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Integrated Classification and Assessment of Lakes in Wales: Phase IV. A Report to the Countryside Council for Wales: Contract No. FC 73-01-71

Editor: D.T. Monteith

December 1997

Environmental Change Research Centre
University College London
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Integrated Classification and Assessment of Lakes in Wales: Phase IV - Final Report

Editor: D.T.Monteith

CCW Science Report No. 214

Environmental Change Research Centre
University College London
26 Bedford Way, London WC1H 0AP

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Executive Summary

1 This is the final report to the Countryside Council for Wales under contract FC 73-01-71: 'Integrated Classification and Assessment of Lakes in Wales: Phase IV' and follows the format adopted in Phase I (Allott *et al.* 1994).

2 Data are presented for the ten lakes surveyed in this phase of the study, all of which occur in North Wales. These are Hanmer Mere, Llyn Tegid, Llyn Alwen. Llyn Glasfryn, Llyn Rhos Ddu, Llynnau Mymbyr, Gloyw Lyn, Llyn yr Wyth Eidion, Llyn Cau and Llyn Llagi.

3 The field survey and analytical methodology incorporates the characterisation of the lake-water chemistry and the following biological groups: epilithic diatoms, surface sediment diatom assemblages, aquatic macrophytes, littoral zooplankton, open water zooplankton and littoral macroinvertebrates. Previously collected data on the study lakes is referred to.

4 All data collected during this study are stored in a relational database at the Environmental Change Research Centre. The database allows flexible data retrieval, suitable for both this research programme and other potential uses and users.

5 The survey data are used to classify the lake systems according to existing, commonly employed schemes.

6 The report completes the data-set for 31 Welsh lakes surveyed during Phases I - IV of the Integrated Classification and Assessment of Lakes in Wales project. The data are now being applied to the development and evaluation of methods for the integrated classification of Welsh lakes.

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1 Introduction

This report presents data for the fourth phase of the study on the integrated classification and assessment of lakes in Wales. The classification and assessment project is described in detail by Allott *et al.* (1994).

Ten lakes in North Wales have been assessed over the period 1996 - 1997. The report includes data on water chemistry and physical variables, aquatic macrophyte species lists and distribution maps, epilithic diatoms, surface sediment diatoms, open water zooplankton, littoral zooplankton and littoral macroinvertebrates. Methodologies follow those described by Allott *et al.* (1994).

In addition the data have been used to place the lakes into existing schemes discussed in the Phase I report. The project database is now complete, encompassing 31 lakes across Wales, and work is ongoing to apply it to the development and evaluation of integrated classification techniques.

Figure 1.1 The location of sites in the CCW classification and assessment project

