error 1 std. dev. (dpm/g)	214Bi error 1 std. dev. (dpm/g)	137Cs error 1 std. dev. (dpm/g)	Sample Descrip	Date	Pb (bkgr) cpm	Pb(bkgr) std	214BI (bkgr) cpm	214Bi (bkgr) std
2.34	0.11	1.34	0.26	0.01	0.13	0.0 - 0.5	30/1/2006	0.01	0.00	0.06	0.01
5.71	(0.12)	1.28	0.48	0.02	0.12	0.5 - 1.0	5/8/2005	(0.01)	0.00	0.03	0.00
1.84	(0.09)	1.38	0.21	0.01	0.12	1.0 - 1.5	7/8/2005	0.01	0.00	0.06	0.01
5.51	0.09	1.16	0.44	0.01	0.11	1.5 - 2.0	8/8/2005	(0.01)	0.00	0.03	0.00
3.46	(1.09)	1.18	0.31	0.20	0.11	2.0 - 2.5	9/8/2005	0.01	0.00	0.06	0.01
3.81	0.80	1.49	0.41	0.10	0.14	2.5 - 3.0	13/8/2005	(0.01)	0.00	0.03	0.00
2.59	(1.01)	1.82	0.26	0.18	0.14	3.0 - 3.5	10/8/2005	0.01	0.00	0.06	0.01
3.84	(1.16)	1.16	0.50	0.82	0.12	3.5 - 4.0	13/10/2005	(0.03)	0.01	0.03	0.01
3.86	(0.42)	0.98	0.43	0.08	0.10	4.0 - 4.5	11/8/2005	(0.03)	0.01	0.03	0.01
1.85	0.20	1.65	0.34	0.03	0.12	4.5 - 5.0	24/1/2006	(0.03)	0.01	0.03	0.01
4.30	0.63	0.72	0.37	0.07	0.07	5.0 - 5.5	12/8/2005	(0.03)	0.01	0.03	0.01

Appendix 2.
Geochronology of Bathurst Island (B-AO and B-AP)



Bathurst Island (Pond B-AP) alpha spectrometry profile



Bathurst Island (Pond B-AO) alpha spectrometry profile

Raw data from alpha spectrometry Pb-210 analysis of Bathurst Island cores by MyCore Scientific Inc.

Sample Number	**Disk #**	**Section Top (cm)**	**of Core Bottom (cm)**	**% Moisture**	**Pb-210 (Bq/g)**	**Precisn 1 STD (%)**	
B-AO	Date	2005.52	Friday, July 08, 2005				
	191	0.0	0.5	87	0.092	6.4	0.250
	192	0.5	1.0	85	0.089	5.6	0.750
	193	1.0	1.5	85	0.092	4.7	1.250
	194	1.5	2.0	84	0.100	4.7	1.750
	195	2.0	2.5	84	0.103	4.9	2.250
	196	3.0	3.5	83	0.083	5.8	3.250
	197	4.0	4.5	82	0.057	6.8	4.250
	198	4.5	5.0	81	0.044	7.3	4.750
B-AP		2005.52	Friday, July 08, 2005				
	199	0.0	0.5	85	0.073	7.8	0.250
	200	0.5	1.0	82	0.061	8.4	0.750
	201	1.0	1.5	81	0.052	6.8	1.250
	202	1.5	2.0	81	0.050	8.1	1.750
	203	2.0	2.5	81	0.051	7.8	2.250
	204	3.0	3.5	79	0.048	9.6	3.250
	205	4.0	4.5	77	0.031	8.8	4.250
	206	5.0	5.5	78	0.032	6.4	5.250
	207	6.0	6.5	79	0.027	6.5	6.250
Controls							
	CV1A				0.621	2.5	
	CV1B				0.626	2.3	
	CV2A				0.055	6.5	
	CV2B				0.060	8.6	

Appendix 3. List of all diatom taxa and their relative abundances from the Bathurst Island surface sediment calibration set.

Site Name	*Achnanthes childanos*	*Achnanthes hostii*	*Achnanthes flexella*	*Achnanthes kryophila*	*Achnanthes laevis*	*Achnanthes lanceolata*	*Achnanthes marginulata*	*Achnanthes minutissima*	*Achnanthes oestrupii*	*Achnanthes petersenii*
BC	0.50	0.00	0.00	1.01	0.00	0.00	0.00	2.01	0.00	0.00
BD	0.00	0.00	9.22	0.34	2.05	0.00	0.00	18.43	0.00	0.00
BE	1.24	0.00	21.05	0.62	3.41	0.00	0.00	12.69	0.00	0.00
BF	0.33	0.00	1.63	7.84	0.00	0.00	2.29	7.52	0.00	0.00
BG	2.39	0.00	1.37	3.07	0.00	0.00	0.34	0.68	0.00	0.00
BH	0.00	0.00	0.00	0.00	0.00	0.00	9.09	0.00	0.00	0.00
BJ	1.31	0.00	0.98	0.00	3.61	0.00	0.66	14.10	0.00	0.00
BK	0.00	0.00	0.33	0.00	0.65	0.00	1.63	4.56	0.00	0.00
BM	0.59	0.00	0.59	0.00	1.18	0.00	0.00	4.41	0.88	0.00
BN	0.00	0.00	1.96	0.00	0.00	0.00	0.00	0.00	0.33	0.00
BP	0.00	0.00	0.64	0.00	0.00	0.00	0.00	14.79	0.00	0.00
BR	1.93	0.00	0.00	0.00	0.00	0.00	0.00	6.43	0.00	0.00
BT	1.89	0.00	3.77	1.26	1.57	0.00	0.00	4.09	0.00	0.00
BU	0.65	0.00	0.00	0.00	2.90	0.00	0.00	17.74	1.94	0.00
BV	2.53	0.00	6.01	1.27	2.85	0.00	8.86	20.89	0.32	0.00
BW	0.00	0.00	6.39	0.00	0.96	0.00	1.92	39.62	0.00	0.00
BX	2.74	0.00	9.76	0.00	1.52	0.00	1.22	16.77	0.00	0.00
BZ	3.33	0.00	3.33	0.00	0.00	0.00	0.83	5.00	8.33	0.00
BAC	0.00	0.00	1.89	0.00	0.00	0.00	0.00	17.30	0.00	0.00
BAD	0.63	0.00	1.56	0.00	0.94	0.00	0.00	2.50	0.00	0.00
BAE	1.26	0.00	1.57	0.00	0.00	0.00	0.94	0.63	0.00	0.00
BAG	1.94	0.00	0.32	0.00	0.00	0.00	2.91	0.65	0.00	0.00
BAH	4.75	0.00	2.85	3.16	0.32	0.00	7.59	2.22	0.00	0.00
BAI	0.00	0.00	2.56	0.00	0.64	0.00	0.00	11.50	0.00	0.00
BAJ	0.00	0.00	1.25	0.00	0.00	0.00	0.00	5.64	0.00	0.00
BAK	1.89	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.95	0.00
BAL	0.00	0.00	8.85	0.00	0.00	0.00	0.59	1.18	0.00	0.00
BAM	0.93	0.00	0.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BAN	1.95	0.00	0.00	0.00	0.00	0.00	1.30	3.58	0.00	0.00
B-AO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.98	0.00	0.47
B-AP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.53	0.00	1.43
B-AR	0.00	1.35	0.00	0.00	0.00	0.00	1.12	6.28	0.00	0.67
B-AS	0.00	8.78	0.00	0.00	0.00	0.00	9.04	5.32	0.00	0.53
B-AT	0.00	0.00	0.00	0.00	0.00	0.00	2.95	7.01	0.00	15.50
B-AU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00
B-AV	0.00	0.00	3.86	0.00	0.64	0.00	0.00	48.87	0.00	5.47
B-AW	0.00	0.00	0.00	0.00	0.00	0.00	4.52	0.50	0.00	0.25
B-AX	0.00	0.00	0.00	0.80	0.00	8.22	0.27	6.90	14.85	1.86
B-AY	0.00	0.00	0.56	0.00	0.00	0.00	3.36	13.45	0.00	0.56
B-AZ	0.00	0.00	0.00	0.60	0.00	0.00	0.60	3.90	0.00	9.01

Site *Name*	*Achnanthes* sp . 2	*Achnanthes* sp. 1	*Achnanthes subatomoides*	*Achnanthes ventralis*	*Amphora auqualis*	*Amphora inariensis*	*Amphora libyca*	*Amphora veneta*	*Brachysira* cf. *procera*	*Caloneis* cf. *silicula*
BC	0.00	0.25	0.00	0.00	0.50	0.50	4.02	2.26	0.00	0.00
BD	0.00	0.00	0.00	0.00	0.68	0.00	0.00	0.00	0.00	0.00
BE	0.00	1.55	5.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BF	0.00	3.27	3.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BG	0.00	0.00	0.00	0.00	2.05	3.41	0.00	1.37	0.00	0.00
BH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BK	0.00	0.00	0.00	0.00	0.98	2.61	1.30	0.00	0.00	0.00
BM	0.00	0.00	0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BR	0.00	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BT	0.00	0.94	0.00	0.00	0.63	0.63	0.63	0.00	0.00	0.00
BU	2.26	0.00	0.00	0.00	0.00	0.65	0.32	0.00	0.00	0.00
BV	0.63	0.63	0.00	6.96	0.63	0.00	0.00	0.00	0.00	0.00
BW	0.32	0.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BX	1.83	0.00	0.00	1.22	0.61	0.61	0.00	0.00	0.00	0.00
BZ	0.00	0.00	0.00	3.33	0.00	0.00	0.00	3.33	0.00	0.00
BAC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BAD	0.63	0.00	0.00	1.25	0.00	0.00	0.63	0.00	0.00	0.00
BAE	0.00	0.00	0.00	0.00	0.63	0.00	0.00	0.00	0.00	0.00
BAG	0.00	0.00	0.00	0.65	0.65	8.09	0.00	0.00	0.00	3.88
BAH	0.97	0.00	0.00	0.00	0.00	1.90	0.00	0.00	0.00	0.63
BAI	0.63	0.00	0.64	0.00	0.64	0.00	2.24	0.00	0.00	0.00
BAJ	0.00	0.00	0.00	0.63	0.00	0.00	1.25	0.00	0.00	0.00
BAK	0.00	0.00	0.00	2.52	0.00	0.95	0.00	0.00	0.00	0.00
BAL	0.00	0.00	0.00	1.77	0.00	0.59	0.00	0.00	0.00	0.59
BAM	1.24	0.00	0.00	0.00	0.00	0.00	1.55	0.00	0.00	0.00
BAN	0.00	0.00	0.00	1.30	0.65	2.93	0.98	2.61	0.00	1.95
B-AO	1.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B-AP	0.00	0.00	0.00	0.00	0.00	0.00	0.82	0.00	0.00	0.00
B-AR	0.90	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00
B-AS	0.00	0.00	0.00	1.33	0.00	0.00	0.00	0.00	9.04	0.00
B-AT	4.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B-AU	0.00	0.00	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B-AV	0.00	0.00	1.61	0.00	0.00	0.00	0.00	0.00	0.00	10.29
B-AW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B-AX	1.33	0.00	1.86	1.06	0.00	0.00	0.00	0.00	0.00	0.00
B-AY	0.00	0.00	1.40	0.84	0.00	0.00	0.00	0.00	0.00	0.00
B-AZ	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Site Name	*Caloneis schumanniana*	*Caloneis sp. 1*	*Cymbella angustata*	*Cymbella arctica*	*Cymbella arctica T1*	*Cymbella cesatii*	*Cymbella designata*	*Cymbella latens*	*Cymbella microcephala*	*Cymbella minuta*
BC	1.51	0.00	0.00	6.53	0.00	0.00	0.75	1.76	1.26	0.25
BD	2.73	0.34	9.22	6.48	1.71	3.41	1.71	0.00	6.14	0.00
BE	2.17	1.55	5.88	4.02	0.62	6.50	0.93	1.24	1.55	0.00
BF	0.00	0.65	2.29	6.21	0.00	0.65	9.80	1.96	21.90	0.33
BG	0.68	0.00	0.68	2.05	0.00	0.68	0.68	2.73	0.00	3.07
BH	0.00	0.00	9.09	0.00	0.00	0.00	0.00	0.00	0.00	31.82
BJ	1.31	1.31	1.31	3.61	0.00	2.62	0.66	0.66	3.28	4.59
BK	1.30	0.00	1.95	5.21	1.30	5.21	1.63	2.61	1.63	3.91
BM	0.00	0.00	0.00	0.59	0.00	1.18	0.00	0.00	0.00	0.00
BN	0.00	0.65	0.00	0.65	0.00	0.65	0.65	0.00	0.00	0.00
BP	0.00	0.00	9.97	7.07	0.00	0.00	3.22	0.00	0.32	0.00
BR	0.00	0.00	6.75	2.57	0.00	0.00	0.00	0.00	0.00	0.00
BT	2.20	0.94	3.46	2.83	1.26	4.40	0.63	0.63	3.14	0.00
BU	0.00	0.00	0.32	0.97	0.00	1.29	0.00	0.65	0.32	1.29
BV	0.63	0.00	1.27	0.00	0.00	1.27	0.63	1.27	0.63	0.00
BW	0.64	1.28	4.79	2.56	0.00	1.92	1.28	1.92	2.56	1.92
BX	1.52	1.83	2.13	3.05	0.00	3.66	1.22	3.05	2.74	0.00
BZ	0.00	0.00	0.00	3.33	0.00	0.00	1.67	3.33	3.33	1.67
BAC	0.00	0.63	15.72	11.01	5.03	1.57	0.00	0.00	16.04	0.00
BAD	0.94	0.00	0.63	1.88	0.00	0.00	0.00	4.38	0.31	3.75
BAE	3.77	0.63	1.26	1.89	1.89	1.26	0.63	0.63	0.00	0.63
BAG	0.00	0.65	1.94	5.83	0.65	2.59	1.94	1.29	5.18	0.00
BAH	0.00	0.95	6.01	9.18	19.94	1.58	3.16	0.00	2.53	1.27
BAI	0.64	3.19	5.75	8.31	1.92	4.79	1.92	0.64	1.92	1.60
BAJ	0.00	0.00	0.63	1.88	0.63	0.00	0.00	0.00	0.31	2.82
BAK	0.00	0.32	0.00	0.00	0.63	0.00	0.00	0.32	0.00	1.26
BAL	0.00	0.00	1.18	0.59	0.00	0.00	0.00	0.59	0.59	1.18
BAM	0.00	0.00	0.00	2.48	0.00	0.00	0.00	0.62	0.00	0.62
BAN	0.00	0.65	0.65	6.51	2.61	1.30	0.65	0.65	0.65	2.93
B-AO	0.00	0.00	0.00	3.96	0.00	0.00	0.00	0.00	0.00	5.83
B-AP	0.00	0.00	0.00	2.24	0.00	0.00	0.00	0.20	0.00	2.86
B-AR	0.00	0.00	0.00	1.35	0.00	0.00	0.00	0.45	0.00	0.00
B-AS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B-AT	0.00	0.00	0.00	0.74	0.00	0.00	0.00	0.00	0.00	2.58
B-AU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B-AV	0.00	0.00	0.32	0.00	0.00	0.00	0.32	0.00	0.00	0.00
B-AW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B-AX	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53	0.00	1.86
B-AY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.96	0.00	1.12
B-AZ	0.00	0.00	0.00	0.90	0.00	0.00	0.00	0.00	0.00	3.00

