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**Proceedings of
The Fourth Arctic-Antarctic Diatom Symposium
(Workshop), Canadian Museum of Nature
Ottawa, Ontario, Canada
September 18-21, 1993**

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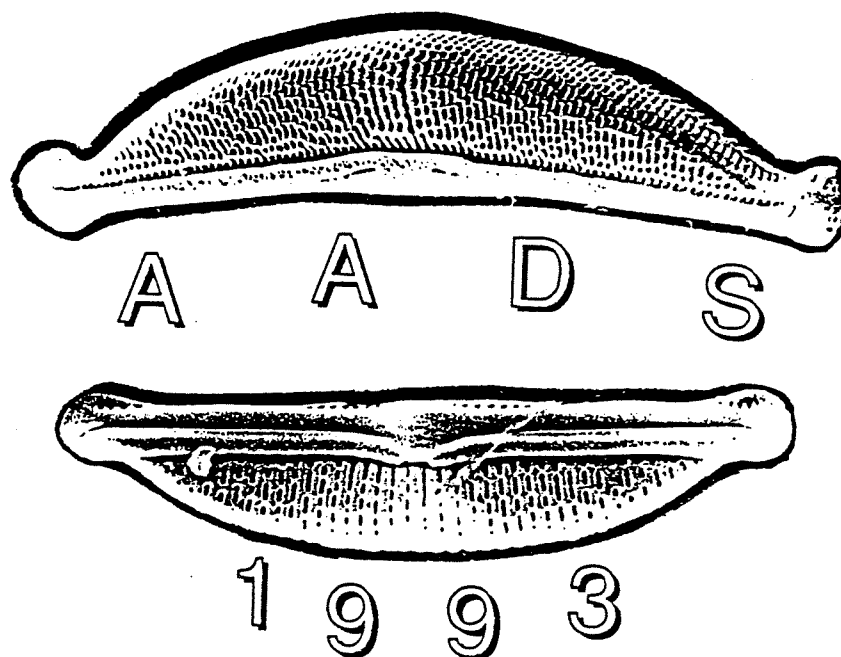
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CONTENTS

ABSTRACT/Résumé	iv
INTRODUCTION	1
POLAR RESEARCH	
Håkansson, A. Taxonomical and nomenclatural problems in some species of the genus <i>Cyclotella</i> (Kütz.) Brébisson.	3
Wolfe, A.P. Modern and Holocene Diatoms from Ukalik Lake, Baffin Island, Northwest Territories: Preliminary Results.	5
Douglas, M.S.V. & J.P. Smol. The geographical and physicochemical characteristics of 35 ponds from Cape Herschel, Ellesmere Island.	13
Jones, V.J., Juggins, S. & J.C. Ellis-Evans. Physicochemical and biological (Diatom) relationships in maritime Antarctic lakes.	19
Moser, K.A. Impact of fire, climatic change, and nonlinear population dynamics on a boreal forest lake.	27
Pienitz, R. & J.P. Smol. The ecology and physicochemical characteristics of lakes in the subarctic and arctic regions of the Yukon Territory, Fennoscandia (Finland, Norway), the Northwest Territories and northern Québec.	31
Hamilton, P.B., McNeely, R. & M. Poulin. The morphology and distribution of <i>Neidium distincte-punctatum</i> Hustedt an interesting taxon from the Canadian Arctic	45
Fritz, S.C. Diatoms in small lakes and ponds in Glacier Bay National Park, Alaska, USA.	49
Kingson, J.C. Diatom research in Labrador: one component of freshwater biodiversity.	53
Hamilton, P.B., Lean, D.R.S. & M. Poulin. The physicochemical characteristics of lakes and ponds from the northern regions of Ellesmere Island.	57
Douglas, M.S.V. & J.P. Smol. Diatoms from epilithic, epiphytic and epipelagic microhabitats in ponds from Cape Herschel, Ellesmere Island.	65
POLAR FLORA SUMMARY	
Håkansson, H. & V.J. Jones. The compiled freshwater diatom taxa list for the Maritime Antarctic region of the South Shetland and South Orkney Islands.	77
Hamilton, P.B., Douglas, M.S.V., Fritz, S.C., Pienitz, R., Smol, J.P. & A.P. Wolfe. A compiled freshwater diatom taxa list for the Arctic and Subarctic regions of North America.	85
SPECIAL TOPICS	
Håkansson, H. Lake development: temperate and Antarctic Ecosystems - similarities and differences.	103
Kociolek, J.P. Electronic Information Resources for Diatom Identification.	105
Charles, D. Opportunities for museums in diatom research in the "90's": Notes from a workshop discussion.	107
Smol, J.P. Approaches Towards Unifying North American Diatom Research: Notes from a workshop discussion.	109
APPENDIX	
I. List of Participants at the Arctic-Antarctic workshops (1-4)	111
II. 4th Arctic-Antarctic Symposium (Workshop) AADS, Agenda.	113
III. 1st Arctic-Antarctic diatom taxonomy workshop, Brighton, England, Sept.1991.	115
IV. 2nd(a) Arctic-Antarctic diatom taxonomy workshop, Kingston, Canada, Feb. 1992.	119
V. 2nd(b) Arctic-Antarctic diatom taxonomy workshop, Kingston, Canada, April 1992.	123
VI. 3rd Arctic-Antarctic diatom taxonomy workshop, Kingston, Canada, October 1992.	131

ABSTRACT

The Arctic-Antarctic Diatom Symposium and Workshops (AADS) were initiated in 1991 in order to assist paleoecologists working with diatom taxonomic problems in polar environments. Four workshops were completed and it became evident that similar systematic and taxonomic problems exist in the floras of both the south and north poles. The Fourth Symposium, held at the Canadian Museum of Nature (Ottawa, Canada) from 18th-21st September 1993, was divided into taxonomic workshop sessions and current research sessions with a special emphasis on the roles of Museums and computer database managements systems. The taxonomic sessions dealt with the family Naviculaceae emphasizing the genera *Navicula* Bory, *Luticola* Mann, *Diadesmis* Kützing, and *Craticula* Grunow. Database management systems, voucher collections and standardization of taxonomic practices were discussed in special topic lectures with a session on the future of "electronic communications" in diatom and research. This proceedings consists of 11 papers, 2 summary floras (Antarctic, Arctic), 4 session reports, and a list of participants.

RÉSUMÉ

Les symposiums sur les diatomées de l'Arctique et de l'Antarctique ont débuté en 1991, afin de prêter assistance aux paléoécologistes lesquels sont très souvent confrontés à des problèmes de nature taxonomique relatifs aux diatomées de régions polaires. Depuis, quatre ateliers de travail ont eu lieu, et il appert que des problèmes similaires, relatifs à la taxonomie et la systématique de cette microflore, existent aux pôles nord et sud. Le Quatrième symposium s'est déroulé du 18 au 21 septembre 1993 au Musée canadien de la nature à Ottawa, au Canada, et il a été divisé en sessions portant sur la résolution de problèmes taxonomiques et la recherche actuelle, avec une attention particulière sur le rôle des musées et des systèmes informatiques de gestion des données. Les sessions taxonomiques ont traité des Naviculaceae, et plus spécialement des genres *Navicula* Bory, *Luticola* Mann, *Diadesmis* Kützing et *Craticula* Grunow. Les systèmes de gestion de données, les collections témoins et l'uniformisation des procédures taxonomiques ont fait l'objet de discussions sous la forme de conférences avec une session spéciale sur la vision d'avenir des communications électroniques dans la recherche sur les diatomées. Le compte-rendu contient 12 manuscrits scientifiques, deux sommaires floristiques (Antarctique, Arctique), quatre rapports de session et une liste des participants.

INTRODUCTION

The importance of uniformity in taxonomy is an issue that faces all ecologists and environmental scientists when looking at species-specific or group responses to changes in the environment. Paleolimnologists using microfossils are especially concerned about precise and consistent taxonomy as they construct transfer functions and model current environmental conditions in the hope of reconstructing our environmental past. The importance of consistency in taxonomy is relevant to current and future ecological monitoring programs in which comparisons will be made within floras and faunas. Along with environmental change, biological change is also a significant scientific concern and the current thrust into biodiversity is our attempt to understand the complexity, and stability of biological life. Thus, taxonomy and systematics are important components of "the basic tools and knowledge" needed to answer significant environmental and biological questions.

Ultimately the most significant contributions we can make to science are the dissemination of discovered knowledge and the retention of our research materials for verification and future re-evaluation. The process of evaluation and re-evaluation in scientific research is the core thread which links all research towards the advancement of science. Natural history museums have traditionally been a major force in the development of scientific knowledge through teaching, and the long-term preservation of biological research materials. As the age of the "information highway" develops we must still maintain and support the basic tools that we routinely use in the study of our biological world.

The new developments in communication gives us the opportunity to develop new tools that will further improve our research methods and practices. The newest tool now available is "electronic communication". With improved communications between colleagues it is faster and more feasible to check, verify and update biological and environmental databases. It is now more important than ever that a standardization in practices and procedures be developed in order to enhance the quality of our research data. Unified efforts to standardize procedures and practices obviously include taxonomy and it is taxonomic workshops like the Arctic-Antarctic Symposium that fill this niche.

Finally, it should be stated that diatoms and other siliceous microfossils are important as both biological and environmental indicators and will play a significant role in research discoveries of the future. The production of a technical report hopefully improves the basic predictive tools of taxonomy and systematics in the field of diatom research.

TAXONOMICAL AND NOMENCLATURAL PROBLEMS IN SOME SPECIES OF THE GENUS *CYCLOTELLA* (KÜTZING) BRÉBISSE

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Investigations on the original material of some species in the genus *Cyclotella* (Kützing) Brébisson has revealed important information. It was demonstrated by Håkansson (1979) that *C. operculata* (Agardh) Kützing is in fact a *Rhopalodia* and that no centric diatoms were found in the Agardh type material. Agardh first described *Frustulia ventricosa et operculata* in 1827, but later in 1830 transferred these to the genus *Cymbella*. Kützing (1834) made *Cyclotella* a subgenus of *Frustulia* with *F. operculata* (Agardh) Kützing as the type species. Later Brébisson (1838) made *Cyclotella* a genus with *C. ovalis* (today known as *Amphora ovalis*) and *C. operculata* (known as *Rhopalodia operculata* Håkansson) as the species (see Håkansson & Ross 1984). It was proposed by Håkansson & Ross (op. cit.) that the specimen from Tennstaedt, misidentified by Kützing (1834) as *Frustulia operculata*, should be conserved as the type of *Cyclotella*. This was done (Greuter *et al.* 1988), with the new name *C. tecta* Håkansson & Ross. Further investigation has shown that *C. distinguenda* Hustedt is in fact conspecific with *C. tecta* and the name *C. distinguenda* has priority (Håkansson 1989).

Thwaites' original material of *C. kuetzingiana* and Kützing's of *C. meneghiniana* were investigated by Håkansson (1990a). She found that these taxa were conspecific and that the name *C. meneghiniana* had priority. The new name *C. krammeri* was given by Håkansson to the taxon long misidentified as *C. kuetzingiana*. The two varieties: *C. kuetzingiana* var. *planetophora* Fricke and *C. kuetzingiana* var. *radiosa* Fricke were validly published by Fricke (1900 in Schmidt (1874-1959), Tafel 222, Fig. 8 (*C. kuetzingiana* var. *radiosa*) Figs 9-12 (*C. kuetzingiana* var. *planetophora*)). Fricke's type material could not be found and a detailed investigation of these two varieties was therefore impossible. Even if *C. krammeri* has broad morphological variability it seems unwise to include into *C. krammeri* the two varieties *planetophora* and *radiosa*. Other investigations have shown how difficult it can be to see morphological differences by comparing a drawing with LM pictures from the microscope.

Håkansson (1986, 1990a) investigated both *Discoplea oligactis* Ehrenberg and *C. comta* var. *oligactis* (Ehr.) Grunow. No material of *D. oligactis* could be found in the Ehrenberg collection, and the figures published by Ehrenberg were insufficient to allow certain identification, therefore Håkansson regarded *D. oligactis* as *nomen nudum*. Another interesting taxon was observed on slide no 2146 in the Grunow Collection (with material from "Lara" and not from the Ganges). This taxon has a narrow marginal area, but regularly striated without any "Schattenlinien" (shadow lines). This means that this taxon does not belong to the *C. radiosa*-complex. In the literature no validly published name could be found, therefore the name *C. rossii* was chosen.

Håkansson (1990b) stated that the name *C. kisselevii* Korotkevich was not validly published because there was no holotype indicated (Greuter *et al.* 1988). Later when Loginova & Vishnevskaya (1987) published the variety *C. kisselevii* var. *leprindica*, it was also invalidly published, because name of the species to which it is assigned is not validly published. Therefore this taxon was given the new name *C. tripartita* Håkansson.

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MODERN AND HOLOCENE DIATOMS FROM UKALIK LAKE, BAFFIN ISLAND, NORTHWEST TERRITORIES: PRELIMINARY RESULTS

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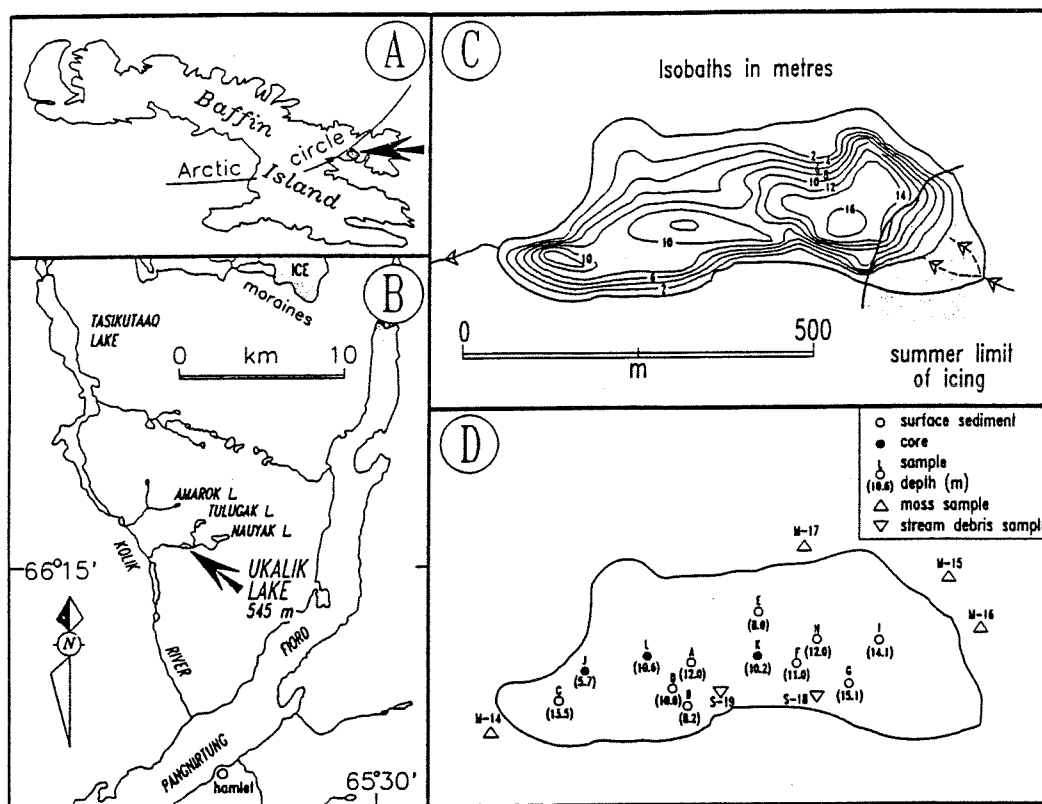
INTRODUCTION

Although areal patterns of diatom distribution have been studied in a number of temperate lakes, producing results that corroborate, validate and/or facilitate interpretations of paleolimnological records (Bradbury & Winter 1976, Kingston *et al.* 1983, DeNicola 1986, Earle *et al.* 1988, Charles *et al.* 1991), no prior study has addressed an arctic lake, despite the recommendation within PALE (Paleoclimates of Arctic Lakes and Estuaries), that: "multiple cores from individual lakes should be collected and studied" (Andrews & Brubaker 1991). Such studies permit assessments of the reproducibility of paleolimnological results (Charles *et al.* 1991) and of microfossil and sedimentological variability between cores from different water depths (Anderson 1990). When coupled with analyses of specific within-lake diatom habitats (e.g. DeNicola 1986, Jones & Flower 1986), these types of data provide powerful tools for the interpretation of diatom stratigraphies, especially in regions that lack expansive modern sedimentary diatom assemblage calibrations to limnological conditions. This report presents the initial results of diatom studies from surface sediments, multiple cores, plankton tows and moss periphyton from a small lake on Baffin Island, N.W.T.

STUDY SITE AND METHODS

Ukalik Lake is a small (18.4 ha), steep-sided, deep ($Z_{\max} = 16.4$ m), soft-water lake on Cumberland Peninsula, Baffin Island (66°16' N, 65°45' W; Figure 1a,b). The chemistry of this ultra-oligotrophic lake is summarized in Table 1. Severe acid shock characterizes the brief nival melt period in June. Lake ice exceeds 2 m and does not disappear until late July; August is the only ice-free month. Furthermore, an unusually large (c. 20 ha) and thick (4 m) icing (aufeis) occupies the inflowing valley and impinges well onto Ukalik Lake (Figure 1c). A geothermal origin for this icing is not dismissed. Local geology comprises Archean granites, granitic gneisses and quartz monzonites. Bedrock and thin Quaternary deposits of local origin are highly weathered at the site, which lies on an upland plateau unmodified by continental glaciation during at least the last 70 ka (Dyke 1979).

Short and long cores were taken from twelve surveyed stations on the lake (Figure 1d) with a percussion corer (Gilbert & Glew 1985). For short cores, the sampler was eased into the sediment under the hammer's weight, rather than pounded, and disturbance is estimated at 1 cm or less from observations of live moss and chironomid larvae at the core tops during packing, and, subsequently, examination of core x-radiographs. The entire Holocene record was retrieved at four sites and varies in thickness from 24 to 95.5 cm. Inorganic sediments of unknown thickness, mostly barren of diatoms, underlie the Holocene gyttja. Three radiocarbon dates provide a chronology for core UKL-L, the longest, and this is correlated to the other cores by the matching of diatom zone boundaries (Figure 2). Twelve surface sediment samples (0-1



cm) and three cores, sampled at 5 cm intervals (less near the base), were analyzed for diatoms, as were four through-ice plankton tows (25 µm mesh) of the entire water column at site E, four moss samples, and two samples of organic debris from small streams entering the lake from the south (Figure 1D). All samples were acid-cleaned using standard reagents (H₂O₂, H₂SO₄ and K₂Cr₂O₇). Diatom concentrations were determined in sediment samples by the addition of exotic markers (Kaland & Stabell 1981). At least 500 diatom valves were counted in transects on all slides from the sediment. Counts of 250 microfossils (diatoms and chrysophyte cysts) were made on the other samples. Taxonomic references included Foged (1981), Hustedt (1959), Patrick & Reimer (1966, 1973), and Krammer & Lange-Bertalot (1986, 1988, 1991a, 1991b). The specific and subspecific taxonomy of *Aulacoseira* followed that of Camburn & Kingston (1986) as *Melosira sensu lato*. There were floristic similarities to naturally and anthropogenically acid lakes, and thus the PIRLA Iconograph (Camburn *et al.* 1986) was also used, usually with respect to problem taxa.

RESULTS AND DISCUSSION

Seventy diatom taxa from sixteen genera were identified (Hamilton *et al.* 1994), representing an overwhelmingly acidophilous and acidobiontic flora, with both benthic and planktonic components typical of low alkalinity nutrient-poor lakes. The only exceptions to this are the small and generally considered alkaliphilous *Fragilaria* (i.e. *F. pinnata* and *F. construens* var. *venter*) that occur sporadically in plankton tows and consistently in sediments of the earliest Holocene age. A brief taxonomic comment is made regarding the identification of two diatoms from Ukalik and surrounding lakes. *Brachysira* sp. 3 PIRLA conforms to the specifications of Camburn *et al.* (1986) for *Anomoeoneis* sp. 3 PIRLA, as illustrated in their plate 33, Figure 32. This is most likely an undescribed variety of *Brachysira serians* (Brébisson *ex* Kützing) Round & Mann; it is probably acidobiontic. The taxon *Eunotia* sp. 21 PIRLA (Camburn *et al.* 1986, plate 10, Figure 49) also occurs abundantly in the study area. This undescribed diatom has a valve shape closely resembling *E. denticulata* (Brébisson) Rabenhorst, but falls in the smaller size range for this species and, more importantly, lacks the diagnostic spines on the ventral valve margin.

Modern samples

The frequencies of dominant diatoms from all the modern samples are illustrated in Figure 3. In modern sediments, *Aulacoseira* and *Achnanthes* spp. are quite evenly distributed between stations, and this suggests that they are at least partially mixed in the water column prior to deposition. This is supported by the results from plankton tows, which, while not showing any pronounced seasonal variations (between June 11 and July 24, 1991), bear strong similarities with the assemblages from surface sediments. However, other important taxa, such as *Eunotia* spp. and *Frustulia rhomboides*, are highly variable between surface sediment stations. This is interpreted as reflecting primarily epipellic habitats that appear unrelated to water depth. For example, *Pinnularia biceps* is most abundant at stations G, K and L (15.1, 10.2 and 10.6 m, respectively), while the *Eunotia rhomboidea-pectinalis* var. *minor* complex dominates stations E and H (8.0 and 12.0 m). Conversely, only the shallowest modern sediment sample contains *Fragilaria virescens* var. *exigua* (J, 5.7 m), and although its frequency is <5 %, this implies that it is restricted to littoral environments.

Counts from moss and debris entering Ukalik Lake are invariably dominated by *Achnanthes altaica* and *A. helvetica* var. *minor*, and also have large numbers of chrysophyte

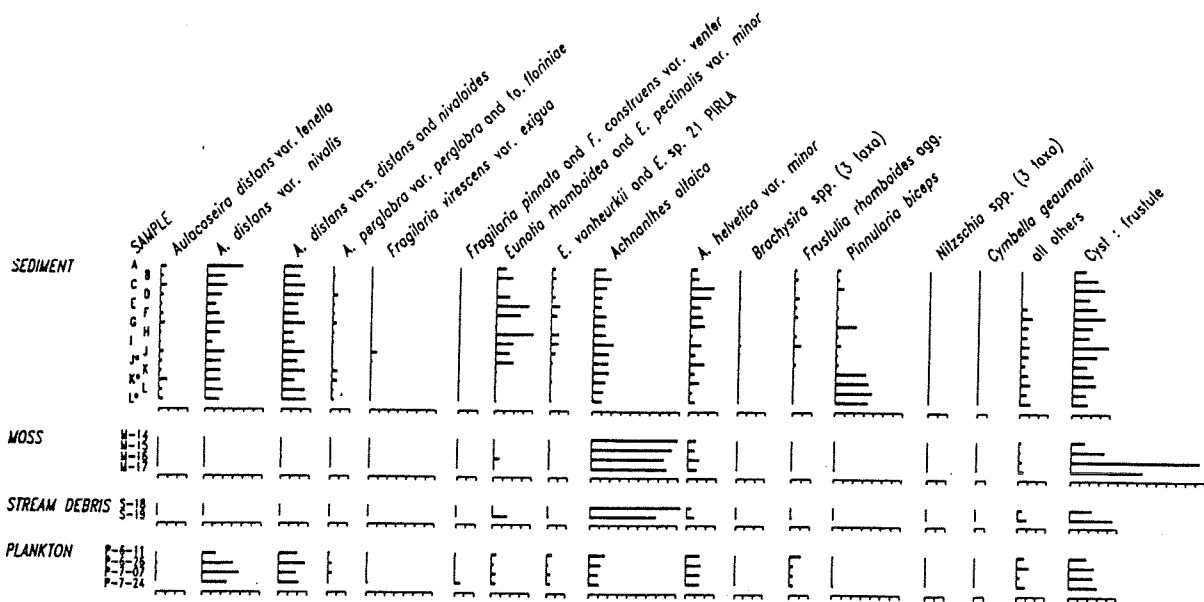


Figure 3. Relative frequencies of the most common modern and fossil diatoms in the surface sediments, moss periphyton, organic debris from streams on the lake ice surface, and plankton tows. Duplicate counts are identified by an asterisk.



Figure 4. Holocene stratigraphies of the relative frequencies of dominant diatoms in three cores (L, J, K) from Ukalik Lake.

Parameter	Level
pH	6.13 (5.4-7.1)
Conductivity	5 μ S
Potassium	0.29
Sodium	1.05
Magnesium	0.14
Calcium	2.55
Iron	0.05
Copper	0.02*
Zinc	0.05*
Chloride	2.78*
Nitrate	3.06*
Sulphate	1.13*

TABLE 1. Mean water chemistry values for Ukalik Lake (in mg.l⁻¹, except where indicated).

* average for inflow streams

cysts. *Pinnularia lagerstedtii* is the most common other diatom in these samples, although it was rarely recorded in sediment or plankton samples. Combined with the other results, the plankton data imply that *Aulacoseira* spp. are euplanktonic, and that portions of the *Achnanthes* and *Eunotia* populations are tychoplanktonic.

Holocene samples

Cores taken from stations K, L and J illustrate between-site differences within the entire postglacial diatom stratigraphy, as all three cores contain the well defined lithological transition from inorganic to organic sediments that has been dated, throughout the area, to circa 10 ka BP (Wolfe unpublished data). All three stratigraphies (Figure 4) coherently preserve three biostratigraphic zones, the durations of which are established by extrapolation of the radiocarbon chronology of core L (Figure 2).

Zone 1 (10-9 ka BP). Alkaliphilous *Fragilaria* spp comprise 5-10 % of this short-lived but important zone, which is also characterized by less than 5 % *Aulacoseira* spp., and abundant (10-70 %) *F. virescens* var. *exigua*. This zone, which marks the onset of organic sedimentation, indicates retention of base cations derived from pre-Holocene weathering and erosion.

Zone 2 (9-7 ka BP). Diatom diversity and concentrations peak in this zone. *Aulacoseira* spp. comprise 5-30 % of the assemblages, and *F. virescens* var. *exigua* remains abundant. The acidophilic and acidobiontic taxa of *Frustulia* and *Brachysira* are conspicuous elements that indicate a severe natural acidification event during the early Holocene.

Zone 3 (7 ka BP to present). The mid and late Holocene are characterized by 50-75 % *Aulacoseira* spp, and 10-30 % *Achnanthes* spp. Although the lake appears to have remained somewhat acidic during this period, approaching conditions similar to present, it was certainly less so than during zone 2.

Of considerable interest are the discrepancies between the diatom stratigraphies of these three cores, in particular between core J (5.7 m) and the deep water cores K and L (10.2 and 10.6 m). The dominant diatom in cores K and L, *Pinnularia biceps*, never exceeds 5 % , and this confirms its affinity for relatively deep water (cf. Smol 1983). Furthermore, the representations of *Fragilaria virescens* var. *exigua* in zone 2 and *Eunotia* spp. in zone 3 are far greater in core J than in cores K and L, implying preference for littoral habitats, despite the afore-mentioned variability of the distribution of *Eunotia* spp. within surface sediment.

CONCLUSIONS

Multiple core studies are shown to be useful in verifying the integrity of paleolimnological reconstructions based upon single cores. Samples from a variety of modern habitats provide useful autecological data which supplement these interpretations. However, direct paleoclimatic inferences from the diatom records of Ukalik Lake are somewhat incompatible with the nearest detailed paleoclimatic record, the pollen stratigraphy from Iglutalik Lake, 25 km to the south (Short *et al.* 1985). For example, maximum diatom productivity and the development of complex diatom communities in zone 2 of Ukalik Lake coincides with their period of lowest terrestrial productivity. Further, the importance of *Aulacoseira* during the well documented Neoglacial (late Holocene) cool period contradicts the hypothesis that habitats available to planktonic diatoms are necessarily limited during cold paleoclimatic periods (Smol 1983, 1988). A more detailed discussion of these problems, in addition to the results from another core from Ukalik Lake (sites A and H) and the statistical treatment of the data, are to be presented elsewhere.

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THE GEOGRAPHICAL AND PHYSICOCHEMICAL CHARACTERISTICS OF 35 PONDS FROM CAPE HERSCHEL, ELLESMERE ISLAND

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SITE DESCRIPTION

Ellesmere Island is the northernmost island in the Canadian Arctic archipelago (Figure 1). Cape Herschel (78°37'N, 74°42'W), which is located on the east-central coast of Ellesmere Island facing Smith Sound, is a rugged peninsula (approximately 2 x 5 km) of high relief (0-285 m asl) and consists principally of massive red granite or gneissic bedrock, overlain by small patches of calcareous tills (Christie 1962; Frisch 1984). No glaciers presently occupy the Cape proper, but many small patches of snow persist throughout the summer. Glaciers are present to the immediate north and south of the Cape. As in other high arctic locations, vegetation is scant consisting mainly of mosses, grasses, sedges, *Salix* and a few flowering plants (Bridgland and Gillett, 1983).

Cape Herschel is the site of a scientific field station that was established in 1973 as part of the North Water Project by the late professor Fritz Müller, a Swiss glaciologist who was associated with McGill University. The project's mandate was to examine the east-lying polynya called the "North Water", and to determine its effects upon weather, climate, flora and fauna (Müller 1977). Since then, the station has been host to a series of field parties all under the direction of W. Blake Jr., Geological Survey of Canada. Diverse physical and biological aspects of the region were studied over a 15 year period as the Cape Herschel Project.

The main emphasis of the studies was to unravel the glacial history of the region. Blake (1977, 1992) described the glacial sculpture of the east-central coast of Ellesmere Island, and detailed the glacial and post-glacial history of Smith Sound, focusing on the area surrounding Cape Herschel. He produced an emergence curve for the Cape Herschel area based on radiocarbon dates from molluscs, driftwood, whale bones, charred material from archaeological sites and organic sediment from ponds. Many cores of Holocene sediments have been examined from small ponds in the area. The first ponds to be cored were chosen because they were located below the limit of Holocene marine submergence and it was thought that information about postglacial emergence could be gained by dating the basal pond sediments (Blake 1978). Lichti-Federovich (unpublished GSC Diatom Reports) did not find marine littoral diatoms at any depths in these cores. Additional ponds from higher elevations have since been cored (e.g., Moraine Pond). Radiocarbon dates from the basal lacustrine sediment provide a minimum age for deglaciation, and for the onset of organic accumulation (Blake 1981a, 1982, 1987). Areas close to Cape Herschel (e.g., Makinson Inlet) were free of ice by 9000 years ago (Blake 1981b). A greater than 52,000 year old peat deposit has also been identified, which is an interglacial deposit that contains fossils of several insects and plants that are no longer found at such latitudes. The fossils suggest that a warmer climate existed (Blake and Matthews 1979).

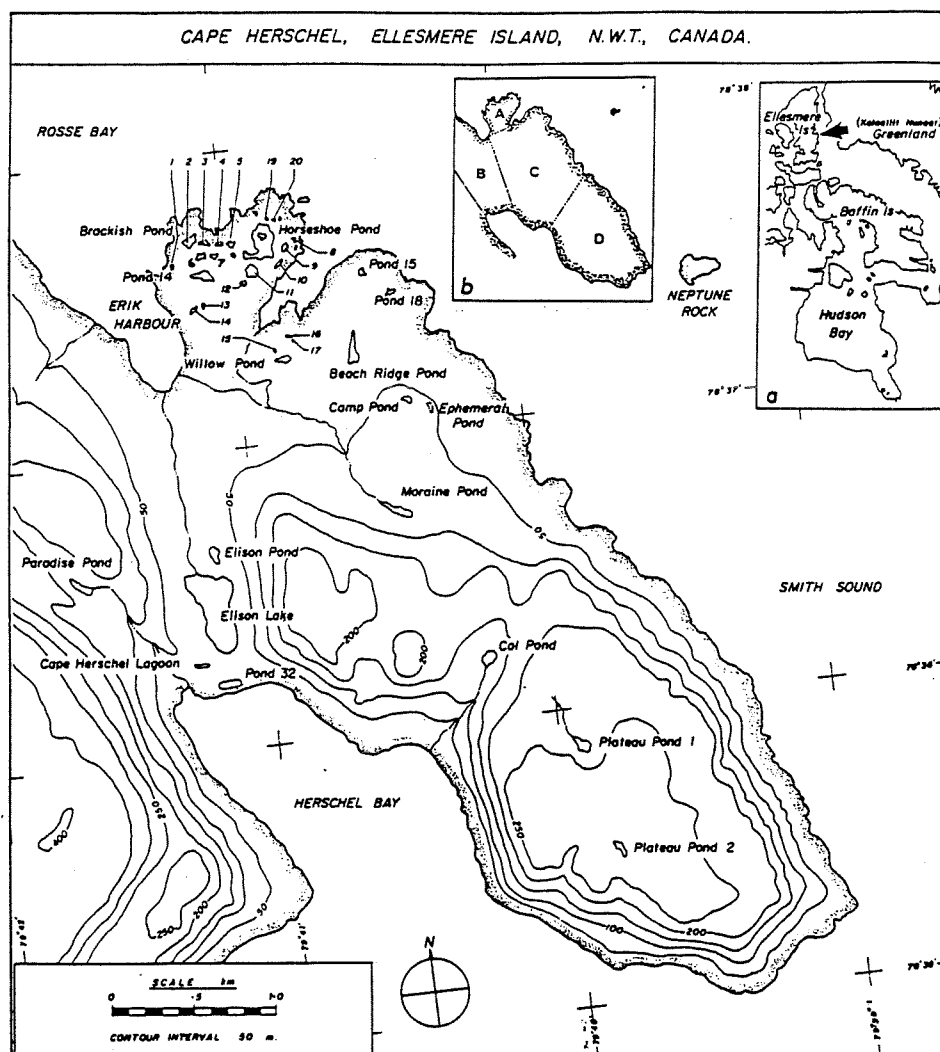


Figure 1. Map of Cape Herschel, Ellesmere Island, N.W.T., showing the 36 principal study sites (From Douglas, 1993). With the exception of Elison Lake, all pond names are unofficial. Figure 1a. The arrow indicates Cape Herschel's location on Ellesmere Island. Figure 1b. The Cape is subdivided into 4 geographic groups. Each of these 4 groups (A, B, C and D) is described in detail in Douglas (1989). A, Lower Peninsula; B, Elison Pass; C, Camp Area and D, High Plateau. Numbers on the map correspond to the following pond names:

1	Cold Pond	8	Pond 26	15	Pond NW Willow
2	Brackish Pond	9	Pond 24	16	Pond 2
3	Pond 1	10	Pond 6	17	Pond 3
4	Pond 10	11	Pond 7	19	Pond NW Horseshoe
5	Pond 8	12	Pond S of Pond 7	20	Poppy Pond
6	Pond 13	13	Pond 27		
7	Pond 12	14	Pond 28		

Topographic data courtesy of Dr. G. Holdsworth, Arctic Institute of North America. Produced by Special Projects Section, Surveys and Mapping Branch, E.M.R.

An assessment of the snow quality and extent of anthropogenic pollution was carried out by McNeely and Gummer (1984). They determined that a variety of pesticide residues are globally dispersed via the atmosphere and are deposited on sites even as remote as Cape Herschel. Their study of the surface waters provides background data on water quality for this area. The only other limnological data available for Cape Herschel is a brief 1981 survey of the pH and alkalinity of precipitation and surface waters by McNeely (1982) and Environment Canada (1982, 1984).

Bridgland and Gillett (1983) published a checklist of vascular plants, and increased the number of vascular plants known from the area to 117 species. The present climate was identified as the principal determinant of plant distributions and floral diversity. In addition to the above data, aviation weather reports were maintained by W. Blake Jr. and reported twice daily (07:00 and 19:00) during the field seasons. Cape Herschel lies close to the northern extent of the North Water, a polynya or water body that remains almost completely ice-free most of the year due to coastal configurations and currents (Dunbar, 1969; Barr 1985). This body of open water has a moderating effect on local climate. Maximum summer air temperatures at the station are often near 0-5°C, but may attain 14°C (see Figure 2 in Douglas 1989). Significant inter-year differences are also apparent. These annual variations may seem slight in absolute terms, but have important implications when one considers the brevity (only a few weeks) of the "summer" growing season: even modest climatic changes can profoundly influence when the ponds will begin to thaw and when aquatic primary production will begin.

SPECIES LIST

The species identified from this area (Hamilton *et al.* 1994) consist of the diatom taxa observed from epiphytic (moss), epilithic (rock) and epipellic (sediment) habitats in the Cape Herschel ponds. Detailed taxonomic and autecological notes and photographic plates are to be found in Douglas (1989) and Douglas & Smol (1993). Taxa identified by number, e.g., *Cymbella* sp. 1 are described in these references. Additional autecological data can be found in Douglas (1993) and Douglas & Smol (in prep).

WATER CHEMISTRY

The marked relief of the Cape results in pronounced inter-pond differences in microclimate, as well as variations in water chemistry, vegetation, and drainage characteristics. In addition, a pond's proximity to the sea and the geologic variations in drainage composition (Precambrian granite family bedrock, with overlying tills containing Palaeozoic carbonates) affect the water chemistry of each pond.

Douglas (1989) and Douglas & Smol (1994) monitored limnological changes over parts of four field seasons (1983, 1984, 1986, 1987) on 36 major study ponds on Cape Herschel. The main objectives of these studies were to describe and interpret seasonal changes in limnological variables, and compare these data to other regions. Douglas (1989) provided a lengthy written and graphic description of the study ponds, and discusses the physical and chemical characteristics of the study sites within the four geographic zones she delineated on Cape Herschel, namely: A) Lower Peninsula; B) Elison Pass; C) Camp Area, and D) Plateau Area (Figure 1b). All pond names are unofficial with the exception of Elison Lake. The ponds range in elevation from sea level to 255 m asl. Few ponds exceed 1 m in depth, and none are deeper than 3 m. Elison Lake (~7 ha) and Horseshoe Pond (~4 ha) are the largest ponds sampled; all other ponds are smaller than 1 ha. The ponds freeze completely for at least 10 months of the year;

Table 1. Water chemistry and substrate characteristics for the 35 sites. Alkalinity (Alk) and major ions (SiO_2 , Cl^- , Na^+ , Ca^{2+} , SO_4^{2-} , Mg^{2+} , K^+) are measured in $\text{mg}\cdot\text{l}^{-1}$. Conductivity (Cond) is measured in $\mu\text{S}\cdot\text{cm}^{-1}$ and pH is measured in pH units. The values for rock, moss and sediment (Sed) are based on percentages present in each of the sampled ponds.

SITE	Ca^{2+}	Mg^{2+}	Na^+	K^+	SO_4^{2-}	Cl^{-1}	SiO_2	Alk	pH	Cond	Rock	Moss	Sed
Col P.	8.9	5.4	5.7	0.4	2.2	10.1	0.9	33.6	7.6	93.8	50.0	1.0	50.0
P. 15	12.4	4.4	6.2	0.5	1.7	12.6	0.8	39.5	7.7	114.7	10.0	1.0	90.0
P. 18	14.8	5.0	5.3	0.5	1.4	8.6	1.2	53.1	7.8	115.7	50.0	1.0	50.0
P. NW HS	16.6	10.2	14.6	1.2	2.7	26.7	1.2	68.6	7.7	114.6	25.0	1.0	75.0
Elison P.	21.9	7.5	8.6	0.7	2.4	14.5	2.0	76.2	7.9	124.2	55.0	1.0	45.0
Paradise L.	1.4	0.7	2.6	0.2	0.8	4.9	0.6	4.0	6.5	21.8	80.0	1.0	20.0
C.H. Lagoon	15.6	5.9	8.1	0.7	2.3	11.3	1.1	59.0	7.8	115.1	45.0	1.0	50.0
Beach Ridge	20.5	11.2	11.1	1.1	3.0	17.8	2.3	88.6	8.1	177.4	50.0	1.0	50.0
Plateau P. 1	5.9	3.4	3.9	0.3	2.0	6.9	0.8	23.0	7.5	69.8	90.0	1.0	10.0
Plateau P. 2	5.3	3.4	4.5	0.3	2.6	7.5	0.5	20.9	7.4	68.9	95.0	1.0	5.0
Horseshoe P.	9.3	6.4	12.9	1.1	2.6	23.4	0.8	43.1	7.8	137.7	85.0	40.0	15.0
Willow P.	13.8	5.4	5.5	0.5	2.6	9.4	1.1	52.2	7.9	122.8	10.0	20.0	90.0
Pd. N Willow	6.2	4.0	8.1	0.7	2.3	14.8	0.6	17.9	7.5	45.0	40.0	1.0	60.0
Moraine P.	12.6	5.7	6.5	0.5	3.7	12.1	1.3	45.8	7.7	112.6	1.0	1.0	100.0
P. 13	10.2	6.6	15.1	1.1	3.3	24.7	0.8	46.1	7.8	170.6	60.0	5.0	35.0
P. 12	9.0	4.3	10.3	0.8	2.2	17.4	0.5	34.9	7.7	131.2	65.0	5.0	30.0
Pond 10	14.4	7.5	11.7	1.1	2.9	19.5	1.4	61.0	7.8	176.4	40.0	10.0	50.0
Pond 8	13.9	7.7	11.4	1.0	2.4	18.7	1.1	58.3	7.9	131.0	1.0	10.0	90.0
Pond 2	23.2	8.8	7.1	0.6	1.9	10.0	2.8	90.2	7.9	156.7	15.0	10.0	85.0
Pond 3	24.1	9.2	7.6	0.6	2.0	11.6	3.3	93.7	7.7	123.0	25.0	20.0	75.0
Pond 28	15.4	8.9	16.9	1.3	8.4	28.8	1.3	58.5	7.9	220.8	75.0	5.0	20.0
Pond 6	9.0	5.0	6.4	0.7	1.5	9.3	0.6	39.3	7.6	102.3	75.0	5.0	25.0
Pond 24	9.6	5.4	7.6	0.7	1.5	10.4	0.9	44.6	8.0	129.0	55.0	5.0	45.0
Pond 32	9.2	4.7	13.8	0.8	3.7	23.6	0.6	32.2	7.7	159.1	30.0	40.0	70.0
P. S. 7	13.0	5.6	7.9	0.9	2.5	13.7	1.1	47.6	7.9	148.6	65.0	10.0	35.0
Pond 7	8.7	4.7	7.2	0.7	2.2	13.6	0.3	33.0	7.8	107.9	40.0	10.0	50.0
Pond 14	12.5	7.4	13.8	1.2	3.0	18.8	1.0	53.0	8.0	192.7	60.0	25.0	15.0
Pond 1	14.5	8.3	14.2	1.2	3.1	23.4	1.0	63.0	8.0	180.7	45.0	10.0	45.0
P. 27	5.6	3.4	8.5	0.7	1.8	14.2	0.4	22.8	7.7	186.5	30.0	10.0	60.0
Ephemeral P.	22.2	6.7	6.7	0.6	1.4	13.9	0.4	82.0	7.9	99.0	90.0	1.0	10.0
Camp P.	22.7	7.9	7.5	0.6	3.9	9.9	2.2	87.0	8.0	152.9	10.0	5.0	85.0
Elison L.	21.0	7.2	8.2	0.7	2.4	13.5	1.5	74.3	7.8	122.0	70.0	1.0	30.0
Poppy P.	12.5	8.5	11.3	0.9	2.5	23.4	0.8	47.7	8.5	119.0	15.0	1.0	85.0
Cold P.	9.0	6.7	25.4	1.7	5.4	37.8	1.4	42.1	7.7	177.0	50.0	1.0	50.0
P.26	3.6	2.0	4.6	0.4	0.8	7.3	0.3	14.7	7.9	134.0	50.0	1.0	50.0

(Figure 1b). All pond names are unofficial with the exception of Elison Lake. The ponds range in elevation from sea level to 255 m asl. Few ponds exceed 1 m in depth, and none are deeper than 3 m. Elison Lake (~7 ha) and Horseshoe Pond (~4 ha) are the largest ponds sampled; all other ponds are smaller than 1 ha. The ponds freeze completely for at least 10 months of the year; however, during the short summers, water temperatures warm substantially (to a recorded maximum of 17°C) and fluctuate diurnally. All the ponds are clear and oligotrophic. With the exception of one site (Paradise Pond, pH = 6.5), the ponds are alkaline (pH range = 7.4 - 8.6), reflecting the presence of calcareous tills overlying granitic bedrock. Conductivity values fluctuated seasonally, but were generally between 100 and 300 $\mu\text{S}\cdot\text{cm}^{-1}$. The only exception was one tidally influenced brackish pond, with conductivity measured at 10 393 $\mu\text{S}\cdot\text{cm}^{-1}$, and the dilute Paradise Pond, with a minimum conductivity of 22 $\mu\text{S}\cdot\text{cm}^{-1}$. Major ion concentrations are relatively similar among the remaining sites, although environmental gradients exist (reflecting, for example, differences in local drainage basins and proximity to the sea). Ca^{2+} and Na^{+} are the major cations, whereas Cl^{-} is the major anion. Ionic concentrations change over the summer, due to the combined effects of cryoconcentration, snowmelt dilution, evaporation, and other factors. Douglas & Smol (1994) concluded that high arctic ponds such as these may be especially sensitive monitors of future environmental change. Table 1 lists the average water chemistry (major ions, pH, alkalinity, and conductivity) and substrate characteristics for the 36 Cape Herschel ponds referred to in this study. Data on the seasonal variation of water chemistry over the course of four field seasons can be found in Douglas (1989), Duff *et al.* (1992) and Douglas & Smol (1994).

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PHYSICOCHEMICAL AND BIOLOGICAL (DIATOM) RELATIONSHIPS IN MARITIME ANTARCTIC LAKES¹.

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Lakes from two areas of the maritime Antarctic were studied (Figure 1), the Byers Peninsula (Livingston Island, South Shetland Islands, latitude 62° 40' S, longitude 61° 00' W) and Signy Island (South Orkney Islands, latitude 60° 43' S, longitude 45° 38' W). The Byers Peninsula is the largest ice-free area of the South Shetland Islands covering an area of about 50 km². The highest part of the Peninsula (Chester Cone) is 193 m high, but most of the area consists of a central platform lying between 85 and 100 m. The geology of the area consists of Jurassic-Cretaceous sediments (shales and sandstones) and Upper Jurassic-Lower Cretaceous volcanic rocks (basaltic agglomerates, augite-andesites, volcanic breccias and tuffs) (Hobbs 1968). The Holocene history of the Peninsula is summarised by Björck *et al.* (1991). Most of the inland area is not vegetated but scattered clumps of mosses and lichens do occur. The coastal area is somewhat richer and supports two flowering plant species (*Deschampsia antarctica* and *Colobanthus quitensis*) with a limited development of coastal moss carpets.

