THE SURFACE WATERS ACIDIFICATION PROJECT PALAEOLIMNOLOGY PROGRAMME : MODERN DIATOM/LAKE-WATER CHEMISTRY DATA-SET

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CONTENTS

PREFACE

In 1983, when the Surface Waters Acidification Programme (SWAP) was announced, we were asked to design and implement a palaeolimnology sub-project involving scientists from Sweden, Norway, and the UK. Our aim was to reconstruct the acidification history of a range of sites in the three countries and to identify and evaluate the various alternative causes of lake acidification. The results of the project have been published recently (Battarbee *et al.* 1990, Renberg and Battarbee 1990). Although a comprehensive range of palaeolimnological methods and approaches was used in the study we recognised diatom analysis as central to the entire project. We consequently committed considerable effort to improving our diatom methodology and we were especially concerned with the pursuit of a common approach to diatom taxonomy and pH reconstruction. This effort centred on the creation and analysis of a large data-set of surface-sediment diatom assemblages and associated environmental variables from 170 sites representing the full range of lake types in the acid-sensitive and acidified regions of the three countries.

We achieved taxonomic harmonisation by agreeing on taxonomic distinctions in workshop discussions and by testing and reinforcing the decisions we took by "blind" analysis of quality control test slides from the calibration set (Munro *et al.* 1990). For pH reconstruction we achieved a common methodology by using the calibration data-set along with the help and inspiration of Cajo ter Braak to develop a new, statistically robust technique for pH reconstruction (Birks *et al.* 1990a), which is implemented by the program WACALIB (Line and Birks 1990). Most recently this approach has been extended for dissolved organic carbon (DOC) and total aluminium reconstructions (Birks *et al.* 1990b).

This paper describes the calibration data-set, summarises the taxonomic decisions taken, and presents an initial statistical analysis of both the diatom and environmental data. It also includes a summary of the approach taken in the project for water chemistry reconstruction and lists potentially good diatom indicators for pH, DOC, and total aluminium.

The Palaeolimnology Programme within SWAP owes thanks to the many participants in Norway, Sweden, and the UK, to the SWAP Management Committee, and to the sponsors, the Central Electricity Generating Board (UK) and the National Coal Board (UK). At this final point we are especially indebted to Tony Stevenson, Steve Juggins, and John Birks for the time and acumen they have devoted to this ultimate stage of our combined work. We would also like to thank Hazel Juggins for her help with preparing text and camera-ready copy, Sylvia Peglar for her assistance with diagram preparation, Simon Patrick of ENSIS for organising publication, and Cajo ter Braak for providing a pre-release version of CANOCO 3.10 and for his invaluable statistical advice throughout.

R.W. Battarbee, London

I. Renberg, Umeå

INTRODUCTION

The development of a large calibration, training set of over 170 surface-sediment diatom assemblages and associated environmental variables for the Surface Waters Acidification Programme (SWAP) Palaeolimnology Sub-Project necessitated the amalgamation of several existing regional training sets from Scotland, England, Wales, Norway, and Sweden so that the samples would represent a wide range of water chemistry, catchment sensitivity to acidic deposition, and pollution loadings. This paper documents the SWAP training set, both its diatom assemblages and the associated chemical and physical variables, outlines the methods used in sampling, diatom quality control, and taxonomic harmonisation, and provides a summary of the major patterns of variation in both the environmental and the diatom data using a range of numerical procedures. The joint variation of the diatoms in relation to the environmental variables in the training set is explored using multivariate direct gradient analytical techniques. Finally the ability of the training set to reconstruct lake-water pH, total aluminium, and dissolved organic carbon (DOC) is evaluated, and the possible use of diatoms as "indicator species" is investigated.

FIELD AND LABORATORY METHODS

Sample collection and diatom preparation

Surface-sediment samples were usually taken from the deepest point in each lake using modified Kajak, Hongve, or mini-Mackereth corers operated from boats or from the frozen lake surface. In a few cases the deepest point was not the optimal location and an alternative sampling location was selected nearby. In all cases the top 0.5 cm was used for diatom preparation following the procedures outlined in Stevenson *et al.* (1987). At least 500 valves were counted from each sample or, if planktonic diatoms were common, at least 300 valves of periphyton taxa were counted.

The diatom/water chemistry training set used within the SWAP project is derived from five regional data-sets, some of which were already extant at the commencement of the project (Table 1). A total of 178 samples derived from 170 sites is included in the data-set.

Table 1 Origin of samples by region and analyst

	Number of samples
1. Sweden - provided by I. Renberg & N.J. Anderson	30
2. Norway - provided by F. Berge, D.S. Anderson, & R.B. Davis	51
3. Scotland - provided by R.J. Flower	60
4. Wales - provided by R.J. Flower	32
5. Lake District - provided by E.Y. Haworth	5

Table 2 presents a summary of the site data including the country-specific short code, grid reference, latitude and longitude, lake area, and forest status. The variables forested, unforested, conifer forest, and deciduous forest are nominal (presence/absence) variables. The percentage afforestation is the approximate percentage of the lake's catchment that is afforested, usually by planted conifers. This variable is only relevant for the Welsh, Scottish, and English sites. Sites are individual lakes, and there are some lakes with replicate samples collected at different times. Figure 1 shows the site locations in relation to current sulphur deposition loadings.

Chemistry and other environmental features of the lakes sampled

Water samples were collected from each lake at either the outflow or the lake centre using acid-washed plastic bottles and kept cool and in the dark until analysis.

Most lakes were sampled at three to four monthly intervals over the period 1985 - 1988 and the results presented here are arithmetic means except for pH which is a geometric mean. In some cases, especially for some remote sites and lakes with difficult access, the chemistry is based on one sample.

As far as possible a standardised water-analytical procedure was used between all laboratories involved in the SWAP project. The participating laboratories included:

i) Scotland	Department of Agriculture and Fisheries for Scotland, Pitlochry (R. Harriman)
	Solway River Purification Board, Dumfries (D. Tervet)
ii) Wales	Welsh Water, Swansea (R. West)
iii) England	Institute of Freshwater Ecology, Ambleside (D.W. Sutcliffe)

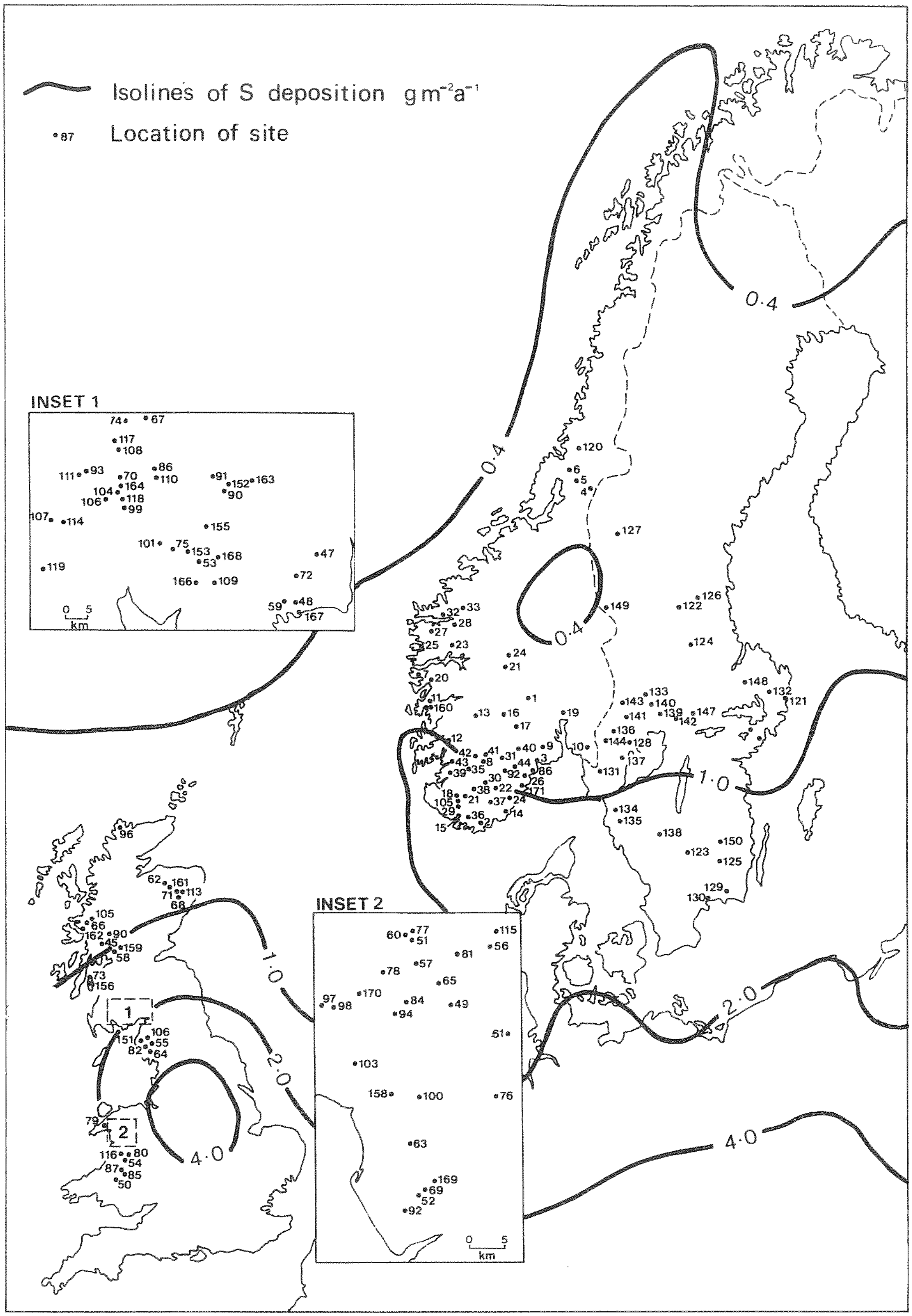


Figure 1 Map of the 170 sites where surface-sediments for diatom analysis and samples for chemistry were obtained. Superimposed are the sulphur deposition isolines derived from Eliassen et al. (1988). Site numbers follow Table 2.

Table 2 *Details of the 170 lakes from which the 178 diatom surface assemblages were collected. Site numbers refer to the numbers on Figure 1. Forestry status refers to: P = forestry present, C = conifer forest present, D = deciduous forest present, % = approximate percentage of catchment afforested. Country codes are N = Norway, SCO = Scotland, CYM = Wales, ENG = England, S = Sweden.*

Site Number	Site Code	Site Name	Country	Grid	Grid Square	Easting	Northing	Latitude	Longitude	Altitude (m)	Forest Status P	C	D	%	Maximum Depth (m)	Lake Area (ha)
1	1	Langtjern	N	32V	NM	540	6692	60.374	9.731	516	1	1	0		12.0	23
2	1.2	Moglandsvatn	N	32V	MK	407	6440	58.090	7.423	176	1	1	0		28.7	77
3	10.2	Langvatn	N	32V	NL	525	6537	58.971	9.435	70	1	1	0		34.0	17
4	111.1	Gronlivatn	N	33W	UM	383	7100	64.006	12.607	514	1	1	0		13.9	215
5	113.2	Store Reinsjoen	N	33W	UM	362	7141	64.365	12.141	454	1	1	0		43.5	170
6	115.1	Grassjoen	N	33W	UM	365	7169	64.617	12.177	153	1	1	0		30.0	60
7	12	Ovre Botnatjonn	N	32V	FH	301	6758	60.907	5.334	180	1	1	0		9.0	5
8	12.1	Brarvatn	N	32V	ML	427	6574	59.297	7.718	902	0	0	0		27.2	125
9	15.1	Myklevann	N	32V	NL	540	6587	59.418	9.705	422	1	1	0		61.0	600
10	17.2	Klosa	N	32V	PL	645	6577	59.306	11.547	172	1	1	0		14.0	100
11	18	Rodlivatn	N	31V	FG	306	6687	60.272	5.492	50	1	1	0		20.0	25
12	18.1	Botnavatn	N	32V	LM	365	6630	59.784	6.595	865	0	0	0		46.0	110
13	19.2	Fjellsjaen	N	32V	MM	425	6663	60.096	7.651	1197	0	0	0		14.2	212
14	2	Hogkleivvatn	N	32V	MK	455	6469	58.361	8.231	160	1	1	0		11.0	8
15	2.1	Handelandsvatn	N	32V	LK	371	6456	58.225	6.804	188	1	1	0		24.7	27
16	20.1	Rosja	N	32V	MM	468	6662	60.092	8.425	1147	0	0	0		8.5	195
17	21.1	Heivann	N	32V	MM	498	6642	59.914	8.964	529	1	1	0		12.3	72
18	3.1	Nedre Malmesvatn	N	32V	LK	373	6489	58.522	6.820	504	1	1	0		25.0	27
19	3.51	Store Gorja	N	32V	NM	596	6661	60.082	10.743	376	1	1	0		25.0	4
20	34.1	Blavatn	N	31V	FH	332	6734	60.705	5.922	837	0	0	0		20.8	50
21	37.1	Reinsennvatnet	N	32V	MN	494	6757	60.947	8.889	923	0	0	0		13.5	100
22	4.1	Hovvatn	N	32V	MK	443	6497	58.608	8.019	493	1	1	0		9.6	120
23	42.1	Gravevatn	N	32V	LP	339	6808	61.390	6.997	600	1	1	0		52.0	130
24	44.2	Fiskeloyse	N	32V	MK	493	6771	61.072	8.870	1037	0	0	0		20.0	110
25	49.1	Langevatn	N	31V	FJ	297	6844	61.674	5.164	70	1	1	0		34.0	70
26	5.1	Sandvatn	N	32V	ML	498	6506	58.693	8.965	150	1	1	0		27.0	30
27	58.1	Movatn	N	32V	LP	352	6876	61.986	6.175	422	1	1	0		27.0	110
28	59.1	Oppljosvatn	N	32V	MP	414	6875	61.996	7.358	1146	0	0	0		60.0	200
29	6	Ovre Malmesvatn	N	32V	LK	373	6490	58.529	6.829	511	1	1	0		15.0	13
30	6.2	Kjosevatn	N	32V	ML	421	6514	58.757	7.635	613	1	1	0		16.0	60
31	60	Oytjern	N	32V	ML	457	6574	59.301	8.245	929	0	0	0		4.8	3
32	65.2	Jutevatn	N	32V	LQ	399	6935	62.531	7.037	525	0	0	0		30.5	70
33	66.1	Ovre Mardalsvatn	N	32V	MQ	452	6933	62.523	8.068	918	0	0	0		54.0	60
34	7	Risvatn	N	32V	MK	457	6479	58.455	8.273	103	1	1	0		26.0	19
35	8.2	Myklevatn	N	32V	ML	407	6548	59.060	7.378	785	1	1	0		33.0	60
36	80.1	Kleivvatn	N	32V	LK	390	6456	58.230	7.127	228	1	1	0		18.5	30
37	81.2	Eilandsvatn	N	32V	MK	441	6478	58.410	7.990	204	1	1	0		9.0	80
38	82.1	Bliksvatn	N	32V	ML	409	6517	58.782	7.426	760	1	1	0		23.5	20
39	83.1	Dorsvatn	N	32V	LL	358	6557	59.127	6.519	850	0	0	0		44.0	50
40	86.1	Tveitvatn	N	32V	NL	510	6591	59.456	9.176	539	1	1	0		17.0	40
41	87.2	Oyusvatn	N	32V	ML	436	6572	59.281	7.877	748	1	1	0		11.2	300
42	88.2	Ovre Brandsvatn	N	32V	ML	419	6596	59.493	7.570	1246	0	0	0		29.2	60
43	89.1	Svinstolvatn	N	32V	LL	366	6591	59.435	6.638	705	0	0	0		47.0	150
44	9.1	Holmvatn	N	32V	ML	480	6555	59.132	8.651	671	1	1	0		27.0	180
45	ACH	Loch na hAchlaise	SCO	NGR	NN	310	480	56.594	-4.753	305	0	0	0	0	9.2	
46	ARR	Loch Coire nan Arr	SCO	NGR	NG	808	422	57.417	-5.651	130	0	0	0	0	12.0	
47	ARTH	Loch Arthur	SCO	NGR	NX	904	688	55.002	-3.714	80	1	1	0	50	13.5	31

Site Number	Site Code	Site Name	Country	Grid	Grid Square	Easting	Northing	Latitude	Longitude	Altitude (m)	Forestry Status P	C	D	%	Maximum Depth (m)	Lake Area (ha)
48	BARE	Loch Barean	SCO	NGR	NX	861	557	54.883	-3.776	40	1	1	0	60	11.0	10
49	BARL	Llyn Barlwyd	CYM	NGR	SH	713	486	53.019	-3.919	558	0	0	0	0	3.0	7
50	BER	Llyn Berwyn	CYM	NGR	SN	743	568	52.195	-3.839	438	1	1	0	60	14.0	13
51	BODG	Llyn Bodgynedd	CYM	NGR	SH	762	593	53.116	-3.850	300	1	1	0	50	17.0	
52	BODL	Llyn Bodlyn	CYM	NGR	SH	648	238	52.794	-4.005	450	0	0	0	0	20.0	16
53	BREC	Lochenbreck	SCO	NGR	NX	643	655	54.966	-4.120	200	1	1	0	70	7.5	16
54	BUGE	Llyn Bugeilyn	CYM	NGR	SN	822	923	52.515	-3.736	457	0	0	0	0	2.3	8
55	BURNMT	Burnmoor Tarn	ENG	NGR	NY	184	44	54.428	-3.258	260	0	0	0	0	13.0	24
56	BYCH	Llyn Bychan	CYM	NGR	SH	753	593	53.116	-3.863	320	1	1	0	50	8.0	2
57	CFYN	Llyn Cwm Ffynnion	CYM	NGR	SH	648	564	53.087	-4.019	380	0	0	0	0	11.0	9
58	CHN	Loch Chon	SCO	NGR	NN	421	51	56.212	-4.546	100	1	1	0	50	25.0	100
59	CLON	Loch Clonyard	SCO	NGR	NX	857	554	54.880	-3.782	34	1	1	0	10	8.5	5
60	CLYD	Llyn Clyd	CYM	NGR	SH	635	597	53.117	-4.040	660	0	0	0	0	6.0	1
61	CON	Llyn Conwy	CYM	NGR	SH	780	463	53.000	-3.818	450	0	0	0	0	22.0	40
62	COR	Loch Coire an Lochan	SCO	NGR	NH	943	4	57.083	-3.744	1000	0	0	0	0	20.0	
63	CWBY	Llyn Cwm Bychan	CYM	NGR	SH	640	313	52.862	-4.020	191	1	0	1	10	14.5	10
64	DEVOKE	Devoke Water	ENG	NGR	SD	163	970	54.361	-3.288	240	0	0	0	0	14.0	
65	DIWA	Llyn Diawaunedd	CYM	NGR	SH	685	536	53.063	-3.963	375	1	1	0	10	15.5	
66	DOI	Loch Doilet	SCO	NGR	NM	808	678	56.750	-5.586	10	1	1	0	41	16.8	53
67	DOON	Loch Doon	SCO	NGR	NX	495	985	55.258	-4.368	215	1	1	0	40	30.5	
68	DUH	Dubh Loch	SCO	NGR	NO	238	828	56.930	-3.252	700	0	0	0	0	21.0	20
69	DUL	Llyn Dulyn	CYM	NGR	SH	662	244	52.800	-3.985	520	0	0	0	0	6.8	2
70	ENO	Loch Enoch	SCO	NGR	NX	445	851	55.136	-4.440	490	0	0	0	0	36.0	50
71	EUN	Loch nan Eun	SCO	NGR	NO	230	854	56.954	-3.266	900	0	0	0	0	23.0	
72	FERN	Loch Fern	SCO	NGR	NX	863	624	54.943	-3.775	85	1	1	0	20	2.5	5
73	FHI	Coire Fhionn Lochan	SCO	NGR	NR	902	459	55.661	-5.336	340	0	0	0	0	9.5	7
74	FINL	Loch Finlas	SCO	NGR	NX	460	983	55.255	-4.423	255	1	1	0	20	13.5	78
75	FLE	Loch Fleet	SCO	NGR	NX	560	697	55.001	-4.252	340	1	1	0	20	16.5	17
76	GARN	Llyn y Garn	CYM	NGR	SH	762	377	52.922	-3.842	510	0	0	0	0	18.5	
77	GEIR	Llyn Geirionydd	CYM	NGR	SH	763	606	53.128	-3.849	228	1	1	0	50	14.5	
78	GLAS	Llyn Glas	CYM	NGR	SH	601	547	53.071	-4.088	520	0	0	0	0	6.5	1
79	GLFR	Llyn Glasfryn	CYM	NGR	SH	402	422	52.953	-4.379	120	0	0	0	0	1.0	
80	GLYN	Llyn Glaslyn	CYM	NGR	SN	826	941	52.532	-3.731	490	0	0	0	0	11.0	23
81	GOD	Llyn Goddionduon	CYM	NGR	SH	754	585	53.109	-3.862	292	1	1	0	100	7.0	6
82	GREENT	Greendale Tarn	ENG	NGR	NY	146	74	54.455	-3.317	400	0	0	0	0	9.0	2
83	GULSPET	Gulspettvatn	N	32V	NL	505	6503	58.668	9.090	56	1	1	0		25.0	32
84	GWYN	Llyn Gwynant	CYM	NGR	SH	644	519	53.056	-4.023	70	1	0	1	10	17.0	
85	GYN	Llyn Gynon	CYM	NGR	SN	800	647	52.267	-3.759	420	0	0	0	0	11.0	25
86	HARR	Loch Harrow	SCO	NGR	NX	527	867	55.153	-4.312	250	1	1	0	100	9.0	16
87	HIR	Llyn Hir	CYM	NGR	SN	789	675	52.292	-3.776	435	0	0	0	0	8.8	5
88	HOLET	Holetjorn	N	32V	MK	371	6482	58.479	6.813	485	1	1	0		16.0	2
89	HOLMEV	Holmevatn	N	32V	ML	463	6547	59.061	8.355	583	1	1	0		28.0	100
90	HOWI	Loch Howie	SCO	NGR	NX	697	834	55.128	-4.044	230	1	1	0	100	13.0	18
91	INVA	Lochinvar	SCO	NGR	NX	659	853	55.144	-4.104	220	1	1	0	5	5.5	33
92	IRD	Llyn Irddyn	CYM	NGR	SH	630	220	52.778	-4.031	300	0	0	0	0	8.8	9
93	KIRR	Loch Kierriereoch	SCO	NGR	NX	363	865	55.146	-4.569	213	1	1	0	75	3.5	8
94	LAG	Llyn Llagi	CYM	NGR	SH	649	483	53.015	-4.014	380	0	0	0	0	16.5	6
95	LAI	Loch Laidon	SCO	NGR	NN	380	542	56.652	-4.643	280	0	0	0	0	39.0	473
96	LAR	Loch na Larach	SCO	NGR	NC	217	583	58.477	-5.058	61	0	0	0	0	8.5	
97	LCSL	Llyn Cwm Silyn Lower	CYM	NGR	SH	512	508	53.033	-4.219	340	0	0	0	0	17.0	4
98	LCSU	Llyn Cwm Silyn Upper	CYM	NGR	SH	515	505	53.031	-4.215	342	0	0	0	0	17.0	5
99	LDE	Loch Dee	SCO	NGR	NX	470	790	55.082	-4.397	230	1	1	0	20	14.5	100
100	LENY	Llyn Llennych	CYM	NGR	SH	655	377	52.920	-4.001	255	0	0	0	0	10.0	3
101	LGR	Loch Grannoch	SCO	NGR	NX	541	691	54.995	-4.281	210	1	1	0	70	20.5	114
102	LJOSV	Ljosvatn	N	32V	MK	366	6476	58.425	6.710	385	1	1	0		21.0	11
103	LLDU	Llyn Du	CYM	NGR	SH	564	425	52.960	-4.138	255	0	0	0	0	7.0	2
104	LLGH	Long Loch of Glenhead	SCO	NGR	NX	446	808	55.097	-4.436	300	0	0	0	0	11.5	9

Site Number	Site Code	Site Name	Country	Grid	Grid Square	Easting	Northing	Latitude	Longitude	Altitude (m)	Forestry Status				Maximum Depth (m)	Lake Area (ha)
											P	C	D	%		
105	LOD	Lochan Dubh	SCO	NGR	NM	895	710	56.783	-5.446	230	0	0	0	0	9.0	9
106	LOWT	Low Tarn	ENG	NGR	NY	163	91	54.470	-3.292	480	0	0	0	0	3.0	4
107	MABE	Loch Mayberry	SCO	NGR	NX	286	750	55.040	-4.683	118	1	1	0	40	4.5	70
108	MACA	Loch Macaterick	SCO	NGR	NX	440	912	55.190	-4.451	290	1	1	0	50	12.5	55
109	MANN	Loch Mannoch	SCO	NGR	NX	664	605	54.921	-4.085	128	0	0	0	0	7.0	24
110	MINN	Loch Minnoch	SCO	NGR	NX	530	857	55.144	-4.307	275	1	1	0	100	7.0	6
111	MOAN	Loch Moan	SCO	NGR	NX	346	858	55.139	-4.595	200	1	1	0	100	3.0	49
112	MUCK	Loch Muck	SCO	NGR	NS	513	7	55.278	-4.341	290	1	1	0	5	8.0	11
113	NAGA	Lochnagar	SCO	NGR	NO	252	859	56.958	-3.230	790	0	0	0	0	24.0	10
114	OCHI	Loch Ochiltree	SCO	NGR	NX	317	745	55.036	-4.634	107	1	1	0	10	8.0	62
115	PARC	Llyn y Parc	CYM	NGR	SH	793	587	53.112	-3.803	246	1	1	0	100	11.0	
116	PENR	Llyn Penrhaiadr	CYM	NGR	SN	753	933	52.523	-3.838	410	0	0	0	0	7.0	5
117	RIEC	Loch Riecawr	SCO	NGR	NX	434	934	55.210	-4.461	280	1	1	0	100	9.0	92
118	RLGH	Round Loch of Glenhead	SCO	NGR	NX	450	805	55.095	-4.429	300	0	0	0	0	13.5	13
119	RONA	Loch Ronald	SCO	NGR	NX	265	644	54.944	-4.709	102	1	1	0	40	17.5	37
120	R\O	Royrtjorna	N	33W	UM	783	646	64.810	12.380	163	1	1	0		14.0	26
121	S1	Skaren	S					59.370	18.230	49	1	1	0		5.5	29
122	S10	Hundsjon	S					61.380	15.100	276	1	1	0		15.0	33
123	S11	Algarydssjon	S					57.080	14.450	201	1	1	0		6.5	33
124	S12	Ljusacksen	S					60.540	15.250	295	1	1	0		17.0	54
125	S13	Storasjo	S					56.570	15.170	252	1	1	0		12.0	40
126	S14	St. Bjorken	S					61.450	15.590	221	1	1	0		11.0	61
127	S15	V. Helgtjarnen	S					63.100	13.100	648	1	1	0		5.0	29
128	S16	Botungen	S					59.220	12.430	99	1	1	0		7.5	80
129	S17	Skaravattnet	S					56.230	15.170	99	1	1	0		10.0	14
130	S18	Orsjon	S					56.170	14.410	87	1	1	0		10.0	18
131	S19	Rotehogstjarn	S					58.490	11.370	121	1	1	0		8.5	17
132	S2	Edasjon	S					59.480	17.540	18	1	1	0		4.5	17
133	S20	Lill Jangen	S					60.000	13.210	193	1	1	0		9.0	90
134	S21	Gaffeln	S													
135	S22	Harsvatten	S					58.001	12.030	129					24.0	19
136	S24	Ulvsjon	S					59.370	12.170	200	1	1	0		23.5	51
137	S25	Flatsjon	S					59.000	12.240	126	1	1	0		15.0	50
138	S26	Hagasjon	S					57.320	13.250	177	1	1	0		4.0	80
139	S27	Vagsjoarna	S					59.480	13.340	187	1	1	0		14.0	59
140	S28	Stor En	S					59.550	12.250	263	1	1	0		9.0	173
141	S29	Orvattnet	S					59.440	12.450	276	1	1	0		13.0	72
142	S3	Limmingsjon	S					59.350	14.300	234	1	1	0		17.0	114
143	S30	Amten	S					59.570	12.350	273	1	1	0		15.0	47
144	S31	Skardalsvattnet	S					59.210	11.570	105	1	1	0		11.0	64
145	S4	Djupa Holmsjon	S					59.110	17.020	60	1	1	0		23.0	20
146	S5	Hedsjon	S					58.590	17.170	33	1	1	0		6.5	11
147	S6	Olsjon	S					59.390	15.070	173	1	1	0		7.0	26
148	S7	Raksjon	S					60.030	17.040	65	1	1	0		9.5	115
149	S8	Flickersjon	S					61.480	12.250	645	1	1	0		16.5	17
150	S9	Hagserydssjon	S					57.180	15.260	180	1	1	0		9.5	41
151	SCOATT	Scoat Tarn	ENG	NGR	NY	159	104	54.482	-3.298	602	0	0	0	0	20.0	5
152	SKAK	Loch Skae	SCO	NGR	NX	710	837	55.130	-4.020	263	1	1	0	100	13.0	
153	SKE	Loch Skerrow	SCO	NGR	NX	605	682	54.989	-4.181	120	1	1	0	55	10.0	51
154	SKOMAKV	Skomakarvatn	N	31V	FG	301	6699	60.377	5.399	564	0	0	0	0	3.0	
155	STRO	Loch Stroan	SCO	NGR	NX	644	704	55.010	-4.121	70	1	1	0	70	12.5	23
156	TANN	Loch Tanna	SCO	NGR	NR	921	428	55.634	-5.303	330	0	0	0	0	3.5	33
157	TEAN	Loch Teanga	SCO	NGR	NF	818	383	57.324	-7.288	20	0	0	0	0	21.0	
158	TECW	Llyn Tecwyn	CYM	NGR	SH	629	370	52.913	-4.039	100	1	0	1	5	7.0	
159	TINK	Loch Tinker	SCO	NGR	NN	445	68	56.228	-4.509	420	0	0	0	0	9.8	11
160	TROO	Loch Trool	SCO	NGR	NX	412	798	55.087	-4.488	75	1	1	0	60	17.0	60
161	UAI	Lochan Uaine	SCO	NGR	NO	1	981	57.063	-3.648	950	0	0	0	0	20.0	4

Site Number	Site Code	Site Name	Country	Grid	Grid Square	Easting	Northing	Latitude	Longitude	Altitude (m)	Forestry Status P	C	D	%	Maximum Depth (m)	Lake Area (ha)
162	UIS	Loch Uisge	SCO	NGR	NM	808	550	56.636	-5.575	152	0	0	0	0	11.0	18
163	URR	Loch Urr	SCO	NGR	NX	760	845	55.139	-3.946	198	1	1	0	5	13.2	44
164	VAL	Loch Valley	SCO	NGR	NX	445	817	55.105	-4.438	340	0	0	0	0	16.5	35
165	VEREV	Verevatn	N	32V	MK	453	6472	58.383	8.200	268	1	1	0		13.9	9
166	WHIN	Loch Whinyeon	SCO	NGR	NX	625	608	54.923	-4.146	220	1	1	0	30	13.0	41
167	WHIT	White Loch	SCO	NGR	NX	864	547	54.874	-3.771	30	1	1	0	60	13.5	11
168	WOOD	Loch Woodhall	SCO	NGR	NX	673	675	54.984	-4.074	50	1	1	0	50	16.5	67
169	YBI	Llyn y Bi	CYM	NGR	SH	670	265	52.819	-3.974	445	0	0	0	0	3.0	3
170	YGAD	Llyn y Gadair	CYM	NGR	SH	648	564	53.087	-4.019	380	0	0	0	0	3.0	

iv) Norway NIVA, Oslo

Botanical Institute, University of Bergen (J.F. Boyle)

v) Sweden Environmental Protection Agency, Freshwater Section, Uppsala

Up to twenty chemical determinands were measured on each water sample using standard procedures (Golterman 1969, APHA 1980, Ahl 1972). pH and conductivity were measured after the sample had equilibrated to room temperature (20°C) and ambient CO_2 conditions. Ca, Na, Mg, K, Mn, Zn, and Fe were determined, after filtration, by atomic absorption spectrophotometry. SO_4, NO_3, Cl, and total organic nitrogen (TON) were determined by ion chromatography, and SiO_2 was measured colorimetrically. Dissolved organic carbon (DOC) was determined as absorbance at 254nm by spectrophotometry and estimated using the linear calibration of Vik (1982). In most cases only total aluminium was measured. However, for a number of samples labile aluminium concentrations were determined after separation on an ion exchange column packed with DOWEX 50w Na type resin (Driscoll 1984). Total and non-labile monomeric aluminium were measured using the pyrocatchecol violet method. However, in this paper the term total aluminium is used to refer to total aluminium *s.s. plus* total monomeric aluminium. All measurements are given as follows: Na, Ca, K, Mg, alkalinity, NO_3, Cl, SO_4 are in µeq l^{-1}; conductivity in µs cm^{-1}, Zn, Fe, total Al, Mn, TON, $Si0_2$ in µg l^{-1}; DOC in mg l^{-1}.

Before entry to the SWAP diatom-environment database the results of the chemical determinations were screened to identify spurious or discordant values that may have arisen either as a result of analytical error or from unusual meteorological conditions, such as sea-salt events. In addition, because of logistical problems within laboratories not all analyses were performed on all samples (Table 3).

Table 3 Summary of the number of diatom samples with associated environmental determinations for the 178 sample data-set

Determinand	Number of samples	Determinand	Number of samples
pH	178	Conductivity	177
Dissolved Organic Carbon	148	Ca	175
Mg	174	Na	144
K	174	SO_4	175
Cl	175	NO_3	126
Total Organic Nitrogen	117	Alkalinity	161
Total Al*	173	Zn	108
Mn	136	Fe	139
SiO_2	137	Altitude	176
Maximum Water Depth	176	Lake Area	128

* some of these determinations refer to Total Al, others to the monomeric fraction.

DIATOM TAXONOMY AND NOMENCLATURE

Introduction

Despite the general availability of major diatom floras (e.g. Hustedt 1930-1966, Cleve-Euler 1951-1955, Patrick and Reimer 1966, 1975), there can be considerable variation in taxonomic and nomenclatural usage between diatomists in different laboratories. Floras differ in their definitions and use of names, diatomists develop laboratory-based concepts for inter- and intra-specific taxonomic division, and errors can easily be made. Moreover, reference to "type material" is often not practical or, in some cases, not possible. Such differences can hinder the comparison of data between laboratories and, in situations where diatoms are used as environmental indicators, misleading conclusions can arise.

In palaeolimnological projects where diatomists from several laboratories are involved, it is essential to establish agreed protocols for diatom taxonomy and nomenclature. Diatomists involved in the Palaeoecological Investigation of Recent Lake Acidification (PIRLA) project in the USA (Charles and Whitehead 1986) have developed a rigorous system of taxonomic control (Kingston 1986) including a diatom iconograph series (PIRLA 1984-1986), regular workshops, and the circulation of diatom slides between laboratories. In SWAP diatomists from Norway, Sweden, and the UK adopted a similar approach to taxonomic harmonization through regular workshops, diatom slide exchange, and the circulation of agreed taxonomic protocols.

Slide exchange and analytical quality control

Initial identification of problems

The first SWAP diatom taxonomy workshop was held in March 1987. Prior to this, each of the four laboratories involved circulated diatom slides and accompanying count sheets for three sediment samples, to each of the other laboratories. The slides were chosen to represent the range of soft-water floras encountered within SWAP. All 12 slides were then recounted by the other laboratories and a comparison of the results made at the taxonomy workshops. Figure 2a summarizes the results of one of the 12 slides, Lingmoor Tarn. Figure 2b shows the same results after revision of the taxonomy and nomenclature at the 1987 workshop. This example demonstrates the three main problems that arose, namely:

a) *Nomenclature*

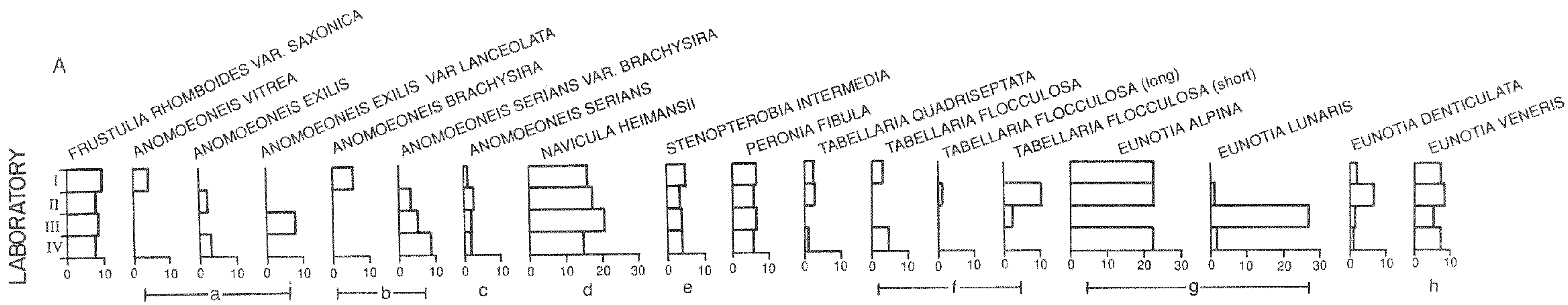
In this analysis there was a problem within the genus *Anomoeoneis* with both former and revised names being allocated to the same taxon. *A. vitrea* (Grun.) Ross was used by laboratory **I** and *A. exilis* Cleve, including var. *lanceolata*, was used by laboratories **II**, **III**, and **IV** for the same diatom. Likewise *Anomoeoneis brachysira* (Bréb.) Grun. and *A. serians* var. *brachysira* (Bréb) Cleve were both applied to the same taxon. These two taxa have now been transferred to the genus *Brachysira*, *A. vitrea* becoming *B. vitrea* (Grun.) Ross and *A. brachysira* becoming *B. brebissonii* Ross.

b) *Splitting and amalgamation of taxa*

Anomoeoneis exilis var. *lanceolata* was split from the nominate by one laboratory. This has also been transferred to the genus *Brachysira* and after some discussion it was agreed to amalgamate the variety with the nominate taxon within SWAP.

c) *Identification*

The criteria used to separate *Eunotia alpina* (Naeg.) Hust. from *E. lunaris* (Ehr.) Grun. differed between laboratories. A mutually agreed list of criteria was drawn up to differentiate the two taxa. The revised names for *E. alpina* and *E. lunaris* are *E. naegelii* Migula and *E. curvata* (Kütz.) Lagerst., respectively.