Site Name	*Cymbella silesiaca*	*Cymbella similis*	*Cymbella subaequealis*	*Cymbella tumidula*	*Denticula elegans*	*Denticula kuetzingii*	*Diadesmis sp. 1*	*Diatoma moniliformis*	*Diatoma oculata*
BC	0.75	0.25	0.00	0.00	0.00	0.00	0.00	0.00	3.02
BD	0.00	0.68	3.07	0.00	1.37	8.19	0.00	0.00	0.00
BE	0.62	0.62	0.31	0.62	1.24	6.19	0.00	0.00	0.00
BF	1.96	0.33	0.00	9.15	0.00	0.00	0.00	0.00	0.98
BG	2.05	0.68	0.00	0.68	0.00	0.00	6.83	0.00	3.41
BH	9.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BJ	0.66	0.00	0.00	0.00	0.00	5.90	0.00	0.00	0.33
BK	1.30	2.93	0.00	0.33	0.00	4.56	2.28	5.21	0.00
BM	1.76	0.00	0.00	0.00	0.00	0.00	0.59	0.00	0.00
BN	0.00	0.65	0.00	0.00	0.00	0.00	1.31	0.00	0.00
BP	0.00	0.00	0.00	0.00	22.19	0.64	0.00	0.00	0.00
BR	0.00	0.00	0.00	0.00	0.00	37.94	0.00	0.00	0.00
BT	0.63	0.00	0.00	0.63	0.00	0.00	0.00	0.00	1.26
BU	3.87	0.00	0.00	0.00	0.00	2.26	3.23	0.65	1.61
BV	0.63	2.53	0.00	0.63	0.00	1.90	6.65	0.32	1.27
BW	0.64	0.00	0.00	0.00	5.75	0.00	0.00	0.00	0.00
BX	2.44	1.22	0.61	0.61	0.61	3.66	0.00	0.00	0.61
BZ	0.00	1.67	0.00	0.00	0.00	0.00	10.00	0.00	1.67
BAC	0.00	0.00	5.66	7.55	1.89	0.63	0.00	0.00	0.00
BAD	0.00	0.63	0.94	0.63	0.00	0.63	23.44	6.56	0.00
BAE	0.00	0.63	0.00	0.00	0.00	0.00	1.26	0.00	0.00
BAG	1.29	1.94	0.00	0.65	1.29	2.59	0.65	0.00	3.24
BAH	0.63	0.63	0.00	0.63	2.53	5.70	0.00	0.00	0.00
BAI	0.00	0.00	0.00	0.00	1.92	3.19	1.28	0.00	1.28
BAJ	1.25	0.00	0.00	0.00	0.63	2.51	1.25	0.00	0.00
BAK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BAL	0.00	0.59	0.00	0.59	1.18	0.00	1.77	0.00	0.00
BAM	0.00	0.00	0.00	0.62	0.00	0.00	1.86	0.00	0.00
BAN	0.00	0.00	0.00	0.00	0.00	1.95	1.30	0.00	3.91
B-AO	4.66	0.00	0.00	0.00	0.00	0.00	0.00	4.43	4.43
B-AP	3.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B-AR	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B-AS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B-AT	0.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B-AU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.13	2.13
B-AV	0.96	0.00	0.00	0.00	0.00	6.11	0.00	0.00	0.00
B-AW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B-AX	0.80	0.00	0.00	0.00	0.00	0.00	0.00	2.65	2.65
B-AY	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.84	0.84
B-AZ	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Site Name	*Cymbella silesiaca*	*Cymbella similis*	*Cymbella subaequealis*	*Cymbella tumidula*	*Denticula elegans*	*Denticula kuetzingii*	*Diadesmis* sp. 1	*Diatoma moniliformis*	*Diatoma oculata*
BC	0.75	0.25	0.00	0.00	0.00	0.00	0.00	0.00	3.02
BD	0.00	0.68	3.07	0.00	1.37	8.19	0.00	0.00	0.00
BE	0.62	0.62	0.31	0.62	1.24	6.19	0.00	0.00	0.00
BF	1.96	0.33	0.00	9.15	0.00	0.00	0.00	0.00	0.98
BG	2.05	0.68	0.00	0.68	0.00	0.00	6.83	0.00	3.41
BH	9.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BJ	0.66	0.00	0.00	0.00	0.00	5.90	0.00	0.00	0.33
BK	1.30	2.93	0.00	0.33	0.00	4.56	2.28	5.21	0.00
BM	1.76	0.00	0.00	0.00	0.00	0.00	0.59	0.00	0.00
BN	0.00	0.65	0.00	0.00	0.00	0.00	1.31	0.00	0.00
BP	0.00	0.00	0.00	0.00	22.19	0.64	0.00	0.00	0.00
BR	0.00	0.00	0.00	0.00	0.00	37.94	0.00	0.00	0.00
BT	0.63	0.00	0.00	0.63	0.00	0.00	0.00	0.00	1.26
BU	3.87	0.00	0.00	0.00	0.00	2.26	3.23	0.65	1.61
BV	0.63	2.53	0.00	0.63	0.00	1.90	6.65	0.32	1.27
BW	0.64	0.00	0.00	0.00	5.75	0.00	0.00	0.00	0.00
BX	2.44	1.22	0.61	0.61	0.61	3.66	0.00	0.00	0.61
BZ	0.00	1.67	0.00	0.00	0.00	0.00	10.00	0.00	1.67
BAC	0.00	0.00	5.66	7.55	1.89	0.63	0.00	0.00	0.00
BAD	0.00	0.63	0.94	0.63	0.00	0.63	23.44	6.56	0.00
BAE	0.00	0.63	0.00	0.00	0.00	0.00	1.26	0.00	0.00
BAG	1.29	1.94	0.00	0.65	1.29	2.59	0.65	0.00	3.24
BAH	0.63	0.63	0.00	0.63	2.53	5.70	0.00	0.00	0.00
BAI	0.00	0.00	0.00	0.00	1.92	3.19	1.28	0.00	1.28
BAJ	1.25	0.00	0.00	0.00	0.63	2.51	1.25	0.00	0.00
BAK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BAL	0.00	0.59	0.00	0.59	1.18	0.00	1.77	0.00	0.00
BAM	0.00	0.00	0.00	0.62	0.00	0.00	1.86	0.00	0.00
BAN	0.00	0.00	0.00	0.00	0.00	1.95	1.30	0.00	3.91
B-AO	4.66	0.00	0.00	0.00	0.00	0.00	0.00	4.43	4.43
B-AP	3.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B-AR	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B-AS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B-AT	0.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B-AU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.13	2.13
B-AV	0.96	0.00	0.00	0.00	0.00	6.11	0.00	0.00	0.00
B-AW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B-AX	0.80	0.00	0.00	0.00	0.00	0.00	0.00	2.65	2.65
B-AY	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.84	0.84
B-AZ	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Site Name	*Diatoma tenuis*	*Eunotia arcus*	*Fragilaria* cf. *construens*	*Fragilaria capucina* var. *capucina*	*Fragilaria capucina* var. *gracilis*	*Fragilaria capucina* var. *vaucheriae*	*Fragilaria pinnata*	*Frustulia rhomboides* var. *crassinervia*	*Navicula* cf. *bacilllum*
BC	0.00	0.00	7.29	0.00	0.00	0.00	18.84	0.00	0.00
BD	0.00	6.83	0.00	5.46	0.00	0.00	0.00	0.00	0.00
BE	0.00	1.24	0.00	2.48	0.00	0.00	0.00	0.00	0.00
BF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BG	0.00	0.00	5.80	13.65	0.00	0.00	7.17	0.00	0.00
BH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BJ	0.00	2.30	0.00	6.89	0.00	0.00	0.00	0.00	0.00
BK	0.00	0.00	0.00	31.27	0.00	0.00	0.00	0.00	0.00
BM	0.00	0.00	0.00	1.76	0.00	0.00	23.82	0.00	0.00
BN	0.00	0.00	2.61	0.33	0.00	0.00	25.16	0.00	0.00
BP	0.00	0.00	0.00	2.57	0.00	0.00	0.00	0.00	0.00
BR	0.00	0.00	0.00	1.29	0.00	0.00	0.00	0.00	0.00
BT	0.00	1.89	0.63	0.00	0.00	0.00	0.00	0.00	0.00
BU	0.00	0.00	0.00	28.71	0.00	0.00	0.00	0.00	0.00
BV	0.00	1.27	0.00	12.97	0.00	0.00	0.00	0.00	0.00
BW	0.00	0.00	0.00	3.19	0.00	0.00	0.00	0.00	0.00
BX	0.00	1.52	0.00	0.61	0.00	0.00	0.00	0.00	0.00
BZ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BAC	0.00	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BAD	0.00	0.00	0.00	19.06	0.00	0.00	0.00	0.00	0.00
BAE	0.00	0.00	1.57	0.94	0.00	0.00	39.94	0.00	0.00
BAG	0.00	0.00	0.00	0.97	0.00	0.00	12.94	0.00	0.00
BAH	0.00	0.63	0.00	1.27	0.00	0.00	0.32	0.00	0.00
BAI	0.00	2.56	0.00	1.92	0.00	0.00	0.00	0.00	0.00
BAJ	0.00	0.00	0.00	0.63	0.00	0.00	49.53	0.00	0.00
BAK	0.00	0.00	0.00	3.15	0.00	0.00	55.84	0.00	0.00
BAL	0.00	0.00	0.00	2.36	0.00	0.00	52.21	0.00	0.00
BAM	0.00	0.00	3.72	0.00	0.00	0.00	42.41	0.00	0.00
BAN	0.00	0.00	0.00	3.91	0.00	0.00	0.65	0.00	0.00
B-AO	1.40	0.00	0.23	3.03	0.00	7.70	0.23	0.00	0.00
B-AP	5.10	0.00	0.00	0.00	0.20	15.10	0.41	0.00	0.00
B-AR	0.00	0.00	0.00	2.02	0.00	1.12	0.00	0.00	0.00
B-AS	0.00	0.00	0.00	5.32	0.00	0.00	0.00	23.67	0.00
B-AT	0.00	0.00	0.00	8.86	0.00	1.11	0.74	0.00	0.00
B-AU	0.27	0.00	0.00	0.00	0.00	0.00	92.82	0.00	0.00
B-AV	0.00	0.00	0.00	0.00	5.14	0.00	0.00	0.00	0.00
B-AW	0.00	0.00	0.00	32.91	0.00	20.35	0.75	0.00	0.00
B-AX	0.00	0.00	0.00	3.45	0.00	0.80	0.00	0.00	1.06
B-AY	0.00	0.00	0.00	4.20	0.00	2.52	0.00	0.00	1.68
B-AZ	0.00	0.00	0.00	7.81	0.00	16.52	3.30	0.00	0.00

Site Name	*Navicula bryophila*	*Navicula* cf. *gallica*	*Navicula cryptocephala*	*Navicula crypototenella*	*Navicula jaernefeltii*	*Navicula pseudoscutiformis*	*Navicula pupula* var. *pupula*	*Navicula salinarum*
BC	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.50
BD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BE	0.00	0.00	0.62	0.00	0.00	0.00	0.00	0.00
BF	0.00	0.00	1.96	0.00	0.00	0.00	0.00	0.65
BG	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.39
BH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BJ	0.00	0.00	1.31	0.00	0.00	0.00	0.00	0.00
BK	0.00	0.00	0.00	0.00	0.00	0.65	0.00	1.95
BM	0.00	0.00	0.00	0.00	0.00	0.59	0.00	0.00
BN	1.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BT	4.40	0.00	0.00	0.00	0.00	0.00	0.00	0.63
BU	0.00	0.00	0.00	0.00	1.29	1.29	0.00	0.65
BV	0.63	0.00	0.63	0.00	0.00	0.00	0.00	0.00
BW	0.00	0.00	0.64	0.00	0.00	0.00	0.00	0.00
BX	0.00	0.00	2.74	0.00	0.00	0.00	0.00	0.30
BZ	0.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00
BAC	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BAD	0.00	0.00	0.00	0.00	0.00	5.63	0.00	0.00
BAE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BAG	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BAH	1.90	0.00	7.03	0.00	0.00	0.00	0.00	0.00
BAI	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.00
BAJ	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.63
BAK	0.00	0.00	0.59	0.00	4.42	0.00	0.00	0.95
BAL	0.59	0.00	0.00	0.00	0.00	0.59	0.00	0.00
BAM	1.24	0.00	6.19	0.00	0.31	0.00	0.00	1.86
BAN	0.65	0.00	0.00	0.00	0.00	0.65	0.00	1.30
B-AO	0.00	0.00	0.00	0.00	0.00	0.00	1.86	0.00
B-AP	0.00	0.00	0.00	0.00	0.00	0.00	1.84	0.00
B-AR	0.00	48.65	3.59	0.00	0.00	0.00	0.00	0.00
B-AS	0.00	1.33	0.27	4.52	0.00	0.00	0.53	0.00
B-AT	0.00	1.85	0.74	2.21	0.37	0.00	0.00	0.00
B-AU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B-AV	0.00	1.28	0.00	0.00	0.00	0.00	0.00	0.00
B-AW	0.00	0.25	1.26	0.00	0.00	0.00	0.00	0.00
B-AX	0.00	1.06	0.00	6.90	0.00	0.80	0.53	0.00
B-AY	0.00	15.97	0.00	3.36	0.00	13.45	5.32	0.00
B-AZ	0.00	4.80	0.00	0.30	0.00	3.00	0.00	0.00