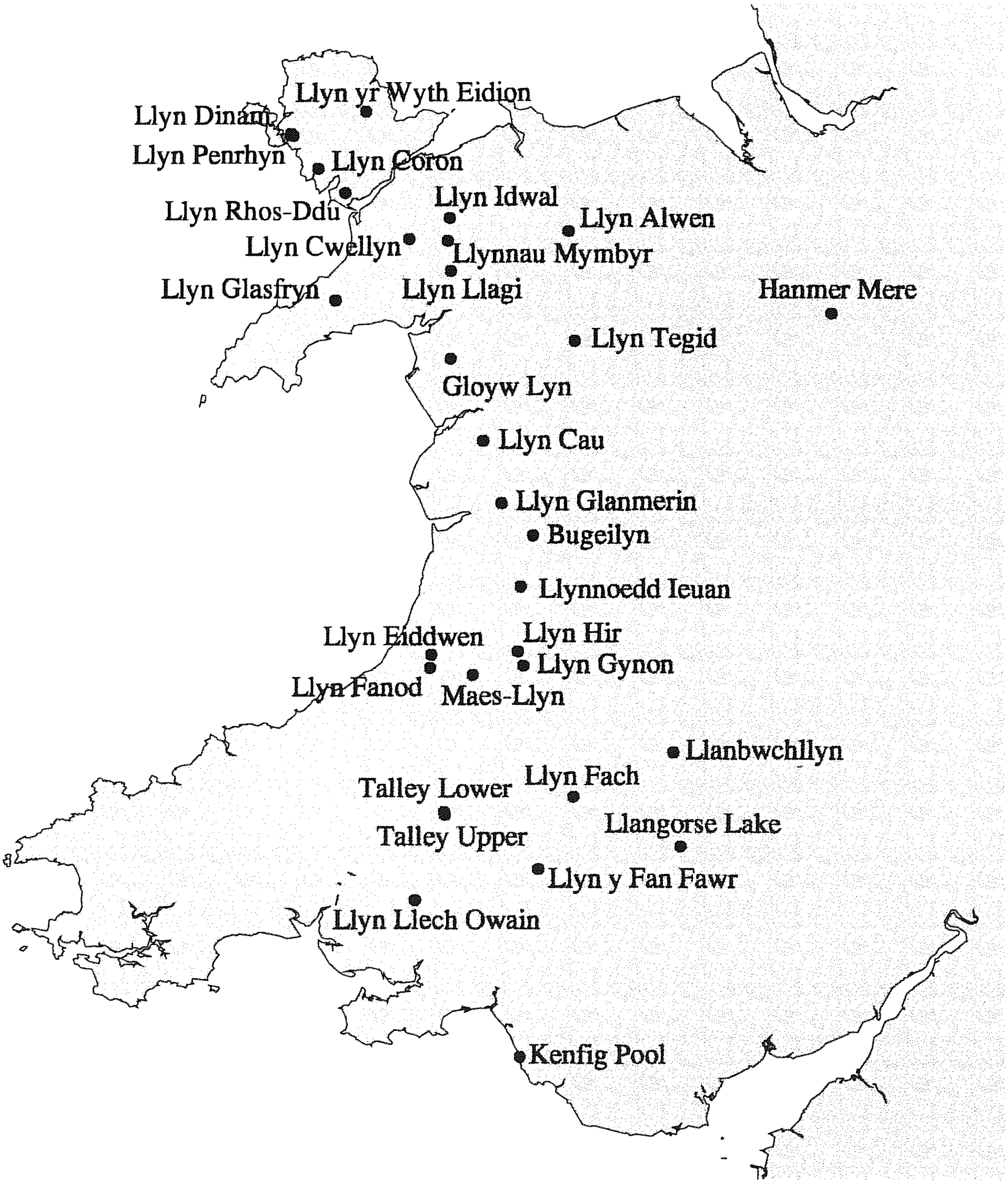


Table 1.1 Summary of physical parameters of the 31 lakes

Site name	Grid reference	Lake altitude (m)	Lake area (ha)	Lake catchment area (ha)	Lake maximum depth (m)	Lake mean depth (m)	Approximate lake volume (10^3 m^3)
Llyn Idwal	SH 646595	370	14	319	13.0	3.4	480
Llyn Cwellyn	SH 560550	150	85	2073	36.0	22.6	19000
Llyn Coron	SH 378700	10	26	1743	2.8	1.8	470
Llyn Dinam	SH 311775	4	9	657	1.8	1.4	130
Llyn Penrhyn	SH 315770	4	19	62	3.0	2.2	420
Bugeilyn	SN 822923	455	9	143	2.1	1.9	171
Llyn Eiddwen	SN 605670	305	10	45	7.2	2.6	260
Llyn Fanod	SN 603643	310	5	40	8.7	3.8	190
Llyn Glanmerin	SN 755991	195	3	36	3.1	2.5	48
Llyn Gynon	SN 800647	425	25	225	11.0	2.1	525
Llyn Hir	SN 789677	435	5	22	8.8	2.8	140
West Ieuan	SN 795815	525	4	12	8.7	3.9	156
Maes-Llyn	SN 693628	180	3	59	5.5	2.7	81
Upper Talley Lake	SN 632337	105	5	37	4.2	1.9	95
Lower Talley Lake	SN 633332	105	10	166	4.3	1.9	190
Kenfig Pool	SS 790820	10	23	----	2.6	1.8	414
Llyn Llech Owain	SN 569151	240	6	32	1.7	1.2	67
Llyn Fach	SN 905370	455	3	46	5.0	1.7	54
Llanbwchllyn	SO 118464	300	10	260	8.0	3.0	303
Llangorse Lake	SO 132265	155	139	2091	7.5	2.0	2780
Llyn y Fan Fawr	SN 831217	610	17	49	20.0	6.0	1020
Hanmer Mere	SJ453392	75	17	108	5.7	3.0	510
Llyn Tegid	SH910335	160	414	26200	43.0	24.0	85000
Llyn Alwen	SH898567	380	26	130	13.5	6.0	1560
Llyn Glasfryn	SH404422	130	6	19	1.3	0.7	42
Llyn Rhos-Ddu	SH425648	5	2	40	1.1	0.6	12
Llyn Mymbyr	SH708574	180	35	2470	7.8	4.5	1575
Gloyw Lyn	SH647298	380	3	63	7.2	3.0	90
Llyn yr Wyth Eidion	SH470820	64	1.2	----	9.0	6.0	72
Llyn Cau	SH715124	470	14	99	47.0	21.0	2940
Llyn Llagi	SH649483	380	63	163	16.5	5.8	330
RANGE		4 - 610	2 - 414	12 - 26200	1.1 - 47.0	0.6 - 24.0	12 - 85000