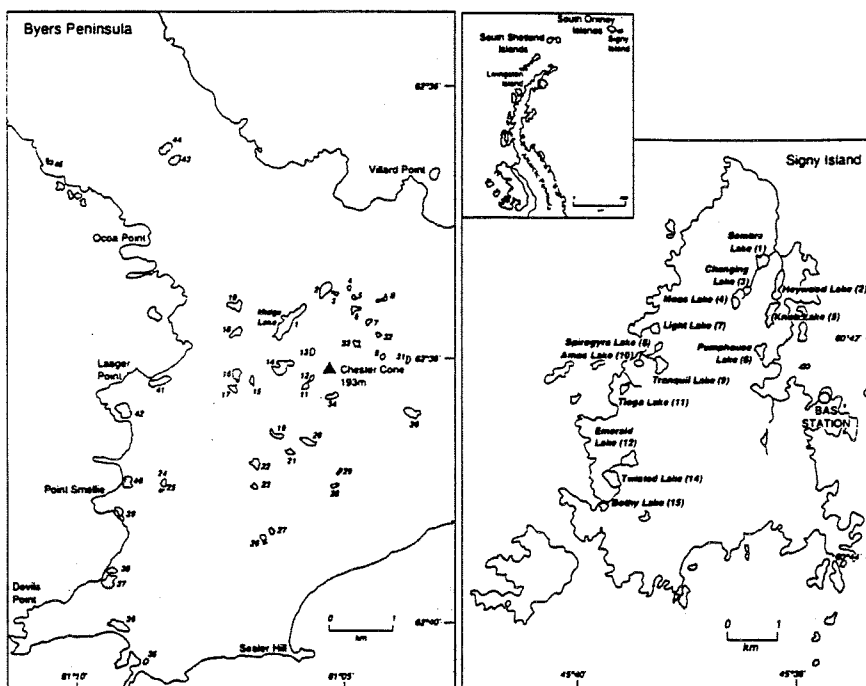


Figure 1. Location of sample sites on Signy & Livingston Islands. Lakes are referred to by number on Livingston Island, and by name and number on Signy Island.

Signy Island covers an area of about 20 km² and is low lying, with a maximum height of 279 m. The terrain is rugged and large areas (32%) are covered with permanent snow and ice.

1 * This paper is extracted from Jones, V.J., Juggins, S. & Ellis-Evans, J.C. 1993. The relationship between water chemistry and surface sediment diatom assemblages in maritime Antarctic lakes. *Antarctic Science* 5: 339-348.

The geology consists of intensely folded metamorphic sediments, mainly garnetiferous quartz-mica-schists, with some amphibolites and marbles (Matthews & Maling 1967). The ice-free areas of Signy Island are comparatively well vegetated with extensive areas of moss and lichen as well as patches of *C. quitensis* and *D. antarctica* (Smith 1972). Large peat banks have accumulated on Signy Island which reflect greater stability and more acid soils compared to the generally unstable, porous and more alkaline volcanic soils of Livingston Island. Signy Island lakes are, with one exception, in more vegetated catchments than virtually all the Livingston Island lakes which are mainly on the barren central plateau (Figure 1).

Livingston and Signy Islands share a Maritime Antarctic climate which is moister and milder than Continental Antarctica. Mean annual air temperatures are sub-zero (-3°C) but mean monthly temperatures exceed 0°C for at least one month in summer. Permafrost is present below an active layer of 0.3-0.7 m (Chambers 1966, John & Sugden 1971).

The Signy Island lakes are glacial in origin and range from oligotrophic clearwater to turbid eutrophic systems (Heywood *et al.* 1979, 1980). The lakes at Signy Island are all relatively shallow (generally <10 m deep) and ice-covered to a depth of 1-1.5 m for 8-12 months each year. The Livingston Island lakes are also shallow and appear to have a similar depth of ice cover. However, the greater winter snow accumulation insulates these lakes from early summer air temperatures, and ice-out appears to be several weeks later than the majority of systems at Signy Island. In summer all lakes are ice-free and well mixed by wind.

The major source of nutrients in maritime Antarctic lakes is from bird and seal excreta. By contrast, terrestrial ecosystems are very unproductive. Nutrients are thus largely transferred from the much more productive marine ecosystem either directly into lakes by animals or indirectly via runoff from the catchment (Smith 1988). This has become particularly pronounced at Signy Island where over the past 10 years, the catchments of some lakes have been colonised by large numbers of Antarctic fur seals (*Arctocephalus gazella*), representing the overspill from rapidly expanding populations on sub-Antarctic South Georgia (Figure 1). In some areas the effects of these seals have been profound, with almost complete destruction of catchment moss communities (Lewis Smith 1988, 1990), enhanced nutrient runoff and increased organic carbon and nitrogen loadings in the lakes and lake sediments (Ellis-Evans 1990). In contrast, most freshwater Livingston Island lakes are situated inland and receive virtually no animal inputs, although the brackish coastal lakes are heavily influenced by sea spray and in some cases have large animal and bird populations in summer.

WATER CHEMISTRY

Principal components analysis (PCA) and cluster analysis are used to summarise the major patterns of variation within this data, and these results are presented as a PCA correlation biplot and dendrogram in Figure 2. In the biplot, variables with high positive correlation generally have small angles between their biplot arrows. Variables with long arrows have high variance, and are generally the most important within the data.

The cluster analysis divides the lakes into four groups. Groups 1 and 2 consist of the inland and coastal Livingston Island lakes respectively. Group 3 contains the Signy Island lakes, and Group 4 contains three outliers, separated on the basis of high nutrient concentrations, in the case of SG10 (Amos Lake), or high conductivities (LN37 and LN40). The first two principal components ($\lambda_1=0.50$, $\lambda_2=0.16$) account for 66% of the total variance, and

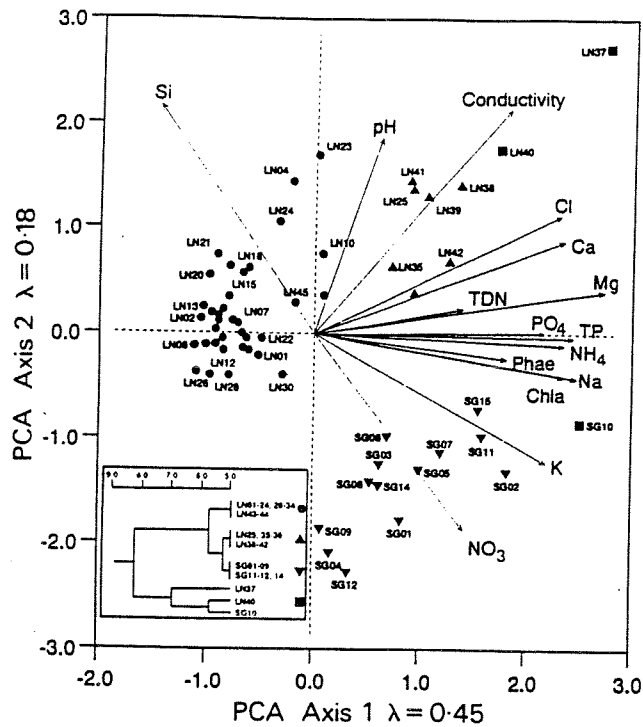
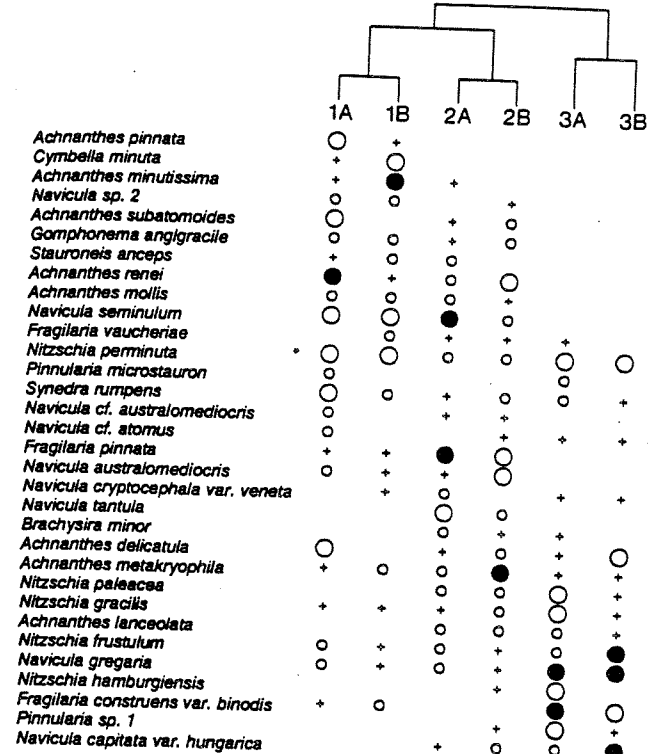


Figure 2. Principal components analysis (PCA) correlation biplot. Symbols for the lake sites are according to the groups defined by cluster analysis, see inset. Sites numbered as in Fig. 1 with the prefix LN to denote Livingston Island samples and SG to denote Signy Island.

Figure 3. TWINSPLAN results showing groups of sites and associated mean percent diatom abundances; +: <2%, o: 2-5%, 0: 5-10%, * >10%. Group 1a = sites SG2, 5, 6, 8, 10, 11, 15; Group 1b = sites SG1, 3, 4, 7, 9, 12, 14; Group 2a = sites LN1-7, 9, 10, 14-19, 21-24, 27, 31; Group 2b = sites LN8, 11-13, 20, 26, 28-30, 32-34, 36, 43-45; Group 3a = sites LN35, 38-40; Group 3b = sites LN25, 37, 41, 42.



effectively capture the main patterns of variation in the environmental data. The first axis is related to indicators of trophic status (total phosphate, orthophosphate, total dissolved nitrogen, chlorophyll-a and phaeopigments) and associated ions (calcium and magnesium), and contrasts the nutrient poor inland Livingston sites of Group 1, plotted on the left of the diagram, with the nutrient-rich coastal Livingston and Signy sites such as SG10 (Amos Lake), SG02 (Heywood Lake) and LN42.

Axis 2 reflects two gradients. The first running from top right to bottom left is related to lake-water salinity and separates the high conductivity coastal Livingston sites of Groups 2 and 4 from the remainder. Some sites, plotted top right, exhibit a very strong marine influence, particularly LN37 which has a conductivity of $2960 \mu\text{S}\cdot\text{cm}^{-1}$ and associated high sodium and chloride values. The second is related to dissolved silica, potassium and nitrate and runs from top left to bottom right, separating the generally high nitrate and potassium, low dissolved silica lakes on Signy Island, plotted bottom right, from low nitrate and potassium, high dissolved silica sites on Livingston Island.

DIATOM ANALYSIS

Twinspan classification was used to group sites on the basis of their diatom assemblages. Three main groups of sites were identified and these are represented in the dendrogram at the top of Figure 3. Group 1 consists of the Signy Island sites and is further divided into two. Group 1a contains the coastal, more eutrophic sites, whereas Group 1b contains the inland oligotrophic sites. Group 2 consists of the majority of the Livingston Island sites, and includes all the inland sites plus LN45 which although situated near the coast, is at an altitude of 80 m. Group 3 consists of the low-lying coastal Livingston Island sites.

Figure 3 also shows the major patterns of diatom distribution and abundance within these groups. Group 1a has high frequencies of *Achnanthes pinnata*, *A. subatomoides*, *A. renei*, *A. delicatula*, *N. seminulum*, *Nitzschia perminuta* and *Synedra rumpens*. Group 1b has a high frequency of *Cymbella minuta* and *A. minutissima*, and a lower frequency of *Synedra rumpens*. In Group 2 *N. seminulum*, *Fragilaria pinnata*, *Navicula tantula* and *A. metakryophila* are important. Group 2b also has high percentage abundances of *A. renei* and *N. australomediocris*. In Group 3 there are high percentage abundances of *N. perminuta*, *Navicula gregaria* and *Fragilaria construens* var. *binodis*. Group 3a also has high abundances of *Nitzschia paleacea*, *Nitzschia gracilis*, *Nitzschia hamburgiensis* and *Pinnularia* specie 1. Whilst Group 3b has high abundances of *Nitzschia frustulum* and *Navicula capitata* var. *hungarica*.

The three main groups identified on the basis of their diatom assemblages are broadly similar to the groups identified by water chemistry alone. This suggests that diatom distribution is strongly related to the main gradients in the chemical environment.

DISCUSSION

The lakes sampled on Livingston Island and Signy Island have quite distinct water chemistries with the former having higher silicate, and lower potassium and nitrate values than the Signy Island sites. Silicate is present in large amounts at both sites, being the major rock matrix component. However, tephra deposits may also provide an additional source of silica at Livingston Island (Björck *et al.* 1991) and silicate is probably released more readily at Byers than at Signy due to the higher weathering rate, and is thus present at high concentrations during the ice-free periods. Potassium is very mobile compared to silicate and would be quickly depleted from the weathered surface layers of Byers mineral particles. Slower

weathering rates at Signy would result in a slower release rate and thus lower amounts of potassium moving into the water phase, but over a more extended period of time.

Work by Christie (1987) and Hawes (1983) suggests that precipitation, largely in the form of ammonium, is the main source of external nitrogen for oligotrophic systems, and this would quickly be converted to nitrate in soils and lakes. At Signy there are substantial penguin colonies which could potentially enhance this ammonium precipitation component (Christie 1987) whereas lakes on the central plateau of Livingston Island are not close to penguin colonies or even downwind, judging from wind direction data (Ellis-Evans, unpublished).

Although there are differences in the diatoms of Livingston and Signy Islands, the combined flora found in this study resembles that observed in Southern America (Cleve-Euler 1948, Krasske 1939, 1949), the sub-Antarctic e.g. Kerguelen (Bourrelly & Manguin 1949, 1954) and the maritime and continental Antarctic (Pankow *et al.* 1987, Schmidt *et al.* 1990, Björck *et al.* 1991). The flora consists of a mixture of taxa, some of which appear to be endemic to this region, for example *Achnanthes metakryophila*, *Achnanthes renei* and *Navicula australomediocris*, while other species are cosmopolitan, for example, *Navicula seminulum* and *Achnanthes minutissima*.

An unusual feature of the diatom flora is that no typical planktonic diatoms occur on either Livingston or Signy Islands, and although planktonic forms have been reported from Antarctic lakes (eg. Lavrenko 1965, Baker 1967) they are not common. This is in marked contrast to lakes in more temperate areas where diatom assemblages are often dominated by planktonic forms, for example the genera *Stephanodiscus* and *Cyclotella*. The absence of planktonic diatoms in the Antarctic may be related to their lack of morphological or physiological characteristics (e.g. high bouyancy capacity or inability to form resting stages) which would enable them to survive prolonged periods of ice cover (Heywood 1978, Guilizzoni *et al.* 1992). In addition, summer open water temperatures are low, for example when compared to arctic lakes. The shallow nature of some of the lakes is probably not important since even small shallow ponds in temperate areas commonly develop a diatom plankton (e.g. Guzkowska & Gasse 1990).

The patterns of diatom distribution and abundance are clearly related to the main chemical gradients of the lakes. Forward selection and associated Monte Carlo unrestricted permutation tests (99 permutations) of the significance of the environmental variables (ter Braak 1990) suggest that conductivity, potassium, sodium and ammonium make significant ($p < 0.05$) contributions to explaining the variation in the diatom assemblages. Chlorophyll-*a* which is highly correlated with other nutrient variables (e.g. NH_4 , NO_3 , TP, TDN) also makes a significant contribution to explaining the variation in the diatom assemblages. Chlorophyll-*a* can therefore be considered as a summary variable for the nutrient status of these waters. Although there is no planktonic diatom response to trophic status in these lakes, benthic diatoms in Antarctic lakes appear to act similarly to those in lakes in the rest of the world. For example species which are associated with nutrient-rich waters in the Antarctic such as *Fragilaria construens* var *binodis*, *Achnanthes pinnata*, *Gomphonema angustatum* and *Achnanthes subatomoides* have a total phosphorous optima of $>10 \mu\text{g} \cdot \text{l}^{-1}$ in a Canadian data set (Hall & Smol 1992). Although little is known about the relationships between diatoms and environmental variables in Antarctic lakes, available data do support the results found here. Oppenheim (1990) in a study of 11 Signy Island lakes identified diatom species which were characteristic of proglacial, oligotrophic and mesotrophic lakes. In a further study of two of these lakes (Sombre Lake and Light Lake) redundancy analysis was used to show that the nutrient status was important in determining the epiphytic diatom assemblages (Oppenheim & Greenwood 1990).

This exploratory analysis of the relationship between diatom species and chemistry in

the Maritime Antarctic has shown that diatom abundance can be related to environmental variables. This will enable the environmental reconstruction of nutrient and salinity histories of Antarctic lakes using diatoms preserved in lake sediments. It will therefore be possible to test hypotheses concerning lake development or the influence of recent animal populations in determining present day nutrient levels.

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IMPACT OF FIRE, CLIMATE CHANGE, AND NONLINEAR POPULATION DYNAMICS ON A BOREAL FOREST LAKE

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INTRODUCTION

Fossil diatoms have been used to infer past environmental conditions including acidity, conductivity, salinity, temperature, hydrologic conditions and eutrophication (Smol 1990). Microfossil assemblages (including pollen, diatoms, chrysophytes, and chironomids) are used increasingly to test models of past and future climate change. The necessity to refine these models has magnified the importance of deducing non-climatic factors that have affected changes in these complex fossil communities. Of special relevance is the distinction of fossil variations due to average climate from those due to local disturbances (fire, wind storms, disease) and from natural population dynamics. The focus of this study will be to examine temporal changes in the composition of a diatom community from a lake in Wood Buffalo National Park (WBNP), where a variety of environmental variables, most prominently fire, climate and intrinsic population dynamics, may be controlling diatom populations and community structure. The lake selected for study, Rainbow Lake A (RLA) (Figure 1), contains annually-laminated sediments (varves), has a reconstructed fire history based on dendrochronology for the last 200 years

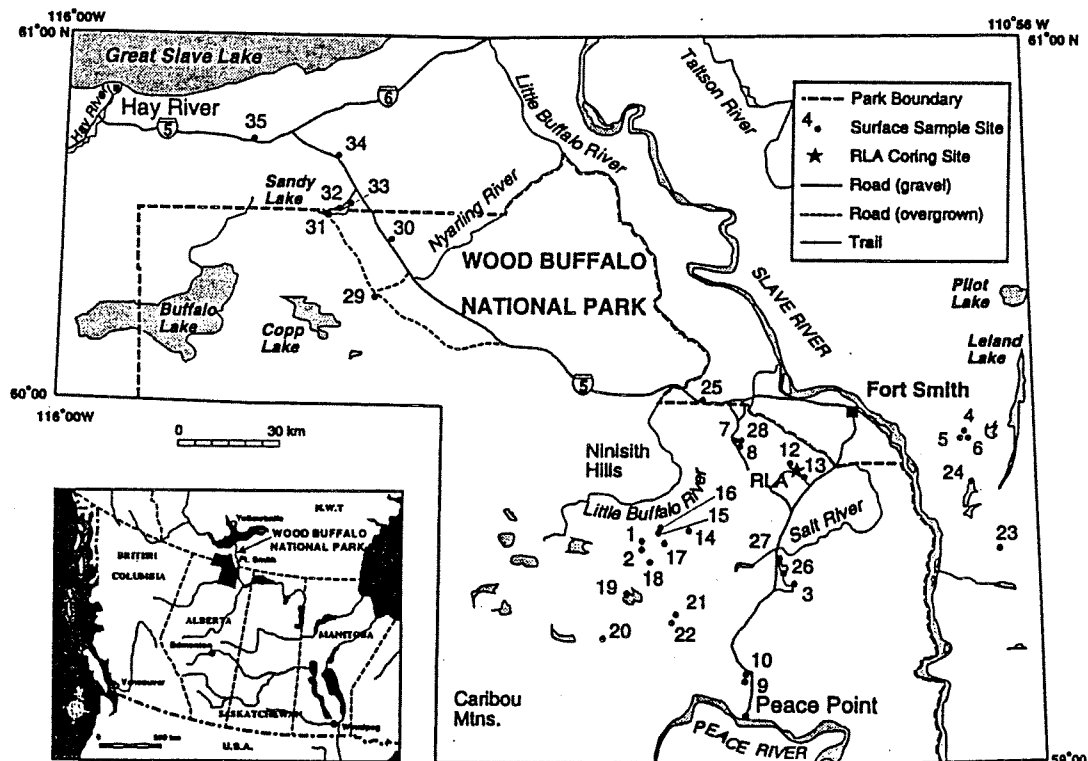


Figure 1. The study site of Wood Buffalo National Park from Western Canada. Surface samples are indicated with dots and the Rainbow Lake coring site is indicated with a star.

(MacDonald *et al.* 1991) and has a documented fossil pollen record for the last 1000 years (Larsen 1989a). Fossil diatom analyses will be made at three different temporal resolutions and will be studied in conjunction with information gleaned from a modern 'calibration set' (Smol 1990). The results of this research will help to elucidate the importance of each of these environmental variables on the composition and population of the diatom community. This brief report will provide a description of the study area, examine the specific hypotheses being tested, and report on the progress to date.

STUDY AREA

Wood Buffalo National Park, a world heritage site and one of the largest parks in the world, is located on the border of the Northwest Territories and Alberta Canada (Figure1). It is approximately the same size as Switzerland, with an area of 44807 km². The park is located in the northern Boreal forest and has a climate characterized by long cold winters and relatively warm dry summers. Average climate values for Fort Smith, located at the northeast corner of the park, are summarized in Table 1.

The vegetation of the park is composed of forests interspersed with muskegs and prairies. The dominant tree species include: *Pinus banksiana*, *Picea mariana*, *Picea glauca*, *Larix laricina*, *Populus tremuloides*, *Populus balsamifera* and *Betula papyrifera*. Characteristic shrubs include *Alnus crispa*, *Salix sp.*, *Shepherdia canadensis*, *Juniperus communis* and *Rosa acicularis*. A variety of grasses and herbs are also common. Fire frequency in the park is high and plays an important role in determining the vegetation patterns of the park. The average interval between fires at any given site is 66 years (Larsen 1989b).

The terrain of WBNP is generally flat but is occasionally broken by eskers that were deposited over 10500 years ago (Dyke & Prest 1987). Glacial, glacio-lacustrine, lacustrine and aeolian deposits cover most of the area and, although few exposures of bedrock exist, the subsurface geology plays an important role in developing the park's characteristic landscape. The park is underlain by approximately 26000 km² of gypsum, one of the most extensive gypsum karst terrains in North America (Drake 1970). The high solubility of gypsum results in a landscape dominated by karst features of which the most abundant are

Table 1. Climatic averages for Fort Smith. Data from Environment Canada (1993) .

Mean July Temperature (°C)	Mean January (°C)	Mean Annual (°C)	Mean Annual Precipitation (cm)	Percent Precipitation as Snow (%)	Days above 0°C
16.3	-25.4	-3.0	35.3	44	212

sinkholes. These sinkholes are formed by solution, collapse or some combination of the two (Tsui 1982). In WBNP the impervious nature of the granitic gneiss of the Canadian Shield, which lies just below the limestone and gypsum, maintains a high water table. Thus, the sinkholes of WBNP are often filled with water forming small, regularly shaped and relatively deep lakes. These lakes are ideal for paleoecological and paleolimnological studies.

OBJECTIVES

There are three hypotheses which this study will address. The first is that wild fires result in changes to chemical and/or physical limnic properties significant enough to alter the population and/or composition of the diatom community. Fire causes the destruction of terrestrial vegetation which results in increases of allocthonous (dissolved and particulate) matter and nutrients which can lead to a change in lake chemistry (reviewed in Rhodes 1991). As well as affecting the chemical regime of the lake, fires may affect several physical properties including; increased turbulence due to increased winds, and changes in the photic zone depth due to increased ash and turbidity. Relationships between fire and diatom community changes will be examined using surface sediment samples collected from lakes with different fire histories. Canonical correspondence analysis will be used to search the data for distinct diatom communities and to examine the relationship between communities and environmental parameters. A second approach will involve studying a 500 year fossil diatom record at a 1 in 5 year resolution from RLA, where fire history has been previously determined using dendrochronological techniques and pollen and charcoal analyses (Larsen 1989a).

The second hypothesis is that changes in diatom population and community structure correspond to climatic variations. This will be tested using three approaches. The first will be to compare the changes in diatom community structure over the last 200 years (1 in 5 year resolution) with historical meteorological data from Fort Smith and dendroclimatological data from the western NWT including WBNP (MacDonald *et al.* submitted 1993). These results will provide a basis for interpretation of a longer-term record. The last 5000 years, which encompasses two well documented climatic events, the Little Ice Age and the Medieval Warm Period, will be studied at a resolution of 1 in 25 years.

The last hypothesis to be considered is that diatom populations reflect nonlinear dynamic behaviour. It is possible that non-periodic fluctuations of the diatom population may be the result of deterministic, but nonlinear, control by a small number of variables endogenous to the lake. Analyses of a diatom fossil record at high chronological resolution coupled with new algorithms, which require fewer observations (e.g. Sugihara and May 1990; Fowler and Roach 1993), will provide a means to test for nonlinear dynamics in this diatom population. This analysis will be made for a 100 to 200 year period.

PRELIMINARY RESULTS

This project is still in its infancy. Fossil diatoms have been studied from RLA for the last 200 years at a resolution of 1 in 5 years. These preliminary results were not conclusive and further interpretation is awaiting the results of the surface sediment calibration set. During the summer of 1993 surface sediment samples from lakes (Figure 1), many of which were sinkholes, were collected along with environmental information including last fire (which was obtained from forest fire maps available from the park and tree ring analysis), vegetation present at the lake (determined using a photo revelee), water chemistry, lake size, drainage basin size, water transparency, pH and conductivity. Diatom analysis of these samples will be undertaken during the winter and spring of 1994. Additional analyses of RLA, both at a higher resolution and further back in time, will be made during the summer and fall of 1994.

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THE ECOLOGY AND PHYSICOCHEMICAL CHARACTERISTICS OF LAKES IN THE SUBARCTIC AND ARCTIC REGIONS OF THE YUKON TERRITORY, FENNOSCANDIA (FINLAND, NORWAY), THE NORTHWEST TERRITORIES AND NORTHERN QUÉBEC

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INTRODUCTION

High latitude regions are receiving increased attention as important reference sites for the study of environmental change. Equally, the strength and versatility of using diatoms and other aquatic bioindicators as monitors of environmental change continues to be recognized (e.g. Dixit *et al.* 1992). Unfortunately, relatively little ecological and distributional data are as yet available on diatom assemblages from northern latitudes, and additional data on distributions with respect to latitudinal gradients are still needed.

In an attempt to identify species distributions, and to determine the ecological optima and tolerances of diatoms, diatom distributions in the surficial sediments of a large number of lakes were studied and the species distributions were then related to environmental variables of interest. Recently, a series of limnological and paleolimnological studies have been conducted on lakes in Canadian arctic and subarctic regions (e.g. Pienitz & Smol 1993; Pienitz *et al.* 1994a; Pienitz *et al.* 1994d). For example, using multivariate statistical techniques, the relationship between diatom taxa preserved in surficial lake sediments (top 1 cm) and a large number of measured limnological and environmental variables in more than 100 freshwater lakes in the Yukon and Northwest Territories was explored, showing marked floristic changes that could be related to drainage basin characteristics (such as the presence of trees) as well as other related limnological and climatic variables (Pienitz & Smol 1993; Pienitz *et al.* 1994a). These autecological data and transfer functions can then be used in paleolimnological studies in climatically sensitive northern regions (e.g. MacDonald *et al.* 1993).

The Canadian Arctic, however, represents just one portion of the northern circumpolar ecosystem. Lakes at similar latitudes but in other regions, such as Fennoscandia, may share similar light/dark cycles and similar nutrient levels, for example, but because of differences in oceanic currents and other factors, experience a significantly warmer climate. Comparisons of the biota found in different regions of the northern hemisphere are necessary to shed light on the major factors determining the distributions of aquatic organisms in these high latitude environments.

YUKON

The 59 sampling sites are located between Whitehorse in the Yukon Territory and Tuktoyaktuk in the Northwest Territories (N.W.T.), ranging from 60°37' to 69°35'N and 132°04' to 138°23'W (Figure 1). No previous limnological information was available for most of the study lakes. Likewise, many of these lakes are unnamed, and so they are numbered in consecutive order of sampling and are referred to as lakes 1 to 59. Surficial sediment samples were collected during the month of July 1990. Between Whitehorse and Inuvik, the

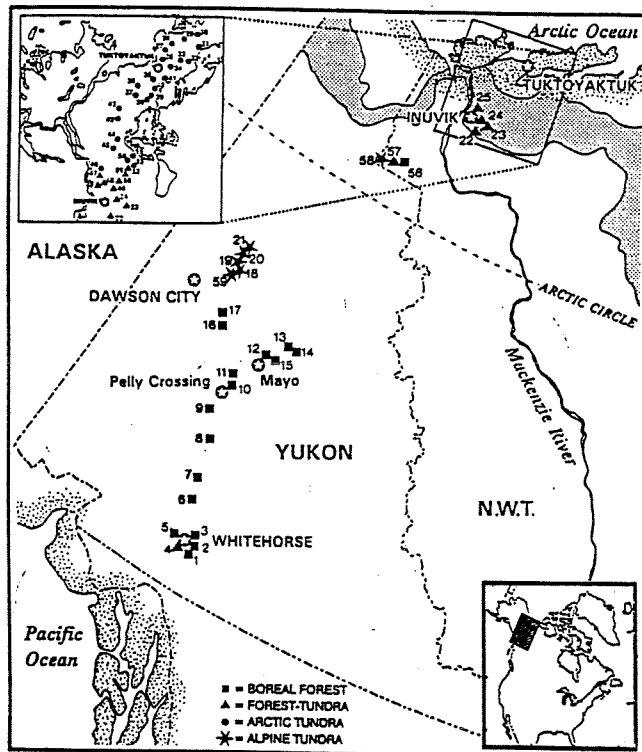
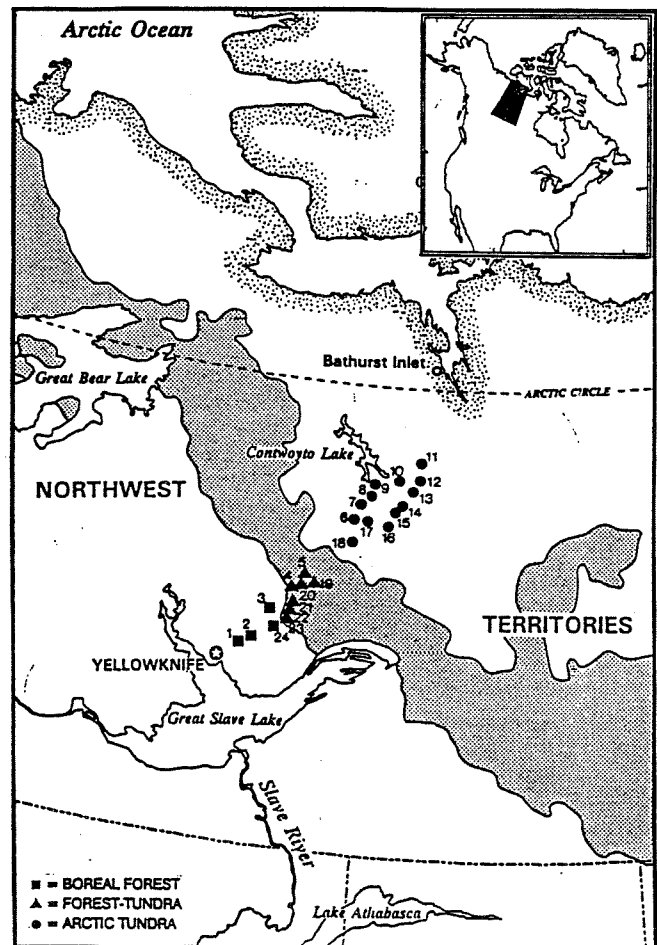


Figure 1. Site locations for the Yukon and Tuktoyaktuk regions of northern Canada. Figure 1a, represents the locations in North America. Figure 1b, samples sites from the Tuktoyaktuk and Inuvik region. Figure 1 c, the north-south transect of samples sites from the Yukon Territory. Map extracted from Pienitz, *et al.* (1994a).

Figure 2. Site locations for the Yellowknife to Contwoyto Lake region of northern Canada. Figure 2a, represents the locations in North America. Figure 2b, the north-south transect of samples sites for the area between Yellowknife and Contwoyto Lake. Map extracted from This map is reproduced from Pienitz *et al.* 1994c.



lakes are distributed along a vast south-north transect within short distances from the Klondike and Dempster highways. Between these two localities, all lakes were sampled from an inflatable boat, whereas sampling of lakes on the Tuktoyaktuk Peninsula (26 to 55) (Figure 1b) was carried out from helicopter on pontoons. All lakes studied are natural, with the exception of site 4, which is an artificially dammed lake.

The topography, geology, climate (Table 1), vegetation and soils along the sampling transect are very heterogeneous (for more details see Pienitz 1993; Pienitz *et al.* 1994a, 1994b). As a consequence, the water-chemistry characteristics of the study lakes were very diverse. Most of the lakes were dilute (mean conductivity = $160 \mu\text{S}\cdot\text{cm}^{-1}$), and ranged from slightly acidic to alkaline (pH range from 5.9 to 9.3). Water transparency was generally lowest within peatland areas of the forest-tundra zone (e.g. sites 23, 24, as well as sites 47 to 52), where many lakes were tea-coloured due to high inputs of humic and fulvic acids from the catchment. Lake elevations ranged from 15 to 1387 m above sea level. Most of the lakes are small to intermediate in size, with surface areas varying between 1.1 and 547.4 ha, and an average size of 71.5 ha. Maximum depths ranged from 1 to 49 m, with a mean of 7.4 m. Lake locations and physicochemical conditions of the study sites are summarized in Tables 2 and 3.

The 59 study lakes were specifically chosen to span a broad climatic gradient, and therefore the study area included the following five ecoclimatic provinces: Pacific Cordilleran, Cordilleran, Subarctic Cordilleran, Subarctic, and Arctic (Environment Canada 1989). Lakes located in the south-central portion of the Yukon are mostly dimictic (Shortreed & Stockner 1986) and showed thermal stratification during the summer of 1990 (e.g. sites 1 to 17). The duration of ice cover on these lakes usually extends from October-November to May-June (Environment Canada 1975-1990). In the forest-tundra zone near Inuvik, small (5 to 10 ha) lakes are usually ice free by June 15th and freeze over by October 15th, and these events occur roughly two weeks later and earlier, respectively, in the arctic tundra zone of the study area (Koivo & Ritchie 1978). Large (> 50 ha) lakes become ice-free roughly two weeks later than smaller ones.

NORTHWEST TERRITORIES

The 24 study lakes located between Yellowknife and Contwoyto Lake in the Northwest Territories (Canada) (Figure 2) are distributed across treeline along a latitudinal gradient ($62^{\circ}27'\text{N}$, $114^{\circ}21'\text{W}$ to $65^{\circ}30'\text{N}$, $110^{\circ}00'\text{W}$) that includes a strong vegetational gradient of boreal forests in the south to arctic tundra conditions in the north. The surficial sediments from the 24 study sites were sampled from a helicopter equipped with pontoons on July 12, 1991. The study area belongs to the Precambrian Shield geological region (the so-called "Canadian Shield"), which is characterized by rolling terrain with gentle relief. The Yellowknife area lies within the Slave Structural Province, which is an Archean craton comprising numerous supracrustal belts and extensive gneissic-granitoid plutons (Padgham & Fyson 1992).

The majority of the study lakes are shallow ($Z_{\text{max}} = 2.5$ to 20 m), oligotrophic (3.4 to $12.7 \mu\text{g}\cdot\text{l}^{-1}$ TP) lakes with slightly acidic to alkaline pH (6.2 to 8.9), low conductivity (at detection limit to $100 \mu\text{S}\cdot\text{cm}^{-1}$), and low concentrations of calcium ($< 5 \text{ mg}\cdot\text{l}^{-1}$). Many of the lakes are slightly coloured with a DOC range of 1.6 to 9.1 $\text{mg}\cdot\text{l}^{-1}$. Strong colour is restricted to sites surrounded by peatlands, especially in the forest-tundra and boreal forest zones. Sodium and chloride as well as nutrient levels are very low, indicating the dilute character of the lakes. A summary of selected environmental data for the 24 lakes is given in Tables 4 and 5. More data on the geology, vegetation, and climate of the study area (Table 1), as well as detailed

Table 1. Climate data for the Yukon and Northwest Territories study areas.

Location	Latitude Longitude	Mean Annual Temperature (°C)	Mean Annual Precipitation (mm)	Growing degree- days above 5°C
Yellowknife	62°27'N, 114°21'W	-5.4	266.7	1027.1
Contwoyto L.	65°30'N, 110°00'W	-12.0	251.3	339.8
Whitehorse	60°43'N, 135°04'W	-1.3	268.9	897.1
Mayo	63°36'N, 135°53'W	-4.0	293.0	983.0
Dawson City	64°04'N, 139°26'W	-5.0	325.1	996.5
Inuvik	68°21'N, 133°43'W	-10.0	266.0	654.0
Tuktoyaktuk	69°27'N, 133°02'W	-11.0	137.6	372.0

Table 2. Physicochemical data for the 59 Yukon and Tuktoyaktuk study sites, including minimum, maximum, mean, and sample standard deviation values. TEMP = temperature; COND = conductivity; TRANS = transparency; ZOOPL = zooplankton biomass; DIST = shortest distance from northern treeline. This data is extracted from Pienitz *et al.* (1994a).

Lake #	LAT [°N]	LONG [°W]	ALT [m]	DEPTH [m]	AREA [ha]	pH	TEMP [°C]	COND [µS/cm]	O2 [mg/l]	TRANS [m]	ZOOPL [µg/l]	DIST [km]
1	60.39	134.37	871	32.00	181.20	8.70	17.50	700	13.70	9.10	25.30	NA
2	60.40	134.59	871	10.50	56.90	8.80	19.00	1900	14.20	8.50	22.85	NA
3	60.44	135.02	825	17.50	21.20	8.50	20.00	490	13.70	5.00	10.45	NA
4	60.37	135.14	1113	7.00	1262.10	8.10	14.00	87	14.60	6.50	1.87	NA
5	60.42	135.17	1021	12.00	32.50	7.80	17.00	73	13.30	2.30	106.42	NA
6	61.21	135.39	823	49.00	89.00	8.30	20.00	179	13.30	3.20	164.15	NA
7	61.42	135.56	834	27.00	163.00	8.30	20.80	230	12.90	10.60	1.69	NA
8	62.11	136.15	686	5.50	23.70	8.70	23.00	339	14.30	2.70	82.85	NA
9	62.43	136.41	579	3.00	331.50	8.70	20.70	220	14.40	1.90	180.15	NA
10	63.01	136.28	655	8.00	88.60	8.60	22.00	242	13.70	4.40	62.82	NA
11	63.09	136.30	732	5.00	8.60	8.50	23.00	49	11.60	3.30	512.50	NA
12	63.39	136.54	579	9.20	23.40	8.40	22.00	149	12.20	6.00	156.85	NA
13	63.59	135.24	701	10.10	10.10	7.80	20.80	45	11.80	3.60	215.58	NA
14	63.59	135.22	701	16.50	23.10	8.30	21.50	260	13.00	11.50	36.85	NA
15	63.39	135.51	594	3.00	24.10	7.50	19.40	48	11.80	1.50	632.58	NA
16	63.45	137.43	810	5.00	80.30	7.60	22.00	42	11.60	2.75	316.91	NA
17	63.51	138.02	810	4.00	18.90	8.20	19.40	24	12.10	1.65	419.10	NA
18	64.35	138.18	1173	7.50	18.10	8.60	17.00	113	12.70	4.60	184.04	NA
19	64.39	138.23	1128	3.80	20.40	8.70	16.00	111	13.20	3.20	254.65	NA
20	64.44	138.22	1097	1.90	13.70	9.30	14.30	39	12.60	1.90	788.25	NA
21	64.51	138.21	1006	3.80	144.00	7.50	17.50	32	11.70	3.70	188.38	NA
22	68.11	133.27	78	5.50	8.20	7.90	18.00	153	12.10	4.05	148.21	-21.25
23	68.18	133.16	30	2.50	6.60	7.20	18.10	72	12.10	1.80	196.45	-7.50
24	68.19	133.22	91	2.60	15.10	8.90	18.00	35	11.10	1.10	979.09	-6.25
25	68.24	133.42	122	3.00	1.10	7.60	20.00	140	13.40	3.00	528.10	0.00
26	69.28	132.49	18	2.00	85.10	8.10	17.00	100	NA	2.00	NA	125.00
27	69.32	132.47	15	2.00	94.60	8.00	17.00	343	NA	1.00	NA	132.50
28	69.33	132.45	15	2.00	170.30	7.80	17.00	145	NA	1.20	NA	135.00
29	69.33	132.25	15	2.00	847.40	8.10	17.00	152	NA	2.00	NA	135.00
30	69.35	132.04	21	4.00	195.80	8.00	16.00	179	NA	3.20	NA	137.50
31	69.32	132.04	21	3.00	57.60	8.10	16.00	165	NA	2.80	NA	133.75
32	69.28	132.12	21	9.00	73.80	8.00	12.00	198	NA	6.00	NA	126.25
33	69.29	132.19	15	1.00	5.40	7.30	19.00	87	NA	1.00	NA	126.25
34	69.25	132.40	24	2.50	116.20	7.90	17.00	159	NA	2.50	NA	118.75
35	69.19	132.59	24	7.00	86.30	8.20	17.00	128	NA	2.70	NA	107.50
36	69.10	133.16	21	4.00	103.20	8.40	17.00	105	NA	3.20	NA	87.50
37	69.08	133.17	21	6.50	69.00	8.10	17.00	98	NA	4.00	NA	83.75
38	69.07	133.11	21	3.00	49.70	8.20	18.00	139	NA	3.00	NA	82.50
39	69.12	133.02	24	12.00	104.90	8.20	15.50	141	NA	6.00	NA	91.25
40	69.13	133.00	24	3.00	81.90	8.20	17.50	104	NA	2.50	NA	92.50
41	69.20	132.44	24	7.00	88.50	8.10	16.00	167	NA	2.50	NA	108.75
42	69.03	133.27	46	15.00	84.80	7.80	16.00	150	NA	7.00	NA	72.50
43	68.59	133.28	30	14.00	36.00	7.50	17.00	105	NA	7.00	NA	66.25
44	68.50	133.33	30	4.00	61.20	8.20	18.50	129	NA	2.80	NA	47.50
45	68.46	133.39	78	2.00	65.40	6.90	19.00	85	NA	1.50	NA	41.25
46	68.29	133.39	122	2.50	63.10	7.10	19.00	81	NA	2.50	NA	10.00
47	68.28	133.38	122	1.50	21.10	8.30	19.50	220	NA	1.50	NA	7.50
48	68.25	133.35	114	1.50	96.20	8.40	20.50	71	NA	0.95	NA	2.50
49	68.23	133.25	84	3.50	5.30	6.40	19.00	41	NA	0.70	NA	0.00
50	68.25	133.22	78	2.00	21.70	7.00	20.30	71	NA	1.60	NA	5.00
51	68.29	133.22	128	1.50	87.30	8.50	19.50	72	NA	1.00	NA	12.50
52	68.34	133.20	145	6.00	19.50	7.00	18.00	116	NA	1.80	NA	21.25
53	68.36	133.15	152	3.50	25.70	7.20	18.20	48	NA	2.50	NA	25.00
54	68.38	133.17	91	10.00	40.00	7.50	18.00	85	NA	1.90	NA	30.00
55	68.42	133.15	30	18.50	87.90	7.70	18.00	70	NA	3.50	NA	37.50
56	67.14	133.26	366	4.00	35.00	7.50	18.00	35	11.40	1.40	147.47	NA
57	67.13	133.36	396	1.20	7.20	7.40	18.00	140	13.30	1.00	512.28	NA
58	67.06	138.00	549	5.50	19.30	5.90	16.20	77	12.90	1.90	190.47	NA
59	64.29	138.17	1387	15.50	4.20	7.90	13.50	65	NA	9.50	155.19	NA
MINIMUM	60.37	132.04	15	1.00	1.10	5.90	12.00	24	11.10	0.70	1.70	-21.25
MAXIMUM	69.35	138.23	1387	49.00	1262.10	9.30	23.00	1500	14.60	11.50	979.09	137.50
MEAN			355.86	7.40	81.41	7.93	18.19	159.68	12.80	3.45	247.95	63.75
STDS			392.10	8.31	177.57	0.62	2.26	210.68	1.00	2.53	244.39	53.33

NA = not available

Table 3. Physicochemical data for the 59 Yukon and Tuktoyaktuk study sites, including minimum, maximum, mean, and sample standard deviation values. TPU = total phosphorus (unfiltered); TPF = total phosphorus (filtered); SRP = soluble reactive phosphorus; DOC = dissolved organic carbon; DIC = dissolved inorganic carbon; TKN = total kjeldahl nitrogen; TN = total nitrogen; CHLaU = chlorophyll *a* (uncorrected); CHLaC = chlorophyll *a* (corrected); POC = particulate organic carbon; PN = particulate nitrogen; TN:TP = total nitrogen to total phosphorus ratio; POC:PN = particulate organic carbon to particulate nitrogen ratio. This data is extracted from Pienitz *et al.* (1994a).