Site Name	*Navicula soehrensis*	*Navicula* sp. 2	*Navicula vulpina*	*Neidium umiatense*	*Nitzschia alpina*	*Nitzschia frustulum*	*Nitzschia inconspicua*	*Nitzschia palea*	*Nitzschia perminuta*	*Nitzschia perminuta* T1
BC	0.50	1.51	0.25	0.00	0.00	2.01	1.01	0.00	1.01	1.51
BD	0.34	0.00	2.39	0.00	0.00	1.71	0.00	0.00	0.34	0.00
BE	1.24	0.00	0.62	0.00	0.00	1.24	1.24	0.31	0.00	0.00
BF	0.65	0.00	0.00	8.17	0.00	0.00	0.00	0.00	0.00	0.00
BG	0.00	0.00	0.00	1.37	1.37	1.37	0.68	4.10	0.68	1.71
BH	0.00	0.00	0.00	9.09	9.09	0.00	0.00	0.00	0.00	0.00
BJ	0.66	0.00	0.33	0.00	4.59	9.84	1.64	0.00	5.25	13.77
BK	0.00	0.00	1.63	0.00	0.00	1.30	0.65	0.00	1.95	0.00
BM	0.00	0.00	0.00	0.00	0.00	2.94	0.00	0.00	0.59	1.76
BN	0.00	0.00	0.65	0.00	0.00	0.65	0.00	0.00	1.31	0.00
BP	0.00	0.00	0.00	0.00	0.00	9.97	0.00	0.00	26.05	2.57
BR	0.00	0.00	0.00	0.00	1.93	30.87	0.00	0.00	8.36	1.29
BT	0.00	2.52	0.00	5.97	3.77	8.18	11.64	1.26	2.52	15.09
BU	0.00	0.00	0.00	0.00	0.65	7.74	2.58	0.65	5.16	2.58
BV	0.00	0.00	0.00	0.00	0.00	2.53	0.00	0.63	3.16	1.90
BW	0.00	0.00	1.92	0.00	0.00	6.71	0.00	1.92	3.83	1.28
BX	0.00	0.00	2.44	0.61	2.13	2.74	1.22	0.00	9.45	5.18
BZ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	3.33
BAC	0.00	0.00	1.57	0.00	0.63	2.52	0.00	0.00	3.77	3.14
BAD	0.00	0.00	2.50	0.00	0.00	3.13	0.63	0.63	0.63	0.63
BAE	0.00	1.26	0.63	0.00	0.00	0.00	0.00	0.00	1.26	1.89
BAG	0.00	0.65	0.00	0.65	0.65	4.85	0.00	0.65	12.62	5.18
BAH	5.38	0.00	0.00	0.00	1.27	1.27	0.00	0.00	7.59	0.63
BAI	1.28	0.00	4.79	0.00	2.56	7.03	0.00	0.00	7.03	0.64
BAJ	0.00	0.00	0.00	0.00	0.00	3.13	3.76	0.00	1.88	5.02
BAK	0.00	0.00	0.63	0.00	0.00	0.63	0.00	0.00	1.26	2.52
BAL	0.00	0.00	0.00	0.00	0.00	1.18	2.36	0.59	1.18	1.77
BAM	0.00	0.00	0.31	0.00	0.00	3.41	0.00	1.24	1.24	1.24
BAN	0.00	2.61	1.30	1.30	2.61	5.86	1.95	3.26	9.77	7.17
B-AO	0.00	0.00	10.96	0.00	0.00	9.32	16.78	0.23	0.00	0.00
B-AP	0.00	0.00	5.10	0.00	0.00	12.04	19.18	0.41	4.69	0.00
B-AR	0.00	0.00	0.00	0.00	0.00	13.45	0.90	0.00	6.95	0.00
B-AS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.33	0.00
B-AT	0.00	0.00	0.00	0.00	0.00	36.90	1.11	1.48	0.74	0.00
B-AU	0.00	0.00	2.39	0.00	0.00	1.06	0.00	0.00	0.00	0.00
B-AV	0.00	0.00	0.64	0.00	0.00	0.64	0.00	0.00	7.07	0.00
B-AW	0.00	0.00	0.00	0.00	2.01	19.60	2.01	0.00	2.26	0.00
B-AX	0.00	0.00	0.27	0.00	1.33	11.41	20.16	0.80	2.92	0.00
B-AY	0.00	0.00	1.12	0.00	0.00	11.48	0.00	0.84	1.12	0.00
B-AZ	0.00	0.00	0.00	0.00	0.00	14.41	20.72	2.40	0.60	0.00

Site Name	*Pinnularia balfouriana*	*Pinnularia digerntissima*	*Pinnularia interupta*	*Pinnularia subrostrata*	*Stauroneis anceps*	*Tabellaria flocculosa*
BC	28.39	0.00	0.00	0.75	1.01	0.00
BD	0.34	0.00	0.00	0.00	1.71	0.00
BE	0.00	0.00	0.00	0.00	0.00	0.00
BF	0.00	0.00	0.00	0.00	0.65	0.00
BG	10.92	0.00	0.00	1.37	0.68	0.00
BH	0.00	0.00	0.00	9.09	0.00	0.00
BJ	1.31	0.00	0.00	0.00	0.00	0.00
BK	2.28	0.00	0.00	0.65	0.00	0.00
BM	55.59	0.00	0.00	0.00	0.00	0.00
BN	58.50	0.00	0.00	1.31	0.00	0.00
BP	0.00	0.00	0.00	0.00	0.00	0.00
BR	0.00	0.00	0.00	0.00	0.00	0.00
BT	0.00	0.00	0.00	0.00	0.00	0.00
BU	4.19	0.00	0.00	0.32	0.00	0.00
BV	0.00	0.00	0.00	0.63	0.00	0.00
BW	0.00	0.00	0.00	2.56	0.00	0.00
BX	0.00	0.00	0.00	0.00	0.00	0.00
BZ	6.67	0.00	0.00	5.00	0.00	0.00
BAC	0.00	0.00	0.00	0.00	0.00	0.00
BAD	7.19	0.00	0.00	1.25	1.25	0.00
BAE	26.73	0.00	0.00	0.31	0.00	0.00
BAG	7.77	0.00	0.00	0.00	0.65	0.00
BAH	0.00	0.00	0.00	0.32	0.00	0.00
BAI	0.00	0.00	0.00	0.00	1.28	0.00
BAJ	12.23	0.00	0.00	0.00	0.00	0.00
BAK	13.88	0.00	0.00	0.00	0.63	0.00
BAL	11.21	0.00	0.00	0.00	1.18	0.00
BAM	31.89	0.00	0.00	0.00	0.00	0.00
BAN	0.00	0.00	0.00	3.26	0.00	0.00
B-AO	0.00	0.23	0.00	0.00	0.00	0.00
B-AP	0.00	0.00	0.00	0.00	0.00	0.00
B-AR	0.00	0.45	1.12	0.00	0.00	0.00
B-AS	0.00	0.00	3.72	0.00	0.00	11.44
B-AT	0.00	0.00	0.00	0.00	0.00	0.00
B-AU	0.00	0.00	0.00	0.00	0.00	0.00
B-AV	0.00	0.00	0.00	0.00	0.00	0.00
B-AW	0.00	1.01	0.00	0.00	0.00	12.06
B-AX	0.00	0.00	0.00	0.00	0.00	0.00
B-AY	0.00	1.68	0.00	0.00	0.00	0.00
B-AZ	0.00	0.60	0.00	0.00	0.00	2.70

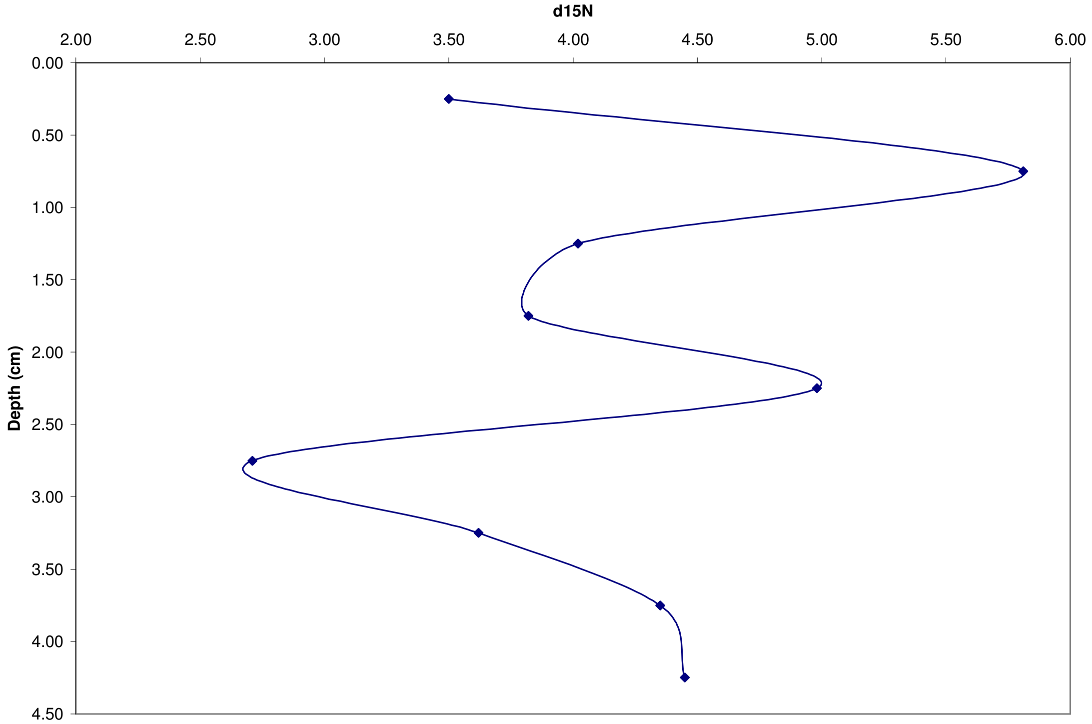
Appendix 4. List of all Environmental variables measured for the Bathurst Island calibration se an d the transformation applied to each.

	Ca	Mg	Na	K	SO4	Cl	Al	Ba	Fe	Li	Mn	Mo
B-AO	11.3	2.256	0.806	-0.569	-0.387	1.107	-1.854	0.190	-0.863	*0.0001*	-2.670	0.000285
B-AP	10.9	2.245	0.701	-0.432	-0.292	0.974	-1.611	0.237	-0.801	0.0004	-2.562	0.000199
B-AQ	15.1	2.494	1.149	-0.229	0.255	1.519	-2.398	0.245	-1.943	0.0004	-3.284	0.000229
B-AR	0.8	0.529	-0.377	-0.569	-0.432	-0.237	-0.592	0.062	-0.493	0.0003	-2.288	*0.000003*
B-AS	0.2	0.316	-0.387	-1.097	-0.276	-0.149	-1.421	0.054	-1.183	*0.0001*	-2.166	*0.000003*
B-AT	0.4	0.600	-0.046	-0.678	-0.319	0.225	-1.107	0.038	-1.007	0.0002	-2.714	*0.000003*
B-AU	10.9	3.975	2.017	0.968	0.680	2.265	-1.372	0.106	-1.114	0.0031	-2.148	0.000091
B-AV	6.3	1.503	0.822	-0.337	-0.119	1.072	-0.793	0.041	-0.611	0.0005	-2.854	0.000027
B-AW	0.3	0.566	-0.398	-0.638	-0.432	-0.187	-0.740	0.036	-0.526	0.0002	-2.318	0.000005
B-AX	9.6	2.313	1.201	-0.009	-0.201	1.507	-1.860	0.079	-0.907	0.0021	-2.514	0.000079
B-AY	23.9	2.400	0.769	0.053	0.547	0.865	-0.876	0.349	-0.278	0.0025	-1.845	0.001190
B-AZ	1.6	0.671	-0.509	-0.745	-0.357	-0.260	-0.767	0.051	-0.521	0.0004	-2.336	0.000005
BC	36.6	2.828	0.663	-0.222	0.690	0.929	-2.301	0.258	-1.921	0.0010	-2.886	0.001000
BD	43.2	4.347	0.591	-0.222	0.322	0.854	-2.301	0.273	-0.622	0.0040	-2.092	0.001000
BE	43.9	3.847	0.785	-0.301	0.591	1.111	-2.301	0.292	-0.614	0.0030	-2.357	0.001000
BF	9.2	2.025	-0.155	-1.000	-0.222	0.064	-2.301	0.069	-1.824	0.0010	-3.155	*0.000500*
BG	24.7	1.304	0.041	-0.398	0.663	0.253	-1.699	0.126	-1.319	0.0020	-2.509	0.002000
BH	19.4	1.549	0.146	-0.301	0.826	0.170	-2.301	0.082	-1.745	0.0020	-2.721	0.001000
BI	35.9	2.387	0.778	-0.046	0.908	0.977	-2.301	0.259	-1.585	0.0040	-2.292	*0.000500*
BJ	35.1	2.608	0.756	0.114	0.833	1.000	-2.301	0.238	-1.420	0.0040	-2.229	0.001000
BK	53.3	3.240	0.792	0.114	1.199	1.021	-0.027	0.345	0.384	0.0080	-1.099	0.001000
BL	29.9	1.673	0.279	-0.398	0.763	0.520	-1.699	0.162	-1.222	0.0020	-2.377	*0.000500*
BM	29.1	2.121	0.556	-0.301	0.556	0.733	-2.301	0.292	-1.276	0.0020	-2.420	*0.000500*
BN	28.8	2.168	0.505	-0.301	0.681	0.751	-1.699	0.271	-1.194	0.0020	-2.456	0.001000
BO	27.1	1.612	-0.097	-1.000	0.146	0.164	-2.301	0.075	-2.097	0.0010	-2.796	*0.000500*
BP	33.0	2.098	0.114	-0.699	0.230	0.377	-2.000	0.133	-1.284	0.0020	-1.971	0.001000
BQ	28.9	2.049	0.079	-0.699	0.342	0.405	-2.000	0.127	-1.678	0.0020	-3.000	0.002000
BR	29.1	2.000	0.000	-1.000	-0.097	0.276	-2.301	0.095	-1.509	0.0010	-3.046	0.003000
BS	34.5	0.949	0.041	-0.699	0.000	0.354	-2.301	0.125	-1.959	0.0020	-3.046	*0.000500*
BT	25.6	1.449	-0.046	-1.000	-0.097	0.260	-2.301	0.115	-1.469	0.0020	-3.301	*0.000500*
BU	21.9	2.864	0.799	-0.523	0.580	1.029	-0.721	0.256	0.107	0.0020	-1.971	0.001000
BV	23.1	2.898	0.813	-0.699	0.839	1.004	-1.699	0.209	-0.442	0.0020	-2.432	0.001000
BW	26.9	2.983	0.716	-0.523	0.380	0.993	-1.398	0.210	-0.604	0.0010	-2.456	0.001000
BX	26.4	2.720	0.813	-0.523	0.568	1.009	-2.301	0.227	-0.987	0.0020	-2.745	0.001000
BY	24.2	2.490	0.806	-0.301	0.544	1.182	-1.000	0.327	-0.418	0.0020	-2.194	0.002000
BZ	33.8	2.933	0.898	-0.046	0.699	1.281	-0.538	0.418	-0.111	0.0040	-1.971	0.002000
BAA	30.1	1.789	-0.046	-0.699	0.716	0.340	-2.301	0.181	-1.770	0.0010	-3.046	*0.000500*
BAB	37.6	2.191	0.041	-0.523	1.017	0.358	-2.301	0.187	-1.770	0.0020	-3.602	0.001000
BAC	41.8	2.280	0.176	-0.398	1.270	0.452	-2.000	0.362	-1.398	0.0010	-2.770	0.002000
BAD	19.9	2.280	0.462	-0.301	0.398	0.668	-1.046	0.140	0.149	0.0020	-1.759	*0.000500*
BAE	32.0	1.703	0.176	-0.699	0.845	0.458	-2.301	0.198	-1.538	0.0010	-2.770	0.001000
BAF	26.2	1.761	0.146	-0.523	0.892	0.396	-2.301	0.171	-1.337	0.0020	-3.046	0.001000
BAG	28.3	1.612	0.176	-0.699	0.845	0.459	-2.301	0.184	-1.377	*0.0005*	-3.155	*0.000500*
BAH	33.8	2.470	0.204	-0.523	1.210	0.294	-1.398	0.158	-1.180	0.0030	-2.854	*0.000500*
BAI	38.0	2.627	0.255	-0.398	1.342	0.452	-2.301	0.178	-1.367	0.0020	-3.097	0.001000
BAJ	43.7	2.793	0.505	-0.046	1.272	0.649	-2.301	0.401	-0.857	0.0030	-2.367	0.003000
BAK	15.7	1.449	0.041	-0.699	0.447	0.146	-2.301	0.237	-1.018	0.0020	-2.481	0.001000
BAL	36.7	2.387	0.398	-0.301	1.134	0.542	-2.301	0.348	-1.102	0.0010	-2.678	0.003000
BAM	28.6	1.643	0.519	-0.523	0.380	0.931	-2.000	0.296	-1.456	0.0010	-2.770	0.001000
BAN	33.1	1.975	0.447	-0.523	0.556	0.719	-2.000	0.237	-0.854	0.0010	-2.770	*0.000500*
Transformation	None	sqrt	log (x)	log (x)	log (x)	log (x)	log (x)	sqrt	log (x)	none	log (x)	none