Table 1.2 Summary of mean water chemistry of the 31 lakes (continued overleaf)

Determinand		mean for site														
		Idwal	Cwellyn	Coron	Dinam	Penrhyn	Bugeilyn	Eiddwen	Fanod	Glanmerin	Gynon	Hir	Ieuan	Maes-	U.Talley	L.Talley
lab pH		6.72	6.35	8.61	7.84	8.07	5.17	6.55	6.71	6.50	5.43	5.57	4.92	7.31	6.99	6.81
Alkalinity 1**	$\mu eq\ l^{-1}$	70	37	1869	1533	2153	7	89	108	97	13	14	-9	527	448	343
Alkalinity 2**	$\mu eq\ l^{-1}$	61	29	1878	1552	2178	2	83	103	91	4	5	-11	528	449	342
lab Conductivity	$\mu S\ cm^{-1}$	28	36	322	335	442	31	57	56	66	33	35	35	109	100	93
Sodium	$\mu eq\ l^{-1}$	109	175	1050	1341	1846	149	280	240	315	162	171	154	276	335	315
Potassium	$\mu eq\ l^{-1}$	4	7	70	65	134	6	16	15	7	6	6	5	24	21	27
Magnesium	$\mu eq\ l^{-1}$	34	46	634	567	524	58	119	123	133	70	65	50	254	177	186
Calcium	$\mu eq\ l^{-1}$	101	89	1988	1516	2202	58	160	187	181	63	74	45	623	495	411
Chloride	$\mu eq\ l^{-1}$	105	192	957	1497	1824	144	299	257	332	162	182	163	282	353	342
Aluminium total monomeric	$\mu g\ l^{-1}$	2	4	7	1	1	81	5	7	18	23	25	80	5	5	8
Aluminium non-labile	$\mu g\ l^{-1}$	2	3	3	1	1	59	5	7	18	16	18	24	3	4	6
Aluminium labile	$\mu g\ l^{-1}$	0	2	4	0	0	22	0	0	0	7	7.3	56	2	1	2
Absorbance	(250nm)	0.027	0.038	0.262	0.378	0.242	0.326	0.245	0.295	0.128	0.187	0.099	0.070	0.170	0.118	0.157
Carbon total organic	$mg\ l^{-1}$	1.1	1.3	6.8	10.3	8.8	4.9	5.5	6.1	6.4	4.0	3.1	2.2	4.5	3.4	3.7
Phosphorus total	$\mu gP\ l^{-1}$	5.3	7.1	156.1	111.9	1085	18.0	20.5	18.1	14.7	7.7	6.8	5.0	52.6	51	69
Phosphorus total soluble	$\mu gP\ l^{-1}$	4.2	4.7	99.4	87.1	1038	11.9	10.9	11.1	7.8	5.5	4.9	2.7	18.4	27.3	26.0
Phosphorus soluble reactive	$\mu gP\ l^{-1}$	2.4	4.7	73.8	65.3	1016	6.8	4.2	3.1	1.8	2.4	1.3	0.7	5.9	10.4	12.2
Nitrate	$\mu gN\ l^{-1}$	112	170	700	68	142	61	54	151	151	65	63	77	508	256	291
Silica soluble reactive	$mg\ l^{-1}$	0.84	1.36	7.79	2.99	2.22	1.94	1.56	2.58	1.65	0.96	0.48	0.70	2.47	2.50	3.50
Chlorophyll *a*	$\mu g\ l^{-1}$	1.1	1.9	21.2	7.8	4.3	3.1	8.4	2.9	2.9	1.7	1.7	0.8	23.1	10.5	24.6
Sulphate	$\mu eq\ l^{-1}$	64	80	393	256	449	63	93	90	127	67	77	75	165	133	142
Copper total soluble	$\mu g\ l^{-1}$	<1*	<1*	<1*	<1*	<1*	39	<1	<1	<1	10	1.8	<1	5	4	<1
Iron total soluble	$\mu g\ l^{-1}$	3*	23*	279*	237*	151*	621	91	238	315	189	66	57	277	192	183
Lead total soluble	$\mu g\ l^{-1}$	<1*	<1*	<1*	<1*	<1*	3	<1	<1	2	2	3	2	4	3	3
Manganese total soluble	$\mu g\ l^{-1}$	1*	12*	53*	161*	174*	39	10	82	51	28	46	91	11	102	1
Zinc total soluble	$\mu g\ l^{-1}$	<5*	21*	<5^{8}	<5*	<5*	10	5	4	38	3	10	8	4	4	4