Site	TPU [µg/l]	TPF [µg/l]	NO2 [µg/l]	NO3 [µg/l]	SRP [µg/l]	NH3 [µg/l]	DOC [mg/l]	DIC [mg/l]	TKN [µg/l]	TN [µg/l]	SiO2 [mg/l]	SO4 [mg/l]	Ca [mg/l]	Na [mg/l]	K [mg/l]	Cl [mg/l]	CHLaU [µg/l]	CHLaC [µg/l]	POC [µg/l]	PN [µg/l]	Fe [µg/l]	Mn [µg/l]	TN/TP TP	POC/PN PN
1	14.1	11.0	0.3	208.0	2.2	12.0	10.6	88.2	309	559	2.81	300.2	21.50	46.30	10.10	63.6	0.3	0.1	321	42	8.4	5.0	40	8
2	15.8	14.1	1.0	15.0	7.5	31.0	16.3	134.2	654	734	0.78	1242.0	15.60	187.00	29.90	24.5	0.1	0.1	493	64	11.4	12.0	46	8
3	6.5	4.5	1.0	14.0	0.5	7.0	7.8	52.9	407	514	12.47	82.1	26.70	16.30	4.30	1.5	1.5	0.1	704	92	10.8	7.0	79	8
4	3.7	2.9	0.9	10.0	1.4	5.0	3.8	14.4	121	158	7.84	8.8	19.00	2.80	0.77	0.3	1.7	0.1	158	26	8.6	5.0	43	6
5	8.7	4.9	1.4	10.0	0.5	5.0	8.6	12.4	260	323	7.86	3.9	16.60	1.95	0.56	0.6	2.3	1.3	369	52	76.0	4.0	37	7
6	5.1	4.3	0.2	10.0	3.3	5.0	10.1	33.1	271	321	9.26	24.5	44.20	4.60	1.21	0.9	0.3	0.1	354	40	15.8	12.0	63	9
7	4.9	3.5	0.2	10.0	0.6	5.0	8.4	40.8	208	259	9.19	29.0	50.30	7.56	1.85	0.9	0.2	0.1	279	41	5.9	7.0	53	7
8	14.6	0.2	0.2	10.0	1.8	6.0	35.1	53.5	1293	1403	4.98	90.5	37.60	20.70	1.93	1.4	1.5	0.7	848	100	19.4	16.0	96	8
9	15.4	0.2	0.6	10.0	1.3	27.0	26.9	30.8	1178	1585	7.26	23.8	37.70	4.32	2.84	1.3	1.9	1.3	3280	396	17.4	21.0	103	8
10	12.0	8.1	0.2	10.0	2.0	5.0	14.2	35.1	743	885	6.54	28.9	30.00	4.36	2.94	1.5	0.9	0.7	828	132	6.3	17.0	74	6
11	12.3	9.0	0.5	10.0	1.6	5.0	17.1	3.8	572	667	0.19	2.0	7.78	0.73	1.57	4.2	0.9	0.7	592	84	50.2	2.0	54	7
12	8.7	5.5	0.2	10.0	1.1	5.0	13.5	22.5	352	418	3.08	0.5	31.00	1.32	1.45	1.0	2.8	1.0	412	56	26.5	11.0	48	7
13	9.8	5.6	1.5	10.0	1.2	5.0	16.2	4.6	437	521	0.23	2.8	7.27	0.39	0.46	0.5	1.7	0.7	495	72	36.5	4.0	53	7
14	4.3	2.9	0.9	10.0	2.4	6.0	15.9	35.1	350	409	8.84	57.1	45.40	3.69	1.60	0.4	2.7	0.1	398	48	10.0	7.0	95	8
15	28.8	13.9	2.9	10.0	2.1	5.0	24.2	4.2	699	1036	0.16	4.2	8.55	0.53	1.10	0.9	4.9	1.1	2170	324	165.0	18.0	36	7
16	21.6	11.4	0.2	10.0	1.3	5.0	15.3	4.9	615	769	1.00	0.5	6.84	0.94	1.57	0.5	2.5	0.8	1060	144	124.0	21.0	36	7
17	25.0	13.0	0.2	10.0	1.3	5.0	18.1	2.2	904	1258	0.17	0.5	3.52	0.75	1.26	0.7	4.9	2.3	2320	344	134.0	19.0	50	7
18	11.4	6.2	0.8	10.0	1.0	5.0	6.5	18.1	239	302	2.03	11.5	23.00	3.71	0.39	0.3	0.8	0.1	308	52	56.9	35.0	26	6
19	10.0	6.9	0.8	10.0	1.4	5.0	10.2	20.5	348	415	1.95	9.0	31.60	3.40	0.58	0.4	1.1	0.8	396	56	35.2	11.0	42	7
20	23.1	14.1	2.0	10.0	2.4	11.0	12.3	5.7	498	606	0.37	1.9	9.66	0.34	0.10	0.4	0.9	0.6	664	96	664.0	22.0	26	7
21	7.8	4.9	0.6	10.0	1.2	5.0	11.4	3.8	327	422	0.30	4.1	5.82	0.34	0.39	0.6	1.1	0.1	608	84	127.0	17.0	54	7
22	10.3	7.9	0.9	10.0	1.6	5.0	17.8	14.4	532	591	3.16	38.9	39.20	2.26	1.04	6.1	1.8	1.3	300	48	52.7	11.0	57	6
23	17.5	11.3	1.6	10.0	2.3	5.0	10.6	4.6	637	717	0.94	13.2	13.90	1.60	0.65	3.7	2.0	1.4	472	68	287.0	11.0	41	7
24	44.9	34.1	4.3	27.0	10.1	11.0	22.6	4.0	700	803	2.37	5.2	6.50	1.32	0.80	2.0	1.1	0.1	536	72	1280.0	33.0	18	7
25	16.1	12.1	0.8	10.0	2.0	22.0	13.1	11.5	631	710	0.57	32.6	20.20	8.28	2.07	3.2	2.6	2.1	464	68	136.0	20.0	44	7
26	15.3	7.1	1.1	10.0	1.5	19.0	6.6	6.3	305	380	0.14	1.9	9.14	8.16	1.11	15.5	1.5	0.7	416	64	170.0	14.0	25	7
27	19.8	8.0	0.2	15.0	2.2	36.0	12.3	27.7	535	630	0.32	17.9	43.80	33.40	3.23	75.2	1.4	0.6	544	80	754.0	16.0	32	7
28	16.7	8.1	0.4	10.0	0.7	5.0	6.7	12.9	281	403	0.29	6.0	19.30	9.42	1.79	18.8	1.1	0.5	780	112	376.0	13.0	24	7
29	9.2	4.8	0.2	10.0	0.5	5.0	5.8	17.5	239	309	0.10	1.1	20.80	10.30	0.90	18.7	0.8	0.2	444	60	65.5	11.0	34	7
30	12.6	6.0	0.2	10.0	0.5	38.0	18.2	19.6	567	649	0.09	24.7	26.90	10.40	1.22	21.5	1.8	0.1	504	72	80.6	11.0	52	7
31	6.6	3.7	0.2	10.0	0.5	18.0	8.0	19.2	343	401	0.17	10.5	24.70	8.97	1.43	16.3	0.8	0.3	364	48	44.6	7.0	61	8
32	3.0	2.9	0.9	15.0	0.5	8.0	4.8	27.4	172	220	1.52	9.2	36.20	7.63	1.36	13.2	0.2	0.1	204	32	15.6	6.0	73	6
33	13.8	11.4	1.9	11.0	1.9	51.0	19.0	6.8	862	955	0.40	4.7	11.50	6.05	1.14	10.0	0.9	0.3	572	80	297.0	13.0	69	7
34	13.7	6.3	0.2	10.0	0.5	20.0	10.7	17.9	391	473	0.57	3.0	24.00	9.72	1.43	17.3	1.8	0.5	492	72	153.0	46.0	35	7
35	11.3	6.6	0.2	10.0	0.5	22.0	8.5	17.5	282	364	0.42	2.8	21.80	6.10	1.63	10.1	1.9	1.3	440	72	143.0	11.0	32	6
36	20.8	6.2	0.2	10.0	0.7	19.0	9.6	14.1	459	541	0.43	1.4	18.30	4.71	1.15	7.2	1.8	1.1	480	72	92.5	18.0	26	7
37	10.5	5.6	0.6	10.0	0.5	17.0	8.9	12.7	309	404	0.51	1.4	16.40	4.58	1.02	6.8	1.0	0.3	548	84	58.0	13.0	38	7
38	13.3	5.3	0.2	10.0	0.5	15.0	9.6	20.8	384	506	0.57	2.1	24.20	7.27	1.31	8.9	1.9	1.0	616	112	38.9	16.0	38	6
39	5.0	3.7	0.2	10.0	0.5	5.0	6.1	21.4	211	273	1.37	4.7	29.60	5.04	1.16	7.4	1.4	0.6	320	52	24.2	7.0	55	6
40	13.1	10.3	0.2	10.0	0.5	6.0	10.1	13.3	497	587	0.64	0.8	18.90	4.86	1.15	8.2	2.6	1.4	496	80	165.0	18.0	45	6
41	7.5	4.2	0.2	10.0	0.5	9.0	7.9	24.0	247	305	0.61	9.2	32.20	7.83	1.96	12.2	1.0	0.6	304	48	51.7	9.0	41	6
42	3.5	2.7	7.2	51.0	2.2	10.0	4.6	15.7	139	229	1.54	1.9	20.80	3.36	0.89	5.2	1.1	0.6	228	32	21.1	160.0	65	7
43	5.0	3.2	29.0	23.0	0.5	9.0	5.7	10.3	197	305	0.81	1.6	14.00	3.08	0.98	5.6	1.0	0.6	352	56	19.1	14.0	61	6
44	12.3	6.6	3.7	30.0	1.1	8.0	8.1	14.2	336	451	0.73	2.1	19.80	3.08	1.10	3.7	1.2	0.7	456	81	72.0	19.0	37	6
45	17.8	12.6	0.2	20.0	0.5	14.0	11.8	3.4	397	497	1.92	12.9	7.78	2.22	0.90	1.9	1.4	0.9	508	80	348.0	23.0	28	6
46	16.2	10.9	0.2	14.0	0.6	19.0	11.4	4.9	439	541	1.18	14.6	9.74	2.39	1.39	1.9	1.1	0.6	588	88	235.0	33.0	33	7
47	9.3	6.0	0.2	15.0	0.5	5.0	9.1	18.9	334	401	0.94	42.3	33.90	5.02	1.64	2.7	0.7	0.4	272	52	26.7	8.0	43	5
48	48.8	12.7	1.4	15.0	3.2	5.0	11.6	5.5	518	1058	0.39	8.1	9.23	1.60	1.38	1.6	20.4	18.1	3480	524	272.0	39.0	22	7
49	43.9	21.2	0.6	16.0	2.0	5.0	21.5	2.0	612	781	3.31	9.1	6.73	1.38	0.45	1.4	1.8	0.7	1180	152	1660.0	61.0	18	8
50	28.6	24.3	2.9	16.0	0.6	37.0	29.9	3.9	823	922	0.75	9.3	9.17	4.93	1.10	5.2	0.6	0.2	572	80	774.0	50.0	32	7
51	55.1	13.6	1.9	16.0	0.6	26.0	17.2	7.4	688	1114	1.73	3.8	10.20	4.21	1.22	2.0	4.9	4.0	2940	408	771.0	43.0	20	7
52	9.7	6.6	1.5	14.0	0.6	16.0	11.3	1.8	316	388	1.54	49.4	12.60	7.23	1.14	1.7	0.5	0.1	304	56	348.0	72.0	40	5
53	11.4	7.8	1.4	9.0	1.4	21.0	10.8	3.7	263	341	0.96	6.1	5.89	3.06	0.77	1.6	1.3	0.6	468	68	110.0	14.0	30	7
54	11.7	7.5	0.8	10.0	1.4	5.0	13.0	5.1	301	364	1.26	19.0	11.90	4.01	1.01	1.9	2.0	0.1	360	52	265.0	14.0	31	7
55	9.0	7.2	0.2	10.0	0.5	5.0	8.5	7.4	237	319	0.62	3.2	10.40	2.07	0.98	2.5	1.5	0.1	480	72	160.0	20.0	35	7
56	35.4	14.5	1.0	10.0	1.6	14.0	12.3	2.4	409	620	1.02	7.6	5.48	0.77	0.84	0.7	10.5	8.0	1380	2				

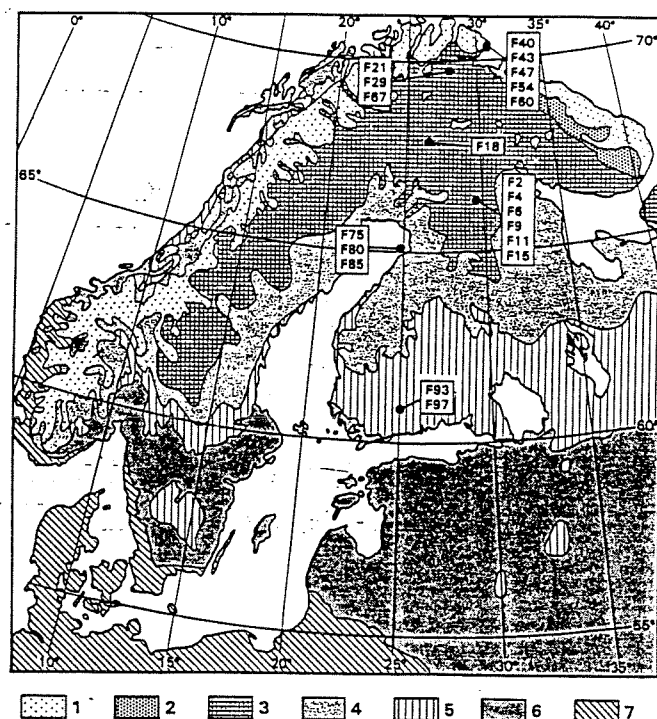


Figure 3. Site locations for the Fennoscandia sampling region. The numbers denoted with the letter F represent the samples sites. The vegetation zones are outlined as 1: Oroarctic, 2: Orohemiarctic, 3: Northern Boreal, 4: Middle Boreal, 5: Southern Boreal, 6: Hemiboreal, and 7: Temperate. This map is reproduced from Pienitz *et al.* (1994d).

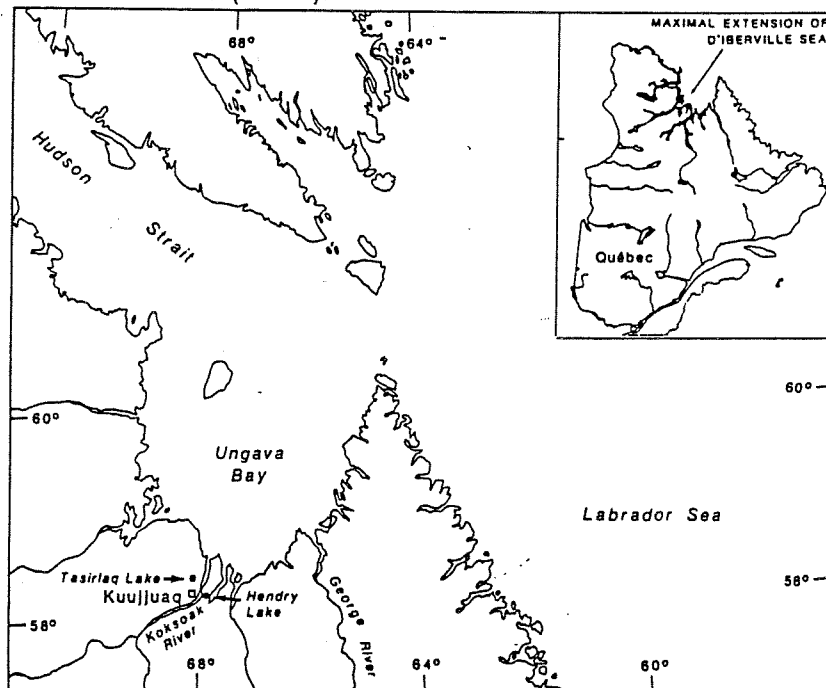


Figure 4. Site locations for the Ungava Bay region of Canada. Figure 4a, represents the location in northern Québec. Figure 4b, Locations of Hendry and Tasirlaq-sud Lakes just south of Ungava Bay. The map is reproduced from Pienitz *et al.* 1991.

information on the limnology and water chemistry of the study sites can be found in Pienitz 1993, Pienitz & Smol 1993, and Pienitz *et al.* 1994c.

FENNOSCANDIA

Surficial sediments were collected in August 1988 from a total of 20 sites, including diverse aquatic habitats such as lakes and ponds, ditches, string bogs, thermokarst ponds, and rivers. The sampling sites are distributed along a latitudinal transect between roughly 60° and 70°N, including several vegetation zones in Finland and northern Norway (Figure 3). The basic limnological measurements that were taken in the field (surface water temperature, pH, and specific conductance), as well as site descriptions are summarized in Table 6.

In order to group the study sites according to vegetation zones, the widely used scheme of Ahti *et al.* (1968) was adopted. These authors suggest that the boreal coniferous forest zone in Fennoscandia can be divided into several subzones. From south to north, the major sampling areas were as follows: a) Southern Boreal Forest Zone: Lammi Biological Station (61°03'N, 25°03'E), about 100 km north of Helsinki (F93, F97); b) Middle Boreal Forest Zone: Hailuoto Island (65°01'N, 24°43'E) near Oulu in northern Gulf of Bothnia (F75, F80, F85); c) Northern Boreal Forest Zone: Kuusamo area (66°22'N, 29°19'E) in the northeastern corner of the Oulu district (F2, F4, F6, F9, F11, and F15); Sodankylä area (67°42'N, 26°46'E) in the more densely forested part of Finnish-Lapland (F18); Utsjoki area (69°45'N, 27°02'E) in fjell-dominated northern Lapland (F21, F29, F67); and d) Oroarctic Zone: Vardö area (70°21'N, 31°00'E) on Varanger Peninsula near the Arctic Ocean (F40, F43, F47, F54, F60), which is western Europe's northernmost mainland area (Figure 3).

The two southernmost sites (F93, F97) lie within coniferous forests that are interspersed with areas of mixed deciduous forests. Within the zone of continuous coniferous forests, Scots pine (*Pinus sylvestris*) usually predominate. The understorey vegetation is dominated by lichens, mainly *Cladina* and *Stereocaulon* (Oksanen 1983). In Finnish-Lapland, the subarctic forest-tundra ecotone is situated near Utsjoki, where birch (*Betula pubescens* ssp. *tortuosa*) is the predominant tree species. In the north, permafrost is scattered and occurs only in some bogs where palsas contain small isolated ice lenses.

The structural geology of Fennoscandia and the Yellowknife area is similar. In both areas, the bedrock consists mainly of acid granitic gneisses of Precambrian age, belonging to the Baltic Shield and Canadian Shield physiographic regions, respectively. Likewise, the topography of both areas is typified by a rolling terrain with only gentle relief.

The study area encompassing the 20 sites contains significant climatic gradients which are summarized in Table 7. The mean annual temperature in the south is about 4°C, and about -2°C in the north. The length of the growing season, defined as the number of days with mean ambient temperature greater than 5°C, ranges from about 170 days in the south to approximately 110 days in northern Fennoscandia (Tuhkanen 1980), and mean monthly July temperatures vary from 17°C near Helsinki to 13°C near the coast of the Arctic Ocean. Mean annual precipitation in Finland ranges between 400 to 700 mm and shows no distinct trend along the latitudinal sampling transect.

Diatom preparation methods for surface sediment samples from the Yukon, Northwest Territories, and Fennoscandia.

About 1 g (wet weight) of surface sediment (top 1 cm) from each site was placed in 15 ml polypropylene centrifuge tubes and oxidized in a strong solution of sulphuric (H_2SO_4) and

Table 4. Physicochemical data the 24 Yellowknife to Contwoyto Lake study sites, including minimum, maximum, mean, and sample standard deviation values. TEMP = temperature; COND = conductivity; TRANS = transparency; ZOOPL = zooplankton biomass; DIST = shortest distance from northern treeline. This data is reproduced from Pienitz *et al.* 1994c.

Site #	LAT [N]	LONG [W]	ALT [m]	AREA [ha]	DEPTH [m]	pH	TEMP [C]	COND [uS/cm]	TRANS [m]	ZOOPL [µg/l]	DIST [km]
1	62.47	113.40	274	180.3	13.0	8.5	14.5	100	4.8	1464.0	-120.0
2	62.50	113.28	305	83.4	25.0	8.0	14.5	48	3.3	404.5	-112.5
3	63.18	112.55	396	223.7	10.0	8.7	13.0	30	7.5	2015.3	-55.0
4	63.33	112.22	427	113.8	2.5	8.2	12.0	12	2.0	947.0	-15.0
5	63.43	112.05	427	79.2	3.0	7.7	12.0	11	3.0	635.5	12.5
6	64.37	110.43	457	254.4	8.0	8.0	10.0	10	4.0	1380.3	130.0
7	64.51	110.25	471	488.5	5.0	8.1	8.0	10	5.0	648.4	157.5
8	64.55	110.12	457	111.6	6.0	7.9	9.0	10	5.5	792.4	170.0
9	65.06	110.13	488	262.5	8.0	8.2	8.0	8	5.0	551.5	185.0
10	65.13	109.11	457	175.6	20.0	8.6	7.5	9	6.5	1728.6	220.0
11	65.27	108.33	427	263.1	5.0	8.4	9.0	8	4.5	989.0	262.5
12	65.16	108.29	396	421.1	15.0	8.0	8.0	10	5.0	1385.2	242.5
13	65.05	108.30	442	244.5	8.5	6.3	8.5	10	6.5	1733.1	227.5
14	64.50	109.11	440	68.3	3.5	7.4	8.0	8	2.3	1181.0	195.0
15	64.47	109.13	440	52.7	3.5	7.5	9.5	8	3.5	694.7	190.0
16	64.31	109.38	430	501.7	7.0	6.2	9.5	8	4.3	1954.9	155.0
17	64.35	110.17	457	119.8	6.0	6.2	10.5	8	3.5	1400.4	142.5
18	64.18	110.38	459	317.1	8.0	8.0	10.5	8	3.5	2067.4	107.5
19	63.35	111.54	450	130.5	7.0	8.2	13.0	0	2.5	367.6	12.5
20	63.39	112.08	427	288.4	6.0	8.2	11.5	0	2.5	2085.7	5.0
21	63.22	112.23	427	97.5	2.5	7.5	14.0	20	2.0	NA	-30.0
22	63.16	112.28	389	283.8	10.0	7.8	13.0	20	2.8	NA	-47.5
23	63.13	112.29	396	98.2	5.5	8.8	14.0	22	2.5	2120.8	-52.5
24	63.1	112.42	380	301.1	9.0	8.9	14.0	32	3.0	NA	-68.0
MIN.	62.47	108.29	274	52.7	2.5	6.2	7.5	0	2.0	367.6	-120.0
MAX.	65.27	113.40	488	501.7	25.0	8.9	14.5	100	7.5	2120.8	262.5
MEAN			421.6	215.0	8.2	7.9	10.9	17.1	3.9	1264.2	79.8
STD			49.1	129.5	5.4	1.0	2.4	20.6	1.5	598.9	123.6

NA = not available

ADL = at detection limit

Table 5. Physicochemical data for the 24 Yellowknife to Contwoyto Lake study sites, including minimum, maximum, mean, and sample standard deviation values. TPU = total phosphorus (unfiltered); TPF = total phosphorus (filtered); SRP = soluble reactive phosphorus; DOC = dissolved organic carbon; DIC = dissolved inorganic carbon; TKN = total kjeldahl nitrogen; TN = total nitrogen; CHLaU = chlorophyll a (uncorrected); CHLaC = chlorophyll a (corrected); POC = particulate organic carbon; PN = particulate nitrogen; TN:TP = total nitrogen to total phosphorus ratio; POC:PN = particulate organic carbon to particulate nitrogen ratio. This data is reproduced from Pienitz *et al.* 1994c.

Site	TPU [µg/l]	TPF [µg/l]	NO2 [µg/l]	NO3 [µg/l]	SRP [µg/l]	NH3 [µg/l]	DOC [mg/l]	DIC [mg/l]	TKN [µg/l]	TN [µg/l]	SiO2 [mg/l]	SO4 [mg/l]	Ca [mg/l]	Na [mg/l]	K [mg/l]	Cl [mg/l]	CHLaU [µg/l]	CHLaC [µg/l]	POC [µg/l]	PN [µg/l]	Fe [µg/l]	Mn [µg/l]	TN/TP	POC/PN
1	9.5	5.2	2.0	ADL	0.6	ADL	5.6	12.1	352	425	0.41	2.1	13.5	4.66	1.95	4.8	0.8	0.5	488	60	36.6	4.0	45	8
2	9.6	7.6	2.0	ADL	0.8	13.0	8.5	5.6	371	478	0.92	2.3	6.3	1.82	1.16	1.0	0.8	0.6	641	94	31.2	2.0	50	7
3	3.9	2.3	2.0	ADL	0.6	6.0	4.7	3.5	176	247	0.61	0.6	5.1	0.81	0.58	0.7	0.4	0.2	390	58	17.5	3.0	63	7
4	9.6	4.7	3.0	ADL	1.0	12.0	8.7	0.4	325	389	0.32	1.4	1.2	0.79	0.51	0.7	0.8	0.6	532	50	178.0	8.0	41	11
5	3.6	2.7	ADL	ADL	0.5	9.0	4.0	0.6	178	242	0.24	0.3	1.1	0.67	0.40	0.6	0.8	0.7	483	52	43.6	4.0	67	9
6	7.7	2.8	1.0	ADL	0.4	11.0	1.7	0.5	63	135	0.08	0.5	0.7	0.44	0.46	0.6	0.5	0.1	595	60	49.3	ADL	18	10
7	5.5	9.0	1.0	ADL	0.4	6.0	2.4	0.3	102	212	0.10	0.4	0.6	0.46	0.37	0.7	1.2	0.9	484	98	16.1	ADL	39	5
8	6.3	3.3	ADL	ADL	0.5	11.0	2.0	0.2	150	266	0.26	1.0	0.5	0.42	0.34	0.5	0.8	0.2	550	104	27.2	ADL	42	5
9	4.5	8.7	3.0	ADL	0.5	5.0	2.2	0.2	141	211	0.19	0.4	0.6	0.38	0.33	0.6	1.3	1.1	375	56	10.2	ADL	47	7
10	3.4	2.2	1.0	ADL	0.5	ADL	2.7	0.2	126	240	0.18	0.9	0.7	0.42	0.34	0.8	0.8	0.1	387	102	10.3	ADL	71	4
11	9.7	3.0	1.0	ADL	0.5	12.0	2.6	0.3	147	211	0.27	0.3	0.7	0.46	0.30	0.6	1.0	0.7	521	52	34.3	ADL	22	10
12	3.6	3.1	1.0	ADL	0.4	8.0	2.0	0.1	105	161	0.21	1.5	0.7	0.44	0.35	0.6	1.1	0.4	484	44	17.1	ADL	45	11
13	4.6	9.2	2.0	ADL	0.4	5.0	1.6	0.5	88	147	0.26	1.4	1.2	0.36	0.27	0.5	0.9	0.8	354	46	7.5	ADL	32	8
14	7.3	2.7	1.0	ADL	0.6	8.0	3.2	0.2	160	233	0.19	1.0	0.7	0.38	0.40	0.5	1.0	0.8	578	61	134.0	ADL	32	9
15	5.5	1.8	1.0	ADL	0.5	9.0	2.5	0.3	123	164	0.18	0.7	0.7	0.42	0.38	0.6	1.8	1.4	528	29	21.7	ADL	30	18
16	7.7	2.9	3.0	ADL	0.6	ADL	3.2	0.2	32	146	0.19	1.0	0.7	0.46	0.47	0.7	0.7	0.6	598	100	53.1	26.0	19	6
17	4.0	2.9	2.0	ADL	0.5	ADL	2.4	0.3	115	222	0.33	0.9	0.6	0.46	0.44	0.5	0.6	0.2	549	94	51.3	4.0	56	6
18	6.7	2.3	3.0	ADL	0.6	6.0	3.8	0.1	157	213	0.29	1.2	0.8	0.40	0.34	0.8	0.7	0.3	577	42	33.5	2.0	32	14
19	6.1	3.2	3.0	ADL	1.3	6.0	4.9	0.6	173	260	0.34	1.2	1.3	0.67	0.42	0.8	0.7	0.3	580	73	30.1	ADL	43	8
20	5.2	4.0	1.0	ADL	0.6	12.0	4.5	1.1	183	264	0.13	0.9	1.6	0.77	0.60	0.7	0.7	0.4	899	69	44.3	3.0	51	13
21	12.7	7.8	3.0	ADL	1.1	6.0	9.1	1.7	321	429	0.16	0.8	2.6	0.93	0.70	0.8	1.4	0.9	1080	94	210.0	12.0	34	11
22	6.5	5.3	3.0	ADL	0.7	8.0	5.7	2.1	203	267	0.64	1.4	2.9	0.79	0.68	0.6	0.6	0.2	465	50	18.7	ADL	41	9
23	5.9	5.7	2.0	ADL	0.8	9.0	6.4	2.4	270	375	0.38	1.0	3.4	0.83	0.83	0.6	0.8	0.5	592	92	17.0	10.0	64	6
24	9.2	5.8	2.0	14.0	0.8	13.0	8.1	3.1	282	344	0.77	1.4	4.9	1.55	0.67	2.1	0.6	0.4	525	46	23.9	ADL	37	11
MIN.	3.4	1.8	1.0	ADL	0.4	5.0	1.6	0.1	32	135	0.08	0.3	0.5	0.36	0.27	0.5	0.4	0.1	354	29	7.5	2.0	18	4
MAX.	12.7	9.2	3.0	14.0	1.3	13.0	9.1	12.1	371	478	0.92	2.3	13.5	4.66	1.95	4.8	1.8	1.4	1080	104	210.0	26.0	71	18
MEAN	6.6	4.5	1.9		0.6	8.1	4.3	1.5	181.0	261.7	0.32	1.0	2.2	0.82	0.55	0.9	0.9	0.5	552.3	67.8	46.5	4.3	43	9
STD	2.5	2.4	0.9		0.2	2.9	2.4	2.6	92.5	96.2	0.21	0.5	2.9	0.89	0.36	0.9	0.3	0.3	157.0	23.2	52.2	5.4		

NA = not available

ADL = at detection limit

Table 6. Site descriptions for the 20 lake sites of the Fennoscandia region of Finland and Norway. This map is reproduced from Pienitz *et al.* 1994d.

Site	Elevation (m asl)	pH	Conductivity ($\mu\text{S cm}^{-1}$)	Temperature (°C)
Sirkkalampi (F2)	285	7.8	NA	14
Upper Sirkkalampi (F4)	285	8.0	NA	14
Putaanlampi (F6)	246	7.5	162	14
Kourulampi (F9)	156	7.2	30	16
Hiidenlampi (F11)	219	6.0	24	14
Ruoppilampi (F15)	224	7.2	NA	14
Ilmakkiaapa (F18)	NA	6.3	27	10
Skallivarri (F21)	NA	5.7	NA	9
Pingo Lake (F29)	NA	5.0	NA	8
Vestereiva River (F40)	NA	6.8	NA	7.0
Lake #1 (F43)	NA	6.5	NA	9
Pond #2 (F47)	NA	6.8	NA	8
Pond #3 (F54)	NA	6.2	NA	7.2
Pond #4 (F60)	NA	6.7	NA	9
Kevojärvi (F67)	NA	6.9	NA	11
Hannuksenrantalampi (F75)	1.8	6.4	NA	17
Hannuksenlampi (F80)	4.0	5.3	NA	16
Kangasjärvi (F85)	9.2	4.7	NA	14
Rautajärvi (F93)	NA	6.3	NA	NA
Unnamed Lake (F97)	NA	NA	NA	NA

Table 7. Climate data from the study area of the Fennoscandia region. Reproduced from Pienitz *et al.* 1994d.

Station	mean annual temperature [°C]	mean annual precipitation [mm]	growing season [days]	average ice freeze-up [date]	average ice break-up [date]
Lammi (61°03'N; 25°03'E)	3.5 to 4.0	550 to 600	165 to 170	25.-30.11.	5.-10.5.
Hailuoto (65°01'N; 24°43'E)	2.5 to 3.0	400 to 450	145 to 150	10.-15.11.	10.-15.5.
Kuusamo (66°22'N; 29°19'E)	0.0 to 0.5	500 to 550	125 to 130	30.10.-5.11.	25.-30.5.
Utsjoki (69°45'N; 27°02'E)	-1.0 to -0.5	400 to 450	115 to 120	25.-30.10.	5.-10.6.
Vardø (70°21'N; 31°00'E)	-2.0 to -1.1	500 to 700	about 110	N.A.	N.A.

N.A. = not available

chromic ($K_2Cr_2O_7$) acids. Usually 9 ml of this solution was required. Digestion of the organic material proceeded over 5 to 6 days. In order to accelerate the reaction, the samples were placed in a boiling water bath for two hours near the end of the digestion process. Digested samples were centrifuged, the supernatant was removed, and the pellet was resuspended in distilled water. The centrifuging/washing step was repeated six times. An aliquot of the resulting siliceous material/slurry was evaporated onto coverslips, which were subsequently mounted onto glass microscope slides with Hyrax® (R.I. = 1.71). Between 300 to 500 diatom valves were identified and enumerated along random transects using oil immersion objectives on an Olympus BHS microscope (1000x magnification, N.A. = 1.40). Taxonomically difficult taxa were studied using a Hitachi S-2500 scanning electron microscope at 20 kV. Identifications were made to the lowest taxonomic level (e.g. variety) using primarily the following standard floras, as well as many other taxonomic sources: Hustedt (1927-1966), Mölder & Tynni (1967-1973), Patrick & Reimer (1966, 1975), Tynni (1975-1980), Foged (1981), Germain (1981), Camburn *et al.* (1984-1986), Hein 1990, and Krammer & Lange-Bertalot (1986-1991). Many light and SEM micrographs were taken to confirm and document the identifications. Sediment samples are stored at the Department of Biology, Queen's University, and a set of microscope slides will be curated at the Phycological Collection, Canadian Museum of Nature, Ottawa, Canada.

NORTHERN QUÉBEC

The diatoms preserved in long core sections from two lakes located near Ungava Bay in northern Québec were identified. The two study sites, Hendry Lake (58°07'N, 68°14'W) and Tasirlaq-sud Lake (58°14'N, 68°27'W), are located on opposite sides of the Koksoak River near Kuujuaq at altitudes of 40 and 45 m, respectively (Figure 4). Local bedrock consists mainly of granite-gneisses belonging to the Churchill Geological Province of the Canadian Shield. Both lakes lie within the physiographic region of the George Plateau (Bostock 1970) characterized by landscapes of moderate relief with mean elevations ranging from 75 to 170 m asl. The widespread and discontinuous mantle of surface deposits covering the bedrock is mainly of glacial origin and can be attributed to the last Wisconsinan glaciation. Intensive reworking of these deposits was caused by the subsequent marine incursion of D'Iberville Sea (Delisle *et al.* 1986).

Tasirlaq-sud Lake is a small (0.35 km²) elongated basin located about 15 km northwest of Kuujuaq. It lies within a narrow structural depression extending in a south-north direction towards Ungava Bay. To the east and the west, it is surrounded by higher terrain (75-155 m). Hendry Lake, with a surface area of 7.35 km², is situated 10 km east of Kuujuaq on a plateau which is separating the important estuaries of Koksoak River and False River.

The subarctic climate of the region is characterized by long winters, short summers, and by a mean annual temperature of -5.2°C. The mean total annual precipitation is 476 mm of which about 40% fall in the form of snow. The frost-free season lasts about 60 days. Both lakes are ice-covered for a very long period; freeze-up and break-up generally occur in early November and late June, respectively (Québec 1984).

Phytogeographically, the Kuujuaq region lies within the shrub subzone of the forest-tundra zone (Payette 1983). This transitional zone that extends between the forest-tundra and the tundra, is dominated by a shrubby vegetation composed principally of birch (*Betula glandulosa*) and alder (*Alnus crispa*) with isolated stands of coniferous trees (*Picea mariana*, *Larix laricina*).

Sampling was carried out in May 1987 through 1.5 m of ice, using a Livingstone piston

corer and casing of plastic drainpipe. Two sediment cores, 1.25 and 3.85 m in length, were recovered from the central part through 7 m and 4 m of water in Lakes Hendry and Tasirlaq-sud, respectively. The cores were extruded in the laboratory of paleoecology at Laval University, surface cleaned, subsampled and then wrapped in plastic and aluminium foil for storage in a dark room at 4°C.

Samples for diatom analysis (1 cm³) were taken from the cores at intervals of 5 cm. All samples were first treated with hydrogen peroxide (30% H₂O₂) in order to bleach and destroy the organic matter and then repeatedly rinsed to neutrality. A 0.5 ml aliquot of the resulting siliceous solution was transferred to a 22x22 mm cover slip and allowed to dry overnight. Diatom slides were made using the mounting medium Naphrax (R.I. = 1.73).

For each sample 500 to 1000 valves were counted and identified on a Zeiss II Photomicroscope using oil immersion objectives at 500x and 1250x magnifications. Taxonomically different taxa were studied using a JEOL-25IIS scanning electron microscope. Identifications were made with reference primarily to the works of Bérard-Therriault *et al.* (1986, 1987), Cardinal *et al.* (1984, 1988), Cleve-Euler (1951-1955), Foged (1964, 1974, 1977, 1981), Germain (1981), Hendey (1964), Hustedt (1927-1966), Krammer & Lange-Bertalot (1986-1991), Mölder & Tynni (1967-1973), Patrick & Reimer (1966, 1975), Patrick & Freese (1961), Poulin *et al.* (1984a, 1984b, 1984c, 1987), Tynni (1975-1980), and Van der Werff & Huls (1957-1974).

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THE MORPHOLOGY AND DISTRIBUTION OF *NEIDIUM DISTINCTE-PUNCTATUM* HUSTEDT AN INTERESTING TAXON FROM THE CANADIAN ARCTIC

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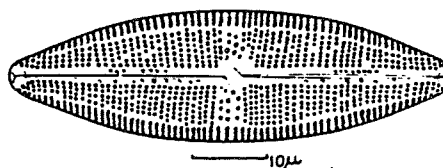
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Hustedt in 1922 first described *Neidium distincte-punctatum* from the bottom mud samples of lower Lake Lunz in the Austrian Alps. As the epithet implies, the punctae are very large and distinct, making this species easy to identify (Figure 1). Currently this species is recorded from Europe (Austria; Germany, Krammer & Lange-Bertalot 1986), Scandinavia (Finland; Sweden, Cleve-Euler 1955, Fig. 1175 I, M), Russia (Neizvesten?, Sabelina *et al.* 1951) Greenland (Perry Land, Foged 1955), Canada (Sreenivasa 1971, Hamilton *et al.* 1994), and U.S.A. (Iowa, Stoermer 1963; Alaska, Patrick & Freese 1961, Foged 1981). Although this taxon is reported from Asia, we have not seen any strong evidence that it is present in the region.

Figure 1. Line drawing of *Neidium distincte-punctatum* Hustedt. Copied from Stoermer (1963, Figure 7).

Scale bar is 10 μ m.



The nominate form of this species is elliptical-lanceolate ranging from 35-70 μ m in length, 12-21 μ m in width and has a striae count of 10-12 in 10 μ m (Krammer & Lange-Bertalot 1986). In this arctic study, *N. distincte-punctatum* populations are observed from seven localities on Ellesmere Island (Table 1). The valve lengths and widths range from 32-63 μ m, and 12-19 μ m, respectively. The frustule depths range from 12-21 μ m. The overlap in size between frustule width and depth is indicative of the fact that frustules are routinely observed in both valve and girdle views. The striae counts are very consistent ranging from 10-12 in 10 μ m. The narrow range in the striae count is explained by the presence of large depressions associated with the areolae. These depressions occupy a large part of the valve surface area, thus reducing the space available for areolae.

One distinct longitudinal canal is present along each of the margins of the valve. In the light microscope (LM), the canals do not appear to extend to the apices. The depressions associated with the areolae are also evident throughout the central area, although in this region, no areolae are associated with these depressions (per. obs.). The axial area is broad with small isolated depressions occasionally observed (Figure 1.). The raphe is filiform with the characteristic deflected central raphe endings varying from obliquely slanted to distinctly hooked. The apical fissures have flaps (bifurcation appearance) covering the apical raphe endings. Four to five girdle bands connect the hypo- and epivalves. The internal valve has a costate-like rib structure between the striae rows with a velum covering the internal surface (pers. obs.) The areolae are not chambered but simple pores extending through the silica

matrix.

The distribution of this taxon in the Northern Hemisphere clearly indicates that it is a cold-tolerant species. The exceptions to this observation are the two reported occurrences in

Table 1. Morphometric measurements for *Neidium distincte-punctatum* from 7 sites on Ellesmere Island

Site	No. of observations	Length μm	Width μm	Depth μm	Striae in 10 μm	Areolae in 10 μm
Ellesmere Island National Park						
57	35	38-63	16.5-19	19-21	(9) 10-12	11-15 (17)
108	12	45-63	16-17.5	15-18.5	10-12	10-13
103	2	44-57	15-16.5	12	10	
80	2	45-49	16-16.5		10-11	12-15
132	5	46-62	17.5	15-18.5	10-11	12-14 (17)
Fosheim Peninsula						
158	29	32-62	12-16	12-16	10-11	10-14
180	34	43-63	13.5-17.5	14.5-17	10-11	10-15

central North America (Iowa, Stoermer 1963; Ontario, Sreenivasa 1971). The disjunct nature of these occurrences is very interesting and worth further study. At present, it is evident that *N. distincte-punctatum* is not an "acid tolerant" species with no reports from the exposed Precambrian Shield region between the Arctic islands, and central North America. It is interesting to note that the identified specimens from Ontario (*N. distincte-punctatum* var. *major* Sreenivasa) were found at a depth of 320 cm in a sediment core section collected from the bottom of Sunfish Lake, thereby representing postglacial sediments. The present day occurrence of *N. distincte-punctatum* from Lake Okoboji (Iowa) is surprising, although, as pointed out by Stoermer (1964), there are a number of diatom taxa present in Iowa that are rare or have disjunct distributions. Further, Stoermer reports the presence of marine or fossil species in some Iowa lakes and streams. Given the disjunct nature of its distribution and its cold water preference, it is possible that the exposure of postglacial diatom deposits is occurring through erosional processes. If in fact the disjunct species are living in the modern sediments then we have an extremely interesting biological system in the state of Iowa.

Table 2. Water chemistry data for the lakes or ponds having *N. distincte-punctatum* populations.

Site	pH	Cond.	K ⁺	Cl ⁻	SiO ₂	SO ₄ ²⁻	Ca ²⁺	Na ⁺	TKN	TP	DOC
57	8.1	>2000	44.9	171	5.9	1259	117	63.9	2.3	0.033	31.9
80	7.9	463	4.0	61.8	0.2	11.6	20.9	49.5	0.3	0.005	3.8
103	7.3	79	0.6	0.6	0.8	1.0	12.3	0.4	0.2	0.007	3.0
158	8.3	505	25.6	29.5	4.2	19.4	36.5	25.6	1.05	0.025	21.0
180	7.8	545	6.8	38.4	2.7	14.9	36.0	36.1	1.2	0.015	20.3

Cond. is Conductivity, measured in $\mu\text{S}\cdot\text{cm}^{-1}$, TKN is Total Kjeldahl nitrogen, TP is total phosphorus, DOC is dissolved organic carbon. Ions and nutrients are measured in $\text{mg}\cdot\text{l}^{-1}$

Although primarily reported from lake sediments, in the Canadian Arctic, this taxon is routinely found in shallow ponds (<2.0 m) in the benthic sediments. Only one of the study sites has this species in moss collections and we suspect that this species is truly an epipelagic taxon. The aquatic conditions for growth are highly variable with conductivities ranging from 79 to >2000 $\mu\text{S}\cdot\text{cm}^{-1}$ (Table 2). Not only major ions, but nitrogen, phosphorus and dissolved organic carbon concentrations are highly variable, indicating that water chemistry does not appear to be limiting for the growth of *N. distincte-punctatum*. The range in water quality, in addition to the distributional patterns (European Alps, Scandinavia, Russia, Greenland, Ellesmere Island, and Alaska) indicates that this taxon is truly cold-tolerant. Krammer & Lange-Bertalot (1986) note that this species is infrequent and probably subfossil. If this taxon has a subfossil period of prominence, it does not seem to extend back to the Pleistocene in northern Canada (Lichti-Federovich 1983). Finally, we predict that this species should be found in the Canadian Rocky Mountains, northern Siberia, the Ural Mountains, and Franz Josef Land. The absence of this taxon from Iceland may be related to the warmer maritime climate and warmer freshwaters due to volcanic activity, or simply the need for better sampling. The absence of *N. distincte-punctatum* from Svalbard, specifically from the Lagerstedt collection (pers. obs.), is surprising, however we predict that this taxon should be found in future studies.

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DIATOMS IN SMALL LAKES AND PONDS IN GLACIER BAY NATIONAL PARK, ALASKA, USA

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Glacier Bay National Park and Preserve is in southeastern Alaska, about 60 km northwest of Juneau. The Park was set aside as a National Monument in 1925 primarily for scientific observation of glacial processes. The core of the Park is a fjord system named Glacier Bay, presently over 100 km long and 20 km wide with many arms and tributaries. Glacier Bay is flanked by the Chilkat Mountains to the east and the Fairweather Mountains to the west, with the highest peaks reaching over 4600 m in elevation. The Bay was occupied by glaciers during the Neoglacial Period, which began their gradual retreat about 200 years ago and exposed land surfaces to the processes of colonization and primary succession. Deglaciation began much earlier at sites to the west along Lituya Bay and the outer coast. Within Glacier Bay itself the position of the ice at various points in time is known from reports of early explorers and scientists, including Vancouver in 1794 and John Muir in the late 19th century. In the two centuries since Vancouver first recorded the position of the ice margin, the ice has receded over 100 km, and today nearly all of the tidewater glaciers are grounded.

Glacier Bay National Park has been the site of extensive studies of glacial geology, beginning with Wright (1887) and Reid (1896) in the 1890's and of ecological processes, including the classic work of Cooper (1923), Crocker & Major (1955), and Lawrence (1958). Our work in Glacier Bay is intended to complement the studies of terrestrial succession by examining patterns of lake ontogeny in relationship to primary succession in vegetation and soils. Our approach utilizes two complementary research strategies to investigate long-term biological and chemical changes in lacustrine systems. The first approach is the comparison of modern limnological conditions, including water chemistry, diatoms, macrophytes, and zooplankton, in a series of lakes along a deglaciation chronosequence, with catchments in different stages of primary succession. The second involves stratigraphic analysis of fossil diatoms in sediment cores to reconstruct development trends in pH, alkalinity, and trophic state at individual sites. The Glacier Bay lakes provide a model for early Holocene lake evolution in north-temperate regions and serve as a natural laboratory to test hypotheses generated in the paleolimnological literature concerning land/water interactions and the factors controlling lake development. Presented here is a brief description of the study lakes and a summarization of the modern diatom flora. A complete listing of the modern diatom taxa is given in Hamilton *et al.* (1994).

ENVIRONMENTAL SETTING

Southeastern Alaska has a temperate climate. The Glacier Bay region is dominated by maritime influences and thus has small annual temperature variations, frequent cloud cover, and heavy precipitation. Lowland areas have mean annual temperatures near 5°C, with summer and winter extremes no greater than 24°C and -23°C. Precipitation is poorly documented but ranges from about 150 to 300 cm·yr⁻¹ (Loewe 1966).