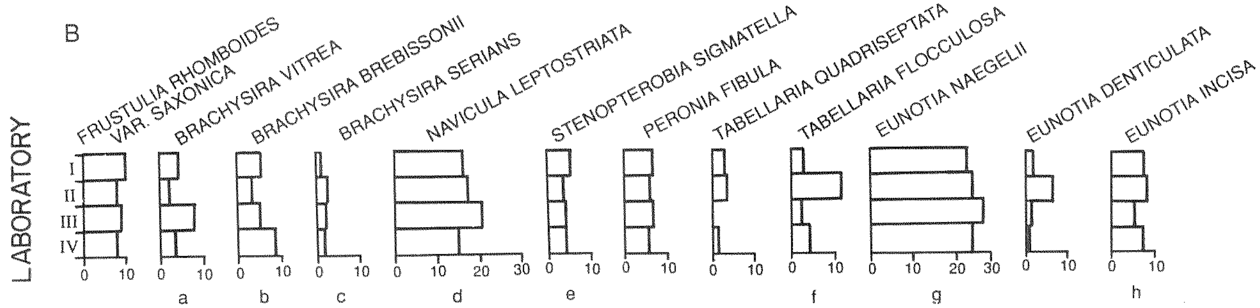


Figure 2 a (upper) Dominant taxa in the Lingmoor Tarn slide illustrating (i) problems of nomenclature in groups a,b,c,d,e,g, and h, (ii) problems of splitting versus amalgamation in groups a and f, and (iii) the use of differing identification criteria in group g. Horizontal scale is percentage occurrence.

b (lower) Dominant taxa in the Lingmoor Tarn slide after taxonomic and nomenclatural revision. Horizontal scale is percentage occurrence.

The agreements resulting from the discussion of these and other taxa were circulated to all the workshop participants in a SWAP taxonomic guide (Appendix A). Decisions on taxonomy and nomenclature were based on the *Checklist of British Diatoms* (Hartley 1986) which formed the framework for *A Coded Checklist of British Diatoms* (Williams *et al.* 1988). The SWAP taxonomic guide also included agreements on definitions for boundaries between certain species and their varieties. If possible, published descriptions were referred to or failing this, the criteria for identification were agreed between the analysts.

Applying and refining the SWAP taxonomic guide

The next stage in the harmonization of diatom taxonomy was to put the protocols agreed at the 1987 workshop to the test. Three slides from lake-sediment samples representing the range of pH values encountered within SWAP (one sample from each of the ranges pH < 5.0, pH 5.0 - 6.0, and pH > 6.0) were circulated to all SWAP diatomists. This time, count sheets were not included so the slides were counted without prior knowledge of the diatom assemblages. The results were discussed at a diatom taxonomy workshop in July 1988.

Many potential problems had been avoided by following the protocols agreed at the previous workshop. However, due to the inclusion of taxa additional to those already encountered, some further problems were raised concerning nomenclature, splitting/amalgamation, and identification. Figure 3 shows the predominant taxa from one slide, Botungen. In this slide the use of both *Cyclotella comta* and *C. radiosa* was identified as a problem in nomenclature and *C. radiosa* Håkansson was adopted then as the valid name for this taxon. Also, the four forms of *Tabellaria flocculosa* had been split by each diatomist using different criteria. In this case, no common set of criteria could be agreed upon for consistently separating the forms so it was agreed to amalgamate the longer forms of this species into a *T. flocculosa* aggregate category within the SWAP data-set. Similarly, it was agreed to combine *Achnanthes minutissima* and *A. microcephala* for the purposes of data analysis within SWAP, although with these and all other combinations of taxa made, it was agreed that diatomists could retain the original distinctions in their own data-sets, if they wished. In addition this workshop produced a guide for the classification of unknown diatoms.

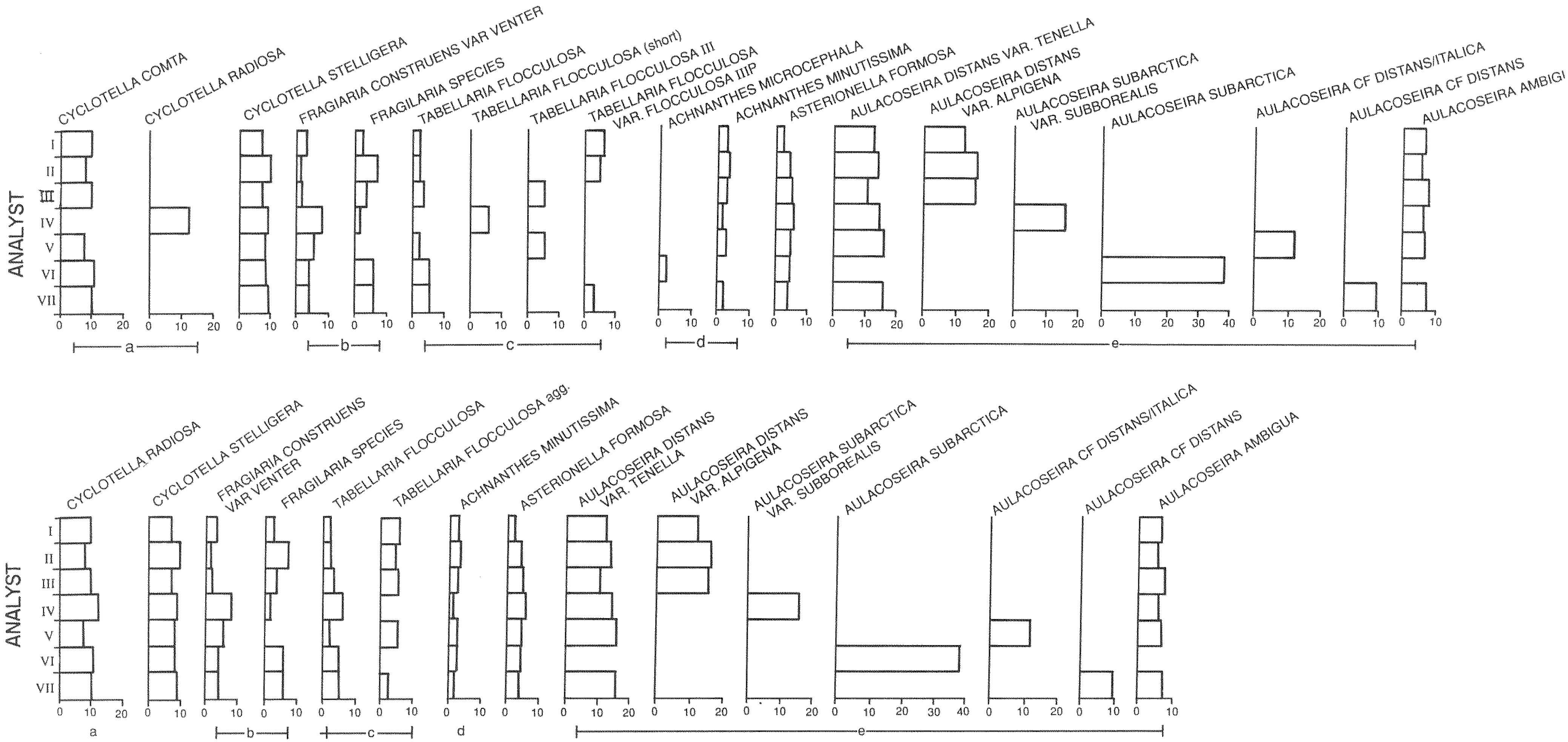


Figure 3 a (upper) Dominant taxa in the Botungen slide illustrating similar problems of nomenclature in groups a,d, and e, problems of splitting versus amalgamation in groups c and e, and the use of differing identification criteria in the same groups. Horizontal scale is percentage occurrence.

b (lower) Dominant taxa in the Botungen slide after taxonomic and nomenclatural revision in 1988. Horizontal scale is percentage occurrence.

Protocols for handling unknowns

There are two main groups of unknown diatoms:

1) those that occur infrequently and cannot be allocated a name due to damage or deformation or are too rare to justify detailed taxonomic work, and

2) those that occur frequently enough to be identified as a discrete taxon but no published description of the diatom can be found.

Within SWAP it was agreed to name unknown diatoms in group **1** as follows:

i) Diatoms that cannot be identified to genus level due to breakage, being in girdle view or being partly obscured on the slide should be called "unknown pennate", "unknown centric", or simply "unknown".

ii) Diatoms that cannot be identified to species level due to the reasons listed above should be allocated a genus if possible. For example, *Achnanthes* spp., *Pinnularia* spp., "unknown Naviculaceae", or "unknown *Achnanthes/Navicula*".

iii) Unknown diatoms occurring infrequently which do not resemble a particular species but can be allocated to a genus should also be classified as in ii) above.

iv) Diatoms which do not exactly fit a description for a taxon but have some features in common with that taxon and that do not occur often enough to warrant classifying them separately from the taxon they resemble, should be put in a "*cf.*" category. For example, in a count of 500 valves there may be several valves of a diatom which closely resembles *Achnanthes marginulata* but which do not fit the published descriptions of the species. In this case, if the diatoms have not been observed elsewhere it may be convenient to put these valves into *Achnanthes cf. marginulata* rather than list them individually as in group **2**.

In group **2** unknown diatoms that occur with sufficient regularity or in sufficient numbers to be identifiable as a discrete taxon should be named using [ ]. The square brackets can contain anything that readily identifies that diatom to the diatomist who finds it. The name of the "type" site for the diatom and the initials of the diatomist making the identification should appear as the "authority" after the name. Some examples are given below:

Unknown [sp.1 *Stauroneis/Navicula*] Loch Doilet AK

In this case the diatom could not be placed in either genus so the two possible genera are included within the brackets. The diatom was first noted at Loch Doilet by Annette Kreiser (AK).

Achnanthes [sp.2 *nodosa*] Loch Chon AK

Here the diatom is clearly an *Achnanthes*. The information in the brackets shows that it is the second unknown *Achnanthes* named at this site and that *A. nodosa* is the closest published description to it.

Aulacoseira [sp.1 PIRLA *distans* var. 5] Llyn Tecwyn RJF

This name indicates that the diatomist (R.J. Flower) has found a similar unknown (*Aulacoseira distans* var. 5) in the PIRLA (1984-1986) diatom iconograph.

Pinnularia [sp.2 small, capitate] Llyn Berwyn AK

In this case the unknown does not resemble any other known or published taxon so other memory-joggers are included in the name.

Information contained within the square brackets only has significance for the diatomist who put it there, unless a full description has been circulated by the diatomist. This is particularly important in the case of a name containing a reference to a published description or illustration. The reference given does not necessarily accurately describe the diatom in question. This allows a diatomist to call an unknown *Eunotia, Eunotia* [PIRLA sp.13] because it exactly matches PIRLA *Eunotia* sp.13 (which is not an officially published name so has to remain in square brackets) but also enables another diatomist to use the same name for a diatom from a different site which only resembles PIRLA *Eunotia* sp.13 in certain respects. Clearly in cases like this the two occurrences should be listed separately with the different site names and the diatomist's initials, indicating that they may be different taxa, unless circulated descriptions confirm that they are the same taxon. Descriptions of important unknowns were circulated to other diatomists to help prevent the use of different names for the same taxon. A list of the final taxonomic decisions made for the SWAP training set is given in Appendix A.

As a result of the 1988 workshop, a revised edition of the SWAP taxonomic guide was circulated to all SWAP diatomists. It was also decided to distribute a reference set of the surface-sediment (training data-set) slides to each SWAP laboratory so that particular unknown or problematic taxa could be readily examined by diatomists with reference to their own material.

Problems within the genus **Aulacoseira**

A major problem encountered at the 1988 workshop was one of identification within the genus *Aulacoseira* (Figure 3b). This genus presents particular taxonomic problems due to the difficulties of matching side (girdle) views of the diatom valves with front (valve) views. Difficulties with identification of the rarer and smaller taxa within the genus, such as those within the *A. subarctica / subborealis* group remained unresolved.

As a result of the 1988 workshop it was decided to concentrate on the taxonomy of the *Aulacoseira* genus at the next workshop. Three samples containing *Aulacoseira* were selected from SWAP sites and slides were circulated to all SWAP diatomists. Three hundred valves of *Aulacoseira* were counted from each slide and the results discussed at the diatom taxonomy workshop in February 1989. There were no problems with the most abundant *Aulacoseira* taxa, such as *A. lirata* and *A. distans* var. *nivalis*. For *A. lirata* var. *alpigena* a description was agreed (see Appendix A). Work is continuing on the *A. subarctica / A. subborealis* group. For the purposes of SWAP, it was decided to amalgamate these taxa into a *A.* [*subarctica* agg.] category. Although the analysis of surface and core samples had been completed by this stage, it was agreed to recount samples containing the problematic *Aulacoseira* taxa since considerable revision of their taxonomy had occurred as a result of the 1989 workshop.

This series of workshops and quality-control exercises enabled all the diatom data generated within SWAP to be compatible between laboratories. Nomenclature follows Williams *et al.* (1988) but names for taxa or amalgamated groups of taxa found only within SWAP are also used. This standardization of the diatom data was essential before the data could be stored and manipulated in the computerized data-base.

DIATOM DATABASE

The diatom database (DISCO) at University College London (Munro *et al.* 1990) combines archives of diatom counts, chemical analyses, and catchment descriptions for SWAP sites. It uses the commercial program ORACLE and the standard database language SQL. The database includes a diatom checklist which allocates a code to each taxon on the list using an alphanumeric code to represent the original name of the taxon.

Diatomists submitting counts to the database provided an outline code dictionary for their data. The dictionary was checked to ensure that it contained valid checklist codes, and was compared to previous lists from the same laboratory. The counts were then converted to percentages of the total number of diatoms counted in each sample; any amalgamations and other re-definitions of taxa were performed. The database also provided a list of the more frequently occurring taxa for each group of samples, defined as those present in at least two of the samples and having a frequency of more than 1% in at least one sample. These lists were compared to help identify unresolved taxonomic problems.

The SWAP training data-set was created by merging full sets of surface-sediment percentages in this way for the regional data-sets from Scotland, Wales, English Lake District, Norway, and Sweden. All the aggregates to genus level and above (e.g. *Navicula* spp.) were deleted and the remainder of the list was used to select the taxa to be exported to the data-analytical and calibration programs.

NUMERICAL ANALYSIS OF THE CHEMICAL AND OTHER ENVIRONMENTAL DATA

The training data-set consists of 170 lakes with diatom, chemical, and other environmental data. Of these, eight have a replicate set of diatom and chemical variables (collected in 1987 from Round Loch of Glenhead, Loch Howie, Loch Grannoch, Loch Skerrow, Loch Dee, Loch Skae, Loch Woodall, Loch Whinyeon; Stevenson *et al.* 1989) to give a basic 178 sample data-set. These replicates differ in collection date by 3 - 4 years. Figure 1 illustrates the geographical coverage of the 170 SWAP training lakes.

Overall, the samples are derived from lakes with varying geologies giving varying sensitivities to acidification and from a range of different pollution settings. Land-use within the modern data-set varies from upland farming with some improvement to unimproved moorland and forest (both natural and planted). In general, the majority of the UK sites are derived from unforested catchments while the Scandinavian sites are predominantly forested.

Basic statistics

The available mean chemical data for all 178 samples with associated diatom counts are tabulated along with the available basic catchment vegetation and site physical variables in Table 4. Frequency histograms of the distribution of selected chemical and site physical variables are presented in Figure 4. Summary statistics for selected variables are given in Table 5 as mean, median, standard deviation, minimum, maximum and lower and upper quartiles. Basic scatter plots for the major chemical determinands are shown in Figures 5 and 6.

Table 4 ***Summary of the available chemical data for the 170 lakes from which the 178 sample diatom / chemistry SWAP training-set is derived***

Sample Number	Sample Code	Site Number	Site Code	pH	Cond uS cm-1	DOC mg l-1	Ca (ueq l-1)	Mg (ueq l-1)	Na (ueq l-1)	K (ueq l-1)	SO4 (ueq l-1)	Cl (ueq l-1)	Alkal (ueq l-1)	NO3 (ueq l-1)	TON (ug l-1)	Altot (ug l-1)	Zn (ug l-1)	Mn (ug l-1)	Fe (ug l-1)	SiO2 (ug l-1)
1	1.21	2	1.2	4.5	58.0	1.9	70.0	61.9	241.4	12.0	142.0	239.2	0.0	27.5	477.5	299.0	23.7	75.0	73.3	1000
2	10.21	3	10.2	5.3	42.6	4.1	127.9	92.1	132.9	15.7	174.9	138.2	7.5	20.2	577.5	176.4	22.3	31.5	55.0	2425
3	11	1	1	4.9	17.6		66.9	21.4		4.1	81.2	19.7				227.0				
4	111.11	4	111.1	6.5	16.8	2.5	65.3	27.0	69.7	6.0	22.6	71.3	22.8	3.4	112.5	41.9	4.0	15.0	66.7	
5	113.21	5	113.2	6.4	25.1	2.8	104.6	34.0	105.8	4.9	27.1	114.4	102.2	2.7	192.5	37.1	2.7	2.5	23.3	
6	115.11	6	115.1	5.7	33.2	5.0	46.1	54.9	193.2	6.8	40.8	217.2	14.2	2.5	210.0	68.1	3.3	10.5	133.3	
7	12.11	8	12.1	5.2	12.1	1.4	32.0	15.0	30.1	3.8	51.6	23.2	0.0	11.3	232.5	95.8	10.8	21.8	40.8	775
8	121	7	12	4.8	26.6		14.5	32.1	119.2	5.1	45.8	138.2				90.0				
9	15.11	9	15.1	5.4	20.3	4.6	69.0	31.1	46.3	8.2	97.0	39.9	0.0	8.8	332.5	175.7	23.6	86.3	141.4	2450
10	17.21	10	17.2	4.9	44.7	5.7	114.4	74.3	168.8	8.3	167.2	145.5	0.0	6.3	367.5	168.6	25.7	38.0	140.0	
11	18.11	12	18.1	5.4	12.9	.9	34.8	15.6	39.1	6.7	42.6	40.4	18.5	8.3	118.8	43.6	10.6	20.5	98.0	1000
12	181	11	18	6.3	31.7		79.8	47.7	156.6	3.8	75.0	158.0				35.0				
13	19.21	13	19.2	6.3	10.4	1.5	55.7	11.9	29.4	4.9	34.9	18.8	31.4	1.2	105.0	28.9	8.6	7.0	53.4	1450
14	2.11	15	2.1	5.0	47.8	1.5	67.9	67.9	246.8	8.4	114.5	243.7	0.0	10.6	280.0	125.0	9.0	11.0	20.0	1550
15	20.11	16	20.1	6.6	13.7	1.8	99.7	13.2	25.3	5.7	40.0	14.4	37.7	1.8	142.5	26.4	8.8	3.0	28.8	975
16	21	14	2	4.5	37.2		32.4	34.6	85.3	8.4	114.5	90.3				321.0				
17	21.11	17	21.1	6.0	24.3	5.0	112.4	36.2	40.6	6.3	94.0	27.8	0.0	3.3	185.0	107.6	12.2	24.0	192.0	3225
18	3.11	18	3.1	4.6	35.0	3.8	23.8	28.4	89.0	3.3	70.8	96.8	0.0	24.3		150.0	8.3	12.0	35.0	1025
19	3.511	19	3.51	7.0	47.0	3.7	369.3				156.2	39.5	264.0			40.0				
20	34.11	20	34.1	5.0	9.5	.6	6.2	9.0	30.7	2.4	18.7	27.3	0.0	4.3		36.7	12.3	7.5	41.7	300
21	37.11	21	37.1	6.5	16.8	4.9	89.5	54.3	27.2	3.1	57.5	15.2		1.1	220.0	16.7	9.0	11.0	84.0	1500
22	4.11	22	4.1	4.4	32.6	4.0	24.5	24.0	68.2	6.2	94.2	68.9	0.0	18.6	637.5	212.9	18.6	15.3	108.0	525
23	42.11	23	42.1	5.1	17.0	1.2	15.9	21.5	83.5	3.2	27.7	83.8	0.0	2.1	140.0	62.4	8.4	7.5	47.0	650
24	44.21	24	44.2	6.6	12.9	1.4	71.4	51.0	16.6	2.3	52.1	10.4	0.0	.7		20.0	5.0	1.5	35.5	325
25	49.11	25	49.1	4.8	27.3	.8	20.5	33.0	136.8	4.1	49.1	133.2	0.0	11.0	203.8	59.7	10.5	7.7	30.5	300
26	5.11	26	5.1	4.6	39.9		63.2	60.5	121.6	8.4	145.8	128.8	0.0	6.8		320.0	27.0	27.5	466.7	1625
27	58.11	27	58.1	5.7	17.6	1.9	26.3	27.5	88.6	4.7	33.3	102.2	0.0	2.4	83.8	52.4	6.8	5.3	39.4	
28	59.11	28	59.1	5.5	10.4	.7	43.8	7.8	26.1	4.0	40.2	18.2	0.0	5.1	162.5	37.9	6.8	3.0	45.4	550
29	6.21	30	6.2	4.6	22.9	3.1	26.2	21.2	47.8	4.3	73.6	46.7	0.0	10.2	375.0	226.2	12.8	17.0	90.0	950
30	601	31	60	4.8	15.2	2.7	31.4	19.7	29.1	2.6	57.3	24.0		.7		221.5				
31	61	29	6	4.6	30.3	1.5	10.0	14.6	46.6	2.0	34.8	53.9				159.0				
32	65.21	32	65.2	6.2	21.2	1.3	36.1	32.2	117.6	5.5	34.8	123.7	16.4	1.3	125.0	21.7	13.0	6.0	103.3	1550
33	66.11	33	66.1	6.0	7.4	1.0	21.2	9.9	30.4	3.1	20.8	28.2	0.0	2.9			8.7	2.5	41.7	600
34	71	34	7	5.7	45.3		129.7	69.1	151.4	15.9	156.2	158.0				117.0				
35	8.21	35	8.2	4.9	12.9		24.5	14.0	30.3	2.2	43.7	31.9	0.0	3.3		110.0	3.0	8.0	98.3	1075
36	80.11	36	80.1	4.7	41.1	2.7	47.6	49.1	192.5	8.6	105.0	179.4	0.0	10.7	460.0	198.0	17.0	25.0	80.0	
37	81.21	37	81.2	4.5	33.3	5.4	45.4	38.0	108.4	6.8	105.0	109.4	0.0	10.9	452.5	235.0	15.3	29.0	100.0	1700
38	82.11	38	82.1	4.6	21.4	5.0	27.8	19.2	44.9	2.7	56.8	48.3	0.0	5.0	245.0	160.4	11.0	10.3	147.0	1175
39	83.11	39	83.1	4.9	16.2	1.1	10.1	19.3	65.7	2.6	31.2	75.2	0.0	7.8	158.8	108.3	9.4	5.0	471.2	350
40	86.11	40	86.1	4.9	22.6	5.5	86.5	28.4	37.7	5.6	105.8	37.9	0.0	6.5	343.8	169.6	19.2	84.0	199.0	2000
41	87.21	41	87.2	5.1	12.8	2.8	39.3	16.0	29.8	3.0	56.2	24.8	0.0	4.6	230.0	74.0	14.0	16.0	46.7	1100
42	88.21	42	88.2	5.3	9.0	1.0	24.1	9.9	21.3	2.8	38.2	17.8	0.0	8.3		123.3	14.0	17.0	60.0	900
43	89.11	43	89.1	5.8	16.7	1.0	47.3	27.1	67.0	3.9	42.6	71.7	0.0	6.5	132.5	23.0	5.2	8.3	24.0	750
44	9.11	44	9.1	4.7	20.1	2.2	22.0	16.8	32.3	5.1	72.9	27.9	0.0	9.5	370.0	111.3	14.0	103.3	127.5	475
45	ACH1	45	ACH	5.1	32.3	2.8	37.5	28.0	192.5	5.5	42.7	212.3	4.3	1.7		17.0				
46	ARR1	46	ARR	6.2	35.0	2.2	40.4	49.4	193.0	13.6	43.0	219.8	56.9	3.6		26.0				
47	ARTH1	47	ARTH	7.1	101.1	4.6	395.7	166.6	328.4	29.9	244.8	428.6	315.9	44.9	250.0	133.3	6.0	22.5	16.0	1650
48	BARE1	48	BARE	6.7	147.3	6.6	241.5	207.2	369.8	16.0	261.3	684.7	279.3	20.4	180.0	73.3	4.0	46.5	66.0	2639
49	BARL1	49	BARL	6.4	34.3	2.1	116.1	55.8	127.9	5.4	69.0	148.1	97.9			53.3	24.5	3.5	43.0	300
50	BER1	50	BER	4.3	58.3		41.1	50.0	261.5	6.5	165.4	234.2	.1			125.4	18.2	480.4	229.4	468
51	BODG1	51	BODG	6.5	75.7	1.9	214.4	99.4	267.5	9.3	175.7	291.5	103.4		400.0	54.3	44.0	19.0	18.7	733
52	BODL1	52	BODL	5.4	31.8	1.2	48.7	45.3	150.1	5.9	72.6	176.3	3.2		200.0	52.3	17.7	31.3	9.3	350
53	BREC1	53	BREC	6.6	77.0		189.2	116.8	262.1	5.0	188.4	437.3	83.4	15.3	90.0	235.0	13.5	17.0	180.0	1550
54	BUGE1	54	BUGE	4.8	52.8	4.6	46.8	51.2	152.0	5.1	78.9	232.7	3.5			117.0	26.0	25.8	383.8	650
55	BURNMT1	55	BURNMT	6.4	45.7	.2	87.5	61.5	183.0	9.5	89.0	203.0		11.0		12.0				1930
56	BYCH1	56	BYCH	6.4	55.3	1.8	154.2	115.9	228.5	10.0	111.6	261.0	144.8		200.0	15.0	55.0	12.5	16.3	700
57	CFYN1	57	CFYN	5.5	26.8	1.2	35.3	27.5	108.4	5.5	48.8	112.8	8.3			33.5	15.3	17.3	20.0	200

Sample Number	Sample Code	Site Number	Site Code	pH	Cond uS cm-1	DOC mg l-1	Ca	Mg	Na	K	SO4	Cl	Alkal	NO3	TON	Altot	Zn	Mn	Fe	SiO2
							ueq l-1								ug l-1					
58	CHN1	58	CHN	5.1	38.5	2.3	78.5	48.5	173.5	7.5	85.8	207.0	4.4	16.8		93.0				
59	CLON1	59	CLON	6.9	152.8	6.6	416.5	337.3	671.7	40.8	352.4	838.7	360.7	64.2		158.3	3.0	123.5	116.0	2850
60	CLYD1	60	CLYD	6.1	29.3	.5	55.9	48.0	123.9	10.6	65.8	134.0	33.9		200.0	16.3	13.7	6.3	5.0	475
61	CON1	61	CON	4.8	33.0	2.1	41.8	36.3	134.6	6.6	69.7	155.2	0.0			65.8	29.5	93.8	82.3	250
62	COR1	62	COR	5.3	17.8	.2	28.8	19.8	67.0	7.8	47.3	81.7	13.7	17.0		150.3				
63	CWBY1	63	CWBY	5.2	38.0	1.4	55.7	48.8	181.6	8.2	99.7	183.4	2.4		250.0	131.0	38.5	54.8	20.3	550
64	DEVOKE1	64	DEVOKE	6.1	57.8	.8	116.0	83.0	229.0	10.5	126.0	269.0		15.0		18.0				1500
65	DIWA1	65	DIWA	5.7	27.3	1.0	46.3	39.1	129.9	6.4	62.3	141.0	11.3			46.7	16.7	12.8	11.3	525
66	DOI1	66	DOI	5.9	43.8	2.4	54.0	60.5	238.7	12.5	70.6	277.0	15.4	6.4		54.7				
67	DOON1	67	DOON	5.2	47.0	3.7	69.4	77.5	193.3	10.4	116.4	225.4	31.4	15.1	100.0	125.0				
68	DUH1	68	DUH	5.1	20.0	1.4	30.0	24.0	82.3	6.0	59.8	76.8	2.1	13.0		137.7				
69	DUL1	69	DUL	5.2	35.4	1.6	44.0	54.3	168.1	8.1	83.0	189.8	.4		400.0	107.2	22.0	30.0	12.8	669
70	ENO1	70	ENO	4.5	32.7	1.1	12.5	23.4	86.1	5.6	50.7	136.2	0.0	7.3	105.0	74.9	10.5	12.4	22.9	393
71	EUN1	71	EUN	5.0	22.3	.5	29.7	26.3	82.3	5.7	62.3	75.7	0.0	27.0		256.3				
72	FERN1	72	FERN	6.8	119.8	8.7	369.5	231.1	385.1	54.1	.283.2	498.1	303.2	91.5	170.0	173.3	6.5	601.5	837.5	7000
73	FHI1	73	FHI	5.3	52.4	1.0	51.2	73.0	277.8	12.8	106.7	301.7	1.4	12.7		255.4				
74	FINL1	74	FINL	5.8	49.6	3.6	80.4	68.7	247.8	12.7	112.2	246.1	52.3	4.2	20.0	312.5	2.0	45.0	87.0	1750
75	FLE1	75	FLE	4.5	39.8	4.0	28.8	30.0	95.2	5.0	79.5	133.9	0.0	12.7		133.5	22.0	190.8	70.8	596
76	GARN1	76	GARN	6.3	36.8	1.3	112.9	46.1	153.0	9.0	90.0	176.3	41.9			33.3	9.8	4.3	9.0	325
77	GEIR1	77	GEIR	6.8	75.0	1.7	226.1	111.7	253.6	10.9	196.8	296.2	138.2		400.0	36.0	719.0	13.0	31.5	950
78	GLAS1	78	GLAS	6.2	28.3	.5	71.2	43.4	130.1	7.8	57.3	126.9	33.4		366.7	13.0	18.5		3.5	850
79	GLFR1	79	GLFR	6.9	99.0	5.7	390.7	143.1	372.8	35.8	93.7	479.5	394.2			26.0	8.0		58.0	
80	GLYN1	80	GLYN	4.9	32.8	1.2	39.7	58.9	150.6	7.4	92.9	148.1	0.0			90.3	16.7	69.5	59.0	400
81	GOD1	81	GOD	5.7	60.5	1.6	102.1	99.5	297.5	6.7	128.9	338.5	26.6		350.0	68.0	40.0	20.5	18.5	767
82	GREENT1	82	GREENT	5.2	44.7	.1	47.0	57.5	181.5	6.0	83.5	203.5	0.0	10.0		117.0				1430
83	GULSPET1	83	GULSPET	4.8	38.9											340.0				
84	GWYN1	84	GWYN	6.7	35.5	1.1	135.0	47.0	142.7	6.1	72.9	141.1	100.1		200.0	23.5	12.5	11.0	6.0	550
85	GYN1	85	GYN	5.1	33.6	3.6	41.4	54.7	141.1	7.2	79.3	164.2	5.7			62.6	26.8	130.8	214.6	788
86	HARR1	86	HARR	5.0	36.2	1.7	43.8	44.4	147.8	6.2	87.9	173.9	16.7	21.0	150.0	340.0	11.5	34.5	48.5	2900
87	HIR1	87	HIR	4.8	44.1		46.3	50.0	170.1	8.3	120.5	216.7	0.0			88.5	20.6	161.5	60.6	264
88	HOLET1	88	HOLET	4.5	21.2	1.6	26.0	36.0	121.9	4.7	74.6	154.4		14.0	142.0	149.0				
89	HOLMEV1	89	HOLMEV	4.7	19.1		21.3	11.7	26.8	5.4	56.5	28.5								
90	HOWI1	90	HOWI	5.6	67.7	3.4	150.3	99.0	250.5	8.5	179.6	341.1	25.5	42.6	360.0	230.7	18.0	27.5	24.5	3200
91	HOWI2	90	HOWI	5.6	56.0		130.7	85.6	201.8	5.4	185.3	289.4	5.3		350.0	111.0	14.0	31.0	28.0	2100
92	INVA1	91	INVA	6.6	70.8	7.6	180.1	135.3	202.2	10.9	174.9	262.3	97.7	17.6	160.0	135.0	10.5	159.0	205.5	2100
93	IRD1	92	IRD	5.3	40.0	1.0	60.4	57.6	194.3	6.1	95.4	197.5	2.0		250.0	65.5	12.5	28.0	9.5	450
94	KIRR1	93	KIRR	5.1	49.7		37.2	64.6	225.6	6.0	79.2	341.4	16.7	3.2	20.0	253.5	5.5	119.0	319.5	600
95	LAG1	94	LAG	5.2	30.8	2.4	60.5	47.9	165.2	4.2	63.1	198.5	1.3		200.0	78.3	12.5	48.8	46.8	323
96	LAI1	95	LAI	5.4	24.8	3.1	41.3	31.0	132.0	6.3	45.5	130.0	12.8	2.8		24.3				
97	LAR1	96	LAR	4.9	135.4	5.8	63.4	188.8	1004.0	24.4	120.8	947.0	0.0	2.7		61.3				
98	LCSL1	97	LCSL	5.2	36.5	.5	35.4	54.2	183.8	9.9	75.2	176.3	0.0		300.0	102.5	21.0	37.5	9.8	1350
99	LCSU1	98	LCSU	5.4	33.0	.5	35.9	56.6	185.3	10.9	83.6	155.2	3.8		400.0	62.5	11.5	30.0	5.5	1350
100	LDE1	99	LDE	5.3	33.5	2.5	38.7	38.6	98.8	8.9	62.4	154.4	42.8	12.3		78.7	7.0	38.8	35.6	1128
101	LDE2	99	LDE	5.7	22.0		38.9	38.7	85.7	4.4	54.6	83.2	2.9		40.0	94.0	6.0	10.0	61.0	1100
102	LENY1	100	LENY	6.2	44.5	2.4	139.0	62.3	178.7	6.3	104.6	190.5	52.8		366.7	36.5	10.8	4.0	11.8	325
103	LGR1	101	LGR	4.6	41.8	5.5	31.7	30.6	106.9	5.5	75.3	190.9	0.0	11.1	140.0	193.0	17.5	167.2	70.6	1157
104	LGR2	101	LGR	4.8	47.0		35.4	39.5	134.8	5.1	80.4	151.5	0.0		20.0					1900
105	LJOSV1	102	LJOSV	4.4	42.0	.5	14.6	39.4	138.4	4.4	78.6	180.6		21.0	250.0	145.5				
106	LLDU1	103	LLDU	5.8	56.3	1.7	127.4	86.1	250.5	9.8	118.8	291.5	48.7		300.0	41.0	10.0	8.0	48.7	533
107	LLGH1	104	LLGH	4.6	40.4	3.4	36.1	44.6	157.3	6.6	88.7	198.1	11.4	5.3	80.0	146.7	10.0	32.0	106.5	1700
108	LOD1	105	LOD	5.5	29.0	2.8	33.2	40.2	163.0	8.0	39.5	185.4	8.1	2.5		43.3				
109	LOWT1	106	LOWT	5.0	43.0	.7	48.0	46.5	159.0	6.0	80.5	172.0	0.0	18.0		80.0				1120
110	MABE1	107	MABE	5.3	83.0	10.5	104.4	129.6	288.8	10.1	160.7	329.9	24.1	9.1	90.0	242.5	11.0	36.0	768.0	2900
111	MACA1	108	MACA	5.0	38.3	3.7	36.3	49.6	164.3	8.2	78.4	198.1	15.7	1.0		170.0	6.5	111.0	265.0	1600
112	MANN1	109	MANN	6.4	89.3	4.0	285.8	175.6	319.5	18.7	195.6	381.5	165.6	46.6	200.0	206.7	8.0	51.0	203.5	4150
113	MINN1	110	MINN	5.2	40.0	2.5	45.1	50.2	157.0	7.5	97.2	184.9	44.0	16.7	80.0	417.5	11.0	87.0	419.0	3050
114	MOAN1	111	MOAN	5.1	60.0	5.7	82.7	89.3	257.7	7.3	159.6	334.6	13.6	4.0	30.0	250.0	14.5	207.0	573.5	2250
115	MUCK1	112	MUCK	5.4	62.6	9.7	90.6	98.5	259.1	9.3	113.7	319.6	43.7	0.0		262.5	11.0	87.0	419.0	2450
116	NAGA1	113	NAGA	5.0	21.3	.8	29.8	34.3	87.3	7.3	64.8	76.5	0.0	22.3		129.0				
117	OCHI1	114	OCHI	6.0	71.1	9.9	134.6	142.2	278.6	15.1	165.1	407.9	60.3	11.9	30.0	185.0	8.0	22.0	224.0	1300
118	PARC1	115	PARC	6.8	81.0	1.1	208.6	159.7	336.2	9.7	234.0	394.9	112.5		300.0	59.0	730.0	43.0	11.0	1300