* = one sample (March 1993) only ** Alkalinity 1 = standard titration to 5.0 Alkalinity 2 = Gran titration

Table 1.2 (continued) Summary of mean water chemistry of the 31 lakes

Determinand		mean for site																
		Kenfig	Owain	Fach	Bwch	Llangorse	Fawr	Hanmer	Tegid	Alwen	Glasfryn	RhosD	Mymbyr	Gloyw	Eidion	Cau	Llagi	Range
lab pH		7.90	4.95	6.28	7.51	8.00	6.56	7.50	6.36	4.74	6.74	8.24	5.49	5.86	7.93	5.84	5.36	4.74 - 8.61
Alkalinity 1**	$\mu eq\ l^{-1}$	2079	-8	99	1391	2446	86	1440	75	-19	439	2483	25	25	3997	17	na	-19 - 3997
Alkalinity 2**	$\mu eq\ l^{-1}$	2106	-8	92	1404	2476	78	1708	68	-20	442	2514	19	15	4056	7	3	-20 - 4056
lab Conductivity	$\mu S\ cm^{-1}$	345	78	63	217	312	37	358	57	52	129	395	34	44	585	32	25	25 - 585
Sodium	$\mu eq\ l^{-1}$	964	331	189	271	392	129	1105	224	227	488	1063	160	217	712	143	157	109 - 1846
Potassium	$\mu eq\ l^{-1}$	56	10	16	30	54	5	329	17	13	49	46	7	7	40	6	4	4 - 329
Magnesium	$\mu eq\ l^{-1}$	387	84	210	259	474	40	768	92	89	210	688	48	75	389	61	47	34 - 768
Calcium	$\mu eq\ l^{-1}$	2279	183	159	1837	2646	168	1506	191	59	469	2472	87	88	5824	86	53	45 - 5824
Chloride	$\mu eq\ l^{-1}$	1058	387	209	319	485	145	1329	254	247	618	1239	167	232	954	148	177	105 - 1823
Aluminium total monomeric	$\mu g\ l^{-1}$	6	78	27	6	3	4	4	17	56	10	15	11	21	6	4	67	1 - 81
Aluminium non-labile	$\mu g\ l^{-1}$	5	57	20	2	3	3	4	14	27	6	4	7	14	4	4	45	1 - 59
Aluminium labile	$\mu g\ l^{-1}$	1	21	7	4	1	1	<0.5	4	29	4	11	3	7	2	0	22	0 - 56
Absorbance	(250nm)	0.125	0.447	0.052	0.147	0.135	0.046	0.340	0.158	0.173	0.184	0.242	0.056	0.075	0.296	0.017	na	0.017 - 0.447
Carbon total organic	$mg\ l^{-1}$	6.1	8.5	2.7	4.6	5.1	2.01	14.6	4.2	3.9	13.3	8.7	2.1	2.8	8.2	0.8	2.5	0.8 - 14.6
Phosphorus total	$\mu gP\ l^{-1}$	31.8	48.0	9.5	35.6	117.8	10.8	1806	13	16	146	42	5	5	17	3.5	3	3 - 1806
Phosphorus total soluble	$\mu gP\ l^{-1}$	13.8	13.8	4.1	16.5	77.8	4.7	1628	8	7	43	15	3	3	9	2	na	3 - 1628
Phosphorus soluble reactive	$\mu gP\ l^{-1}$	5.8	10.4	2.4	5.1	58.0	3.4	1579	5	5	14	7	2	2	4	1	na	1 - 1579
Nitrate	$\mu gN\ l^{-1}$	86	99	116	859	602	86	231	453	132	47	37	46	30	1937	190	103	30 - 1937
Silica soluble reactive	$mg\ l^{-1}$	0.69	2.20	1.96	8.13	3.17	0.20	3.2	1.3	1.5	0.9	4.9	0.8	0.7	3.4	1.3	0.2	0.2 - 8.1
Chlorophyll *a*	$\mu g\ l^{-1}$	13.5	38.1	8.9	15.3	14.5	3.7	3.9	7.2	2.9	101.3	12.5	1.5	2.1	4.1	0.9	5.3	0.8 - 101.3
Sulphate	$\mu eq\ l^{-1}$	222	185	209	341	234	71.8	275	105	100	63	194	61	88	1007	71	62	61 - 1007
Copper total soluble	$\mu g\ l^{-1}$	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0 - 39
Iron total soluble	$\mu g\ l^{-1}$	45	241	26	19	12.5	18.5	65	63	453	863	333	30	70	88	18	74	3 - 863
Lead total soluble	$\mu g\ l^{-1}$	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	na	0 - 4
Manganese total soluble	$\mu g\ l^{-1}$	10	37	21	3	20.5	5	20	6	198	421	96	22	11	34	3	43	0 - 421
Zinc total soluble	$\mu g\ l^{-1}$	0	14	6	<1	0	5	0	2	3	0	1	5	0	1	1	0	0 - 38