The recent deglaciated land surfaces are colonized by scattered mosses, lichens, dryads (*Dryas drummondii*), fireweed (*Epilobium latifolium*), dwarf willows (*Salix* sp.), and

cottonwood (*Populus balsamifera* var. *trichocarpa*), and dense colonies of *Dryas* soon spread across the landscape. Within 20-40 years of deglaciation these are followed by shrub thickets of alder (*Alnus crispa* var. *sinuata*), as well as willow and cottonwood, which in turn are eventually replaced by an overstory of spruce (*Picea sitchensis*) and cottonwood. Closure of the spruce forest canopy occurs after about 75-100 years and is accompanied by the appearance of western and mountain hemlock (*Tsuga heterophylla* and *T. mertensiana*), with a dense groundcover of pleurocarpous mosses. Muskegs have expanded to varied degrees in the older lake catchments along the outer coast and Lituya Bay, with open mires interspersed with stunted woodlands of western and mountain hemlock, lodgepole pine (*Pinus contorta*), and Alaskan yellow cedar (*Chamaecyparis nootkatensis*).

LAKE DESCRIPTIONS

Diatoms have been studied in 32 modern lakes formed by glacial retreat and ranging in age from 5 years to >10,000 years. The lakes are in lowland regions at the foothills of the mountains, at elevations <200 m. They are small (3-16 ha), of moderate depth (3-18 m), and all are in small primary catchments receiving no drainage from other lakes and streams. Ten of the lakes are <100 years in age, 10 range from 100 to 250 years, 9 range from ca 350 to 1200 years, and 3 lie outside the neoglacial ice limit and were formed about 13,000 years ago.

Epilimnetic water chemistry (Engstrom unpublished, Engstrom & Fritz 1990) shows a wide range of ionic concentrations from 0.1-5 meq·l⁻¹. The lakes with ion sums exceeding 1 meq·l⁻¹ are dominated by Ca²⁺ and HCO₃⁻ ions, while the more dilute lakes are more varied in ionic composition and tend to have Na⁺ and Cl⁻ in greater proportion. Most of these dilute lakes are in the outer coast region and receive significant sea spray. Epilimnetic pH is >8.0 for lakes less than 200 years old but declines with age among older sites. The older lakes also have lower alkalinity in comparison to the young sites. Chlorophyll *a* concentrations are generally below 2 µg·l⁻¹, and total phosphorus is less than 10 ppb implying extremely oligotrophic conditions. All lakes were sampled a minimum of 3 times over a 3 year period, once in each spring, mid-summer, and autumn, to assess seasonal and inter-annual variability.

DIATOM ANALYSIS

Surface sediment samples integrating the uppermost 0.5 cm of sediment were collected from each of the lakes, and each lake was cored with a piston corer. Additional collections were made at each sampling date from all available modern habitats, including epiphytic, epilithic, epipelagic, and epipsammic samples. The species presented in this technical report include only taxa from counts of the surface sediment samples. A minimum of 500 valves was identified in each sample on an Olympus BH-2 microscope with an oil immersion objective (N.A. = 1.4).

A total of 361 taxa are identified from the surface sediments. The Naviculales comprise 136 taxa, followed by , Fragilariales 43, Achnanthes 40, Cymbellales 35, Eunotiales 34, Bacillariales 25, Aulacoseirales 15, Thalassiosirales 12, Surirellales 9, Rhopalodiales 4, Thalassiosiphysales 4, Tabellariales 3, and Melosirales 1. The youngest lakes, on newly deglaciated terrane, are high in Ca²⁺ and HCO₃⁻ and are dominated by taxa such as *Achnanthes plonensis*, *A. minutissima*, *Amphora perpusilla*, *Gyrosigma spencerii* var. *curvula*, *Cymbella microcephala*, and several *Navicula* spp. Benthic *Fragilaria* spp. are not presently in the youngest lakes, but appear to develop in lakes older than 50 years, where nitrate concentrations are higher. The oldest lakes, which have lower pH and alkalinity, typically develop acidophilous

diatoms floras with moderate percentages of several *Aulacoseira* spp., *Cymbella pseudostelligera*, *Fragilaria virescens* var. *exigua*, *Cymbella gaeumannii*, *Navicula mediocris*, and *Fragilaria rhomboides* var. *saxonica*.

The flora of Glacial Bay is consistent with other taxonomic works for Alaska (Patrick & Freese 1961, Foged 1981, Heins 1990). A striking association of *Eunotia* spp. is observed from Baffin Island in eastern North America to Glacial Bay in the west, although in Glacier Bay *Eunotia* spp. are rare. Typical taxa included *Eunotia serra* Ehrenberg, *E. diodon* Ehrenberg, *E. incisa* Gregory, and *E. flexuosa* (Brébisson) Kützing. An association of taxa representing the Cymbellaceae and Naviculaceae is observed here and in other Arctic regions, such as Ellesmere Island, including *Cymbella descripta* Hustedt, *C. heteropleura* (Ehrenberg) Kützing, *C. similis* Krasske, *C. subaequalis* Grunow, *Navicula cari* Ehrenberg and *N. cincta* (Ehrenberg) Ralfs. In summary, the large variation in lake age and water chemistry is indicative of the high diversity of species observed in this study.

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DIATOM RESEARCH IN LABRADOR: ONE COMPONENT OF FRESHWATER BIODIVERSITY

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INTRODUCTION

Northern Labrador is part of the Arctic in terms of both ecological and cultural regions, and yet it often has been overlooked in Arctic research initiatives. This oversight is especially unfortunate in ecological terms, as Labrador contains strong ecological gradients and spans many Arctic to Boreal ecoregions within a comparatively short distance. Generally arranged from North to South, the major ecoregions have been defined (W. Meades 1989, S. Meades 1990) as:

- | | |
|--------------------------|-------------------------|
| 1. Low Arctic Tundra | 6. High Boreal Forest |
| 2. Alpine Tundra | 7. Mid Boreal Forest |
| 3. High Subarctic Tundra | 8. Low Subarctic Forest |
| 4. Coastal Barrens | 9. String Bog |
| 5. Mid Subarctic Forest | 10. Forteau Barrens |

Although these ecoregions have been defined without specific reference to algae, there is every reason to believe that algal assemblages will vary predictably across the major climatic, landscape, and aquatic gradients present in Labrador. Paleoecological investigations using gradient analysis (Dixit *et al.* 1992) provide the potential to greatly enhance the understanding of climatic change in this region of diversified ecotones, which is so strongly influenced by the cold Labrador Current.

The water resources of Labrador have been described, although in much less detail than for the island of Newfoundland (Water Resources Division 1992). Improved ecological monitoring and sustainable resource development also require significant knowledge of biodiversity of many groups of organisms. It is the purpose of this brief paper to document the known studies of freshwater diatoms and related water quality reports for the Labrador portion of the province of Newfoundland. Many of the sites mentioned in this report were included on the map of diatom research sites in North America (Dixit *et al.* 1992).

In this report, I have overly simplified the list of people involved in past research; more complete descriptions are in the primary literature listed below, as are the detailed site locations. I am not sure that I have discovered all past research on diatoms in Labrador, and other important collections may exist. Thanks to Bob Sheath (Biology, Dept. Memorial University, Newfoundland) for directing me to some of the literature.

PAST DIATOM RESEARCH

One of the earliest reports of freshwater diatoms comes from the marine and estuarine collections of Gardner (1949).

Herbert Wright and his colleagues, post-docs, and students at the Limnological Research

Center, University of Minnesota, pursued many paleoecological and paleolimnological studies in Labrador, making use of the ecozones, ecotones, and gradients mentioned above, much as they have across the prairie-forest ecotones in the center of the continent. Daniel Engstrom and David Foster collected over 70 surface sediment samples for pollen and diatom analyses throughout Labrador (Lamb 1984). Richard Brugam counted a small subset of 7 of these Labrador surface sediments for use in his paleolimnological interpretations of sediment cores in Minnesota (Brugam 1980). The collection of corresponding water samples at these sites makes it possible to construct transfer functions using diatoms and water quality in Labrador (Clair *et al.* 1982, Engstrom 1984), as has been done for chironomids and environmental variables from the same samples (Walker *et al.* 1991). Keith Camburn counted 48 of these samples and the data are in the Paleoecological Investigation of Recent Lake Acidification (PIRLA) database; the remainder are to be counted in 1994 by Reinhard Pienitz (J.P. Smol, pers. comm.).

Kingston (1984) analyzed diatoms from two cores and a few surface sediment samples, all from the Eagle Plateau in southeastern Labrador.

Hamish Duthie and his students published a series of papers including phytoplankton analyses in western Labrador, most of this funded as a result of the massive hydroelectric development on the Churchill River (Duthie 1979, Duthie & Ostrofsky 1974 1975, Ostrofsky and Duthie 1975a 1975b 1980). Phytoplankton were enumerated on an inverted microscope, and most of the diatom data only identifies a few dominant organisms. Two papers provide a detailed list of diatoms from these ecological studies (Duthie *et al.* 1975, Duthie & Ostrofsky 1978).

The Department of Fisheries and Oceans Canada has been a leading agency promoting research into lake acidification in Newfoundland and Labrador (Scruton 1984a, 1984b), building on water quality monitoring begun in the province in 1965. One of the contracted projects analyzed near-surface phytoplankton from 95 lakes in Labrador (Earle *et al.* 1986, Scruton *et al.* 1987), and included diatom identifications using the Utermohl counting technique.

Macroscopic algal growth in Labrador rivers includes several species of diatoms (Sheath *et al.* 1989). Finally, there have also been diatom studies in northern Québec (Pienitz *et al.* 1991) and further comparisons to such studies will be desired.

MATERIAL

Regarding the major set of University of Minnesota surface sediment collections, Brugam has diatom slides from his counts, and replicates exist at the Limnological Research Center (S.C. Fritz, pers. comm.). Material may also exist in storage at the Limnological Research Center. Subsamples of most of the 70 samples have gone to Queen's University. John Kingston retains the samples and slides from Leech Fen and Leech Lake. The 95 phytoplankton samples from the DFO study are curated in the phycological herbarium of the Canadian Museum of Nature (CANA 25040 - 25134). Hamish Duthie can be contacted for material from his research.

CONCLUSIONS

Although research on Labrador diatoms has been concentrated in a few studies, the remarkable ecological gradients and a climate dominated by the cold ocean provide great potential for future research using diatoms to interpret the past and present ecology of this region. The dramatic combination of ecotones makes Labrador an ideal research area for paleoecological analysis of global climate.

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THE PHYSICOCHEMICAL CHARACTERISTICS OF LAKES AND PONDS FROM THE NORTHERN REGIONS OF ELLESMERE ISLAND

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The Canadian Arctic has always been, and continues to be, a region of significant interest to Canadians. From the impact of the arctic ice masses on ocean water levels to the biological integrity of the tundra ecosystem, we have much to learn about the role of this polar region on the global ecosphere. Currently, research efforts in the sciences are looking at biological stability, diversity, arctic geology, climate change, contamination and ozone depletion over northern Greenland and Ellesmere Island. In the future we can expect increased interest and study on the impact of resource development on the Arctic terrestrial environment.

Although man's recent activities date back to the 1800's with the fishing and hunting of Arctic waters by Europeans and Scandinavians, human activities in the Arctic date well back to prehistoric >4000 BP times (Sutherland 1992) with the Independence Civilization. The most significant developments in natural resource utilization has occurred in the last 25-30 years with the exploration for oil in the 1970's.

In this study two regions on Ellesmere Island are examined (Figure 1). The first is a national park reserve in the northern part of the Island (81°N). In 1988, the Government of Canada established a 39,500 km² park in the northern most part of the country, protecting a significant natural area of the high arctic glacier and tundra region. Almost half the region is covered by glaciers with the remaining areas representing a dry arid climate with streams lakes and ponds scattered throughout the whole region. Lake Hazen, the largest lake in the Arctic archipelago, is located within the park boundaries. The second study area is the Fosheim peninsula (80°N) located on west coast of Ellesmere Island (Figure 1). The Sawtooth mountains on the eastern side of the peninsula effectively separates this area from the rest of the island. This peninsula is generally dry. Tundra ponds, more specifically polygon ponds are scattered throughout the peninsula area. The Fosheim peninsula was selected by the government of Canada as a monitoring area for high arctic ecosystems, with the ongoing monitoring of air quality, ozone depletion, changing ground-frost levels, stream water transport, mud slides, and biological diversity and stability (Edlund & Alt 1989).

The two study areas are contained within three mountain ranges (United States Range, Axel Heiberg Mountain Range, Victoria and Albert Mountain range including the Sawtooth Mountains). These ranges extend around the exterior of Ellesmere and Axel Heiberg Islands creating an insular affect from the northern ocean currents and northern weather systems, which gives this region significantly higher temperatures and less rainfall than other regions in the Arctic (Edlund & Alt 1989). The large area coupled with the "stable" environment makes this a biologically significant ecosystem in Canada. With relatively low rainfall, freshwater sources with ice-free periods are important biological systems in the region. Mammals, birds, and insects center their activities around these wetland systems.

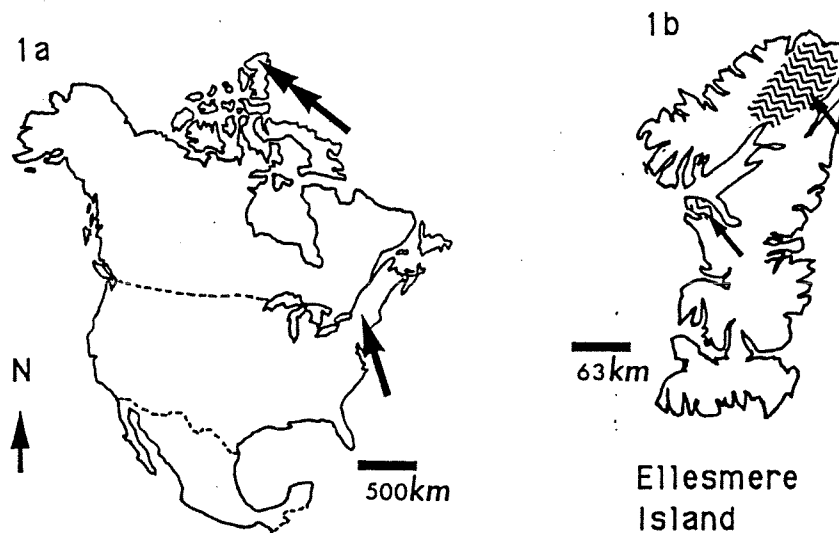


Figure 1. Sampling locations in the Arctic. Figure 1a. Double arrow represents location on Ellesmere Island. Figure 1b. Single arrows indicate the two study areas; the most northerly location represents Ellesmere Island National Park and the southern location indicates the Fosheim peninsula.

Further, within the small ponds and lakes, large populations of zooplankton and phytoplankton are frequently observed (pers. obs.). Thus, an understanding of the physicochemical conditions of these freshwater systems is important in studying biological activities and arctic food webs.

Two geologic formations, the Franklinian Mobile Belt and the Sverdrup Basin, represent the dominant geology for the sampled area (Bell 1992). The Franklinian Mobile Belt is comprised of rock formations ranging from Cambrian to Late Devonian which have undergone both uplifting and much folding and faulting, thereby giving the region extensive geographic relief. The Hazen Fold Belt in the north is comprised predominantly of dolomitic sandstones, mudrock, and slates, although pockets of Tertiary sandstones, siltstones, mudstones, and coal are responsible for some differences in water chemistry. The Fosheim Peninsula is part of the Sverdrup Basin formation, which is a rift formation overlying the Franklinian Mobile Belt. The Sverdrup Basin, representing Tertiary deposits and clastic sediments, extends from the southwest to the northeast. These deposits are comprised of sandstones, siltstones, mudstones, and coal. Marine sediments are present over much of the western part of the Fosheim Peninsula and influence the local water chemistry. The geology of the region is based on geological maps produced by Thornsteinsson (1971), Mayr *et al.* (1990), and Trettin & Mayr (1990a,b,c).

The purpose of this study is to define climatic and physicochemical conditions in the northern region of Ellesmere Island, examine nutrient variability within the study areas and to relate water chemistry to the physical factors of bedrock geology and soils.

METHODS

systems ranging from alpine lakes to valley ponds. An aquatic survey throughout Ellesmere Island National Park (east to west coast), was made in the summers of 1989 and 1990. An attempt was made to sample all the representative aquatic systems, ranging from large lakes (524 ha) to small shallow ponds (0.001 ha), in the different regions of the park. Sampling the aquatic systems on the Fosheim Peninsula followed the same selection process during the summers of 1989, 1990 and 1992. Biological samples from as many different microhabitats as possible were collected and preserved with Lugol's solution. Water samples were collected 60 cm below the water surface at or close to the center of the lake or pond. The water samples were stored under cool dark conditions and transported back to a base camp where sample processing was conducted. Processing followed the procedures of Environment Canada (1979). After processing, samples for ions, nitrogen, phosphorus and carbon analyses were stored in permafrost coolers at the base camps. Particulate carbon and nitrogen samples were filtered at the base camp, dried close to a camp stove and stored in dry conditions. Samples for Chlorophyll *a* were filtered and the filters were stored frozen in either propane fridges or in a permafrost ice freezer. All the samples were shipped with the researcher back to Ottawa and then to Burlington. This mode of transport means that only two single separate days of shipping were needed to get the samples from Resolute Bay (Cornwallis Island) to Burlington (Ontario) for analysis.

RESULTS AND DISCUSSION

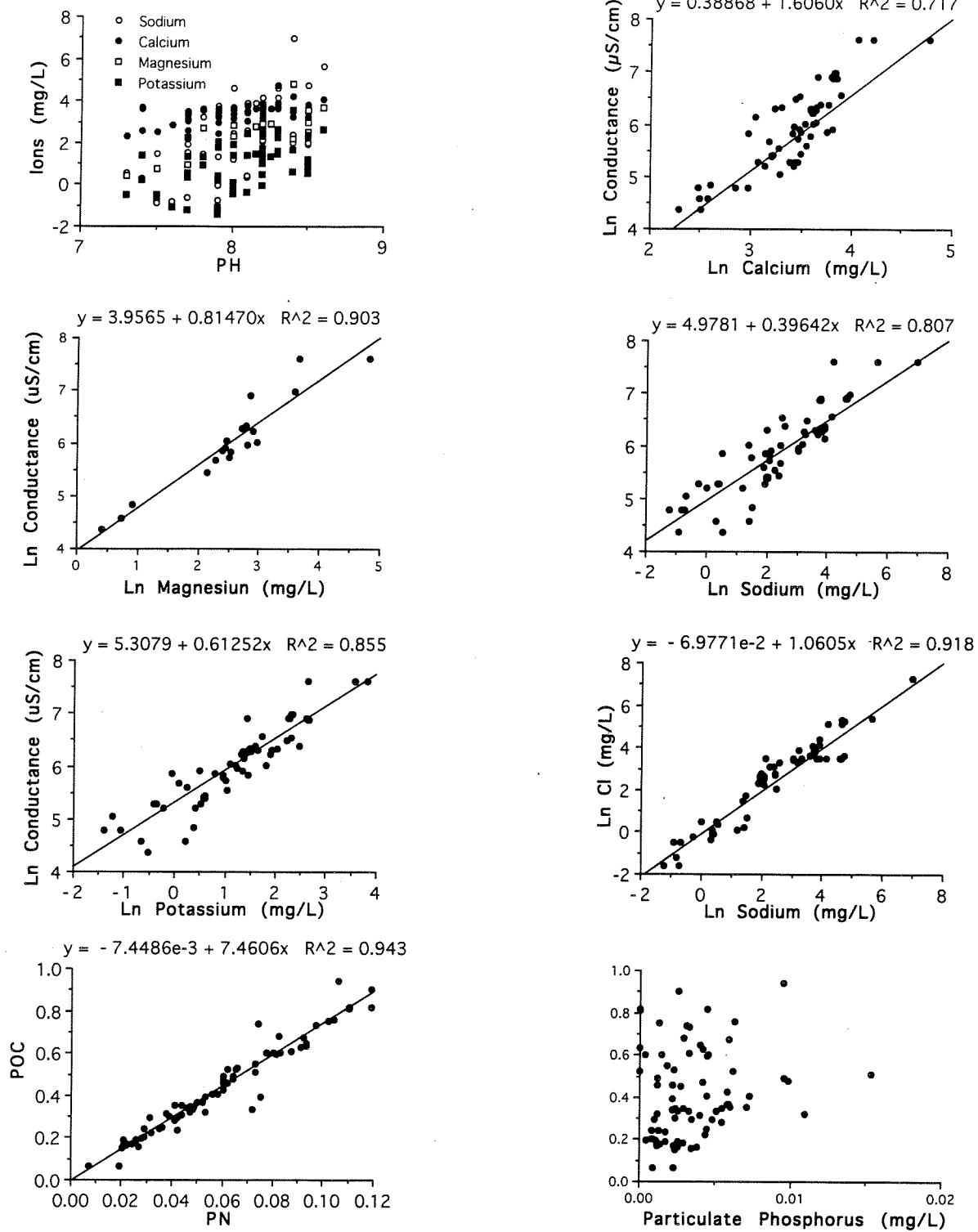
The physicochemical data for Ellesmere Island National Park and the Fosheim Peninsula are presented in Tables 1. The large range in surface areas from ponds to lakes gives a good representation of the physicochemical variations observed in the interior waters of Table 1. Ellesmere Island. The pH levels range from 7.4 to 8.5 with a mean value of 8.1. Even with the large seasonal input of glacial and snowmelt water, pH levels were consistent. In the shallow ponds (<2m), visibility was always to the bottom unless strong winds were turning-over benthic sediments. Sediment disruption was observed only once in a shallow lake (Gemini Lake <2 m) on the Fosheim peninsula.

Calcium, magnesium and sodium ions are all controlling the conductivity of the ponds and lakes of Ellesmere Island (Figures 1-4). Calcium is the most important ion over the complete pH range, although magnesium and sodium contribute more as the pH increases. Sodium is clearly the dominant cation at the higher pH levels. The importance of calcium in most of the study area ponds and lakes is visibly evident by the presence of marl deposits. A strong positive correlation exists between the observed marl deposits and the Silurian bedrock (Danish River Formation comprising calcareous-dolomite, sandstone and mudstone) which covers much of the study area. The lower R^2 (0.717) is easily explained by the patchy distribution of calcium values in the dataset. As pH levels increase, sodium and chlorine contribute to water conductivity. As expected, sodium and chlorine ions are highly correlated with each other (Figure 6). It is not surprising that NaCl is influencing the conductance of waters on the Fosheim Peninsula knowing that marine sediments are present over parts of the peninsula. Further, aeolian deposition of sediments (including marine sediments) is regularly observed on the Fosheim. Magnesium deposits are visible as a white crusts both in Ellesmere Island National Park and the Fosheim Peninsula. It is not surprising that along with calcium, magnesium is strongly influences conductivity (Figure 4). Potassium concentrations are 30 to 99% lower than calcium and do not have a significant influence on conductance, like the other ions potassium is highly correlated with conductivity (Figures 2, 6).

Calcium and dissolved inorganic carbon (DIC) are not strongly correlated in this dataset

Table 1. Physicochemical data for the Ellesmere Island study sites (1989-1992). Particulate organic carbon; DOC, dissolved organic carbon; DIC, Dissolved inorganic carbon; TKN, Total Kjeldahl nitrogen; PN, particulate nitrogen; NO₂, nitrite; NO₃&NO₂, nitrite-nitrate; NH₄, ammonium; TP, total phosphorus; TFP, Total filtered phosphorus; SRP, soluble reactive phosphorus; K⁺ potassium; Cl⁻, Chloride; SiO₄, silicate; SO₄²⁻, sulfate; Ca²⁺, calcium; Na⁺, sodium. All except depth (m), conductivity ($\mu\text{S}\cdot\text{cm}^{-1}$), secchi depth (m), and pH are measured in $\text{mg}\cdot\text{l}^{-1}$.

SITE	DEPTH	COND	PH	SECCH	POC	DOC	DIC	TKN	PN	NO2	NO3&NO	NH4	TP	TFP	SRP	K	CL	SiO2	SO4	Ca	NA
E1	1.5	545	8	1.5	0.522	20.3	51.8	1.237	0.062	0.011	0.01	0.029	0.0149	0.0087	0.0015	6.84	38.4	2.7	14.9	36	36.1
E2	1	563	7.9	1	0.491	21	52.9	1.098	0.06	0.009	0.01	0.028	0.02	0.0104	0.0005	7.58	44.9	2.73	9	27	41.3
E3	0.5	505	7.9	5	0.508	21	49.1	1.052	0.073	0.008	0.01	0.009	0.0246	0.0093	0.0017	6.55	29.5	4.18	19.4	36.5	25.6
E4	1.9	198	7.7	1.9	0.291	6.3	19.5	0.491	0.031	0.009	0.01	0.005	0.0092	0.0044	0.0005	1.7	14	0.18	1.6	21.6	6.93
E5	5	527	7.4	1.5	0.35	7.1	39.6	0.342	0.044	0.007	0.01	0.005	0.0104	0.0033	0.0001	4.01	58.8	1.03	9.2	38.2	38.7
E6	1.2	369	7.7	1.2	0.478	12.8	31.1	0.885	0.064	0.005	0.01	0.005	0.0199	0.01	0.0011	3.79	30.7	1.39	8.6	32.3	20.6
E7	0.9	320	7.8	0.9	0.633			0.796	0.093		0.012	0.031	0.0204	0.0261	0.0034	2.62	5.5	0.8	3.9	36	4.33
E8	6.1	650	7.7	4	0.333	7	30.3	0.429	0.072	0.01	0.01	0.005	0.0076	0.0043	0.0011	9.3	32.1	0.16	160	31.3	26.9
E9	4	297	8.1	4	0.248	6.2	25.6	0.325	0.036	0.005	0.01	0.005	0.0075	0.003	0.0005						
E10	1.1	695	8.2	1.1	0.353	16.3	61.3	1.034	0.041	0.008	0.01	0.016	0.0127	0.0067	0.0017	9.89	7.6	2.99	123	32.5	12.1
E11	10	98.2	7.4	0.219	4.1	10.8	0.24	0.032	0.01	0.01	0.005	0.0078	0.0034	0.0005	1.25	0.7	1.86	13.7	13.2	1.36	
E12	1.7	183	7.9	1.7	0.404	9	22.5	0.75	0.058	0.005	0.01	0.006	0.0083	0.0038	0.0006	1.51	1.6	0.96	2.1	30.6	0.99
E13	1.8	589	8.1	1.8	0.298	15.4	29.9	1.06	0.039	0.007	0.01	0.016	0.0101	0.0077	0.0005	11.8	27.2	0.46	110	43.3	13.2
E14	0.8	2000	8.3	0.8	0.943	31.9	58.3	2.312	0.106	0.009	0.01	0.045	0.0329	0.0234	0.0037	44.9	171	5.88	1259	117	63.9
E15	1.2	407	7.9	1.2	0.406	3.7	30	0.252	0.056	0.007	0.01	0.005	0.0117	0.0044	0.0023	6.14	4.2	0.36	79.8	34.4	3.91
E16	1	463	8.1	1	0.168	3.8	33.6	0.271	0.024	0.003	0.01	0.005	0.0051	0.0028	0.0009	3.96	61.8	0.15	11.8	20.9	49.5
E17	20	272	7.9		0.318	4.7	24.7	0.14	0.053	0.005	0.024	0.005	0.013	0.002	0.001	1.29	10.2	1.97	25.3	34.8	6.85
E18	3	156	7.7	3	0.164	15.2	92.9	0.09	0.022	0.005	0.03	0.005	0.004	0.0014	0.0007	0.29	0.6	1.16	2.5	26.6	0.52
E19	3	552	8.4	3	0.191	5.5	57.8	0.474	0.026	0.007	0.01	0.014	0.0055	0.0038	0.0009	5.14	12.6	0.9	53.3	25.5	7.27
E20	2	196	8	2	0.19			0.152	0.021		0.058	0.005	0.0044	0.0018	0.0005	0.66	0.8	1.3	5.1	29.3	0.78
E21		119	7.6	0.8	0.284	3.9	12.7	0.184	0.041	0.007	0.01	0.005	0.0087	0.0032	0.0005	0.34	0.3	1.79	2.7	17.3	0.45
E22	3.5	79	7.5	1.5	0.314	3	10.6	0.183	0.038	0.005	0.01	0.005	0.0067	0.0027	0.0005	0.6	0.6	0.84	1	12.3	0.41
E23	6.1	973	8.2	4	0.236	7.3	44.5	0.846	0.042	0.001	0.01	0.005	0.0079	0.0062	0.0006	14.2	52	0.13	261	45.3	42.6
E24	6	182	8	5	0.154	3	17.8	0.234	0.027	0.001	0.01	0.005	0.0063	0.0028	0.0005	0.8	1.1	1.08	9.3	22.9	3.26
E26	2.2	342	8.2	2.2	0.737	15.6	30.6	1.085	0.074	0.002	0.01	0.033	0.0129	0.0098	0.0005	4.27	9.6	1.49	38.4	19.6	8.02
E27	10	352	8.2	8	0.241	2	28.1	0.163	0.029	0.001	0.01	0.008	0.0034	0.0026	0.0002	0.95	1.6	1.8	49.2	42.6	1.64
E28	100	119	7.9	30	0.064	0.3	7.9	0.034	0.019	0.001	0.014	0.005	0.0024	0.0015	0.0013	0.25	0.2	0.51	6.6	11.9	0.3
E29	100	119	7.9	30	0.067	0.7	12.6	0.018	0.007	0.001	0.019	0.01	0.0033	0.001	0.0014	0.34	0.2	0.85	8.9	19.6	0.48
H1	1	255	8.2	1	0.647	9.1	21.3	0.723	0.093	0.0002	0.01	0.009	0.0108	0.0068	0.0053	2.82	21.8	1.09	0.8	26.5	9.47
H2	1.9	220	8.5	1.9	0.393	7	19.7	0.529	0.075	0.0007	0.01	0.021	0.0062	0.004	0.0014	1.76	15	1.21	0.3	24.8	7.16
H3	1.9	222	8.5	1.9	0.608	7	19.8	0.526	0.087	0.0005	0.01	0.021	0.0075	0.0042	0.0019	1.79	15.6	1.27	0.3	24.8	7.25
H4	1.9	222	8.5	1.9	0.597	7	19.8	0.514	0.081	0.0006	0.01	0.038	0.0088	0.0043	0.0016	1.77	15.2	1.18	0.3	24.9	7.47
H5	1.9	220	8.5	1.9	0.449	6.7	20	0.45	0.061	0.0002	0.01	0.044	0.007	0.0043	0.0011	1.82	14.9	1.23	0.3	24.8	7.47
H6	9	528	8.3	5.5	0.201	4.4	33.2	0.187	0.029	0.0007	0.01	0.005	0.0027	0.0019	0.0005	4.43	32.1	1.01	4.1	36.5	44.8
H7	9	529	8.3	5.5	0.347	4.2	33.2	0.221	0.047	0.0002	0.013	0.009	0.0051	0.0027	0.0023	4.4	32	1.03	4.2	36.3	44.3
H8	9	532	8.3	5.5	0.322	4.2	33.2	0.226	0.047	0.0009	0.01	0.008	0.004	0.0028	0.0014	4.46	32	1.03	4.5	36.4	45.2
H9	9	528	8.3	5.5	0.183	4.2	33.2	0.204	0.026	0.0002	0.01	0.005	0.0034	0.0022	0.0013	4.4	32	1.11	4.1	36.3	44.8
H10	9	582	8.3	5.5	0.196	4.5	37	0.236	0.028	0.0002	0.01	0.005	0.004	0.0029	0.0014	4.84	32	1.28	4.2	39.9	48.5
H11	9	716	8.2	5.5	0.183	5.2	46.8	0.246	0.026	0.0002	0.01	0.005	0.0054	0.0025	0.0018	5.58	32	1.81	4.5	48.8	61.2
H12	8	999	8.3	1.4	0.331	10.1	50.3	0.426	0.048	0.001	0.01	0.005	0.0091	0.004	0.0013	9.47	31.9	0.79	22	45.2	98.8
H13	8	999	8.3	1.4	0.364	10.9	50.2	0.435	0.05	0.001	0.01	0.005	0.0096	0.0037	0.0012	9.83	31.9	0.77	22.4	44.6	101
H14	8	1000	8.3	1.4	0.344	10.7	50.3	0.446	0.049	0.005	0.01	0.005	0.0096	0.0041	0.0033	9.83	168	0.81	27.8	45.6	101
H15	8	1011	8.3	1.4	0.426	10.5	50.2	0.461	0.06	0.001	0.01	0.005	0.0096	0.0038	0.0025	9.83	168	0.79	27.5	45	101
H16	8	1010	8.3	1.4	0.367	10.6	50.2	0.472	0.052	0.0007	0.01	0.005	0.01	0.0042	0.0021	9.83	168	0.8	28	44.9	100
H17	6	985	8.3	4.2	0.345	7.7	42.6	0.503	0.049	0.0002	0.01	0.005	0.0074	0.0045	0.0021	13.8	46.4	0.07	246.3	45.7	41.8
H18	6	980	8.3	4.2	0.331	8.9	42.9	0.498	0.048	0.0002	0.01	0.007	0.0077	0.0051	0.0017	13.9	46.4	0.06	249.7	46.8	41.4
H19	6	980	8.3	4.2	0.291	7.1	42.4	0.5	0.042	0.0002	0.01	0.009	0.0076	0.0041	0.0014	13.8	46.1	0.06	250.3	46.3	41.4
H20	6	980	8.3	4.2	0.306			0.044													
H21	6	982	8.3	4.2	0.289			0.041													
H24	20.5	199	8.1	5.3	0.201	2.2	21.3	0.077	0.029	0.0004	0.01	0.005	0.0026	0.0017	0.0003	0.69	0.9	2.32	4	31.7	1.47
H25	20.5	198	8.1	5.3	0.197	2.4	20.9	0.078	0.028	0.0002	0.01	0.005	0.0028	0.0023	0.0005	0.71	0.9	2.32	3.9	31	1.49
H26	20.5	198	8.1	5.3	0.296	2.1	21.4	0.075	0.042	0.0002	0.01	0.005	0.0032	0.0022	0.0007	0.7	1	2.32	3.6	31.6	1.45
H27	20.5	198	8.1	5.3	0.166	2.3	20.9	0.075	0.021	0.0002	0.01	0.005	0.0053	0.0015	0.0006	0.7	1				



Figures 2-9. Simple regressions or plots of the water chemistry data for Ellesmere Island.

($R^2 = 0.536$). A notable exception is Long Lake (E22) located in the interior of the Park. Long lake is on Tertiary bedrock (Iceberg Bay Formation) composed of sandstones, siltstones mudstone and minor coal. With low Na, Cl, Mg, and SO_4 levels calcium bicarbonate is clearly controlling the alkalinity of the lake (Table 1).

Based on the particulate nitrogen (PN) to particulate organic carbon (POC) ratio (1:1) and the PN to particulate phosphorus (PP) ratio (>12:1) it appears nitrogen is not limiting in the phytoplankton community (Figures 7, 8). The strong correlation between PN and POC is interesting and appears to be directly related to the well developed zooplankton communities (pers. obs.). This PN:POC correlation has not been observed by Pienitz *et al.* (1994a,b) from the Yukon and Northwest territories. However, it must be pointed out that the introduction of PN and POC from allothomous sources is a possible concern especially in these shallow pond systems (<2 m).

No correlations were observed between chlorophyll-*a* and carbon, nitrogen, and phosphorus. This was puzzling especially given that the strong correlation with PN and POC. However, we have noted along with Douglas & Smol (1994a,b) that pond systems on Ellesmere Island do not have extensive phytoplankton communities, but instead have well developed epilithic, epipellic and epiphytic communities. Croasdale (1973) has also noted a large flora of algae found in the squeezings of mosses. Further, as pointed out earlier, PN and POC levels maybe controlled by the zooplankton community.

The high levels of dissolved organic carbon (DOC), on average 33 times more DOC to POC are very different from Lake Ontario (4-7 times more DOC), although high DOC:POC ratios are observed by Pienitz *et al.* (1994a,b) in the Yukon and Northwest Territories. The significance of the higher DOC levels is not clear, and further study is needed.

SUMMARY

Conductance, and cation concentrations are well correlated with significant associations with the physical parameters of bedrock type or sediment compositions overlying the bedrock. Calcium appears to be the most significant cation throughout the aquatic systems. Particulate organic carbon is highly correlated with particulate nitrogen, which has not been observed elsewhere and may be related to the large degree of zooplankton observed. The phytoplankton community is not the main primary producer in these Arctic aquatic systems. Instead it is the epiphytic, epipellic and epilithic algal communities, which are contributing the most to primary production.

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DIATOMS FROM EPILITHIC, EPIPHYTIC AND EPIPELIC MICROHABITATS IN PONDS FROM CAPE HERSCHEL, ELLESMERE ISLAND

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INTRODUCTION

Douglas (1989) and Douglas and Smol (1993) undertook a taxonomic and preliminary ecologic description of diatom assemblages identified from the surficial sediments of 36 shallow ponds from Cape Herschel, Ellesmere Island. They chose to use the ponds' surface sediments for this initial survey because they expected that surface sediments would provide an integrated sample of a pond's diatoms, both spatially (from several pond habitats) and temporally (from several growing seasons). Surface sediment calibration sets have been widely used in other studies directed at defining the distributions and the ecological optima and tolerances of freshwater diatoms to environmental variables (Battarbee 1991). Over 122 diatom taxa from 27 genera were identified in the surface sediment survey, some of which are as yet undescribed. Benthic diatoms were abundant, whereas planktonic taxa were absent. Overall species richness on the Cape was high, but was low within each pond. Striking differences in species composition was evident amongst the ponds (Douglas 1989). A CCA (Canonical Correspondence Analysis) ordination indicated that Ca^{2+} , and pH were the measured environmental variables most significant to the diatom flora but only accounted for 11.4% of the floristic variation. Douglas (1989) hypothesized that benthic diatoms may more closely be reflecting substrate composition (e.g., rock, moss, sediment), rather than simply water chemistry.

Periphytic communities are often responsible for a large portion of a lake's primary production (Loeb *et al.* 1983) and in many arctic ponds, which are often both oligotrophic and shallow, the entire substratum can be considered littoral zone, consisting of diverse microhabitats. The fact that we did not record any planktonic, but only periphytic diatoms living on either submerged mosses, rocks or sediments (Douglas 1989, Douglas & Smol 1993) prompted us to examine the diatom assemblages from submerged moss and rock microhabitats within the same shallow high arctic ponds we had previously studied (Douglas & Smol 1994b). This paper provides a brief summary of the distribution of diatoms amongst moss, rock and sediment microhabitats. A more detailed description of the analyses and the results can be found in Douglas (1993) and Douglas and Smol (in prep).

MATERIALS AND METHODS

The location and site descriptions were outlined in Douglas & Smol (1994b). The same 35 study ponds from our previous studies were used for these periphyton investigations; Brackish Pond was omitted as an outlier because it is tidally influenced. During the 1983, 1984, 1986, and 1987 fieldwork periods at Cape Herschel, the study ponds were extensively studied for a variety of limnological (e.g., physical, chemical and biological) variables. Many detailed observations were made at each pond, including the dimensions of each pond, vegetation

within and around the ponds, drainage characteristics, and bottom substrate composition (e.g., moss, rock, sediment). Observations pertaining to ice-cover, avifaunal presence, etc. were routinely made. Numerous photographs were also taken.

Samples were collected from a wide diversity of freshwater ponds on Cape Herschel. Ponds were selected in order to obtain collections over as broad an environmental spectrum as possible (e.g., differences in salinity, altitude, bedrock composition, size, and drainage characteristics). Routine sampling protocols examined abiotic and biotic components. Detailed outlines of sampling and lab procedures were outlined in Douglas (1989, 1993) and Douglas and Smol (1994a). Microhabitats within each pond were sampled during each site visit. Epilithic communities were sampled by collecting five submerged rocks from each pond and brushing the periphytic community into a small vial with a soft toothbrush. The rocks were chosen to reflect the various epilithic habitats available in each pond (e.g., depth, rock type, etc.); however, given the small size and shallowness of the ponds, the substrates were fairly homogenous.

Epiphytic communities, if present, were sampled. Bryophytes were, by far, the most common plant substrates in the ponds. Emergent vascular plants, when present, in some ponds were also sampled. However, analyses presented in this paper deal exclusively with the bryophyte epiphytes. For each pond, on each sampling date, a "submerged moss collection" was made. Mosses along a moisture gradient were collected from the catchment as well as the pond itself, with the moisture content of the moss noted. These moss samples were classified as xeric, moist, wet, or submerged. The distinction between "moist" and "wet" was based on whether water could be squeezed from the moss (the latter). Because water levels fluctuated over the sampling season, we also noted whether the moss's moisture content had changed (i.e., a wet moss might have been submerged earlier in the season or vice versa). Moisture affects the composition of the diatom assemblages and therefore the differences between wet and submerged moss samples could be quite significant. Submerged mosses were present and sampled from 22 of the 36 ponds. An additional six "wet" moss samples were collected from ponds which supported no submerged moss.

All samples were stored in 15 ml plastic scintillation vials and preserved in Lugol's iodine solution (Lind, 1974). Physical and water chemistry data from all years were used in this study (see Douglas 1989). Only 1986 periphyton collections were analyzed for this study.

Sample Preparation

For the purposes of this study, submerged moss and rock samples, collected during mid-season (preferably on the same day) in 1986, were examined. Preparation of diatom samples followed standard techniques (Battarbee, 1986; Smol, 1983; Kingston, 1986). A small sample (approximately 1 cm³) of the collected moss material or approximately 3 ml of the epilithon material was placed in Nalgene™ centrifuge tubes for sample digestion. A strong solution of sulphuric (H₂SO₄) and chromic (K₂Cr₂O₇) acids (400 ml:20 g) was added to digest the organic material. Usually 9 ml of this solution was required. Digestion of organic matter proceeded over several days. In order to speed up the reaction, or remove residual residue, some samples were placed in a boiling water bath for several hours. Removing the acid solution from the sample was achieved through a washing and settling process using distilled water.

Following the digestions, the resulting siliceous material was diluted with distilled water (if necessary), the pellet was resuspended using a Fisher vortex mixer or a glass stirring rod, and a small subsample was transferred by pipette onto glass cover slips. Strawn slurries were applied to coverslips on a slide warmer at low heat. Once dry, the coverslips were

mounted onto glass slides using Hyrax®, a permanent mounting medium with a high refractive index (RI) of 1.65. Light microscope photomicrographs were obtained using one of two camera systems. Both microscopes were equipped with Nomarski optics. The Nikon-Optiphot microscope was attached to a FX-35 camera. The Leitz-Dialux 20 camera used a Wild Photoautomat MPS45 camera system. All photographs were taken using an oil-immersion lens (100 X, NA 1.25(Nikon); 100 X, NA 1.32 (Leitz)). Two high resolution black and white films: Kodak PanX 50 ASA and Tech Pan were used.

In addition to the light microscope slides, a small portion of the siliceous suspension was dried onto small circular (diameter = 12 mm) coverslips. When dry, the coverslips were mounted on aluminium SEM stubs using double-sided tape. The stubs were then coated with ca. 20 nm of gold using a Polaron Instruments Sputter Coater. A Hitachi-S-2500 SEM operated at 20 kV and equipped with a Polaroid camera was used for higher resolution SEM photographs.

A reference catalogue of all diatom taxa was assembled, and is archived with John Smol's diatom collection at Queen's University. Taxonomic determinations were made using the following references: Barber & Haworth (1981); Bourrelly (1968); Camburn *et al.*, 1984-86); Cleve-Euler (1951, 1952, 1953, 1955); Foged (1953, 1955, 1958, 1964, 1968, 1971, 1972, 1974, 1977, 1981, 1989); Germain (1981); Hustedt, (1928, 1930, 1933, 1937, 1959, 1961, 1962, 1966); Lichti-Federovich (1980, 1984); Manguin (1960); McLaughlin and Stone (1976); Patrick & Freese (1961); Patrick & Reimer (1966, 1975); Petersen, (1928); Ross (1947); VanLandingham (1967, 1968, 1969, 1971, 1975, 1978a, 1978b, 1979).

Diatoms were identified and counted along transects. Usually, a minimum of 250 diatom valves were counted from each sample. In the case of "wet mosses", diatoms were scarce and so fewer diatoms were counted (usually 100 valves). In certain instances, when a diatom taxon could not be identified, it was given a species number, e.g., *Navicula contenta* var. 1. In some cases, these taxa are described in Douglas and Smol (1993). In the case of certain genera, species were not determined, e.g., *Diatoma* spp..

All of the material collected has been catalogued and forms part of an extensive collection from the Arctic. All unprocessed samples are stored in a dark cold room. Raw material is available for future studies or for verification. As well, the diatom slides will eventually be deposited in the herbarium of the Canadian National Collection at the Canadian Museum of Nature (CANM).

Statistical Analyses

Two data sets were obtained from the periphyton samples: one representing rock assemblages (35 ponds) and one representing moss assemblages (22 ponds which had submerged mosses and another six ponds where wet mosses were examined due to the absence of submerged mosses). From the raw counts, data sets were first screened to remove rare and unusual taxa. If a diatom taxon was not present in at least three sites with a relative abundance of at least 1%, it was considered a "rare taxon" and was removed from further statistical analyses. To these data are added the surface sediment diatom enumerations from the previous study (Douglas, 1989; Douglas and Smol, 1993). These three data sets were combined and a canonical correspondence analysis (CCA) of diatom species constrained to habitat (i.e., moss, rock, and sediment) was performed.

TABLE 1. List of diatoms common to rocks (R), mosses (M) and sediment (S). These diatoms are present in at least 3 sites at abundances < 1%.