Sample Number	Sample Code	Site Number	Site Code	pH	Cond uS cm-1	DOC mg l-1	Ca	Mg	Na	K	SO4	Cl	Alkal	NO3	TON	Altot	Zn	Mn	Fe	SiO2
							ueq l-1								ug l-1					
119	PENR1	116	PENR	5.0	32.3	3.4	49.5	53.1	148.0	6.2	80.3	148.1	3.7		250.0	135.7	12.3	95.8	104.5	500
120	RIEC1	117	RIEC	5.3	43.3	5.1	51.3	62.8	176.0	7.1	96.4	227.4	45.1	1.0	10.0	177.5	3.0	44.0	15.0	1500
121	RLGH1	118	RLGH	4.7	33.5	2.5	20.9	29.1	100.4	5.0	60.8	170.9	0.0	4.8	70.0	109.4	11.5	42.2	36.3	538
122	RLGH2	118	RLGH	4.8	25.0		19.5	27.1	91.3	4.1	60.8	107.2	0.0			156.0	7.0	27.0	111.0	500
123	RONA1	119	RONA	6.5	98.3		246.8	175.2	430.9	22.6	183.3	598.1	138.0	7.9	110.0	130.0	5.0	41.0	53.0	1950
124	R\O1	120	R\O	6.7	27.4	4.8	66.4	35.9	42.5	7.8	24.1	120.1		1.4	170.0	33.3			68.0	179
125	S101	122	S10	6.7	31.1	7.3	144.0	72.0		14.0	82.0	21.0	119.0	2.3	309.0	106.0		13.0	200.0	2760
126	S11	121	S1	6.8	62.3	9.1	371.0	88.0		15.0	165.0	82.0	239.0	2.7	431.0	62.0		18.0	89.0	1130
127	S111	123	S11	5.3	64.3	11.6	178.0	102.0		20.0	224.0	206.0	3.0	5.6	581.0	302.0		160.0	735.0	1270
128	S121	124	S12	6.5	25.2	4.7	119.0	33.0		10.0	92.0	24.0	65.0	1.4	262.0	39.0		8.0	32.0	1340
129	S131	125	S13	5.2	44.0	8.4	105.0	68.0		14.0	151.0	129.0	2.0	3.1	470.0	135.0		169.0	710.0	1130
130	S141	126	S14	6.4	27.6	7.5	120.0	50.0		12.0	81.0	27.0	72.0	2.3	330.0	94.0		22.0	224.0	2900
131	S151	127	S15	7.3	76.9	7.3	605.0	69.0		37.0	55.0	48.0	619.0	.8	654.0	38.0		44.0	30.0	540
132	S161	128	S16	6.4	44.4	8.8	175.0	87.0		20.0	149.0	93.0	73.0	4.7	498.0	113.0		58.0	220.0	1230
133	S171	129	S17	5.8	78.7	3.0	258.0	117.0		23.0	340.0	233.0	13.0	3.9	340.0	112.0		70.0	35.0	890
134	S181	130	S18	5.8	67.3	5.4	189.0	99.0		16.0	240.0	230.0	17.0	4.5	578.0	91.0		157.0	290.0	620
135	S191	131	S19	5.0	58.3	12.1	97.0	95.0		12.0	149.0	244.0	1.0	3.4	517.0	275.0		67.0	529.0	1390
136	S201	133	S20	5.5	22.8	6.1	63.0	34.0		13.0	84.0	49.0	1.0	2.2	340.0	119.0		59.0	241.0	660
137	S21	132	S2	7.2	140.8	12.7	938.0	214.0		35.0	227.0	161.0	903.0	6.9	722.0	75.0		30.0	265.0	2810
138	S211	134	S21	4.5																
139	S221	135	S22	4.4	83.0	2.1	63.0	91.0		12.0	205.0	348.0	0.0	9.6	332.0	546.0		102.0	66.0	410
140	S241	136	S24	6.0	35.6	7.3	140.0	53.0		11.0	133.0	79.0	21.0	5.9	396.0	110.0		25.0	156.0	1230
141	S251	137	S25	7.0	66.5	5.3	377.0	79.0		11.0	178.0	127.0	237.0	5.6	362.0	66.0		12.0	51.0	1140
142	S261	138	S26	6.6	95.8	17.0	464.0	137.0		24.0	237.0	265.0	220.0	16.6	982.0	140.0		306.0	487.0	2820
143	S271	139	S27	5.1	28.5	12.5	87.0	47.0		10.0	101.0	54.0	0.0	2.1	409.0	280.0		66.0	783.0	2260
144	S281	140	S28	4.9	24.4	6.6	59.0	33.0		11.0	92.0	42.0	0.0	5.9	353.0	176.0		71.0	267.0	1560
145	S291	141	S29	5.0	26.8	4.3	62.0	37.0		10.0	112.0	52.0	0.0	4.9	303.0	139.0		121.0	67.0	720
146	S301	143	S30	5.5	26.3	8.1	90.0	49.0		12.0	99.0	48.0	5.0	2.6	386.0	141.0		59.0	367.0	1000
147	S31	142	S3	6.7	34.6	6.1	163.0	61.0		13.0	108.0	58.0	82.0	3.4	319.0	54.0		28.0	50.0	1130
148	S311	144	S31	5.9	51.2	8.0	146.0	94.0		13.0	168.0	168.0	18.0	4.8	425.0	201.0		35.0	98.0	1990
149	S41	145	S4	5.8	36.4	11.6	140.0	79.0		15.0	137.0	57.0	20.0	4.9	486.0	171.0		68.0	312.0	1690
150	S51	146	S5	6.3	69.4	6.3	257.0	182.0		24.0	285.0	112.0	146.0	6.2	489.0	33.0		26.0	99.0	360
151	S61	147	S6	6.0	66.9	14.9	183.0	83.0		19.0	126.0	279.0	59.0	3.7	648.0	202.0		37.0	425.0	1360
152	S71	148	S7	6.5	42.6	15.4	221.0	78.0		10.0	149.0	56.0	68.0	3.0	489.0	152.0		30.0	424.0	2380
153	S81	149	S8	6.7	25.3	3.4	129.0	59.0		9.0	28.0	39.0	147.0	.6	240.0	18.0		9.0	79.0	1960
154	S91	150	S9	6.2	82.7	14.3	312.0	161.0		15.0	313.0	207.0	58.0	4.1	737.0	151.0		167.0	463.0	1460
155	SCOATT1	151	SCOATT	5.0	42.8	.5	38.0	50.0	166.0	8.5	62.0	196.0	0.0	24.0		223.0				1370
156	SKAK1	152	SKAK	5.8	64.0		146.0	97.9	245.4	3.8	171.8	327.2	58.6	3.2	80.0	205.0	12.5	6.5	29.5	1050
157	SKAK2	152	SKAK	5.8	49.0		125.7	78.2	163.1	3.1	139.9	205.6	41.9		10.0	63.0	14.0	24.0	73.0	700
158	SKE1	153	SKE	5.1	51.4	6.5	112.9	72.0	186.4	8.1	134.3	256.6	62.8	9.0		290.0	5.0	56.0	143.0	
159	SKE2	153	SKE	5.1	36.0		66.4	52.6	140.9	3.8	72.7	141.0	0.0		30.0	187.0	8.0	73.0	119.0	1300
160	SKOMAKV1	154	SKOMAKV	4.7	19.7		16.4	23.1	80.4	3.5	41.0	83.9	0.0			120.5				
161	STRO1	155	STRO	4.8	49.4	5.8	89.4	63.6	204.5	4.7	147.9	226.7	37.7	2.7	20.0	465.0	10.0	136.0	269.0	3800
162	TANN1	156	TANN	5.0	45.0	1.7	35.2	64.6	232.2	11.8	91.0	218.3	0.0	19.0		197.6				
163	TEAN1	157	TEAN	5.7	16.3		110.0	255.0	981.0	23.0	233.0	1160.0	12.0	7.0						
164	TECW1	158	TECW	6.1	59.0	1.7	157.2	93.0	262.6	9.1	163.7	282.1	36.5		500.0	26.0	7.0	16.0	27.5	200
165	TINK1	159	TINK	6.0	25.3	3.6	78.0	35.0	101.0	6.7	62.3	101.7	24.2	4.0		24.2				
166	TROO1	160	TROO	5.0	39.8	2.7	43.3	50.1	166.6	8.7	96.2	233.9	11.4	9.7	50.0	241.7	10.0	32.0	102.0	2050
167	UAI1	161	UAI	5.8	40.5	.4	69.0	59.5	191.0	10.0	82.0	215.0	14.8	10.0		112.5				
168	UIS1	162	UIS	6.2	33.6	4.8	67.8	49.2	191.2	16.0	46.8	166.8	60.8	2.3		34.0				
169	URR1	163	URR	6.8	59.3		166.5	129.9	181.8	11.3	148.7	247.3	60.5	14.7	130.0	227.7	6.3	23.7	194.0	1933
170	VAL1	164	VAL	4.7	33.1	2.6	17.7	23.8	93.1	5.5	57.1	171.1	0.0	9.8	130.0	126.5	11.0	33.8	31.0	495
171	VEREV1	165	VEREV	4.5	64.3											802.0				
172	WHIN1	166	WHIN	6.9	80.0		316.1	116.0	278.4	15.5	140.6	363.9	305.7	6.1	120.0	215.0	4.0	15.5	38.5	1100
173	WHIN2	166	WHIN	6.9	60.0		292.4	86.4	182.7	6.9	90.0	197.4	158.8		50.0	32.0	3.0	11.0	48.0	500
174	WHIT1	167	WHIT	7.0	154.0		244.6	157.2	305.6	16.4	161.4	640.0	415.5	5.9	30.0	70.7	3.5	33.2	52.6	2292
175	WOOD1	168	WOOD	6.8	98.4	5.8	324.8	239.0	325.7	16.5	190.1	397.7	278.2	69.9	440.0	138.3	7.5	48.0	111.0	3450
176	WOOD2	168	WOOD	6.9	77.0		309.4	198.3	204.4	14.1	119.3	207.0	203.8		190.0	78.0	5.0	146.0	253.0	2900
177	YBI1	169	YBI	5.1	34.0	1.2	53.1	57.1	195.7	8.1	100.4	225.4	.3		200.0	134.8	24.1	60.1	19.4	641
178	YGAD1	170	YGAD	5.7	32.0	1.8	79.3	42.1	156.7	8.6	73.6	169.3	29.7			62.0	9.0	19.0	33.0	450

Table 5 Summary statistics for selected environmental variables in the SWAP training set (Stan. dev. = standard deviation, min. = minimum, max. = maximum, quar. = quartile, N = number of determinations, afforest = afforestation)

	N	Mean	Median	Stan. dev.	Min.	Max.	Lower Quar.	Upper Quar.
pH	178	5.59	5.40	0.77	4.33	7.25	4.96	6.25
Conductivity	177	44.5	37.2	27.6	7.4	154.0	26.5	57.0
DOC	148	3.9	2.8	3.5	0.1	17.0	1.4	5.5
Ca	175	109.5	66.4	120.2	6.2	938.0	37.5	134.6
Mg	174	67.5	51.1	52.8	7.8	337.3	33.0	85.7
Na	144	171.8	156.7	138.0	16.5	1004.0	88.7	204.4
K	174	9.8	8.0	7.4	2.0	54.1	5.5	11.8
SO_4	175	106.9	90.0	64.4	18.7	352.4	60.8	145.8
Cl	175	187.4	164.2	161.6	10.4	1160.0	79.0	233.0
NO_3	126	10.4	6.2	13.3	0.0	91.5	3.1	12.4
TON	117	271.7	245.0	183.4	10.0	982.0	130.0	380.5
Alkalinity	161	57.3	12.8	116.5	0.0	903.0	0.0	58.8
Total Al	173	130.9	112.0	106.2	12.0	802.0	54.2	175.9
Zn	109	26.2	11.0	96.3	2.0	730.0	7.3	17.3
Mn	136	55.0	30.0	78.9	1.5	601.5	12.8	66.8
Fe	139	143.4	70.6	175.7	3.5	837.5	33.0	199.0
SiO_2	137	1329.9	1128.0	991.7	179.0	7000.0	550.0	1725.0
Altitude (m)	176	349.2	270.5	267.4	10.0	1246.0	165.3	488.7
% afforest	112	22.3	0.0	33.0	0.0	100.0	0.0	50.0
Max Depth (m)	176	15.9	13.5	10.8	1.0	61.0	9.0	20.0

Figure 4 shows that the majority of the sites are acidic, oligotrophic, and clearwater with low modal pH (5.0 - 5.4), conductivity (25 - 35 $\mu S\ cm^{-1}$), calcium (< 50 $\mu eq\ l^{-1}$), and alkalinity (< 50 $\mu eq\ l^{-1}$) classes. As might be expected from this distribution the majority of the lakes are slightly coloured with a modal DOC range of 1 - 3 mg l^{-1}. Strong colour is restricted to a few sites, especially in northern Scotland and a large number of sites from Sweden (e.g. Hagasjön, Vågsjöarna). Throughout the acid end of the data-set, aluminium levels are high (modal class 50 - 150 $\mu g\ l^{-1}$ total Al).

Sodium and chloride are in approximate marine proportions (data-set Na/Cl = 0.92 ± 0.21; marine ratio = 0.85) throughout the data-set (Figure 6) indicating a contribution predominantly from rainfall. A few lakes from coastal locations such as Loch na'Larach and Loch Teanga in Scotland have very high conductivities, sodium, and chloride levels. A number of lakes subject to past and current mining activities in their catchments have high trace-metal concentrations, e.g. Llyn Geirionydd and Llyn y Parc (Zn >700 $\mu g\ l^{-1}$).

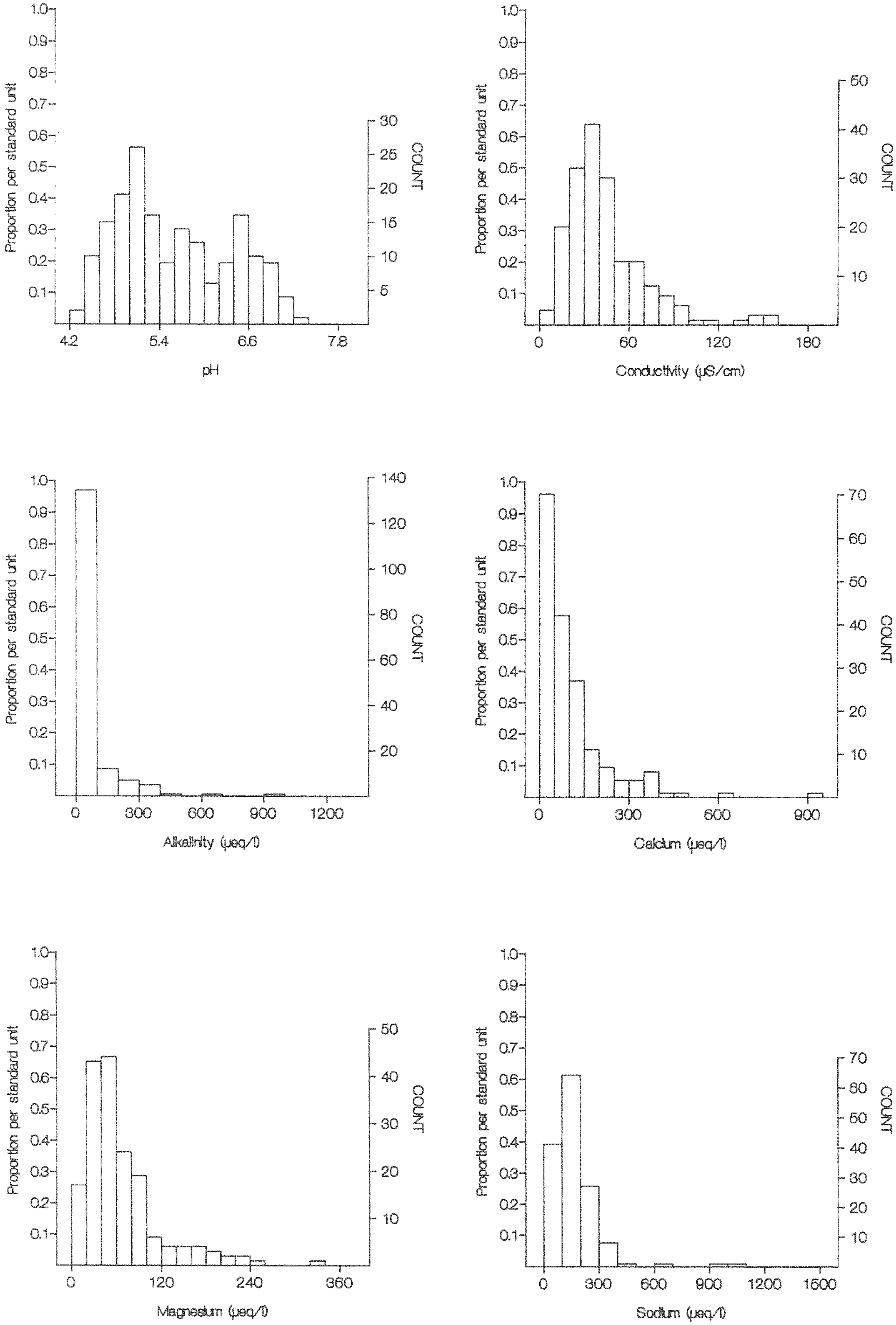


Figure 4 Frequency histograms for major chemical determinands and catchment variables, showing the proportion of different classes for the major variables.

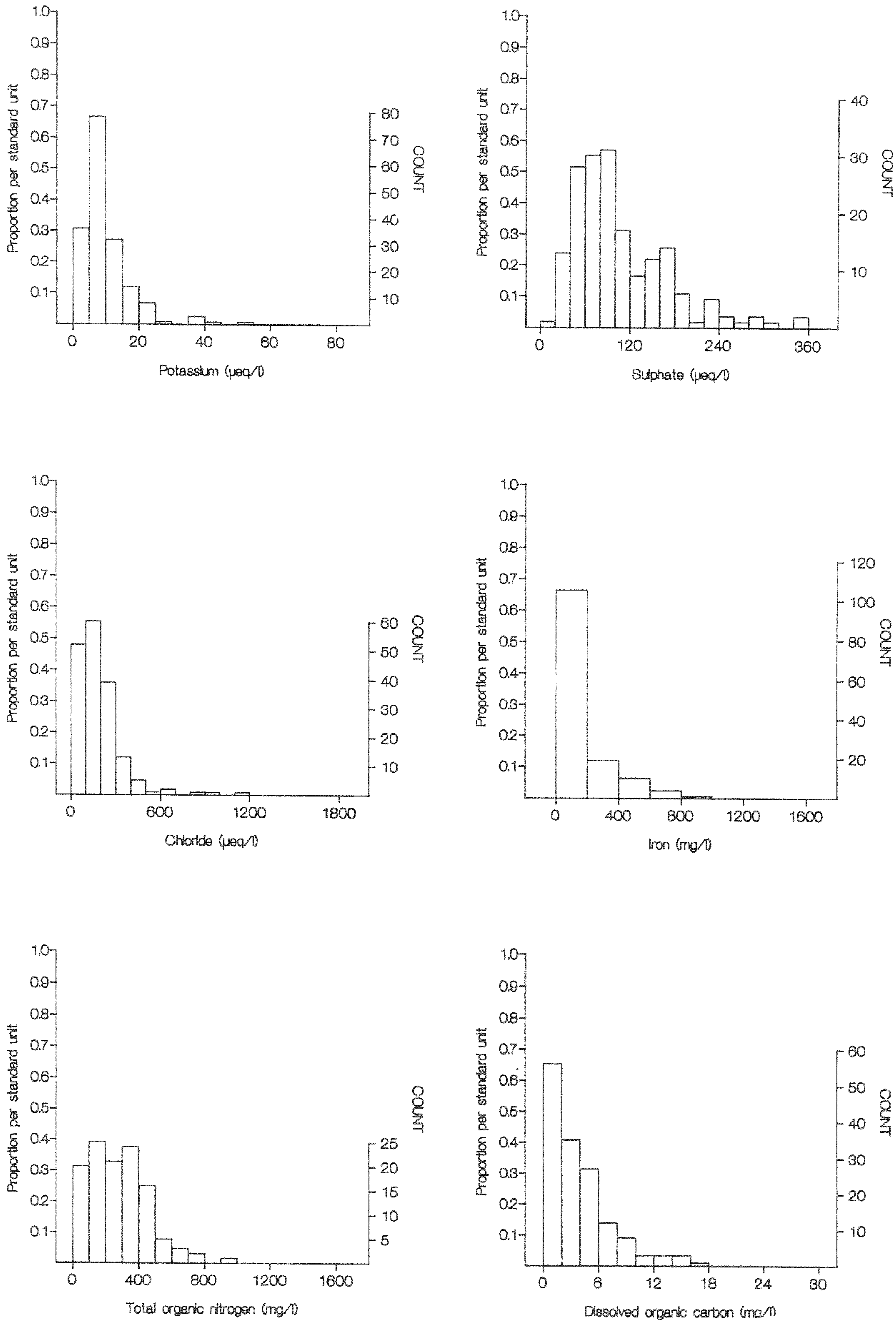


Figure 4 Continued.

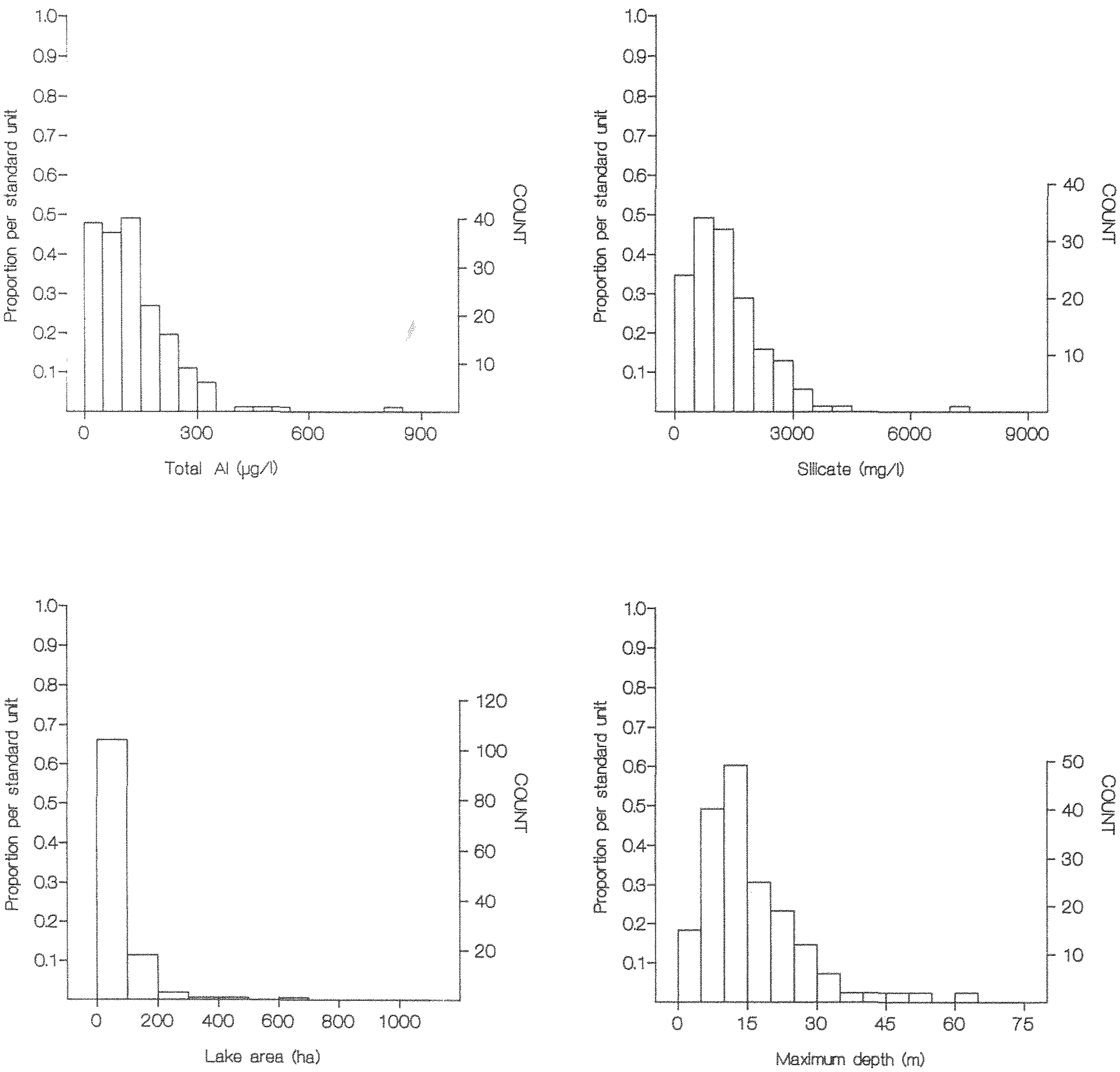


Figure 4 Continued.

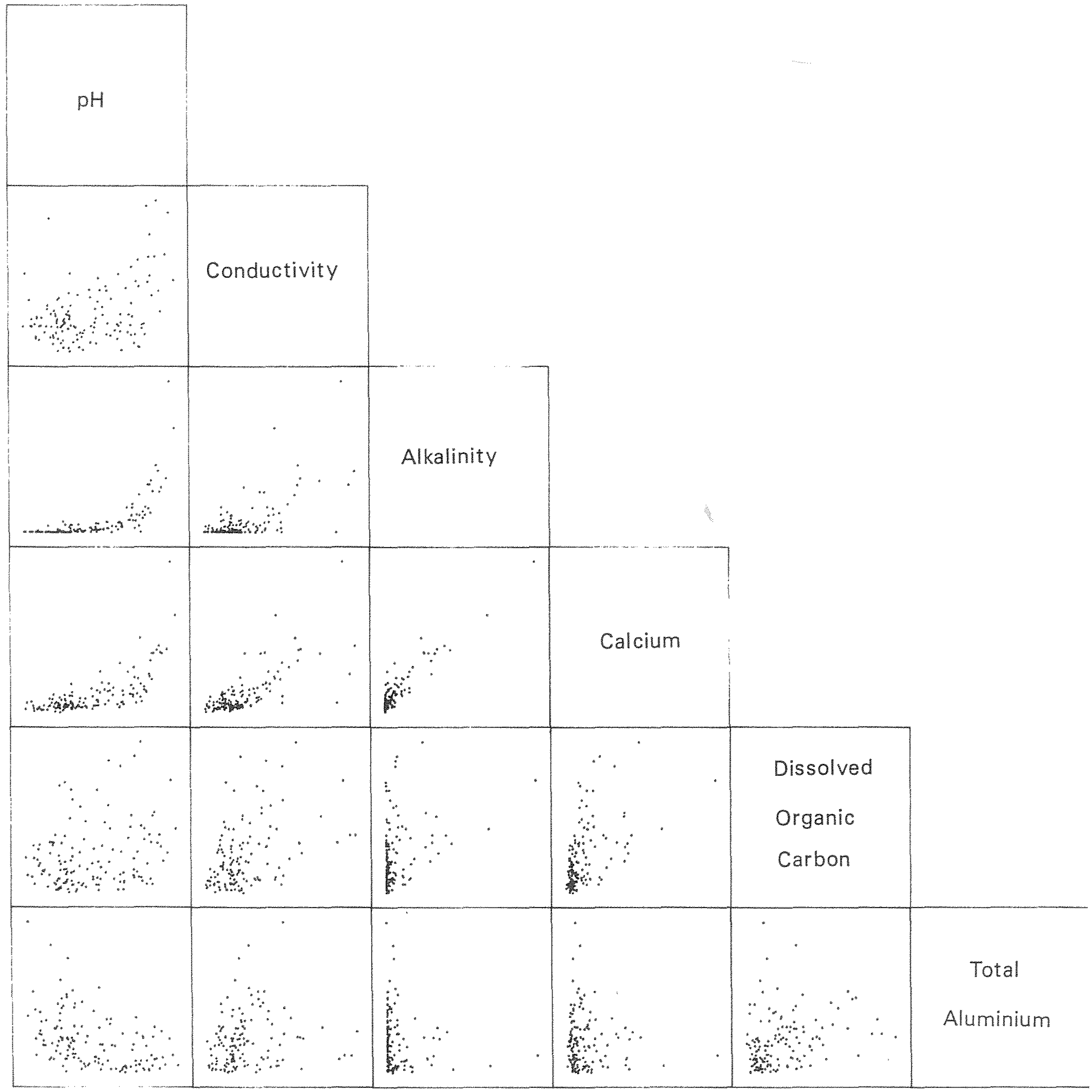


***Figure 5** Matrix of uniformly scaled scatter plots for major chemical determinands, showing the patterns between pairs of chemical determinands.*

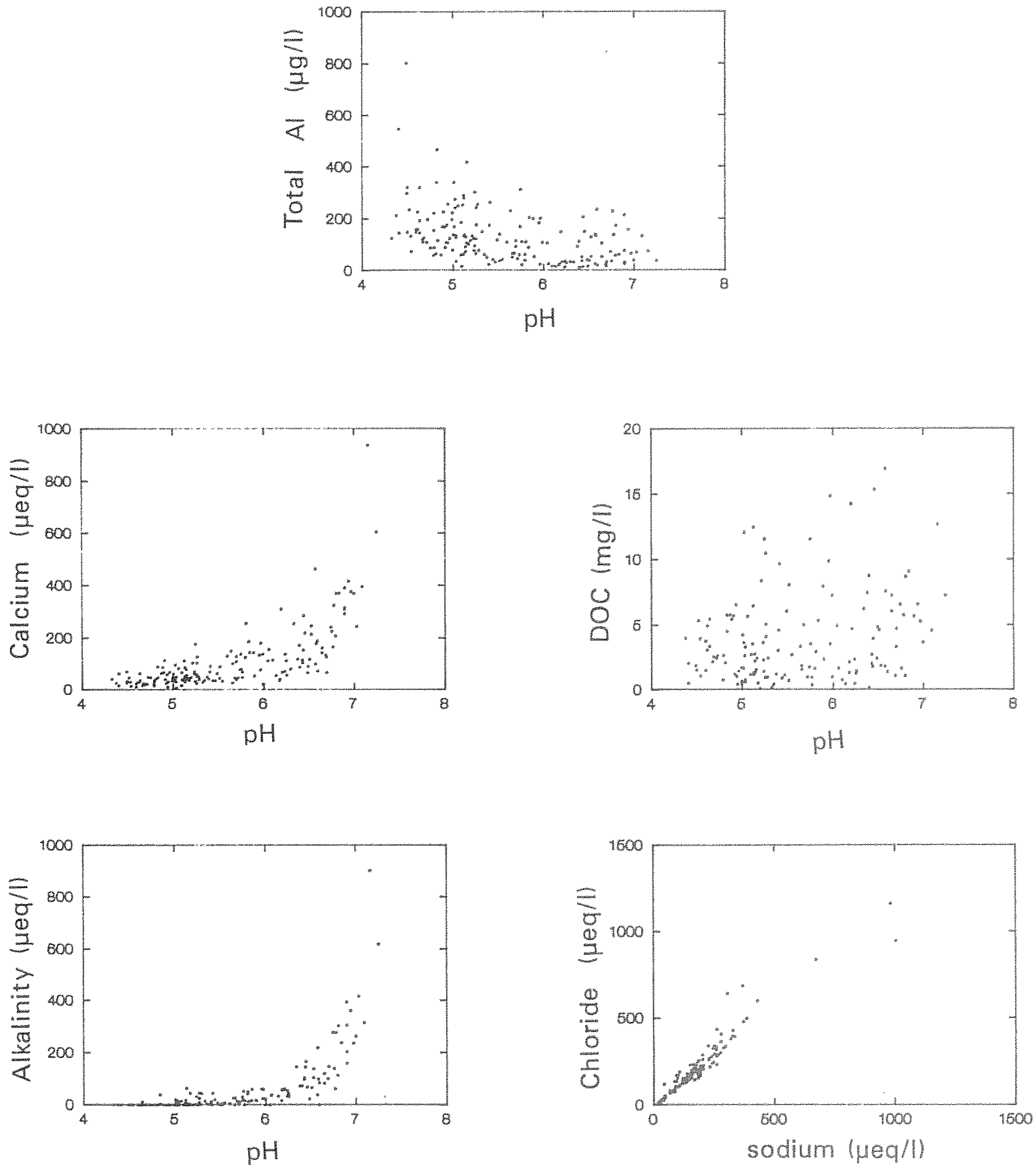


Figure 6 Scatter plots between selected chemical determinands.

The correlation matrix (Table 6) of environmental variables, with the significance levels adjusted for varying sample numbers, shows expected patterns of correlation between the variables. pH is positively correlated with both alkalinity and calcium levels (see also Figures 6 and 7), and negatively correlated with total aluminium. Altitude is negatively correlated with conductivity, DOC, magnesium, sodium, and potassium. The most acid sites are also the highest. Lake depth appears to have little correlation with lake-water chemistry.

Table 6 Matrix of product-moment correlations between environmental variables

	pH	Cond	DOC	Ca	Mg	Na	K	SO_4
Conductivity	0.423*							
DOC	0.260	0.442*						
Ca	0.705**	0.714**	0.531*					
Mg	0.528**	0.856**	0.455*	0.704**				
Na	0.275	0.706**	0.361*	0.511*	0.823**			
K	0.494*	0.712**	0.495*	0.749**	0.755**	0.680**		
SO_4	0.333*	0.764**	0.509*	0.629**	0.820**	0.672**	0.64**	
Cl	0.211	0.718**	0.138	0.295	0.788**	0.959**	0.517*	0.570*
NO_3	0.117	0.446 *	-0.039	0.277	0.514*	0.310*	0.474*	0.410*
TON	0.107	0.198	0.542*	0.438*	0.209	0.003	0.423*	0.400*
Alkalinity	0.681**	0.674**	0.354*	0.914**	0.600*	0.424*	0.692**	0.400*
Total Al	-0.437*	0.139	0.279	-0.097	0.079	0.080	0.025	0.271
Zn	0.191	0.146	-0.128	0.159	0.155	0.164	0.019	0.256
Mn	-0.108	0.319*	0.395*	0.161	0.290	0.301*	0.430*	0.394*
Fe	-0.082	0.205	0.708**	0.145	0.234	0.191	0.303*	0.308*
SiO_2	0.267	0.454*	0.435*	0.376*	0.523*	0.433*	0.496*	0.419*
Altitude	-0.186	-0.576**	-0.470*	-0.374*	-0.560*	-0.559*	-0.449*	-0.571*
Unforested	-0.118	-0.298	-0.503*	-0.308*	-0.249	-0.072	-0.188	-0.407*
Forested	0.118	0.298	0.503*	0.308*	0.249	0.072	0.188	0.407*
Conifer F.	0.099	0.295	0.530*	0.303*	0.249	0.064	0.196	0.400*
Deciduous F.	0.063	-0.001	-0.107	0.007	-0.011	0.025	-0.036	0.012
%afforest.	0.067	0.366*	0.279	0.252	0.261	0.165	-0.012	0.446*
Max Depth	-0.165	-0.394*	-0.312*	-0.280*	-0.337*	-0.299	-0.303*	-0.332*

Table 6 Continued.

	Cl	NO_3	TON	Alkal	Tot. Al	Zn
NO_3	0.375*					
TON	-0.157	0.025				
Alkalinity	0.276	0.277	0.227			
Total Al	0.137	0.191	-0.010	-0.153		
Zn	0.123	-0.027	0.185	0.090	-0.121	
Mn	0.260	0.461*	0.165	0.081	0.252	-0.035
Fe	0.081	0.102	0.235	0.015	0.443*	-0.090
SiO_2	0.348*	0.587*	-0.021	0.343	0.386*	-0.042
Altitude	-0.498*	-0.171	-0.183	-0.269	-0.195	-0.072
Unforested	-0.042	-0.058	-0.184	-0.239	-0.323*	-0.103
Forested	0.042	0.058	0.184	0.239	0.323*	0.103
Conifer F.	0.038	0.058	0.163	0.240	0.344*	0.105
Deciduous F.	0.013		0.040	-0.013	-0.090	-0.012
%afforest.	0.253	0.109	-0.177	0.192	0.428*	0.217
Max Depth	-0.274	-0.102	-0.174	-0.232	-0.118	-0.055

	Mn	Fe	SiO_2	Altit	Unfor	Forest	Conif	Decid	%Aff
Fe	0.517*								
SiO_2	0.385*	0.466*							
Altitude	-0.221	-0.250	-0.354*						
Unforested	-0.189	-0.272	-0.357*	0.503*					
Forested	0.189	0.272	0.357*	-0.503*	-1.000**				
Conifer F.	0.202	0.300*	0.393*	-0.468*	-0.964**	0.964**			
Deciduous F.	-0.052	-0.107	-0.137	-0.113	-0.098	0.098	-0.170		
%afforest.	0.151	0.149	0.355*	-0.419*	-0.769**	0.769**	0.799**	-0.070	
Max Depth	-0.231	-0.208	-0.159	0.347*	0.042	-0.042	-0.032	-0.037	0.171

(* = significant at $p \leq 0.05$, ** = significant at $p \leq 0.01$; all significance tests have been adjusted for varying sampling size)
(Max = maximum, afforest. = afforestation, F. = forest)

Principal Components Analysis

Principal components analysis (PCA) was used to summarise the major patterns of variation within the environmental data. Since not all determinands were available for all samples or all sites, a reduced data-set of 157 samples with nine chemical variables (pH, Cl, SO_4, conductivity, Mg, K, Ca, alkalinity, total Al) in common was selected for PCA. Figure 7 is a PCA correlation biplot derived from a PCA of the correlation matrix of the untransformed chemical data. The individual sample scores and variable loadings for this analysis are listed in Table 8. The seven catchment and physical variables (maximum depth, altitude, unforested, forested, forested with deciduous trees, forested with coniferous trees, percentage afforested) were included as passive variables (ter Braak 1987). In a PCA correlation biplot, variables with high positive correlations generally have small angles between their biplot arrows. Variables with long arrows have high variance and are often the most important within the data (Jongman *et al.* 1987).