** Alkalinity 1 = standard titration to 5.0 Alkalinity 2 = Gran titration na = no data available

2 Site Descriptions

2.1 Hanmer Mere

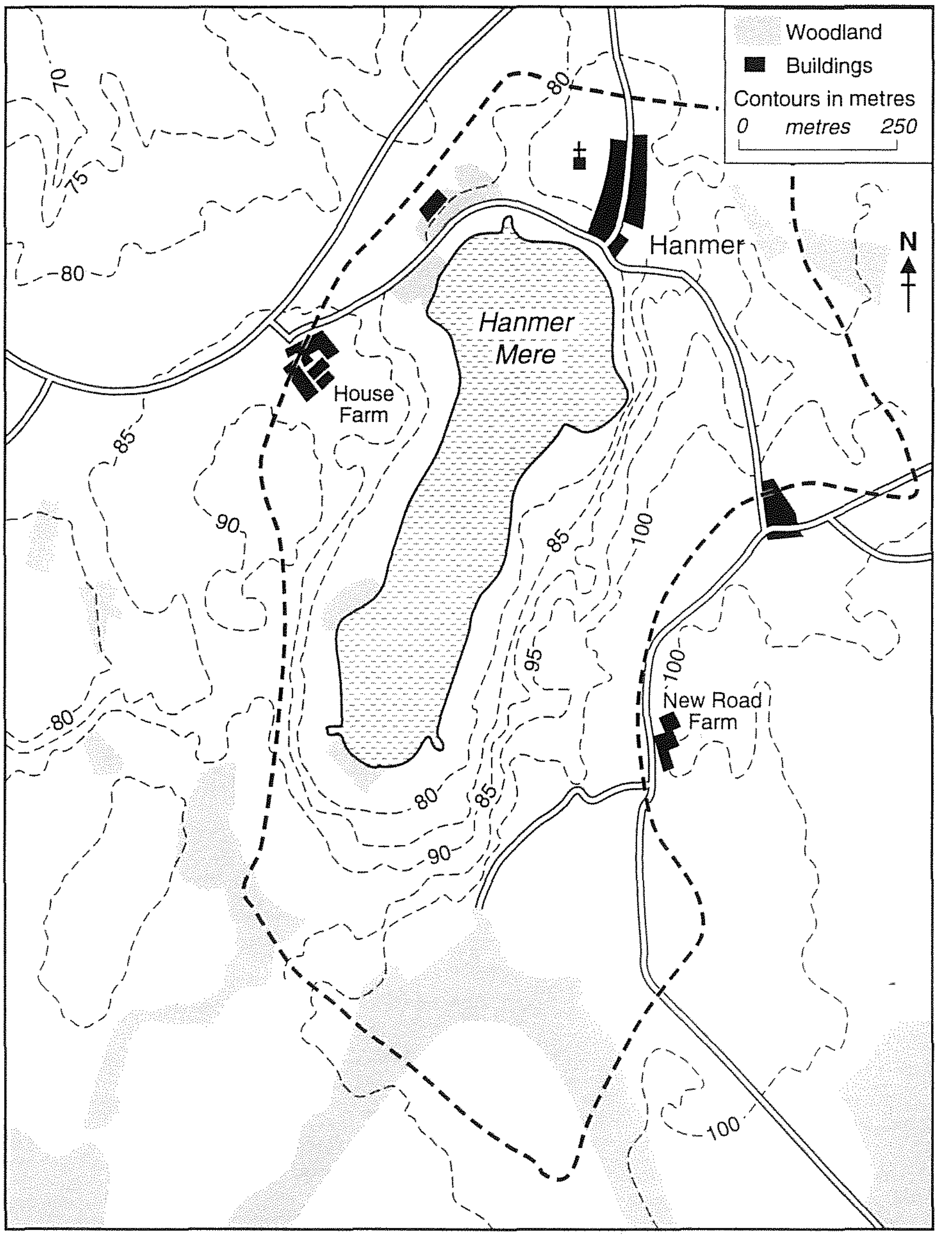
Hanmer Mere is an elongate lake, flanked by woodland to the east and west, and Hanmer village to the north, 10 km south-west of Whitchurch in Cheshire. Together with the major part of its catchment it forms the Hanmer Mere SSSI. The Mere lies in a shallow valley in the low Keuper Saliferous beds which are overlain by boulder clay. The catchment soils are typical stagnogleys of the Salop association, a type common in the Midlands and north of England and characteristically slowly permeable during the summer and prone to waterlogging in winter. The hydrological catchment boundary to the north of the lake is difficult to define as the nature and extent of urban drainage from the village is unclear, although it is believed that the lake received some overflow from a septic tank serving bungalows at the north-eastern end of the site before 1994.