	POC*	PON	Temp	pH	Cond	TN	Lat °N	Long °W	Elev
BC	347.9	1.114	11.0	8.2	14.526	2.623758	75 03.74	97 59.74	1.964
BD	679.7	1.591	19.5	8.4	16.793	2.996349	75 04.63	98 02.96	1.491
BE	695.7	1.623	19.5	8.3	16.613	3.008878	75 04.63	98 02.96	1.491
BF	392.4	0.954	16.5	8.3	8.307	2.516724	75 08.25	98 28.94	1.342
BG	357.8	0.845	4.0	8.1	10.536	2.559564	75 27.43	99 26.67	1.342
BH	286.4	0.903	10.0	8.0	10.440	2.428055	75 27.16	99 32.12	2.090
BJ	473.3	1.342	18.0	8.4	14.526	2.854154	75 37.64	99 38.30	0.000
BK	1100.0	2.068	16.0	8.1	16.310	2.872563	75 78.63	99 20.20	1.964
BM	450.6	1.279	3.5	8.2	11.790	2.679312	75 08.26	97 47.42	0.000
BN	366.1	1.041	5.0	8.1	11.446	2.62425	75 08.26	97 47.42	0.000
BP	608.3	1.643	9.0	8.3	11.705	2.941624	75 19.02	98 50.58	2.526
BR	705.0	1.732	8.5	8.3	11.446	2.885887	75 19.02	98 50.58	2.526
BT	389.9	1.255	6.0	8.2	10.583	2.472554	75 31.42	98 11.90	1.792
BU	1334.2	2.292	7.5	8.1	12.329	2.97215	75 38.79	98 05.65	1.491
BV	925.7	1.964	9.0	8.2	12.649	2.94882	75 39.14	98 02.59	2.185
BW	527.3	1.415	13.0	8.3	13.266	3.029477	75 39.14	98 02.59	2.185
BX	595.8	1.653	9.5	8.3	12.961	2.893777	75 39.14	98 02.59	2.185
BZ	1195.8	2.127	7.0	8.2	14.663	2.810862	75 43.25	98 40.68	0.000
BAC	503.0	1.255	8.0	8.3	14.142	2.781926	75 56.66	99 04.76	2.090
BAD	833.1	1.857	9.0	8.3	11.314	2.873797	75 36.01	97 50.99	0.000
BAE	469.0	1.362	4.0	8.3	11.832	2.550361	76 23.18	98 52.05	1.792
BAG	447.2	1.322	8.0	8.4	11.619	2.521915	76 23.18	98 52.05	1.792
BAH	473.3	1.114	9.0	8.5	10.488	2.764197	76 23.18	98 52.05	1.792
BAI	586.5	1.491	10.5	8.5	14.000	2.781906	76 23.18	98 52.05	1.792
BAJ	640.3	1.633	12.0	8.6	14.697	2.961506	76 39.52	98 52.82	2.090
BAK	515.8	1.477	5.0	8.3	9.381	2.617497	76 39.52	98 52.82	2.090
BAL	630.9	1.602	12.0	8.5	13.153	2.871322	76 39.52	98 52.82	2.090
BAM	474.3	1.204	5.0	8.3	12.207	2.579973	76 30.14	98 10.05	1.792
BAN	725.3	1.732	8.0	8.5	13.000	2.75801	76 30.14	98 10.05	1.792
B-AO	810.56	1.851	7.0	8.1	9.220	2.890655	75 29.047	97 28.150	1.362
B-AP	915.42	1.857	7.0	7.8	9.000	2.858123	75 29.073	97 28.138	1.380
B-AR	560.36	0.954	6.0	7.0	3.162	2.589756	75 47.953	101 50.300	2.186
B-AS	713.44	1.708	6.0	6.9	2.236	2.486996	75 44.249	100 55.285	2.090
B-AT	493.96	1.114	1.5	6.8	3.162	2.43767	75 40.130	102 29.006	2.090
B-AU	485.80	1.114	9.0	8.3	22.583	2.827964	75 46.360	102 38.733	1.211
B-AV	544.06	1.230	9.5	7.8	7.746	2.768082	76 04.127	102 50.749	1.211
B-AW	504.98	1.204	9.0	7.3	3.317	2.423081	76 12.861	103 01.865	2.140
B-AX	658.03	1.613	7.5	8.1	11.180	2.824041	76 21.316	103 16.055	1.498
B-AY	1679.29	2.449	13.0	8.4	11.619	3.10513	76 22.868	100 29.540	1.792
B-AZ	629.29	1.653	2.0	7.3	3.606	2.573957	76 12.483	99 52.542	2.265
	sqrt	log (x)	none	none	sqrt	log (x)			log (x+1)

	Ni	Sr	Zn	SiO2	DOC	DIC	SRPF	NH_	TKN	TPU	TPF	ChlaU
BC	0.032	-1.114	0.071	-0.824	0.519	26.2	1.049	-2.602	-0.801	0.857	5.9	-0.699
BD	0.032	-1.231	0.045	0.670	1.049	39.9	1.265	-2.222	-0.047	1.146	10.0	-0.046
BE	0.032	-1.162	0.032	0.526	1.029	35.8	0.949	-1.699	-0.023	1.064	10.0	-0.301
BF	0.032	-2.284	0.084	-0.745	0.398	9.3	1.183	-2.602	-1.004	1.243	3.8	-0.046
BG	0.045	-1.015	0.045	-0.638	0.176	14.3	1.000	-2.602	-0.910	0.740	4.3	-0.398
BH	0.032	-1.088	0.032	-0.824	0.230	11.8	1.183	-2.602	-1.187	0.519	3.6	-1.301
BJ	0.045	-0.747	0.089	-0.398	0.763	23.7	1.000	-2.222	-0.325	0.845	5.4	0.114
BK	0.084	-0.371	0.118	0.326	0.763	29.2	1.049	-2.602	-0.410	1.806	8.8	-1.000
BM	0.063	-1.202	0.122	-0.886	0.415	19.2	1.095	-2.301	-0.686	0.898	2.8	-1.301
BN	0.032	-1.253	0.077	-0.310	0.279	18.9	0.949	-2.602	-0.785	0.681	3.1	-1.301
BP	0.055	-1.520	0.055	-1.301	0.826	20.9	1.095	-1.886	-0.167	1.179	8.6	-1.301
BR	0.032	-1.388	0.084	-1.222	0.771	20.1	1.342	-1.959	-0.298	1.238	11.5	-0.398
BT	0.032	-1.672	0.045	-0.357	0.230	15.8	1.049	-2.602	-1.125	0.568	3.9	-0.155
BU	0.095	-1.499	0.077	-0.071	0.792	18.8	1.183	-2.301	-0.265	1.582	9.4	0.531
BV	0.032	-1.572	0.032	-0.041	0.813	18.8	1.225	-2.155	-0.203	1.146	6.9	-0.097
BW	0.032	-1.551	0.032	-0.854	1.037	21.7	1.183	-1.770	0.033	0.940	6.5	-0.699
BX	0.032	-1.461	0.032	-0.208	0.690	19.7	2.074	-2.602	-0.287	0.991	5.6	-0.097
BZ	0.055	-1.020	0.063	-0.301	0.568	22.1	1.517	-2.602	-0.588	1.657	9.0	0.204
BAC	0.071	-0.893	0.055	-0.066	0.580	22.5	1.342	-2.222	-0.470	0.602	10.5	0.041
BAD	0.032	-1.648	0.170	0.318	0.708	15.1	1.183	-2.301	-0.347	1.447	11.5	0.301
BAE	0.032	-0.600	0.022	-0.678	0.255	18.3	1.183	-1.886	-0.971	0.681	4.3	0.114
BAG	0.032	-0.668	0.045	-0.824	0.204	15.9	1.183	-2.301	-1.027	0.763	5.4	0.230
BAH	0.032	-0.548	0.032	-0.260	0.505	19.7	1.183	-1.959	-0.499	1.179	4.4	0.204
BAI	0.032	-0.455	0.063	-0.051	0.580	21.2	1.183	-2.046	-0.489	0.881	4.5	0.398
BAJ	0.055	-0.815	0.130	0.049	0.839	26.6	1.183	-1.456	-0.124	1.204	8.8	0.204
BAK	0.063	-1.455	0.063	-0.824	0.342	10.1	1.183	-2.155	-0.842	0.987	4.3	-1.301
BAL	0.055	-0.975	0.071	-0.180	0.681	22.2	1.183	-2.155	-0.312	0.982	4.6	-0.097
BAM	0.055	-1.389	0.071	-0.699	0.255	16.4	1.183	-2.301	-0.889	0.863	1.7	-1.301
BAN	0.063	-1.495	0.045	-0.119	0.431	20.2	1.183	-2.222	-0.578	1.090	3.6	-0.523
B-AO	0.009	-1.780	0.023	-0.921	0.799	10.4	0.632	-2.222	-0.314	1.188	5.9	0.041
B-AP	0.016	-1.824	0.028	-0.770	0.672	10.7	0.632	-2.097	-0.387	1.170	3.8	0.041
B-AR	0.026	-2.730	0.039	-0.174	0.653	1.5	1.049	-2.155	-0.857	0.968	5.5	0.000
B-AS	0.013	-2.917	0.022	-0.721	0.204	0.6	0.316	-1.678	-1.229	0.833	1.1	0.301
B-AT	0.018	-2.703	0.023	-1.301	0.279	1.1	0.316	-2.000	-1.222	1.068	1.6	0.176
B-AU	0.018	-1.012	0.021	-0.824	0.643	14.2	0.837	-1.721	-0.372	1.009	6.1	-1.301
B-AV	0.026	-1.611	0.030	-0.481	0.914	5.3	0.632	-1.854	-0.502	0.813	**3.8**	-1.301
B-AW	0.024	-2.827	0.037	-0.678	0.380	1	0.316	-2.155	-1.229	0.959	3.2	-0.046
B-AX	0.020	-1.378	0.022	-0.569	0.813	8.7	0.707	-1.959	-0.417	0.954	5	-0.301
B-AY	0.037	-1.199	0.060	-1.155	1.179	18.8	1.000	-1.569	-0.013	1.430	7.7	0.845
B-AZ	0.023	-2.644	0.031	-0.770	0.531	1.9	0.316	-2.097	-0.987	0.987	2.9	0.146
	sqrt	log (x)	sqrt	log (x)	log (x)	none	sqrt	log (x)	log (x)	log (x)	none	log (x)

Appendix 5. Skraeling Island geochemistry data



Appendix 6. All diatoms species and relative abundances from pond B-AO

Depth(cm)	Depth Midpoint (cm)	*Achnanthes minutissima*	*Achnanthes minutissima*	*Achnanthes sp. 1*	*Achnanthes sp. 2*	*Achnanthes sp. 6*	*Achnanthes suchlandtii*	*Amphora cf. pediculus*	*Amphora libyca*	*Amphora libyca 3*	*Amphora sp. 1*	*Amphora sp. 2*
0.0 - 0.5	0.25	19.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00
0.5 - 1.0	0.75	18.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.19	0.00
1.0 - 1.5	1.25	14.99	0.00	0.25	0.25	0.00	0.00	0.49	0.25	0.00	0.49	0.00
1.5 - 2.0	1.75	22.72	0.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.00
2.0 - 2.5	2.25	20.77	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.30	0.00
2.5 - 3.0	2.75	25.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00
3.0 - 3.5	3.25	22.02	0.00	0.00	0.61	0.00	0.00	0.00	0.00	0.00	0.00	1.83
3.5 - 4.0	3.75	27.02	0.00	0.23	0.92	0.00	0.00	0.00	0.46	0.00	0.69	0.00
4.0 - 4.5	4.25	16.92	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.60	1.21
4.5 - 5.0	4.75	8.08	0.00	0.00	0.00	0.00	0.00	3.03	0.00	0.00	0.67	0.00
5.0 - 5.5	5.25	14.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.64
5.5 - 6.0	5.75	13.86	0.00	0.00	0.29	0.00	0.00	0.00	0.29	0.00	0.59	0.00
6.0 - 6.5	6.25	15.73	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.45
6.5 - 7.0	6.75	11.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.22	1.71
7.0 - 7.5	7.25	15.51	0.00	0.00	0.00	0.32	0.32	0.00	0.00	0.00	0.00	0.00
7.5 - 8.0	7.75	16.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.0 - 8.5	8.25	6.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.00	0.00