The PCA and all the other ordinations presented here were implemented by means of the computer program CANOCO 3.10 (ter Braak 1987, 1990).

Table 7 Eigenvalues and cumulative variance accounted for in a PCA of the 157 sample x 9 chemical variable data-set

	Eigenvalue	Cumulative variance represented
Axis 1	0.608	60.8%
Axis 2	0.184	78.1%
Axis 3	0.082	86.3%
Axis 4	0.047	91.0%

The variance within the data-set is efficiently captured with over 78% accounted for by the first two components. The first axis (60.8%) is effectively contrasting lakes with high pH/alkalinity and associated variables (Ca, K, Mg, SO_4, Cl) with acid sites, such as Bliksvatn (**82.1** on Figure 7) and the Round Loch of Glenhead (**RLGH**), positioned to the left-hand side of the PCA biplot. Alkaline sites such as Loch Fern (**FERN**), Loch Clonyard (**CLON**), and Edasjön (**S2**) are located on the right-hand side. Lake altitude and maximum depth, included as passive variables, are negatively correlated with this set of variables. Axis two (18.7%) is more complex and may reflect contrasts in aluminium, with high aluminium sites such as Loch Stroan (**STRO**), Loch Minnoch (**MINN**), and Härsvatten (**S22**), located at the positive end of axis 2 and low aluminium sites such as V. Helgtjärnen (**S15**), Flickersjön (**S8**), and Loch Whinyeon (**WHIN**) located at the negative end of axis 2. The contrast in the relative sizes of axes 1, 2, and 3 (eigenvalues 0.608, 0.184, 0.082, respectively) suggests that there is only one overriding gradient of variation in the chemical data, namely axis 1 reflecting the strong gradient from high to low pH, alkalinity, calcium, conductivity, etc. There is very little scatter of sites on axis 2, with the exception of two Swedish sites (**S22, S15**), and axis 2 may be primarily influenced by extreme values in these sites.

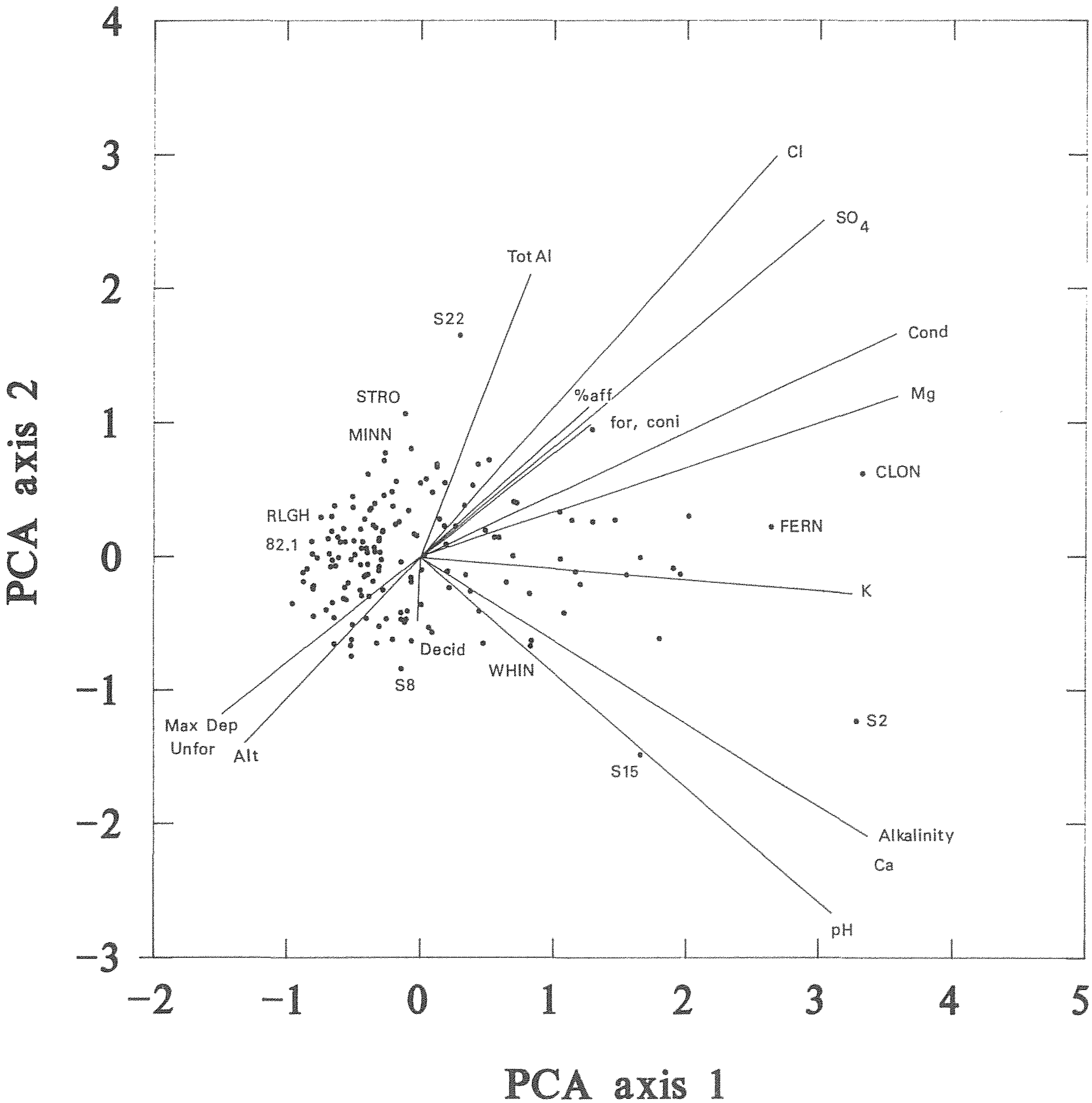


Figure 7 Principal components correlation biplot of the 157 sample x 9 chemical variable data-set. Catchment and other environmental variables are analysed as passive variables. The individual sample scores and variable loadings are listed in Table 8. See Table 2 for site codes. Abbreviations: tot = total, aff = afforestation, for = forested, coni = conifer, cond = conductivity, alt = altitude, unfor = unforested, decid = deciduous, max dep = maximum depth, PCA = principal components analysis.

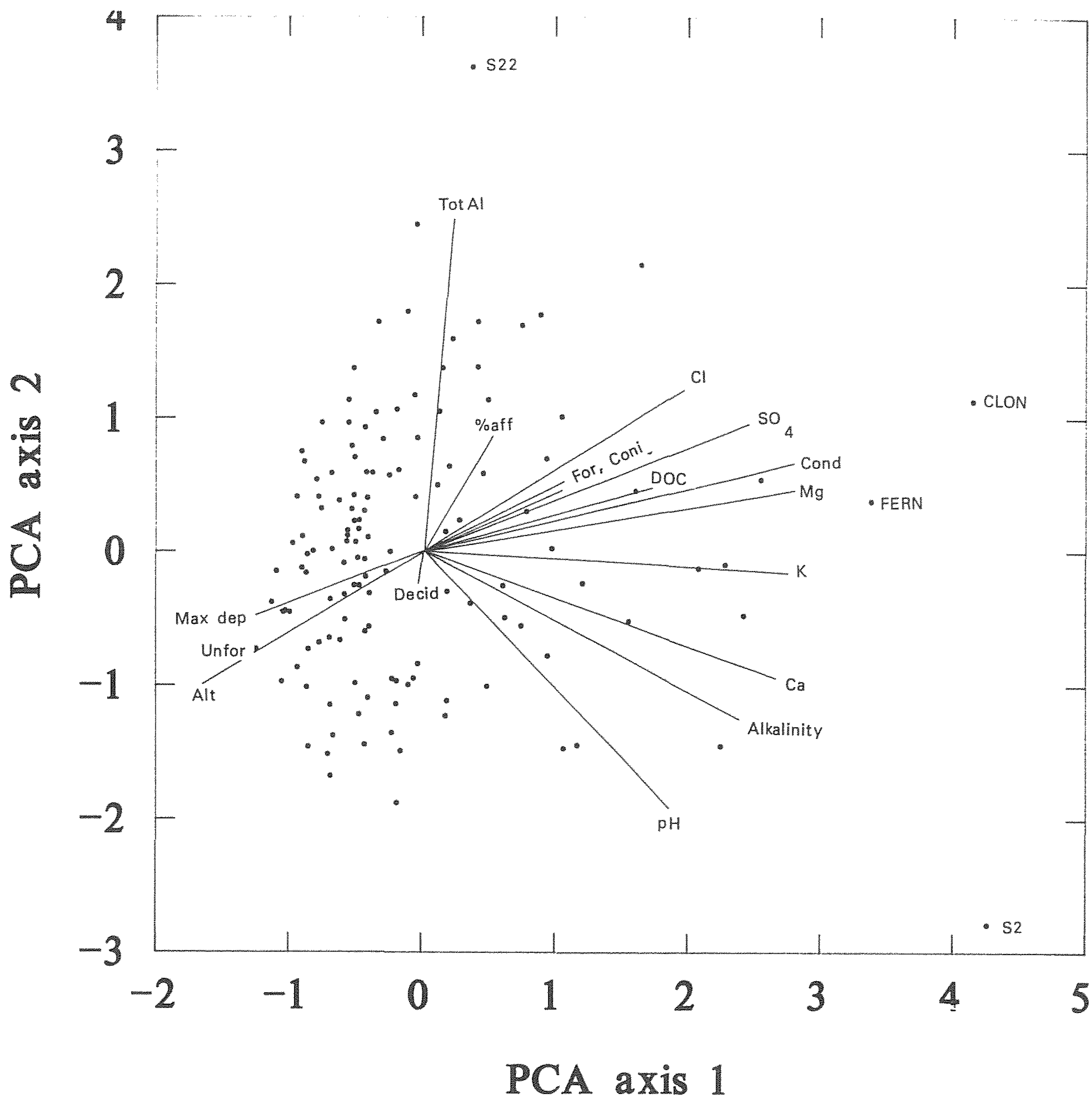


Figure 8 Principal components correlation biplot of the 138 x 10 chemical variable data-set. Catchment and other environmental variables are analysed as passive variables. The individual sample scores and variable loadings are listed in Table 8. See Table 2 for site codes. Abbreviations follow the caption for Figure 7.

Table 8 Sample scores and environmental variable loadings for the PCAs of the 157 and 138 sample data-sets.

		157 sample data-set				138 sample data-set			
		Axis 1	Axis 2	Axis 3	Axis 4	Axis 1	Axis 2	Axis 3	Axis 4
Variable loadings									
	pH	0.6219	-0.6453	0.0120	-0.2047	0.8556	-1.3713	0.1815	-1.0496
	Conductivity	0.9326	0.2283	0.2078	0.0417	1.1999	0.5589	0.5208	0.4665
	DOC					0.5742	0.1637	-0.6619	-0.3308
	Ca	0.8858	-0.3118	-0.2258	0.1607	1.1294	-0.6969	-1.0525	-0.0215
	Mg	0.9344	0.1599	0.2020	-0.1072	1.2026	0.4038	0.5040	-0.4662
	K	0.8770	-0.0480	-0.0444	0.1254	1.0880	-0.0879	-0.5255	0.6240
	SO4	0.8187	0.3257	-0.0409	-0.2284	1.0163	0.8415	-0.2766	-2.0332
	Cl	0.6516	0.4073	0.5819	-0.0345	0.8965	0.9998	1.7918	0.9214
	Alkalinity	0.7929	-0.4151	-0.1132	0.3971	1.0413	-0.8933	-0.8445	1.4136
	Total Al	0.0727	0.8320	-0.3688	0.2874	0.0411	1.9092	-1.7487	0.3041
	Altitude	-0.5546	-0.3304	0.0320	0.1753	-0.6978	-0.7510	-0.1018	0.4185
	Unafforested	-0.3599	-0.2127	0.4031	0.1217	-0.4360	-0.4583	1.0890	1.1294
	Forested	0.3532	0.1582	-0.3994	-0.1579	0.4281	0.3382	-0.9932	-1.1553
	Conifer F.	0.3535	0.1799	-0.4311	-0.1460	0.4249	0.3797	-1.0689	-1.0496
	Deciduous F.	-0.0109	-0.0777	0.1182	-0.0360	-0.0037	-0.1594	0.3041	-0.3359
	% afforested	0.1730	0.2895	0.1796	0.0949	0.2839	0.7094	0.4663	-0.1474
	Max. depth	-0.4215	-0.1567	0.0221	0.0360	-0.4922	-0.3865	0.0565	0.0582
Sample scores									
Sample number	Sample code								
1	1.21	-0.0778	0.8051	-0.2540	0.1288	-0.1045	1.8021	0.1107	1.4889
2	10.21	0.1347	0.2803	-0.2154	-0.2352	0.2067	0.6454	-0.3514	-0.1510
4	111.11	-0.5203	-0.6220	0.0846	-0.0426	-0.6633	-1.3766	0.0209	-0.4591
5	113.21	-0.3311	-0.6494	0.0801	0.0843	-0.4264	-1.4435	0.0973	0.0432
6	115.11	-0.3576	-0.1833	0.2784	0.1290	-0.3857	-0.3111	0.2554	-0.6728
7	12.11	-0.8007	-0.2170	-0.0976	-0.0105	-1.0225	-0.4400	-0.2066	0.3170
9	15.11	-0.4983	0.0154	-0.2968	-0.1136	-0.5550	0.1197	-0.9998	-0.0099
10	17.21	-0.0946	0.3418	-0.1329	-0.2082	-0.0278	0.8559	-0.5559	-0.4970
11	18.11	-0.7096	-0.3968	0.0083	0.0355	-0.9317	-0.8625	0.1247	0.2634
13	19.21	-0.6519	-0.6538	0.0102	-0.0858	-0.8519	-1.4595	-0.0519	-0.2365
14	2.11	-0.1635	0.2589	0.1619	0.0323	-0.2397	0.5766	0.8460	0.2405
15	20.11	-0.5231	-0.7463	-0.0291	-0.1375	-0.6855	-1.6774	-0.1813	-0.3511
17	21.11	-0.3888	-0.2969	-0.1631	-0.2522	-0.4202	-0.5953	-0.8573	-0.7865
18	3.11	-0.6712	0.1895	-0.0664	0.1180	-0.7878	0.5414	-0.3380	0.3774
20	34.11	-0.9605	-0.3494	0.0670	0.1053	-1.2460	-0.7249	0.2044	0.3554
22	4.11	-0.6503	0.3787	-0.2868	0.1007	-0.7483	0.9669	-0.7877	0.8015
23	42.11	-0.8082	-0.2254	0.0993	0.1231	-1.0416	-0.4487	0.2927	0.3031
24	44.21	-0.5293	-0.6663	0.0963	-0.3085	-0.7050	-1.5149	0.1319	-0.9994
25	49.11	-0.6803	-0.0738	0.1764	0.1440	-0.8954	-0.1214	0.6529	0.3881
26	5.11	-0.2779	0.7136	-0.4504	-0.0404				
27	58.11	-0.6639	-0.3422	0.1443	0.0336	-0.8493	-0.7257	0.2818	-0.2048
28	59.11	-0.8041	-0.4441	0.0072	-0.0329	-1.0535	-0.9688	0.0682	0.0830

Table 8 Continued.

Sample number	Sample code	157 sample data-set Axis 1	Axis 2	Axis 3	Axis 4	138 sample data-set Axis 1	Axis 2	Axis 3	Axis 4
36	80.11	-0.3468	0.3951	-0.0976	0.0927	-0.4216	0.9309	0.0348	0.7039
37	81.21	-0.5138	0.4470	-0.2886	0.0708	-0.5439	1.1348	-0.9367	0.5331
38	82.11	-0.8190	0.1137	-0.1834	0.1122	-0.9353	0.4145	-0.8947	0.3161
39	83.11	-0.8496	-0.0893	-0.0089	0.1400	-1.0918	-0.1449	0.1095	0.6483
40	86.11	-0.5708	0.1122	-0.2986	-0.0855	-0.6179	0.3841	-1.1531	0.0054
41	87.21	-0.8060	-0.2399	-0.0522	-0.0250	-0.9913	-0.4492	-0.3648	-0.0590
42	88.21	-0.8767	-0.1849	-0.1530	0.0301	-1.1266	-0.3753	-0.2655	0.6134
43	89.11	-0.6516	-0.4567	0.1478	-0.0561	-0.8631	-1.0111	0.3977	-0.2920
44	9.11	-0.7794	-0.0082	-0.1318	0.0376	-0.9688	0.0636	-0.3294	0.4745
45	ACH1	-0.5458	-0.1944	0.3591	0.1904	-0.6816	-0.3544	0.7492	-0.2603
46	ARR1	-0.1503	-0.4188	0.2994	0.1599	-0.2201	-0.9462	0.8654	-0.1588
47	ARTH1	1.9557	-0.1288	-0.1294	-0.0003	2.4230	-0.4717	0.7026	0.9739
48	BARE1	2.0155	0.3022	0.7497	0.0215	2.5513	0.5461	2.3842	-0.9427
49	BARL1	-0.1217	-0.4914	0.1029	-0.0388	-0.1886	-1.1362	0.3952	-0.0741
50	BER1	-0.2164	0.4815	0.1495	-0.0327				
51	BODG1	0.6487	-0.1912	0.2500	-0.2507	0.7506	-0.5489	1.1684	-0.5334
52	BODL1	-0.4228	-0.1463	0.2338	0.0147	-0.5723	-0.3198	0.7780	-0.1397
53	BREC1	0.7226	0.3983	0.1553	-0.2181				
54	BUGE1	-0.3387	0.2175	0.2122	0.1656	-0.3653	0.5938	0.3290	-0.1236
56	BYCH1	0.4403	-0.4079	0.3146	-0.0403	0.4874	-1.0017	1.2266	-0.2317
57	CFYN1	-0.5799	-0.3119	0.1832	0.0449	-0.7675	-0.6768	0.5518	-0.0501
58	CHN1	-0.3094	0.0335	0.1518	0.0671	-0.4002	0.1070	0.5503	0.0901
59	CLON1	3.3234	0.6187	0.4663	0.0291	4.1512	1.1346	2.6187	0.0634
60	CLYD1	-0.2599	-0.4656	0.2058	-0.0444	-0.4007	-1.0915	0.8243	-0.2172
61	CON1	-0.5274	-0.0207	0.1590	0.1160	-0.6694	0.0172	0.4662	0.1460
62	COR1	-0.6436	-0.0682	-0.1516	0.1124	-0.8630	-0.1582	0.0683	1.0511
63	CWBY1	-0.3145	0.1367	0.0501	0.0182	-0.4271	0.3057	0.5005	0.3498
65	DIWA1	-0.4448	-0.2909	0.1878	-0.0152	-0.6077	-0.6592	0.6540	-0.1577
66	DOI1	-0.0727	-0.1556	0.3546	0.0965	-0.1142	-0.3530	1.0410	-0.3889
67	DOON1	-0.0530	0.1689	0.1099	0.0206	-0.0424	0.4142	0.3693	-0.0980
68	DUH1	-0.6675	-0.0240	-0.1115	0.0593	-0.8581	-0.0204	-0.0715	0.6351
69	DUL1	-0.3529	0.0687	0.1318	0.0564	-0.4702	0.1686	0.6074	0.1876
70	ENO1	-0.6896	0.0231	0.1372	0.2178	-0.8942	0.1143	0.5543	0.6335
71	EUN1	-0.6716	0.2998	-0.3587	0.1176	-0.8791	0.6754	-0.3281	1.5963
72	FERN1	2.6373	0.2218	-0.1908	0.1500	3.3830	0.3834	0.3597	0.7305
73	FHI1	-0.0010	0.5469	-0.0284	0.1450	-0.0468	1.1734	0.7316	1.0814
74	FINL1	0.0874	0.4776	-0.2927	0.1005	0.1368	1.0523	-0.2826	1.0908
75	FLE1	-0.5811	0.2110	0.0069	0.1396	-0.6730	0.5915	-0.1534	0.2702
76	GARN1	-0.1034	-0.4075	0.1835	-0.0995	-0.1871	-0.9628	0.7200	-0.3330
77	GEIR1	0.8166	-0.2764	0.2518	-0.3151	0.9452	-0.7734	1.2701	-0.6088
78	GLAS1	-0.3134	-0.5226	0.2104	-0.0607	-0.4669	-1.2166	0.7768	-0.2761
79	GLFR1	1.7961	-0.6129	0.0994	0.7303	2.2468	-1.4500	0.9890	2.0303
80	GLYN1	-0.4122	0.0630	0.1096	0.0077	-0.5522	0.1587	0.5769	0.1784
81	GOD1	0.1861	0.0916	0.4417	-0.0686	0.1812	0.1527	1.5325	-0.5483
82	GREENT1	-0.3159	0.1186	0.1662	0.0559	-0.4659	0.2356	0.9708	0.4482
84	GWYN1	-0.0713	-0.6325	0.1290	-0.0876	-0.1576	-1.4887	0.5878	-0.1191
85	GYN1	-0.4027	-0.0564	0.1938	0.0370	-0.4767	-0.0479	0.3134	-0.4099
86	HARR1	-0.3980	0.6127	-0.3964	0.1517	-0.5042	1.3708	-0.3754	1.7484
87	HIR1	-0.2860	0.1947	0.1888	0.0218				
90	HOWI1	0.3916	0.5300	0.0309	-0.1519	0.4974	1.1404	0.5481	-0.0251

Table 8 Continued.

Sample number	Sample code	157 sample data-set Axis 1	Axis 2	Axis 3	Axis 4	138 sample data-set Axis 1	Axis 2	Axis 3	Axis 4
95	LAG1	-0.4552	-0.0583	0.2135	0.0721	-0.5784	-0.0845	0.5634	-0.1090
96	LAI1	-0.5617	-0.3206	0.2104	0.0812	-0.6908	-0.6406	0.2866	-0.3727
97	LAR1	1.2840	0.9481	1.4318	0.6788	1.6426	2.1511	3.9893	-1.0271
98	LCSL1	-0.3481	0.0380	0.1240	0.0882	-0.4943	0.0740	0.7797	0.4483
99	LCSU1	-0.3190	-0.1032	0.1651	0.0083	-0.4647	-0.2522	0.8338	0.1122
100	LDE1	-0.3972	-0.1312	0.1009	0.1502	-0.5018	-0.2500	0.3256	0.2910
101	LDE2	-0.5722	-0.2294	0.0309	-0.0474				
102	LENY1	0.0026	-0.3578	0.2090	-0.1499	-0.0252	-0.8327	0.6281	-0.6155
103	LGR1	-0.5116	0.3669	-0.0391	0.2071	-0.5429	0.9657	-0.4091	0.3221
106	LLDU1	0.1968	-0.1088	0.3549	-0.0342	0.1935	-0.2929	1.2900	-0.3542
107	LLGH1	-0.4230	0.2795	0.0525	0.1576	-0.4984	0.7086	0.1727	0.4025
108	LOD1	-0.4564	-0.2491	0.2684	0.1334	-0.5722	-0.5036	0.5688	-0.2793
109	LOWT1	-0.4049	0.0315	0.1817	0.0695	-0.5601	0.0754	0.8338	0.3078
110	MABE1	0.4320	0.6860	0.0860	-0.0204	0.7559	1.6974	-0.5043	-1.1041
111	MACA1	-0.3587	0.2356	0.0031	0.1547	-0.4120	0.5982	0.0350	0.3999
112	MANN1	1.2868	0.2600	-0.0445	-0.0691	1.6005	0.4606	0.7085	0.5176
113	MINN1	-0.2684	0.7714	-0.5659	0.1837	-0.3181	1.7205	-0.7518	2.1448
114	MOAN1	0.1193	0.6873	0.0324	-0.0207	0.2346	1.5969	0.0875	-0.1530
115	MUCK1	0.1793	0.5478	-0.0148	0.1322	0.4209	1.3852	-0.6944	-0.4508
116	NAGA1	-0.6216	-0.0058	-0.0927	0.0543	-0.8179	0.0066	0.0979	0.6962
117	OCHI1	0.7002	0.4071	0.2224	-0.0490	1.0536	1.0125	-0.0266	-1.4011
118	PARC1	1.0438	-0.0143	0.4303	-0.4552	1.2079	-0.2340	1.9178	-1.1270
119	PENR1	-0.4384	0.1118	0.0118	0.0485	-0.5215	0.3201	0.0015	0.1102
120	RIEC1	-0.1921	0.2407	0.0200	0.1028	-0.1701	0.6173	-0.0981	0.0706
121	RLGH1	-0.6077	0.1102	0.1155	0.1826	-0.7534	0.3262	0.3230	0.3775
122	RLGH2	-0.6984	0.1351	-0.0786	0.1213				
123	RONA1	1.4558	0.2734	0.4664	0.0993				
125	S101	0.0600	-0.5312	-0.2806	-0.1015	0.1902	-1.1108	-1.3009	-0.4745
126	S11	0.8223	-0.6709	-0.3789	-0.1850	1.1665	-1.4471	-1.4891	-0.3254
127	S111	0.5131	0.7182	-0.4354	-0.2479	0.8936	1.7773	-1.8247	-0.8881
128	S121	-0.2128	-0.6206	-0.0985	-0.2185	-0.2214	-1.3529	-0.6577	-0.8069
129	S131	-0.0324	0.1558	-0.1132	-0.1633	0.1218	0.5040	-1.0014	-1.0673
130	S141	-0.1486	-0.4699	-0.2083	-0.1224	-0.0580	-0.9410	-1.2831	-0.7979
131	S151	1.6496	-1.4784	-1.0020	0.8583	2.1129	-3.3329	-1.9708	4.4456
132	S161	0.3770	-0.2596	-0.2320	-0.2409	0.6247	-0.4882	-1.2533	-1.1299
133	S171	1.0401	0.3339	-0.0981	-0.7379	1.2769	0.6174	0.4494	-1.2025
134	S181	0.5886	0.1419	0.0646	-0.4657	0.7887	0.3061	0.1521	-1.4535
135	S191	0.1201	0.6652	-0.1762	-0.0156	0.4237	1.7252	-1.5134	-1.0002
136	S201	-0.4162	-0.1397	-0.1799	-0.0488	-0.4169	-0.1857	-0.9944	-0.4566
137	S21	3.2779	-1.2273	-1.2559	0.6987	4.2564	-2.7824	-2.5659	4.7998
139	S221	0.2929	1.6497	-0.5734	0.1067	0.3747	3.6315	-0.1663	2.4726
140	S241	-0.0728	-0.1874	-0.1574	-0.2674	0.0336	-0.3168	-1.0576	-1.1412
141	S251	0.8286	-0.6308	-0.3033	-0.2405	1.0640	-1.4707	-0.6515	0.1554
142	S261	1.5459	-0.1347	-0.3595	-0.1706	2.2845	-0.0933	-2.2978	-1.4738
143	S271	-0.3854	0.3472	-0.5051	-0.0211	-0.1823	1.0669	-2.6607	-0.6701
144	S281	-0.5060	0.1184	-0.3063	0.0091	-0.5049	0.4265	-1.3086	-0.0141
145	S291	-0.4490	0.0631	-0.2079	-0.0868	-0.5038	0.2316	-0.7028	-0.0224
146	S301	-0.3156	-0.0727	-0.2321	-0.1110	-0.2352	0.0038	-1.4078	-0.8056
147	S31	0.0824	-0.5670	-0.1177	-0.2275	0.1797	-1.2249	-0.7761	-0.9447
148	S311	0.2538	0.2265	-0.1919	-0.2759	0.4604	0.5918	-0.9577	-1.0020

Table 8 Continued.

Sample number	Sample code	157 sample data-set Axis 1	Axis 2	Axis 3	Axis 4	138 sample data-set Axis 1	Axis 2	Axis 3	Axis 4
153	S81	-0.1479	-0.8408	-0.0382	0.0528	-0.1857	-1.8751	-0.2424	0.0810
154	S91	1.1299	0.2711	-0.1630	-0.7587	1.7083	0.7573	-1.6814	-3.1043
155	SCOATT1	-0.3755	0.3596	-0.0865	0.2226	-0.5194	0.7938	0.4549	1.3799
156	SKAK1	0.3259	0.3789	0.0808	-0.1798				
157	SKAK2	0.0050	-0.0997	0.2179	-0.2361				
158	SKE1	0.0390	0.5764	-0.2547	0.0923	0.1611	1.3764	-0.7114	0.6028
159	SKE2	-0.4544	0.2054	-0.0890	0.0599				
160	SKOMAKV1	-0.8156	0.0209	-0.0362	0.1696				
161	STRO1	-0.1199	1.0655	-0.6244	0.0735	-0.0371	2.4521	-1.3273	1.5831
162	TANN1	-0.2140	0.3753	-0.0190	0.1488	-0.2871	0.8465	0.4483	0.8230
164	TECW1	0.3373	-0.1344	0.3597	-0.2683	0.3648	-0.3805	1.2905	-0.9536
165	TINK1	-0.4116	-0.4615	0.1378	-0.0693	-0.4956	-0.9809	0.0326	-0.7185
166	TROO1	-0.2796	0.4546	-0.1120	0.1439	-0.3391	1.0435	0.0758	0.8940
167	UAI1	-0.1524	-0.0393	0.1369	0.0263	-0.2627	-0.1440	0.8966	0.3189
168	UIS1	-0.1121	-0.4680	0.1587	0.1328	-0.0979	-0.9902	0.0980	-0.4431
169	URR1	0.5517	0.1436	-0.0936	-0.2605				
170	VAL1	-0.6271	0.1465	0.0727	0.2162	-0.7729	0.4121	0.2243	0.5361
172	WHIN1	1.1587	-0.1114	-0.2475	0.2437				
173	WHIN2	0.4714	-0.6510	0.0739	-0.0485				
174	WHIT1	1.8959	-0.0859	0.5932	0.5425				
175	WOOD1	1.6483	-0.0054	0.1100	-0.0318	2.0838	-0.1200	0.8519	0.1595
176	WOOD2	1.0748	-0.4202	0.0223	-0.0802				
177	YBI1	-0.2904	0.1841	0.1036	0.0306	-0.4034	0.4051	0.6824	0.3178
178	YGAD1	-0.2852	-0.2484	0.1382	0.0182	-0.3894	-0.5575	0.5169	-0.0319

In order to incorporate DOC into the analysis, the data-set was further restricted to the 138 samples with DOC data. The correlation biplot of an analysis of the correlation matrix is shown in Figure 8. The summary statistics are shown in Table 9 while the variable loadings and sample scores for this analysis are listed in Table 8.

Table 9 Eigenvalues and cumulative variance accounted for in a PCA of the 138 sample x 10 chemical variable data-set

	Eigenvalue	Cumulative variance represented
Axis 1	0.574	57.4%
Axis 2	0.176	75.0%
Axis 3	0.106	85.6%
Axis 4	0.050	90.6%

As with the PCA of the 157 sample data-set, the PCA of the 138 sample data-set represents an efficient summary of the data with 75% of the variance of the data-set accounted for by the first two axes (Figure 8). The dominant trends appear to be the same as the 157 lake analysis, namely high to low pH, calcium, etc. Samples with high DOC values lie mid-way along axis 1. The inclusion of a limited range of catchment characteristics albeit run as passive variables, suggests that conifer-forested catchments tend to have high DOC values, and that deep, high-altitude lakes that have unforested catchments have low DOC values (Figure 8). The most acid lakes show no strong correlations with any catchment characteristics.

NUMERICAL ANALYSIS OF THE DIATOM DATA

Basic statistics

A total of 277 diatom taxa was recorded in the 178 samples within the SWAP training set with a relative abundance of greater than 1% in at least one sample. A total of 210 taxa was present in fewer than 25% of all samples. Appendix B lists full names, authorities, codes for all taxa, and environmental optima estimated by weighted averaging regression for selected taxa.

The principal patterns of floristic variation in these data have been explored using detrended correspondence analysis (DCA), whereas the patterns of floristic variation in the data that can be explained statistically by the measured environmental variables are detected by means of canonical correspondence analysis (CCA).

Detrended correspondence analysis

DCA (Hill and Gauch 1980) is one of the most powerful and numerically robust ordination or indirect gradient analytical techniques currently available (Jongman *et al.* 1987). It provides a good approximation to the problem of ordinating samples and species in two or more dimensions when the underlying model of species responses to their environment is unimodal, when the data contain many zero values for samples at which a species is absent, and when the number of species is large (ter Braak and Prentice 1988).

In the DCA presented here (Table 10, Figures 9 and 10), detrending was by segments with nonlinear rescaling of axes. Rare species were downweighted (ter Braak 1987). Not surprisingly with 277 taxa and many zero values in the data, the DCA axes do not capture a large proportion of the cumulative variance of the species data (Table 10). Despite the low (14.6%) of the variance or "inertia" of the species data explained by two dimensions, the ordination plot is still informative. Low percentages explained commonly result from noisy data containing many zero values.

Table 10 Eigenvalues and cumulative variance accounted for in a DCA of the 178 diatom samples

	Eigenvalue	Cumulative variance represented
Axis 1	0.598	9.3%
Axis 2	0.338	14.6%
Axis 3	0.256	18.6%
Axis 4	0.187	21.5%

It is not possible statistically to relate these axes to the measured environmental variables by, for example, regression because only one variable (pH) is available for all 178 samples (Table 5). Preliminary interpretation of the DCA axes is therefore attempted solely on the basis of the known ecological preferences of the major diatom taxa. Axis 1 appears to be partly a pH axis with alkaline species and sites positioned on the right-hand side of the plot, e.g. *Aulacoseira ambigua* (**Au002a** on Figure 10), *Aulacoseira granulata* var. *angustissima* (**Au003d**), *Cyclostephanus dubius* (**Cc001a**), Hagasjön (**S26** on Figure 9), Vagsjöarna (**S25**), and Glasfryn (**GLAS**), and acid species such as *Tabellaria binalis* (**Ta003a**), *Semiorbis hemicyclus* (**Se001a**), *Eunotia bactriana* (**Eu046c**), *Aulacoseira tethera* (**Au023a**), and *Surirella biseriata* var. *biseriata* (**Su004a**) and acid lakes, e.g. Llyn y Bi (**YBI**), Ljosvatn (**LJOSV**), and Scoat Tarn (**SCOAT**) positioned to the left. No interpretation is presented for axis 2 or later axes. Interpretation of the diatom data in relation to the available environmental

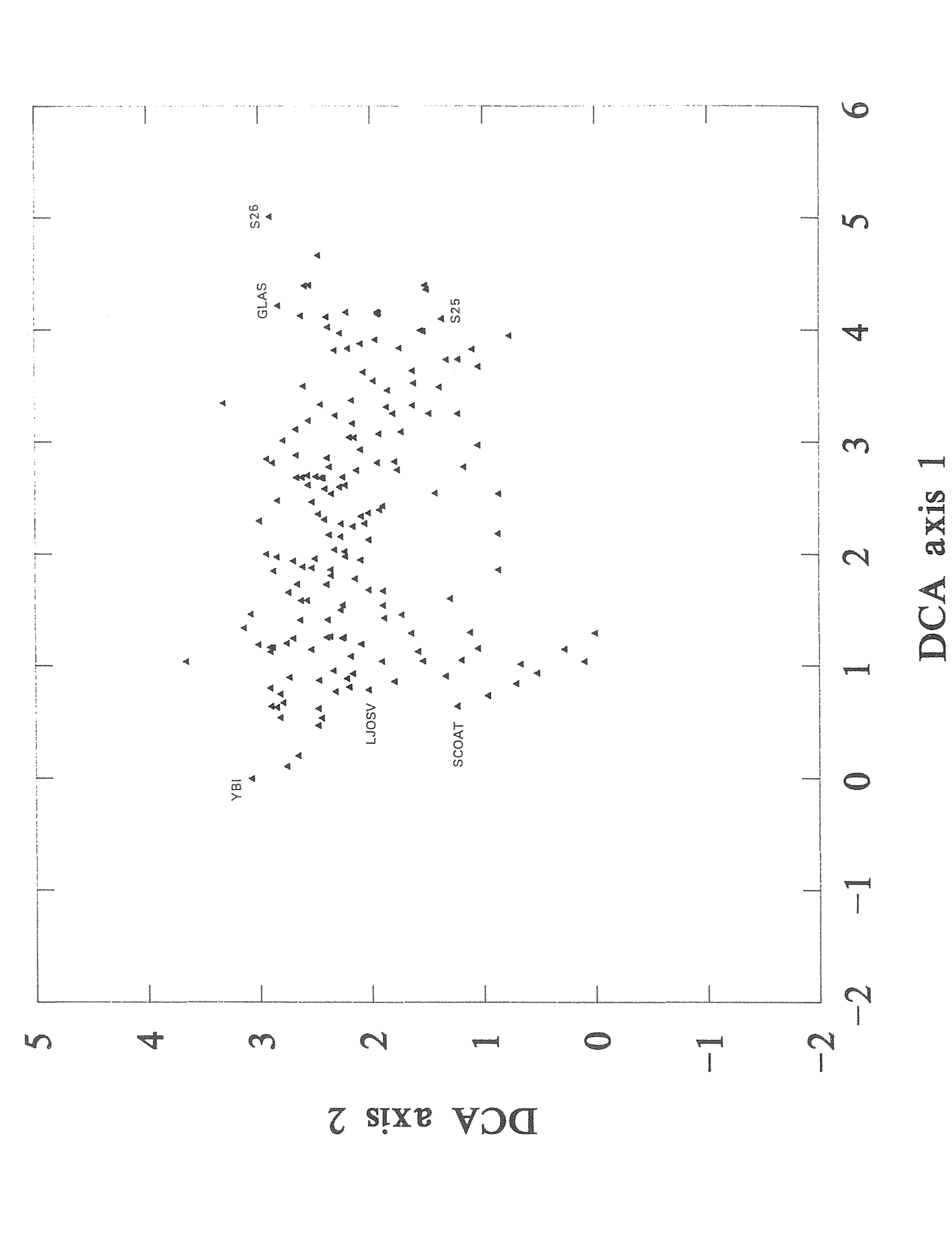


Figure 9 Detrended correspondence analysis (DCA) plot of the 178 diatom samples on axes 1 and 2. See Table 2 for site codes. Only selected samples are labelled.