Species	Code	R	M	S
<i>Achnanthes coarctata</i>	ACH COA	.		
<i>A. flexella</i>	ACH FLX	.	.	.
<i>A. lapponica</i>	ACH LAP	.		.
<i>A. marginulata</i>	ACH MAR	.	.	.
<i>A. minutissima</i>	ACH MIN	.	.	.
<i>Achnanthes</i> sp. 1	ACH SP1	.	.	.
<i>Achnanthes</i> sp. 2	ACH SP2	.	.	.
<i>A. broenlundensis</i>	ACH BRO	.	.	.
<i>A. kryophila</i>	ACH KRY	.		
<i>Amphora libyca</i>	AMP LIB	.	.	.
<i>Amphora triundatulata</i>	AMP TRI	.		
<i>Amphora veneta</i>	AMP VEN	.		.
<i>A. veneta</i> var. <i>capitata</i>	AMP VCP	.		.
<i>Amphora</i> sp. 1	AMP SP1	.		.
<i>Caloneis schumanniana</i>	CAL SCH	.		.
<i>Caloneis</i> sp.1	CAL SML	.	.	.
<i>Cyclotella antiqua</i>	CYC ANT	.	.	.
<i>Cymbella angustata</i>	CYM ANG	.	.	.
<i>C. cesatii</i>	CYM CES	.	.	.
<i>C. designata</i>	CYM DES	.	.	.
<i>C. hybrida</i>	CYM HYB	.	.	.
<i>C. minuta</i> f. <i>latens</i>	CYM MFL	.	.	.
<i>C. microcephala</i>	CYM MIC	.	.	.
<i>C. minuta</i>	CYM MIN	.	.	.
<i>C. minuta</i> var. <i>pseudogracillis</i>	CYM PSE	.	.	.
<i>C. rupicola</i>	CYM RUP	.	.	.
<i>C. similis</i>	CYM SIM	.	.	.
<i>C. stauroneiformis</i>	CYM STA	.	.	.
<i>C. subaequalis</i>	CYM SUB	.	.	.
<i>Cymbella turgidula</i>	CYM TUR	.	.	.
<i>Cymbella</i> sp. 1	CYM SP1	.	.	.
<i>Cymbella</i> sp. 2	CYM SP2	.	.	.
<i>Cymbella</i> sp. 3	CYM SP3	.	.	.
<i>Denticula kuetzingii</i>	DEN KUE	.	.	.
<i>D. tenuis</i>	DEN TEN	.	.	.
<i>Diatoma</i> spp.	DIA SPP	.	.	.
<i>Diploneis elliptica</i>	DIP ELL	.	.	.
<i>D. oculata</i>	DIP OCU	.	.	.
<i>Eunotia arcus</i>	EUN ARC	.	.	.
<i>E. praerupta</i>	EUN PRA	.	.	.
<i>E. suecica</i>	EUN SUE	.	.	.
<i>Fragilaria pinnata</i>	FRA PIN	.	.	.
<i>F. cf. vaucheriae</i>	FRA VAU	.	.	.
<i>Gomphonema</i> sp. 1	GOM SP1	.	.	.
<i>Hantzschia amphioxys</i>	HAN AMP	.	.	.
<i>Kraskella kriegneriana</i>	KRA KRI	.	.	.
<i>Navicula bryophila</i>	NAV BRY	.	.	.
<i>N. contenta</i>	NAV CON	.	.	.
<i>N. contenta</i> f. <i>biceps</i>	NAV CB1	.	.	.
<i>N. contenta</i> var. 1	NAV CVA	.	.	.
<i>N. perpusilla</i>	NAV PER	.	.	.
<i>N. radiosa</i> var. <i>tenella</i>	NAV RAD	.	.	.
<i>N. radiosa</i> cf. var. <i>tenella</i>	NAV RAV	.	.	.
<i>N. schoenfeldii</i>	NAV SCH	.	.	.
<i>N. soehrensii</i>	NAV SOH	.	.	.
<i>N. tuscula</i>	NAV TUS	.	.	.
<i>N. vulpina</i>	NAV VUL	.	.	.
<i>Navicula</i> sp. 5	NAV SP5	.	.	.
<i>Navicula</i> sp. 7	NAV SP7	.	.	.
<i>Neidium affine</i>	NEI AFF	.	.	.
<i>Nitzschia amphibia</i> var. <i>thermalis</i>	NIT AVT	.	.	.
<i>N. debilis</i>	NIT DEB	.	.	.
<i>N. frustulum</i>	NIT FRU	.	.	.
<i>Pinnularia balfouriana</i>	PIN BAL	.	.	.
<i>Pinnularia microcephala</i>	PIN MIC	.	.	.
<i>Synedra</i> spp.	SYN SPP	.	.	.

TOTAL NUMBER OF TAXA: 66

Table 2: List of samples available and analysed from each pond. Included is the date the sample was obtained as well as the matching ordination code number associated with each sample, e.g., Col Pond epilithic sample = 29 and epiphytic sample = 1. NA = Sample Not Available.

Pond Site Sample	Epilithic Sample Submerged (Date Collected)	Ordination #	Epiphytic (Date Coll.)	Wet (moss)	#
Col Pond	1295-MD-86 (29.07.86)	29	1301-MD-86 (29.07.86)	W	1
Pond 15	1360-MD-86 (30.08.86)	30	1367-MD-86 (30.08.86)	S	2
Pond 18	1377-MD-86 (30.07.86)	31	1374-MD-86 (30.07.86)	S	3
Pond NW of Horseshoe	284-MD-86 (02.07.86)	32	NA		
Elison Pond	1494-MD-86 (03.08.86)	33	1495-MD-86 (03.08.86)	S	4
Paradise Pond	1117-MD-86 (22.08.86)	34	NA		
Cape Herschel Lagoon	1106-MD-86 (22.07.86)	35	1104-MD-86 (22.07.86)	S	5
Beach Ridge Pond	1178-MD-86 (23.07.86)	36	1177-MD-86 (23.07.86)	S	6
Plateau Pond 1	423-MD-86 (06.07.86)	37	NA		
Plateau Pond 2	430-MD-86 (06.07.86)	38	NA		
Horseshoe Pond	1415-MD-86 (01.08.86)	39	1423-MD-86 (01.08.86)	S	7
Willow Pond	473-JPS-83 (21.07.83)	40	1405-MD-86 (01.08.86)	S	8
Pond N of Willow	317-MD-86 (04.07.86)	41	NA		
Moraine Pond	487-MD-86 (08.07.86)	42	494-MD-86 (08.07.86)	S	9
Pond13	496-MD-86 (08.07.86)	43	503-MD-86 (08.07.86)4	W	10
Pond 12	1644-MD-86 (05.08.86)	44	1646-MD-86 (05.08.86)	S	11
Pond 10	531-MD-86 (08.07.86)	45	NA		
Pond 8	540-MD-86 (08.07.86)	46	551-MD-86 (07.08.86)	S	12
Pond 2	1465-MD-86 (02.08.86)	47	1472-MD-86 (02.08.86)	S	13
Pond 3	1463-MD-86 (02.08.86)	48	1458-MD-86 (02.08.86)	S	14
Pond 28	604-MD-86 (10.07.86)	49	606-MD-86 (10.07.86)	S	15
Pond 6	633-MD-86 (11.07.86)	50	641-MD-86 (11.07.86)	W	16
Pond 24	644-MD-86 (11.07.86)	51	649-MD-86 (11.07.86)	W	17
Pond 32	1097-MD-86 (22.07.86)	52	1099-MD-86 (22.07.86)	S	18
Pond S of Pond 7	1034-MD-86 (21.07.86)	53	1041-MD-86 (21.07.86)	S	19
Pond 7	1044-MD-86 (21.07.86)	54	1053-MD-86 (21.07.86)	S	20
Pond 14	1058-MD-86 (21.07.86)	55	1065-MD-86 (21.07.86)	S	21
Pond 1	1072-MD-86 (21.07.86)	56	1077-MD-86 (21.07.86)	S	22
Pond 27	1319-MD-86 (29.07.86)	57	1320-MD-86 (29.07.86)	S	23
Ephemeral Pond	1384-MD-86 (31.07.86)	58	1398a-MD-86 (31.07.86)	S	24
Camp Pond	1485-MD-86 (02.08.86)	59	1486-MD-86 (02.08.86)	S	25
Elison Lake	1501-MD-86 (03.08.86)	60	1504-MD-86 (03.08.86)	S	26
Poppy Pond	471-MD-86 (07.07.86)	61	477-MD-86 (07.07.86)	W	27
Cold Pond	613-MD-86 (10.07.86)	62	NA		
Pond 26	668-MD-86 (11.07.86)	63	671a-MD-86 (11.07.86)	W	28

RESULTS AND DISCUSSION

Diatoms are well preserved in all the samples analyzed. After data screening, only 66 diatom taxa are included in the statistical analyses (Table 1). Most of these taxa are discussed and included in photographic plates in Douglas and Smol (1993). A list of the samples analyzed is summarized in Table 2. As can be seen, submerged moss samples are not available from each pond. In these cases a wet moss sample is substituted whenever possible. Ponds with their corresponding sample numbers and codes are also listed. This table is included for reference purposes as these samples will eventually be deposited with the Canadian National Museum of Nature.

A qualitative examination of Table 1 shows that many of the recorded diatom taxa are common to both moss and rock substrates as well as being present in the sediment. Nonetheless, some taxa are present only in one habitat, i.e., only on rock, on moss, or on sediment.

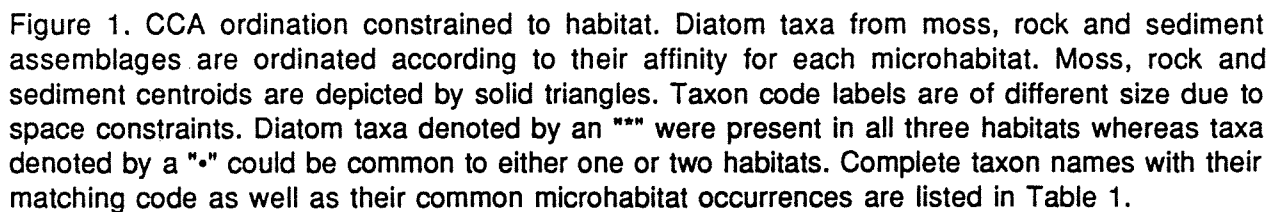
As noted above, all the taxa listed in Table 1 are pre-screened to meet abundance and frequency conditions, with the net result that relatively few taxa occur exclusively in one habitat. If one examines the raw data (Appendices C and D of Douglas, 1993), which includes all taxa, then more specificity appears to be apparent as the rarer taxa are included. However, the strength of such an interpretation must be tempered by the fact that rare taxa are present at lower abundances, making ecological interpretations somewhat tenuous.

Nine taxa, *Caloneis schumanniana*, *Cymbella hybrida*, *Cymbella minuta* f. *latens*, *Cymbella turgidula*, *Diploneis oculata*, *Fragilaria pinnata*, *Neidium affine*, *Nitzschia* cf. *amphibia* var. *thermalis*, and *Nitzschia debilis* are commonly recorded in surface sediment assemblages, but not in moss and rock assemblages. These taxa may constitute an epipelton assemblage on Cape Herschel. Meanwhile, three taxa are found exclusively on moss substrates: *Cymbella minuta* var. *pseudogracilis*, *Eunotia praerupta* and *Eunotia suecica*. Eighteen diatom taxa are observed from the epilithon and not in the epiphyton. These taxa are: *Achnanthes coarctata*, *Achnanthes lapponica*, *Achnanthes kryophila*, *Amphora triundatulata*, *Amphora veneta*, *Amphora veneta* var. *capitata*, *Amphora* sp. 1, *Cymbella subaequalis*, *Cymbella* sp. 1, *Diploneis elliptica*, *Kraskella kriegleriana*, *Navicula contenta*, *Navicula contenta* f. *biceps*, *Navicula schoenfeldii*, *Navicula tuscula*, *Navicula* sp. 5, *Navicula* sp. 7, and *Navicula contenta* var. 1. Of these 18 taxa, four are not observed in the epipelton: *Achnanthes kryophila*, *Amphora triundatulata*, *Navicula contenta* f. *biceps* and *Navicula schoenfeldii*.

The influence of habitat on species distributions is perhaps best shown in an ordination of the three assemblages with respect to habitat type. A CCA ordination (constrained to habitat) places the diatom taxa according to their habitat affinity (Figure 1). There is a strong affinity of certain diatoms for a specific habitat, whereas the diatom taxa located near the centre of the ordination tend to be common in both rock and moss habitats, as well as being represented in the sediment assemblages. *Navicula contenta* f. *biceps*, *Achnanthes kryophila*, *Achnanthes coarctata*, *Cymbella* sp. 1, *Amphora triundatulata* and *Navicula schoenfeldii* show a strong affinity for epilithic habitats. *Eunotia suecica*, *Eunotia praerupta*, *Navicula perpusilla*, *Cymbella minuta* var. *pseudogracilis*, *Eunotia arcus* and *Achnanthes* sp. 2 show a strong tendency towards moss habitats. Clustering around the sediment extreme are diatoms such as *Caloneis schumanniana*, *Cymbella hybrida*, *Cymbella minuta* f. *latens*, *Cymbella turgidula*, *Diploneis oculata*, *Fragilaria pinnata*, *Fragilaria* sp., *Navicula tuscula*, *Neidium affine*, *Nitzschia* cf. *amphibia* var. *thermalis* and *Nitzschia debilis*. Those diatom taxa identified in Table 1 that did not exhibit any microhabitat specificity or are considered common to all three microhabitats are identified by an asterisk. Their relative positions, however, shows which microhabitat they would be more

Table 3: Occurrence of diatom taxa on "other" substrates. Sediment statistics are included for comparison purposes as well as to identify which species are epipelagic and/or specific to sediment habitat.

	Occurrence on:		Occurrence on:	
	Rock	@<1%	Sediment	@<1%
<hr/>				
Moss only species:				
Cym pse	5	0	11	0
Eun pra	1	1	9	0
Eun sue	1	0	0	0
<u>Totals:</u>	7	1	20	0
% (<1%)	14.3		0	
<hr/>				
	Moss	@<1%	Sediment	@<1%
Rock only species:				
Ach coa	2	0	2	1
Ach lap	4	0	12	3
Ach kry	1	0	0	0
Amp tri	3	2	13	2
Amp ven	0	0	10	6
Amp vcp	3	0	23	11
Amp sp1	0	0	11	7
Cym sub	7	2	15	7
Cym sp1	1	1	3	2
Dip ell	1	1	17	3
Kra kri	3	0	9	5
Nav cb1	0	0	1	1
Nav con	4	2	24	9
Nav sch	1	1	11	9
Nav tus	6	2	9	2
Nav sp5	2	1	12	9
Nav sp7	2	1	14	10
Nav cva	0	0	6	5
<u>Totals:</u>	40	13	192	92
% (<1%)	33		48	
<hr/>				
	Rock	@<1%	Moss	@<1%
Sediment only species:				
Cal sch	NA		NA	
Cym hyb	2	1	0	0
Cym mfl	4	0	1	1
Cym tur	3	2	1	1
Dip ocu	4	1	0	0
Fra pin	1	0	1	1
Nei aff	7	1	2	2
Nit avt	3	2	1	1
Nit deb	5	0	2	0
<u>Totals:</u>	29	7	8	6
% (<1%)	24		75	
<hr/>				



likely to be found at higher abundances. Diatom taxa lying between two microhabitat types are observed in both habitats, e.g., *Amphora* sp. 1 (AMP SP1) is found in both rock and sediment microhabitats, and *Navicula radiosa* cf. var. *tenella* (NAV RAV) is observed in both moss and rock habitats (Figure 1). Interestingly, there are no diatoms observed exclusively in both moss and sediment microhabitats.

In order to assess how exclusive habitat specificity actually is, the frequency and abundance at which a habitat-specific taxon is observed in a different habitat is examined (Table 3). In essence, this is examining how often a taxon is observed outside its habitat at a frequency and abundance which did not meet the imposed prescreening criteria. In most instances the taxa are not present at high frequencies or abundances. For instance, of all 18 "rock-only" species, 33% of the 40 "unqualified" occurrences are present at frequencies <1% on moss substrates. For moss, 14% of seven occurrences are present at frequencies <1% on rock substrates. For sediment-only species, 24% of 29 "unqualified" occurrences are observed on rocks and 75% of eight "unqualified" occurrences are observed in moss assemblages. It is not surprising that 48% of 192 "unqualified" rock-specific species are observed in the sediments as the sediments represent an integrated sample of all the habitats within the pond and the catchment itself. These data may also help explain the overlap exhibited by taxa between different microhabitats as graphed in Figure 1.

Many Cape Herschel periphytic diatom taxa are common to one or more microhabitats. The fact that so many diatoms are present in both epilithic and epiphytic communities could indicate that there is little if any substrate-interaction between, for example, a diatom epiphyte and the moss substrate. Such habitat overlap is also recorded in the Thames River (Juggins, 1992). Nevertheless, as observed in the Cape Herschel assemblages, some taxa did show a marked habitat preference for either moss, rock or sediment habitats, indicating that substrata are more than physical habitats for some diatoms to simply attach to. A more detailed discussion of what some of these reasons might be is to be found in Douglas (1993) and Douglas and Smol (in prep).

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THE COMPILED FRESHWATER DIATOM TAXA LIST FOR THE MARITIME ANTARCTIC REGION OF THE SOUTH SHETLAND AND SOUTH ORKNEY ISLANDS.

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The list of taxa identified from the Maritime Antarctic region of South Shetland and South Orkney Island; 1: Livingston Island, James Ross Island, King George Island and Horseshoe Island, 2: Livingston Island, Byers Peninsula and Signy Island. Many which are as yet unknown or can't be assigned to described taxa are recorded and photographed but are not included in this list.

There are a lot of discussions about the conflicting classification systems of Round *et al.* (1990) and Krammer & Lange-Bertalot (1991). Of specific concern are the different publications by Williams & Round, Round, and Lange-Bertalot, which have only increased confusion. With this in mind, we have chosen for practical purposes to use *Fragilaria* in Hustedt's (1930) sense.

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TAXA LIST

<i>Achnanthes abundans</i> Manguin	1, 2?
<i>Achnanthes austriaca</i> Hustedt	2
<i>Achnanthes austriaca</i> var. <i>helvetica</i> Hustedt	2
<i>Achnanthes bicapitata</i> Hustedt	2

<i>Achnanthes bioretii</i> Germain	1
<i>Achnanthes brevipes</i> Agardh	1
<i>Achnanthes brevipes</i> var. <i>angustata</i> (Greville) Cleve	2
<i>Achnanthes brevipes</i> var. <i>intermedia</i> (Kützing) Cleve	1
<i>Achnanthes brevipes</i> var. <i>parvula</i> (Kützing) Cleve	1
<i>Achnanthes</i> sp. [cf. <i>affinis</i> Grunow]	1
<i>Achnanthes clevei</i> Grunow	1
<i>Achnanthes coarctata</i> (Brébisson) Grunow	1
<i>Achnanthes coarctata</i> var. <i>elliptica</i> Krasske	1
<i>Achnanthes conspicua</i> Mayer	1, 2
<i>Achnanthes crenulata</i> Grunow	1
<i>Achnanthes delicatula</i> (Kützing) Grunow	1, 2
<i>Achnanthes delicatula</i> ssp. <i>hauckiana</i> Lange-Bertalot & Ruppel	1
<i>Achnanthes delicatula</i> ssp. <i>septentrionalis</i> (Østrup) Lange-Bertalot	1
<i>Achnanthes delicatula</i> var. <i>australis</i> Manguin	1
<i>Achnanthes delicatula</i> var. <i>robusta</i> Hustedt	1
<i>Achnanthes delicatula</i> var. <i>subcapitata</i> (Østrup) Cleve-Euler	1
<i>Achnanthes engelbrechtii</i> Cholnoky	1
<i>Achnanthes exigua</i> Grunow in Cleve & Grunow	1, 2
<i>Achnanthes exigua</i> var. <i>heterovalvata</i> Krasske	1
<i>Achnanthes flexella</i> (Kützing) Brun	2
<i>Achnanthes frequentissima</i> Lange-Bertalot	1
<i>Achnanthes germainii</i> Mauguin in Bourelly & Manguin	1, 2
<i>Achnanthes groenlandica</i> (Cleve) Grunow	1
<i>Achnanthes helvetica</i> var. <i>alpina</i> Flower & Jones	2
<i>Achnanthes hungarica</i> (Grunow) Grunow in Cleve & Grunow	2
<i>Achnanthes incognita</i> Krasske	1, 2
<i>Achnanthes inflata</i> (Kützing) Grunow	1
<i>Achnanthes kryophila</i> Petersen	1, 2?
<i>Achnanthes laevis</i> Østrup	2
<i>Achnanthes lanceolata</i> (Brébisson) Grunow in Cleve & Grunow	1, 2
<i>Achnanthes lanceolata</i> var. <i>elliptica</i> Cleve	1
<i>Achnanthes lapponica</i> (Hustedt) Hustedt	1
<i>Achnanthes latissima</i> Cleve-Euler	2
<i>Achnanthes levanderi</i> Hustedt	1
<i>Achnanthes linearis</i> (W. Smith) Grunow	1
<i>Achnanthes linkei</i> Hustedt (A. <i>delicatula</i> (Kützing) Grunow)	1
<i>Achnanthes manguinii</i> Hustedt	2
<i>Achnanthes marginulata</i> Grunow in Cleve & Grunow	1, 2
<i>Achnanthes marginulata</i> var. <i>major</i> Flowers & Jones	2?
<i>Achnanthes metakryophila</i> Lange-Bertalot & Schmidt	1, 2
<i>Achnanthes minutissima</i> Kützing	1, 2
<i>Achnanthes mollis</i> Krasske	1, 2
<i>Achnanthes okamuræ</i> Skvortzow	1
<i>Achnanthes petersenii</i> Hustedt	1
<i>Achnanthes pinnata</i> Hustedt	2
<i>Achnanthes pinnata</i> var. <i>japonica</i> Hustedt	1
<i>Achnanthes pusilla</i> (Grunow) De Toni	1

<i>Achnanthes renei</i> Lange-Bertalot & Schmidt	1, 2
<i>Achnanthes rostrata</i> Østrup	2
<i>Achnanthes saxonica</i> Krasske	1
<i>Achnanthes stauroneiodes</i> Bourrelly & Manguin	2
<i>Achnanthes subatomoides</i> (Hustedt) Lange-Bertalot & Archibald in Krammer & Lange-Bertalot	1, 2
<i>Actinocyclus actinochilus</i> (Ehrenberg) Simonsen	1
<i>Amphora libyca</i> Ehrenberg	1
<i>Amphora obscura</i> Reichelt	1
<i>Amphora veneta</i> Kützing	1, 2
<i>Aulacoseira italica</i> (Ehrenberg) Simonsen	1
<i>Brachysira minor</i> (Krasske) nov. com. in prep.	1, 2
<i>Brachysira vitrea</i> (Grunow) Ross in Hartley	2
<i>Caloneis bacillum</i> (Grunow) Cleve	1, 2
<i>Caloneis silicula</i> (Ehrenberg) Cleve	1, 2
<i>Caloneis tenuis</i> (Gregory) Krammer	1
<i>Caloneis ventricosa</i> (Ehrenberg) Meister	2
<i>Cocconeis costata</i> Gregory	1
<i>Cocconeis fasciolata</i> (Ehrenberg) Brown	1
<i>Cocconeis imperatrix</i> Schmidt	1
<i>Cocconeis scutellum</i> var. <i>parva</i> Grunow	1
<i>Cyclotella</i> sp.	2
<i>Cymbella amphioxys</i> (Kützing) Cleve	1
<i>Cymbella microcephala</i> Grunow in Van Heurck	2
<i>Cymbella minuta</i> Hilse ex Rabenh.	2
<i>Diadesmis contenta</i> (Grunow in Van Heurck) Mann	1, 2
<i>Diadesmis contenta</i> fo. <i>biceps</i> (Arnott) Mann	1
<i>Diadesmis perpusilla</i> (Grunow) Mann in Round <i>et al.</i>	1
<i>Diatomella balfouriana</i> Greville	1
<i>Diatomella hustedtii</i> Manguin	1
<i>Diploneis reichardtii</i> (Grunow) Heiden	1
<i>Denticula kuetzingii</i> Grunow	1
<i>Eunotia fallax</i> A. Cleve	2
<i>Eunotia paludosa</i> Grun.	2
<i>Eunotia praerupta</i> Ehrenberg	1
<i>Eunotia praerupta</i> var. <i>inflata</i> Grunow	1
<i>Fallacia naumannii</i> (Hustedt) Mann	1
<i>Fragilaria brevistriata</i> Grunow in Van Heurck	1,
<i>Fragilaria</i> sp. [cf. <i>capucina</i> Desmazières]	1
<i>Fragilaria construens</i> (Ehrenberg) Grunow	1, 2
<i>Fragilaria construens</i> var. <i>binodis</i> (Ehrenberg) Grunow	1, 2
<i>Fragilaria construens</i> var. <i>exigua</i> (W. Smith) Schulz	2
<i>Fragilaria construens</i> var. <i>venter</i> (Ehrenberg) Grunow in Van Heurck	1, 2
<i>Fragilaria crotonensis</i> Kitton	1
<i>Fragilaria elliptica</i> Schumann	2
<i>Fragilaria intermedia</i> Grunow	1
<i>Fragilaria pinnata</i> Ehrenberg	1, 2
<i>Fragilaria pinnata</i> var. <i>lancettula</i> (Schumann) Cleve-Euler	1
<i>Fragilaria vaucheriae</i> (Kützing) Petersen	1, 2

<i>Fragilaria virescens</i> Ralfs	1
<i>Fragilaria virescens</i> var. <i>exigua</i> Grunow in Van Heurck	2
<i>Gomphonema affine</i> Kützing	2
<i>Gomphonema angustatum</i> (Kützing) Rabenhorst	1, 2
<i>Gomphonema</i> sp. [cf. <i>angustatum</i> / <i>gracile</i>]	2
<i>Gomphonema angustatum</i> var. <i>productum</i> Grunow in Van Heurck	2
<i>Gomphonema angustum</i> Agardh	1
<i>Gomphonema bohemicum</i> Reichelt & Fricke in A. Schmidt	2
<i>Gomphonema clavatum</i> Ehrenberg	1, 2
<i>Gomphonema clevei</i> Fricke	1
<i>Gomphonema gracile</i> Ehrenberg	1, 2
<i>Gomphonema intricatum</i> Kützing	1, 2
<i>Gomphonema kamtschatica</i> Grunow	1
<i>Gomphonema lagerheimii</i> A. Cleve	1
<i>Gomphonema lanceolatum</i> Agardh	1
<i>Gomphonema longiceps</i> Ehrenberg	2
<i>Gomphonema minutum</i> (Agardh) Agardh	2
<i>Gomphonema olevaceum</i> (Hornemann) Brébisson	1
<i>Gomphonema parvulum</i> (Kützing) Kützing	1, 2
<i>Gomphonema parvulum</i> var. <i>micropus</i> (Kützing) Cleve	2
<i>Gyrosigma balticum</i> (Ehrenberg) Rabenhorst	1
<i>Gyrosigma distortum</i> (W. Smith) Cleve	1
<i>Hantzschia amphioxys</i> (Ehrenberg) Grunow	1, 2
<i>Luticola cohnii</i> (Hilse) Mann in Round <i>et al.</i>	1
<i>Luticola goeppertiana</i> (Bleisch) Mann in Round <i>et al.</i>	1
<i>Luticola heufleriana</i> (Grunow) Mann in Round <i>et al.</i>	1
<i>Luticola mutica</i> (Kützing) Mann in Round <i>et al.</i>	1, 2
<i>Luticola mutica</i> var. <i>ventricosa</i> (Kützing) Mann in Round <i>et al.</i>	1
<i>Luticola muticopsis</i> (Van Heurck) Mann in Round <i>et al.</i>	1, 2?
<i>Melosira arentii</i> (Kolbe) Nagumo & Kobayasi	2
<i>Navicula accomoda</i> Hustedt	1
<i>Navicula angusta</i> Grunow	1
<i>Navicula</i> sp. [cf. <i>arvensis</i> Hustedt in Schmidt]	2
<i>Navicula atomus</i> (Kützing) Grunow	2
<i>Navicula australomediocris</i> Lange-Bertalot & Schmidt	1, 2
<i>Navicula begeri</i> Krasske	1
<i>Navicula bicephala</i> Hustedt	2
<i>Navicula bremensis</i> Hust. 1957	2
<i>Navicula bryophila</i> Petersen	1, 2
<i>Navicula cancellata</i> Donkin	1
<i>Navicula capitata</i> Ehrenberg	1
<i>Navicula capitata</i> var. <i>hungarica</i> (Grunow) Ross	1, 2
<i>Navicula</i> sp. [cf. <i>siberica</i> (Grunow) Cleve]	1
<i>Navicula cuspidata</i> (Kützing) Kützing	1, 2
<i>Navicula</i> sp. [cf. <i>difficillima</i> Hustedt]	2
<i>Navicula elginensis</i> (Gregory) Ralfs in Pritchard	1, 2
<i>Navicula explanata</i> Hustedt	1
<i>Navicula festiva</i> Krasske	1

<i>Navicula frugalis</i> Hustedt	2
<i>Navicula gebhardii</i> Krasske	1
<i>Navicula gibbula</i> Cleve	1, 2
<i>Navicula glaciei</i> Van Heurck	1
<i>Navicula gracilis</i> Ehrenberg	1
<i>Navicula gregaria</i> Donkin	1, 2
<i>Navicula hansenii</i> Möller	1
<i>Navicula joubaudii</i> Germain (= <i>Navicula seminulum</i> var. <i>radiosa</i> Hustedt)	2
<i>Navicula molesta</i> Krasske	1
<i>Navicula naumanii</i> Hustedt	2
<i>Navicula paramutica</i> Bock	2
<i>Navicula perminuta</i> Grunow	1
<i>Navicula perpusilla</i> (Kützing) Grunow	2
<i>Navicula phyllepta</i> Kützing	1
<i>Navicula pseudoscutiformis</i> Hustedt	1, 2
<i>Navicula rhynchocephala</i> Kützing	1
<i>Navicula seminuloides</i> Hustedt	2
<i>Navicula soehrensensis</i> var. <i>hassiacae</i> (Krasske) Lange-Bertalot	1
<i>Navicula submolesta</i> Hustedt	1
<i>Navicula tabellariaeformis</i> Krasske	1, 2
<i>Navicula tantula</i> Hustedt	2
<i>Navicula tripunctata</i> (O.F. Müller) Bory	1
<i>Navicula veneta</i> Kützing	1, 2
<i>Neidium affine</i> (Ehrenberg) Pfitzer	2
<i>Nitzschia alpina</i> Hustedt	1
<i>Nitzschia amphibia</i> Grunow	1, 2
<i>Nitzschia fonticola</i> Grunow in Van Heurck	2
<i>Nitzschia frustulum</i> (Kützing) Grunow in Cleve & Grunow	1, 2
<i>Nitzschia gracilis</i> Hantzsch	1, 2
<i>Nitzschia hamburgiensis</i> Lange-Bertalot	2
<i>Nitzschia hantzschiana</i> Rabenhorst	1, 2
<i>Nitzschia homburgensis</i> Lange-Bertalot	1
<i>Nitzschia</i> sp. [cf. <i>inconspicua</i> Grunow]	2
<i>Nitzschia laevis</i> Hustedt	1
<i>Nitzschia microcephala</i> Grunow in Cleve & Grunow	2
<i>Nitzschia palea</i> (Kützing) W. Smith	1, 2
<i>Nitzschia paleacea</i> (Grunow in Cleve & Grunow) Grunow in Van Heuck	1, 2
<i>Nitzschia perminuta</i> (Grunow in Van Heurck) M. Peragallo	1, 2
<i>Nitzschia rhombica</i> Hustedt	1
<i>Opephora</i> sp. [cf. <i>olsenii</i> Møller]	2
<i>Orthoseira dendrophila</i> (Ehrenberg) Crawford	1, 2
<i>Orthoseira roseana</i> (Rabenhorst) O'Meara	1
<i>Pinnularia abaujensis</i> (Pantocsek) Ross in Hartley	2
<i>Pinnularia appendiculata</i> (Agardh) Cleve	2
<i>Pinnularia borealis</i> Ehrenberg	1, 2
<i>Pinnularia brandellii</i> Cleve	2
<i>Pinnularia brebissonii</i> (Kützing) Rabenhorst	2
<i>Pinnularia</i> sp. [cf. <i>obscura</i> Krasske]	1

<i>Pinnularia divergens</i> W. Smith	1, 2
<i>Pinnularia gibba</i> (Ehrenberg) Ehrenberg	1, 2
<i>Pinnularia gibba</i> var. <i>linearis</i> Hustedt	1
<i>Pinnularia globiceps</i> Gregory	1
<i>Pinnularia ignobilis</i> (Krasske) Cleve-Euler	1, 2
<i>Pinnularia interrupta</i> W. Smith	1
<i>Pinnularia krookii</i> (Grunow) Cleve	1
<i>Pinnularia major</i> (Kützing) W. Smith	2
<i>Pinnularia microstauron</i> (Ehrenberg) Cleve	1, 2
<i>Pinnularia microstauron</i> var. <i>brebissonii</i> (Kützing) Mayer	1, 2
<i>Pinnularia obscura</i> Krasske	2
<i>Pinnularia spitsbergensis</i> Cleve	1
<i>Pinnularia subcapitata</i> Gregory	1, 2
<i>Pinnularia subrostrata</i> (A. Cleve) Cleve-Euler	1
<i>Pinnularia viridis</i> (Nitzsch) Ehrenberg	1, 2
<i>Sellaphora bacillum</i> (Ehrenberg) Mann	1
<i>Sellaphora disjuncta</i> (Hustedt) Mann	1
<i>Sellaphora pupula</i> (Kützing) Mann	1
<i>Sellaphora seminulum</i> (Grunow) Mann	1, 2
<i>Sellaphora seminulum</i> var. <i>intermedia</i> (Hustedt) Mann	1
<i>Stauroneis agrestis</i> Petersen	1
<i>Stauroneis alpina</i> Hustedt	2
<i>Stauroneis anceps</i> Ehrenberg	1, 2
<i>Stauroneis anceps</i> fo. <i>gracilis</i> Rabenhorst	1, 2
<i>Stauroneis anceps</i> var. <i>hyalina</i> Brun & Peragallo	1
<i>Stauroneis</i> sp. [cf. <i>producta</i> Grunow]	1
<i>Stauroneis phoenicenteron</i> (Nitzsch) Ehrenberg	1, 2
<i>Stauroneis salina</i> W. Smith	1
<i>Surirella angusta</i> Kützing	1
<i>Surirella linearis</i> W. Smith	2
<i>Surirella ovata</i> Kützing	2
<i>Surirella salina</i> W. Smith	1
<i>Synedra acus</i> Kützing	2
<i>Synedra rumpens</i> Kützing	1, 2
<i>Synedra rumpens</i> var. <i>familiaris</i> (Ehrenberg) Grunow	1
<i>Tryblionella</i> sp. [cf. <i>debilis</i> Arnott ex O'Meara]	1
<i>Tryblionella levidensis</i> (W. Smith) Grunow	1
<i>Tryblionella</i> cf. <i>littoralis</i> (Grunow) Mann in Round <i>et al.</i>	1

Marine taxa observed in the sediments but not included in freshwater list

<i>Eucampia antarctica</i> (Castracane) Manguin and resting spores	1
<i>Fragilariopsis curta</i> (Van Heurck) Hustedt	1
<i>Fragilariopsis cylindrus</i> (Grunow) Krieger	1, 2
<i>Fragilariopsis kerguelensis</i> (O'Meara) Hustedt	1
<i>Fragilariopsis sublinearis</i> (Van Heurck) Heiden	1
<i>Gyrosigma subsalsum</i> (Wislouch & Kolbe) Cardinal <i>et al.</i>	1

<i>Gyrosigma arcticum</i> (Cleve) Cleve	1
<i>Licmophora</i> sp.	2
<i>Navicula directa</i> (W. Smith) Ralfs	1
<i>Navicula salinarum</i> Grunow in Cleve & Grunow	1
<i>Nitzschia kerguelensis</i> (O'Meara) Hasle	1
<i>Pinnularia quadratarea</i> (A. Schmidt) Cleve	1
<i>Tabularia investiens</i> (W. Smith) Williams & Round	1
<i>Trachyneis aspera</i> (Ehrenberg) Cleve	1
<i>Thalassiosira antarctica</i> Comber (and resting spores)	1

A COMPILED FRESHWATER DIATOM TAXA LIST FOR THE ARCTIC AND SUBARCTIC REGIONS OF NORTH AMERICA.

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The list of taxa identified from the Canadian Arctic. 1: Glacier Bay National Park (Alaska), 2: Baffin Island, 3: Cape Herschel (Ellesmere Island), 4: Ellesmere Island National Park, 5: Ungava Bay (Québec), 6: Yellowknife (Northwest Territories), 7: Yukon, and 8: Baird Inlet (Ellesmere Island). Many unidentified taxa were recorded and photographed but were not included here. The presence of "???" indicates that the taxon is likely in the stated genus, however, no new combination has been made. A single "?" indicates that this is a tentative taxon identification for the region.

There are a lot of discussions about the conflicting classification systems of Round *et al.* (1990) and Krammer & Lange-Bertalot (1991). Of specific concern are the different publications by Williams & Round, Round, and Lange-Bertalot, which have only increased confusion. With this in mind, we have chosen for practical purposes to use *Fragilaria* in Hustedt's (1930) sense. For a listing of these references see Håkansson & Jones (1994).

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TAXA LIST

<i>Achnanthes altaica</i> (Poretzky) Cleve-Euler	1, 2
<i>Achnanthes austriaca</i> Hustedt	1
<i>Achnanthes austriaca</i> var. <i>helvetica</i> Hustedt	1
<i>Achnanthes amoena</i> Hustedt	7
<i>Achnanthes biasolettiana</i> (Kützing) Grunow	1, 5, 6, 7
<i>Achnanthes bicapitata</i> Hustedt	1

<i>Achnanthes bioretii</i> Germain	1, 4
<i>Achnanthes</i> sp. [cf. <i>broenlundensis</i> Foged]	3
<i>Achnanthes calcar</i> Cleve	5, 7
<i>Achnanthes carissima</i> Lange-Bertalot in Lange-Bertalot & Krammer	1, 4, 6, 7
<i>Achnanthes clevei</i> Grunow in Cleve & Grunow	1, 5, 6, 7
<i>Achnanthes conspicua</i> A. Mayer	1, 5, 6, 7, 8
<i>Achnanthes daonensis</i> Lange-Bertalot in Lange-Bertalot & Krammer	4
<i>Achnanthes depressa</i> (Cleve) Hustedt	5, 6
<i>Achnanthes detha</i> Hohn & Hellerman	1
<i>Achnanthes didyma</i> Hustedt	1, 4, 6, 7
<i>Achnanthes dispar</i> var. <i>angulata</i> Hustedt	7
<i>Achnanthes dispar</i> Cleve	7
<i>Achnanthes exigua</i> Grunow in Cleve & Grunow	1, 5, 7
<i>Achnanthes exigua</i> var. <i>heterovalva</i> Krasske	5, 7
<i>Achnanthes flatbukensis</i> Foged	8
<i>Achnanthes flexella</i> (Kützing) Brun	1, 3, 4, 5, 6, 7, 8
<i>Achnanthes flexella</i> var. <i>alpestris</i> Brun	1, 3, 4
<i>Achnanthes flexella</i> var. <i>arctica</i> (Lagerstedt) A. Cleve	3, 4
<i>Achnanthes fragilarioides</i> Petersen	4, 7
<i>Achnanthes gracillima</i> Hustedt	1, 5, 7
<i>Achnanthes</i> sp. [cf. <i>hauckiana</i> var. <i>elliptica</i> Schulz]	3
<i>Achnanthes helvetica</i> (Hustedt) Lange-Bertalot in Lange-Bertalot & Krammer	2, 4, 6, 7
<i>Achnanthes helvetica</i> var. <i>minor</i> Flower & Jones	2
<i>Achnanthes holstii</i> Cleve	2, 4, 5, 6
<i>Achnanthes ingratiformis</i> Lange-Bertalot in Lange-Bertalot & Krammer	4
<i>Achnanthes</i> sp. [cf. <i>impexiformis</i> Lange-Bertalot in Lange-Bertalot & Krammer]	4?, 6, 7
<i>Achnanthes joursacense</i> Héribaude	7
<i>Achnanthes kriegei</i> Krasske	1, 2, 6
<i>Achnanthes kryophila</i> Petersen	1, 3, 4
<i>Achnanthes kuelbsii</i> Lange-Bertalot	1
<i>Achnanthes laevis</i> Østrup	1, 4, 6
<i>Achnanthes laevis</i> var. <i>austriaca</i> (Hustedt) Lange-Bertalot in Lange-Bertalot & Krammer	4, 7
<i>Achnanthes lanceolata</i> (Brébisson ex Kützing) Grunow in Cleve & Grunow	1, 5, 6, 7
<i>Achnanthes lanceolata</i> fo. <i>capitata</i> O. Müller	1
<i>Achnanthes lanceolata</i> var. <i>elliptica</i> Cleve	5
<i>Achnanthes lanceolata</i> var. <i>frequentissima</i> Lange-Bertalot	7
<i>Achnanthes lapidosa</i> Krasske	1
<i>Achnanthes lapponica</i> (Hustedt) Hustedt	1, 3
<i>Achnanthes laterostrata</i> Hustedt	5, 6, 7
<i>Achnanthes laterostrata</i> var. <i>capitata</i>	7
<i>Achnanthes lauenbergiana</i> Hustedt	1
<i>Achnanthes lemmermannii</i> Hustedt	7
<i>Achnanthes levanderi</i> Hustedt	1, 2, 5, 6, 7
<i>Achnanthes linearis</i> (W. Smith) Grunow in Cleve & Grunow	1, 4, 5, 6, 7, 8
<i>Achnanthes marginulata</i> Grunow in Cleve & Grunow	1, 2, 3, 4, 5, 6, 7, 8
<i>Achnanthes microcephala</i> (Kützing) Cleve	1, 3, 5, 6, 7, 8
<i>Achnanthes minutissima</i> Kützing	1, 2, 3, 4, 5, 6, 7, 8
<i>Achnanthes</i> sp. [cf. <i>nitidiformis</i> Lange-Bertalot]	6

<i>Achnanthes nodosa</i> A. Cleve	8
<i>Achnanthes oblongella</i> Østrup	1
<i>Achnanthes oestrupii</i> (Cleve-Euler) Hustedt	5, 4, 6, 7
<i>Achnanthes peragalli</i> Brun & Héribaude in Héribaude	4, 5, 7
<i>Achnanthes peragalli</i> var. <i>fossilis</i> Tempère & H. Peragallo	3
<i>Achnanthes petersenii</i> Hustedt	4, 6, 7
<i>Achnanthes pinnata</i> Hustedt	1
<i>Achnanthes ploenensis</i> Hustedt	1
<i>Achnanthes pusilla</i> Grunow in Cleve & Grunow	1, 2, 4, 5?, 6, 7
<i>Achnanthes rosenstockii</i> Lange-Bertalot in Lange-Bertalot & Krammer	7
<i>Achnanthes</i> sp. [cf. <i>rossii</i> Hustedt]	7
<i>Achnanthes rupestris</i> Krasske	4
<i>Achnanthes subatomoides</i> (Hustedt) Lange-Bertalot & Archibald in Lange-Bertalot & Krammer	6, 7
<i>Achnanthes sublaevis</i> Hustedt	1
<i>Achnanthes suchlandtii</i> Hustedt	1, 4, 5, 6, 7
<i>Achnanthes umara</i> Carter	1
<i>Achnanthes ventralis</i> (Krasske) Lange-Bertalot in Lange-Bertalot & Krammer	4, 6, 7
<i>Amphipleura kriegeriana</i> (Krasske) Hustedt	6, 7
<i>Amphipleura pellucida</i> (Kützing) Kützing	1, 7
<i>Amphora commutata</i> Grunow in Van Heurck	7
<i>Amphora</i> sp. [cf. <i>dubiosa</i> Østrup]	3
<i>Amphora dusenii</i> Brun	3, 4, 5
<i>Amphora fogediana</i> Krammer	5, 6, 7
<i>Amphora inariensis</i> Krammer	4, 5, 6, 7
<i>Amphora libyca</i> Ehrenberg	3, 4, 5, 6, 7
<i>Amphora ovalis</i> (Kützing) Kützing	4, 6, 7
<i>Amphora ovalis</i> var. <i>affinis</i> (Kützing) Van Heurck	1
<i>Amphora pediculus</i> (Kützing) Grunow ex A. Schmidt	1, 4, 5, 6, 7
<i>Amphora perpusilla</i> (Grunow in Van Heurck) Grunow in Van Heurck	1
<i>Amphora</i> cf. <i>spitzbergensis</i> VanLandingham	3, 4
<i>Amphora tenerrima</i> Aleem & Hustedt	4
<i>Amphora terroris</i> Ehrenberg (= <i>A. dusenii</i> Brun)	5
<i>Amphora thumensis</i> (A. Mayer) Cleve-Euler	5, 7
<i>Amphora veneta</i> Kützing	1, 3, 4, 7
<i>Amphora veneta</i> var. <i>capitata</i> Haworth	3, 4
<i>Aneumastis tuscula</i> (Ehrenberg) Mann & Stickle in Round <i>et al.</i>	1, 3, 4, 5, 7
<i>Anomoeoneis sphaerophora</i> (Kützing) Pfitzer	5, 7
<i>Anomoeoneis sphaerophora</i> fo. <i>costata</i> (Kützing) Schmidt	7
<i>Anomoeoneis sphaerophora</i> fo. <i>sculpta</i> (Ehrenberg) Krammer	5
<i>Asterionella formosa</i> Hassal	6, 7
<i>Asterionella ralfsii</i> W. Smith	1, 5
<i>Aulacoseira alpigena</i> (Grunow in Van Heurck) Krammer	1, 4
<i>Aulacoseira ambigua</i> (Grunow in Van Heurck) Simonsen	1, 5
<i>Aulacoseira crassipunctata</i> Krammer	1
<i>Aulacoseira distans</i> (Ehrenberg) Simonsen	1, 2, 5, 7, 8
<i>Aulacoseira distans</i> var. <i>humilis</i> (Cleve-Euler) Ross in Hartley	1, 5, 6
<i>Aulacoseira distans</i> var. <i>nivalis</i> (W. Smith) Haworth	1, 2, 4, 6, 7
<i>Aulacoseira distans</i> var. <i>nivaloides</i> (Camburn in Camburn & Kingston) Haworth	1, 2