Asterionella sp. 2	*Caloneis sp. 1*	*Cocconeis placentula*	*Cocconeis placentula2*	*Cyclotella bodanica*	*Cyclotella bodanica var. bodanica*	*Cyclotella bodanica var. lemanica*	*Cyclotella krammerii*	*Cyclotella rossii*	*Cyclotella sp. 1*	*Cyclotella stelligera*	*Cymbella arctica*	*Cymbella fragment (unIDable)*	*Cymbella proxima*	*Cymbella silesiaca*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.60	0.00	1.20
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.89	0.00	0.30	0.00
0.00	0.00	0.00	0.00	1.47	0.00	0.00	0.00	0.00	0.00	0.25	0.98	0.00	0.00	0.25
0.47	0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.94	0.00	0.00	0.47
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.97	0.00	0.30	0.00
0.00	0.51	0.00	0.00	0.00	0.00	0.00	0.26	0.26	0.00	0.00	1.80	0.00	0.00	0.51
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.83	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.85	0.00	0.00	0.23
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.60	0.00	0.30	0.00
0.00	0.00	0.00	0.00	0.00	1.01	0.00	0.00	0.00	0.34	0.00	0.34	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.23	0.47	0.00	0.00	0.47	0.00	3.04	0.00	0.00	0.23
0.00	0.00	0.29	0.00	0.00	0.00	0.29	0.00	0.00	0.29	0.00	1.18	0.00	0.00	0.88
0.00	0.22	0.00	0.00	0.00	0.45	0.00	0.00	0.00	0.22	0.00	0.22	0.00	0.00	0.22
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49	0.00	0.00	0.00	1.47	0.00	0.00	0.24
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	1.27	0.00	0.00	0.63
0.00	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.00	0.00	0.60

Cymbella silesiaca 2	*Cymbella sp. 1*	*Cymbella sp. 2*	*Cymbella sp. 3*	*Cymbella sp. 4*	*Denticula sp. 1*	*Diatoma moniliformis*	*Diatoma moniliformis2*	*Diatoma moniliformis girdle*	*Diatoma tenuis*	*Eunotia sp. 1*	*Eunotia sp. 1 ends*	*Fragilaria ALL (10 species)*	*Fragilaria brevistriata*	*Fragilaria capucina var. capucina*
0.30	1.20	0.30	0.00	0.00	0.00	5.11	5.11	7.51	1.20	0.00	0.00	22.52	0.00	1.20
0.00	1.48	0.89	0.00	0.00	0.00	3.56	3.56	7.72	0.89	0.00	0.00	18.40	0.00	0.00
0.74	3.19	1.47	0.00	0.00	0.00	1.23	1.23	5.65	0.49	0.00	0.00	14.25	0.00	11.06
0.00	4.22	2.34	0.00	0.00	0.00	0.00	0.00	5.15	0.70	0.00	0.00	12.88	0.00	7.03
0.00	4.15	2.37	0.00	0.00	0.00	1.19	1.19	2.37	1.19	0.00	0.00	12.76	1.48	3.26
0.00	4.37	2.06	0.00	0.00	0.00	1.03	1.03	3.86	0.00	0.00	0.00	12.85	0.00	5.91
0.00	3.06	1.83	0.00	0.00	0.00	0.00	0.00	5.50	0.00	0.00	0.00	10.40	0.00	2.75
0.00	5.08	1.15	0.00	0.00	0.00	0.00	0.00	3.23	0.23	0.23	0.46	10.62	0.00	1.85
0.00	3.02	2.11	0.60	0.00	0.00	0.00	0.00	0.60	0.30	0.30	0.00	7.25	0.00	0.00
0.00	4.04	1.68	0.00	0.00	0.00	0.00	0.00	2.02	0.00	0.34	0.00	8.08	0.00	0.00
0.00	2.34	1.17	0.00	0.00	0.00	0.23	0.23	3.75	0.94	0.00	0.00	8.90	0.00	2.34
0.00	2.95	1.18	0.00	0.00	0.00	2.95	2.95	1.18	0.00	0.00	0.00	12.09	0.00	1.18
0.00	3.15	1.57	0.00	0.00	0.00	0.90	0.90	4.94	0.00	0.00	0.00	11.69	0.22	1.35
0.00	3.18	0.49	0.24	0.00	0.00	0.49	0.49	3.91	0.49	0.24	0.00	9.78	0.24	1.96
0.00	2.22	1.58	0.00	0.00	0.00	0.00	0.00	4.75	0.00	0.00	0.00	9.18	0.00	2.53
0.00	4.78	2.39	0.00	0.48	0.00	3.83	3.83	0.48	0.48	0.00	0.00	16.75	0.00	0.00
0.00	1.20	0.60	0.00	0.00	1.20	4.82	6.02	13.25	0.00	0.00	0.00	27.71	0.00	1.81

Fragilaria capucina var. capucina (GIRDLE)	*Fragilaria capucina var. gracilis*	*Fragilaria capucina var. vaucheriae*	*Fragilaria construens f. binodis*	*Fragilaria construens f. venter*	*Fragilaria girdle (cf. const or cap v. var??)*	*Fragilaria girdle 2*	*Fragilaria girdle 3*	*Fragilaria pinnata*	*Fragilaria pinnata*	*Fragilaria sp. 3*	*Fragilaria ulna var. acus*	*Frustulia sp. 1*	*Gomphonema sp. 1*
0.00	3.00	2.70	0.00	4.80	3.00	4.20	0.00	0.60	0.00	0.00	0.00	0.00	0.00
0.00	0.30	0.30	0.00	10.68	0.00	6.53	0.00	4.75	0.00	0.00	0.00	0.00	0.59
0.00	0.00	0.00	0.00	5.41	0.00	4.18	0.00	2.46	5.90	0.00	0.25	0.00	0.25
0.00	0.47	6.56	0.00	0.00	0.94	0.00	0.00	2.11	1.87	0.00	0.00	0.00	0.23
0.00	0.89	2.97	0.00	1.19	12.46	0.00	0.00	2.97	0.00	0.00	0.00	0.00	0.00
0.00	0.00	3.60	0.00	1.03	12.85	0.00	0.00	2.06	0.00	0.00	0.00	0.00	0.00
0.00	0.92	1.53	0.00	4.28	7.03	0.00	0.00	6.42	0.00	0.00	0.00	0.00	0.31
0.00	0.00	0.92	0.00	5.31	2.31	0.00	0.46	1.15	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.30	0.30	4.83	6.34	0.00	0.00	2.42	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	2.02	5.72	0.00	1.35	18.52	0.00	0.00	0.00	0.34	0.00
0.00	0.94	0.94	0.00	2.34	9.37	0.00	0.47	8.20	0.00	0.00	0.00	0.00	0.23
0.00	0.88	0.29	0.00	3.24	7.67	0.00	1.18	5.90	0.00	0.00	0.00	0.00	0.00
0.00	0.22	1.80	0.00	3.15	12.36	0.00	3.60	5.62	0.00	0.22	0.00	0.00	0.22
0.00	0.98	1.47	0.00	3.67	7.33	0.00	0.49	11.25	0.00	0.00	0.00	0.00	0.00
0.00	0.32	0.32	0.00	2.85	15.19	0.00	0.00	2.53	0.00	0.00	0.00	0.32	0.00
3.83	1.91	0.48	0.00	2.39	3.83	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.00
0.00	1.20	1.81	0.00	5.42	7.23	0.00	1.81	3.01	0.00	0.00	0.00	0.00	0.00

Navicula cryptocephala	*Navicula pupula var. pupula*	*Navicula radiosa*	*Navicula reinhardtii*	*Navicula sp. 1*	*Navicula sp. 11*	*Navicula sp. 1B*	*Navicula sp. 2*	*Navicula sp. 3*	*Navicula sp. 6*	*Navicula tenera*	*Navicula tuscula*	*Navicula veneta*	*Neidium ampliatum*	*Nitzschia complex*	*Nitzschia frustulum*
0.60	0.90	7.21	2.70	0.30	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.30	12.01
0.30	2.08	8.31	0.30	0.00	0.00	0.30	0.30	0.00	0.00	0.00	0.00	0.30	0.30	0.89	11.87
0.00	1.97	5.90	0.74	1.97	0.00	0.49	0.25	0.00	0.00	0.49	0.00	0.00	0.25	0.98	8.35
0.47	2.11	10.54	0.47	0.23	0.00	0.00	0.23	0.00	0.00	0.00	0.94	0.00	0.00	1.17	6.32
0.00	2.08	11.28	0.30	0.59	0.00	0.59	0.00	0.30	0.00	0.30	0.30	0.00	0.30	1.19	5.93
0.77	2.57	7.97	0.00	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.00	1.03	1.54	5.91
0.61	2.45	15.29	0.61	1.83	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.61	0.92	7.95
0.00	2.08	14.32	0.23	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.46	0.69	7.85
0.00	3.63	28.10	0.00	0.91	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.60	0.91	3.02
0.00	1.68	21.21	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.00	1.68	2.36	2.36
0.23	1.87	15.93	0.47	1.17	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.94	0.94	3.28
0.00	0.88	18.58	0.29	0.00	0.00	0.29	0.00	0.00	0.00	0.29	0.00	0.00	0.59	0.88	5.31
0.00	1.80	10.56	0.00	0.45	0.00	0.00	0.00	0.00	0.22	0.90	0.00	0.00	0.00	1.12	4.72
0.00	1.47	9.78	1.71	0.24	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.00	0.24	8.56
0.00	1.90	15.19	2.85	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.32	0.63	7.28
0.00	1.91	10.53	0.96	0.48	0.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.48	9.57
0.00	2.41	14.46	1.20	0.60	0.00	0.00	0.00	0.00	0.00	1.20	0.00	0.00	1.81	3.01	6.02

Nitzschia sp. 1	*Nitzschia sp. 2*	*Nitzschia sp. 3*	*Nitzschia sp. 4*	*Nitzschia sp. 5*	*Pinnularia cf. interupta*	*Pinnularia intermedia*	*Stauroneis phoenicenteron*	*Stephanodiscus medius*	*Stephanodiscus min 2*	*Stephanodiscus minutulus*	*Stephanodiscus minutulus*	*Stephanodiscus minutulus*
2.10	0.30	3.60	1.50	0.90	0.00	0.30	0.30	0.00	0.00	1.50	0.00	1.80
0.00	0.59	0.00	0.59	5.64	0.00	0.00	0.30	0.00	0.00	6.23	0.00	6.53
0.25	0.00	0.00	0.49	5.90	0.00	0.00	0.25	0.25	0.00	2.95	4.67	8.11
0.00	0.00	0.00	0.23	3.75	0.00	0.00	0.70	0.00	4.45	0.23	0.00	5.39
0.00	0.00	1.19	0.00	5.64	0.00	0.00	0.59	0.00	0.00	0.59	0.00	1.19
0.00	0.51	1.03	0.00	6.17	0.26	0.00	0.00	0.00	0.00	0.77	0.00	0.77
0.00	1.22	0.00	0.31	3.67	0.00	0.00	0.61	0.00	0.00	1.22	0.00	1.83
0.00	0.00	2.31	0.00	6.00	0.00	0.00	0.69	0.00	0.00	0.69	0.00	1.39
0.00	0.00	1.21	1.51	8.46	0.00	0.00	0.60	0.00	0.00	0.91	0.00	1.51
0.00	0.00	0.00	0.00	2.36	0.00	0.00	0.34	0.00	0.00	2.69	0.00	3.03
0.00	0.47	0.94	1.41	6.79	0.00	0.00	0.47	0.00	0.00	0.70	0.00	1.17
0.00	0.00	0.00	0.59	7.96	0.00	0.00	0.29	0.00	0.00	2.95	0.00	3.24
0.00	0.00	0.90	0.00	7.87	0.22	0.00	0.00	0.00	0.00	2.02	0.00	2.02
0.00	0.00	0.00	0.49	8.31	0.00	0.00	0.49	0.00	0.00	2.69	0.00	3.18
0.00	0.00	0.00	0.00	11.08	0.95	0.00	0.32	0.00	0.00	0.32	0.00	0.63
0.00	0.00	1.91	0.00	22.01	0.00	0.00	0.48	0.00	0.00	0.00	0.00	0.48
0.00	0.00	2.41	0.00	8.43	0.00	0.00	0.60	0.00	0.00	0.00	0.00	0.60

Stephanodisus minutulus 3	*unknown 1*	*unknown 15*	*unknown 3*	*unknown 4*	*unknown 5*	*unknown 9*	*Unknown girdle 1*	*unknown girdle 2*	*unknown girdle 3*	*unknown girdle 4*	*unknown girdle 5*
0.00	0.90	0.00	0.00	0.00	0.00	0.00	1.80	1.20	3.30	0.30	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.19	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.47	0.00	0.00
0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.11	0.00	0.00
0.59	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	2.37	0.00	0.00
0.77	0.00	0.00	0.00	0.26	0.00	0.00	0.00	0.00	0.77	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.61	0.00
0.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.85	0.00	0.00
0.30	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00
2.36	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00
1.17	0.00	0.00	0.00	0.00	0.70	0.00	0.00	0.00	0.00	0.00	0.00
1.77	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.25	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.69	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.63	2.53	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.83	0.00	0.00
1.20	0.00	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.20

Appendix 7. All Diatom Taxa and relative abundances for Bathurst Island pond B-AP.