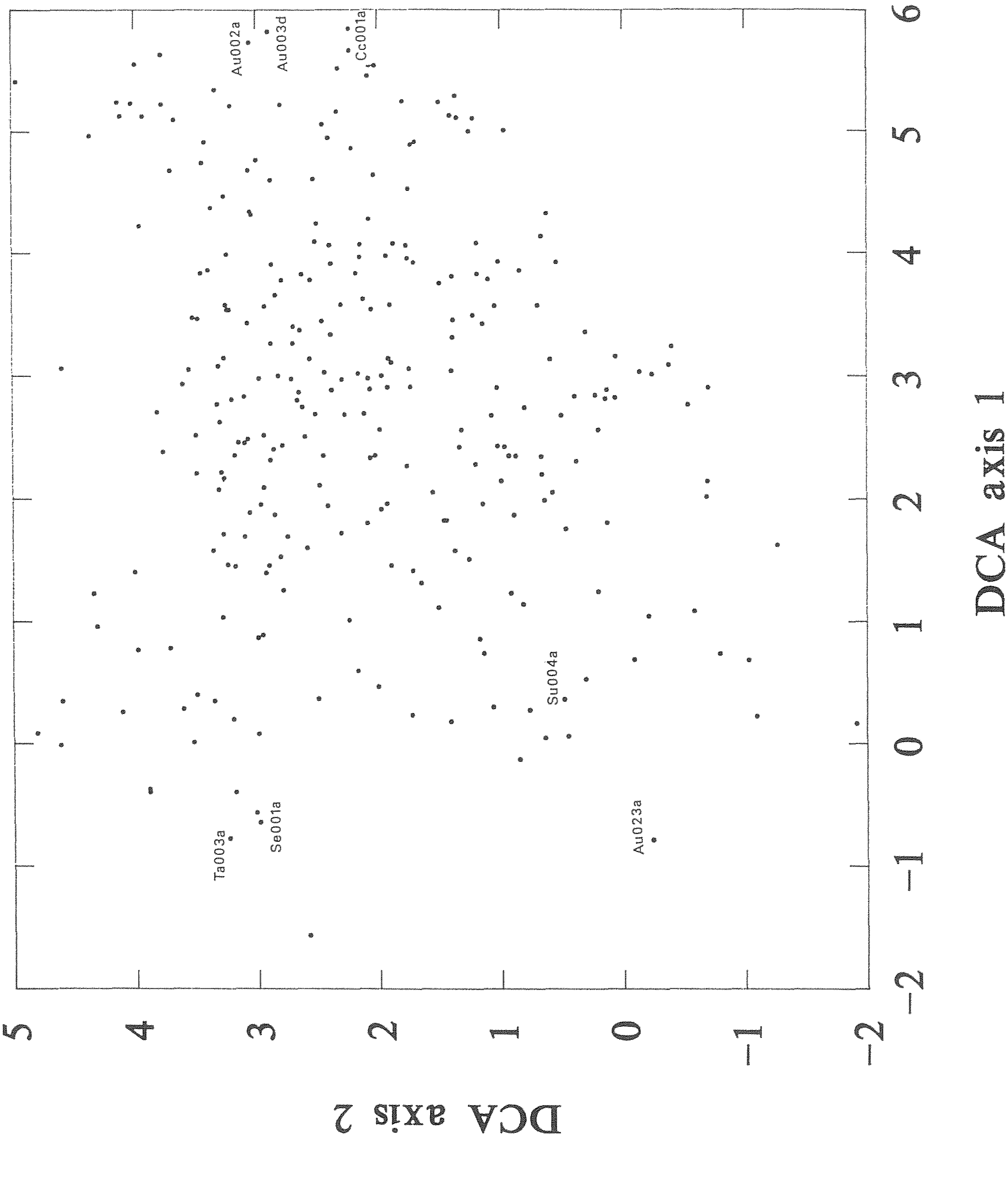


Figure 10 Detrended correspondence analysis (DCA) plot of the diatom taxa in the 178 samples on DCA axes 1 and 2. See Appendix B for taxon codes. Only selected taxa are labelled.

data is more readily attempted by means of the direct gradient technique of canonical correspondence analysis.

Canonical correspondence analysis

Like DCA, canonical correspondence analysis (ter Braak 1986) derives a set of ordination axis scores for species and for samples. For the first axis, species scores and sample scores are chosen to maximise the correlation between them. For subsequent axes, the sample and species scores are also maximally correlated but are chosen to be uncorrelated to species and sample scores on previous axes. In CCA the sample scores are also constrained to be simple linear combinations of the available environmental variables. A CCA ordination diagram can thus include not only the sample and site scores but also vectors representing the different environmental variables. In such a diagram, the vector for an environmental variable points in the direction of maximum variation of that variable across the diagram, and its length is proportional to its importance. Environmental variables with long vectors are more strongly correlated with the ordination axes than those with short vectors, and are more closely related to the patterns of biological variation displayed in the diagram (ter Braak 1986, 1987). A CCA diagram thus simultaneously displays the major patterns of variation in the diatom assemblages, as far as these can be related to the available environmental variables and the major patterns in the weighted averages of the individual species in relation to the environmental variables. CCA assumes a common unimodal response model for all species in relation to the measured environmental gradients.

The same 138 samples that were used for in the PCA of the chemical data were used here. The CCA presented is similar to that shown in Birks *et al.* (1990b) except that here the environmental data were not subjected to logarithmic transformation, all 138 samples were included, and physical variables such as maximum depth and altitude and catchment attributes such as forest status and forest type were included. In both analyses rare species were downweighted. The results using untransformed environmental data are very similar to those obtained with logarithmically transformed data.

The CCA results are shown in Figures 11 and 12. The CCA plot can be interpreted in a broadly similar manner to that of the PCA biplot with small angles between those environmental variables that are highly correlated, and with variables with the highest variance and hence often being the most important having the longest arrows. Tables 11 and 12 present a summary of the CCA statistics while Table 13 presents the full species and site scores and environmental variable loadings. The CCA of the 138 data-set captures the variance in the species abundance-environmental relationship well with over 46% of the variance of the species weighted averages being accounted for by the first two axes.

Table 11 Summary statistics of the environmental variables included in the CCA of the 138 diatom-environmental data-set

	Weighted mean	Standard deviation	Variance inflation factor
pH	5.5598	.7050	3.7455
Conductivity	43.6492	26.2270	46.0034
DOC	3.8761	3.2846	3.0576
Ca	101.5286	107.7411	27.4217
Mg	64.9368	49.5752	15.5114
K	9.9082	6.9200	3.4507
SO_4	105.1257	64.1189	15.6147
Cl	182.5068	141.3208	22.2756
Alkalinity	46.2302	98.4989	20.0193
Total Al	125.3340	94.9714	2.5304
Altitude	352.1492	262.1623	2.3075
Unforested	.3984	.4896	46.5526
Forested	.5938	.4911	55.5266
Conifer F.	.5709	.4949	12.5739
Deciduous F.	.0228	.1494	.0000
Maximum depth	15.7617	11.2323	1.4453

CCA axes	1	2	3	4
Eigenvalues	.483	.248	.179	.141
Species-environment correlations	.932	.847	.783	.788
Cumulative percentage variance				
of species data	7.8	11.8	14.6	17.0
of species-environment relationship	30.4	46.1	57.4	66.7

(F. = forest)

The CCA results (Tables 11 and 12, Figures 11 and 12) clearly show that axis 1 is strongly related to pH (r = 0.84), along with conductivity (0.58), calcium (0.78), and alkalinity (0.69), and negatively correlated with altitude (-0.45), maximum depth (-0.35), and total aluminium (-0.21). Thus high pH lakes with associated high alkalinity, calcium, potassium, magnesium, and conductivity contrast with low pH lakes of low alkalinity, calcium, potassium, magnesium, and conductivity. The low pH lakes tend to be at high altitudes, to be deep, to have unforested catchments,and to have high total aluminium. Acid lakes such as Loch Enoch (**ENO** on Figure 11), Hovvatn (**4.1**), and Övre Brandsvatn

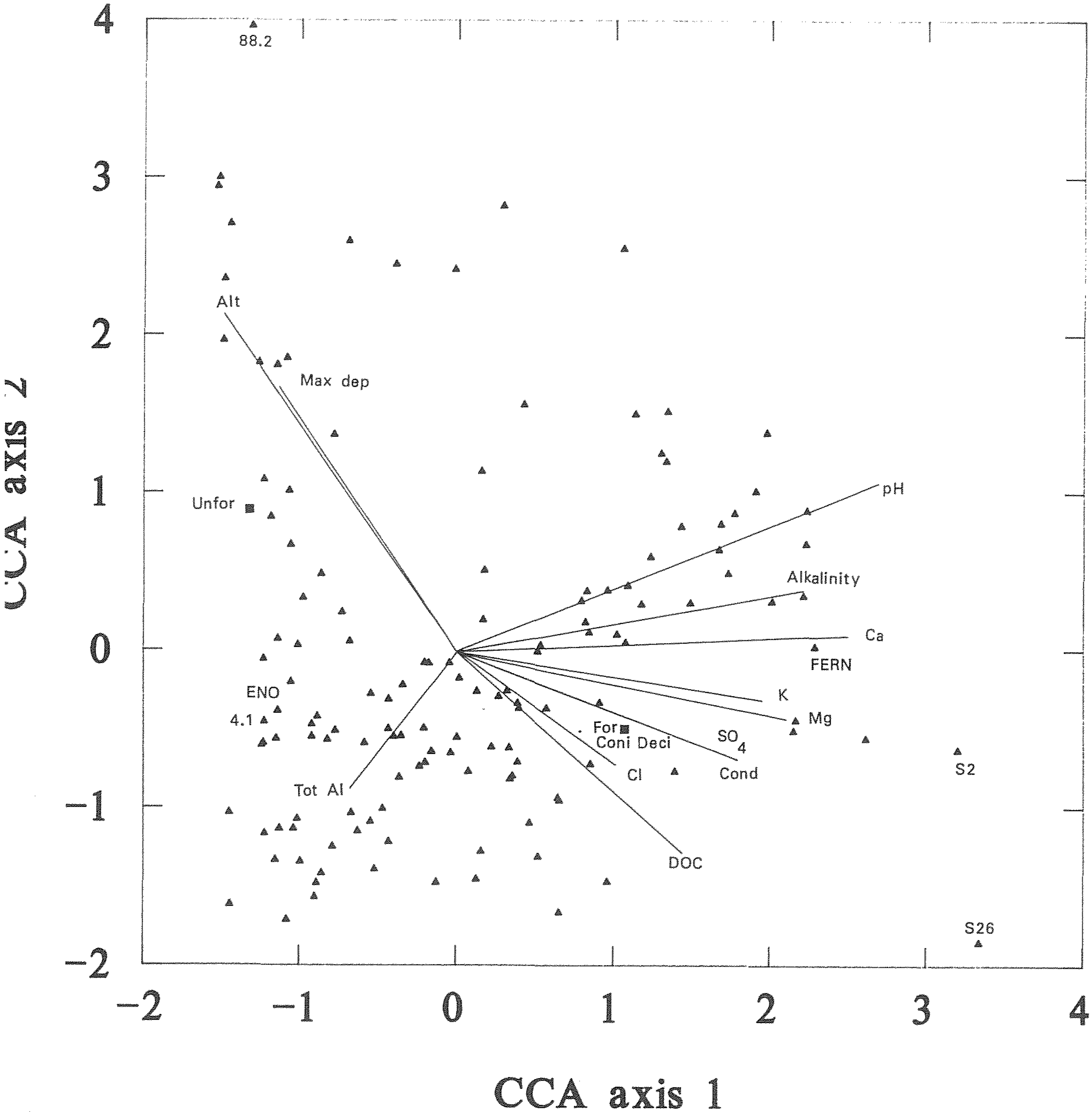


Figure 11 Canonical correspondence analysis (CCA) plot of the 138 samples on CCA axes 1 and 2 in relation to the 16 environmental variables included in the analysis. Continuous environmental variables are shown as vectors from the plot origin, nominal variables are plotted as centroids and shown as solid squares. Only selected samples are labelled. See Table 2 for site codes. Abbreviations follow the caption for Figure 7.

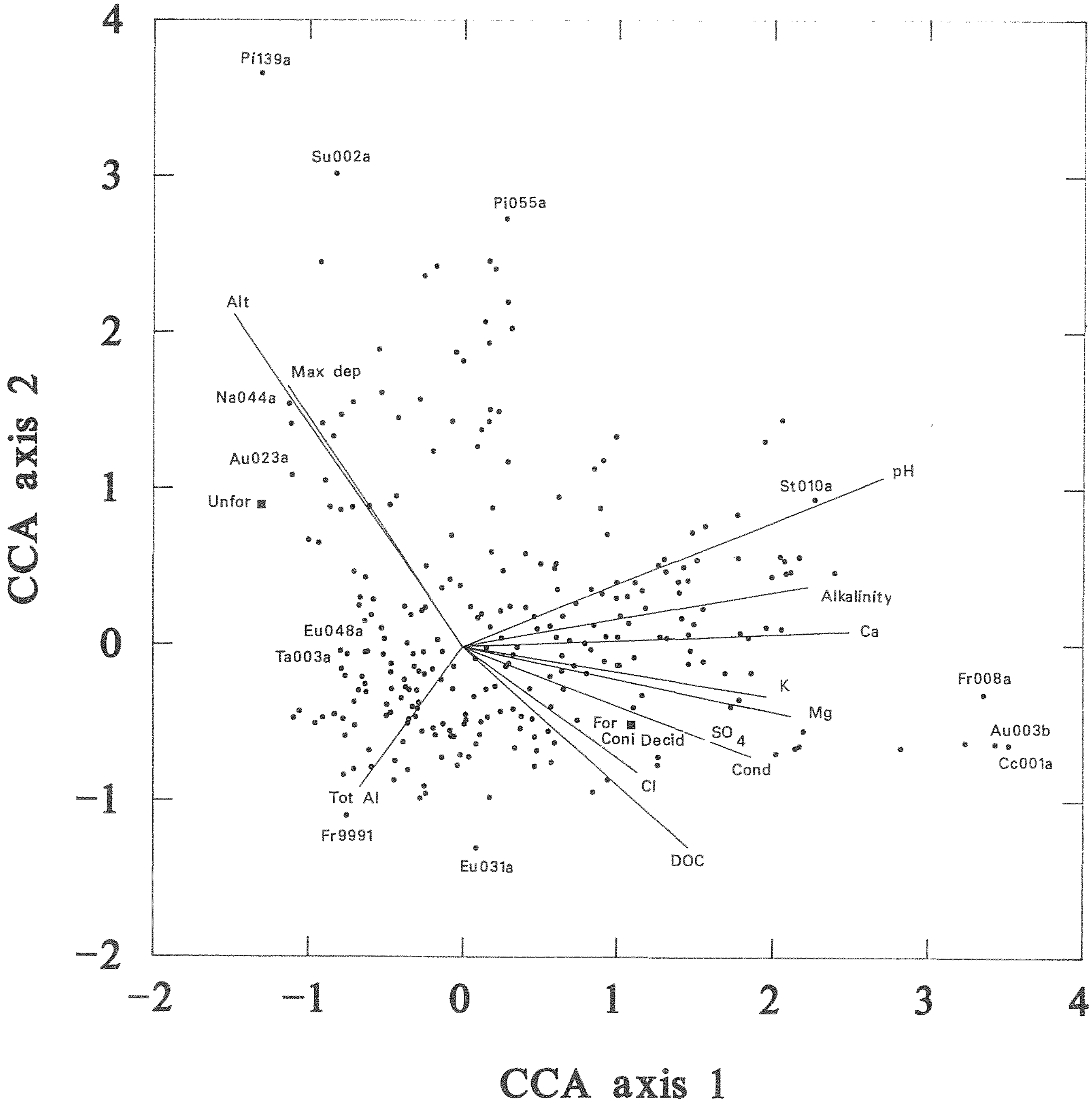


Figure 12 Canonical correspondence analysis (CCA) plot of all diatom taxa included in the CCA of the 138 samples on CCA axes 1 and 2 in relation to the 16 environmental variables included in the analysis. The diagram is constructed in the same way as Figure 11. Only selected taxa are labelled. See Appendix B for taxon codes. Abbreviations follow the caption for Figure 7.

Table 12 Weighted correlations between ordination axes and the environmental variables in the CCA of the 138 sample data-set. The species-environment correlations are 0.932, 0.847, 0.783 and 0.788, respectively.

	Spec axis 1	Spec axis 2	Spec axis 3	Spec axis 4	Env. axis 1	Env. axis 2	Env. axis 3	Env. axis 4	pH	Cond.
Species axis 1	1.00									
Species axis 2	0.00	1.00								
Species axis 3	-0.02	0.02	1.00							
Species axis 4	-0.06	-0.03	-0.00	1.00						
Env. axis 1	0.93	0.00	0.00	0.00	1.00					
Env. axis 2	0.00	0.85	0.00	0.00	0.00	1.00				
Env. axis 3	0.00	0.00	0.78	0.00	0.00	0.00	1.00			
Env. axis 4	0.00	0.00	0.00	0.79	0.00	0.00	0.00	1.00		
pH	0.84	0.31	-0.09	-0.02	0.90	0.36	-0.11	-0.02	1.00	
Conductivity	0.58	-0.20	0.08	0.25	0.62	-0.23	0.10	0.32	0.37	1.00
DOC	0.45	-0.36	0.37	-0.30	0.48	-0.43	0.48	-0.38	0.22	0.40
Ca	0.78	0.03	0.29	0.07	0.84	0.03	0.38	0.09	0.70	0.70
Mg	0.66	-0.12	0.11	0.27	0.71	-0.14	0.14	0.34	0.49	0.93
K	0.61	-0.09	0.31	0.25	0.66	-0.10	0.40	0.31	0.50	0.74
SO4	0.56	-0.19	0.14	0.00	0.60	-0.23	0.18	0.00	0.33	0.80
Cl	0.32	-0.20	-0.17	0.35	0.34	-0.24	-0.22	0.45	0.17	0.86
Alkalinity	0.69	0.11	0.28	0.27	0.74	0.13	0.36	0.34	0.67	0.62
Total Al	-0.21	-0.25	0.19	0.09	-0.23	-0.30	0.24	0.12	-0.44	0.18
Altitude	-0.45	0.61	0.11	-0.09	-0.49	0.72	0.14	-0.11	-0.15	-0.58
Unforested	-0.32	0.21	-0.14	0.21	-0.35	0.25	-0.17	0.26	-0.14	-0.28
Forested	0.34	-0.20	0.12	-0.22	0.37	-0.23	0.15	-0.28	0.17	0.25
Conifer F.	0.33	-0.19	0.16	-0.26	0.35	-0.22	0.21	-0.33	0.14	0.25
Deciduous F.	0.05	-0.02	-0.16	0.13	0.05	-0.02	-0.21	0.17	0.09	0.00
Max. depth	-0.35	0.47	0.06	-0.17	-0.37	0.56	0.08	-0.21	-0.17	-0.42

	DOC	Ca	Mg	K	SO4	Cl	Alk.	Tot. Al	Alt.	Unforest
DOC	1.00									
Ca	0.49	1.00								
Mg	0.41	0.71	1.00							
K	0.47	0.76	0.76	1.00						
SO4	0.47	0.66	0.83	0.64	1.00					
Cl	0.12	0.32	0.79	0.52	0.56	1.00				
Alkalinity	0.31	0.91	0.61	0.70	0.41	0.31	1.00			
Total Al	0.30	-0.07	0.11	0.06	0.29	0.14	-0.14	1.00		
Altitude	-0.46	-0.36	-0.54	-0.44	-0.57	-0.50	-0.23	-0.25	1.00	
Unforested	-0.50	-0.32	-0.29	-0.23	-0.45	-0.06	-0.21	-0.35	0.50	1.00
Forested	0.51	0.33	0.28	0.23	0.43	0.04	0.22	0.28	-0.47	-0.98
Conifer F.	0.54	0.32	0.28	0.24	0.42	0.04	0.22	0.31	-0.43	-0.94
Deciduous F.	-0.12	0.02	-0.01	-0.05	0.02	0.02	0.00	-0.11	-0.14	-0.12
Max. depth	-0.28	-0.29	-0.38	-0.33	-0.36	-0.35	-0.23	-0.19	0.38	0.04

	Forested	Conif.	Decid.
Conifer F.	0.95	1.00	
Deciduous F.	0.13	-0.18	1.00
Max. depth	-0.02	-0.01	-0.04

(Env. = environmental, max. = maximum, F. = forest)

Table 13 Scores for samples and diatom taxa and environmental variable loadings for the CCA of the 138 sample data-set. Sample codes follow Table 4, species codes follows Appendix B.

	Axis 1	Axis 2	Axis 3	Axis 4
Environmental variable loadings				
pH	0.9034	0.3620	-0.1136	-0.0220
Conductivity	0.6216	-0.2325	0.1041	0.3228
DOC	0.4845	-0.4289	0.4753	-0.3758
Ca	0.8375	0.0343	0.3754	0.0941
Mg	0.7076	-0.1440	0.1429	0.3446
K	0.6559	-0.1027	0.3995	0.3137
SO4	0.6029	-0.2271	0.1779	0.0020
Cl	0.3437	-0.2398	-0.2229	0.4452
Alkalinity	0.7441	0.1305	0.3579	0.3401
Total Al	-0.2286	-0.2970	0.2373	0.1187
Altitude	-0.4868	0.7165	0.1412	-0.1146
Unforested	-0.3466	0.2499	-0.1735	0.2639
Forested	0.3684	-0.2327	0.1492	-0.2762
Conifer F.	0.3498	-0.2239	0.2105	-0.3255
Deciduous F.	0.0523	-0.0234	-0.2071	0.1705
Max. depth	-0.3713	0.5600	0.0784	-0.2114
Sample scores				
1.21	-1.1471	-0.5617	0.6353	0.3855
10.21	0.1685	0.1936	-0.6498	-0.6172
111.11	0.1561	1.1350	-0.7459	-1.1987
113.21	0.1728	0.5094	-0.8235	-0.7099
115.11	-0.4269	-0.3134	0.2246	-1.2361
12.11	-1.1415	1.8089	1.0289	-0.5172
15.11	-0.6783	0.0564	-0.0816	-0.2813
17.21	-0.5435	-0.2769	0.1103	-0.8524
18.11	-0.6896	2.5975	0.5552	-0.2183
19.21	-0.3891	2.4497	-0.1441	-2.2105
2.11	-0.7273	0.2427	0.1554	-0.2671
20.11	0.2888	2.8203	-0.1651	-1.4961
21.11	-0.2000	-0.0794	-0.3185	-0.4726
3.11	-1.1254	-1.1334	0.9413	0.1623
34.11	-1.4422	2.7048	1.5552	-0.4943
4.11	-1.2384	-0.6001	1.8519	-0.2491
42.11	-1.0566	0.6691	0.4842	-0.1637
44.21	1.0556	2.5510	0.1396	-1.2088
49.11	-0.7809	1.3701	0.2307	-0.4350
58.11	-1.1816	0.8461	0.8887	-0.2904
59.11	-1.3152	3.9592	1.8019	-0.9078

	Axis 1	Axis 2	Axis 3	Axis 4
Sample scores				
6.21	-1.2255	-0.0560	0.9862	0.0859
65.21	0.4235	1.5593	-1.5094	-2.6249
80.11	-1.0089	0.0326	0.2277	0.3841
81.21	-1.1516	-1.3351	1.0141	0.0595
82.11	-1.1343	-0.3871	1.0484	-0.3473
83.11	-1.5118	2.9970	1.2716	-0.0912
86.11	-0.9211	-0.4700	0.6921	-0.6041
87.21	-0.8612	0.4848	0.5990	-1.0980
88.21	-1.5960	4.2539	1.8824	-0.8744
89.11	-0.0140	2.4163	-0.5482	-1.2441
9.11	-1.2212	-0.4524	1.2701	-0.2514
ACH1	-0.4668	-1.0056	-0.3973	-0.2629
ARR1	0.5146	-0.0067	-1.2303	1.0377
ARTH1	2.0141	0.3096	1.0324	1.6511
BARE1	1.6819	0.8016	-0.9070	0.1328
BARL1	1.0772	0.0491	-0.9091	0.8466
BODG1	1.3430	1.5162	-2.1564	-2.5975
BODL1	-0.3949	-0.5468	-0.6654	0.2639
BUGE1	-0.5194	-1.3916	-0.0129	0.2552
BYCH1	1.6687	0.6397	-1.3262	1.7077
CFYN1	-0.4280	-1.2173	-0.6664	-0.1417
CHN1	-0.2034	-0.4965	-0.8927	0.6296
CLON1	2.2385	0.8853	0.5155	2.6972
CLYD1	0.5683	-0.3670	-1.4655	0.1425
CON1	-0.1584	-0.6425	-0.8268	-0.6600
COR1	-1.5236	2.9395	1.1582	0.7675
CWBY1	-0.8200	-0.5668	-0.4101	0.8955
DIWA1	0.0203	-0.1791	-1.0860	0.3516
DOI1	-0.1735	-0.0830	-0.8156	0.8699
DOON1	0.3936	-0.3670	0.2425	0.6098
DUH1	-1.2242	1.0827	0.4939	1.0607
DUL1	-0.5851	-0.5873	-0.2583	0.4362
ENO1	-1.2261	-0.5873	0.5281	0.4753
EUN1	-1.4776	2.3548	0.9548	2.0384
FERN1	2.5696	0.0915	4.5015	3.8387
FHI1	-1.1347	0.0719	-0.1302	2.1341
FINL1	0.3854	-0.3361	-0.7594	0.4544
FLE1	-0.8873	-1.4799	-0.1210	0.2352
GARN1	1.1352	1.5006	-2.4793	-3.0029
GEIR1	1.2322	0.5953	-2.5188	0.9907

Table 13 Continued.

	Axis 1	Axis 2	Axis 3	Axis 4
Sample scores				
GLAS1				
GLFR1	2.2882	0.0246	1.2022	3.6458
GLYN1	-1.0532	-0.2031	0.0000	0.6694
GOD1	0.4605	-1.0976	-1.2519	-0.8773
GREENT1	-0.8819	-0.4223	0.0419	0.6327
GWYN1	1.4296	0.7857	-2.0587	2.2169
GYN1	-0.1273	-1.4752	-0.7044	-0.7741
HARR1	-0.3355	-0.2233	-0.7051	0.4806
HOWI1	1.3018	1.2509	-2.1252	-1.3549
INVA1	1.7270	0.4914	0.3179	2.0218
IRD1	0.1282	-0.2612	-0.9386	-0.3910
LAG1	-1.0781	-1.7110	-0.2040	0.7220
LAI1	-0.3487	-0.5441	-0.5827	-0.2191
LAR1	-0.5441	-1.0894	-0.5702	0.4182
LCSL1	-0.9772	0.3340	-0.0239	1.9584
LCSLU1	-1.0640	1.0108	-0.2573	3.4904
LDE1	-0.0451	-0.0807	-1.0411	0.3703
LENY1	0.8174	0.1820	-1.6711	0.2654
LGR1	-1.0373	-1.1337	0.0488	0.7541
LLDU1	0.9098	-0.3335	-1.2841	0.9025
LLGH1	-0.6266	-1.1489	-0.3428	0.1284
LOD1	-0.6671	-1.0323	-0.4304	0.4063
LOWT1	-0.9183	-0.5482	-0.2469	1.2544
MABE1	0.6508	-0.9521	0.0222	-0.3539
MACA1	-0.2307	-0.7373	-0.7929	-0.0048
MANN1	1.7710	0.8694	-1.3416	3.4906
MINN1	0.3192	-0.2579	-1.0182	0.2420
MOAN1	0.9592	-1.4696	0.3610	-0.5984
MUCK1	0.2229	-0.6128	-0.4098	0.3991
NAGA1	-1.2566	1.8234	0.7883	1.6440
OCHI1	0.8494	-0.7185	-0.1555	0.2797
PARC1	0.9579	0.3835	-2.2672	0.5901
PENR1	-0.8996	-1.5666	0.0912	0.3248
RIEC1	0.2671	-0.2951	-0.4266	0.4924
RLGH1	-0.9942	-1.3425	0.0509	0.4663
S101	1.1769	0.2943	-0.3208	0.0906
S11	2.1663	-0.4443	2.7228	-0.7423
S111	0.3536	-0.7962	0.2809	-1.2691
S121	1.3345	1.1996	-0.8224	-2.5011
S131	0.1261	-1.4548	0.6285	-1.5302
S141	1.0874	0.4129	0.6541	-1.5422
S151	1.9793	1.3815	0.8897	1.2983
S161	2.1517	-0.5117	3.2695	-0.8750
S171	0.7911	0.3159	-0.2482	-1.9843
S181	0.5154	-1.3095	-0.0136	-2.0656

	Axis 1	Axis 2	Axis 3	Axis 4
Sample scores				
S191	0.1544	-1.2776	0.9721	-2.0814
S201	-0.3589	-0.8067	-0.0120	-0.6478
S21	3.2049	-0.6306	7.2128	1.7697
S221	-1.4422	-1.0326	1.4979	0.8276
S241	0.5333	0.0324	-0.0425	-1.3076
S251	1.9078	1.0080	-0.2704	-1.8208
S261	3.3389	-1.8518	8.6923	-5.3154
S271	-0.7847	-1.2494	0.6840	-0.5911
S281	-0.8558	-1.4173	0.6950	-0.2853
S291	-0.1962	-0.7128	0.6257	-0.2689
S301	-0.0349	-0.6498	0.0919	-0.9483
S31	2.2321	0.6759	1.9231	0.1556
S311	0.0043	-0.5514	0.0070	-0.9578
S41	0.6489	-1.6628	1.4248	-2.8840
S51	2.6145	-0.5579	4.2589	-0.4855
S61	0.6436	-0.9340	-0.3674	-1.2659
S71	1.4897	0.3028	0.6374	-2.7576
S81	1.0228	0.1024	1.4228	-1.0042
S91	1.3904	-0.7665	1.4638	-1.9251
SCOATT1	-1.4821	1.9646	1.1985	1.1321
SKE1	0.3369	-0.8150	-0.8077	-0.6101
STRO1	-0.4286	-0.4988	-0.4410	0.2891
TANN1	-1.2181	-1.1639	0.6951	0.9731
TECW1	0.3855	-0.7076	-1.5762	0.1959
TINK1	0.3329	-0.6169	-1.4092	-0.4088
TROO1	-0.7679	-0.5100	-0.1374	0.4022
UAI1	-1.0791	1.8543	0.1875	0.9741
UIS1	0.8414	0.1170	-1.0813	1.2269
VAL1	-1.0127	-1.0700	0.1326	0.4675
WOOD1	2.2146	0.3460	1.6022	3.2482
YBI1	-1.4369	-1.6170	0.6667	1.9031
YGAD1	0.0760	-0.7692	-1.3832	-0.0943
Species scores				
AC001A	1.6899	-0.1795	1.5185	1.5867
AC002A	1.3914	0.3388	-0.1467	1.1984
AC004A	0.789	0.0113	-0.9852	-0.2666
AC013A	0.9944	0.3003	-0.4687	0.5173
AC014A	-0.7764	-0.8351	-0.147	0.0952
AC014B	-0.6728	0.2492	-0.0227	0.4389
AC014C	-0.8404	1.3334	0.3423	-0.1842
AC017A	-0.4366	0.9487	-0.2655	-0.2601
AC018A	0.8966	0.3299	0.7267	-0.5418
AC019A	-0.0461	1.8739	-0.1859	-0.675

Table 13 Continued.

Species scores

	Axis 1	Axis 2	Axis 3	Axis 4
AC022A	-0.8934	1.0497	0.2627	0.1962
AC025A	1.0026	0.0521	0.1306	-0.2750
AC028A	-0.0873	0.4214	-0.5534	0.5572
AC029A	-0.1956	1.2400	0.0517	-0.0506
AC030A	0.7973	-0.1837	-0.1701	0.8590
AC034A	0.1173	1.3782	-0.2199	-0.2014
AC035A	1.1584	-0.3236	0.3864	-0.6356
AC039A	0.8483	1.1260	0.1301	-0.5480
AC042A	0.4621	0.1834	-0.7294	0.1896
AC044A	-0.7153	1.5517	0.3013	-0.4542
AC046A	0.2070	-0.2669	-0.2009	-0.1041
AC048A	-0.2426	0.5060	-0.4113	0.2841
AC9964	1.0190	0.1866	-1.6164	0.2052
AC9965	-0.5441	1.8883	-0.0912	0.2523
AC9968	-0.8644	0.8802	0.2628	0.7370
AC9969	0.6456	0.1851	-1.2039	0.0431
AC9975	-0.7954	-0.0413	-0.0414	0.4196
AC9996	0.4068	0.2414	-0.9895	0.2815
AM001A	0.2296	1.4951	-0.5444	-0.6865
AM001B	2.0718	0.5413	0.2810	1.9810
AM001D	1.2727	0.0521	0.3781	0.3339
AS001A	1.9559	0.1141	1.2662	0.9593
AS003A	-0.3820	-0.2260	0.1476	0.0699
AT001A	-0.2538	-0.9039	0.6460	-0.6040
AU001C	0.2428	-0.4280	0.8089	-0.7820
AU002A	2.0185	-0.6951	2.3578	-1.5464
AU003B	3.4368	-0.6324	5.5688	2.3286
AU003D	2.8253	-0.6595	4.2602	1.4549
AU004A	-0.1396	0.3659	0.6744	-0.8001
AU004B	0.6408	-0.1681	0.2916	-0.5637
AU004C	1.0122	-0.6119	0.0806	-0.7998
AU004D	-0.3524	-0.4759	-0.4553	0.3050
AU005A	-0.9096	1.4167	0.5598	-0.5133
AU005B	1.2562	-0.7694	0.9576	-1.4014
AU005D	0.8397	-0.9422	1.0091	-1.3301
AU005E	-0.9348	0.6500	0.5300	0.0533
AU005J	0.5691	-0.3965	-1.4348	0.6434
AU005L	2.1700	-0.6461	0.5880	-1.4765
AU009A	0.9369	-0.8632	-0.1322	-0.2217
AU009B	0.1715	-0.9776	1.2412	-1.1978
AU010A	-0.1366	-0.7201	0.0342	-0.2616
AU010B	-0.2670	-0.5542	0.3032	-0.0429
AU014A	0.4788	-0.6774	-0.0070	-0.8122
AU022A	3.2431	-0.6231	5.3677	2.1436
AU023A	-1.1026	1.0837	0.2047	1.3545

Species scores

	Axis 1	Axis 2	Axis 3	Axis 4
AU9983	1.4653	-0.0343	1.0601	0.1300
AU9984	0.4651	-0.7769	0.9543	-1.2948
AU9987	0.4662	-0.5886	0.6692	-0.5432
AU9988	-0.6335	-0.2560	0.0643	0.3239
BR001A	0.4828	0.1031	-0.5508	-0.0190
BR003A	-0.7787	-0.4764	0.5013	0.1473
BR004A	-0.1307	-0.5056	0.0891	-0.3544
BR005A	1.4196	0.5004	0.9003	0.2126
BR006A	-0.2876	-0.1699	-0.0470	0.0521
BR9997	0.0815	-0.6336	0.1409	-0.2974
CA018A	1.2971	0.5499	0.5456	0.0118
CC001A	3.5205	-0.6385	5.7894	2.5756
CM004A	1.0637	0.3120	-0.1595	0.5018
CM010A	-0.3728	-0.2709	-0.2461	0.1346
CM013A	1.5485	0.2330	-0.2750	0.3461
CM014A	-0.6358	0.1504	-0.2602	0.8818
CM015A	0.9905	1.3333	0.5498	0.0402
CM015B	0.1895	0.8767	-0.5612	0.4271
CM017A	-0.6678	0.3027	0.1392	-0.0302
CM020A	0.1751	0.1159	-0.3104	0.1169
CM031A	0.6091	0.3567	0.1409	0.4928
CM031C	-0.7942	0.8607	0.5024	-0.2224
CM038A	1.7701	0.8351	-0.4588	-0.9251
CM048A	0.2781	-0.1382	-0.3317	-0.1613
CM050A	1.9456	1.3046	2.5753	0.8923
CM051A	0.7304	0.2687	0.1119	-0.2407
CM052A	1.1110	0.4021	0.1356	0.2407
CM101B	1.5050	0.5467	1.7817	0.1523
CM9989	-0.2803	-0.9832	0.6341	-0.3240
CM9995	-0.6088	-0.6766	-0.6281	0.6764
CO001A	2.0440	0.5675	1.5978	2.2770
CO001B	1.8583	-0.1782	0.8582	2.5966
CY001A	1.7893	0.0776	0.8165	-0.0609
CY002A	2.0824	0.4612	2.6205	2.7430
CY003A	2.1145	0.4705	2.9871	2.8811
CY004A	1.1053	-0.4011	0.6230	-0.7413
CY007A	1.4767	0.7214	0.9250	-0.4488
CY010A	1.3850	0.4074	-0.4482	-0.8744
CY9991	0.6017	0.5226	-0.4854	-0.6902
DE001A	1.4473	0.4164	-0.3033	0.5709
DT002A	-0.0771	0.7017	-0.7876	-0.1078
DT003A	1.1811	0.2373	-0.3030	1.7729
DT004B	1.9895	0.4393	2.4925	2.6469
EU002A	-0.0600	-0.1388	-0.0377	-0.0259
EU002B	-0.1970	-0.1557	-0.0692	0.0781

Table 13 Continued.