<i>Aulacoseira distans</i> var. <i>tenella</i> (Nygaard) Ross in Hartley	1, 2
<i>Aulacoseira granulata</i> (Ehrenberg) Simonsen	4?, 8
<i>Aulacoseira italica</i> (Ehrenberg) Simonsen	1, 5
<i>Aulacoseira italica</i> var. <i>valida</i> (Grunow in Van Heurck) Simonsen	5
<i>Aulacoseira lirata</i> (Ehrenberg) Ross in Hartley	1, 5, 6, 7
<i>Aulacoseira lirata</i> var. <i>lacustris</i> Ross in Hartley	1
<i>Aulacoseira nygaardii</i> Camburn	1
<i>Aulacoseira perglabra</i> (Østrup) Haworth	1, 2, 5
<i>Aulacoseira perglabra</i> fo. <i>floriniae</i> (Camburn) Haworth	1, 2, 5, 6
<i>Aulacoseira subarctica</i> (O. Müller) Haworth	1, 4, 6, 7
<i>Aulacoseira subarctica</i> fo. <i>recta</i> (O. Müller) Krammer	7
<i>Aulacoseira valida</i> (Grunow in Van Heurck) Krammer	2
<i>Bacillaria paradoxa</i> Gmelin	4
<i>Brachysira brebissonii</i> Ross in Hartley	1, 2, 5, 6
<i>Brachysira</i> sp. cf. <i>Anomoeoneis</i> spp. 3 PIRLA	2
<i>Brachysira styriaca</i> (Grunow in Van Heurck) Ross in Hartley	1, 3, 5
<i>Brachysira vitrea</i> (Grunow) Ross in Hartley	1, 2, 5, 6, 7, 8
<i>Brachysira zellensis</i> (Grunow) Round & Mann	1, 4, 5, 6, 7
<i>Brachysira</i> sp. (= <i>Anomoeoneis</i> sp. 3 PIRLA)	2
<i>Caloneis bacillum</i> (Grunow) Cleve	1, 2, 5, 6, 7
<i>Caloneis bacillum</i> var. <i>lancettula</i> (Schultz) Hustedt	7
<i>Caloneis faciata</i> fo. <i>acuta</i> Petersen	3
<i>Caloneis lauta</i> Carter in Carter & Bailey-Watts	6
<i>Caloneis obtusa</i> (W. Smith) Cleve	5
<i>Caloneis schumanniana</i> (Grunow in Van Heurck) Cleve	3?, 4
<i>Caloneis silicula</i> (Ehrenberg) Cleve	4, 5, 6, 7
<i>Caloneis silicula</i> fo. <i>truncatula</i> (Grunow in Van Heurck) Cleve	7
<i>Caloneis sublinearis</i> (Grunow) Krammer	4
<i>Caloneis tenuis</i> (Gregory) Krammer	1, 4, 5, 6
<i>Caloneis undulata</i> (Gregory) Krammer	1?, 5, 6, 7
<i>Caloneis ventricosa</i> (Ehrenberg) Meister	1, 3
<i>Campylodiscus hibernicus</i> Ehrenberg	7
<i>Campylodiscus levanderii</i> Hustedt in Järnefelt	4
<i>Campylodiscus noricus</i> var. <i>hibernicus</i> (Ehrenberg) Grunow	5
<i>Cavinula cocconeiformis</i> (Gregory ex Greville) Mann & Stickle in Round <i>et al.</i>	1, 4, 5, 6, 7
<i>Cavinula jaernefeltii</i> (Hustedt) Mann & Stickle in Round <i>et al.</i>	5, 6, 7
<i>Cavinula pseudoscutiformis</i> (Hustedt) Mann & Stickle in Round <i>et al.</i>	1, 2, 3, 4, 5, 6, 7, 8
<i>Cavinula variostrata</i> (Krasske) Mann in Round <i>et al.</i>	6
<i>Cocconeis</i> cf. <i>diminuta</i> Pantocsek	1, 5, 6, 7
<i>Cocconeis</i> cf. <i>neothumensis</i> Krammer	7
<i>Cocconeis placentula</i> Ehrenberg	3, 4, 5, 7
<i>Cocconeis placentula</i> var. <i>euglypta</i> (Ehrenberg) Grunow	5, 6, 7
<i>Cocconeis placentula</i> var. <i>lineata</i> (Ehrenberg) Van Heurck	1, 4
<i>Cocconeis thumensis</i> A. Mayer	8
<i>Craticula cuspidata</i> (Kützing) Mann in Round <i>et al.</i>	1, 3?, 4, 5, 7
<i>Craticula halophila</i> (Grunow) Mann in Round <i>et al.</i>	1, 4, 7
<i>Cyclostephanos dubius</i> (Fricke in A. Schmidt <i>et al.</i>) Round	1
<i>Cyclostephanos invisitatus</i> (Hohn & Hellerman) Theriot <i>et al.</i>	1

<i>Cyclotella antiqua</i> W. Smith	3, 4, 5, 7
<i>Cyclotella atomus</i> Hustedt	6, 7
<i>Cyclotella bodanica</i> Eulenstein	5
<i>Cyclotella bodanica</i> var. <i>affinis</i> Grunow	1
<i>Cyclotella bodanica</i> var. <i>lemanica</i> O. Müller in Schröter	4, 6, 7
<i>Cyclotella</i> sp. [cf. <i>caspia</i> Grunow]	5, 7
<i>Cyclotella comta</i> (Ehrenberg) Kützing	5, 8
<i>Cyclotella delicatissima</i> Carter in Carter & Bailey-Watts	6, 7
<i>Cyclotella glomerata</i> Bachman	1, 4, 5, 6, 7
<i>Cyclotella kuetzingiana</i> Thwaites	1, 5
<i>Cyclotella meneghiniana</i> Kützing	7
<i>Cyclotella michiganiana</i> Skvortzow	1, 7
<i>Cyclotella ocellata</i> Pantocsek	5, 6, 7
<i>Cyclotella pseudostelligera</i> Hustedt	1, 2, 4, 5
<i>Cyclotella rossii</i> Håkansson	4?, 6, 7
<i>Cyclotella tripartita</i> Håkansson	4, 6, 7
<i>Cyclotella stelligera</i> (Cleve & Grunow) Van Heurck	1, 4, 5, 6, 7, 8
<i>Cylindrotheca gracilis</i> (Brébisson) Grunow in Van Heurck	4
<i>Cymatopleura elliptica</i> (Brébisson ex Kützing) W. Smith	1
<i>Cymatopleura solea</i> (Brébisson & Godey) W. Smith	1, 4, 5
<i>Cymbella affinis</i> Kützing	4, 5
<i>Cymbella amphicephala</i> Nägeli	1?, 4, 7
<i>Cymbella</i> sp. [cf. <i>amphicephala</i> var. <i>variostriata</i> Foged]	3
<i>Cymbella angustata</i> (W. Smith) Cleve	1, 3, 4, 5, 6, 7
<i>Cymbella aspera</i> (Ehrenberg) H. Peragallo in Pelletan	4, 5, 7?
<i>Cymbella austriaca</i> Grunow in A. Schmidt <i>et al.</i>	4
<i>Cymbella brehmii</i> Hustedt	5, 7
<i>Cymbella cesatii</i> (Rabenhorst) Grunow in A. Schmidt <i>et al.</i>	1, 2, 3, 4, 5, 6, 7
<i>Cymbella cistula</i> (Ehrenberg in Hemprich & Ehrenberg) Kirchner	1, 3, 4, 5, 6, 7
<i>Cymbella</i> sp. [cf. <i>cistula</i> var. <i>gibbosa</i> Brun]	4
<i>Cymbella cuspidata</i> Kützing	1, 2, 3, 4, 5, 6, 7
<i>Cymbella cymbiformis</i> Agardh	1, 5, 7
<i>Cymbella delicatula</i> Kützing	4, 5, 7
<i>Cymbella descripta</i> (Hustedt) Krammer & Lange-Bertalot	1, 4
<i>Cymbella designata</i> Krammer	3, 4
<i>Cymbella diluviana</i> (Krasske) Florin	7
<i>Cymbella ehrenbergii</i> Kützing	5, 7
<i>Cymbella</i> sp. [cf. <i>elginensis</i> Krammer]	7
<i>Cymbella</i> sp. [cf. <i>falaisensis</i> (Grunow) Krammer & Lange-Bertalot]	1, 4
<i>Cymbella gaeumannii</i> Meister	1, 2, 5, 6, 7
<i>Cymbella gracilis</i> (Ehrenberg) Kützing	5, 6, 7
<i>Cymbella</i> sp. [cf. <i>hauckii</i> Van Heurck in Hauck & Richter]	4
<i>Cymbella hebridica</i> (Grunow) Cleve	1, 2, 3?, 6
<i>Cymbella helmckeii</i> Krammer	4
<i>Cymbella heteropleura</i> (Ehrenberg) Kützing	1, 4
<i>Cymbella hustedtii</i> Krasske	1, 5, 7
<i>Cymbella hybrida</i> Grunow	3?, 4, 5
<i>Cyclotella inaequalis</i> (Ehrenberg) Rabenhorst	1

<i>Cymbella incerta</i> (Grunow) Cleve	1, 4, 5, 6, 7
<i>Cymbella laevis</i> Nägeli ex Kützing	1
<i>Cymbella lanceolata</i> (Ehrenberg) Kirchner	5
<i>Cymbella lapponica</i> Grunow	4
<i>Cymbella leptoceros</i> (Ehrenberg) Kützing	5
<i>Cymbella microcephala</i> Grunow in Van Heurck	1, 3, 4, 5, 6, 7, 8
<i>Cymbella naviculiformis</i> Auerswald	1, 6, 7
<i>Cymbella naviculiformis</i> var. <i>linearis</i> Foged	3
<i>Cymbella</i> sp. [aff. <i>naviculacea</i> Grunow]	4
<i>Cymbella norvegica</i> Grunow in A. Schmidt	1
<i>Cymbella prostrata</i> var. <i>auerswaldii</i> (Rabenhorst) Reimer in Patrick & Reimer	5
<i>Cymbella proxima</i> Reimer in Patrick & Reimer	4
<i>Cymbella pusilla</i> Grunow	1, 5, 7
<i>Cymbella</i> sp. [cf. <i>rupicola</i> Grunow]	3
<i>Cymbella similis</i> Krasske	1, 3, 4
<i>Cymbella sinuata</i> Gregory	1, 4, 5, 6, 7
<i>Cymbella spuria</i> Cleve	3
<i>Cymbella stauroneiformis</i> Lagerstedt	3, 4
<i>Cymbella subaequalis</i> Grunow in Van Heurck	1, 3, 4
<i>Cymbella subcuspidata</i> Krammer	4
<i>Cymbella tumidula</i> Grunow	3, 7
<i>Cymbella turgidula</i> Grunow	3, 7
<i>Cymbella tynnii</i> Krammer	4
<i>Denticula elegans</i> Kützing	3, 4, 7
<i>Denticula kuetzingii</i> Grunow	1, 3, 4, 5, 6, 7
<i>Denticula subtilis</i> Grunow	4
<i>Denticula tenuis</i> Kützing	4, 5, 7
<i>Denticula tenuis</i> var. <i>crassula</i> (Nägeli ex Kützing) W. & G.S. West	1, 5
<i>Diadismus contenta</i> (Grunow in Van Heurck) Mann in Round <i>et al.</i>	1, 3, 4, 6, 7
<i>Diadismus contenta</i> var. <i>biceps</i> (Arnott ex Grunow in Van Heurck) Hamilton	2, 3, 4, 8
<i>Diadismus contenta</i> fo. <i>parallela</i> (Petersen) ??	4
<i>Diadismus gallica</i> W. Smith	1, 4?
<i>Diadismus perpusilla</i> (Grunow) Mann in Round <i>et al.</i>	3, 4
<i>Diatoma elongatum</i> Lyngbye	5
<i>Diatoma hiemale</i> var. <i>mesodon</i> (Ehrenberg) Kirchner	1, 4
<i>Diatoma moniliformis</i> Kützing	4
<i>Diatoma tenuis</i> Agardh (= <i>Diatoma tenuis</i> var. <i>elongatum</i> Lyngbye)	1, 4, 6, 7
<i>Diatomella balfouriana</i> Greville	3
<i>Diploneis</i> cf. <i>parma</i> Cleve	7
<i>Diploneis elliptica</i> (Kützing) Cleve	1, 3, 4, 5, 7
<i>Diploneis elliptica</i> var. <i>ladogensis</i> Cleve	7
<i>Diploneis finnica</i> (Ehrenberg) Cleve	5
<i>Diploneis interrupta</i> (Kützing) Cleve	3
<i>Diploneis marginestriata</i> Hustedt	1, 5, 6, 7
<i>Diploneis maulerii</i> (Brun) Cleve	7
<i>Diploneis modica</i> Hustedt	7
<i>Diploneis oblongella</i> (Nägeli) Cleve-Euler	1, 7
<i>Diploneis oculata</i> (Brébisson) Cleve	1, 3, 4, 5, 6, 7

<i>Diploneis ovalis</i> (Hilse) Cleve	4, 5, 7
<i>Diploneis parma</i> Cleve	1
<i>Diploneis pseudovalis</i> Hustedt	1
<i>Diploneis puella</i> (Schumann) Cleve	5
<i>Diploneis smithii</i> (Brébisson) Cleve	1, 4?
<i>Diploneis smithii</i> var. <i>rhombica</i> Mereschkowsky	7
<i>Ellerbeckia arenaria</i> fo. <i>teres</i> (Brun) Crawford	5
<i>Encyonema latens</i> (Krasske) Mann in Round <i>et al.</i>	3, 4
<i>Encyonema lunatum</i> (W. Smith) ??	1
<i>Encyonema lunatum</i> var. <i>alaskaensis</i> (Foged) ??	4
<i>Encyonema mesianum</i> (Cholnoky) Mann in Round <i>et al.</i>	4, 7?
<i>Encyonema minutum</i> (Hilse ex Rabenhorst) Mann in Round <i>et al.</i>	1, 2, 3, 4, 5, 6, 7, 8
<i>Encyonema minuta</i> var. <i>pseudogracilis</i> (Reimer) ??	3
<i>Encyonema muellerii</i> (Hustedt) Mann in Round <i>et al.</i>	1, 4, 5
<i>Encyonema muellerii</i> fo. <i>ventricosa</i> (Temp. & H. Peragallo) ??	5
<i>Encyonema</i> cf. <i>reinhardtii</i> (Krammer) Mann in Round <i>et al.</i>	4
<i>Encyonema silesiacum</i> (Bleisch in Rabenhorst) Mann in Round <i>et al.</i>	1, 4, 6, 7
<i>Entomoneis ornata</i> (Bailey) Reimer in Patrick & Reimer	5, 7
<i>Entomoneis paludosa</i> var. <i>subsalina</i> (Cleve) Krammer	7
<i>Epithemia adnata</i> (Kützing) Brébisson	1, 5, 7
<i>Epithemia adnata</i> var. <i>saxonica</i> (Kützing) Patrick in Patrick & Reimer	5
<i>Epithemia argus</i> (Ehrenberg) Kützing	1, 7
<i>Epithemia argus</i> var. <i>alpestris</i> Grunow	4
<i>Epithemia argus</i> var. <i>constricta</i> Cleve-Euler	4
<i>Epithemia reicheltii</i> Fricke in A. Schmidt <i>et al.</i>	5
<i>Epithemia smithii</i> Carruthers	4, 5
<i>Epithemia sorex</i> Kützing	1, 4, 5, 7
<i>Epithemia turgida</i> (Ehrenberg) Kützing	5, 7
<i>Epithemia turgida</i> var. <i>granulata</i> (Ehrenberg) Brun	7
<i>Eunotia arcus</i> Ehrenberg	1, 2?, 3, 4, 8
<i>Eunotia arcus</i> var. <i>bidens</i> Grunow in Van Heurck	7
<i>Eunotia bidentula</i> W. Smith	1
<i>Eunotia bigibba</i> Kützing	1
<i>Eunotia bigibba</i> var. <i>pumila</i> Grunow in Van Heurck	2, 6
<i>Eunotia bilunaris</i> (Ehrenberg) Mills	2
<i>Eunotia circumborealis</i> Lange-Bertalot & Nörpel	6
<i>Eunotia curvata</i> var. <i>subarcuata</i> (Nägeli ex Kützing) Woodhead & Tweed	1
<i>Eunotia curvula</i> (Kützing) Lagerstedt	1
<i>Eunotia denticulata</i> (Brébisson ex Kützing) Rabenhorst	1
<i>Eunotia diodon</i> Ehrenberg	1, 5, 6
<i>Eunotia elegans</i> Østrup	1
<i>Eunotia exigua</i> (Brébisson ex Kützing) Rabenhorst	1, 5, 6
<i>Eunotia fallax</i> A. Cleve	1
<i>Eunotia flexuosa</i> (Brébisson) Kützing	1, 5, 6, 7
<i>Eunotia formica</i> Ehrenberg	7
<i>Eunotia hemicyclus</i> (Ehrenberg) Ralfs	6, 7
<i>Eunotia iatriaensis</i> Foged	1, 6
<i>Eunotia incisa</i> Gregory	1, 2, 6, 7

<i>Eunotia lapponica</i> A. Cleve	6
<i>Eunotia lunaris</i> (Ehrenberg) Grunow in Van Heurck	6, 7
<i>Eunotia major</i> (W. Smith) Rabenhorst	3
<i>Eunotia meisteri</i> Hustedt	1
<i>Eunotia microcephala</i> Krasske ex Hustedt	1, 6
<i>Eunotia monodon</i> Ehrenberg	2, 4, 5, 7
<i>Eunotia monodon</i> var. <i>major</i> (W. Smith) Hustedt	5
<i>Eunotia muelleri</i> Hustedt	1
<i>Eunotia naegellii</i> Migula	1, 7?
<i>Eunotia nymmanniana</i> Grunow in Van Heurck	6
<i>Eunotia pectinalis</i> (Kützing) Rabenhorst	1, 4, 5, 6, 7
<i>Eunotia pectinalis</i> var. <i>minor</i> (Kützing) Rabenhorst	1, 2, 6, 7, 8
<i>Eunotia polydentula</i> Brun	2, 8
<i>Eunotia praerupta</i> Ehrenberg	1, 2, 4, 5, 6, 7
<i>Eunotia praerupta</i> var. <i>bidens</i> (W. Smith) Grunow in Cleve & Grunow	4, 5, 6, 7, 8
<i>Eunotia praerupta</i> var. <i>bigibba</i> (Kützing) Grunow in Van Heurck	6
<i>Eunotia praerupta</i> var. <i>inflata</i> Grunow in Van Heurck	3, 4, 5, 8
<i>Eunotia rhomboidea</i> Hustedt	2, 5
<i>Eunotia serra</i> Ehrenberg	1
<i>Eunotia serra</i> var. <i>diadema</i> (Ehrenberg) Patrick	2, 6
<i>Eunotia serra</i> var. <i>tetraodon</i> (Ehrenberg) Nörpel	7
<i>Eunotia suecica</i> A. Cleve	1, 3?
<i>Eunotia</i> sp. 21 PIRLA	2
<i>Eunotia tassei</i> Berg	1
<i>Eunotia tenella</i> (Grunow in Van Heurck) A. Cleve	1, 2?, 8
<i>Eunotia trinacria</i> var. <i>undulata</i> Hustedt	1
<i>Eunotia triodon</i> Ehrenberg	2
<i>Eunotia valida</i> Hustedt	1
<i>Eunotia vanheurckii</i> Patrick	1, 2, 6, 7
<i>Eunotia vanheurckii</i> var. <i>intermedia</i> (Krasske ex Hustedt) Patrick	1
<i>Eunotia vanheurckii</i> var. <i>rhomboidea</i> Foged	2
<i>Fallacia pygmaea</i> (Kützing) Stickle & Mann in Round, Crawford & Mann	4, 5, 7
<i>Fragilaria capucina</i> Desmazières	1, 3, 6, 7
<i>Fragilaria capucina</i> var. <i>mesolepta</i> Rabenhorst	1
<i>Fragilaria constricta</i> Ehrenberg	1, 6
<i>Fragilaria construens</i> (Ehrenberg) Grunow	1, 4, 5, 6, 7, 8
<i>Fragilaria construens</i> var. <i>binodis</i> (Ehrenberg) Grunow	1, 5
<i>Fragilaria construens</i> var. <i>pumila</i> Grunow in Van Heurck	1
<i>Fragilaria construens</i> var. <i>subsalina</i> Hustedt	5
<i>Fragilaria construens</i> var. <i>venter</i> (Ehrenberg) Grunow in Van Heurck	1, 2, 3, 4, 5, 6, 7, 8
<i>Fragilaria crotonensis</i> Kitton	4, 6, 7
<i>Fragilaria elliptica</i> Schumann	1
<i>Fragilaria famelica</i> (Kützing) Lange-Bertalot	6, 7
<i>Fragilaria hungarica</i> var. <i>tumida</i> Cleve-Euler	1
<i>Fragilaria intermedia</i> (Grunow) Grunow in Van Heurck	5, 6, 7
<i>Fragilaria lapponica</i> Grunow in Van Heurck	1, 2, 5, 7
<i>Fragilaria lata</i> Renberg	1
<i>Fragilaria leptostauron</i> (Ehrenberg) Hustedt	1, 5, 7, 8

<i>Fragilaria leptostauron</i> var. <i>dubia</i> (Grunow) Hustedt	1
<i>Fragilaria nitzschioides</i> Grunow in Van Heurck	4
<i>Fragilaria oldenburgiana</i> Hustedt	1?, 7
<i>Fragilaria pinnata</i> Ehrenberg	1, 2, 3, 4, 5, 6, 7, 8
<i>Fragilaria pinnata</i> var. <i>intercedens</i> (Grunow in Van Heurck) Hustedt	1, 4, 5, 6, 7
<i>Fragilaria pinnata</i> var. <i>lancettula</i> (Schumann) Hustedt in Schmidt <i>et al.</i>	1, 5, 7
<i>Fragilaria pinnata</i> var. <i>trigona</i> (Brun & Héribaude) Hustedt	1
<i>Fragilaria pinnata</i> var. <i>ventriculosa</i> (Schumann) Mayer	1?, 4, 7
<i>Fragilaria vaucheriae</i> (Kützinger) Petersen	1, 3, 4, 5, 6, 7
<i>Fragilaria virescens</i> Ralfs	4, 5, 8
<i>Fragilaria virescens</i> var. <i>exigua</i> Grunow in Van Heurck	1, 2, 6, 7
<i>Fragilaria virescens</i> var. <i>subsalina</i> Grunow in Van Heurck	8
<i>Frustulia rhomboides</i> (Ehrenberg) De Toni	1, 2, 4, 6, 7, 8
<i>Frustulia rhomboides</i> var. <i>crassinervia</i> (Brébisson ex W. Smith) Ross	2, 6, 7
<i>Frustulia rhomboides</i> var. <i>saxonica</i> (Rabenhorst) De Toni	1, 2, 5, 6
<i>Frustulia vulgaris</i> (Thwaites) De Toni	1
<i>Gomphonema acuminatum</i> Ehrenberg	1, 4, 5, 7, 8
<i>Gomphonema acuminatum</i> var. <i>brebissonii</i> (Kützinger) Schönfeld	3, 4
<i>Gomphonema acuminatum</i> var. <i>coronatum</i> (Ehrenberg) W. Smith	5
<i>Gomphonema affine</i> Kützinger	1, 5, 7?
<i>Gomphonema angustatum</i> (Kützinger) Rabenhorst	1, 4, 5, 6, 7, 8
<i>Gomphonema angustatum</i> var. <i>productum</i> Grunow in Van Heurck	4
<i>Gomphonema</i> sp. [cf. <i>angustatum</i> var. <i>undulata</i> Grunow in Cleve]	3
<i>Gomphonema</i> sp. [cf. <i>clavatum</i> Ehrenberg]	7
<i>Gomphonema</i> sp. [cf. <i>constrictum</i> Ehrenberg ex Kützinger]	3, 4
<i>Gomphonema dichotomum</i> Kützinger	1
<i>Gomphonema gracile</i> Ehrenberg	1, 4, 5, 7
<i>Gomphonema hebridense</i> Gregory	4
<i>Gomphonema intricatum</i> Kützinger	3
<i>Gomphonema</i> sp. [cf. <i>lagerheimii</i> A. Cleve]	4
<i>Gomphonema minutum</i> (Agardh) Agardh	7
<i>Gomphonema</i> sp. [cf. <i>montanum</i> Schumann]	4
<i>Gomphonema olivaceoides</i> var. <i>lanceolata</i> Manguin	3
<i>Gomphonema olivaceum</i> (Hornemann) Brébisson	7
<i>Gomphonema</i> sp. [cf. <i>parvulum</i> (Kützinger) Kützinger]	1, 2, 5, 6, 7
<i>Gomphonema pseudotenellum</i> Lange-Bertalot	7
<i>Gomphonema rhombicum</i> Fricke in Schmidt.	5
<i>Gomphonema subclavatum</i> (Grunow) Grunow in Van Heurck	1
<i>Gomphonema subtile</i> Ehrenberg	4?, 5
<i>Gomphonema subtile</i> var. <i>sagitta</i> (Schumann) Cleve	5
<i>Gomphonema truncatum</i> Ehrenberg	1, 4?, 5
<i>Gyrosigma acuminatum</i> (Kützinger) Rabenhorst	5
<i>Gyrosigma attenuatum</i> (Kützinger) Rabenhorst	7
<i>Gyrosigma obtusatum</i> (Sullivant & Wormley) Boyer	1
<i>Gyrosigma</i> cf. <i>spencerii</i> (Quekett) Griffith & Henfrey	6, 7
<i>Gyrosigma spencerii</i> var. <i>lacustris</i> Grunow	1
<i>Hannaea arcus</i> (Ehrenberg) Patrick in Patrick & Reimer	3, 4, 5, 7
<i>Hannaea arcus</i> var. <i>amphioxys</i> (Rabenhorst) Patrick in Patrick & Reimer	4

<i>Hannaea arcus</i> var. <i>linearis</i> (Holmboe) Ross in Hartley	7
<i>Hantzschia amphioxys</i> (Ehrenberg) Grunow	3, 4, 5, 6, 7
<i>Hantzschia marina</i> (Donkin) Grunow	7
<i>Krasskella kriegeriana</i> (Krasske) Ross & Sims	3
<i>Luticola cohnii</i> (Hilse) Mann in Round <i>et al.</i>	4
<i>Luticola hilliardii</i> var. <i>pseudosiliculoides</i> (Foged) ??	4
<i>Luticola interglacialis</i> (Hustedt) ??	4
<i>Luticola mutica</i> (Kützing) Mann <i>et al.</i>	1, 3, 4, 5
<i>Luticola mutica</i> var. <i>ventricosa</i> (Kützing) ??	4
<i>Luticola muticopsis</i> (Van Heurck) Mann in Round <i>et al.</i>	4
<i>Luticola nivalis</i> (Ehrenberg) Mann in Round <i>et al.</i>	4
<i>Luticola</i> sp. [cf. <i>nivaloides</i> (Bock) ??]	4
<i>Luticola palaeartica</i> (Hustedt ex Simonsen) Mann in Round <i>et al.</i>	4
<i>Mastogloia elliptica</i> (Agardh) Cleve ex Schmidt	2, 5
<i>Mastogloia elliptica</i> var. <i>dansei</i> (Thwaites) Cleve	2, 5, 7
<i>Mastogloia grevillei</i> W. Smith ex Gregory	7
<i>Mastogloia smithii</i> var. <i>lacustris</i> Grunow	1, 2, 5, 7
<i>Meridion circulare</i> (Greville) Agardh	1, 3, 4, 5, 7
<i>Meridion circulare</i> var. <i>constrictum</i> (Ralfs) Van Heurck	4
<i>Martyana martyi</i> (Héribaud) Round in Round <i>et al.</i>	5, 7
<i>Navicula abiskoensis</i> Hustedt	5
<i>Navicula aboensis</i> (Cleve) Hustedt	5, 6
<i>Navicula absoluta</i> Hustedt	1?, 6, 7
<i>Navicula acceptata</i> Hustedt	1
<i>Navicula</i> sp. [cf. <i>accomoda</i> Hustedt]	6
<i>Navicula americana</i> Ehrenberg	1
<i>Navicula amphibola</i> Cleve	3, 4
<i>Navicula amphibola</i> fo. <i>alaskaensis</i> Foged	4
<i>Navicula amphibola</i> fo. <i>rectangularis</i> Foged	4
<i>Navicula amygdaliana</i> Hustedt	8
<i>Navicula</i> sp. [cf. <i>angusta</i> Grunow]	4
<i>Navicula angustata</i> W. Smith	1
<i>Navicula</i> sp. [cf. <i>arvensis</i> Hustedt]	1, 6, 7
<i>Navicula atomus</i> (Kützing) Grunow	
<i>Navicula aurora</i> Sovereign	5, 7
<i>Navicula</i> sp. [cf. <i>bahusiensis</i> (Grunow in Van Heurck) Grunow]	7
<i>Navicula begeri</i> Krasske	1, 4, 7
<i>Navicula bremensis</i> Hustedt	1
<i>Navicula bryophila</i> Petersen	1, 3, 4, 5, 7
<i>Navicula</i> sp. [cf. <i>cancellata</i> Donkin]	4
<i>Navicula</i> sp. [cf. <i>capitata</i> Ehrenberg]	1, 4, 7
<i>Navicula capitata</i> var. <i>hungarica</i> (Grunow) Ross	4, 5, 7
<i>Navicula capitata</i> var. <i>luneburgensis</i> (Grunow) Patrick in Patrick & Reimer	1, 5, 7
<i>Navicula</i> sp. [cf. <i>cari</i> Ehrenberg]	1, 4
<i>Navicula cincta</i> (Ehrenberg) Ralfs in Pritchard	1, 4
<i>Navicula</i> sp. [cf. <i>cincta</i> var. <i>heufleuri</i> (Grunow) Grunow in Van Heurck]	3, 4
<i>Navicula clementioides</i> Hustedt	4
<i>Navicula clementis</i> Grunow	4

<i>Navicula concentrica</i> Carter	1, 5, 7
<i>Navicula</i> sp. [cf. <i>constans</i> Hustedt]	4
<i>Navicula</i> sp. [cf. <i>constans</i> var. <i>symmetrica</i> Hustedt]	7
<i>Navicula costulata</i> Grunow in Cleve & Grunow	4, 7
<i>Navicula crucicula</i> (W. Smith) Donkin	5
<i>Navicula crucicula</i> var. <i>alaskana</i> Patrick & Freese	4
<i>Navicula crucicula</i> var. <i>cruciculoides</i> (Brockman) Lange-Bertalot	5
<i>Navicula cryptocephala</i> Kützing	1, 4, 5, 6, 7
<i>Navicula</i> sp. [cf. <i>cryptotenella</i> Lange-Bertalot]	1, 5, 6, 7
<i>Navicula cryptolyra</i> Brockmann	5, 7
<i>Navicula cumbriensis</i> Haworth	1
<i>Navicula detenta</i> Hustedt	1, 6
<i>Navicula dicephala</i> Ehrenberg	4
<i>Navicula difficillima</i> Hustedt	1, 6, 7
<i>Navicula digitoradiata</i> (Gregory) Ralfs in Pritchard	3, 5
<i>Navicula digitulus</i> Hustedt	1, 4, 6, 7
<i>Navicula</i> sp. [aff. <i>digna</i> Hustedt]	1
<i>Navicula diluviana</i> Krasske	5
<i>Navicula disjuncta</i> Hustedt	1, 7
<i>Navicula egregia</i> fo. <i>fennica</i> Hustedt	7
<i>Navicula</i> sp. [cf. <i>eidrigiana</i> Carter]	7
<i>Navicula elginensis</i> (Gregory) Ralfs in Pritchard	1, 4, 5, 6, 7
<i>Navicula exigua</i> var. <i>capitata</i> Patrick	8
<i>Navicula explanata</i> Hustedt	3, 4?, 5, 6, 7
<i>Navicula farta</i> Hustedt	5
<i>Navicula festiva</i> Krasske	1
<i>Navicula fossalis</i> Krasske	5
<i>Navicula fossalis</i> var. <i>obsidialis</i> (Hustedt) Lange-Bertalot	5
<i>Navicula fracta</i> Hustedt	5
<i>Navicula gastrum</i> (Ehrenberg) Kützing	5, 7
<i>Navicula gastrum</i> var. <i>signata</i> Hustedt in Schmidt <i>et al.</i>	7
<i>Navicula</i> sp. [cf. <i>gerloffii</i> Schimanski]	7
<i>Navicula globosa</i> Meister	1
<i>Naviculus glomus</i> Carter	1
<i>Navicula gottlandica</i> Grunow in Van Heurck	1
<i>Navicula gregaria</i> Donkin	7
<i>Navicula gysingensis</i> Foged	1
<i>Navicula hambergii</i> Hustedt	1
<i>Navicula harderii</i> Hustedt in Brendemühl	5
<i>Navicula helensis</i> Schulz	7
<i>Navicula hungarica</i> var. <i>arctica</i> Patrick & Freese	4
<i>Navicula hustedtii</i> Krasske	5
<i>Navicula ignota</i> var. <i>acceptata</i> (Hustedt) Lange-Bertalot	6, 7
<i>Navicula ignota</i> var. <i>palustris</i> (Hustedt) Lund	4, 6, 7
<i>Navicula</i> sp. [cf. <i>impexa</i> Hustedt]	4
<i>Navicula incertata</i> Lange-Bertalot	7
<i>Navicula indifferens</i> Hustedt	1, 7
<i>Navicula integra</i> (W. Smith) Ralfs in Pritchard	7

<i>Navicula ingstaii</i> Foged	8
<i>Navicula jaagii</i> Meister	5, 6
<i>Navicula jaernfeldtii</i> Hustedt	1
<i>Navicula jentzschii</i> Grunow	5
<i>Navicula</i> sp. [cf. <i>krasskei</i> Hustedt]	7
<i>Navicula lacuna</i> Patrick & Freese	5
<i>Navicula laterostrata</i> Hustedt	6
<i>Navicula leptostriata</i> Jørgensen	1
<i>Navicula levanderi</i> Hustedt	5, 6, 7
<i>Navicula libonensis</i> Schoeman	1
<i>Navicula maceria</i> Schimanski	1
<i>Navicula medioconvexa</i> Hustedt	1, 7
<i>Navicula mediocris</i> Krasske	1, 5, 6, 7
<i>Navicula menisculus</i> Schumann	1, 5, 7
<i>Navicula minima</i> Grunow in Van Heurck	1, 4, 5, 6, 7, 8
<i>Navicula minuscula</i> Grunow in Van Heurck	1, 4, 5, 6, 7
<i>Navicula minuscula</i> var. <i>muralis</i> (Grunow) Lange-Bertalot in Lange-Bertalot & Rumrich	5, 6, 7
<i>Navicula modica</i> Hustedt	1, 5, 6, 7
<i>Navicula</i> sp. [cf. <i>molestiformis</i> Hustedt]	1, 4, 7
<i>Navicula</i> sp. [cf. <i>monoculata</i> Hustedt]	4
<i>Navicula muraliforis</i> Hustedt	1
<i>Navicula muralis</i> Grunow in Van Heurck	1
<i>Navicula naumannii</i> Hustedt	4
<i>Navicula notha</i> Wallace	8
<i>Navicula oblonga</i> (Kützing) Kützing	5, 6, 7
<i>Navicula</i> sp. [cf. <i>oppugnata</i> Hustedt]	7
<i>Navicula placentula</i> (Ehrenberg) Kützing	7
<i>Navicula</i> sp. [cf. <i>obsoleta</i> Hustedt]	6
<i>Navicula ordinaria</i> Hustedt	7
<i>Navicula pelliculosa</i> (Kützing) Hilse in Rabenhorst	1, 4
<i>Navicula peregrina</i> (Ehrenberg) Kützing	5
<i>Navicula peregrina</i> var. <i>kefvingensis</i> (Ehrenberg) Cleve	5
<i>Navicula peregrina</i> var. <i>polaris</i> (Lagerstedt) Cleve	4, 5
<i>Navicula permitis</i> Hustedt	1
<i>Navicula placentula</i> (Ehrenberg) Kützing	1
<i>Navicula porifera</i> Hustedt	5, 7
<i>Navicula porifera</i> var. <i>opportuna</i> Hustedt	7
<i>Navicula pseudanglica</i> Cleve-Euler	7
<i>Navicula pseudanglica</i> var. <i>signata</i> Hustedt	7
<i>Navicula</i> sp. [cf. <i>pseudolanceolata</i> Lange-Bertalot]	6, 7
<i>Navicula pseudolanceolata</i> var. <i>denselineolata</i> Lange-Bertalot	7
<i>Navicula pseudomuralis</i> Hustedt	1
<i>Navicula</i> sp. [cf. <i>pseudosilicula</i> Hustedt]	5, 7
<i>Navicula pseudotuscula</i> Hustedt	7
<i>Navicula pseudoventralis</i> Hustedt	1, 5, 6, 7
<i>Navicula radiosa</i> Kützing	1, 4, 5, 6, 7
<i>Navicula radiosa</i> var. <i>tenella</i> (Brébisson ex Kützing) Grunow in Van Heurck	1, 3
<i>Navicula</i> sp. [aff. <i>regularis</i> Hustedt]	1

<i>Navicula reinhardtii</i> Grunow in Van Heurck	4, 5
<i>Navicula rhynchocephala</i> Kützing	1, 3?, 4?, 5, 6, 7
<i>Navicula salinarum</i> Grunow in Cleve & Grunow	5, 6
<i>Navicula schmassmannii</i> Hustedt	1, 2, 5, 6, 7, 8
<i>Navicula schoenfeldii</i> Hustedt	1, 3?, 4, 6, 7
<i>Navicula scutelloides</i> W. Smith ex Gregory	5
<i>Navicula seminuloides</i> Hustedt	1, 5, 6, 7
<i>Navicula seminulum</i> Grunow	1, 6, 7
<i>Navicula slesvicensis</i> Grunow in Van Heurck	5
<i>Navicula soehrensii</i> Krasske	2, 3?, 4, 6
<i>Navicula soehrensii</i> var. <i>hassiacae</i> (Krasske) Lange-Bertalot	1, 5, 6, 7
<i>Navicula stankovicii</i> Hustedt	1
<i>Navicula strenzekei</i> Hustedt	1
<i>Navicula stroemii</i> Hustedt	1
<i>Navicula subatomoides</i> Hustedt ex Patrick	1
<i>Navicula subhamulata</i> Grunow in Van Heurck	8
<i>Navicula subrotundata</i> Hustedt	1, 6?, 7
<i>Navicula subtilissima</i> Cleve	1, 6
<i>Navicula tenera</i> Hustedt	5, 7
<i>Navicula tenuicephala</i> Hustedt	1
<i>Navicula</i> sp. [cf. <i>tridentula</i> Krasske]	7
<i>Navicula trivialis</i> Lange-Bertalot	1, 5, 6, 7
<i>Navicula utermoehlii</i> Hustedt	1, 7
<i>Navicula variostriata</i> Krasske	1, 8
<i>Navicula veneta</i> Kützing	1, 7
<i>Navicula ventosa</i> Hustedt	1
<i>Navicula ventralis</i> Krasske	1
<i>Navicula viridula</i> (Kützing) Ehrenberg	1
<i>Navicula viridula</i> var. <i>linearis</i> Hustedt	7
<i>Navicula vitabunda</i> Hustedt	1, 5, 6, 7
<i>Navicula vitiosa</i> Schimanski	6, 7
<i>Navicula vulpina</i> Kützing	3, 4, 5, 6, 7
<i>Neidium affine</i> (Ehrenberg) Pfitzer	1, 3, 4, 5, 6, 7
<i>Neidium affine</i> var. <i>longiceps</i> (Gregory) Cleve	2, 4, 6
<i>Neidium affine</i> var. <i>lucinensis</i> Hustedt	7
<i>Neidium ampliatus</i> (Ehrenberg) Krammer	1, 2, 4, 5, 6, 7
<i>Neidium bergii</i> (Cleve-Euler) Krammer	4
<i>Neidium</i> sp. [cf. <i>binodeforme</i> Krammer]	4
<i>Neidium binodis</i> (Ehrenberg) Hustedt	1
<i>Neidium bisulcatum</i> (Lagerstedt) Cleve	1, 4, 5, 6
<i>Neidium decoratum</i> Brun	4
<i>Neidium distincte-punctatum</i> Hustedt	3, 4
<i>Neidium distincte-punctatum</i> var. <i>major</i> Sreenivasa	4
<i>Neidium dubium</i> (Ehrenberg) Cleve	4, 6
<i>Neidium hercynicum</i> A. Mayer	6
<i>Neidium hitchcockii</i> (Ehrenberg) Cleve	5, 6, 7
<i>Neidium iridis</i> (Ehrenberg) Cleve	1, 3, 4, 5, 6, 7
<i>Neidium kozlowii</i> Mereschkowsky	4

<i>Neidium kozlowii</i> var. <i>ellipticum</i> Mereschkowsky	3?, 4
<i>Neidium ladogensis</i> (Cleve) Foged	4, 6?
<i>Neidium productum</i> (W. Smith) Cleve	3, 4
<i>Neidium septentrionale</i> Cleve-Euler	6
<i>Neidium temperei</i> Reimer	4, 5
<i>Nitzschia acicularis</i> (Kützinger) W. Smith	7
<i>Nitzschia acuminata</i> (W. Smith) Grunow	5
<i>Nitzschia</i> sp. [cf. <i>agnita</i> Hustedt]	7
<i>Nitzschia alpina</i> Hustedt	6, 7
<i>Nitzschia amphibia</i> Grunow	1, 3, 4, 8
<i>Nitzschia amphibia</i> fo. <i>fraunfeldii</i> (Grunow in Van Heurck) Cleve-Euler	4
<i>Nitzschia</i> sp. [cf. <i>amphibia</i> var. <i>thermalis</i> Petersen]	3
<i>Nitzschia angustata</i> (W. Smith) Grunow in Cleve & Grunow	1, 6, 7
<i>Nitzschia angustata</i> var. <i>acuta</i> Grunow in Cleve & Grunow	5
<i>Nitzschia angustatula</i> Lange-Bertalot	1
<i>Nitzschia</i> sp. [cf. <i>bacillum</i> Hustedt]	1, 7
<i>Nitzschia bryophila</i> Hustedt	8
<i>Nitzschia</i> sp. [cf. <i>commutata</i> Grunow in Cleve & Grunow]	4, 7
<i>Nitzschia dissipata</i> (Kützinger) Grunow	1, 7
<i>Nitzschia dissipata</i> var. <i>media</i> (Hantzsch) Grunow in Van Heurck	4?, 7
<i>Nitzschia dissipata</i> fo. <i>undulata</i> Sovereign	7
<i>Nitzschia</i> sp. [cf. <i>pura</i> Hustedt]	6
<i>Nitzschia flexoides</i> Geitler	4
<i>Nitzschia fonticola</i> Grunow in Van Heurck	1, 2, 4, 5, 6, 7
<i>Nitzschia frustulum</i> (Kützinger) Grunow in Cleve & Grunow	1, 2, 4, 5, 8
<i>Nitzschia frustulum</i> var. <i>bulnheimiana</i> (Rabenhorst) Grunow in Van Heurck	7
<i>Nitzschia frustulum</i> var. <i>perpusilla</i> (Rabenhorst) Grunow in Van Heurck	3
<i>Nitzschia gracilis</i> Hantzsch	1, 4
<i>Nitzschia hantzschiana</i> Rabenhorst	1, 4
<i>Nitzschia heufleriana</i> Grunow	6
<i>Nitzschia hollerupensis</i> Foged	5
<i>Nitzschia inconspicua</i> Grunow	1, 4
<i>Nitzschia incognita</i> Krasske	1
<i>Nitzschia</i> sp. [cf. <i>intermedia</i> Hantzsch ex Cleve & Grunow]	7
<i>Nitzschia</i> sp. [cf. <i>lacuum</i> Lange-Bertalot]	1, 4
<i>Nitzschia</i> sp. [cf. <i>liebetruthii</i> Rabenhorst]	4
<i>Nitzschia linearis</i> W. Smith	1
<i>Nitzschia palea</i> (Kützinger) W. Smith	1, 2
<i>Nitzschia paleacea</i> (Grunow in Cleve & Grunow) Grunow in Van Heurck	1
<i>Nitzschia perminuta</i> (Grunow) M. Peragallo	1, 4, 6
<i>Nitzschia recta</i> Hantzsch ex Rabenhorst	1
<i>Nitzschia sigmoidea</i> (Nitzsch) W. Smith	1, 5, 7?
<i>Nitzschia sinuata</i> (Thwaites ex W. Smith) Grunow in Cleve & Grunow	3, 4, 5
<i>Nitzschia solita</i> Hustedt	1
<i>Nitzschia valdestriata</i> Aleem & Hustedt	1, 5, 7
<i>Nitzschia</i> sp. [cf. <i>vitrea</i> Norman]	4
<i>Oestrupia zachariasii</i> (Reichelt) Hustedt	7
<i>Opephora olsenii</i> Møller	1?, 7