Depth(cm)	Midpoint	*Achnanthes minutissima*	*Achnanthes minutissima*	*Achnanthes sp . 2*	*Achnanthes sp. 1*	*Achnanthes sp. 10*	*Achnanthes sp. 12*	*Achnanthes sp. 6*	*Achnanthes suchlandtii*	*Amphora cf. pediculus*	*Amphora libyca*	*Amphora libyca 3*	*Amphora sp. 1*
0.0 - 0.5	0.25	20.15	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	2.46	0.00	0.00
0.5 - 1.0	0.75	15.61	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	1.46	0.00	0.00
1.0 - 1.5	1.25	15.08	0.00	0.00	0.84	0.00	0.00	0.56	0.56	0.56	0.00	0.00	0.00
1.5 - 2.0	1.75	11.92	0.00	0.00	0.27	0.00	0.00	0.54	0.00	0.00	2.17	0.00	0.00
2.0 - 2.5	2.25	17.25	0.00	0.00	0.64	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.5 - 3.0	2.75	18.94	0.00	0.00	0.62	0.00	0.00	0.93	0.00	0.00	1.55	0.00	0.00
3.0 - 3.5	3.25	16.91	0.00	0.00	0.00	0.00	0.29	0.86	0.00	0.00	2.29	0.00	0.00
3.5 - 4.0	3.75	10.71	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	1.30	0.00	0.00
4.0 - 4.5	4.25	11.34	0.00	0.00	1.26	0.00	0.00	0.76	0.00	0.50	0.00	0.00	0.00
4.5 - 5.0	4.75	10.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.00	0.00
5.0 - 5.5	5.25	12.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.65	0.00	0.00
5.5 - 6.0	5.75	11.15	0.00	0.36	0.00	0.00	0.00	0.36	0.00	0.00	0.00	0.00	0.00
6.0 - 6.5	6.25	12.66	0.00	0.44	0.00	0.00	0.00	0.87	0.00	0.00	0.87	0.00	0.00
6.5 - 7.0	6.75	9.95	0.00	4.74	0.00	0.00	0.00	0.47	0.00	0.00	1.90	0.00	0.00
7.0 - 7.5	7.25	3.08	0.00	1.03	0.00	0.00	0.00	2.05	0.00	0.00	2.05	0.00	0.00

Amphora spp. (all)	*Caloneis sp. 1*	*Cyclotella antiqua*	*Cyclotella sp. 1*	*Cyclotella stelligera*	*Cymbella arctica*	*Cymbella fragment (unIDable)*	*Cymbella minuta*	*Cymbella proxima*	*Cymbella silesiaca*
2.46	0.49	0.00	0.00	0.00	2.46	0.00	0.25	0.25	0.49
1.46	1.71	0.00	0.00	0.00	2.68	0.00	0.00	0.00	1.71
0.56	0.84	0.00	0.00	0.00	1.68	0.00	0.00	0.00	0.00
2.17	1.36	0.00	0.00	0.00	2.71	0.00	0.00	0.00	1.36
0.00	1.60	0.00	0.00	0.00	4.79	0.00	0.00	0.00	0.32
1.55	0.93	0.00	0.00	0.00	3.73	0.00	0.00	0.00	0.31
2.29	2.29	0.00	0.00	0.00	2.01	0.29	0.00	0.00	0.00
1.30	0.65	0.00	0.00	0.00	1.30	0.32	0.00	0.00	0.32
0.50	1.26	0.00	0.00	0.00	2.27	0.00	0.00	0.00	0.76
0.60	1.50	0.00	0.00	0.00	1.20	0.00	0.00	0.00	0.00
0.65	0.32	0.32	0.32	0.00	2.90	0.00	0.00	0.00	0.32
0.00	0.00	0.00	0.00	0.00	1.80	0.00	0.00	0.00	0.36
0.87	1.75	0.00	0.00	0.00	3.49	0.00	0.00	0.00	0.00
1.90	0.00	0.00	0.00	0.00	7.11	0.00	0.00	0.00	0.47
2.05	0.00	0.00	0.00	0.00	5.13	0.00	0.00	0.00	0.51

Cymbella sp. 11	*Cymbella sp. 15*	*Cymbella sp. 16*	*Cymbella sp. 2*	*Cymbella sp. 5*	*Cymbella sp. 6*	*Cymbella sp. 8*	*Cymbella sp. 98*	*Cymbella subcuspidata*	*Cymbella unk. (g)*	*Denticula sp. 1*	*Diatoma moniliformis*
0.00	0.00	0.00	1.72	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.98
0.24	0.00	0.00	0.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49
0.00	0.00	0.00	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	1.36	0.27	0.27	0.54	0.00	0.00	0.00	0.00	0.54
0.00	0.00	0.96	1.60	0.00	0.32	0.00	0.00	0.00	0.64	0.32	0.64
0.31	0.31	0.31	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	1.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29
0.65	0.00	0.00	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.25	0.00	0.00	1.26	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00
0.00	0.00	0.00	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.30
0.00	0.65	0.65	1.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.97
0.00	0.00	0.36	1.08	0.00	0.00	0.00	0.36	0.00	0.00	0.72	1.44
0.00	0.44	0.44	3.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.62
0.00	0.00	0.00	1.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	1.03	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.51

Diatoma moniliformis girdle	*Eunotia sp. 1*	*Eunotia sp. 1 ends*	*Fragilaria ALL*	*Fragilaria capucina var. capucina*	*Fragilaria capucina var. gracilis*	*Fragilaria capucina var.*	*Fragilaria cf. construens*	*Fragilaria construens f. venter*	*Fragilaria girdle (cf. const or cap*	*Fragilaria girdle 2*	*Fragilaria pinnata*
1.47	0.00	0.00	14.99	0.98	1.97	1.23	0.25	0.00	2.70	7.86	0.00
0.49	0.00	0.00	10.73	0.00	0.49	1.46	0.00	0.00	3.41	5.37	0.00
2.51	0.28	0.00	9.50	0.00	1.12	1.12	3.35	0.00	0.00	3.91	0.00
0.00	0.00	0.00	5.15	0.81	0.81	1.08	0.00	0.00	1.08	1.08	0.27
0.00	0.32	0.00	11.18	0.00	0.00	0.32	3.83	0.00	0.00	7.03	0.00
0.00	0.00	0.00	9.32	0.00	0.31	1.55	0.00	0.00	3.73	3.73	0.00
0.00	0.00	0.00	8.31	0.57	0.00	0.00	5.44	0.29	0.00	2.01	0.00
2.92	0.00	0.65	10.06	0.00	1.95	0.00	1.30	0.00	0.00	6.17	0.65
0.00	1.01	0.00	4.28	0.00	0.25	2.02	0.00	0.00	0.00	2.02	0.00
0.00	0.00	0.00	6.29	0.00	0.00	0.30	3.59	0.00	0.00	2.40	0.00
0.00	0.65	0.00	3.23	1.29	0.00	0.65	0.00	0.00	0.00	1.29	0.00
0.00	0.00	0.00	5.76	0.72	0.00	2.88	0.00	0.00	0.00	0.00	2.16
0.00	0.00	1.75	2.18	0.00	0.00	1.75	0.00	0.00	0.00	0.00	0.44
0.00	0.47	0.00	5.69	0.00	0.00	5.69	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	9.23	2.05	0.51	6.15	0.00	0.00	0.00	0.00	0.51

Navicula cryptocephala	*Navicula pupula var. pupula*	*Navicula radiosa*	*Navicula reinhardtii*	*Navicula sp 21*	*Navicula sp 22*	*Navicula sp 23*	*Navicula sp 24*	*Navicula sp 26*	*Navicula sp 27*	*Navicula sp 28*	*Navicula sp 29*
1.23	1.23	6.14	2.46	0.98	0.25	0.98	0.00	0.00	0.00	0.00	0.00
0.24	1.71	14.15	2.68	0.98	0.24	0.49	0.24	0.00	0.00	0.00	0.00
0.00	3.35	18.99	1.40	1.68	0.00	0.00	0.00	0.00	0.00	0.00	0.28
0.00	5.69	23.04	2.17	0.27	0.00	0.00	0.81	0.00	0.27	0.54	0.00
0.64	0.64	13.42	2.88	0.32	0.00	0.00	0.96	0.00	0.00	0.00	0.00
0.00	4.04	13.04	4.04	0.31	0.00	0.00	0.31	0.00	0.00	0.00	0.00
0.57	2.01	13.18	0.86	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.00
0.65	2.27	18.18	3.25	0.00	0.00	0.00	0.97	0.00	0.00	0.65	0.00
0.00	3.53	21.16	3.27	0.25	0.00	0.00	0.50	0.25	0.00	0.00	0.00
0.00	1.50	22.75	2.69	0.30	0.00	0.00	0.00	0.00	0.00	0.60	0.00
0.00	2.90	26.45	4.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.65
0.00	2.52	23.02	3.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	5.24	24.02	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.47	1.42	12.80	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	2.05	22.56	2.05	0.00	0.00	0.00	1.03	0.00	0.00	0.00	0.00

Navicula sp 87	*Navicula sp. 1*	*Navicula sp. 11*	*Navicula sp. 12*	*Navicula sp. 1B*	*Navicula sp. 2*	*Navicula sp. 3*	*Navicula sp. 30*	*Navicula sp. 90*	*Navicula sp. 91*	*Navicula tenera*
0.00	1.23	1.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.24	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.98
0.00	0.56	1.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.96	0.00	4.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	1.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.29	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.97	0.32	0.00
0.00	0.25	1.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25
0.00	0.00	1.20	0.00	0.00	0.00	0.30	0.30	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	1.80	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	6.11	0.00	0.87	0.44	0.00	0.00	0.00	0.00	0.00
0.00	0.00	1.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.51	2.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Neidium ampliatum	*Nitzschia frust 2*	*Nitzschia frustulum*	*Nitzschia palea*	*Nitzschia sp. 1*	*Nitzschia sp. 2*	*Nitzschia sp. 3*	*Nitzschia sp. 4*	*Nitzschia sp. 4 (girdle)*	*Nitzschia sp. 5*	*nitzschia sp. 5 (girdle)*
1.72	0.00	8.85	0.98	0.00	0.00	3.93	1.97	0.49	8.60	0.49
0.49	0.00	3.17	0.49	0.00	0.49	0.00	5.37	4.88	7.56	0.00
3.07	0.00	3.63	0.00	0.00	0.00	5.03	4.47	0.00	11.45	0.00
0.54	0.00	5.69	0.27	0.00	0.00	0.00	0.00	8.94	13.28	0.00
0.00	0.64	5.75	0.64	0.00	0.00	3.19	3.19	0.00	10.86	0.00
0.31	0.00	6.83	0.00	0.00	0.00	1.24	1.24	4.35	14.60	0.00
1.15	0.29	8.31	0.00	0.00	0.00	5.73	5.16	0.00	13.75	0.00
0.65	0.00	4.55	0.00	0.00	0.32	2.27	6.17	0.00	17.53	0.00
0.00	0.00	11.84	0.50	0.25	0.00	1.51	2.77	0.50	14.11	0.00
0.00	0.00	11.38	0.30	0.00	0.00	4.19	7.49	0.00	15.57	0.00
0.97	0.00	5.81	0.65	0.00	0.00	3.87	7.74	0.00	18.06	0.00
0.72	0.00	5.04	0.72	0.00	0.00	11.51	7.19	0.00	12.23	0.00
0.00	0.00	10.48	0.00	0.00	1.31	3.49	3.49	0.00	9.17	0.00
0.47	0.00	13.74	0.47	0.00	5.69	1.90	0.47	0.00	18.01	0.00
0.51	0.00	15.38	0.00	0.00	0.00	5.13	0.00	0.00	9.74	0.00

Nitzschia unk 2	*Nitzschia unk 3 (sp. 5)*	*Nitzschia unk girdle 1*	*Pinnularia biceps*	*Pinnularia sp. 5*	*Stauroneis phoenicenteron*	*Stephanodiscus medius*	*Stephanodiscus min 2*	*Stephanodiscus minutulus*	*Tabellaria flocculosa*	*unknown 10*
0.25	0.00	0.00	0.00	0.25	2.70	0.00	0.00	0.00	0.00	0.00
0.00	5.12	0.24	0.24	0.00	3.90	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	1.68	0.00	0.00	0.28	0.00	0.00
0.00	0.00	0.00	0.00	0.27	3.25	0.00	0.00	0.00	0.27	0.27
0.00	0.00	0.00	0.00	0.00	1.92	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	5.28	0.00	0.00	0.62	0.00	0.00
0.00	0.00	0.00	0.86	0.00	2.29	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	2.60	0.00	0.00	1.30	0.00	0.00
0.00	0.00	0.00	0.00	0.76	3.53	0.00	0.00	0.25	0.00	0.00
0.00	0.00	0.00	0.00	1.20	0.90	0.30	0.00	0.30	0.00	0.60
0.00	0.00	0.00	0.00	0.32	0.97	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	2.52	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	1.42	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	2.05	0.00	0.00	0.00	0.00	0.00

unknown 12	*unknown 13*	*unknown 4*	*unknown 45*	*Unknown 5*	*Unknown 6*	*Unknown 7*	*unknown 8*	*unknown 9*	*unknown girdle 3*	*unknown girdle 4*	*unknown girdle 5*
0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.24	0.73	0.24	0.00	1.95	0.49	0.00
0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.23	0.56	1.12
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.28	0.00	0.64
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.57	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.15	0.57	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.65	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.25	0.00	0.00	0.00
0.30	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.20	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.36	0.00	0.36	0.00	0.00	0.00	0.00	0.00	0.00	1.44	0.72	0.00
0.00	0.00	0.00	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.90	1.42	0.00
1.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.05	0.00	0.00

Appendix 8. All diatom species and relative abundances for E-KNUD pond on Ellesmere Island.

Depth(cm)	Midpoint	*Achnanthes minutissima*	*Achnanthes unk 1*	*Amphora cf. veneta (unknown*	*Amphora libyca*	*Amphora veneta (unknown*	*Amphora veneta (unknown 8)*	*Aulacoseira ambigua (aulacoseira*	*Caloneis silicula*	*Cocconeis placentula*	*Cyclotella antiqua (Cyclotella*	*Cyclotella antiqua (Cyclotella*	*Cyclotella ocellata*
0.0 - 0.5	0.25	13.78	0.00	0.00	18.62	0.00	0.00	0.00	0.26	0.00	0.00	0.00	0.00
0.5 - 1.0	0.75	17.05	0.28	0.00	16.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.0 - 1.5	1.25	14.59	0.00	0.00	24.59	0.00	0.00	0.00	0.00	0.27	0.00	0.00	1.35
1.5 - 2.0	1.75	11.46	0.00	0.00	23.21	0.00	0.00	0.00	1.43	0.00	0.00	0.00	0.00
2.0 - 2.5	2.25	8.22	0.00	0.00	33.33	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00
2.5 - 3.0	2.75	5.76	0.00	0.00	24.81	0.00	0.75	0.00	0.00	0.00	0.00	0.00	0.00
3.0 - 3.5	3.25	9.09	0.00	0.00	27.02	0.00	0.00	0.00	0.76	0.00	0.00	0.00	0.00
3.5 - 4.0	3.75	6.52	0.00	0.00	22.25	0.00	0.00	0.00	0.45	0.00	0.00	0.00	0.00
4.0 - 4.5	4.25	5.91	0.00	0.00	27.25	0.00	0.00	0.00	0.51	0.00	0.00	0.00	0.00
4.5 - 5.0	4.75	7.92	0.00	0.00	24.34	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.00
5.0 - 5.5	5.25	6.13	0.00	0.00	19.36	0.00	0.49	0.00	0.98	0.00	0.00	0.00	0.00
5.5 - 6.0	5.75	5.97	0.00	0.00	23.15	0.00	0.00	0.00	0.72	0.48	0.00	0.00	0.00
6.0 - 6.5	6.25	5.57	0.00	0.00	17.03	0.00	0.00	0.00	0.00	0.93	0.00	0.00	0.00
6.5 - 7.0	6.75	8.09	0.00	0.00	18.06	0.00	0.00	0.00	1.35	1.89	0.00	0.27	0.00
7.0 - 7.5	7.25	2.37	0.00	0.00	16.32	0.00	0.00	0.00	0.59	0.59	0.00	0.00	0.00
7.5 - 8.0	7.75	5.65	0.00	0.00	16.25	0.00	0.00	0.00	1.41	1.41	0.00	0.00	0.00
8.0 - 8.5	8.25	3.05	0.00	0.00	12.69	0.00	0.00	0.00	1.52	1.02	0.00	0.00	0.00
8.5 - 9.0	8.75	3.43	0.00	0.00	11.76	0.00	0.00	0.00	1.47	1.47	0.00	0.98	0.00
9.0 - 9.5	9.25	5.28	0.00	0.00	16.26	0.00	0.00	0.00	0.41	2.03	0.00	0.00	0.00
9.5 - 10.0	9.75	2.14	0.00	0.00	19.25	0.00	0.00	0.53	0.00	1.60	0.00	0.53	0.53
10.0 - 10.5	10.25	2.78	0.00	0.93	9.72	0.00	0.00	0.00	0.00	0.00	0.00	0.46	0.00
10.5 - 11.0	10.75	1.52	0.00	0.00	20.81	0.00	0.00	0.00	0.51	0.00	0.00	0.51	0.00
11.0 - 11.5	11.25	4.15	0.00	0.00	15.47	0.00	0.00	0.00	0.75	2.26	0.00	0.75	0.00
11.5 - 12.0	11.75	1.55	0.00	0.00	16.49	0.00	0.00	0.00	1.55	0.00	0.00	0.52	0.00
12.0 - 12.5	12.25	3.85	0.00	0.00	10.44	0.00	0.00	0.00	0.00	0.00	0.00	1.65	0.00
12.5 - 13.0	12.75	1.59	0.00	0.00	2.65	0.00	0.00	0.00	0.00	0.00	0.53	1.06	0.00
13.0 - 13.5	13.25	1.48	0.00	0.00	4.93	0.49	0.00	0.00	0.99	0.49	0.00	0.00	0.00
13.5 - 14.0	13.75	2.70	0.00	0.90	6.31	0.00	0.00	0.00	0.00	0.00	0.45	0.45	0.00
14.0 - 14.5	14.25	4.79	0.00	0.00	8.51	0.00	0.00	0.00	0.00	0.53	0.00	0.00	0.00
14.5 - 15.0	14.75	2.49	0.00	0.00	9.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50
15.0 - 15.5	15.25	1.96	0.00	0.00	5.39	0.00	0.00	0.00	0.00	0.49	1.96	0.00	0.00