Species scores	Axis 1	Axis 2	Axis 3	Axis 4	*Species scores*	Axis 1	Axis 2	Axis 3	Axis 4
EU002D	-0.0867	-0.5482	-0.2298	0.0210	FR006A	1.2592	0.5120	0.7383	-0.2438
EU002E	0.1141	-0.4925	-0.3146	0.2006	FR007A	1.1568	0.3497	0.3446	1.0980
EU002K	-0.2968	-0.4065	-0.0457	0.0636	FR008A	3.3606	-0.3173	4.9776	2.9053
EU003A	-0.3385	0.1925	0.5987	0.2130	FR009F	0.4035	0.5858	-1.0782	0.2434
EU004A	-0.5271	0.1042	0.1646	-0.1855	FR010A	0.1059	-0.5736	0.2689	0.0103
EU009A	-0.5928	0.1885	0.0626	0.0118	FR011A	0.7202	-0.1348	0.2391	-1.0642
EU009C	-0.2451	-0.9517	0.6651	-0.3686	FR015A	0.3354	-0.6579	1.0746	-0.9732
EU011A	-0.3908	-0.6246	-0.2106	0.1964	FR018A	1.7816	-0.3498	0.9768	0.7719
EU013A	0.0956	0.1737	-0.3700	0.3136	FR9991	-0.7581	-1.0974	0.5035	-0.0288
EU014A	-1.0547	-0.4261	0.7125	0.0615	FU002A	-0.3516	-0.2884	0.2166	-0.1877
EU015A	-0.6335	-0.0508	-0.1342	0.5919	FU002B	-0.3009	-0.2927	0.0823	-0.2021
EU016A	-0.3102	-0.4595	0.0187	-0.1364	FU002F	-0.1804	-0.5761	-0.0184	-0.1407
EU017A	0.2507	0.0443	-0.3995	-0.1606	GO003A	0.4344	-0.2829	-0.2046	0.1926
EU019A	-0.1941	-0.5327	0.1597	-0.2360	GO004A	0.3255	-0.0642	-0.4147	0.2290
EU020A	-0.5081	0.0356	0.4325	-0.6128	GO006C	0.9164	-0.1068	0.1295	0.1122
EU021A	-0.4224	1.4526	0.0905	-0.4890	GO013A	0.9262	0.0531	0.1584	1.1142
EU022A	-0.4442	-0.7451	-0.8003	0.1016	GO023A	1.3064	0.4697	0.4130	1.5054
EU025A	-0.7041	-0.5174	0.3829	0.3562	GO025B	1.4884	0.1364	-0.1399	0.3359
EU027A	-1.0008	0.6698	0.4752	-0.2126	GO025F	2.1683	0.5641	1.4358	2.9968
EU028A	-0.7668	-0.2033	0.7263	-0.4168	GY005A	2.1432	-0.6588	2.8632	1.1976
EU028B	-0.9582	-0.5036	0.5717	-0.1383	HN001A	0.6079	0.0490	-0.1574	0.9380
EU031A	0.0822	-1.3041	1.2257	-1.0257	ME019A	0.3717	-0.5344	0.2359	-0.0290
EU034A	-0.3601	-0.8009	0.8198	-0.5964	NA002A	0.3793	-0.4572	0.1487	-0.3683
EU039A	-0.7099	0.4672	0.1177	-0.0696	NA003A	0.9933	0.4016	1.0317	0.3748
EU040A	-0.3633	-0.5010	0.0734	0.0537	NA003B	0.6915	0.0290	0.2571	-0.0399
EU046C	-0.7876	-0.1582	0.2058	0.0038	NA005A	0.5923	0.4918	0.1966	-0.3140
EU047A	-0.4962	-0.3850	-0.0425	0.1131	NA005B	1.4538	-0.1194	0.4481	0.1047
EU048A	-0.6280	-0.3058	0.3789	-0.1044	NA006A	-0.2562	-0.0458	0.0012	-0.1402
EU049A	0.1568	-0.4634	0.0272	0.0802	NA006B	-0.4642	-0.2859	-0.0431	0.7012
EU049B	0.0357	-0.7171	0.4150	-0.3418	NA007A	1.4543	0.0694	0.1552	1.4593
EU051A	-0.3995	-0.3453	-0.0462	-0.0689	NA008A	1.8411	0.0471	1.0247	1.4825
EU051B	-0.0663	-0.2831	0.1815	0.0282	NA013A	0.8272	0.3576	0.0654	0.4566
EU056A	-0.2508	-0.1896	-0.0086	0.3938	NA014A	1.0751	0.1401	0.5760	0.1504
EU057A	-0.3611	0.0101	-0.4935	0.5540	NA015A	-0.2445	0.2417	0.0518	-0.4004
EU058A	-1.0916	-0.4690	0.2542	0.1260	NA016A	0.5924	-0.6264	0.1131	-0.4906
EU9961	-0.4984	-0.4568	-0.4172	0.4457	NA032A	-0.0222	0.3806	-0.3645	-0.3483
EU9962	0.0062	-0.5069	-1.1328	0.0293	NA033A	-0.3186	-0.1398	-0.5263	0.5557
EU9965	-0.7097	-0.7981	-0.1753	0.1021	NA037A	0.0780	-0.0876	-0.6700	0.3761
EU9969	-0.7059	-0.3684	-0.1813	0.6706	NA038A	-0.0392	-0.7703	0.8130	-0.5966
FR001A	1.1103	-0.0821	0.2666	0.6491	NA042A	0.1649	1.4311	0.0367	-0.7125
FR001B	-0.0020	1.8173	-0.2127	-1.0213	NA043A	0.2037	2.4077	-0.0389	-0.9120
FR002A	2.1966	-0.5489	2.6001	-0.4854	NA044A	-1.1233	1.5436	0.5569	-0.1500
FR002C	0.9102	-0.4566	0.3945	-0.0793	NA045A	0.4480	-0.4734	-0.0875	0.2308
FR005A	0.2446	0.2192	0.1928	1.0149	NA046A	0.1526	-0.0190	-0.9131	0.5302
FR005D	0.3249	-0.4105	-0.2088	-0.2903	NA048A	-0.6533	-0.2098	0.1917	0.0226

Table 13 Continued.

	Axis 1	Axis 2	Axis 3	Axis 4
Species scores				
NA063A	1.7726	0.5586	0.7394	2.5096
NA068A	0.5721	-0.7508	0.0454	0.0131
NA084A	0.1647	2.4581	-0.2824	-1.2409
NA086A	1.3144	0.0432	0.0488	1.5890
NA099A	-0.3307	-0.3958	-0.3238	0.5438
NA101A	1.5591	0.7624	2.7641	0.9421
NA102A	0.9071	1.1808	0.5036	0.2663
NA112D	0.1379	2.0673	0.0546	-0.9077
NA113A	0.2868	1.1740	0.2575	-1.0593
NA114A	0.1647	2.4581	-0.2824	-1.2409
NA115A	-0.4493	-0.8688	-0.4627	0.4594
NA129A	-0.1786	2.4249	0.0343	-0.8883
NA133A	0.1186	0.2004	-0.7875	0.3057
NA135A	-0.4686	-0.1237	-0.1459	0.9722
NA140A	-0.6777	-0.2944	-0.1395	0.6951
NA149A	0.1797	0.5963	-0.7161	-0.0130
NA151A	0.3135	2.0253	0.2249	-0.6206
NA156A	-0.4718	-0.4372	-0.1554	0.1721
NA158A	-0.5952	-0.7841	0.2172	0.0977
NA160A	-0.7917	1.4718	0.2943	-0.2962
NA167A	-0.7538	-0.0627	0.4082	-0.1466
NA170A	-0.2571	2.3630	-0.0496	-0.5952
NA9904	1.2586	-0.7176	0.9303	-1.7391
NA9919	0.6526	-0.2838	0.6052	-0.4190
NA9955	0.6438	-0.0700	-0.7378	-0.0138
NA9963	0.0714	-0.3313	-0.8740	0.2590
NA9964	-0.2876	-0.3691	-0.3745	0.2331
NE003A	-0.1637	0.0333	-0.1667	-0.1041
NE003B	-0.5156	-0.0650	0.3166	-0.3255
NE003C	0.5523	-0.5526	0.5049	-1.2488
NE004A	-0.5806	0.2897	0.2517	-0.1128
NE012A	-0.6081	0.8839	-0.1527	0.2482
NE020A	-0.9238	2.4475	0.5267	-0.8178
NE023A	-0.5330	1.6142	0.0895	-0.4764
NI002A	0.8847	0.8737	0.1900	0.4981
NI005A	0.1481	-0.2851	-0.4731	0.0012
NI008A	0.6191	0.9456	-0.2453	-0.1595
NI009A	0.9314	0.7083	0.4151	-0.0832
NI009B	0.1734	1.5078	-0.2178	-0.8509
NI017A	0.7381	-0.4811	0.4191	-1.2318
NI021A	0.5666	0.1211	0.2759	-0.9816
NI026A	0.2981	-0.1201	-0.2399	0.8647
NI027A	0.2840	2.1940	-0.3789	-1.0883
NI152A	-0.2825	1.5753	0.0713	-0.4663
NI9984	2.0570	1.4420	3.9939	1.4340

	Axis 1	Axis 2	Axis 3	Axis 4
Species scores				
OP001A	1.7273	-0.3946	1.7120	-1.2102
PE002A	-0.3250	-0.0590	-0.2476	0.1355
PI005A	-0.0214	-0.7035	0.5575	-0.1703
PI007A	0.0135	-0.4462	0.0205	-0.0739
PI011A	-0.2679	0.2199	0.1632	-0.1407
PI014A	-0.0721	1.4322	-0.2448	-0.6244
PI015A	0.3488	-0.0142	0.0993	-0.1741
PI016A	0.0894	1.2693	-0.3503	-0.5264
PI018A	-0.3811	0.2447	0.3234	-0.1105
PI018B	-1.1096	1.4139	0.6403	-0.2014
PI022B	-0.4720	-0.1788	-0.1012	0.0612
PI023A	-0.0808	-0.5824	-0.1682	0.3830
PI055A	0.2775	2.7291	0.0128	-0.5398
PI056A	-0.0605	-0.5861	0.9291	-1.0021
PI139A	-1.3046	3.6570	0.9759	-1.2352
PI164A	-0.4804	0.8943	0.0464	-0.5723
RH006B	0.1646	1.9319	0.1377	-0.5807
SA001A	0.0462	0.2461	-0.0839	-0.4066
SA001B	0.3036	0.2504	-0.2850	-0.2457
SA006A	0.4996	0.5214	0.1635	0.3099
SA042A	-0.6356	0.4317	0.2113	-0.5206
SE001A	-0.8347	-0.4466	0.5961	0.0681
SP002A	0.0164	-0.4808	0.2002	-0.4488
ST004A	2.3952	0.4667	0.7932	2.4064
ST010A	2.2691	0.9322	-0.0762	0.8913
SU002A	-0.8256	3.0145	1.1845	-0.9072
SU004A	-0.7229	0.8787	0.0616	0.6032
SU005A	-0.1439	-0.2227	0.5034	-0.5068
SU006A	-0.6193	-0.0464	0.2716	-0.0799
SY002A	0.8466	0.1270	0.3422	-0.2710
SY003A	1.5476	-0.1047	0.7676	-0.1523
SY004A	1.4098	0.1741	1.5038	-0.0385
SY009A	1.0141	-0.1305	0.1470	-1.1588
SY010A	0.8277	-0.0310	0.0631	1.0540
SY013A	2.0547	0.1031	1.5071	1.6104
SY043A	0.2572	0.4764	0.1217	-1.2400
TA001A	-0.1330	-0.0427	-0.1354	-0.0701
TA002A	0.5643	-0.2020	-0.0689	0.8093
TA003A	-0.9081	-0.4661	0.3138	0.3646
TA004A	-0.7676	-0.5835	0.0316	0.1539
TA9996	1.0004	-0.1313	0.4291	0.2097

(**88.2**) are located on the left of axis 1 and alkaline sites such as Edasjön (**S2**), Loch Fern (**FERN**), and Hagasjön (**S26**) are located on the right-hand side of axis 1. Acid-tolerant diatoms such as *Navicula krasskei* (**Na044a** on Figure 12), *Aulacoseira tethera* (**Au023a**), *Tabellaria binalis* (**Ta003a**), and *Eunotia naegelii* (**Eu048a**) occur with negative scores on the left side of CCA axis 1, whereas alkaline-tolerant diatoms such as *Cyclostephanus dubius* (**Cc001a**), *Aulacoseira granulata* var. *angustissima* (**Au003b**), *Fragilaria crotonensis* (**Fr008a**), and *Stephanodiscus parvus* (**St010a**) are positioned on the right-hand side with positive scores.

Axis 2 is more difficult to interpret. Altitude ($r = 0.61$), maximum depth (0.47), total aluminium (-0.25), DOC (-0.36), and pH (0.31) are the only variables with large correlations with axis 2. The length of the total Al arrow is, however, short. Forward selection and associated Monte Carlo unrestricted permutation tests (99 permutations) of the significance of the environmental variables (ter Braak 1990) suggest that all environmental variables except conductivity, calcium, and alkalinity make significant ($p < 0.05$) contributions to explaining the underlying variation in the diatom assemblages. Axis 3 is correlated with DOC ($r = 0.37$), calcium (0.29), potassium (0.31), and alkalinity (0.28), whereas axis 4 is positively associated with chloride (0.35), conductivity (0.25), magnesium (0.27), potassium (0.25), and alkalinity (0.27) and negatively associated with coniferous forest (-0.26) and DOC (-0.30). No biological interpretations of these axes are presented here.

RECONSTRUCTION OF LAKE SURFACE-WATER CHEMISTRY FROM DIATOM ASSEMBLAGES

The principal reason for developing the SWAP diatom-lake chemistry data-set was to provide a basis for the quantitative reconstruction of lake pH and other chemical variables from fossil diatom assemblages.

Diatoms have long been known to be sensitive ecological indicators of certain lake chemical variables. This feature has been extensively exploited in the last decade to reconstruct pH from fossil assemblages (e.g. Battarbee 1984), and a range of numerical procedures has been developed for quantitative inference of pH. Such reconstructions, in practice, consist of two mathematical stages.

First, the responses of modern diatoms to contemporary lake chemistry are modelled by regression. This involves a modern training set of diatom assemblages ("responses") from surficial sediment samples with associated lake chemical data ("predictors"). Second, these modelled responses are used to infer past chemistry from the composition of fossil assemblages by means of calibration.

Nearly all the numerical procedures used are variants of the basic multiple linear regression model and usually involve grouping diatoms into ecological or chemical categories. Within SWAP we have used the two procedures developed by ter Braak and van Dam (1989), namely maximum likelihood (ML) and weighted averaging (WA) regression and calibration because they are more sound theoretically and perform better than other, more widely used "ad hoc" reconstruction procedures (e.g. Battarbee 1984). Full details of the ML and WA procedures used in SWAP are given by Birks *et al.* (1990a). In a comparison of the two procedures using the SWAP training set and pH, the computationally simple but heuristic approach of WA gave superior results in terms of a lower root-mean-square error of prediction (RMSE) in cross-validation than the computationally demanding but formal statistical approach of ML Gaussian logit regression and ML calibration (Birks *et al.* 1990a; see also ter Braak and van Dam, 1989). For this reason, we used simple WA regression and calibration to infer separately pH, total Al, and DOC using the SWAP training set (Birks *et al.* 1990a, 1990b) implemented by the computer programs WACALIB 2.1 (Line and Birks 1990) and 3.0 written by J.M. Line in conjunction with C.J.F. ter Braak and H.J.B. Birks.

In any large heterogeneous data-set such as the SWAP set, it is inevitable that some samples are "rogues" or atypical observations, for example with unusual diatom assemblages poorly related to chemistry or with poor or unreliable chemical data. It was therefore necessary to screen the data numerically to detect potential "rogues". The procedures used for data-screening are described by Birks *et al.* (1990a). Using these procedures, the 178-sample pH set was reduced to a training set of 167 samples, the 157-sample total Al set was reduced to a training set of 126 samples, and the 138-sample DOC set was reduced to a training set of 123 samples. Details of the three training sets after data screening are given in Table 14, along with lists of the samples deleted.

Simple WA without tolerance downweighting was used as it consistently gives lower RMSE as estimated by bootstrapping (Birks *et al.* 1990a). An inverse deshrinking regression was used to deshrink the inferred DOC and total Al values because it minimises RMSE in the training set. Classical regression was used to deshrink the inferred pH values because it takes inferred values further away from the mean and in these data the mean lies in the pH interval where lake pH is most variable, and because in acidification studies we require our reconstructions to be most precise at the lower end of the pH range in the training set (Birks *et al.* 1990a).

Root-mean-square of the error $(\hat{x}_i - x_i)$ was calculated for each training set, where x_i is the observed value of chemical variable x in sample i (Table 15). The correlation (r) between $\hat{x}_i$ and x_i was also calculated (Table 15). Plots of x_i and of $(\hat{x}_i - x_i)$ against x_i for pH, DOC, and total Al are shown in Figure 13. As the apparent RMSE is invariably an underestimate when based solely on training sets (ter Braak and van Dam, 1989), bootstrapping was used to estimate a more realistic RMSE of prediction for each training set (Table 15). This is partitioned into two components, s_{i1}, that part of the prediction error due to estimation error in the taxon parameter used in WA, namely its WA optimum, and s_2, that part of the error due to imperfections in the calibration function, even if the optima are known without error. Diatom assemblages vary even among lakes with the same chemistry or, conversely, because lakes with the same diatom assemblage may differ chemically. Component s_2 also contains any model specification errors (see Birks *et al.* 1990a).

The s_{i1} component is small compared with the s_2 component (Table 15). The ratio of s_{i1}/s_2 is 0.23 (pH), 0.27 (total Al), and 0.26 (DOC). The training sets are thus adequate to yield reliable estimates of taxon optima by WA regression required for WA calibration. As noted by Birks *et al.* (1990b) there is, however, some trend in the differences $(\hat{x}_i - x_i)$ plotted against x_i for DOC and Al (Figure 13). Inferences are too high at low observed total Al or DOC and too low at high total Al or DOC, probably because of functional interactions between pH, Al, and DOC. Such interactions are not accounted for in WA reconstructions of individual variables. Multivariate calibration procedures that permit inference of more than one environmental variable simultaneously are required to allow for confounding and interacting environmental variables.

The pH, total Al, and DOC optima and tolerances of the diatom taxa in the training sets, as estimated by WA regression are tabulated in Appendix B, along with the number of occurrences of each taxon in the training sets. These optima plus the regression equations listed in Table 16 provide the basis for reconstructing pH, total Al, and DOC for any fossil diatom assemblage with identical taxonomy to the SWAP training sets.

Table 14 Details of the three SWAP training sets before and after data screening (sample numbers follow Table 4)

Training set	Number of samples prior to screening	Number of samples after screening	Range	Mean	Median	Standard deviation
pH	178	167	4.23-7.25	5.56	5.27	0.77
Al (µg l^{-1})	157	126	13.0-256.3	103.2	104.3	60.04
DOC(mg l^{-1})	138	123	0.12-11.60	3.17	2.50	2.29

Training set samples before screening

Training set	Samples
pH	All samples
Al	1, 2, 4-7, 9-11, 13-15, 17-18, 20, 22-29, 32, 35-55, 56-63, 65-82, 84-87, 90-103, 106-123, 125-137, 139-162, 164-170, 172-178.
DOC	1, 2, 4-7, 9-11, 13-15, 17, 18, 20, 22-25, 27-29, 32, 36-49, 51, 52, 54, 56-63, 65-82, 84-86, 90, 92, 93, 95-100, 102, 103, 103-121, 125-137, 139-155, 158, 161, 162, 164-168, 170, 175, 177, 178.

Training set samples deleted after data screening

Training set	Samples
pH	4, 27, 72, 79, 90, 91, 114, 124, 150, 157, 177
Al	1, 2, 26, 27, 32, 45, 53, 57, 74, 86, 90, 96, 108, 109, 110, 112, 113, 114, 115, 127, 135, 139, 143, 151, 156, 158, 159, 161, 166, 172, 177.
DOC	72, 110, 115, 117, 127, 135, 137, 142, 143, 146, 148, 150, 151, 152, 154.

Table 15 Apparent root-mean-square error of prediction (RMSE), correlation (r) between observed and inferred chemistry and RMSE estimated by bootstrapping ($RMSE_{boot}$) and its error components (s_{i1}, s_2) for the three screened SWAP training sets.

Training set	Apparent RMSE	r	RMSE boot	RMSE s_{i1}	RMSE s_2
pH	0.297	0.933	0.320	0.072	0.312
Al (µg l^{-1})	37.820	0.777	49.663	12.985	47.935
DOC (mg l^{-1})	1.251	0.837	1.580	0.403	1.527

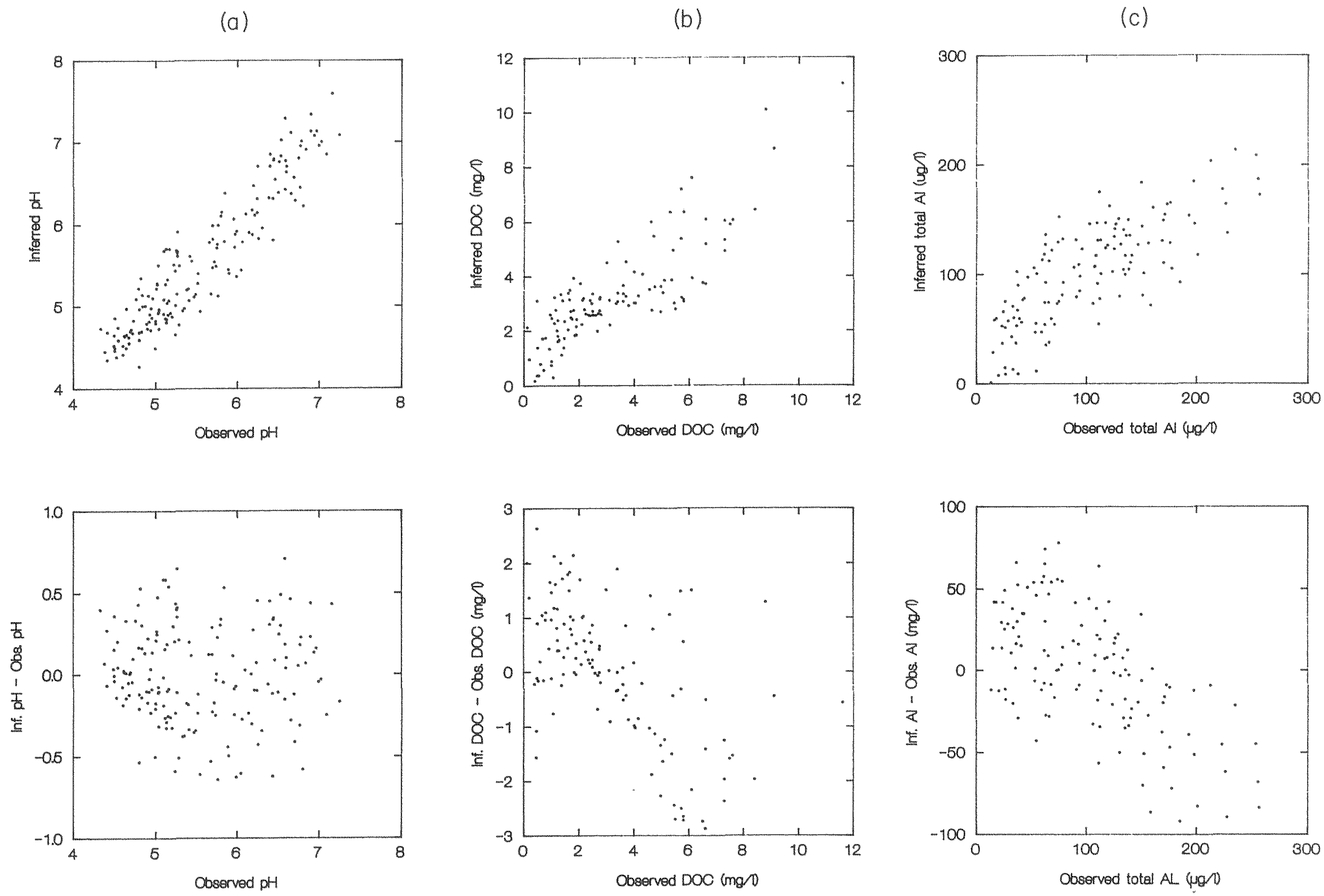


***Figure 13** Plots of (a) inferred pH and of the differences between inferred and observed pH against observed pH based on weighted averaging regression and calibration using the screened SWAP pH training set (n = 167), (b) inferred DOC and of the differences between inferred and observed DOC against observed DOC based on weighted averaging regression and calibration using the screened SWAP DOC training set (n = 123), and (c) inferred total Al and of the differences between inferred and observed total Al against observed total Al based on weighted averaging regression and calibration using the screened SWAP total Al training set (n = 126). Abbreviations: inf = inferred, obs = observed.*

Table 16 Deshrinking regression equations for the three screened SWAP training sets

	Constant a	Coefficient b	Regression type
pH	2.630	0.5264	Classical[1]
Al	-151.2	2.461	Inverse[2]
DOC	-3.775	2.202	Inverse[2]

[1]Classical regression *Final* x_i = *(Initial* x_i - $a)/b$

[2]Inverse regression *Final* $x_i = a + b$ * *Initial* x_i

$$\textit{Initial}\ \hat{x}_i = \frac{\sum_{k=1}^{m} y_{ik}\,\hat{u}_k}{\sum_{k=1}^{m} y_{ik}}$$

where y_{ik} is the abundance of taxon k in fossil sample i ($y_{ik} \geq 0$); u_k is the WA estimate of the optimum of taxon k; x is the chemical variable to be reconstructed; $\hat{x}_i$ is the inferred value of the chemical variable x for the sample i (k = 1, ... m diatom taxa).

DIATOM INDICATOR TAXA

Within a training set such as the SWAP set, some taxa may be sensitive to particular chemical variables, whereas others may be insensitive. Taxa that are sensitive, that have narrow ecological amplitudes ("tolerances") for that variable, and that are frequent may be good "indicator" taxa for particular chemical components. The approach we have adopted in drawing up lists of potential indicator taxa for pH, DOC, and total Al is as follows.

(1) Do separate canonical correspondence analyses of the three screened training sets (Table 14) with pH, Al, and DOC as the sole environmental variables for the three individual sets. This provides a direct gradient analysis of the taxa along the gradient of the single chemical variable of interest.

(2) Examine the fraction of the variance of a taxon fitted by this gradient (ter Braak 1990), namely CCA axis 1. For a taxon to be considered as a potential indicator, we require that 10% or more of a taxon's variance be explained by the chemical variable of interest. Using this criterion (A), there are 31 potential indicators for pH, 8 for Al, and 13 for DOC. The mathematical basis for estimating the fraction of the variance of a taxon fitted or the taxon's relative contribution or the contribution of dimensions to the inertia of the species is given by ter Braak (1990).

(3) Estimate the taxon's tolerance, as estimated by weighted averaging, for the chemical variables of interest, with each tolerance adjusted for the effective number of occurrences of the taxon, N2 (ter Braak, 1990). The WA tolerances are divided by $(1 - 1/N2)^{½}$ where N2 is analogous to Hill's (1973) N2 diversity measure. Select taxa as possible indicators that fulfil criterion A *and* that have tolerances less than the mean tolerance of all taxa in the training set (criterion B). Note that these tolerances are slightly different from the simple WA tolerances listed in Appendix B which are not adjusted for N2.

(4) Consider the number of occurrences of each taxon that fulfils criteria A and B, and tabulate the taxa with 10 or more occurrences (criterion C).

These taxa lists (Table 17) are ordered by number of occurrences. For pH 30 taxa fulfil the three criteria but only the 10 most frequent taxa are listed. For Al only 8 taxa fulfil the criteria and for DOC only 7 taxa qualify. Scatter plots of some of these indicator taxa in relation to pH, Al, and DOC for the total available data, rather than the screened data, are shown in Figure 14. Taxa that appear to be "indicator species" have a star in the top of their relevant scatter plots.

Table 17 List of indicator taxa for pH, DOC, and total Al that fulfil the criteria of having 10% or more of their variance explained by the chemical variable concerned and of having a tolerance (t) that is less than the mean tolerance for all taxa in the training sets. û = WA optimum, n = number of occurrences. For pH only the 10 most frequent taxa are listed.

	n	t	û
pH			
Frustulia rhomboides var. *saxonica*	154	0.61	5.17
Eunotia incisa	145	0.47	5.06
Brachysira brebissonii	143	0.61	5.30
Brachysira vitrea	140	0.68	5.94
Eunotia exigua	121	0.46	5.06
Achnanthes minutissima	118	0.55	6.34
Eunotia naegelii	111	0.41	4.95
Frustulia rhomboides	109	0.55	5.12
Cymbella hebridica	104	0.49	5.09
Cyclotella kuetzingiana agg.	101	0.62	6.29
Dissolved Organic Carbon	n	t	û
Achnanthes marginulata	89	1.22	1.25
Gomphonema acuminatum var. *coronatum*	31	2.47	4.57
Cyclotella comta	21	2.20	6.12
Aulacoseira distans var. *tenella*	20	2.91	9.93
Achnanthes pusilla	20	2.23	5.90
Aulacoseira subarctica agg.	18	1.91	6.40
Navicula indifferens	16	2.50	5.44
Total Aluminium	n	t	û
Achnanthes minutissima	94	51.34	70.76
Frustulia rhomboides	77	54.88	133.36
Navicula hoefleri	56	59.46	140.20
Stauroneis anceps f. *gracilis*	45	52.21	67.87
Brachysira serians	39	57.31	158.51
Stenopterobia sigmatella	38	57.74	156.33
Tabellaria binalis	41	52.03	171.31
Semiorbis hemicyclus	24	45.70	177.20

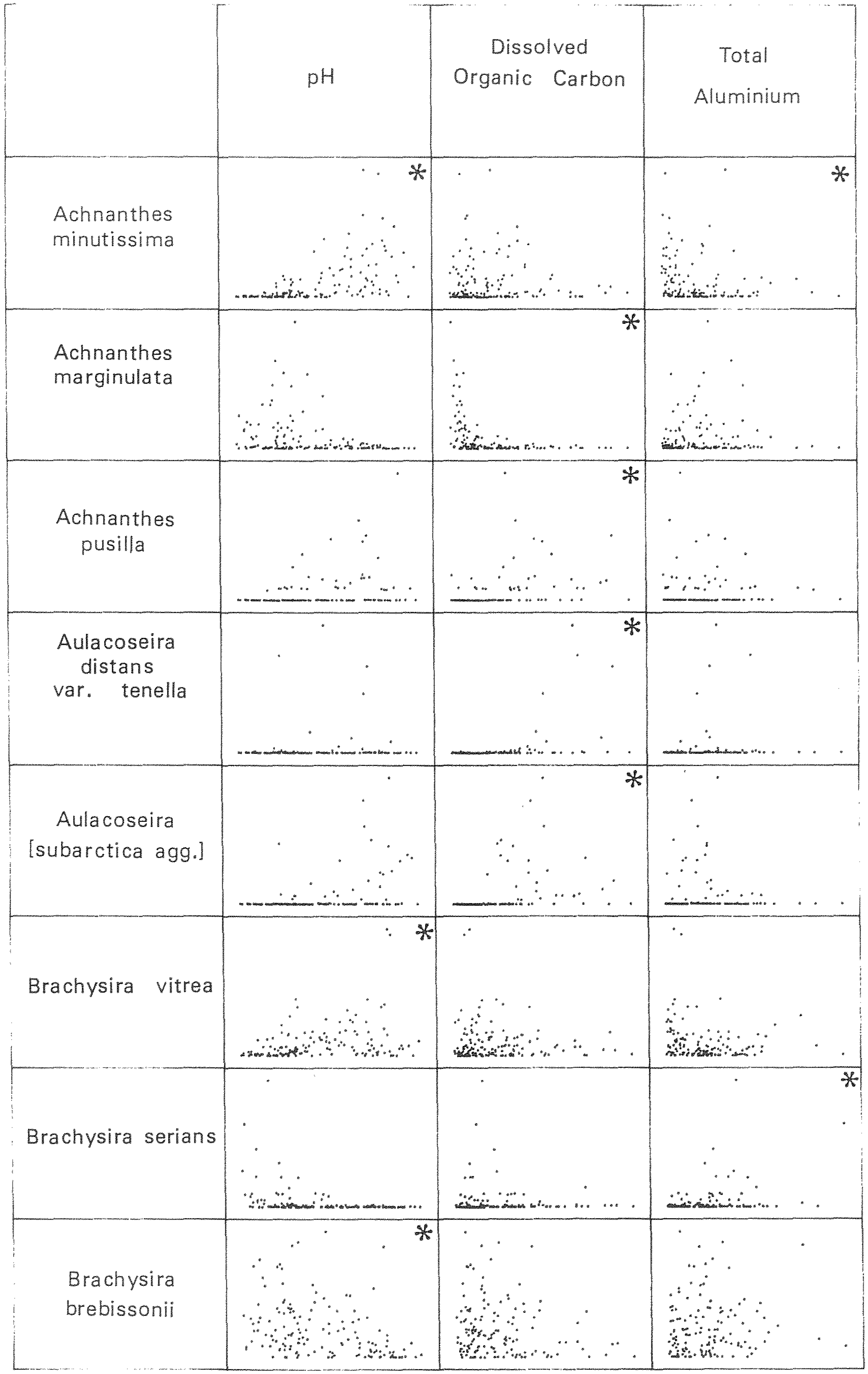


*Figure 14 Scatter plots of selected diatom taxa showing their relative abundance (vertical axis scaled from zero to maximum abundance) in relation to pH, dissolved organic carbon, and total Al in the SWAP training sets for pH (n = 178), DOC (n= 138), and total Al (n= 157). * indicate those taxa that satisfy the criteria for potential indicator taxa (see Table 17) when the screened training data-sets are used.*

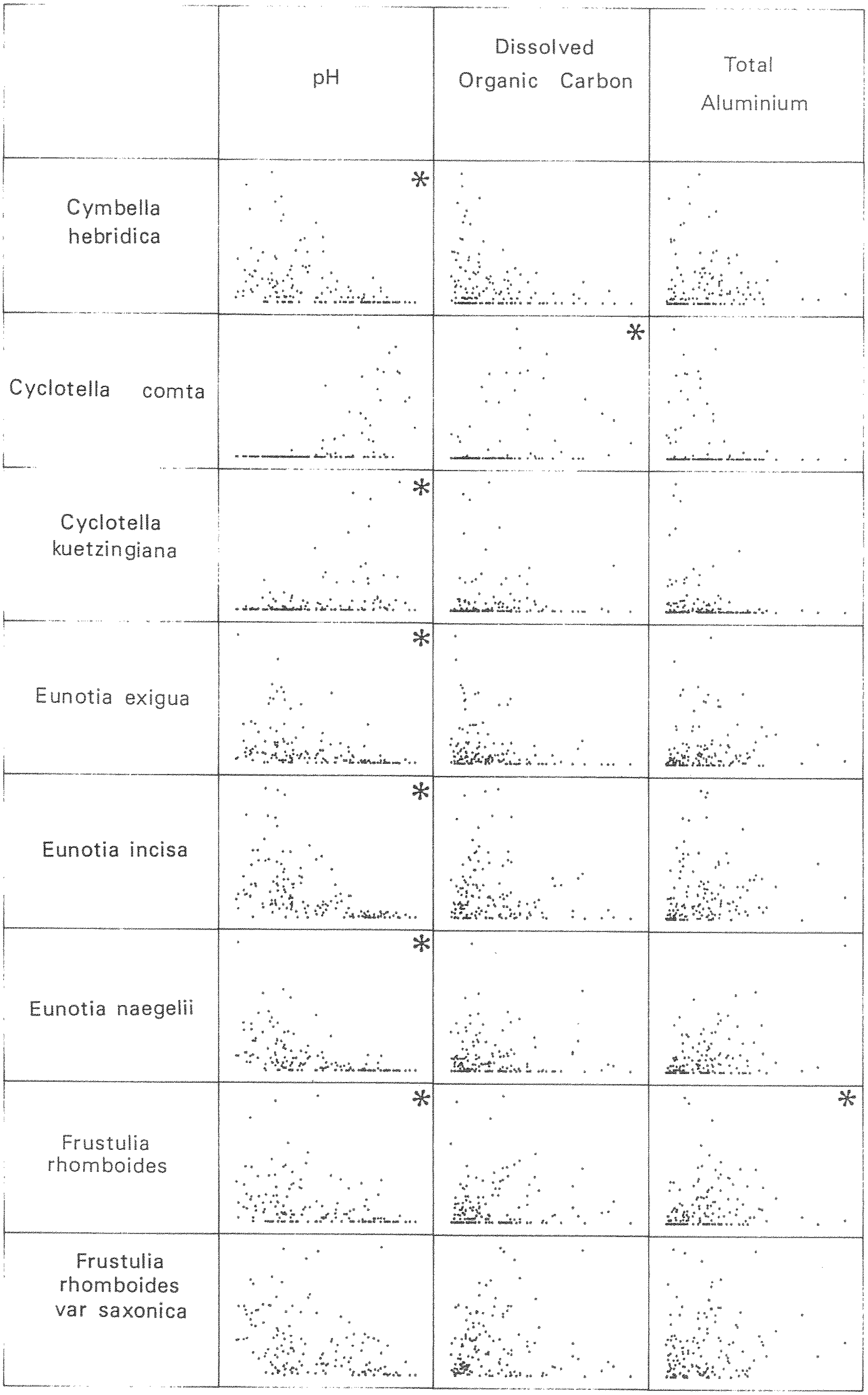


Figure 14 Continued.