<i>Orthoseira roeseana</i> (Rabenhorst) O'Meara	3
<i>Peronia heribaudii</i> Brun ex M. Peragallo in Héribaude	5
<i>Peronia fibula</i> (Brébisson ex Kützing) Ross	1
<i>Pinnularia abaujensis</i> (Pantoscek) Ross	1
<i>Pinnularia</i> sp. [aff. <i>acrosphaeria</i> W. Smith]	1
<i>Pinnularia acrosphaeria</i> var. <i>turgidula</i> Grunow ex Cleve	5
<i>Pinnularia acuminata</i> W. Smith	1
<i>Pinnularia appendiculata</i> (Agardh) Cleve	1
<i>Pinnularia balfouriana</i> Grunow ex Cleve	1, 2, 3, 5, 6, 7, 8
<i>Pinnularia biceps</i> Gregory	1, 2, 4, 5, 6, 7, 8
<i>Pinnularia borealis</i> Ehrenberg	3, 4, 5
<i>Pinnularia borealis</i> var. <i>rectangularis</i> Carlson	4
<i>Pinnularia brebissonii</i> (Kützing) Rabenhorst	1
<i>Pinnularia brevicostata</i> Cleve	4
<i>Pinnularia</i> sp. [cf. <i>lenticula</i> Cleve-Euler]	3
<i>Pinnularia</i> sp. [cf. <i>karelica</i> Cleve]	4
<i>Pinnularia divergens</i> W. Smith	4, 5, 6
<i>Pinnularia episcopalis</i> Cleve	5
<i>Pinnularia gibba</i> Ehrenberg (= <i>P.</i> sp. [cf. <i>parva</i> (Ehrenberg) Gregory])	2, 3, 5, 6
<i>Pinnularia gibba</i> var. <i>mesogongyla</i> (Ehrenberg) Hustedt	2, 5
<i>Pinnularia hilseana</i> Janisch ex Rabenhorst	1
<i>Pinnularia intermedia</i> (Lagerstedt) Cleve	1, 4?, 8
<i>Pinnularia lagerstedtii</i> (Cleve) Cleve-Euler	2
<i>Pinnularia lata</i> (Brébisson) W. Smith	4
<i>Pinnularia legumen</i> Ehrenberg	1, 2, 5, 6
<i>Pinnularia maior</i> (Kützing) Rabenhorst	1, 5, 6, 7
<i>Pinnularia mesolepta</i> (Ehrenberg) W. Smith	1, 3, 4
<i>Pinnularia</i> sp. [cf. <i>mesolepta</i> var. <i>angusta</i> Cleve]	3
<i>Pinnularia microstauron</i> (Ehrenberg) Cleve	1, 3, 4, 5, 6, 7
<i>Pinnularia microstauron</i> fo. <i>robusta</i> Foged	3
<i>Pinnularia microstauron</i> var. <i>brebissonii</i> (Kützing) Hustedt	7
<i>Pinnularia nodosa</i> (Ehrenberg) W. Smith	1, 5, 7
<i>Pinnularia</i> sp. [cf. <i>semicrucata</i> (Ehrenberg) Cleve]	7
<i>Pinnularia subcapitata</i> Gregory	1, 7?
<i>Pinnularia subrostrata</i> (A. Cleve) Cleve-Euler	1
<i>Pinnularia stomatophora</i> (Grunow ex Schmidt) Cleve	6
<i>Pinnularia streptoraphe</i> var. <i>minor</i> (Cleve) Cleve	4
<i>Pinnularia subrostrata</i> (A. Cleve) Cleve-Euler	5, 6
<i>Pinnularia termitiana</i> (Ehrenberg) Patrick	1
<i>Pinnularia viridis</i> (Nitzsch) Ehrenberg	1, 3?, 5, 6, 7
<i>Pinnularia hemiptera</i> (Kützing) Rabenhorst	6
<i>Pseudostaurosira brevistriata</i> (Grunow in Van Heurck) Williams & Round	5, 6, 7, 8
<i>Pseudostaurosira brevistriata</i> var. <i>papillosa</i> (Cleve-Euler) ??	6, 7
<i>Pseudostaurosira pseudoconstruens</i> (Marciniak) Williams & Round	4, 6, 7
<i>Pseudostaurosira robusta</i> Williams & Round	6, 7
<i>Rhoicosphenia abbreviata</i> (Agardh) Lange-Bertalot	5, 7
<i>Rhopalodia gibba</i> (Ehrenberg) O. Müller	1, 5, 7
<i>Rhopalodia gibberula</i> (Ehrenberg) O Müller	4, 5

<i>Sellaphora bacillum</i> (Ehrenberg) Mann	1, 4, 5, 6, 7
<i>Sellaphora laevis</i> (Kützinger) Mann	1, 3, 4, 6, 7
<i>Sellaphora lenzii</i> (Hustedt) ??	1, 4, 7
<i>Sellaphora pupula</i> (Kützinger) Mereschkowsky	1, 2, 4, 5, 6, 7
<i>Sellaphora pupula</i> var. <i>mutata</i> (Krasske) ??	1, 7
<i>Sellaphora pupula</i> fo. <i>rostrata</i> (Hustedt) ??	5
<i>Sellaphora pupula</i> var. <i>pseudopupula</i> (Krasske) ??	7
<i>Sellaphora pupula</i> var. <i>rectangularis</i> (Gregory) ??	1, 5
<i>Sellaphora subhamulata</i> (Grunow in Van Heurck) ??	4, 7?
<i>Semiorbis hemicyclus</i> (Ehrenberg) Patrick in Patrick & Reimer	1
<i>Simonsenia delognei</i> (Grunow in Van Heurck) Lange-Bertalot	7
<i>Stauroneis acuta</i> W. Smith	4, 5
<i>Stauroneis alpina</i> Hustedt	1
<i>Stauroneis anceps</i> Ehrenberg	1, 3, 4, 5, 6, 7
<i>Stauroneis anceps</i> fo. <i>gracilis</i> Rabenhorst	1, 5, 8
<i>Stauroneis anceps</i> var. <i>linearis</i> (Ehrenberg) Brun	3
<i>Stauroneis anceps</i> var. <i>siberica</i> Grunow in Cleve & Grunow	5
<i>Stauroneis barrowiana</i> Patrick & Freese	4?, 5, 6
<i>Stauroneis fluminea</i> var. <i>alaskaense</i> Foged	3
<i>Stauroneis javanica</i> (Grunow) Cleve	4
<i>Stauroneis javanica</i> fo. <i>lapponica</i> Hustedt	4
<i>Stauroneis ignorata</i> Hustedt	1
<i>Stauroneis kriegeri</i> Patrick	1, 2, 3
<i>Stauroneis lauenburgiana</i> Hustedt	7
<i>Stauroneis obtusa</i> Lagerstedt	2, 4
<i>Stauroneis pachycephala</i> var. <i>alaskana</i> Foged	5
<i>Stauroneis phoenicenteron</i> (Nitzsch) Ehrenberg	1, 2, 4, 5, 6, 7
<i>Stauroneis phoenicenteron</i> fo. <i>gracile</i> (Ehrenberg) Hustedt	
<i>Stauroneis producta</i> Grunow in Van Heurck	6, 7
<i>Stauroneis producta</i> fo. <i>minor</i> Foged	3
<i>Stauroneis smithii</i> Grunow	1, 4, 5, 7
<i>Stauroneis</i> sp. [cf. <i>smithii</i> fo. <i>minima</i> Pantocsek]	7
<i>Staurophora wislouchii</i> (Poretzky & Anisimova) Mann	5
<i>Stenopterobia curvula</i> (W. Smith) Krammer	1, 6, 7
<i>Stenopterobia delicatissima</i> (Lewis) Van Heurck	1, 6, 7
<i>Stephanodiscus alpinus</i> Hustedt	7
<i>Stephanodiscus hantzschii</i> Grunow in Cleve & Grunow	1, 7
<i>Stephanodiscus medius</i> Håkansson	5
<i>Stephanodiscus minutulus</i> (Kützinger) Round	1, 5
<i>Stephanodiscus parvus</i> Stoermer & Håkansson	1
<i>Stephanodiscus rotula</i> (Kützinger) Hendey	5
<i>Surirella amphioxys</i> W. Smith	5
<i>Surirella angusta</i> Kützinger	4, 7?
<i>Surirella bifrons</i> Ehrenberg	1
<i>Surirella biseriata</i> Brébisson & Godey	1
<i>Surirella bohémica</i> Maly	7
<i>Surirella constricta</i> W. Smith	1
<i>Surirella elegans</i> Ehrenberg	5

<i>Surirella linearis</i> W. Smith	1, 5, 6, 7
<i>Surirella linearis</i> var. <i>constricta</i> Grunow	5, 7
<i>Surirella linearis</i> var. <i>helvetica</i> (Brun) Meister	1
<i>Surirella ovalis</i> Brébisson	4, 5, 7
<i>Surirella robusta</i> Ehrenberg	6, 7
<i>Surirella robusta</i> var. <i>armata</i> Hustedt	7
<i>Surirella splendida</i> (Ehrenberg) Kützing	7
<i>Surirella</i> sp. [cf. <i>subsalsa</i> W. Smith]	4
<i>Synedra acus</i> Kützing	1, 7
<i>Synedra amphicephala</i> Kützing	1
<i>Synedra amphicephala</i> var. <i>austriaca</i> (Grunow in Van Heurck) Hustedt	7
<i>Synedra cyclopus</i> Brutschy	1?, 4
<i>Synedra delicatissima</i> W. Smith	1
<i>Synedra delicatissima</i> var. <i>angustissima</i> Grunow in Van Heurck	1
<i>Synedra</i> sp. [aff. <i>minuscule</i> Grunow in Van Heurck]	1
<i>Synedra nana</i> Meister	1
<i>Synedra parasitica</i> (W. Smith) Hustedt	1, 5, 7
<i>Synedra radians</i> Kützing	1, 6, 7
<i>Synedra rumpens</i> Kützing	1
<i>Synedra</i> sp. [aff. <i>tenera</i> W. Smith]	1
<i>Synedra ulna</i> (Nitzsch) Ehrenberg	1, 4, 5, 7
<i>Tabellaria fenestrata</i> (Lyngbye) Kützing	1, 4, 5
<i>Tabellaria flocculosa</i> (Roth) Kützing	1, 3, 4, 5, 8
<i>Tabellaria flocculosa</i> (strain-III sensu Koppen)	4
<i>Tabellaria flocculosa</i> (Roth) Kützing (strain IV sensu Koppen)	2, 6, 7
<i>Tabellaria flocculosa</i> var. <i>linearis</i> Koppen	4
<i>Tabellaria quadriseptata</i> Knudson	5, 7
<i>Tetracyclus emarginatus</i> (Ehrenberg) W. Smith	5, 6, 7
<i>Tetracyclus glans</i> Ehrenberg	6, 7
<i>Tetracyclus lacustris</i> Ralfs	1
<i>Tetracyclus rupestris</i> (Braun ex Rabenhorst) Grunow in Van Heurck	4
<i>Tryblionella</i> sp. [cf. <i>levidensis</i> W. Smith]	4
<i>Tryblionella debilis</i> Arnott ex O'Meara	3, 4

Marine taxa observed in the sediments but not included in the freshwater list

<i>Amphora coffeaeformis</i> (Agardh) Kützing	5
<i>Amphora crassa</i> Gregory	5
<i>Amphora proteus</i> var. <i>oculata</i> H & M Peragallo	5
<i>Caloneis westii</i> (W. Smith) Hendey	5
<i>Cocconeis californica</i> Grunow in Van Heurck	5
<i>Cocconeis costata</i> Gregory	5
<i>Cocconeis peltoides</i> Hustedt	5
<i>Cocconeis scutellum</i> Ehrenberg	5
<i>Cocconeis scutellum</i> var. <i>parva</i> (Grunow in Van Heurck) Cleve	5
<i>Cocconeis scutellum</i> var. <i>speciosa</i> (Gregory) Cleve-Euler	5
<i>Cocconeis scutellum</i> var. <i>stauroneiformis</i> W. Smith	5
<i>Diploneis didyma</i> (Ehrenberg) Cleve	5

<i>Diploneis entomon</i> (Ehrenberg) Cleve	5
<i>Diploneis reichardtii</i> var. <i>tschuktschorum</i> (Cleve) Heiden	5
<i>Diploneis splendida</i> (Gregory) Cleve	5
<i>Diploneis stroemii</i> Hustedt	5
<i>Grammatophora arctica</i> Cleve	5
<i>Grammatophora oceanica</i> Ehrenberg	5
<i>Grammatophora oceanica</i> var. <i>macilenta</i> (W. Smith) Grunow	5
<i>Licmophora abbreviata</i> Agardh	5
<i>Navicula forcipata</i> Greville	5
<i>Navicula glacialis</i> (Cleve) Grunow	5
<i>Navicula granulata</i> Bailey	5
<i>Navicula humerosa</i> Brébisson ex W. Smith	5
<i>Navicula litoricola</i> Hustedt	5
<i>Navicula palpebralis</i> Brébisson ex W. Smith	5
<i>Navicula subinflata</i> Grunow	5
<i>Odontella aurita</i> (Lyngbye) Agardh	5
<i>Opephora marina</i> (Gregory) Petit	5
<i>Paralia heribaudii</i> Brun & Peragallo	5
<i>Pinnularia quadratarea</i> (Schmidt) Cleve	5
<i>Pinnularia quadratarea</i> var. <i>constricta</i> (Østrup) Heiden	5
<i>Plagiogramma staurophorum</i> (Gregory) Heiberg	5
<i>Rhabdonema arcuatum</i> (Agardh) Kützing	5
<i>Rhaphoneis</i> cf. <i>nitida</i> (Gregory) Grunow	5
<i>Rhopalodia musculus</i> (Kützing) Müller	5
<i>Rhopalodia parallela</i> (Grunow) Müller	5
<i>Striatella delicatula</i> (Kützing) Grunow in Van Heurck	5
<i>Thalassiosira</i> cf. <i>decipiens</i> (Grunow) Jørgensen	5
<i>Trachyneis aspera</i> (Ehrenberg) Cleve	5
<i>Trigonium arcticum</i> fo. <i>balaena</i> (Brightwell) Cleve	5

LAKE DEVELOPMENT: TEMPERATE AND ANTARCTIC ECOSYSTEMS - SIMILARITIES AND DIFFERENCES

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During the last decade diatoms have been used to study naturally occurring long-term lake developments as well as being used to study environmental changes (e.g. eutrophication, acidification, salinification, thermal effluents, forest fires, and land use changes). Even if it is said that diatoms can be reliably identified and that they often occur in sufficient concentrations and diversity, there are still uncertainties to overcome. It could very well be that an abundant species may represent an inherent source of error, if it is a border-line case in its particular category, or it shows a broad ecological amplitude, or finally if it has simply been wrongly classified because of an uncertain autecology.

The identification of diatom taxa when analysing core samples from such diverse regions of the world (temperate, polar) and from differing ecosystems (freshwater, saline) is difficult and confusing when trying to assimilate the information from the existing literature. The differences between species are often so small that it is difficult to decide which identification is right! A palaeolimnologist identifies his specimens and then tries to find in the literature, ecological information or even equivalent situations where the taxon or community in question may be found. Every kind of aquatic system has its individual environment and its special surrounding or catchment area. Therefore, studying the paleoecology of diatoms in all ecosystems, must be done without the temptation of relying solely on the existing literature for interpretations. Unfortunately, data analyses and interpretation relying solely on published information, are evident in the literature. In summary, each ecosystem gives unique insights into the climatic changes of the past and the potential changes in the ecosystems of the future (e.g. natural disasters, human impacts).

Grouping of diatoms and life-form

1. Salinity.

The earliest use of diatoms in aquatic palaeoecology was in Scandinavia as indicators of former salinity in the debate on land uplift, shore displacement and the isolation of lakes.

Example: Temperate zone: Hunneberg (Björck & Digerfeldt, 1981)
Antarctic: Skua Lake (Wasell & Håkansson, 1992)

2. pH.

This is the most commonly used system for grouping diatoms. However, by classifying the diatoms using only the literature you can find that some species have more than one placing.

Example: Temperate zone: Krageholmssjön (Håkansson 1989)
Antarctic: "Lake Åsa" (Björck *et al.* 1993)

When talking about life-form we mostly think of the plankton/periphyton ratio, which can be interpreted in two main ways: either as due to a change in the morphology of the lake basin as a lake fills in, and/or to a change in productivity. There are, however, some difficulties, because taxa can often be found in the plankton as well as in the periphyton (e.g. Temperate zone: Krageholmssjön, Håkansson 1989). It is therefore useful to demonstrate how different genera in the centrics, for example, can show valuable autecological information (e.g. Lake Trummen, Digerfeldt 1972). *Stephanodiscus* species from Lake Bussjösjön (Håkansson & Regnéll 1993) are good examples illustrating that we need more detailed knowledge about the ecology of different species, since this forms the basis for any classification system and

consequently, the foundation for all interpretations of stratigraphic analyses.

Differences and difficulties in interpretation of the results between Antarctic and temperate ecosystems are clearly evident when looking at the surroundings of the lakes in Sweden and in the Antarctic; thus we would predict that the sediment analyses between the ecosystems must be different. In the lakes we investigated from the Antarctic no planktonic forms were found. This means that we must use other classifications for the grouping of the diatoms. For instance, the presence of aerophilous diatoms in lake sediments can be used. These taxa can form distinct communities, and while many of the taxa occur both in moist terrestrial and aquatic habitats, some are classified as aerobiontic (Florin 1970, Schmidt *et al.* 1992, Björck *et al.* 1993). Again, the information on some of the taxa given in the literature can be misleading, because, even if one and another can be found on soil or on terrestrial lichen and mosses, they may also commonly live in a lake.

Palaeolimnologists over the whole world have contributed extensively to the understanding of the problems concerning acidification and eutrophication. However, to understand the aquatic ecosystems of the Antarctic and to interpret their historical development one must take into consideration, taxonomic and ecological uncertainties, the extreme environmental conditions (at least 8 months' ice-cover every year), and the possibility that some taxa may be derived from sea-spray, birds and terrestrial habitats. It seems easy to point to human influence in the temperate region, to show the eutrophication from nutrient enrichment, or the acidification caused by acid rain, but what can we point to as influences in the lakes from the Antarctic?

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ELECTRONIC INFORMATION RESOURCES FOR DIATOM IDENTIFICATION

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Identification tools for diatom taxonomy have been developed by individuals, research groups in a lab and those who research and maintain natural history collections. Participants in this Symposium, for example, have each developed cards with pictures (light micrographs, SEM's or other illustrations) to facilitate the identification of diatom taxa and chart the distribution of each taxon within a study. Natural history collections also construct these types of card files, usually directing users to a slide/specimen in the collection. These tools allow maximum flexibility in terms of changing the name of identified individuals, but these resources serve only 1-few individuals at (usually) a single place (the individuals home institution/the natural history collection). These tools serve to insure taxonomic consistency within a particular study, within a lab if such a resource is shared amongst the lab members, or by those who reference the resources of the natural history collection. Unless symposia/workshops like AADS are held, these tools, particularly those developed by individuals, are not used across studies.

Alternative diatom identification tools are published floras or iconographs. At this Symposium, for example, we have seen plates for an upcoming floristic study of diatoms in inland saline systems in western Canada. A published flora can serve, simultaneously, many users at many sites. In comparison to the resources produced by individuals for individuals, a flora addresses the need for taxonomic consistency across studies. But once published, the flora is fairly inflexible in terms of changing identifications/offering annotations to the determinations made unless addenda or errata are subsequently published.

A more attractive tool for diatom identification would be one that is flexible in terms of updating/annotating identifications and that serves a large group of users in multiple locations. The resource would be specimen-based, so that if taxonomic/morphological questions arise, the specimen(s) in question could be consulted.

The Internet is a venue to provide users with image resources that are tied to collections/specimens and provide additional data such as distributions over space and time as well as in relation to ecological parameters. Traditional natural history collection databases can be coupled with images of diatoms to provide this resource. Currently, natural history collection databases at CANA, CAS and ANSP can provide information such as a list of the areas where a particular taxon is found, from very general queries ("all records of *Gomphonema acuminatum*") to very specific queries ("records of *Gomphonema acuminatum* from Pliocene deposits of Shasta County, California" or "records of *Gomphonema acuminatum* where pH is greater than or equal to 4.5"). For each specimen record, an image could be captured and be part of the record. So, for each of the examples given above, there could also be an image or range of images for specimens for each record in the database.

One way to access this resource over the Internet is through the GOPHER. GOPHER is a hierarchical search protocol that is not field-based (in contrast to most database systems). Files, whether text or image, can be searched and transferred through GOPHER to a users computer over the Internet. Unfortunately, most versions of GOPHER cannot integrate text and image in a single transaction or query. In the current version of GOPHER, specimen records

must be searched first, then image files based on those records can be examined. However, systems that can search and integrate text and images are being developed (WorldWide Web; newer versions of GOPHER). The system envisioned here is one that provides collection resources to the broad set of users without those users having to physically visit the collections.

Of course, resources other than specimens from collections could also be developed in this information management system. Nomenclatural resources, images and text from historical works, or studies that synthesize bodies of information (e.g. Gaul *et al.*, guide to EM images of diatoms), could be part of this system. As these resources are developed and made available, users may have a computer beside their microscopes instead of several shelves of taxonomic works. The computer may serve to assist in taxonomic identifications, based on specimens in museum collections, images taken from major taxonomic works, and distributional data. This approach may not only lead us to a more consistent taxonomy, but facilitate research in areas not well supported by traditional tools. For example, we may be better able to assess variation in a taxon based on geographic distributions (examine images of a taxon from California and compare them to specimens from Alabama or Newfoundland), water chemistry (comparison of a taxon from habitats with differing pH, metal concentrations or temperature) or identifier (Anton Mayer's species concept versus Lange-Bertalot's).

In addition to providing access to many users distributed over wide geographic areas, the system could be outfitted with a "Comments" field through which users could offer alternative identifications and/or comments about the specimen ("I believe the specimen is not *Gomphonema acuminatum* but var. *brebissoni*-JP Kociolek-02/03/94"), references to specimens with same appearance ("see Foged, 1979, Pl. 23, Fig. 2 for a similar specimen") or additions to the temporal and/or spatial distributions for the taxon ("the taxon from Nevada as illustrated is also present in Australia"). This will facilitate interaction between users of the system, much in the same way workshops/symposia do today.

In summary, computer and database technologies exist today that can bring disparate resources of museum and university collections, specimen images, historical taxonomic works, and information on the temporal, geographic and ecological distributions of diatom taxa to many users worldwide. The potential utility of such a system should be more consistent taxonomy across studies, to facilitate interactions between workers and to support research programs in a way current resources do not. Information management tools developed on computers will allow collection resources to be brought to the users, instead of requiring them to travel to collections across North America and around the world.

OPPORTUNITIES FOR MUSEUMS IN DIATOM RESEARCH IN THE "90'S": NOTES FROM A WORKSHOP DISCUSSION

Donald F. Charles

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The importance and relevance of museums in the nineties is based on the same ideals and goals upon which they were founded. Museums hold the responsibility of passing on scientific information through teaching, preservation of natural history collections, and research. How can we secure existing funding or even increase revenues in order to insure that these roles continue and expand in scope?

Premise - The greatest opportunities in acquiring additional funding, for diatom herbaria and staff, are in Environmental Studies (biological monitoring, biodiversity, paleolimnological studies). Direct funding (internally and externally) for basic taxonomic and collection work is limited, a fact that the private academies in the United States have always had to deal with. The Academy of Natural Sciences of Philadelphia (ANSP) has strong programs in Education, Exhibits, Environmental Research, Systematics, Library development and a world renowned publication series. How is the academy adapting to the nineties? The academy sees a niche to be filled in "support" for environmental research/biodiversity. In addition, the academy recognizes the significance of a leadership role and the contributions that can be made by its research teams. In fact, the ANSP has a long history (since 1947) of environmental research, which at times has represented 40% of the total academy research budget. Strong associations with Federal, State/Province and Universities must be established in order to bring museums into a position that can support and "add value" to environmental research.

What are the Opportunities for Natural History Museums (Institutes)?

1. Taxonomy - Systematic support work; workshops; preparation of floras; taxonomic and systematic publications on environmental indicator species; checklists; training/teaching; the development of libraries of scanned biological images. In general, museums are providing taxonomic quality assurance. The obvious role the natural history institutes can play is long term sample and data preservation. The museums/academies must become involved in development of collection protocols and the standardization of data collection. Natural history Institutions could promote and become involved in a process to certify consultants and biologists for environmental surveys.
2. Ecological Data - The data associated with specimens; compilation of environmental calibration data sets; the creation of data bases to track and make data easily accessible.
3. Communication - Institutes must have Internet access. Natural History Institutions need to link taxonomy and ecological data. The ability to unite these data bases and make them accessible to the researcher community via electronic communication are the pivotal factors that will determine the success or failure of Natural History Institutions having ecological data collections.
4. Consulting - Involvement in environmental monitoring studies.
5. Archiving Samples - Storing and maintaining collections from environmental surveys. This could be the major "support" role or link that museums have with environmental research.

6. Public Education - Tours, lectures, doctoral fellowships, etc.

There are major advantages in linking environmental and biological (sample, count) data .

New Paradigm:

Natural History Institutions as repositories of ecological data as well as specimens. Unfortunately most museums do not see this as their role in science. In aquatics this role requires the long-term curation of water quality data. Environmental data and the ability to link it with specimen data using computer technology is "value added". The advantage of the new paradigm to Natural History is that it will lead to more collaboration and involvement in research and monitoring projects, and ultimately increased funding. Museums are the best place to keep environmentally significant collections over the long-term, they have considerable taxonomic resources available, and Natural History Institutions promote the use of materials by the scientific community.

In short, Natural History Institutions must buy into the concept of data sharing and partnerships in research. Environmental agencies in the U.S. are strongly committed to the concept that "data must become public" and the function of environmental research (Biodiversity) is geared to this requirement (e.g. PIRLA I, PIRLA II, E-MAP, PALE).

The European Perspective (an open discussion by participants)

The European Natural History Institutes (e.g. United Kingdom, Germany, Austria and others) are generally not interested in ecological data associations nor do they have software systems able to make these associations. Dr. Eileen Cox is starting an Ecological Research Program at the Natural History Museum, London which is tied to outside funding.

Questions that need to be addressed.....

1. Pat Kociolek posed the question: will people contribute their data and specimens? The consensus of participants was that researchers are interested in depositing significant collections and data sets, but are concerned about recent changes in natural history institutions (staff and funding reductions) and these effects on the ability of repositories to curate the collections and make data available.
2. What are the limitations in the curation of materials by museums?
3. What Institutions are committed to long-term data storage?
4. Are governments going to continue long-term ecological monitoring?
5. Are environmental data bases to be kept separate from biological data sets?
6. Should government sponsored environmental monitoring programs be required to deposit collections somewhere?
7. Natural History Institutions are having problems dealing with the question of ownership. Is ownership a relevant question in natural history? What is ownership? Who (if any one) owns the data?

M. Poulin What is the point of having algal specimens if you don't have water
(Comment) chemistry data to go with them?

APPROACHES TOWARDS UNIFYING NORTH AMERICAN DIATOM RESEARCH: NOTES FROM A WORKSHOP DISCUSSION

John P. Smol

Paleoecological Environmental Assessment and Research Lab. (PEARL),
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Ecological research dealing with diatoms continues to progress rapidly, and the number of applications, both practical and theoretical, continue to grow. Diatoms are especially powerful environmental indicators and have been successfully used in environmental monitoring and paleoecological reconstructions of past conditions. Major programs such as the Environmental Monitoring and Assessment Program (EMAP), Paleocological Investigation of Recent Lake Acidification (PIRLA I, II), Surface Water Acidification Programme (SWAP), Climate and Salinity Project in Africa and the Americas (CASPIA), Paleolimnological Investigations of Salinity Changes and Environmental Shifts (PISCES), and ongoing projects in high latitude regions are excellent examples of the power of diatom-based approaches. Moreover, researchers are often faced with an expansion of development in related fields that impact on diatom-based work (e.g. statistical methods, taxonomy, limnology, ecology, etc.). With this heightened interest and input of resources, we should seize the opportunity to make important strides in unifying and accelerating some of this research.

Progress has been made in addressing and standardizing some aspects of diatom work, such as in data management, statistical analyses, and field and lab methods. Progress has also been made with taxonomic problems, but considerable work remains. For example, some researchers continue to work in relative isolation. Since all environmentally based diatom research is ultimately dependent on consistent and defensible taxonomic designations, we must continue to emphasize the necessity of this work to administrators, managers, granting agencies, contractors, and the public. In general, we have not been very successful at communicating the importance of this work to most or probably all the above groups.

Environmental biology, for example, is generally supported by the public, government and granting agencies, yet little support has been garnered for the base elements of our work, such as for taxonomy, systematics, and collection management. It must be made clear, perhaps in forceful and creative ways, that these areas form the foundation of diatom-based environmental research. Communicating this information effectively will be a major challenge for diatomists. The onus is on us to get these messages out; no one else will do it for us.

Specific issues that should be addressed include:

1. More emphasis must be placed on diatom taxonomy and related fields. Diatomists must make the case for the resource allocation. Environmental research needs improved taxonomy and systematics.
2. Consistent protocols and other quality assurance and quality control considerations are being developed in the larger projects. This work should be encouraged and built upon.
3. Universities are often not effective users of museum resources, and so collections and personnel are not being used to their fullest potential. Communications should be improved between these two groups.
4. Biomonitoring studies will be used increasingly in the future. Diatoms are a very important biotic indicator groups for these types of studies, and have already been adopted by several agencies, most notably the United States Environmental Protection

Agency.

5. The development of a North American diatom flora may be an important step in achieving some of the above stated goals. Perhaps some of the largest diatom-based projects currently underway could initiate this work. In Canada, studies in the west, central and arctic regions could form the base for a diatom freshwa

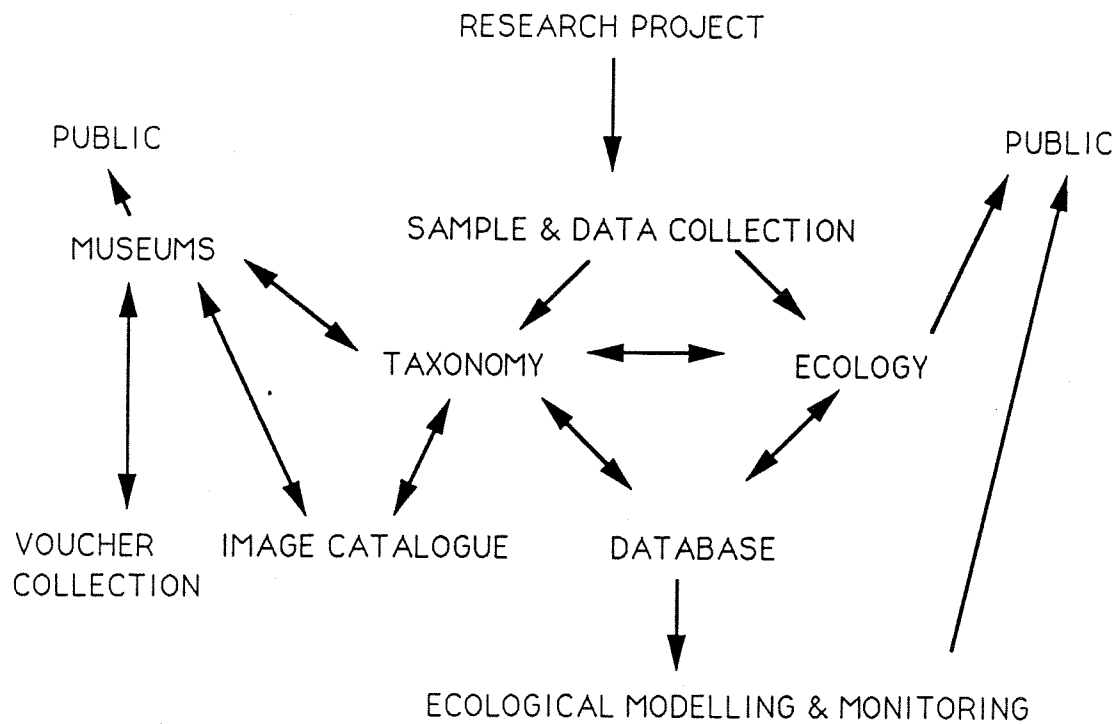


Figure 1. Schematic diagram of the interactions taking place during the period of a research study.

APPENDIX I. List of Participants at the Antarctic Arctic Workshops (1-4)

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**APPENDIX II. 4th Arctic Antarctic Diatom Symposium (Workshop) AADS
18th-21st September, 1994, Agenda**

18 th September	Day 1
9:00 hr	Opening remarks, Special issues & direction of polar research.
9:30 hr	Review & Update of taxonomic problems from previous workshops.
10:15 hr	Session one (Naviculales) <i>Navicula</i> spp.
12:45 hr	Session two (Naviculales) <i>Navicula</i> spp., <i>Sellaphora</i> spp., <i>Luticola</i> spp., <i>Craticula</i> spp.
15:00 hr	Demonstration of CMN Curator software.
15:30 hr	Continuation of Session two.
16:00 hr	Session three Special Topics: Computerized Taxonomic Identification Systems. Led by P. Kociolek
17:00 hr	Daily progress report.
19 th September	Day 2
8:30 hr	Session four (Naviculales continued) <i>Navicula</i> spp., <i>Sellaphora</i> spp., <i>Luticola</i> spp., <i>Craticula</i> spp.
10:15 hr	Session five (Naviculales) Pinnulariaceae, <i>Pinnularia</i> spp., <i>Caloneis</i> spp., <i>Navicula</i> spp.
12:45 hr	Session six (Bacillariales) Bacillariaceae, <i>Nitzschia</i> spp., <i>Tryblionella</i> spp., <i>Denticula</i> spp.
14:00 hr	Public Lecture (VMMB) Dr. John Smol "PAGES of the Past from Lakes"
15:30 hr	Special Topics: Approaches Towards Unifying North American Diatom. Research Led by J. Smol.
17:00 hr	Daily progress Report.
20 th September	Day 3
8:30 hr	Session six (Naviculales continued) <i>Navicula</i> spp.
13:00 hr	Public Lecture (VMMB) Dr. Hannelore Häkansson
14:30 hr	Session eight (Naviculales continued) <i>Navicula</i> spp.
16:00 hr	Special Topics: The Relevance of Museums in the Nineties. Led by D. Charles.
17:45 hr	Supper (Sponsored by the Canadian Museum of Nature and

held at the Victoria Museum building)

21st September

Day 4

8:30 hr

Compilation of data from taxa examined during the workshop. Assignments for the Naviculaceae to be produced from the symposium. Deadlines established.

10:15 hr

Technical Report outline defined. Contributions to the report established.

13:00 hr

Summary of meeting. Progress Report. Summarization of achievements. Future Directions & Publications. Production of minutes to the meeting

**APPENDIX III. 1ST ANTARCTIC-ARCTIC DIATOM TAXONOMY WORKSHOP
CAMBRIDGE ENGLAND, SEPTEMBER 28 - OCTOBER 2 1991**

Participants: A total of 6 participants in the 1st Antarctic Arctic Diatom Taxonomy Workshop.

Queen's University, Canada

Marianne Douglas

John Smol

University of Lund, Sweden

Hannelore Håkansson

University College London, England

Vivienne Jones

University of Stockholm, Sweden

Anders Wasell

Akademie der Wissenschaften, Austria

Roland Schmidt

REMARKS:

A workshop was held to examine the taxonomic problems facing paleoecologists working with freshwater diatoms in the Arctic and Antarctic. The aim of the workshop was to construct a brief taxonomic guide to the Antarctic-Arctic diatoms. Within the framework of this objective three procedures were identified.

1. To create taxonomic guidelines and make taxon related recommendations.
2. To define and document unknown taxa.
3. To identify problems where further research is needed.

A taxonomic guide... Individual species lists were used for comparison, and a list of problematic taxa was constructed. This list formed the basis of discussion (using photomicrographs and examining slides) over the four day period and enabled the production of the taxonomic guide listed below.

Species lists.... It was agreed that 2 taxa lists, one for the Arctic and one for the Antarctic should be drawn up. Marianne agreed to start the Arctic list, using her own taxa and existing literature. Hannelore will give a diskette containing her species to Viv who will include one new species of hers or Roland's (as in Schmidt *et al.* 1990).

In conclusion, we all agreed that the workshop had been very useful and many taxonomic concepts had been clarified. A number of major taxonomic problems were identified and it was hoped that progress on this problems would be achieved.

TAXONOMIC GUIDELINES (Taxa examined)

Achnanthes coarctata

The species seems to be clearly defined in the Arctic. However, Wasell & Håkansson (1990) discuss the problem with *A. coarctata* var. *constricta*. Lange-Bertalot & Krammer (1989) synonymise *A. coarctata* var. *elliptica* Krasske and *A. coarctata* var. *constrictum* with *A. coarctata*. However, they do not illustrate the variety *elliptica* and there is only a poor illustration in Krasske (1939).

Achnanthes delicatula

We all have a species which is identical to that illustrated by K. & L.B. (1989, Pl. 81, Figs. 26-31.) RS notes that there are two sorts of central areas. RS has an "epsilon" area and VJ a more "elliptical" area.

Achnanthes exigua

We seem to have the nominate form in the Antarctic.

Achnanthes lanceolata

Some of these forms have the "tunnel" (Schmidt *et al.* *Achnanthes lanceolata* var. *frequentissima*) whilst others have a "horseshoe" (Schmidt *et al.* *Achnanthes lanceolata*) which can be seen in SEM. Lecohu & Maillard (1983) illustrate these "tunnel" forms.

Achnanthes incognita

This is a common taxon in the Antarctic.

***Achnanthes lapponica-laevis* complex**

L.B. & K. (1989) include *A. lapponica* in *A. laevis* as a variety (*A. laevis* var. *quadratarea*). However, RS believes this is something different.

Achnanthes minutissima

Is abundance in the Antarctic. HH also recognizes *A. affinis* and *A. linearis*.

Achnanthes microcephala

This species appears to be much more common in the Arctic.

Achnanthes mollis

This species is synonymous with *A. abundans* and is common in the Antarctic.

Achnanthes metakryophila

This is described by Schmidt *et al.* (1990) and is common in the Antarctic. The related species *A. kryophila* is discussed in L.B. & K. (1989) and the "lectotype" is illustrated in Figs 23, 24 and we should follow these illustrations.

Achnanthes renei

This species is described and illustrated by Schmidt *et al.* (1990). In SEM this form shows raphe fissures bending in opposite directions (Fig. 7/o). Common in the Antarctic.

Amphora veneta

The Antarctic form appears to be closely related to the *A. veneta* var. *capitata* Haworth (1974). See Schumman & Archibald (1976-80) for illustrations. In the Arctic MD has both the nominate and the variety. AW has another very distinct form, which fits into the range of *A. veneta* but is wider and will be described by AW in the future.

***Aulacoseira* sp.**

VJ has the *A. distans* complex and RS has *A. alpigena* var?. Comparisons will be made.

Brachysira minor sensu Jones

This taxon is found in the Antarctic and will be further studied.

Fragilaria pinnata

This is found in both Arctic and Antarctic as a common species.

Fragilaria construens

AW & HH (in prep) show some very rounded forms they call *F. construens* var. *venter*.

Gomphonema angustatum-angustata-parvulum-gracile

This is a difficult group with few features which can be used in LM identifications.

AW & HH (in prep) have shown that there are differences in the pore fields, which may be useful in SEM, but not so useful in LM. RS distinguishes the variety (*G. angustatum* var. *subelliptica* Cleve). This is nearly symmetrical (12-16 μ m long, 4.5-6 μ m wide with 13-14 striae in 10 μ m). This complex is a serious problem!

Navicula australomediocris

Species described by Schmidt *et al.* (1990) and is common in the Antarctic.

Navicula bergeri

See K & LB (1986, Pl. 78, Figs 17-20.). This species will be transferred to *Pinnularia*. The description reads "valves parallel, but seldom concave, 10-16 μ m long,

1-3.6 μm wide, thin raphe, fairly widely distant in the central area. Axial area is very variable. Central area is big, striae parallel to weakly radiate, striae a little bit shorter in the central area for 1-2 striae, 10-17 in 10 μm . Often found in mosses.

Navicula cancellata

AW & HH (in press) describe this form in the brackish phase of Skua Lake. MD has *N. cf. cancellata*. AW will send Skua Lake material to MD for comparison.

Navicula elginensis

K & LB (1986) illustrate the lectotype of this species (Pl. 46, Fig. 1) and we should follow this. There is a similar species *N. dicephala* described by Ehrenberg, but which is not mentioned by K & LB (1986). HH will look at Ehrenberg material.

Navicula gregaria

AW & VJ have a taxa which is the same as that illustrated by K & LB (1986, Pl. 38, Fig. 15). There are problems locating the type material of this species and this is discussed by AW & HH (in prep). HH will circulate a description of *N. molesta*.

Navicula ignota

MD had *N. cf. ignota* with a finer striae count (Douglas 1989). This species has not been reported from the Antarctic.

Navicula naumanii

This species is found in the Antarctic. See Schmidt *et al.* (1990).

Navicula perminuta

This is illustrated by K & LB (1986, Pl. 35, Fig. 19). The problems with this species, *N. diserta* and *N. hansenii* are discussed by AW and HH (in prep).

Navicula tantula

K & LB (1986, Pl. 76, Fig. 47) illustrates this species from the Hustedt collection. It is a common taxa from VJ's material (Signy Island).

Navicula tabellariaeformis

This species is fairly common in the Antarctic, see Schmidt *et al.* (1990, Fig. 7/r). JS will check to see if he has this form in the Arctic.

***Navicula contenta-perpusilla-gallica* complex**

These forms are difficult to separate when small. K & LB (1986) makes *N. perpusilla* a variety of *N. gallica*, but it is not clear why. RS will check with Lange-Bertalot.

***Navicula mutica-muticopsis-cohnii* complex**

According to K & LB (1986) *N. mutica* has an elongated isolated punctum whilst in *N. muticopsis* and *N. cohnii* this is a round punctum. K & LB (1986, Pl. 53, Figs 8-9) illustrate the distinctive raphe ends of *N. mutica*. It should also be noted that there are problems with the type material of these forms.

***Navicula* sp. 1**

VJ & HH have a taxon which HH calls *N. cohnii*, however it lacks the isolated punctum.

***Nitzschia perminuta* complex**

This complex is extremely difficult with much confusion. See the next series of workshops for more information on these taxa.

Nitzschia hamburgensis* & *Pinnularia divergens

This species are common in the Antarctic material.

Pinnularia spitzbergensis

HH has a form of *P. cf. spitzbergensis*.

Pinnularia microstauron*, *P. gibba

There are problems distinguishing these species according to K & LB (1986). *P. gibba*: "parallel to slightly convex sides, end are blunt, not capitate. 50-140 μm long, 7-13

µm wide". Raphe clearly lateral, relatively small central pores (of raphe ends) and raphe ends are near to each other, It has ? raphe ends. Axial area very variable from small linear to broad, always broadening to a central area. Central area is long elliptical, fascia very variable and can be unsymmetrical, often missing on one side. Direction of striae very variable. Weakly to slightly radial striae 9-12 in 10 µm. Submarginal longitudinal lines can sometimes be seen."

Pinnularia microstauron: "parallel to slightly convex sides, ends can be slightly sharp, 20-90 µm long, 7-11 µm wide. Striae in the middle are parallel to strongly radial, slightly to strongly convergent at the ends, 10-13 striae in 10 µm. Submarginal longitudinal lines can sometimes be seen." We take a liberal view of *P. microstauron* and follow K & LB (1986, Pl. 191-192). We also recognize a variety *P. microstauron* var. *brebissonii* with a distinct "waist". We reserve *P. gibba* for forms with spatulate ends.

Stauroneis phoenicenteron

We distinguish this from *S. anceps* using striae count, following Patrick & Reimer (1966) which should be less than 20 in 10 µm.

Stauroneis anceps

HH has distinguished 3 groups which are illustrated in Björk *et al.* (1991, Fig. 10).

1. "anceps" form with a distinct bow-tie middle, 20s in 10 µm. (a, b, & e).
2. form with a bow-tie middle, but with a squatter shape (c & possible f).
3. "fo. *hyalina*" Form with a more parallel central area, with elongated ends and >25 striae in 10 µm. Patrick & Reimer (1966) also recognize a fo. *linearis* Cleve, which is also described by Foged. In the Arctic MD recognizes a forma *linearis* Cleve, which is also described by Foged. The importance of the presence or absence of a pseudoseptum in *S. anceps* is confusing. According to Cleve-Euler, the presence of a pseudoseptum is used to separate two groups within *Stauroneis*. Lange-Bertalot (1986) states that *S. anceps* does not have a pseudoseptum but then goes on to include a variety *japonica* which does! In our Antarctic material there is no pseudoseptum, but in Arctic material there is often a pseudoseptum. The taxonomic importance of the pseudoseptum needs to be clarified.

Synedra rumpens

A forma *S. rumpens* fo. *familiaris* is distinguished by Hustedt (1922-66) which is characterized by its inflated central area. However, RS uses the fo. *familiaris* for short valves forming long chains.

A photomicrographic plate of 31 taxa was produced for this workshop. Although the plate is not reproduced here, the taxa are listed below.

- | | |
|--|---|
| 1. <i>Fragilaria construens</i> var. <i>binodis</i> | 20. <i>Gomphonema angustatum/gracile</i> |
| 2. <i>Nitzschia</i> sp. | 21. <i>Navicula gregaria</i> |
| 3-4. <i>Nitzschia frustulum</i> var. ? | 22. <i>Achnanthes incognita</i> |
| 5. <i>Nitzschia perminuta</i> ? | 23. <i>Navicula seminulum</i> |
| 6. <i>Nitzschia frustulum</i> ? | 24. <i>Pinnularia</i> sp. 1 |
| 7. <i>Nitzschia perminuta</i> ? | 25. <i>Fragilaria construens</i> var. <i>venter</i> |
| 8. <i>Nitzschia palea</i> sensu Jones | 26-27. <i>Achnanthes</i> sp. |
| 9-10. <i>Achnanthes linkei/delcatula</i> var. <i>australis</i> | 28. <i>Melosira roseana</i> var. <i>dendrophila</i> |
| 11-13. <i>Achnanthes lanceolata</i> | 29-30. <i>Pinnularia microstauron</i> |
| 14-16. <i>Achnanthes lanceolata</i> var. <i>frequentissima</i> | 31. <i>Amphora veneta</i> var. <i>inflata</i> |
| 17. <i>Cyclotella bodanica</i> var. <i>lemanica</i> | |
| 18-19. <i>Cyclotella kiesseleri</i> | |

**APPENDIX IV. 1ST ARCTIC DIATOM TAXONOMY WORKSHOP
(PART 1 OF THE 2ND ARCTIC/ANTARCTIC WORKSHOP),
KINGSTON, ONTARIO, FEBRUARY 27-28, 1992**

Participants: A total of 9 participants in the 1st Arctic Diatom Taxonomy Workshop.

Queen's U.
Marianne Douglas
Roland Hall
Katrina Moser
Reinhard Pienitz
John Smol
Susan Wilson
Alex Wolfe

Universtiy of Western
John Ng

Canadian Museum of Nature
Paul Hamilton

Opening Remarks (John Smol):

John welcomed the participants to the workshop and briefly mentioned some of the topics that he thought should be discussed over the course of the meetings. Given the nature of our sampling sites, we will concentrate on mainly freshwater flora from lakes and ponds. Topics that would eventually be placed and considered on our agenda would be: sampling protocol, statistics, photographic standards and frequency of our meetings.

Workshop notes:

The following is a summary of our workshop discussions, taxon by taxon. We identified photographs in key references as recognized standard examples. In other instances, we identified a specific photo from our own photographic plates to serve as a standard example. Although we dealt mostly with taxonomic concerns, we also noted sites where we had observed the particular taxon. The following is a list of the geographic locations and their abbreviations, included in our samples:

CH	Cape Herschel, Ellesmere Island	YUK	Yukon
FP	Fosheim Penninsula, Ellesmere Island	YEL	Yellowknife
HWKL	Hawk Lake, West Hudson Bay	UNG	Ungava
PD	Pond Inlet, Baffin Island	WBP	Wood Buffalo Park
LH	Lake Hazen, Ellesmere Island	Park	Lake Hazen (National Park)
TL	Truelove Lowland, Devon Island		

REFERENCES:

Rather than listing ALL the diatom references used, it suffices to say that we had most of the standard texts (e.g. Hustedt, Cleve-Euler, Foged, etc) and some of the newer publications (e.g. Krammer & Lange-Bertalot, 1986, 1988, 1991a & b, Round *et al.* 1990) as well as an extensive collection of taxonomic literature.