Like many of the nearby Cheshire Meres, the water chemistry of Hanmer Mere exhibits high ionic concentrations, which are at least in part due to the occurrence of phosphate rich minerals in the underlying drift (Reynolds, 1977). In addition, the area receives particularly low rainfall, a large percentage of which is lost to evaporation, thus resulting in a very long residence time. Meteorological observations by Gorham (1957) suggested the precipitation to evaporation ratio for nearby Shrewsbury to be approximately 1.4. There are no permanent inflows to the Mere but it overspills at the north end.

Table 2.1 Hanmer Mere: site characteristics

Grid reference	SJ 453392
Lake altitude	75 m
Maximum depth	5.7 m
Mean depth	3.0 m
Volume	510000 x 10^3 m^3
Lake area (including lake)	17 ha
Shoreline development index	1.7
Estimated hydraulic residence time	1263 days
Catchment area	108 ha
Catchment:lake ratio	6.4
Net relief	25 m
Mean annual rainfall	641 mm
Total S deposition	0.84 keq H^+ ha^{-1} yr
Total N deposition	1.16 keq H^+ ha^{-1} yr

Figure 2.1 Catchment of Hanmer Mere



2.2 Llyn Tegid (Lake Bala)

With a surface area of 414 ha and a maximum depth of 42 m, Llyn Tegid is the largest lake in Wales, by area and volume. It lies in a glacial trough on a fault line of Ordivician acidic sandstones and shales, 35 km inland from Barmouth in North Wales. The extensive hydrological catchment covers a large range of altitude (>500m), soil types and geology and encompasses a small area of limestone. Soils in the catchments of the main tributary rivers to the south and west are dominated by Cambic stagnogley soils of the Cegin series which are derived from drift from Palaeozoic slaty mudstones and are slowly permeable and seasonally waterlogged. Upland areas to the south-east of the lake are largely covered by ferric stagnopodzols of the Hafren series which are derived from a similar substrate but are loamy permeable with a wet peaty surface horizon, and often have a thin iron-pan. Much of the lower ground flanking the two long sides of the lake consists of typical brown podzols of the Manod series which are well drained fine loamy or silty soils over rocks.

Llyn Tegid is fed by numerous inflows, but the most extensive sub-catchments lie to the south and west, of which the Afon Twrch and the Afon Lliw are the most important. The catchment of the Afon Twrch includes the small upland lake Llyn Lliwbran. Llyn Tegid is drained at its north end by the Afon Dyfrdwy (River Dee).

Llyn Tegid has been hydrologically managed since 1955 as part of the River Dee regulation scheme. Sluice gates 1 km downstream from the lake, at the confluence of the Afon Dyfrdwy and Afon Tryweryn, are used at times to divert water from the latter into Llyn Tegid, potentially increasing its volume by 18×10^6 m^3. This effectively increases the catchment area of the Llyn Tegid at these times to 260 km^2. It is thought that the scheme may have been responsible for a decline in the Brown Trout population in the lake, due to a restriction in spawning locations. More recently there has been concern over possible nutrient enrichment of the lake and the first observation of a blue-green algal bloom was made in the summer of 1995. A palaeoecological study by the Environmental Change Research Centre has indicated a significant rise in the lake total phosphorus concentration over the last one to two decades (Bennion *et al.*, 1997).

Llyn Tegid is of great conservation importance, not least because it is home to an endemic fish sub-species, the Gwyniad (*Coregonus lavaretus*), and because it is one of the few lakes in Wales where the Floating Water Plantain (*Luronium natans*) has been frequently recorded. Records for the latter species extend back to the early 1800's. Eight species of gastropod, including the rare glutinous snail, *Myxas glutinosa* have also been found in the lake. The lake was designated as an SSSI in the early 1970's and was included in the Nature Conservation Review (Ratcliffe, 1977). More recently its international importance was recognised by its designation as a RAMSAR site.