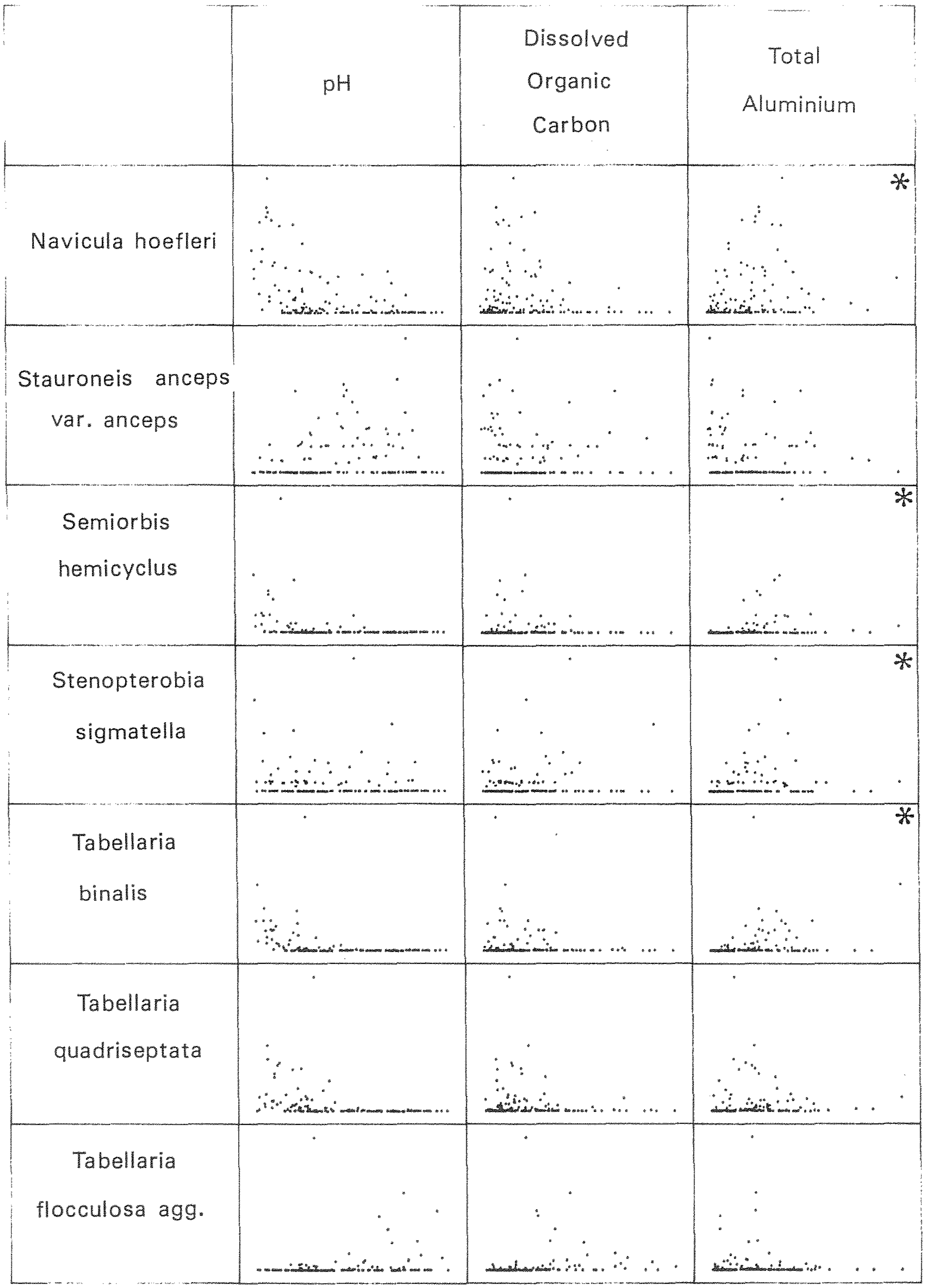


Figure 14 Continued.

CONCLUSIONS

The SWAP set of modern diatom assemblages and associated environmental variables has, to date, been used almost exclusively as a lake-water chemical calibration training set. The 178-sample pH set, reduced to a training set of 167 samples after data-screening, provided the pH reconstructions for all the lakes studied in SWAP palaeolimnological sub-project (Birks *et al.* 1990a, Battarbee 1990, Atkinson and Haworth 1990, Renberg 1990, Birks *et al.* 1990c, Renberg *et al.* 1990a, Anderson and Korsman 1990, Kreiser *et al.* 1990, Berge *et al.* 1990, Renberg *et al.* 1990b, Jones *et al.* 1990, Renberg and Battarbee 1990). The 157-sample total Al training set (screened to 126 samples) and the 138-sample DOC set (screened to 123 samples) were used to reconstruct total Al and DOC at Round Loch of Glenhead (Birks *et al.* 1990b).

The SWAP data-set contains an enormous amount of modern but largely unexplored biological information at the individual taxon, samples, and lake scales, in addition to the basic diatom assemblage/lake chemistry information that has been exploited in the SWAP palaeolimnological investigations. Hopefully this wealth of biological information on diatom ecology will begin to be explored by diatomists. Moreover the data-set will continue to expand as new, but taxonomically and methodologically comparable, surface-sediment data are acquired from, for example, Ireland, Norway, and parts of Scotland. A harmonized modern data-set such as this, when explored from ecological and limnological viewpoints may help to strengthen the "bridges between paleolimnology and aquatic ecology" (Smol 1991).

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Appendix A

THE SWAP TAXONOMIC GUIDE - REVISED 1989

The diatom taxa discussed by participants at the 1987, 1988, and 1989 SWAP diatom workshops are listed below in the following format:

a) Taxon and authority.
b) Taxonomic decisions, agreements, or alterations.
c) Ecological comments.

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a) *Achnanthes altaica* (Poretsky) Cleve-Euler
b) Supposedly synonymous with *A. recurvata* Hust. although both names appear to be valid on the BM checklist. A small non-curved form of this taxon *A.* [*altaica* var. *minor*] has been identified by RJF and is described in the guide circulated at the SWAP workshop, July 1988.

a) *Achnanthes hyperborea* Grun.
b) Synonymous with *A. frigida.*

a) *Achnanthes gibberula* Grun.
b) Synonymous with *A. biasolettiana*

a) *Achnanthes pusilla* Grun.
b) Synonymous with *A. linearis* var. *pusilla* Grun.

a) *Achnanthes austriaca* var. *helvetica*
b) Two new forms of this taxon were discussed at the July 1988 workshop; f. *alpina* (formerly *elongata*) and f. *minor.* They are described in Flower and Jones (1989) but will not be used generally until their distribution in the surface sediment data-set has been assessed.

a) *Achnanthes microcephala* Kütz.
b) Following the results of the 1988 slide counts it was decided not to differentiate between *A. minutissima* and *A. microcephala* in the central data-set although individual analysts could split the two taxa at the local level if they wished.

a) *Achnanthes marginulata* Grun.
b) Counts of this species have possibly included the diatom described as *A.* [*marginulata* f. *major*] by VJJ at the SWAP July 1988 workshop.

a) *Achnanthes* [*scotica*] Jones & Flower
b) This small *Achnanthes* has probably been included in counts of *A. marginulata* in the past. Since it has been found by RJF and VJJ to occur independently of *A. marginulata* in cores, it was agreed to re-examine surface sediment slides to determine its distribution in modern material. Taxonomy follows Flower and Jones (1989).

a) *Achnanthes marginulata* Grun.
b) Synonymous with *A.* [*sp. 5*] Loch Uaine (VJJ).

a) *Amphora ovalis* var. *affinis* Kütz.
b) Synonymous with *Amphora ovalis* var. *libyca.*

a) *Asterionella ralfsii* W. Smith
b) Problems arise in distinguishing this taxon from *A. formosa*, particularly when only broken valves are present. A category *A. ralfsii/formosa* has been created for use when such uncertainty exists.
c) *A. ralfsii* appears to prefer coloured waters and is therefore often associated with basins receiving artificial drainage from peat.

a) *Aulacoseira distans* (Ehr.) Simonsen
b) Synonym *Melosira distans.* All transfers from *Melosira* to *Aulacoseira* follow Hartley (1986). Refer to Camburn and Kingston (1986) for a description of the taxon.

a) *Aulacoseira lirata* var. *alpigena* (Grun.) Haworth
b) Synonym *Melosira distans* var. *alpigena*, *Aulacoseira distans* var. *alpigena* and *Aulacoseira* [sp. 4].

a) *Aulacoseira* [*cf. distans* var. *distans*] SWAP 1989
b) Synonymous with *A. distans* var. *distans* (Ehrenb.) Simonsen 1979.

a) *Aulacoseira distans* var. *nivalis*
b) Synonym *Melosira distans* var. *nivalis*, but has not yet been put into *Aulacoseira* in the BM checklist. Taxonomy follows Camburn and Kingston (1986). Bears some similarity to *A. distans* var. *africana* although the two are separate taxa.

a) *Aulacoseira* [*subborealis/subarctica*]
b) This taxon has a coarsely punctate valve face and large spines. In girdle view the slightly spiral striae consist of two rows of punctae. The reference site for this taxon is Botungen.

a) *Aulacoseira distans* var. *tenella* (Nygaard) Ross
b) Synonym *Melosira distans* var. *tenella.* Taxonomy follows Camburn and Kingston (1986).

a) *Aulacoseira lirata* (Ehr.) Ross
b) Synonym *Melosira lirata.* Taxonomy follows Camburn and Kingston (1986). The valve view maybe confused with that of *A. perglabra* var. *floriniae.*

a) *Aulacoseira lirata* var. *lacustris* (Grun.) Ross
b) Synonym *Melosira lirata* var. *lacustris*. Taxonomy follows Camburn and Kingston (1986).

a) *Aulacoseira lirata* f. *biseriata*
b) Synonym *Melosira lirata* f. *biseriata.* To be transferred to *A. distans* var. *lirata* f. *biseriata.*

a) *Aulacoseira perglabra*
b) Synonym *Melosira perglabra.* Taxonomy follows Camburn and Kingston (1986). This taxon is recorded as *A. lirata* var. *perglabra* on the BM checklist but will be transferred to *Aulacoseira perglabra.*

a) *Aulacoseira perglabra* var. *floriniae*
b) Synonym *Melosira perglabra* var. *floriniae*. Taxonomy follows Camburn and Kingston (1986). Valve view may be confused with that of *A. lirata* if one is not familiar with both taxa. This taxon does not appear on the BM checklist but should be added shortly.

a) *Aulacoseira* [*subarctica* agg.]
b) This includes *Aulacoseira subarctica* var. *subborealis*, a description of which is in Haworth (1988). SEM and LM photographs of *M. italica* var. *subborealis* Nygaard can be found in Engelmark *et al.* (1976), p. 151, fig. 4.

a) *Aulacoseira* [var.5 PIRLA]
b) This unknown taxon from the surface sediments of Llyn Tecwyn closely resembles the PIRLA *Aulacoseira distans* var.5 PIRLA (1984-1986) Iconograph plate 51, fig. 5. It has a punctate valve face with a suggestion of curvature and prominent spines. The sulcus is poorly developed and the valve measures 9-12 µm in diameter. In girdle view the parallel striae are 20 in 10 µm. The valves are 5-6 µm deep. This diatom is similar to the *A. distans* var. *laevissima* found by EYH.

a) *Berkeleya rutilans* (Trentepohl *ex* Roth.) Grun. 1868
b) Synonymous with *Amphipleura rutilans* (Trentepohl *ex* Roth.) Cleve 1894.

a) *Brachysira brebissonii* Ross
b) Synonym *Anomoeoneis brachysira* (Bréb.) Grun. It was decided not to use f. *thermalis* since the two taxa cannot be consistently separated.

a) *Brachysira* [*serians* small]
b) This small form has been found by IR and NJA in some Scandinavian lakes. Although diatomists may separate this form in their counts, it was agreed not to include it in the database.

a) *Brachysira follis* (Ehr.) Ross
b) Synonym *Anomoeoneis follis*.

a) *Brachysira serians* (Bréb. *ex* Kütz.) Round & Mann
b) Synonym *Anomoeoneis serians*.

a) *Brachysira serians* var. *modesta*
b) This small variety of *B. serians* follows Cleve-Euler (1951-1955) described in vol. III p. 197, but is not separated from *B. brebissonii* in the data-set.

a) *Brachysira styriaca* (Grun.) Ross
b) Synonym *Anomoeoneis styriaca*.

a) *Brachysira vitrea* (Grun.) Ross
b) Synonym *Anomoeoneis vitrea*.

a) *Brachysira vitrea* var. *lanceolata*
b) Synonym *Anomoeoneis vitrea* var. *lanceolata*. It was agreed to distinguish this taxon from the nominate at the local level but not in the data-set.

a) *Brachysira* [sp.1 Round Loch]
b) It was agreed to include this unpublished *Brachysira* in the data-set.

a) *Caloneis ventricosa* (Ehrenb.) Meister 1912
b) Synonymous with *Caloneis silicula* (Ehrenb. (Cleve 1894)).

a) *Cyclotella comensis* Grun.
b) This is a separate taxon from *C. kuetzingiana* although it is probable that the two taxa have been confused in the past.

a) *Cyclotella* [*kuetzingiana* agg.]
b) There are no agreed criteria within the group for separating *C. kuetzingiana* from its varieties. Therefore, this name should be used for both the nominate and its varieties in the data-set.

a) *Cyclotella kuetzingiana* Thwaites
b) Only to be used at the local level (see above).

a) *Cyclotella kuetzingiana* var. *planetophora* Fricke
b) Only to be used at the local level (see above).

a) *Cyclotella kuetzingiana* var. *radiosa* Fricke
b) Only to be used at the local level (see above).

a) *Cyclotella comta* (Ehrenb.) Kütz.
b) Synonymous with *C. radiosa* Håkansson but has not been revised in the BM checklist.

a) *Cyclotella glomerata* Bachm.
b) Synonym *C. stelligera* var. *glomerata* Haworth. See Haworth and Hurley (1987). Included in the BM checklist as *C. glomerata*.

a) *Cymbella aequalis* W. Smith
b) This taxon may have been confused with *C. angustata* in the past although it is clear only *C. aequalis* is present in the SWAP slides.

a) *Cymbella gaumannii* Meister
b) There is some taxonomic confusion due to the similarity with *C. perpusilla*. Taxonomy follows the description in Krammer and Lange-Bertalot (1986). The *C. amphicephala* in Hustedt (1930) is synonymous with *C. gaumannii*.

a) *Cymbella lunata* W. Smith
b) Synonym *C. gracilis*. For taxonomy see Patrick and Reimer (1966).

a) *Cymbella minuta* Hilse *ex* Rabh.
b) Synonym *C. ventricosa* Kütz. (the smaller, finer forms). For taxonomy see Krammer and Lange-Bertalot (1986). See also *C. silesiaca*.

a) *Cymbella perpusilla* A. Cleve
b) Follows the description in Krammer and Lange-Bertalot (1986). *C. bipartita* Mayer is synonymous with *C. perpusilla*, and was used to describe the oval forms. See discussion on *C. gaumannii* above.

a) *Cymbella scotica* var. *naviculacea* (Grun. *ex* Cleve) R. Ross 1947.
b) Synonymous with *C. naviculacea* Grun. *ex* Cleve 1881.

a) *Cymbella silesiaca* Bleisch in Rabenhorst (1864).
b) This taxon includes the larger, coarser forms of *C. ventricosa*. See Krammer and Lange-Bertalot (1986).

a) *Cymbella elginensis* Krammer
b) This is synonymous with *C. turgida* Greg. This should not be confused with *C. turgida sensu* Cleve (1894) or *C. turgida sensu* Hustedt (1930) *pro parte*, which are now in *C. mesiana* Cholnoky. See Krammer and Lange-Bertalot (1986) for details.

a) *Diatoma tenue* var. *elongatum* Lyngb. 1819
b) Synonymous with *D. elongatum* (Lyngb.) Ag. 1824

a) *Eunotia arcus* Ehr.
b) No apparent taxonomic problems.

a) *Eunotia bactriana* Ehr.
b) No taxonomic problems.

a) *Eunotia curvata* (Kütz.) Lagerst.
b) Synonym *E. lunaris*. Used for diatoms of the *E. curvata/naegelii* group with width > 3 µm and striae count < 20 in 10µm.

a) *Eunotia curvata* var. *subarcuata* (Naegeli) Woodhead & Tweed
b) This name was probably used for the shorter forms of *E. naegelii* in the past but should now be used with care for the short forms of *E. curvata*, applying the criteria described above. Do not use the Hustedt description of this taxon.

a) *Eunotia denticulata* (Bréb.) Rabh.
b) This name is to be applied to the "classic" *E. denticulata* as described in Hustedt (1930 -1966), vol II, p. 293 figs. a-i.

a) *Eunotia denticulata/lapponica*
b) This combination has been formed to accommodate the broader form of *E. denticulata* with the robust apices characteristic of *E. lapponica*.

a) *Eunotia exigua* (Bréb.) Rabh.
b) This name has been applied to diatoms showing a number of morphological variations. Refer to Hustedt (1930-1966) vol. II p. 287 fig. 751 a-r as a starting point, being aware that Petersen has removed *E. paludosa* and *E. steineckii* from Hustedt's concept of *E. exigua*. See Flower and Kreiser (1988).

a) *Eunotia flexuosa* Kütz.
b) Two forms of this taxon, fine and coarse have been noted.

a) *Eunotia incisa* W. Smith *ex* Greg.
b) Synonymous with the diatom commonly called *E. veneris*

a) *Eunotia major* (W. Smith) Rabh.
b) Synonym *E. monodon* var. *major*

a) *E. minutissima* Cleve-Euler
b) For description see Cleve-Euler (1955) and SWAP taxonomy update (Flower and Kreiser 1988). It is possible that this taxon has been confused with small, fine forms of *E. naegelii* in the past.

a) *Eunotia* [sp.13 *minutissima*]
b) Used to describe a small *Eunotia* similar to *E. minutissima* but finer (see Flower and Kreiser 1988).

a) *Eunotia naegelii* Migula
b) Synonym *E. alpina sensu* Hustedt in Schmidt Atlas vol II plate 291 figs 7 & 8. This name to be used for diatoms in the *E. curvata/naegelii* group with width <3 µm and striae >20 in 10 µm. It is probable that shorter specimens of this taxon have been assigned to *E. curvata* var. *subarcuata* in the past.

a) *Eunotia nodosa* Ehr.
b) Synonym *E. formica.*

a) *Eunotia nymanniana* Grun
b) Synonym *E. exigua* var. *compacta*. Description in Cleve-Euler (1951-1953), vol. II, fig. 445 a & d.

a) *Eunotia pectinalis* (Kütz.) Rabh.
b) No taxonomic problems.

a) *Eunotia pectinalis* var. *minor* (Kütz.) Rabh.
b) See SWAP taxonomy update (Flower and Kreiser 1988).

a) *Eunotia pectinalis* var. *ventricosa* Grun.
b) Synonym *E. pectinalis* var. *ventralis.*

a) *Eunotia praerupta-nana* Berg
b) It was agreed to keep this taxon.

a) *Eunotia rhomboidea* Hust.
b) It was agreed to keep this taxon although its morphology can come close to *E. incisa.*

a) *Eunotia serra* Ehr.
b) Synonym *E. robusta.*

a) *Eunotia serra* var. *diadema* (Ehr.) Patr.
b) Synonym *E. robusta* var. *diadema*. This taxon also includes *E. robusta* var. *tetraodon.*

a) *Eunotia tenella* (Grun.) Hust.
b) See SWAP taxonomy update (Flower and Kreiser 1988).

a) *Eunotia tibia* var. *bidens* (W. Smith) Cleve-Euler
b) Synonym *E. major* var. *bidens* and *E. monodon* var. *bidens.*

a) *Eunotia tridentula* Ehr.
b) Synonym *E. polydentula* and *E. tridentula* var. *perminuta* (see BM list).

a) *Eunotia vanheurckii* Patrick
b) Synonym *E. faba.*

a) *Eunotia vanheurckii* var. *intermedia*
b) Synonym *E. faba* var. *intermedia.* See SWAP taxonomy update (Flower and Kreiser 1988).

a) *Eunotia exgracilis* A. Berg *ex* Cleve-Euler 1953
b) Synonymous with *E.* [PIRLA sp.8] PIRLA (1984-1986).

a) *Fragilaria* [*cf. oldenburgiana*]
b) This taxon does not correspond to Hustedt's type material from Bremerhaven, (Simonsen 1987, vol. 3 plate 680 figs. 1-5) although it is agreed the *F. cf. oldenburgiana* in the PIRLA material is the same as that found in Europe. Reference: PIRLA (1984-1986) Iconograph plate 20 figs. 61-62 & plate 38 fig. 107.

a) *Fragilaria heidenii* Østr. 1910
b) Synonymous with *F. inflata* (Heiden) Hust. 1931.

a) *Fragilaria intermedia* Grun.
a) *Fragilaria vaucheriae* (Kütz.) Boye Petersen
b) Petersen put these two taxa together but EYH separates them using striae count, TEM structure, and whether or not the cells form colonies. It was agreed to separate them if possible but more information is needed on their differences.

a) *Fragilaria virescens* var. *exigua* Grun.
b) This name is applied within PIRLA to the taxon known as *F. virescens* in Europe (PIRLA (1984-1986) Iconograph plate 25 figs. 105-112) since the taxonomy of *F. virescens* is uncertain. It was decided to adopt the above name for the taxon currently called *F. virescens* until the type material of *F. virescens* has been examined.

a) *Frustulia* [*rhomboides* agg.]
b) It was agreed to use this classification for central areas or ends which can not be confidently assigned to the nominate or one of the varieties.

a) *Frustulia rhomboides* (Ehr) De Toni
b) This is split from the variety *saxonica* by its size (generally >60µm) and striae density (<30 in 10µm) but see unpublished notes by RJF. It differs from the variety *viridula* in that it has a straight raphe, symmetrical central area, and the striae continue around the apices of the valve. A good reference is Krammer and Lange-Bertalot (1986), fig. 95, nos. 2 & 3. (No. 1 is ambiguous). See also Haworth *et al.* (1988).

a) *Frustulia rhomboides* var. *viridula* (Bréb. *ex* Kütz.) Cleve
b) This taxon can be separated from the nominate by its curved raphe, asymmetrical central area, and gap in the striae at the apices. It is also usually larger than the nominate. See Krammer and Lange-Bertalot (1986), fig. 96 nos. 1-3 and also Haworth *et al.* (1988).

a) *Frustulia rhomboides* var. *saxonica* (Rab) De Toni
b) Can be distinguished from the nominate by its smaller size (<60 µm) and finer striae (>30 in 10 µm).

a) *Gomphonema olivaceum* (Hornemann) P. Dawson *ex* R. Ross in Hartley (1986)
b) Synonymous with *G. olivaceum* (Hornemann) Bréb. 1838.

a) *Gomphonema vibrio* var. *intricatum* (Kütz.) R.Ross in Hartley (1986)
b) Synonymous with *G. intricatum* Kütz. 1844.

a) *Gomphonema vibrio* var. *pumilum* (Grun.) R. Ross in Hartley (1986)
b) Synonymous with *G. intricatum* var. *pumilum* Grun. 1880

a) *Melosira arentii* (Kolbe) Nagumo & Kobayasi
b) Synonym *Cyclotella arentii.*

a) *Navicula angusta* Grun.
b) Synonyms: *N. cari* var. *angusta* and *N. lobeliae.*

a) *Navicula bremensis* Hust.
b) The *N. bremensis* seen in the SWAP material does not exactly fit the description in Hustedt (1930-1966), although it corresponds with the *N. bremensis* in the PIRLA (1984-1986) Iconograph, plate 1 figs. 3-4. It was decided to continue using the name for the time being.

a) *Navicula capitata* var. *hungarica* (Grun.) R. Ross 1947
b) Synonymous with *N. hungarica* Grun. 1860.

a) *Navicula cocconeiformis* Gregory
b) No taxonomic problem.

a) *Navicula contenta* var. *parallela* Petersen
b) Synonymous with the *Navicula* sp. at 37 cm in the Tveita core. Reference: Hustedt (1930-1966) vol. III p. 210

a) *Navicula cumbriensis* Haworth
b) Synonymous with *N. madumensis* var. 1 (UCL) and *N. subtilissima* var. 2 (I. Renberg). See Haworth (1988). Note that *N. cumbriensis* is strictly an invalid name because it is preempted by Koboyasi and Nagumo's description of this taxon as *N. parasubtilissima* (E.Y. Haworth, personal communication). For the purposes of SWAP, this taxon is still informally termed *N. cumbriensis.*

a) *Navicula* [*cumbriensis* small]
b) This is a small variety of the above but is not *N. cumbriensis* var. *minor* as identified by EYH. It was agreed to make the distinction between this and the nominate at the local level but to amalgamate them in the data-set.

a) *Navicula detenta* Hust. 1943
b) Synonymous with *N. dicephala* Ehrenb. 1838.

a) *Navicula cryptocephala* var. *exilis* (Kütz.) Grun.
b) Synonymous with *N. exilis* Kütz. 1844

a) *Navicula festiva* Krasske
b) No taxonomic problem.

a) *Navicula gysingensis* Foged
b) Previously called *N. cf. arvensis* in the Öresjön SWAP slides. Reference: PIRLA (1984-1986) iconograph, plate 41 figs. 23-24.

a) *Navicula hoefleri* Cholnoky
b) Not to be confused with *N.* [*hoefleri sensu* Ross & Sims]. Reference: Hustedt (1930-1966) vol. III, p. 97.

a) *Navicula* [*hoefleri sensu* Ross & Sims]
b) Synonymous with *N. simsii* and *N. subtilissima* var 4, PIRLA (1984-1986) iconograph, plate 42 figs. 75-77.

a) *Navicula leptostriata* Jorgensen
b) Synonym *N. heimansii.*

a) *Navicula madumensis* Jorgensen
b) Synonymous with *N. subtilissima* var.1 (I. Renberg).

a) *Navicula mediocris* Krasske
b) No taxonomic problem.

a) *Navicula minuscula* var. *muralis* (Grun.) Lange-Bertalot.
b) Synonymous with *N. muralis* Grun.

a) *Navicula radiosa* var. *tenella* (Bréb.) Grun.
b) This includes the concept of *N. cari sensu* Germain, as used at UCL.

a) *Navicula subtilissima* Cleve
b) Reference: Hustedt (1930-1966) vol. III, p. 89

a) *Navicula tenuicephala* Hust.
b) The SWAP concept of this taxon conforms with that found in Simonsen (1987) vol. 3 plate 457, figs. 11-16. There is some variability in the completeness of the stauros and some specimens have an asymmetrical stauros. There is possibly another taxon with a symmetrical central area.

a) *Neidium affine* (Ehr.) Cleve
b) No taxonomic problem.

a) *Neidium glaberrimum* (Østrup) Ross
b) Synonym *N. alpinum*

a) *Nitzschia perminuta* (Grun.) M. Perag.
b) The *N. perminuta* in the SWAP material is synonymous with *Nitzschia* sp.1 PIRLA (1984-1986) iconograph, (plate 44, fig. 123). However, the taxonomy of this species remains unclear. In the BM checklist *N. perminuta* has been put into *N. frustulum* yet the SWAP *N. perminuta* is clearly not related to *N. frustulum.* The above name will be used in the data-set but further work is required.

a) *Nitzschia pusilla* Grun. 1862
b) Synonymous with *N. kuetzinghiana* Hilse 1863.

a) *Pinnularia abaujensis* var. *abaujensis* (Pant.) R. Ross
b) Synonymous with *P. gibba* (Ehrenb.) Ehrenb. 1843.

a) *Pinnularia biceps* Greg.
b) Synonym *P. interrupta.* It was decided not to separate the varieties of *P. biceps.*

a) *Pinnularia irrorata* (Grun.) Hust.
b) Decision made not to synonymise *P. irrorata* with *P. appendiculata* although Krammer and Lange-Bertalot (1986) do so. The concept of *P. irrorata* is represented in plate 193 and figs. 21-26. *P. sylvatica* may need to be included in this taxon but more research is required.

a) *Pinnularia subcapitata* var. *hilseana* (Janisch) O. Mull.
b) Synonym *P. hilseana*

a) *Pinnularia rupestris* Hantzsch
b) Synonym *Pinnularia viridis* var. *rupestris* (Hantzsch) Cleve. Illustrations can be found in Meriläinen (1969), p. 96, fig. 171 and in Renberg (1976), p. 151 plate 5 fig. 12.

a) *Semiorbis hemicyclus* (Ehr.) Patr.
b) Synonym *Amphicampa hemicyclus.*

a) *Stenopterobia sigmatella* (Greg.) Ross
b) Synonym *Stenopterobia intermedia.*

a) *Surirella delicatissima* Lewis
b) It was agreed to split fine and coarse forms at the local level, but not in the data-set.

a) *Tabellaria binalis* (Ehr.) Grun.
b) For the purposes of the data-set, this name will include both the elliptic and panduric forms although the two varieties will probably be split at the local level.

a) *Tabellaria fenestrata* (Lyngbye) Kütz.
b) This may have been confused in the past with the longer forms of *T. flocculosa.* More work is required on morphology and colony structure.

a) *Tabellaria flocculosa* var. *flocculosa* (Roth.) Kütz.
b) This name is to be applied to those diatoms conforming to Koppen's strain IV, i.e. length <39 µm and central inflation distinctly wider than those at the apices.

a) *Tabellaria* [*flocculosa* agg.]
b) For the purposes of the data-set this category is to be applied to all specimens of *T. flocculosa* which do not fit into the above description. This will include Koppen's strain III and the twisted form IIIP plus var. *linearis.* Analysts may differentiate between these forms at the local level if they wish.

Abbreviations

AK Annette Kreiser
EYH Elizabeth Haworth
IR Ingemar Renberg
NJA John Anderson
RJF Roger Flower
UCL University College London
VJJ Vivienne Jones

Appendix B *List of diatoms in the SWAP training set and their optima for pH, DOC (mg l^{-1}), and Total Al (µg l^{-1}) estimated by weighted averaging (WA) regression. (O = WA optimum, T = WA tolerance, N = number of occurrences in total data-set or the different screened training sets, Max = maximum abundance in the total data-set.)*

Taxon code	Taxon name and authority	Total data-set N	Total data-set Max	pH O	pH T	pH N	DOC O	DOC T	DOC N	Al O	Al T	Al N
AC046A	Achnanthes altaica (Poretzky) A. Cleve-Euler 1953	93	5.9	5.7	0.6	88	3.2	2.5	69	98.3	67.1	70
AC014A	Achnanthes austriaca Hust. 1922	7	3.4	4.9	0.4	7	3.5	1.3	7	120.2	36.8	6
AC9965	Achnanthes austriaca var. alpina Uaine (VJJ) 1988	3	6.3	5.8	0.3	3	0.4	0.1	3	103.3	45.3	3
AC014C	Achnanthes austriaca var. helvetica Hust. 1933	94	24.5	5.4	0.4	88	1.5	1.5	73	84.9	47.1	66
AC014B	Achnanthes austriaca var. minor L. Grannoch (RJF) 1986	30	5.5	5.1	0.4	29	2.6	2.1	25	124.0	45.6	25
AC9996	Achnanthes cf. levanderi	21	11.2	6.1	0.4	19	1.4	1.3	17	32.7	25.6	15
AC042A	Achnanthes detha	41	21.7	6.1	0.5	38	1.8	2.2	33	41.3	49.5	33
AC039A	Achnanthes didyma Hust. 1933	7	1.0	6.3	0.6	6	3.8	3.3	4	72.9	60.7	6
AC025A	Achnanthes flexella (Kutz.) Brun 1880	23	1.3	6.3	0.6	21	5.1	2.0	13	77.8	35.8	15
AC017A	Achnanthes kryophila J.B. Petersen 1924	11	3.2	6.0	0.7	10	1.5	0.4	7	63.2	40.6	4
AC001A	Achnanthes lanceolata (Breb. ex Kutz.) Grun. 1880	13	0.9	6.4	0.7	11	4.0	1.8	7	87.6	55.9	11
AC018A	Achnanthes laterostrata Hust. 1933	11	1.4	6.2	0.7	9	4.5	3.4	6	43.2	27.9	8
AC044A	Achnanthes levanderi Hust. 1933	36	12.5	5.6	0.6	34	1.5	1.2	27	79.2	57.1	27
AC002A	Achnanthes linearis (W. Sm.) Grun. in Cleve & Grun. 1880	31	4.6	6.4	0.5	26	5.0	2.0	19	102.0	49.8	22
AC022A	Achnanthes marginulata Grun. in Cleve & Grun. 1880	122	46.9	5.2	0.4	118	1.3	1.2	89	124.2	64.9	89
AC9968	Achnanthes marginulata form major Uaine (VJJ) 1988	20	40.5	5.2	0.3	20	0.7	0.5	20	138.4	76.5	16
AC013A	Achnanthes minutissima Kutz. 1833	127	46.0	6.3	0.5	118	3.4	2.2	92	70.8	50.7	94
AC9964	Achnanthes minutissima var. scotica (Carter) RJF 1988	7	1.3	6.2	0.6	6	1.9	0.6	4	49.3	15.8	5
AC019A	Achnanthes nodosa A. Cleve-Euler 1900	17	5.6	6.2	0.4	17	1.9	1.2	14	29.2	15.4	12
AC004A	Achnanthes pseudoswazi J.R. Carter 1963	31	3.4	6.1	0.5	28	2.9	1.3	18	61.4	38.3	22
AC035A	Achnanthes pusilla Grun. in Cleve & Grun. 1880	35	2.0	6.2	0.6	31	5.9	2.1	20	99.7	54.8	24
AC028A	Achnanthes saxonica Krasske in Hust. 1933	11	0.9	5.7	0.5	11	1.8	1.3	10	83.9	68.7	11
AC048A	Achnanthes scotica Jones & Flower	28	5.3	5.6	0.5	27	1.0	0.8	25	70.7	49.6	23
AC029A	Achnanthes sublaevis Hust. 1936	30	8.0	5.8	0.6	26	2.1	1.6	20	57.5	36.2	22
AC034A	Achnanthes suchlandtii Hust. 1933	12	1.7	6.3	0.4	10	1.5	1.9	7	48.7	48.1	10
AC030A	Achnanthes umara J.R. Carter 1970	11	1.2	6.1	0.5	10	3.3	1.3	5	96.6	69.2	8
AC9975	Achnanthes [altaica var. minor] L. Grannoch (RJF) 1988	31	20.7	4.9	0.3	31	2.6	2.2	28	160.3	67.7	24
AC9969	Achnanthes [scotica/marginulata] Groningen (RJF) 1988	20	3.0	6.1	0.5	19	1.9	0.9	16	53.4	42.1	18
AT001A	Actinella punctata Lewis	13	1.1	5.1	0.3	13	5.3	1.4	8	133.3	30.4	9
AM001A	Amphora ovalis (Kutz.) Kutz. 1844	4	1.4	6.2	0.5	3	2.8	1.1	4	50.5	38.7	3
AM001D	Amphora ovalis var. affinis (Kutz.) Van Heurck 1885	16	1.8	6.4	0.5	13	4.8	2.4	12	62.5	51.9	16