We decided to start our session with a discussion of the centrics, as we thought this would be a nice, simple group to work with (hah). We then considered the pennates. We identified

troublesome groups that we would work on for the next meeting.

***Cyclotella tripartita* Håkansson**

Photo: (see KLB, 1991) See Korotkevich #3c. Is this the same as *Cyclotella kisselevi*.
Locations: HWKL, LH, YUK, YEL, PD, FP

Cyclotella rossi* = *C.kuetzingiana* var *radiosa

2 - 5 lineate depressions

Photo: KLB (1991) Pl.64.

vs *Cyclotella ocellata*: 3 - 5 isolated distinct depressions.

***Cyclotella* cf. *rossi* = Species 1 (Paul Hamilton)**

puncta not in linear pattern and more fan-shaped (branched out), randomized.

Photo: 92-05-20 (PH). Also, see Antarctic WKSP PI 1, 18-19, Korotkevich #3a,b.

Locations: FP, PARK?, UNG

Cyclotella antiqua We all agreed that this benthic taxa was a cold stenotherm and had a uniform distribution.

Cyclotella stelligera

We recognize *C. stelligera* not to include *C. pseudostelligera* and *C. glomerata*.

Cyclotella* cf. *delicatissima

See Carter&Bailey-Watts (1981) Shetland Islands.

Photo: Yuk 8 fig. 22 (RP)

Location: Yuk

***Cyclotella bodanica* var *affinis* fo. 1**

- narrow marginal striae

- coarse, organised punctae

Photo: KLB Pl. 58 fig. 1-4

***Cyclotella bodanica* var *affinis* fo. 2**

- large marinal striae

- coarse organised punctae

Photo: KLB Pl. 58 fig. 5,6

Cyclotella bodanica

- central area is very large and valve face is flat. Marginal area is approx. 1/4 of diameter.

Photo: KLB Pl.54, fig. 2,3,4.

***Cyclotella bodanica* var *lemanica* forma 1**

longer marginal striae.

Photo: Håkansson 1988. (Fig.31) & KLB (1991) p.341. PI 55 Fig 1-7b.

***Cyclotella bodanica* var *lemanica* fo. 2 shorter striae**

Photo: Håkanson (1988) Fig 33; KLB (1991) p.347 PI 58, 1,2,4,6.

Cyclotella bodanica* var *bodanica

- smaller areolae in central area = denser (finer)

- relatively shorter marginal zone (1/4 of entire diameter)

- slightly undulate

Photo: KLB(1991) p.339. Fig 1,2.

***Cyclotella bodanica* var 1**

Photo: Plate 3, fig. 4 (RP)

Location: UNG

Aulacoseira alpigena

Small simple spines. R. Pienitz noted that this could be *A. lirata*; because of potential

confusion, we need to do more work on this.
Photo: KLB (1991) p.235. Pl.2 Fig 7 (SEM)
Location: FP

Aulacoseira subarctica

Photo: KLB (1991) Pl.23, Fig 1-11.
Location: FP

Aulacoseira italica* var *tenuissima

longer, thinner, need to see EM, should see club-shaped, spine not pointed
Photo: KLB (1991) Pl.25 Fig 11.
Location: UNG

Aulacoseira valida

An SEM is required.
Photo: PI 3, fig. 1-3 (RP)
Location: UNG

Aulacoseira distans* var *nivalis

Location : FP, CP

Catenula

This genus resembles an *Amphora* with no striae. See p, Round et al. (1990).
Photo: Plate 6, fig. 30 (MD)
Location: CH. - this particular taxa could represent a new species.

***Ellerbeckii arenaria* var *teres* (= *Melosira arenaria*)**

New genus. The chloroplast is different from *Melosira*. The cell takes up almost the entire field of view.
Location: HWKL

Epithemia sorex* vs *E. smithii

E. sorex has a continuous interfibulum. This is easily seen in K/LB (1991) PI 106, Figs 1 - 13. However, in *E. smithii*, there is a discontinuity in the interfibulum on the proximal side. (See K/LB, PI 106, Fig 1 - 5). In order to distinguish between the two, the following criteria could be used:

E. smithii ≥ 3 inter-interfibular striae

E. sorex < 3 inter-interfibular striae

However, we don't like using the number of inter-interfibular striae as a distinguishing character. It ultimately only reflects the spacing of interfibula, not striae, and therefore we suggest directly looking at the number of interfibula. If this latter is followed, then we find:

interfibula: *E. sorex* > 10 , *E. smithii* ≤ 10

In the case of overlaps (~ 10), one should look at the continuity of interfibula.

Photo: Ungava PI 5, fig. 22 (*E. sorex*) and fig. 23 (*E. smithii*)

Location: PARK, TL, FP, HWL, UNG, YK

Nitzschia acicularis

Briefly, the following points were observed:

- striae too faint to be seen, even in SEM
- straight pointy apices
- no central area/nodules

Location: PARK

Nitzschia* cf. *amphibia

- can see definite punctae (coarsely punctate)
- strongly silicified

- apiculate

We need EM's of this group.

Location: UNG, CH, PARK

Nitzschia sinuata

There is a long type and a short type. These could be distinguished. Also, *N.s.* var *tabellaria* is recognized by R.P in UNG.

Location: CH, TL, PARK, UNG

Nitzschia angustata

Location: UNG, YK, YUK, TL

Nitzschia dissipata

Location: TL, Pd, CH, WBP, YK

Nitzschia* cf. *flexoides

Location: PARK

***Nitzschia commutata* (vs *Hantzshia*)**

The discussion focussed on nitzschoid vs hantzschoid morphologies, concluding that *Hantzshia* cannot be identified by non-paired valves, and that errors have been transmitted in both Germain's and Round et al's books.

At the next meeting, we will "blitz" on *Nitzschia*. This will include the hantzchiana and fonticola groups.

Orthoseira roeseana

Photo: KLB (1991) Pl 10, Fig 1-11

Location: CH

Stephanodiscus

Participants should bring SEMs for further clarification at the next meeting.

S. alpinus appears to have fascicles closer together/?? SW *S. medius* fascicles slightly further apart and sometimes wavy. KM might have *S. parvus* and *S. minutulus*. This will have to be distinguished at a later date. See above note.

Stephanodiscus transylvanicus

Identified by characterization on strutted processes, interstriae, 3-4 rows of punctae in fascicles. SW, KM, RP and RH will put pictures/SEMs into portfolio. 28 species are recognized amongst this group.

Location: UNG

Stephanodiscus niagare

Location: Ungava

Hyalodiscus scoticus

Location: HWKL, UNG, TL

CONCLUSIONS:

We consider this first Arctic meeting to have been quite successful. We were able to become familiar with participants' projects and the direction that future meetings should take. We were able to determine problem groups/taxa which would require more attention than others.

**Appendix V. 2ND ARCTIC DIATOM TAXONOMY WORKSHOP
(PART 2 OF THE 2ND ARCTIC/ANTARCTIC WORKSHOP),
KINGSTON, ONTARIO, APRIL 30 - MAY 1, 1992**

Participants:

Queen's University

Brian Cumming
Marianne Douglas
Katrina Moser
Reinhard Pienitz
John Smol

University of Western

John Ng

Canadian Museum of Nature

Paul Hamilton

Sessional appearances by special guests Roland Hall and Cathy Christie.

Business from the previous minutes (Feb 27 -28, 1992):

The minutes of the 2(a)nd Arctic Diatom Taxonomy Workshop (February 27 - 28) were circulated by J.P. Smol to several people (other than the participants), in order to get feedback from those who would eventually like to participate in these workshops. At least two responses were received (see Appendix A, these minutes), and they concerned the same point. Briefly, both P. Kociolek and G. Stoermer voiced concern over our "lumping" of *C. stelligera* to include *C. pseudostelligera* and *C. glomerata*. The respondents were also concerned about the lack, or near lack, of outside help for the workshops, but John Smol assured everyone that money etc will be available for travel etc for experts to take part in the workshop.

Taxonomic Discussions:

Cyclotella stelligera* vs *C. pseudostelligera* and *C. glomerata

Because of the concern voiced by Kociolek and Stoermer (see above paragraph), we discussed the group once again and came up with the following criteria as to how we could differentiate between the various forms.

C. stelligera* vs *C. pseudostelligera

Can these be distinguished by size? Based on Chang (1991)¹ *C. stelligera* can be distinguished based on the following important characteristics:

- size - usually > than 8 μ m
- distinct dome (central area), well developed star pattern in centre (not well developed in *C. pseudostelligera*)
- distinct marginal striae which are separated from the central dome by a hyaline ring.

Based on KLB, *C. stelligera* size range = 5-40 and

C. pseudostelligera size range = 4-10 ; marginal zone more randomized in the

¹ Chang, T.-P. Elektronenmikroskopische Untersuchungen an dem Typusmaterial der zentrischen kieselalge *Cyclotella stelligera* Cleve et Grunow. Diatom Research 6(1):1-14.

latter form.

Cyclotella glomerata

According to KLB (H. Håkansson):

- size range = 3-8
- Between fine marginal striae, there are convex interstriae (14-17/10 μm).

These are difficult to see in LM.

- Mantle (which is very narrow) has regularly spaced strutted processes; in *C. stelligera*, these are tubelike marginal processes (which look like short spines), situated high on the mantle ; in *C. pseudostelligera* tubelike openings of strutted processes are longer, and strongly developed and situated high on the mantle (in LM, easily interpreted as spines)
- Because of this size overlap, it is imperative to have an SEM of the smaller forms in order to be able to tell which one is present.

KLB still distinguish the species by middle field (starlike or not?) which may or may not be present. So basically they are going by gut feeling: dome like in *C. stelligera* but not in *C. glomerata*.

- From Chang's table, one should be able to distinguish the three based on their striae count. We will examine this relationship to see if it's consistent.

Finally, do both *C. glomerata* and *C. pseudostelligera* coexist? If so, there could be a problem due to overlap?

Nitzschia flexoides

KLB (2/2) Pl.10 fig 1-5.

P. Hamilton showed examples of this one. NB. flap over central area.

Photos: PH (LM 91-05-25) and PH (SEM 70483)

Location: FP LH

Nitzschia sigmoidea

KLB (2/2) PI 4 fig 1,2; PI 5, fig 1-5.

Photo: RP LM (423-34)

Location: UNG

Nitzschia obtusa

KLB (2/2) Pl. 17

Photo: JN (Roll 1 #15)

Nitzschia angustata

KLB 2/2 PI 36 fig 1-5.

Length 25 - 180 μm ; width 4 - 12 μm ; striae count = fibulae count

Location: TL UNG YUK YEL; RP notes that there is a widespread distribution but that it never occurs in high numbers.

Nitzschia cf commutata

var 1: attenuated capitate ends

Photo: PH (7480); RP (PI 3 # 20, 21, 23)

Location: FP, LH, YUK

var 2: capitate ends (i.e., not drawn out)

Photo: PH (3575); RP (PI 3 #22)

Location: FP YUK LH

var 3: This form has a central/hyaline area on the mantle below the central raphe endings. This can be seen from the girdle view. Perhaps these are the same as var 2.

Location: FP, LH

Nitzschia fonticola

Syn *N. romana* according to KLB

KLB 2/2 PI 75 1-22: shape: small condensed lanceolate, stubby, rhombic. Punctae are finer and striae count higher/finer than in *N. frustulum*. At SEM level, near raphe, punctae become bi-multiseriate. Also ridge seems to be the same in both.

Photo: PH (3542) NB: This specimen might actually be *N. lacuum*.

Location: WBP UNG YUK YEL PARK FP

N. frustulum

KLB 2/2 PI 68 fig 1-8: coarser striae, slightly undulate valve surface; form is more linear lanceolate; punctae are situated in troughs/depressions, and there are "ribs" between the striae.

Photo: PH (3591)

NB. The question of the "space" between the interfibulae needs to be examined more closely. PH noted that there doesn't appear to be any difference between internal and external views. i.e., in the internal views, is there a space between the central fibulae? In this respect we differ from the saline lakes workshop in which they do include the central fibulae space as a conservative feature. See Table 1 (these notes).

PH will also check the raphe deflection in terminal raphe ends. Some appear to be going up, others down.

Location: Park FP TL UNG

N. perminuta

KLB ref (see Table 1): more elongated shape/linear, distinctly capitate, higher striae count (generally, some overlap exists with *N. frustulum* 19 - 30 striae/10 μ m; *N. perminuta* 26 - 32 (36) striae/10 μ m) *N. perminuta* 10 - 16 fibulae/10 μ m.

NB: PH in (Photo # 1614) notes a structure, a ridge, on the side opposite the raphe side that goes the length of the valve. He will investigate this further - hopefully he will be able to tilt the valve in order to see more.

Another specimen of PH (DT-78-28) is similar to KLB PL 72 fig 16. There was some thought that this might be *N. suchlandtii*.

N. suchlandtii

KLB PI 66 fig 12 - 16: valves lancetulate and linear, capitate higher striae count (34 - 37 striae/10 μ m), fibulae 13 - 16/10 μ m.

This could be confused with *N. perminuta* individuals. The ends here would be more wedge-shaped.

N. lacuum vs *N. bacillum*

This also adds confusion to the group. Based on KLB, we came up with the following notes to distinguish between the two:

N. lacuum

35 - 40 striae /10 μ m

raphe is continuous, otherwise there is complete overlap with *N. fonticola*.

N. bacillum

27 - 32 striae/ 10 μ m

This diatom has a wider transapical rib structure.

Generally, *N. bacillum*, *N. lacuum* and *N. perminuta* have continuous raphes.

N. liebetruithii

syn. *N. frustulum* var *perpusilla*

KLB state that its ecology is high electrolyte waters and is distinguished from *N.*

suchlandtii and *N. perminuta* based on this ecology.

N. inconspicua

This is KLB's name for *N. frustulum* var *subsalina* (Hustedt). There is some confusion here as this diatom might be related to *N. perminuta* (see CASPIA notes) because *N. inconspicua* might include *N. frustulum* var *perpusilla* and var *perminuta*. This too is a high electrolyte taxon. We stand by to wait and see what TIGER has to say about it.

N. acicularis

KLB PI 85 fig 1-4

Hein (1990) PI 32 fig 8

Location: Park (as noted in last workshop) and RP notes that this is very abundant in YUK (Tuk).

***Nitzschia* spp.**

KM presented her *Nitzschia* species 1., found on RP's YUK slide. Photo (Reference KAM film 91-3). Thought to be *N. cf pura*, see KLB PI 58 fig 1-9.

Nitzschia coarctata

KLB PI 38, figs 13 - 15a

syn *Psammodictyon mediterraneum*

Poulin *et al.* (1990) figs 99 - 102 (striae count too small)

We looked at MD's photo HL3-24,25. Depending on the author's taxonomy (ie. Brits or Germans, the diatom might be either a *Psammodictyon* or a *Nitzschia coarctata*)

N. valdestriata

KLB PI 84 9-12

Location: YUK YEL

Then on to the differentiation of *Nitzschia* vs *Denticula*, e.g., based on its internal valve structure, *Nitzschia denticula* is really *Denticula kuetzingii*.

Table 1: Summary table of various *Denticula* species, based on KLB.

species	KLB reference	Length	Width	striae	fibulae
<i>D. elegans</i>	PI 96, 10-33 PI 97, 1-5	15-45	4-8	15-18	2.5-5
<i>D. kuetzingii</i>	PI 99, 11-33	10-120	3-8	13-18	5-8
<i>D. subtilis</i>	PI 96, 1-9	7-20	2-3	23-30	6-10
<i>D. tenuis</i>	PI 95, 4-25	6-42	3-7	25-30	5-7
<i>D. valida</i>	PI 97, 9-17 PI 98, 1-7	28-65	7-11	16-20	2.5-4

D. elegans

KLB PI 96, fig 10-33, esp. fig 12 & 13 are typical of the variety. PI 97, fig 1-5

Fibula count is comparative with *D. valida* but can differentiate between the two based on L:W.

Location: UNG

D. tenuis

KLB PI 95 fig 4-25

- septa are very prominent and have an even consistency

- high size variability; high striae count

- SEM internal view reveal a row of "knobs" on each side of valve. PH will explore this further and see how consistent they are. In girdle view nodules are not as extensive as in

D. elegans.

Location: Park CH UNG

D. subtilis

- small, high striae count. Striae multiseriate. high septa count
- Septa are not as strongly developed as *D. tenuis*
- flat surface, raphe doesn't seem to be on a ridge in "typical" *Denticula* form

Location: FP, Park

PH finds an unknown, similar to *D. subtilis* (Photo 6503) in which the septa are not complete.

Denticula kuetzingii

- external flat surface
- internal knobs on internal view; however these are not always strongly silicified.

Photos: PH SEM 3579; LM 91-02-20 ; RP LM PI 5, 24

Location: Park UNG TL CH

PH notes a problem species that is difficult to separate out from *D. kuetzingii* and *Nitzschia* because of possible internal fibula that are more similar to *Denticula*. Found in mid to high electrolyte waters.

Fragilaria

Fragilaria is one of the most important genera in the Arctic. Recently, this group has been subdivided into five new genera by Round et al. (1990). As there is still some disagreement with these new divisions (see Lange-Bertalot (1991) Nova Hedwigia 49:79-106 and Krammer and Lange-Bertalot, 1991) the group has agreed to use both the old *Fragilaria* names and the new Round et al. names. Round et al.'s groupings are as follows:

1. *Staurosira* = *F. construens*
= *F. elliptica*
2. *Pseudostaurosira* = *F. brevistriata*
= *F. construens* var. *binodis*
= *F. pseudoconstruens*
3. *Fragilariforma* = *F. acidobionticae* etc.
4. *Punctastriata* = *F. pinnata*
= *F. lancettula*
5. *Staurosirella* = *F. pinnata*
= *F. lapponica*
= *F. leptostauron*

Much of the discussion about *Fragilaria* centered around on Round et al.'s work. Although there was some agreement with this work, there was some criticisms based on observations of arctic material.

Forms of *F. pinnata* have been split into two groups, *Punctastriata* and *Staurosirella*, depending mainly on whether the fine structure of the areolae is slit-like or punctate. Lange-Bertalot (1991) and Krammer & Lange-Bertalot (1991) argue that there are many intermediate forms and that in fact punctae may be eroded to slits. This occurs mainly through erosion of the so-called "Verbindungsörnchen" = linking spinule). Many species exist which contain both punctate and slits. This is illustrated in Lange-Bertalot (1991, table 3, fig.2) and in Krammer & Lange-Bertalot (1991, pg.492, table 131, fig.2).

Another criticism of Round et al.'s divisions is the use of spine shape as a conservative distinction between genera. Dichotomous spines (club-shaped) were used to define the genus *Staurosira*. However as noted by Lange-Bertalot (1991), the ends of the spines are easily broken, giving them the appearance of simple straight spines, suggesting that this is not a good diagnostic feature. Two good illustrations of this are found in PH's work, CANA SEM photographs 2906; 2908.

***Fragilaria pinnata* (= *Staurosirella pinnata*)**

Although Round et al. (1990) suggested that most *Fragilaria pinnata* were punctastriate forms, SEM's of Arctic diatoms consistently showed slit-like aerolae and therefore, have been denoted as *Staurosirella* - it was noted that punctate-like structures should be watched for in future work.

Photo: SEM - 002825 (MD); 002833 (MD); MEB 94 616-623 8190 (RP)

LM - Pl. III #15,16,17 (RP)

Location: CH (downcore), HWLK, WBP, UNG, YUK, YEL, TL, LH, FP

***Fragilaria pseudoconstruens* (= *Pseudostaurosira pseudoconstruens*)**

-differentiated from *F. pinnata* by the following:

1. thicker striae formed by visible areolae

2. striae do not go all the way across the valve - there is a central area

Photo: KLB Pl. 130 #26-30; CANA SEM photograph 2936 (PH); Pl. 3 #10 (RP);

Hawk Lake A19 (MD)

Location: FP, HWKL, LH, YUK, YEL, UNG

***Fragilaria construens* (= *Staurosira construens*)**

- finer striae than *F. pseudoconstruens*; not punctate

- striae complete across valve

Photo: LEM - WBNP 91-1 S24-4 (KM); KLB plate 132 #6

Location: WBP, YUK, YEL, TL, UNG

After discussing these three *Fragilaria* species, varieties of *F. pinnata* were examined in detail. It was agreed that *F. pinnata* would be divided into varieties based mainly on shape. It was also agreed that only those *F. pinnata* exactly meeting the given criteria of a particular variety would be given a var. ending, otherwise they would be included into the nominate variety.

Fragilaria pinnata* var. *acuminata

Photo: PIRLA Pl. 24, #83, 84; YUK-U1 91-3 (KM)

Location: YUK

Fragilaria pinnata* var. *lancettula

- distinct lancettulate form

Photo: Germain Pl. 21, #44-46; LAP 7 (4/3) (RP)

Location: TL, YUK

Fragilaria pinnata* var. *intercedens

- this variety still causes some confusion - different people have interpreted and included a variety of forms into this group indicating that the division is fairly subjective

- the following criteria were agreed on by the group:

1. larger form

2. parallel sides

3. coarser intercostal area and striae

Photo: PIRLA Pl. 24, #90 - disagree with PIRLA Pl. 24 #91 as it seems to be too short

- also disagree with KLB table 133 #19-23

Location: FP, Park, CH (down core), TL, YUK, YEL, UNG

Fragilaria pinnata* var. *ventriculosa

Photo: Foged (Alaska) Pl. IV, #20; YUK-U1 91-2 (KM)

Location: YUK, UNG, YEL, TL

Fragilaria pinnata* var. *cf. subrotunda

- perfectly round in shape

Photo: KLB Pl.133 #2; Stub 181 Hawk Lake 000186 (MD); DT- 80-5 (PH); Pl.1 #1-3 (AW)

Location: UNG, YEL, YUK

A variety of *Fragilaria construens* was also considered.

Fragilaria construens* var. *venter

-circular to elliptical in shape

-simple areolae

N.B. if you can see distinct punctae in the costa, call it something else (for example see KLB Pl. 130 #31-40) - possibly *F. elliptica*

**** Also it was noted that we should be aware of a similar diatom called PIRLA sp.4 (see PIRLA Pl.25 #124, 125, 126). It is also thought that this diatom is illustrated in KLB Pl.132, #9, 10, 14. R. Hall has previously observed and counted this species in material from south eastern Ontario lakes. Also be aware of PIRLA sp. 2 (see PIRLA Pl. 25, #117-120 incl) which may also be illustrated in KLB Pl. 132 #6.****

Photo: KLB Pl. 132 #13, 16, 10(?);

LM: WBNP S24-2 91-7 (KM)

SEM: CANA 2907, 2908 (PH)

Location: TL, UNG, YEL, YUK, WBP, Park, FP, Styge

***Fragilaria lapponica* (= *Staurosirella lapponica*)**

- very coarse and broad striae

- wide central area

Photo: KLB Pl. 134 #1-5; Pl. III #20 (RP)

Location: TL, CH (downcore), UNG

***Fragilaria brevistriata* (= *Pseudostaurosira brevistriata*)**

- highly variable in shape - small rhombic or elliptical to large with capitate ends

Photo: YUK-U1 91-9 (KM); WBNP 91-7 S24-2 (KM)

Location: WBP, YUK, TL, YEL, UNG

Fragilaria brevistrata* var. *papillosa

- very small

- short and fine marginal striae

- strongly protracted, sub-capitate ends

Photo: Cleve-Euler Fig. 343 h-j; Pl. III, #13 (RP)

Location: YUK, YEL, UNG

Fragilaria constricta

Photo: Hein Pl.21, #10; KLB Pl. 129 #1; 4/1, 4/4 (RP)

Location: TUK

Fragilaria virescens* var. *exigua

- highly variable in shape

- very fine striae

- striae leave no central area - almost form continuous lines

Photo: Hein Pl.22, #15-17; 6/3, 3/3 (RP)

Location: YEL, YUK, LAP

CONCLUSIONS:

The second Arctic Workshop provided an opportunity to successfully tackle two groups especially important in Arctic material, *Nitzschia* and *Fragilaria*. There is still work to be done to complete the *Fragilaria* group.

**Appendix VI. 3rd ARCTIC/ANTARCTIC DIATOM TAXONOMY WORKSHOP
QUEEN'S UNIVERSITY, KINGSTON, ONTARIO
5-7 October, 1992.**

Participants:

Queen's University	Marianne Douglas (MD), Katrina Moser (KM) Reinhard Pienitz (RP) John Smol (JS) Alex Wolfe (AW)
University of Lund	Hannelore Håkansson (HH)
University College, London	Vivienne Jones (VJ),
Canadian Museum of Nature	Paul Hamilton (PH)

INTRODUCTION

Over the 3 day meeting period, numerous individual discussions led to the conclusion that 1/2 page or full page format be setup for each taxon. The format would potentially follow the outline of the chrysophyte cyst publication of Smol *et al.* and would include light micrographs (LM), scanning electron micrographs (SEM), locality data, general habitat data and taxonomic descriptions. A light micrograph from each of the participants would be included under the LM section of the description. VJ also suggested that the antarctic material might be included in the iconograph.

VJ reiterated the goals of the previous Antarctic workshop which match those of the arctic workshop and are listed above. It was suggested by VJ and HH that a taxa list be established and that selected taxa from this list be discussed. MD has prepared a preliminary taxa list from published literature and her species lists. The authorities of MD's list must still be identified and valid taxa identified. PH expressed some concern about the evaluation of valid taxa from species lists and suggested that publications with photomicrographs be accepted, while those without LM's or voucher slides be set aside into a secondary list. The format for the meeting then developed into a discussion of taxa the participants have problems with. I hope that I (PH) am able to effectively summarize the discussions.

Over the three day period, 99 taxa were discussed, with more emphasis on the genera *Staurosirella*, *Cyclotella*, *Stephanodiscus*, *Cymbella*, *Pinnularia* and *Nitzschia*. It was suggested that *Gomphonema* be re-examined further in subsequent meetings and that *Navicula* spp. for the arctic region still needs to be discussed.

TAXONOMIC DISCUSSIONS

Achnanthes altaica

Reported by RP, a small *Achnanthes*, elliptical to linear-elliptical, somewhat comparable to *A. marginulata*, except the apices of the valves show distinct deflections. In girdle view the frustule has a " [" appearance. (See K & LB 2/4, tafel 20, figure 24).

Achnanthes exigua

Previously discussed at the first Arctic/Antarctic workshop. Not recorded from the Arctic. There are no problems with this taxon.

***Achnanthes exigua* var.**

Reported by VJ from the Antarctic.

Achnanthes exigua* var. *heterovalvar

Reported by VJ from the Antarctic.

Achnanthes flexella

Common throughout the Arctic and Antarctic.

Achnanthes flexella* var. *alpestris

This variety is similar in size to *A. flexella* var. *arctica*, however in valve outline this variety is much narrower with valve margins that are distinctly parallel as compared to the nominate form. Localities: Ellesmere Island National Park.

Achnanthes flexella* var. *arctica

Generally smaller than the nominate form, with a more rounded valve typical of smaller valves (See Foged 1981, plate XI 7). Localities: Cape Herschel, Fosheim Peninsula, Ellesmere Island National Park.

Achnanthes linearis

Refer to K & LB 2/4 tafel 37 19-23. See *A. pusilla* for the problems associated with our identifications previously *A. linearis*.

Achnanthes minutissima

Found in all locations. There was no discussion on this taxon.

Achnanthes minutissima* var. *scotia

Specimens identical to K & LB 2/4. tafel 34 1-6, have been observed in Ellesmere Island National Park. This variety is recognized by the narrow valve with distinctly capitate apices. The central area of the raphe valve may or may not have a distinctly isolated striae.

Achnanthes pusilla

Valves linear to linear-elliptical (8.5-18 μ m long; 3.5-4.5 μ m wide, 18-23 striae/10 μ m), with broadly rounded ends. Raphe straight filiform with straight terminal raphe endings. Axial area narrow linear with a small distinct central area. The key characteristic is the isolated and distinctly visible central striae. The striae are slightly radiate. PRV looks similar to RV, although the striae often look less radial. The arctic group have the species *A. pusilla* as compared to *A. linearis*. See K & LB 2/4, tafel 37 9-18. Found throughout the arctic.

Achnanthes* cf. *petersenii

See K & LB 2/4 tafel 37, figures 28-39. The central area is somewhat distinct, with a characteristic high striae count (26-36 /10 μ m).

Achnanthes incognita

HH and VJ both find this taxon commonly in their samples. It is not found in the arctic.

Achnanthes scotica

A small elliptical diatom reported by RP, with a similar appearance to *A. marginulata*. The flat valve form with curved apices (See *A. altaica*, K & LB 2/4, tafel 20, figure 24) is distinctive for *A. scotica*. Localities: Yellowknife.

Achnanthes helvetica

AW reported this taxon from Baffin Island. The specimen PH called *A. cf. helvetica* is not the same and is now designated to the unknowns.

Achnanthes* cf. *metakryophila

VJ identified this taxon from the antarctic based on the description by Schmidt et al. 1990, (J. Paleolimnology 3:) See the previous Antarctic and Arctic workshop for a discussion of this taxon. The taxon previously called *A. cf. daonensis* by PH is now converted to *A. cf. metakryophila* until a better understanding of this species is obtained. Similar species include *A. kryophila*, and *A. helvetica*. LM and SEM photomicrographs

are available for this taxon.

Achnanthes kryophila

Found both in the Arctic and Antarctic.

Achnanthes suchlandtii

Reported by PH from Ellesmere Island National Park and maybe in Newfoundland (RP). Linear to linear-elliptical valve with a distinct thickened axial area with no apparent central area. A singular interruption of the striae is evident on the PRV and characteristic for the species. (see the lectotype specimen in K & LB 2/4, tafel 28, figure 9,10).

Achnanthes manguinii

Reported by VJ and HH from the Antarctic, not observed from the Arctic. An aerophilic species with distinctive undulate margins on both valves. The raphe valve with a "stauros" like central area. The type locality is from the Kerguelen region.

Achnanthes germanii

Reported by VJ and HH from the Antarctic, not observed from the Arctic. An aerophilic species also reported from the Antarctic by Bourrelly & Manguin (1954), Hirano (1965), and Larson (1974).

Achnanthes ventralis

See K & LB 2/4 tafel 24, 8-10 for photomicrographs from the holotype material. PH has identified this taxon from Ellesmere Island National Park. Not observed from the Antarctic.

Achnanthes* cf. *oestrupii

Reported by PH from the Fosheim Peninsula and Foged (1981, plate XIII, figure 1) from Alaska. PH must re-examine this material for the structure of the central area of the raphe valve.

Achnanthes groenlandica

HH and VJ have found this taxon in the Antarctic and also recorded by Fukushima 1963 in the Ongul Islands. See Hustedt 1933 fig. 874. The type description, length 60 μm , width 7, girdle view 13 μm , striae coarse, biseriate or triseriate, 4-6 striae in 10 μm . Found initially in marine environments from Spitzbergen and Greenland. Hustedt recorded this taxon from northern Ellesmere Island. This taxon has not been recorded from inland freshwater systems in the Canadian Arctic.

***Achnanthes subatomidus* (?*A. subatomoides*)**

Recorded from the antarctic by VJ and HH. MD thinks that she has identified this taxon from arctic samples. (Help HH) I was unable to find *A. subatomidus* in the literature.

Amphora* cf. *dusenii

PH has identified this taxon however, HH disagrees and calls a similar form from the Antarctic, *A. obscura*. The photomicrograph presented by K & LB (2/1 fig. 152, 7-8) was from Spitzbergen. The Arctic specimens are identical to the photograph presented by K & LB.

***Amphora obscura* Krasske**

HH recognizes this taxon from the Antarctic. She notes that *A. obscura* Krasske is not validly published and must be renamed.

***Amphora* species #1**

This taxon has been reported from both the Antarctic and Arctic. Photographs will be made available for this taxon with the initiation of the iconograph.

Aulacoseira alpigena

This taxon is quite distinctive as illustrated by Krammer & Lange-Bertalot (2/3 tafel

31, figures 1-15; tafel 32, figures 10-16). In SEM the small simple locking spines, along with the single areolae row around the circumference. This taxon is found on Ellesmere Island and in Alaska. This taxon is also reported from the Antarctic.

Aulacoseira distans* var. *africana

This taxon has round to long rectangular parallel areolae on the mantle, 12-15 /10µm. Internally a siliceous ring is present at the sulcus and this ring maybe of taxonomic importance. *A. distans* var. *africana* (called *A. pfaffiana* by K & LB) has a small siliceous ring (see K & LB 2/3 tafel 33; figure 11) as compared to *A. perglabra* (see K & LB tafel 33, figure 12). In LM this ring should be visible in valve view. Further study is needed on the validity of the internal ring as a diagnostic character. Location ???

Aulacoseira distans* var. *nivalis

Specimens from Ellesmere Island were initially identified as this taxon, although the identifications were tentative at best. The discussions centered on the comparisons between *A. distans* var. *nivalis* and *A. perglabra*. *A. distans* var. *nivalis* has true areolate punctation (see K & B 2/3 tafel 1, figure 3) over the complete valve surface. It is very questionable whether this taxon has been observed in the arctic. *A. distans* var. *distans* has been observed in the Antarctic and low Arctic regions.

Aulacoseira perglabra

The photograph for reference is in the PIRLA iconograph, plate 4, figures 59-65; plate 8, figure 77. The apparent punctation in the central region of the valve, is in fact the result of a pitted or undulating surface as is apparent in PIRLA plate 8, figure 77. This taxon is found on Baffin Island (AW) and is probably the same as material found from Ellesmere Island. The Ellesmere Island form (PH, photograph 92-05-26) needs to be studied further.

Cyclostephanos invisitatus

This taxon was discussed by H.H. and K.M. Reported from Wood Buffalo National Park.

Cyclotella glomerata

See discussions from previous workshops. The use of *C. glomerata* verses *C. stelligera* is still in confusion.

Cyclotella krammeri

= *C. kuetzingiana* (pro parte)

HH in her presentation gave a descriptive account of the problems associated with the use of *C. kuetzingiana*. The establishment of *C. krammeri* was an attempt to reduce the confusion by removing the name *C. kuetzingiana* especially considering that *C. kuetzingiana* was not validly published. See Håkansson paper on *Cyclotella* problems.

Cyclotella kuetzingiana* var. *radiosa

The validity of this taxon has not been established. HH will work on the problem.

Cyclotella pseudostelligera

See previous discussions on this taxon. As a result of the concerns of P. Kociolek, we will recognize the distinction of *C. stelligera* and *C. pseudostelligera*.

Cyclotella rossii

= *C. comta* var. *oligactis*

HH confirmed the identification of *C. rossii* from the Ellesmere Island National Park material. HH was not so sure of other arctic material identified using this name. Problems still exist in the identification of this taxon in the arctic.

Cyclotella stelligera

See previous discussions. As a result of the concerns of P. Kociolek, we will recognize the distinction of *C. stelligera* and *C. pseudostelligera*.

Cyclotella suberba

See Schmidt's Atlas tafel 222, figure 35, 36. printed by Fricke. In VanLandingham this taxon has been synonymized with *C. sexnotata* Derby. Specimens from Ungava Bay have been given this name. As far as I know, there was no discussions on the validity of this taxon.

Cyclotella tripartita

See previous discussions. HH has pointed out that *C. kisselevii* is probably not the same taxon and therefore it is appropriate to keep *C. tripartita* as the accepted name. A new note, Loginova has sent HH an earlier valid publication of the form called *C. tripartita*. HH will write a paper on this problem for publication in Diatom reseach hopefully in 1993.

Cymbella gaumanii

An interesting taxon that warranted some discussion. The dorsal margin is convex, with the ventral margin slightly concave or straight. Ends capitate to subcapitate. Maybe confused with *C. microcephala*, however, the distinction in LM, is the apparent deflected raphe 1/2 way between the poles and the central area. (See K & LB, 2/1 figure 119, 37-43.) Located ???

***Cymbella latens* (= *C. minuta* fo. *latens*)**

The distinct capitate ends, that are detached from the main body of the valve, are characteristic for this taxon (see K & LB 2/1 figure 119, 21).

Cymbella minuta

The reference photomicrograph for this taxon is K & LB 2/1 figure 119, 3-9. Common throughout the arctic. The form PH commonly reports from Ellesmere Island National Park and the Fosheim peninsula is similar to K & LB 2/1 figure 119, 10-13.

Cymbella silesiaca

The reference photomicrograph for this taxon is K & LB 2/1 figure 117, 8. Note the eccentric position of the axial area, which is distinctive for this taxon. Present from all Arctic locations.

Gomphonema* cf. *truncatum

= *G. constrictum*?

Antarctic and Arctic regions have this species. The nominate form has the typical capitate apex as illustrated by P & R, Plate 16, fig. 3 and K & LB 2/1 fig. 159, 11.

Gomphonema truncatum* var. *turgidum

PH recognizes this variety from Makinson Inlet.

Gomphonema* cf. *subtile

Reported by RP from Ungava and PH from Ellesmere Island National Park and Fosheim peninsula. See table 2, for more details.

Gomphonema* cf. *lagerheimii

Reported by RP from Ungava and PH from Ellesmere Island National Park. Reference figure K & LB 2/1 fig. 155, 22. Length 30-33µm, width 4-4.5µm, striae 10-11 /10µm, slightly radiate at the center. An isolated stria is evident adjacent to the central area. The obvious comparisons of this species are to *G. montanum* which is larger and has denser striae especially towards the apices, and *G. hebridense* which has more lanceolate apices. The specimens found in the arctic correspond exactly to the K & LB figure listed above.

Gomphonema acuminatum

= *G. acuminatum* var. *coronata*

Recorded by KM and RP from Ungava and Wood Buffalo National Park. Following the

discussions of P & R and K & LB, it would appear to be appropriate not to separate the variety *coronata*.

Gomphonema acuminatum* var. *brebissonii

Recorded by AW and PH from True Love and Ellesmere Island National Park. For the present time it is appropriate to recognize this variety. See table 2, for a more details.

Gomphonema angustatum

The use of the name *G. angustatum* is still challenged and K&LB (2/4) has suggested that the taxon, *G. micropus* Kützing (1844) takes priority over the use of *G. angustatum* (Kützing) Rabenhorst, originally published as *Sphenella angustata* Kützing (1844). Discussions with P. Kociolek are in order concerning this problem. *G. angustatum* does not appear to be present in the arctic, however it is recorded from the Antarctic.

Gomphonema parvulum

The problem with the *G. angustatum*, *G. parvulum*, *G. gracile* complexes is the plasticity within each of the groups and the apparent overlap among the groups. This problem is clearly expressed by K & LB (2/1) with their interpretations of these complexes. The initial discussions on this problem were conducted at the first Antarctic and Arctic diatom workshop and at that time communications were proposed with Erwin Reichard. In an attempt to help with this problem, a table of information is setup below. The best understanding of these splits is presented in K&LB (2/4) Tafels 74,76,78,79. The major problem is the distinction between *G. angustatum* and *G. parvulum*. The degree of radiate striation, the space between striae, the size of the central area, the rostrate formation of the headpole and footpoles (*G. angustatum*) are good characters to examine when trying to make distinctions among these groups. See reference photographs (K&LB 2/4, T:76, 1-7.)

Gomphonema parvulum* fo. *saprophilum

Reported from Ellesmere Island National Park and Wood Buffalo Nation Park. Reference figure K & LB 2/4 tafel 77, figs. 5-6. Length 30µm, width 6-8µm, striae 11-12 /10µm, striae slightly radiate. Also, see reference photographs (K&LB 2/4, T:76, 8-13.)

Gomphonema gracile

Reference photomicrographs are K & LB 2/4 Tafel 79, figures 1-3
Hustedt 1930 Page 374, Figure 702.
Patrick & Reimer 1966 Plate 17, Figure 1

The characters that should be used in identifications are striae, size, terminal ends and the degree of heterpolarity. The question was posed "why was tafel 79, figure 4 included as *G. gracile* in the K & LB work? See table 2, for more details.

Nitzschia* cf. *dubia

Recorded from the Antarctic and the Arctic. PH in his identifications has referred to this taxon as *Nitzschia* sp #4, because the Arctic material does not match the photomicrograph of K & LB from the type material of W. Smith.

Nitzschia frustulum

Commonly found both in the Antarctic and Arctic. *N. frustulum* var. *kerguelensis* has been identified from the Antarctic. At the present time the Arctic specimens have been split into two entities. The nominate form has a typical elongate "*frustulum*" robust appearance along with the perminuta-like constriction in the central region. The presence of central raphe endings along with the low striae count separates this taxon from the *N. perminuta* complex.

Nitzschia gracilis

Reported both from the Antarctic and Arctic. VJ assisted PH in recognizing this taxon.

Nitzschia* cf. *hantzschiana

Identified from Ellesmere Island National Park. The "perminuta-like" appearance, but with the clearly visible central area and therefore central raphe endings are characteristic. The striae count is lower (24-25 /10µm) than *N. perminuta*. It is separated from *N. acidoclinata* on the basis of the striae count (27-34 /10µm).

Nitzschia* cf. *acidoclinata

In my poor notes I have *N. incognita* as potentially synonymous with *N. acidoclinata*. Based on the microphotographs of K & LB and the ecology of these two taxa, it would appear that the best name to use at the present time is *N. acidoclinata*.

Nitzschia* *inconspicua

Reported from the Arctic and Antarctic. This taxon is recognized in our samples as a small *N. frustulum*. In SEM, we are unable to distinguish any significant structural differences between *N. frustulum* and *N. inconspicua*. Further work is needed.

Nitzschia* *liebetruithii

= *N. frustulum* var. *perpusilla*

Reported from the Antarctic and Arctic. See table 1, for more details.

Nitzschia* *linearis

Identified from the Antarctic. There was no discussion regarding this taxon.

Nitzschia* *palea

Reported from the Antarctic and Arctic. See K & LB tafel 59, 1,2 for lectotype photomicrographs. This taxon lacks central raphe endings as compared to *N. paleacea*.

Nitzschia* *paleacea

See K & LB for a more complete description.

Nitzschia* *perminuta

See notes from the last two Arctic workshops. From his recent work, PH has split *N. perminuta* into 3 categories. *N. perminuta*, *N. perminuta* var. 1 and *N. perminuta* var. 2. *N. perminuta* has the typical linear to slightly constricted central region, rostrate to capitate apices, small size (<20µm), and high striae count (>26 /10µm, typically 27-30 /10µm). *N. perminuta* var. 1 is identical to *N. perminuta* except for the larger size (20-28µm). *N. perminuta* var. 2 is identical to *N. perminuta* except for the lower striae count (24-45 /10 µm). The distinctions between these forms are not always that evident and may not be all that relevant.

Nitzschia* *sinuata

Identified from both the Antarctic and Arctic. The nominate form is clearly the most prominent in the Arctic.

Pinnularia* *acrosphaeria* var. *turgida

This taxon has been reported from Ungava.

Pinnularia* cf. *alpina

Material from the Antarctic was shown, however no discussions by our group were conducted and the identification is still tentatively unresolved.

Pinnularia* *biceps

At the present time we accept the use of *P. biceps* over the use of *P. interrupta* as proposed by K & B. Until the taxonomy is fully resolved it would appear to be pointless in combining taxa and potentially missing ecological information. The straight to convex margin is consistently observed and can be used for the separation from *P. mesolepta*.

Pinnularia* *borealis

The nominate form has been reported from the Antarctic and Ungava Bay.

Pinnularia borealis* var. *rectangularis

P.H. has identified this taxon as separate from the nominate variety not so much based on shape as with the lineate nature of the striae. K. & B. show distinctly radiate striae in the center, while this form clearly has parallel striae.

Pinnularia brebissonii

See *P. microstauron* for discussion.

Pinnularia mesolepta

At the present time we accept the use of *P. biceps* over the use of *P. interrupta* as proposed by K & B. As suggested by H.H., the Ehrenberg material should be examined to resolve this problem, but the material is not plentiful and in poor condition. For the present time, *P. mesolepta* will be maintained.

Pinnularia microstauron

The apparent plasticity of valve forms within this taxon has made this species very difficult to discern. The specific problem at present, concerns *P. microstauron* and *P. brebissonii*. The distinction between these two entities is not clear and even Krammer has conflicting comments on the separation of these forms, although Krammer & Lange-Bertalot accept *P. microstauron* var. *brebissonii* as a varietal form. At this time we will use *P. microstauron* as the taxon and it is hoped that the accumulation of photographs will assist us in any potential subdivision of this taxon. This taxon has been observed in all location except Wood Buffalo National Park.

Pinnularia stomatophora

Very distinctive and easy to recognize. *Pinnularia stomatophora* has been recorded from Ellesmere Island National Park.

***Pinnularia stomatophora* var. 1**

P.H. has separated this form from the nominate based on the lineate striae, and the very lineate valve outline. Length 82, width 9, striae 12-13 /10 μm (See P.H. photograph 91-22-35).

Pinnularia* cf. *streptoraphe* var. *minor

M.D. and P.H. have recorded this taxon from Ellesmere Island National Park, Fosheim Peninsula and Cape Herschel. The distinct inversions of the raphe and aviolate chambers (K & B 2/1 figures 199-3) are indicative for the taxon. The foramen in our material has a finer structure than that presented in K&B and the specimens of P.H. are narrower.

Stephanocostis chantacius

No notes were taken on the discussion of this taxon.

Stephanodiscus

Three species from this genus were discussed in the continuing saga of the small *Stephanodiscus* spp. problem. H.H. also took some time to discuss these small *Stephanodiscus* species in her invited presentation.

Stephanodiscus medius

As the name implies H.H. erected this taxon (Br. Phycol. J. 21, page 32) to indicate a potentially intermediate form that is larger than *S. minutulus*. H.H. also stated that the confusion in names between *S. minutulus* and this taxon previously called *S. minutus* by Grunow was the reason that *S. minutus* was not kept for this taxon. A further comment by HH "The name *Stephanodiscus minutus* has never been validly published and there is no other validly published name for it. It must therefore be described as a new species. The name *S. minutus* cannot be used because it is already occupied by the validly published *S. minutus* Pantocsek (1889)".

Stephanodiscus minutulus

H.H. indicated that one important feature in the identification of this taxon in the LM is the undulate valve face as compared to the flat valve face of *S. parvus*. This taxon is reported from Wood Buffalo National Park and Ungava Bay.

Stephanodiscus parvus

In LM the flat appearance of the valve face is an important character.

Thalassiosira pseudonana

This taxon has only been reported from Wood Buffalo National Park.