Cymbella unk 7 (unknown 7)	*Cymbella arctica*	*Cymbella arctica 2 (Cymbella sp*	*Cymbella unk 1*	*Cymbella unk 5*	*Denticula kuetzingii (Denticula sp*	*Denticula kuetzingii girdle*	*Denticula kuetzingii complex*	*Denticula kuetzingii var.*	*Denticula kuetzingii var.*	*Denticula kuetzingii var.*	*Denticula kuetzingii var.*	*Denticula sp 2. (unknown girdle 4)*	*Diploneis interrupta (unknow*
0.00	0.00	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.26	0.26	0.00	0.00	0.00
0.00	0.57	0.00	0.00	0.28	0.00	0.00	0.00	0.57	0.28	0.85	0.28	0.00	0.00
0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.27	0.00	0.00	0.00
0.00	1.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.22	1.57	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.22	0.45	0.00	0.00	0.00
0.00	2.01	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.25	0.75	0.00	0.00	0.00
0.00	0.76	0.00	0.00	0.00	0.00	0.00	0.00	1.77	0.00	1.77	0.00	0.00	0.00
0.00	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.67	0.00	0.45	0.00
0.00	1.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.54	1.54	0.00	0.00	0.00
0.00	1.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.88	0.88	0.00	0.59	0.00
0.25	1.47	0.00	0.00	0.00	0.49	0.00	0.49	0.00	0.49	0.49	0.00	0.00	0.00
0.00	1.43	0.00	0.00	0.00	6.92	0.00	6.92	0.00	3.82	3.82	0.00	0.00	0.00
0.00	0.62	0.00	0.31	0.00	2.17	7.43	9.60	1.55	1.24	2.79	0.00	0.00	0.00
0.00	2.70	0.00	0.27	0.00	3.50	2.43	5.93	1.62	1.35	2.96	0.00	0.00	0.00
0.00	1.48	0.30	0.00	0.00	6.23	2.97	9.20	1.78	1.48	3.26	0.00	0.00	0.00
0.00	3.18	0.71	0.00	0.00	2.12	4.95	7.07	1.77	1.06	2.83	0.00	0.00	0.00
0.00	1.52	0.00	0.00	0.00	15.74	0.00	15.74	2.54	1.52	4.06	0.00	0.00	1.02
0.00	0.98	0.98	0.00	0.00	5.39	3.92	9.31	2.45	0.49	2.94	0.00	0.00	0.00
0.00	1.63	0.41	0.00	0.00	0.00	11.79	11.79	1.63	0.81	2.44	0.00	0.00	0.00
0.00	2.14	0.00	0.00	0.00	0.00	10.16	10.16	2.14	0.00	2.14	0.00	0.00	0.00
0.00	0.46	0.00	0.00	0.00	0.46	8.80	9.26	0.93	0.93	1.85	0.00	0.00	0.46
0.00	1.52	0.00	0.00	0.00	0.51	8.63	9.14	0.51	0.00	0.51	0.00	0.00	0.00
0.00	0.75	0.00	0.00	0.00	7.92	0.00	7.92	3.02	0.00	3.02	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	1.55	10.82	12.37	1.55	1.55	3.09	0.00	0.00	0.00
0.00	2.75	0.00	0.00	0.00	1.10	9.89	10.99	1.65	2.20	3.85	0.00	0.00	0.00
0.00	0.53	0.00	0.00	0.00	2.65	18.52	21.16	1.59	1.59	3.17	0.00	0.00	0.53
0.00	1.48	0.00	0.00	0.00	1.97	11.33	13.30	1.97	1.97	3.94	0.00	0.00	0.99
0.00	0.90	0.00	0.00	0.00	2.70	17.12	19.82	0.45	3.60	4.05	0.00	0.00	0.00
0.00	0.53	0.00	0.00	0.00	3.72	8.51	12.23	0.00	0.53	0.53	0.00	0.00	0.53
0.00	1.49	0.00	0.00	0.00	4.48	8.96	13.43	0.50	0.50	1.00	0.00	0.00	1.00
0.00	1.47	0.00	0.00	0.00	15.69	0.00	15.69	4.90	0.00	4.90	0.00	0.00	0.00

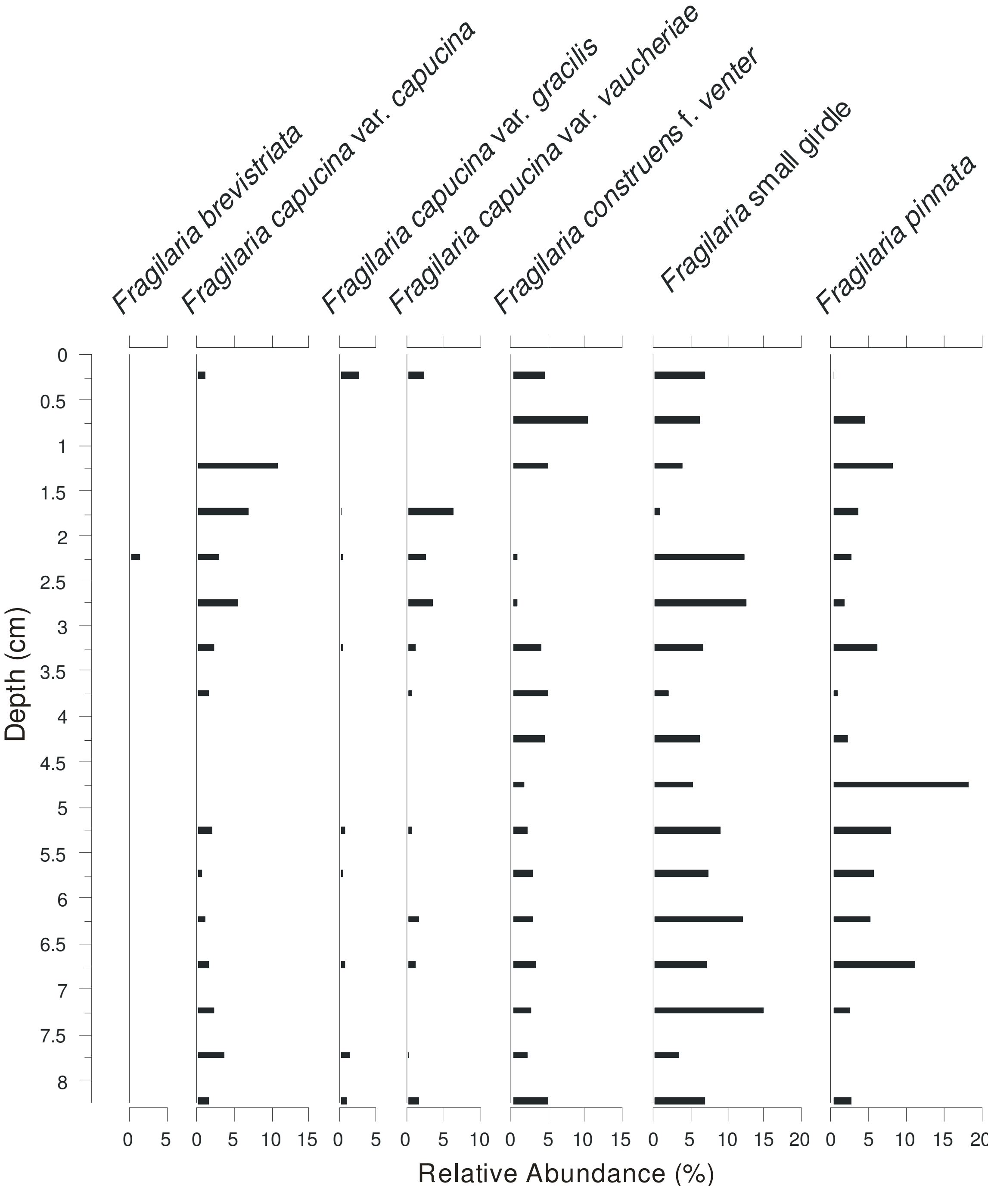
Epithemia sorex (Epithemia	*Epithemia sorex (Epithemia*	*Epithemia sorex (Epithemia*	*Epithemia sorex*	*Eunotia praerupta var. excelsa*	*Fragilaria capucina*	*Fragilaria capucina (unknown girdle 3)*	*Fragilaria pinnata*	*Fragilaria sp 2*	*Fragilaria unk 1*	*Fragilaria unknown 2*	*Gomphonema acum (girdle)*	*Gomphonema acuminatum*
1.53	0.00	0.00	10.20	0.00	0.26	0.00	0.00	0.26	1.02	1.28	0.00	0.00
0.57	0.57	0.00	8.81	0.00	2.56	0.00	0.00	0.00	0.00	0.00	0.00	0.28
0.00	0.00	0.00	4.59	0.00	1.89	0.00	0.54	0.00	0.00	0.00	0.54	0.27
0.00	0.00	0.57	12.89	0.00	0.29	1.15	0.00	0.00	0.00	0.00	0.00	0.29
0.00	0.00	0.22	15.21	0.00	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	14.04	0.00	2.26	0.00	0.00	0.00	0.00	0.00	0.00	1.75
0.00	0.00	0.00	13.64	0.00	1.52	0.00	0.00	0.00	0.00	0.00	0.00	0.51
0.00	0.00	0.00	17.08	0.00	1.35	0.00	0.45	0.00	0.00	0.00	0.00	0.90
0.00	0.00	0.00	14.65	0.00	2.57	0.00	0.00	0.00	0.00	0.00	0.00	1.03
0.00	0.00	0.00	15.54	0.00	4.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	23.53	0.00	1.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	17.90	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.72
0.00	0.00	0.00	15.48	0.00	1.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	19.41	0.00	1.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	21.07	0.00	2.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	10.95	0.00	1.06	0.00	0.00	0.00	0.00	0.00	0.00	0.35
0.00	0.00	0.00	15.23	0.00	2.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	15.20	0.00	0.49	0.00	0.98	0.00	0.00	0.00	0.00	0.49
0.00	0.00	0.00	11.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	18.18	0.00	2.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	6.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	9.64	0.00	1.02	0.00	0.00	0.00	0.00	0.00	0.00	0.51
0.00	0.00	0.00	12.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	10.82	0.00	2.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	13.74	0.55	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	13.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	7.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	11.71	0.00	1.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	11.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	10.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
0.00	0.00	0.00	16.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Navicula cf. cryptotenella (unknown	*Navicula cuspidata*	*Navicula cuspidata (girdle)*	*Navicula cuspidata 2 (unknown 2)*	*Navicula cuspidata complex*	*Navicula halophila*	*Navicula halophila (Navicula sp*	*Navicula halophila girdle*	*Navicula halophila complex*	*Navicula sp. 25 (unknown 25)*	*Navicula sp. 42 (unknown 42)*	*Navicula tuscula*	*Navicula tuscula girdle*	*Navicula tuscula complex*
0.00	0.00	0.00	0.51	0.51	11.48	0.00	3.57	15.05	0.00	0.00	8.42	0.00	8.42
0.00	0.00	0.00	0.00	0.00	8.24	0.00	3.41	11.65	0.00	0.00	7.67	1.70	9.38
0.00	0.27	0.54	0.00	0.81	6.49	0.27	3.24	10.00	0.00	0.00	5.41	1.08	6.49
0.00	0.57	0.00	0.00	0.57	4.87	0.00	2.58	7.45	0.00	0.00	8.02	1.15	9.17
0.00	0.00	0.00	0.00	0.00	1.34	0.00	2.68	4.03	0.00	0.00	10.29	0.00	10.29
0.00	0.75	0.00	0.00	0.75	3.26	0.25	1.00	4.51	0.00	0.00	6.52	0.00	6.52
0.00	0.51	0.00	0.00	0.51	3.79	0.00	0.51	4.29	0.00	0.00	9.09	0.00	9.09
0.00	0.00	0.00	0.00	0.00	2.92	0.00	1.35	4.27	0.00	0.00	9.21	0.00	9.21
0.00	0.00	0.00	0.00	0.00	3.60	0.00	2.57	6.17	0.00	0.00	6.94	0.00	6.94
0.00	0.29	0.00	0.59	0.88	2.93	0.00	1.17	4.11	0.00	0.00	8.50	0.00	8.50
0.00	0.00	0.00	0.00	0.00	2.94	0.00	3.43	6.37	0.00	0.00	7.84	0.00	7.84
0.00	0.00	0.00	0.00	0.00	1.67	0.00	0.95	2.63	0.00	0.00	7.40	0.00	7.40
0.00	0.00	0.00	0.00	0.00	1.24	0.00	1.24	2.48	0.00	0.00	6.19	0.00	6.19
0.00	0.00	0.00	0.00	0.00	0.54	0.00	2.70	3.23	0.00	0.00	7.82	0.00	7.82
0.00	0.00	0.00	0.00	0.00	0.89	0.00	0.59	1.48	0.00	0.00	6.23	0.00	6.23
0.00	0.00	0.00	0.00	0.00	4.95	0.00	0.71	5.65	0.00	0.00	8.13	0.00	8.13
0.00	2.54	0.00	0.00	2.54	0.00	0.00	1.02	1.02	0.00	0.00	5.08	0.00	5.08
0.00	3.43	0.00	0.00	3.43	0.00	0.00	2.94	2.94	0.00	0.00	6.86	0.00	6.86
0.00	5.69	0.00	0.00	5.69	0.81	0.00	1.63	2.44	0.41	0.00	10.98	0.00	10.98
0.00	6.42	0.00	0.00	6.42	0.00	0.00	0.00	0.00	0.00	0.00	6.42	0.00	6.42
0.00	17.59	0.00	0.00	17.59	0.46	0.00	0.00	0.46	0.00	0.00	13.89	0.00	13.89
0.00	12.18	0.00	0.00	12.18	0.51	0.00	0.00	0.51	0.00	0.00	7.61	0.00	7.61
0.00	5.66	0.00	0.00	5.66	0.38	0.00	1.51	1.89	0.00	0.00	12.45	0.00	12.45
0.00	5.67	0.00	0.00	5.67	2.58	0.00	0.00	2.58	0.00	0.00	10.31	0.00	10.31
2.75	8.24	0.00	0.00	8.24	1.10	0.00	1.10	2.20	0.00	0.00	9.89	0.00	9.89
4.76	8.99	0.00	0.00	8.99	0.00	0.00	0.00	0.00	0.00	0.00	10.05	0.00	10.05
8.37	14.29	0.00	0.00	14.29	1.48	0.00	0.00	1.48	0.00	0.49	8.87	0.00	8.87
4.05	11.26	0.00	0.00	11.26	0.00	0.00	0.00	0.00	0.00	0.00	10.81	0.00	10.81
6.91	12.23	0.00	0.00	12.23	0.00	0.00	2.13	2.13	0.00	0.00	11.17	0.00	11.17
5.97	9.45	0.00	0.00	9.45	0.00	0.00	1.99	1.99	0.00	0.00	6.97	0.00	6.97
0.00	7.84	0.00	0.00	7.84	0.00	0.00	0.00	0.00	0.00	0.00	11.27	0.00	11.27