Taxon code	Taxon name and authority	Total data-set N	Max	pH O	T	N	DOC O	T	N	Al O	T	N
AM001B	Amphora ovalis var. pediculus (Kutz.) Van Heurck 1885	11	1.3	6.8	0.2	11	4.9	1.9	4	108.2	62.1	9
AS001A	Asterionella formosa Hassall 1850	30	18.5	6.7	0.4	27	6.2	1.3	15	107.8	45.9	23
AS003A	Asterionella ralfsii W. Sm. 1856	11	25.5	4.9	0.4	11	3.6	0.7	7	125.0	27.9	8
AU002A	Aulacoseira ambigua (Grun. in Van Heurck) Simonsen 1979	13	67.3	6.5	0.4	12	7.6	2.0	8	114.2	41.9	12
AU005A	Aulacoseira distans (Ehrenb.) Simonsen 1979	31	11.9	5.4	0.6	30	2.0	1.5	20	104.6	57.4	19
AU005L	Aulacoseira distans var. humilis (A. Cleve-Euler) R. Ross in Hartley 1986	2	3.8	6.8	0.1	2	9.1	-	1	69.4	24.7	2
AU005J	Aulacoseira distans var. laevissima (Grun.) Haworth	2	9.2	6.0	0.1	2	1.7	0.0	2	27.6	11.1	2
AU005E	Aulacoseira distans var. nivalis	50	9.6	5.0	0.5	49	2.0	1.6	38	132.8	64.0	39
AU005B	Aulacoseira distans var. nivaloides Camburn 1987	6	1.1	6.1	0.7	5	9.1	0.9	3	100.1	41.9	4
AU005D	Aulacoseira distans var. tenella (Nygaard) R. Ross in Hartley 1986	30	31.3	5.8	0.6	28	9.9	2.3	20	146.5	30.1	22
AU003D	Aulacoseira granulata (Ehrenb.) Simonsen 1979	3	2.4	7.1	0.2	2				64.6	32.3	3
AU003B	Aulacoseira granulata var. angustissima (O. Mull.) Simonsen 1979	2	2.4	7.0	0.4	2	5.4	-	1	76.7	4.9	2
AU009A	Aulacoseira islandica (O. Mull.) Simonsen 1979	2	2.7	6.5	0.2	2				137.5	18.9	2
AU009B	Aulacoseira islandica subsp. helvetica (O. Mull.) Simonsen 1979	2	1.8	5.4	0.2	2	9.3	1.4	2	144.9	16.1	2
AU001C	Aulacoseira italica var. valida (Grun. in Van Heurck) Simonsen 1979	6	2.4	5.6	0.6	6	6.7	3.1	5	107.7	50.4	5
AU004A	Aulacoseira lirata (Ehrenb.) R. Ross in Hartley 1986	52	14.9	5.2	0.7	51	3.6	2.5	33	101.8	63.6	36
AU004C	Aulacoseira lirata form biseriata	9	2.0	5.7	0.8	9	6.5	2.7	6	85.1	28.7	7
AU004D	Aulacoseira lirata var. alpigena (Grun.) Haworth	10	9.4	5.3	0.4	9	2.5	1.5	10	88.8	28.3	8
AU004B	Aulacoseira lirata var. lacustris (Grun. in Van Heurck) R. Ross 1986	21	3.4	6.0	0.7	21	4.7	3.6	16	78.7	50.9	15
AU014A	Aulacoseira nygaardii Camburn	21	3.7	5.7	0.5	21	5.1	2.6	16	100.1	42.7	19
AU010A	Aulacoseira perglabra	52	5.2	5.2	0.6	49	4.1	2.3	41	113.3	39.8	35
AU010B	Aulacoseira perglabra var. floriniae	45	10.4	5.2	0.4	42	3.6	2.4	33	113.5	36.4	33
AU022A	Aulacoseira subborealis SWAP 1989	4	12.0	6.9	0.6	4	7.2	1.2	3	81.0	15.7	4
AU023A	Aulacoseira tethera Haworth nov. sp. 1989	1	5.3	5.0	-	1	0.5	-	1	223.0		1
AU9988	Aulacoseira [cf. distans distans] SWAP 1989	13	2.8	5.0	0.3	13	3.1	1.9	9	134.4	34.9	10
AU9984	Aulacoseira [lirata alpigena (small)] SWAP Sweden (IR & NJA) 1989	10	6.8	5.6	0.5	10	8.8	1.8	7	140.2	31.3	10
AU9987	Aulacoseira [lirata alpigena/distans girdle view] SWAP 1989	13	1.8	5.6	0.4	12	6.2	4.3	9	121.9	50.3	11
AU9983	Aulacoseira [subarctica agg.] SWAP 1989	33	19.1	6.4	0.6	29	6.4	1.8	18	114.7	48.9	29
BR006A	Brachysira brebissonii R. Ross in Hartley 1986	149	9.2	5.3	0.6	143	3.0	2.1	110	112.1	57.1	103
BR003A	Brachysira serians (Breb. ex Kutz.) Round & Mann 1981	65	14.5	4.8	0.4	64	2.9	1.7	42	158.5	55.2	39
BR004A	Brachysira styriaca (Grun. in Van Heurck) R. Ross 1986	29	1.6	5.2	0.6	29	3.9	1.5	19	115.0	49.1	15
BR001A	Brachysira vitrea (Grun.) R. Ross in Hartley 1986	149	48.3	5.9	0.7	140	3.0	2.1	105	74.8	50.3	102
BR005A	Brachysira zellensis (Grun.) Round & Mann 1981	2	3.1	6.7	0.1	2	7.3	-	1	102.3	15.4	2
BR9997	Brachysira [sp. 1] Round L. Glenhead (VJJ) 1985	18	9.9	5.4	0.5	18	5.0	2.3	14	105.4	29.0	11

Taxon code	Taxon name and authority	Total data-set N	Max	pH O	pH T	pH N	DOC O	DOC T	DOC N	Al O	Al T	Al N
CA018A	Caloneis tenuis Gregory (Krammer) 1985	3	1.3	6.6	0.0	3	6.6	1.4	3	88.7	32.7	3
CO001A	Cocconeis placentula Ehrenb. 1838	13	3.3	6.7	0.3	12	5.1	1.0	5	137.5	36.5	10
CO001B	Cocconeis placentula var. euglypta (Ehrenb.) Grun. 1884	2	10.1	6.9	-	1	5.7	0.1	2	28.6	18.3	2
CC001A	Cyclostephanus dubius (Fricke in A. Schmidt) Round 1982	2	10.5	7.2	-	1				69.9	13.7	2
CY013A	Cyclotella antiqua W. Sm. 1853	1	1.8	4.5	-	1						
CY010A	Cyclotella comensis Grun. in Van Heurck 1882	32	41.5	6.7	0.3	29	4.9	1.5	21	66.0	43.3	25
CY001A	Cyclotella comta (Ehrenb.) Kutz. 1849	40	15.4	6.7	0.4	39	6.1	2.1	21	85.6	43.8	31
CY007A	Cyclotella glomerata Bachm. 1911	21	19.5	6.7	0.4	20	6.0	1.8	12	88.4	62.5	17
CY9991	Cyclotella kuetzingiana agg.	106	72.3	6.3	0.6	101	3.2	2.1	77	81.1	53.1	82
CY003A	Cyclotella meneghiniana Kutz. 1844	2	5.2	6.9	-	1	6.6	-	1	172.8	2.8	2
CY002A	Cyclotella pseudostelligera Hust. 1939	11	26.1	6.9	0.2	10	5.8	0.7	5	128.3	55.0	9
CY004A	Cyclotella stelligera (Cleve & Grun. in Cleve) Van Heurck 1882	25	7.9	6.2	0.5	24	7.0	2.3	13	91.9	43.4	19
CM014A	Cymbella aequalis W. Sm. ex Grev. 1855	51	20.6	5.1	0.3	48	1.2	1.1	40	166.5	72.7	38
CM015A	Cymbella cesatii (Rabenh.) Grun. in A. Schmidt 1881	24	4.5	6.4	0.5	23	4.1	2.2	16	43.4	23.3	16
CM015B	Cymbella cesatii var. capitata Krieger 1933	2	2.7	6.3	0.1	2	0.5	-	1	16.3	-	1
CM038A	Cymbella delicatula Kutz. 1849	8	1.5	6.3	1.0	8	5.0	1.4	4	58.6	13.9	4
CM052A	Cymbella descripta (Hust.) Krammer & Lange-Bertalot 1985	46	6.0	6.4	0.6	44	4.2	2.3	30	65.9	44.6	31
CM051A	Cymbella elginensis Krammer 1981	11	1.1	6.2	0.6	11	4.6	2.4	8	66.6	46.5	9
CM020A	Cymbella gaeumannii Meister 1934	19	2.6	5.9	0.5	19	2.5	2.5	16	97.0	61.8	13
CM017A	Cymbella hebridica (Grun. ex Cleve) Cleve 1894	109	6.6	5.1	0.5	104	2.3	1.8	78	116.2	54.6	69
CM013A	Cymbella helvetica Kutz. 1844	8	1.4	6.7	0.3	8	3.8	2.4	4	68.7	44.9	6
CM048A	Cymbella lunata W. Sm. in Grev. 1855	124	7.3	5.7	0.6	118	3.2	2.0	92	84.2	56.2	91
CM004A	Cymbella microcephala Grun. in Van Heurck 1880	58	8.8	6.3	0.7	53	3.6	2.4	44	52.0	36.1	45
CM031A	Cymbella minuta Hilse ex Rabenh. 1862	52	4.0	6.1	0.7	46	3.6	2.3	37	89.6	55.5	39
CM031C	Cymbella minuta var. silesiaca (Bleisch ex Rabenh.) Reimer 1975	6	2.5	5.3	0.3	5	1.8	1.4	6	68.2	31.0	4
CM010A	Cymbella perpusilla A. Cleve 1895	127	19.4	5.2	0.5	120	2.7	1.7	91	107.7	63.7	88
CM101B	Cymbella scotica W. Sm. 1853	7	1.4	6.7	0.6	7	6.6	1.3	7	61.6	32.6	7
CM050A	Cymbella subaequalis Grun. in Van Heurck 1880	2	1.2	7.1	0.2	2	5.9	2.5	2	37.5	0.9	2
CM9989	Cymbella [cf. deliculata] SWAP-IR 1988	6	1.3	5.1	0.4	6	4.9	1.4	4	136.2	23.0	4
CM9995	Cymbella [PIRLA sp. 1] PIRLA 1985	4	10.0	5.0	0.3	3	1.6	1.2	4	62.1	1.6	2
DE001A	Denticula tenuis Kutz. 1844	14	4.3	6.8	0.4	13	3.9	2.5	7	66.4	39.2	9
DT002A	Diatoma hyemale (Roth) Heib. 1863	8	1.5	5.8	0.4	8	1.5	0.7	7	43.0	28.1	7
DT004B	Diatoma tenue var. elongatum Lyngb. 1819	15	7.7	6.5	0.5	12	5.5	1.4	6	159.2	30.0	11
DT003A	Diatoma vulgare Bory 1824	5	2.8	6.3	0.3	5	3.6	1.1	4	52.7	50.1	3
EU013A	Eunotia arcus Ehrenb. 1837	47	1.4	5.8	0.7	44	2.4	1.6	26	104.5	61.3	32

Taxon Code	Taxon Name	Total Dataset N	Max	pH O	T	N	DOC O	T	N	Al O	T	N
EU014A	Eunotia bactriana Ehrenb. 1854	42	7.6	4.7	0.3	42	3.0	1.5	26	154.6	57.7	26
EU022A	Eunotia bigibba Kutz. 1849	4	0.4	5.3	0.4	4	2.5	0.2	2	93.0	-	1
EU049A	Eunotia curvata (Kutz.) Lagerst. 1884	60	4.9	5.5	0.6	57	3.9	1.9	40	101.9	49.5	42
EU049B	Eunotia curvata var. subarcuata (Naegeli ex Kutz.) Woodhead & Tweed 1954	34	1.8	5.3	0.5	33	3.6	2.7	21	136.6	39.9	24
EU015A	Eunotia denticulata (Breb. ex Kutz.) Rabenh. 1864	70	9.4	5.1	0.4	69	1.7	1.2	55	143.6	71.6	50
EU9969	Eunotia denticulata/lapponica 1987	5	2.9	5.0	0.1	5	0.7	0.3	5	130.2	56.7	4
EU016A	Eunotia diodon Ehrenb. 1837	20	1.2	5.3	0.5	18	3.9	2.0	14	127.7	43.4	12
EU057A	Eunotia exgracilis A. Berg ex A. Cleve-Euler 1953	38	5.6	5.3	0.5	35	1.3	0.9	27	96.7	47.1	25
EU009A	Eunotia exigua (Breb. ex Kutz.) Rabenh. 1864	126	11.0	5.1	0.5	121	2.4	1.6	93	114.2	54.3	85
EU009C	Eunotia exigua var. tridentula	10	1.3	5.1	0.4	10	5.3	2.2	4	154.5	26.7	6
EU025A	Eunotia fallax A. Cleve 1895	25	1.9	5.1	0.8	24	2.9	2.0	15	129.3	61.4	14
EU017A	Eunotia flexuosa Kutz. 1849	48	1.4	5.7	0.6	48	3.1	2.2	35	97.0	64.0	33
EU019A	Eunotia iatriaensis Foged 1970	35	1.4	5.3	0.6	33	3.6	2.4	22	109.5	41.9	24
EU047A	Eunotia incisa W. Sm. ex Greg. 1854	156	28.0	5.1	0.5	145	3.0	1.7	107	119.9	53.4	109
EU020A	Eunotia meisteri Hust. 1930	54	6.6	5.2	0.5	48	3.7	1.4	34	115.0	49.7	32
EU028A	Eunotia microcephala Krasske ex Hust. 1932	26	3.1	4.9	0.4	25	3.7	2.0	16	138.1	46.7	16
EU028B	Eunotia microcephala var. tridentata (A. Mayer) Hust.	6	1.4	4.7	0.3	6	2.7	2.1	5	117.7	49.7	5
EU056A	Eunotia minutissima A. Cleve-Euler 1934	44	2.6	5.3	0.5	43	2.2	1.7	35	117.1	64.2	34
EU048A	Eunotia naegelii Migula 1907	115	10.9	5.0	0.4	111	2.9	2.0	83	130.2	52.4	78
EU040A	Eunotia paludosa Grun. 1862	38	1.3	5.1	0.6	38	3.4	2.0	29	118.1	52.4	31
EU034A	Eunotia parallela Ehrenb. 1843	9	2.0	5.1	0.4	9	5.6	1.7	6	150.6	45.3	7
EU002A	Eunotia pectinalis (O.F. Mull.) Rabenh. 1864	79	3.2	5.5	0.7	74	3.2	2.2	57	99.4	57.6	57
EU002B	Eunotia pectinalis var. minor (Kutz.) Rabenh. 1864	134	5.2	5.4	0.6	128	3.4	1.8	94	126.7	60.5	95
EU002E	Eunotia pectinalis var. minor form impressa (Ehr.) Hust.	50	1.3	5.5	0.6	48	3.8	1.9	33	115.1	54.5	33
EU002D	Eunotia pectinalis var. undulata (Ralfs) Rabenh. 1864	7	1.1	5.4	0.4	7	2.4	0.5	6	68.9	45.2	6
EU002K	Eunotia pectinalis var. ventricosa Grun. in Van Heurck 1881	58	2.7	5.2	0.6	56	3.3	2.1	45	107.5	51.5	45
EU046C	Eunotia perpusilla Grun. in Van Heurck 1881	4	2.2	4.7	0.2	4	3.0	0.8	2	193.7	8.8	2
EU003A	Eunotia praerupta Ehrenb. 1843	22	3.7	5.4	0.7	20	2.1	2.4	14	64.6	46.5	15
EU011A	Eunotia rhomboidea Hust. 1950	92	7.0	5.1	0.5	86	3.2	1.9	64	112.3	50.2	61
EU058A	Eunotia schwabei Krasske	9	1.7	4.7	0.2	9	2.8	1.9	8	111.2	44.5	7
EU031A	Eunotia septentrionalis Ostr. 1898	7	1.2	5.5	0.6	7	8.8	-	1	113.0	-	1
EU021A	Eunotia sudetica O. Mull. 1898	23	2.5	5.6	0.5	23	2.2	1.9	17	70.0	51.9	14
EU004A	Eunotia tenella (Grun. in Van Heurck) A. Cleve 1895	104	6.9	5.2	0.5	98	3.0	1.6	76	114.4	53.5	69
EU027A	Eunotia trinacria Krasske 1929	24	6.2	4.8	0.4	22	1.9	1.8	16	84.2	52.4	14
EU039A	Eunotia triodon Ehrenb. 1837	25	2.4	5.1	0.6	24	2.2	1.3	18	146.3	61.4	15

Taxon Code	Taxon Name	Total Dataset N	Max	pH O	T	N	DOC O	T	N	Al O	T	N
EU051A	Eunotia vanheurckii Patr. 1958	78	4.0	5.1	0.6	74	3.2	1.5	58	122.5	52.7	54
EU051B	Eunotia vanheurckii var. intermedia (Krasske) Cleve	40	5.1	5.4	0.5	40	3.5	2.8	30	156.8	42.6	25
EU9962	Eunotia [exigua var. 2 (kummer.)] Cranmer Pond (RJF) 1988	5	1.4	5.5	0.5	5	2.3	0.3	4	74.9	30.1	4
EU9965	Eunotia [sp. 10 (minima)] L. Grannoch (RJF) 1988	25	4.7	4.9	0.4	24	3.6	1.6	22	136.6	50.6	15
EU9961	Eunotia [vanheurckii var. 1] Round L. Glenhead (RJF) 1988	39	2.9	5.2	0.5	38	2.4	1.3	31	118.4	58.7	28
FR006A	Fragilaria brevistriata Grun. in Van Heurck 1885	30	9.5	6.5	0.4	28	4.4	3.4	16	58.5	44.0	27
FR009F	Fragilaria capucina var. lanceolata Grun. in Van Heurck 1881	1	2.4	6.2	-	1	0.5	-	1	13.0	-	1
FR010A	Fragilaria constricta Ehrenb. 1843	21	3.3	5.4	0.4	19	5.3	2.8	14	134.4	47.8	14
FR002A	Fragilaria construens (Ehrenb.) Grun. 1862	24	8.0	6.6	0.6	21	5.9	2.9	13	96.8	41.8	20
FR002C	Fragilaria construens var. venter (Ehrenb.) Grun. in Van Heurck 1881	54	27.6	6.2	0.7	49	5.4	2.1	33	104.2	56.1	44
FR008A	Fragilaria crotonensis Kitton 1869	6	1.5	7.0	0.2	6	6.1	0.4	2	89.5	28.7	5
FR018A	Fragilaria elliptica Schum. 1867	35	34.3	6.6	0.5	30	6.2	2.0	21	64.9	51.0	29
FR011A	Fragilaria lapponica Grun. in Van Heurck 1881	4	2.2	6.0	0.4	3	2.9	3.6	2	81.7	65.9	3
FR015A	Fragilaria lata Renberg	23	9.2	5.5	0.5	23	9.1	3.8	11	164.1	23.2	11
FR001A	Fragilaria pinnata Ehrenb. 1843	43	10.4	6.3	0.6	37	4.0	2.3	23	80.8	64.4	32
FR001B	Fragilaria pinnata var. lancettula (Schum.) Hust. in A. Schmidt 1913	2	1.6	6.3	0.7	2	2.3	1.1	2	43.2	35.2	2
FR007A	Fragilaria vaucheriae (Kutz.) J.B. Petersen 1938	65	9.0	6.3	0.6	57	4.4	2.5	40	98.0	54.9	48
FR005A	Fragilaria virescens Ralfs 1843	8	0.5	5.6	0.8	7	2.7	1.8	7	117.8	71.7	6
FR005D	Fragilaria virescens var. exigua Grun. in Van Heurck 1881	122	51.1	5.7	0.5	113	3.4	2.5	87	79.2	48.7	92
FR9991	Fragilaria [cf. oldenburgiana PIRLA pl 20, 61-2] PIRLA 1987	45	27.9	4.7	0.3	45	4.7	2.0	29	187.6	54.0	27
FU002A	Frustulia rhomboides (Ehrenb.) De Toni 1891	114	11.8	5.1	0.5	109	3.4	2.3	82	133.4	54.2	77
FU002B	Frustulia rhomboides var. saxonica (Rabenh.) De Toni 1891	162	32.5	5.2	0.6	154	3.5	2.0	116	116.6	56.2	113
FU002F	Frustulia rhomboides var. viridula (Breb. ex Kutz.) Cleve 1894	99	15.1	5.3	0.5	95	4.0	2.3	71	120.0	66.0	68
GO006C	Gomphonema acuminatum var. coronatum (Ehrenb.) W. Sm. 1853	41	1.0	6.1	0.6	38	4.6	2.4	31	103.3	53.1	31
GO003A	Gomphonema angustatum (Kutz.) Rabenh. 1864	34	3.6	5.8	0.6	31	3.2	1.7	26	82.4	57.1	24
GO004A	Gomphonema gracile Ehrenb. 1838	67	4.2	5.8	0.7	62	3.1	1.9	50	85.1	49.3	51
GO013A	Gomphonema parvulum (Kutz.) Kutz. 1849	23	4.2	6.2	0.6	20	4.3	2.0	15	128.1	61.9	19
GO023A	Gomphonema truncatum Ehrenb. 1832	6	1.3	6.7	0.5	6	4.5	0.8	4	130.9	4.1	4
GO025B	Gomphonema vibrio var. intricatum (Kutz.) R. Ross in Hartley 1986	31	2.7	6.6	0.5	27	5.3	1.9	15	104.1	51.5	20
GO025F	Gomphonema vibrio var. pumilum (Grun. in Van Heurck) R. Ross 1986	2	1.8	6.6	0.5	2	5.8	-	1	138.3	-	1
GY005A	Gyrosigma acuminatum (Kutz.) Rabenh. 1853	2	1.3	7.2	-	1				38.3	13.9	2
HN001A	Hannaea arcus (Ehrenb.) Patr. in Patr. & Reimer 1966	10	1.2	6.0	0.6	9	3.8	1.0	6	108.2	51.8	6
ME019A	Melosira arentii (Kolbe) Nagumo & Kobayasi 1977	15	0.8	5.6	0.6	15	5.4	2.8	10	138.7	38.8	8
NA113A	Navicula acceptata Hust. 1950	10	3.2	6.2	0.7	10	2.7	2.0	7	54.0	51.8	8
NA037A	Navicula angusta Grun. 1860	59	5.6	5.6	0.6	56	2.6	1.6	48	77.0	51.6	42

Taxon Code	Taxon Name	Total Dataset		pH			DOC			Al		
		N	Max	O	T	N	O	T	N	O	T	N
NA038A	Navicula arvensis Hust.	15	1.1	5.2	0.6	14	4.8	2.3	9	127.4	50.2	10
NA084A	Navicula atomus (Kutz.) Grun. 1860	1	1.3	6.6	-	1	1.8	-	1	26.4	-	1
NA099A	Navicula bremensis Hust. 1957	33	2.6	5.0	0.5	31	2.0	1.7	23	119.5	53.9	19
NA045A	Navicula bryophila J.B. Petersen 1928	25	2.4	5.6	0.6	25	4.5	2.1	18	126.1	63.7	16
NA032A	Navicula cocconeiformis Greg. ex Greville 1855	75	3.1	5.7	0.6	72	2.6	1.7	57	81.1	47.1	57
NA046A	Navicula contenta Grun. in Van Heurck 1885	12	0.9	5.8	0.7	12	2.1	2.0	12	83.2	69.5	11
NA007A	Navicula cryptocephala Kutz. 1844	17	1.8	6.6	0.4	15	4.4	2.1	10	108.3	83.2	13
NA158A	Navicula cumbriensis Haworth 1987	42	4.7	4.9	0.3	41	3.3	1.6	32	125.0	44.7	31
NA115A	Navicula difficillima Hust. 1950	11	2.2	5.0	0.3	8	4.3	1.5	8	84.9	32.9	8
NA149A	Navicula digitulus Hust. 1943	17	2.2	6.0	0.6	17	1.6	1.2	15	37.5	27.9	14
NA151A	Navicula gysingensis Foged 1952	3	1.4	6.4	0.5	3	2.0	2.0	2	27.4	25.2	2
NA015A	Navicula hassiaca Krasske 1925	15	1.6	5.4	0.7	15	1.9	1.3	7	98.4	52.6	10
NA167A	Navicula hoefleri Sensu Ross et Sims	88	11.1	4.9	0.4	84	3.1	1.6	65	140.2	58.3	56
NA068A	Navicula impexa Hust. 1961	24	4.7	5.8	0.6	21	4.1	2.5	14	144.9	63.2	18
NA016A	Navicula indifferens Hust. 1942	27	1.8	5.9	0.7	25	5.4	2.3	16	143.0	71.5	19
NA101A	Navicula jaagii Meister 1934	5	1.4	6.9	0.6	4	7.1	0.5	2	57.8	50.2	2
NA002A	Navicula jaernefeltii Hust. 1942	22	1.4	5.5	0.7	22	4.5	1.2	12	120.0	47.3	15
NA044A	Navicula krasskei Hust. 1930	29	13.9	5.3	0.4	28	1.1	0.7	25	94.0	55.5	23
NA102A	Navicula laevissima Kutz. 1844	6	7.3	6.6	0.4	6	3.6	1.2	4	22.9	22.4	4
NA156A	Navicula leptostriata Jorgensen 1948	102	18.7	5.1	0.4	97	2.5	1.7	76	121.7	49.2	68
NA140A	Navicula madumensis E.G. Jorg. 1948	42	6.6	4.9	0.4	40	1.8	1.4	30	148.8	60.9	24
NA006A	Navicula mediocris Krasske 1932	110	2.3	5.4	0.6	105	2.8	2.0	75	104.8	52.8	74
NA006B	Navicula mediocris var. atomus Hust.	14	5.7	5.2	0.5	14	1.5	0.7	13	80.1	24.0	14
NA042A	Navicula minima Grun. in Van Heurck 1880	39	8.7	6.1	0.5	33	2.6	2.0	25	61.0	48.4	25
NA112D	Navicula minuscula var. muralis (Grun. in Van Heurck) Lange-Beralot 1981	7	3.3	6.4	0.3	7	2.0	1.8	5	44.2	44.9	7
NA013A	Navicula pseudoscutiformis Hust. 1930	36	2.5	6.1	0.6	31	3.5	2.2	22	62.4	50.4	26
NA014A	Navicula pupula Kutz. 1844	52	4.0	6.3	0.6	47	4.4	2.3	33	71.9	57.6	39
NA003A	Navicula radiosa Kutz. 1844	62	5.4	6.2	0.8	55	4.9	2.2	36	72.1	57.5	39
NA003B	Navicula radiosa var. tenella (Breb. ex Kutz.) Grun.ex Van Heurck 1885	71	8.4	6.1	0.7	66	3.7	2.6	50	64.7	42.1	55
NA008A	Navicula rhyncocephala Kutz. 1844	21	2.5	6.6	0.4	17	5.9	1.5	12	99.6	62.3	17
NA133A	Navicula schassmannii Hust. 1937	13	4.9	5.9	0.6	13	1.7	2.0	12	40.7	36.3	12
NA129A	Navicula seminuloides Hust. 1937	9	12.3	6.2	0.5	9	1.5	0.3	7	33.3	19.9	9
NA005A	Navicula seminulum Grun. 1860	41	2.4	6.1	0.6	38	3.4	2.7	25	88.1	59.0	34
NA005B	Navicula seminulum var. intermedia Hust.	13	1.2	6.4	0.6	12	7.1	1.6	9	128.5	36.5	10
NA048A	Navicula soehrensis Krasske 1923	13	24.5	5.1	0.2	13	3.4	2.3	8	230.6	50.3	9

Taxon Code	Taxon Name	Total Dataset N	Max	pH O	T	N	DOC O	T	N	Al O	T	N
NA170A	Navicula strenzkii Hust.	3	4.6	6.1	0.4	3	1.1	0.2	3	22.1	1.6	3
NA043A	Navicula subatomoides Hust. ex Patr. 1945	5	1.4	6.5	0.4	5	2.1	1.2	5	41.9	47.2	5
NA160A	Navicula submolesta Hust. 1949	13	1.4	5.5	0.5	13	1.3	0.8	11	74.1	33.5	12
NA114A	Navicula subrotundata Hust. 1945	2	1.3	6.5	0.2	2	1.8	-	1	26.4	-	1
NA033A	Navicula subtilissima Cleve 1891	30	2.2	5.2	0.6	28	1.5	0.8	19	116.9	66.0	17
NA086A	Navicula tantula Hust. 1943	9	5.5	6.3	0.4	7	4.2	1.8	8	42.8	29.9	7
NA135A	Navicula tenuicephala Hust. 1942	23	32.5	5.3	0.2	23	0.9	1.0	12	87.0	33.3	15
NA063A	Navicula trivialis Lange-Bertalot 1980	5	2.9	6.6	0.1	5	4.8	0.9	2	96.4	30.7	3
NA9964	Navicula [cf. spirata] L. Hir (SF) 1986	16	1.3	5.3	0.6	15	2.4	1.6	13	80.6	36.3	13
NA9955	Navicula [cf. vitiosa] L. Hir (SF) 1986	16	2.3	6.1	0.6	14	3.3	2.2	10	116.2	75.2	11
NA9919	Navicula [cumbriensis (small)] Gulspettvatn (IR) 1988	11	2.7	6.0	0.7	11	6.5	1.1	7	114.7	37.6	9
NA9963	Navicula [sp. 1] L. Hir (SF) 1986	29	7.1	5.6	0.5	27	2.0	1.2	21	62.2	30.0	21
NA9904	Navicula [sp. a Merilainen 1969: fig. 143] SWAP Sweden (IR & NJA) 1989	10	1.6	6.1	0.5	9	7.2	1.6	5	105.7	44.2	8
NE003A	Neidium affine (Ehrenb.) Pfitz. 1871	47	2.2	5.3	0.6	45	3.5	1.8	35	119.4	76.7	34
NE003C	Neidium affine var. amphirhynchus (Ehrenb.) Cleve 1894	17	2.6	5.7	0.5	17	4.9	2.5	11	120.4	33.6	11
NE003B	Neidium affine var. longiceps (Greg.) Cleve 1896	20	2.4	5.0	0.4	18	3.1	2.3	15	152.7	83.0	15
NE004A	Neidium bisulcatum (Lagerst.) Cleve 1894	58	2.6	5.1	0.6	57	2.7	1.7	45	128.1	54.7	44
NE012A	Neidium glaberrimum (Ostr.) R. Ross in Hartley 1986	6	1.9	5.5	0.4	6	0.8	1.3	5	83.9	52.8	5
NE020A	Neidium hercynicum A. Mayer 1917	5	2.1	5.5	0.4	4	1.3	0.8	5	64.4	46.1	5
NE023A	Neidium inconspicuum Hust. 1921	8	1.1	5.7	0.7	7	1.4	0.9	8	58.3	43.9	6
NI021A	Nitzschia acula Hantzsch ex Cleve & Grun. 1880	14	1.7	5.9	0.6	14	5.1	2.3	10	90.0	48.5	10
NI002A	Nitzschia fonticola Grun. in Van Heurck 1881	49	4.9	6.3	0.6	43	3.6	2.3	36	59.4	45.4	39
NI008A	Nitzschia frustulum (Kutz.) Grun. in Cleve & Grun. 1880	23	1.4	6.4	0.4	19	3.1	2.1	18	72.9	54.0	20
NI017A	Nitzschia gracilis Hantzsch 1860	30	2.2	5.9	0.5	28	5.1	2.0	17	107.0	42.4	20
NI027A	Nitzschia microcephala Grun. in Cleve & Grun. 1880	7	8.5	6.5	0.2	7	2.2	1.0	4	35.5	30.2	7
NI009A	Nitzschia palea (Kutz.) W. Sm. 1856	34	2.3	6.2	0.6	30	4.3	2.3	22	79.2	50.4	24
NI009B	Nitzschia palea var. tenuirostris Grun. in Van Heurck 1881	9	2.8	6.2	0.4	9	3.2	1.6	9	64.5	44.7	8
NI005A	Nitzschia perminuta (Grun. in Van Heurck) M. Perag. 1903	73	5.6	5.7	0.5	71	2.8	1.9	55	68.1	37.5	55
NI152A	Nitzschia pusilla Grun. 1862	7	2.7	5.8	0.6	6	2.0	1.3	7	40.9	36.4	6
NI026A	Nitzschia romana Grun. in Van Heurck 1881	12	14.9	6.3	0.5	11	3.8	1.6	7	152.3	21.7	4
NI9984	Nitzschia [cf. gracilis] SWAP Sweden (IR & NJA) 1989	1	3.5	7.3	-	1	7.3	-	1	38.0	-	1
OP001A	Opephora martyi Herib. 1902	6	1.8	6.5	0.5	6	2.2	1.9	3	110.1	40.4	6
PE002A	Peronia fibula (Breb. ex Kutz.) R. Ross 1956	135	9.7	5.3	0.5	128	2.3	1.6	96	112.7	59.6	91
PI015A	Pinnularia abaujensis (Pant.) R. Ross in Hartley 1986	69	3.7	5.6	0.8	67	3.4	1.9	44	91.6	57.7	49
PI014A	Pinnularia appendiculata (Ag.) Cleve 1896	9	2.8	5.8	0.6	8	2.6	1.3	8	76.5	62.5	71

Taxon Code	Taxon Name	Total Dataset N	Max	pH O	T	N	DOC O	T	N	Al O	T	N
PI055A	Pinnularia balfouriana Grun. ex Cleve 1896	1	1.4	6.6	-	1	1.4	-	1	20.0	-	1
PI018A	Pinnularia biceps Greg. 1856	95	4.7	5.2	0.6	93	2.7	2.2	66	122.9	60.0	65
PI018B	Pinnularia biceps form petersenii R. Ross 1947	9	2.0	5.3	0.5	9	1.7	1.5	8	99.5	69.1	8
PI016A	Pinnularia divergentissima (Grun.in Van Heurck) Cleve 1896	9	1.6	5.9	0.5	7	2.6	1.9	7	44.1	31.9	4
PI023A	Pinnularia irrorata (Grun. in Van Heurck) Hust. 1939	47	3.0	5.4	0.7	43	4.4	1.7	28	136.8	69.3	32
PI005A	Pinnularia major (Kutz.) W. Sm. 1853	22	2.2	5.3	0.5	21	4.7	2.2	14	134.3	55.9	16
PI011A	Pinnularia microstauron (Ehrenb.) Cleve 1891	81	3.7	5.4	0.6	80	2.8	2.4	59	100.3	49.5	56
PI139A	Pinnularia obscura Krasske 1932	1	1.2	5.5	-	1	0.7	-	1	37.9	-	1
PI056A	Pinnularia rupestris Hantzsch in Rabenh. 1861	21	3.4	4.9	0.5	21	4.7	2.2	8	120.8	20.7	9
PI022B	Pinnularia subcapitata var. hilseana (Janisch ex Rabenh.) O. Mull. 1898	73	9.4	5.0	0.5	69	3.1	2.1	54	115.4	53.9	50
PI164A	Pinnularia termitina (Ehrenb.) Patr. in Patr. & Reimer 1966	8	3.4	5.5	0.7	8	2.2	1.1	7	74.0	45.1	6
PI007A	Pinnularia viridis (Nitzsch) Ehrenb. 1843	41	1.4	5.5	0.7	37	4.0	2.5	30	107.7	63.5	30
RH006B	Rhopalodia operculata (Ag.) Hakansson 1979	2	1.4	6.3	0.7	2	2.3	1.7	2	50.1	59.7	2
SE001A	Semiorbis hemicyclus (Ehrenb.) Patr. in Patr. & Reimer 1966	42	24.8	4.8	0.3	42	3.4	1.4	25	177.2	43.1	24
SA001A	Stauroneis anceps Ehrenb. 1843	51	2.1	5.6	0.6	47	3.0	2.0	34	82.5	56.3	36
SA001B	Stauroneis anceps form gracilis Rabenh. 1864	62	1.8	5.9	0.6	58	2.6	1.8	44	67.9	51.3	45
SA042A	Stauroneis gracillima Hust. 1943	16	1.3	5.1	0.5	14	3.1	1.5	16	118.0	63.1	14
SA006A	Stauroneis phoenicenteron (Nitzsch) Ehrenb. 1943	27	1.8	5.9	0.8	24	3.6	2.1	18	100.6	85.0	18
SP002A	Stenopterobia sigmatella (Greg.) R. Ross in Hartley 1986	56	2.8	5.3	0.7	53	3.8	2.3	37	156.3	56.0	38
ST004A	Stephanodiscus minutula (Kutz.) Round	5	2.1	6.9	0.2	4	6.6	1.5	2	108.0	40.2	5
ST010A	Stephanodiscus parvus Stoermer & Hakansson 1984	1	8.6	7.1	-	1	4.6	-	1	133.3	-	1
SU004A	Surirella biseriata Breb. & Godey 1835	21	4.0	5.3	0.4	21	0.8	0.7	20	125.1	48.7	18
SU006A	Surirella delicatissima Lewis 1864	84	8.2	5.0	0.4	81	2.7	2.1	62	129.9	63.2	60
SU005A	Surirella linearis W. Sm. 1853	40	3.6	5.3	0.6	39	4.2	2.2	29	131.9	50.6	28
SU002A	Surirella ovata Kutz. 1844	2	1.0	5.5	-	1	0.7	-	1	37.2	1.7	2
SY003A	Synedra acus Kutz. 1844	27	3.5	6.4	0.5	24	6.0	1.8	16	89.1	52.9	23
SY043A	Synedra famelica Kutz. 1844	2	2.8	5.9	0.3	2	4.8	0.3	2	107.6	-	1
SY010A	Synedra minuscula Grun. in Van Heurck 1881	29	3.6	6.0	0.6	26	3.7	1.5	23	117.3	70.8	23
SY009A	Synedra nana Meister 1912	5	2.7	6.2	0.7	5	5.8	0.5	4	80.8	62.6	3
SY004A	Synedra parasitica (W. Sm.) Hust. 1930	9	1.4	6.7	0.4	8	4.2	1.9	4	51.6	40.0	9
SY002A	Synedra rumpens Kutz. 1844	20	2.6	6.4	0.6	18	4.5	1.8	12	80.6	30.0	14
SY013A	Synedra tenera W. Sm. 1856	26	4.3	6.6	0.7	24	6.0	1.3	12	113.5	43.3	17
TA003A	Tabellaria binalis (Ehrenb.) Grun. in Van Heurck 1881	63	51.5	4.7	0.3	60	2.6	1.7	43	171.3	50.5	41
TA002A	Tabellaria fenestrata (Lyngb.) Kutz. 1844	18	1.0	5.9	0.7	18	4.0	2.1	15	110.6	54.9	13
TA001A	Tabellaria flocculosa (Roth) Kutz. 1844	171	28.3	5.4	0.6	161	3.4	1.9	118	106.0	51.1	122

Taxon Code	Taxon Name	Total Dataset		pH			DOC			Al		
		N	Max	O	T	N	O	T	N	O	T	N
TA9996	Tabellaria flocculosa agg.	44	24.5	6.1	0.7	43	5.6	2.2	28	108.7	41.5	32
TA004A	Tabellaria quadriseptata Knudson 1952	89	47.8	4.9	0.3	87	2.7	1.4	66	119.3	45.0	58