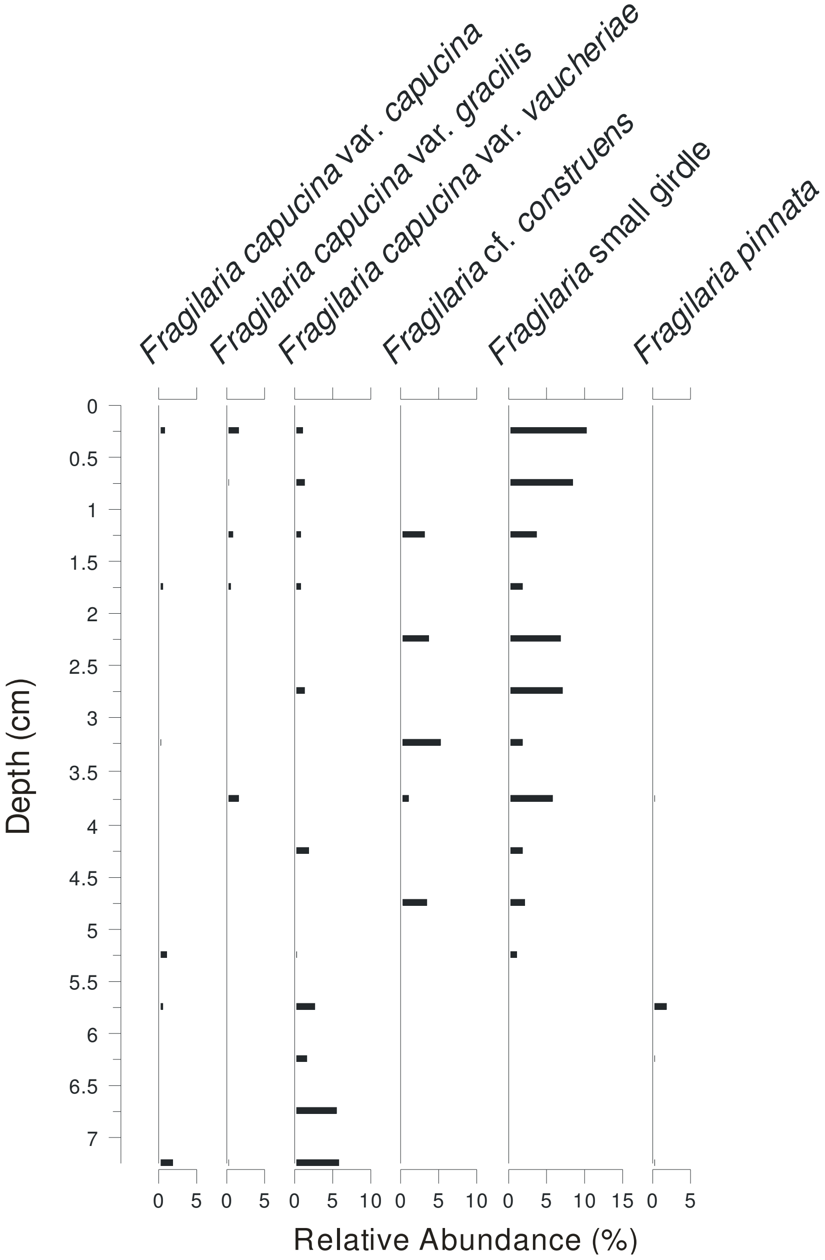
Navicula vulpina	*Neidium ampilatum*	*Nitzschia frustulum (Nitzschia sp 4)*	*Nitzschia inconspicua (Nitzschia sp 1 girdle)*	*Nitzschia inconspicua (Nitzschia sp. 1)*	*Nitzschia liebetruthii var. liebetruthii (Nitzschia sp 2 Girdle)*	*Nitzschia liebetruthii var. liebetruthii (Nitzschia sp 2)*	*Nitzschia sp 3. (Girdle) (unknown 3)*	*Nitzschia sp 5*	*Nitzschia sp. 13 (unknown 13)*	*Nitzschia sp. 3*
14.29	0.26	0.00	0.00	8.67	4.85	0.51	0.26	0.00	0.00	0.51
15.63	0.85	0.00	0.00	7.10	5.68	1.70	0.00	0.00	0.00	0.00
22.70	0.54	0.00	0.00	4.32	3.78	1.08	0.00	0.00	0.00	0.00
19.77	0.29	0.00	0.00	6.30	1.43	0.57	0.00	0.00	0.00	0.00
23.04	0.45	0.22	0.00	3.58	3.58	0.22	0.00	0.00	0.00	0.00
22.56	1.75	0.00	0.00	5.26	3.51	1.50	0.00	0.00	0.00	0.50
20.45	1.01	0.00	0.00	3.54	1.01	2.53	0.00	0.00	0.00	0.51
20.22	0.67	2.25	0.00	6.74	3.15	1.35	0.00	0.00	0.00	0.00
15.94	0.77	1.29	2.06	6.68	2.83	1.03	0.00	0.00	0.00	0.51
20.82	0.59	0.00	1.17	2.64	2.93	2.05	0.00	0.00	0.00	0.00
19.85	0.49	1.47	0.49	2.94	2.70	1.72	0.00	0.00	0.00	0.00
17.66	1.19	0.72	0.00	5.01	0.95	1.43	0.00	0.00	0.00	0.00
20.43	0.00	0.31	1.86	9.29	3.10	1.24	0.00	0.00	0.00	0.00
15.09	0.27	1.89	1.62	5.12	1.08	0.54	0.00	0.00	0.54	0.00
17.51	0.30	2.97	3.56	8.90	0.59	1.19	0.00	0.00	0.00	0.00
18.73	0.71	1.41	1.41	9.54	0.71	1.41	0.00	0.00	0.71	0.00
17.77	0.00	2.03	3.05	9.14	0.00	1.02	0.00	0.00	0.00	0.00
25.00	0.00	1.96	0.00	7.35	0.00	0.98	0.00	0.00	0.00	0.00
17.89	0.81	0.00	0.00	5.28	0.00	3.66	0.00	0.00	0.00	0.00
16.04	1.07	2.14	0.00	4.81	0.00	0.53	0.00	0.00	0.00	0.00
26.39	0.46	0.00	0.00	6.48	0.00	1.85	0.00	0.00	0.00	0.46
21.83	1.02	0.00	0.00	5.08	0.00	5.08	0.00	0.00	0.00	0.00
20.38	0.00	0.38	0.00	8.68	0.00	2.64	0.00	0.00	0.00	0.00
22.68	0.00	1.55	0.00	6.19	0.00	1.03	0.00	0.00	0.00	0.00
18.13	0.55	1.10	0.00	0.00	6.59	0.55	0.00	0.00	0.00	0.00
17.46	0.53	0.00	0.00	7.94	2.65	2.65	0.00	0.00	0.00	0.00
15.27	0.99	0.99	0.00	7.39	1.97	1.97	0.00	0.00	0.00	0.00
13.51	0.00	0.00	0.90	6.31	0.90	1.80	0.00	0.00	0.00	0.00
15.96	1.06	0.00	2.66	5.85	0.00	1.60	0.00	0.00	0.00	0.00
21.39	1.00	0.00	0.00	6.97	0.00	2.99	0.00	1.49	0.00	0.00
19.61	0.49	2.45	0.00	9.31	0.00	0.98	0.00	0.00	0.00	0.00

Stauroneis phoenicentron	*Stephanodiscus cf. niagarae (unknown 29)*	*Stephanodiscus cf. niagarae (unknown 60)*	*Stephanodiscus minutulus*	*unknown 41*	*unknown 6*	*unknown 65*	*unknown 74*	*unknown 75*	*Unknown girdle 1*	*unknown girdle 2*	*unknown girdle 9*
0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.54	0.00	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.57	0.00
0.22	0.00	0.00	0.00	0.00	1.34	0.00	0.00	0.00	0.00	0.00	0.00
0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00
1.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.00
0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.00
1.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.98	0.00
0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.00
0.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.53	0.53	0.00	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.07
0.00	0.00	0.00	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.52	0.00	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.10	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.99	0.00	0.49	0.49	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.45	0.45	0.00	0.00	0.00	0.00	0.45	0.00	0.00	0.00	0.00	0.00
0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.53	0.53	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix 9. Summary diagram of *Fragilaria* species from Bathurst Island Thule Ponds.



Pond B-AO



Fragilaria capucina var. capucina
Fragilaria capucina var. gracilis
Fragilaria capucina var. vaucheriae
Fragilaria cf. construens
Fragilaria small girdle
Fragilaria pinnata
Depth (cm)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
0 5 0 5 0 5 10 0 5 10 0 5 10 15 0 5
Relative Abundance (%)

Pond B-AP

Appendix 10. Taxonomic authorities for diatom species presented in the Bathurst Island calibration

Taxa Name	Taxonomic Authority
Achnanthes childanos	Hohn & Hellerman
Achnanthes holstii	Cleve
Achnanthes flexella	(Kütz.) Brun
Achnanthes kryophila	J. B. Petersen
Achnanthes laevis	Østrup
Achnanthes lanceolata	(Breb. ex Kütz.) Grun.
Achnanthes marginulata	Grunow
Achnanthes minutissima	Kütz.
Achnanthes oestrupii	(H. Bachm. & A. Cleve) Hust.
Achnanthes petersenii	Hustedt
Achnanthes sp. 2	
Achnanthes sp. 1	
Achnanthes subatomoides	(Hust.) Lange-Bertalot & Archibald
Achnanthes ventralis	(Krasske) Lange-Bertalot
Amphora aequalis	Krammer
Amphora inariensis	Krammer
Amphora libyca	Ehrenberg
Amphora veneta	Kützing
Brachysira cf. *procera*	H. Lange-Bertalot & G. Moser
Caloneis cf. *silicula*	Ehrenberg
Caloneis schumanniana	(Grunow) Cleve
Caloneis sp. 1	
Cymbella angustata	(W. Smith) Cleve
Cymbella arctica	(Lagerstedt) Schmidt
Cymbella cf. *arctica*	(Lagerstedt) Schmidt
Cymbella cesatii	(Rabenhorst) Grunow
Cymbella designata	Krammer
Cymbella latens	Krasske
Cymbella microcephala	Grunow
Cymbella minuta	Hilse
Cymbella silesiaca	Bleisch
Cymbella similis	Krasske
Cymbella subaequealis	Grunow
Cymbella tumidula	Grunow
Denticula elegans	Kützing
Denticula kuetzingii	Grunow
Diadesmis sp. 1	

Taxa Name	Taxonomic Authority
Diatoma moniliformis	Kütz.
Diatoma oculata	(Bréb.) Cleve
Diatoma tenuis	Agardh
Eunotia arcus	Ehrenberg
Fragilaria cf. *construens*	(Ehrenberg) Grunow
Fragilaria capucina var. *capucina*	Desmazières
Fragilaria capucina var. *gracilis*	(Oestrup) Hustedt
Fragilaria capucina var. *vaucheriae*	(Kützing) Lange-Bertalot
Fragilaria pinnata	Ehrenberg
Frustulia rhomboides var. *crassinervia*	(Brebisson) Ross
Navicula cf. *bacilllum*	Ehrenberg
Navicula bryophila	Petersen
Navicula cf. *gallica*	(W. Smith) Lagerstedt
Navicula cryptocephala	Kützing
Navicula crypototenella	Lange-Bertalot
Navicula jaernefeltii	Hustedt
Navicula pseudoscutiformis	Hustedt
Navicula pupula var. pupula	Kützing
Navicula salinarum	Grunow
Navicula soehrensis	Krasske
Navicula sp. 2	
Navicula vulpina	Kützing
Neidium umiatense	Foged.
Nitzschia alpina	Hustedt
Nitzschia frustulum	(Kützing) Grunow
Nitzschia inconspicua	Grunow
Nitzschia palea	(Kützing) W. Smith
Nitzschia perminuta	(Grunow) M. Peragallo
Nitzschia perminuta T1	
Pinnularia balfouriana	Grunow
Pinnularia digerntissima	Gregory
Pinnularia interrupta	W. Smith
Pinnularia subrostrata	(A. Cleve) Cleve-Euler
Stauroneis anceps	Ehrenberg
Tabellaria flocculosa strain IV	(Roth) Kütz. (str. IV sensu Koppen)