Figure 2.2 Catchment of Llyn Tegid

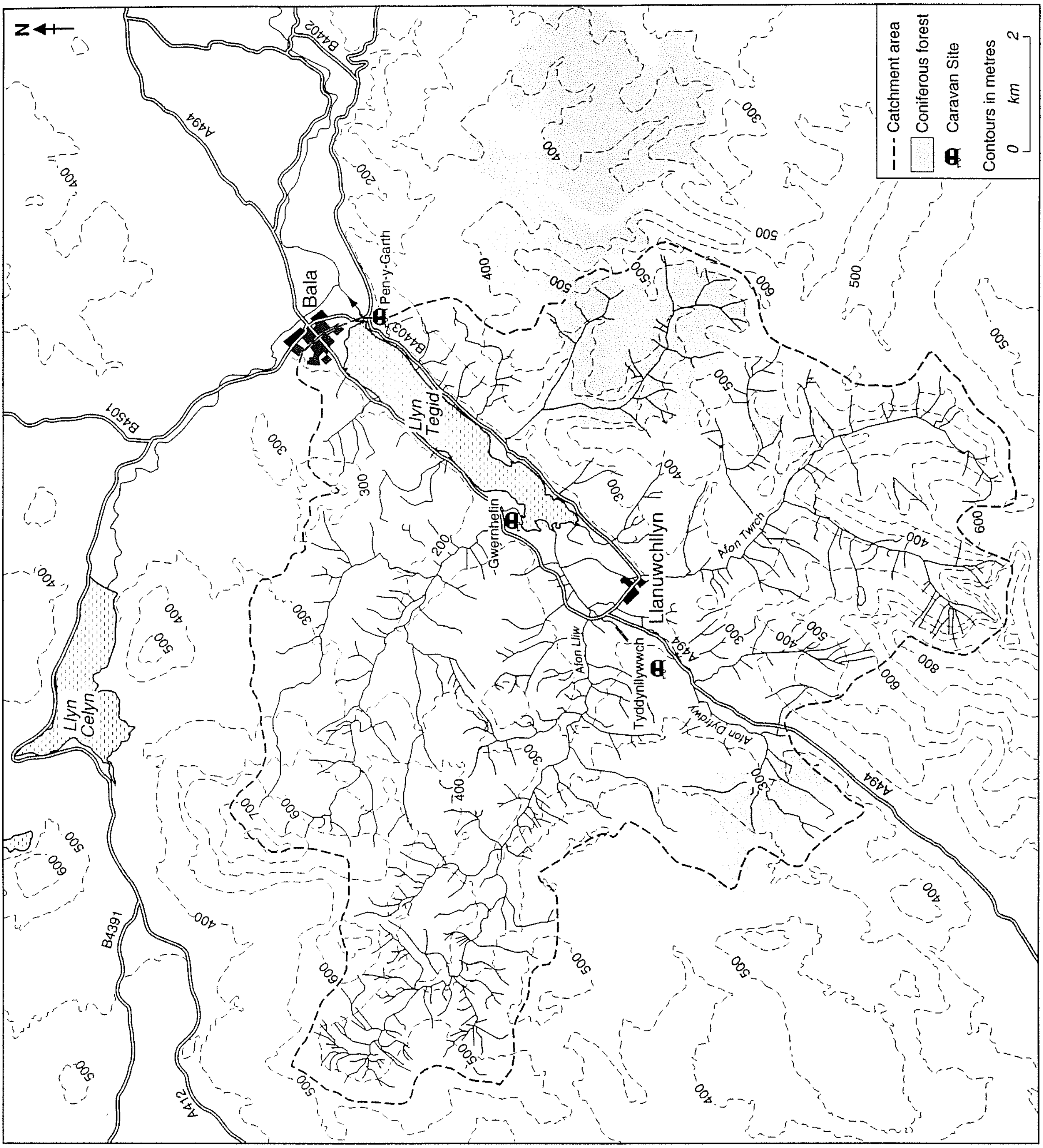


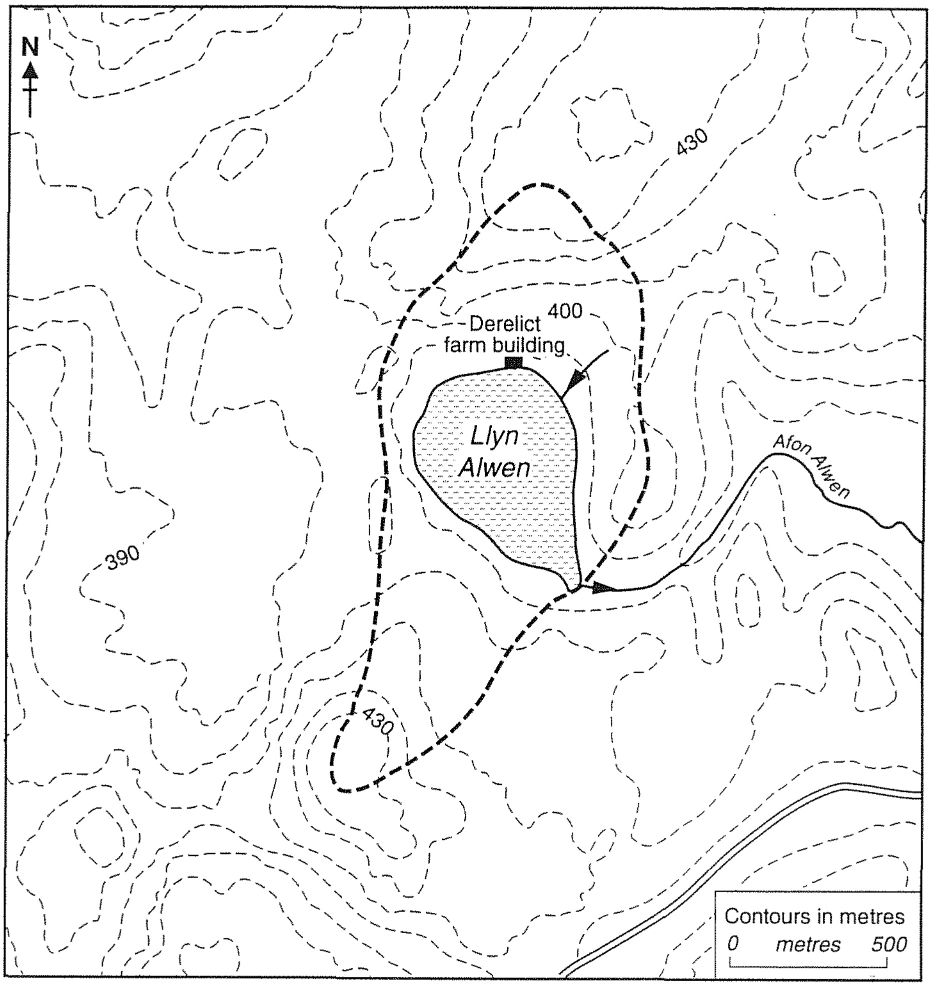
Table 2.2 Llyn Tegid: site characteristics	
Grid reference	SJ 910335
Lake altitude	160 m
Maximum depth	43 m
Mean depth	24 m
Volume	85000 x 10^6 m^3
Lake area (including lake)	414 ha
Shoreline development index	1.8
Estimated hydraulic residence time	86 days
Catchment area	26200 ha
Catchment:lake ratio	63
Net relief	600 m
Mean annual rainfall	1827 mm
Total S deposition	1.42 keq H^+ ha^{-1} yr
Total N deposition	2.05 keq H^+ ha^{-1} yr

2.3 Llyn Alwen

Llyn Alwen is a small but relatively deep lake which lies in the Mynydd Hiraethog SSSI, an area of sub-montane heath, approximately 12 km east of Betws-y-Coed in North Wales. The underlying geology of the site is of Silurian origin. In this region of high rainfall and impeded drainage, the overlying soils of the small catchment are Cambic stagnohumic of the Wilcocks 2 series, slowly permeable, seasonally waterlogged upland soils with a peaty surface horizon. They support an ericaceous shrub community, including *Calluna vulgaris*, *Empetrum nigrum* and *Vaccinium vitis-idaea,* which is influenced by traditional grouse moor management. The soils grade to acid wet blanket bog vegetation around the lake perimeter where they are dominated by *Polytrichum* sp. and *Juncus effusus*. A small inflow feeds the lake to the north-east, while drainage is to the south-east via the Afon Alwen. A derelict farmhouse is situated on the north shore.

Table 2.3 Llyn Alwen: site characteristics	
Grid reference	SH 898567
Lake altitude	380 m
Maximum depth	13.5 m
Mean depth	6.0 m
Volume	1560 x 10^6 m^3
Lake area (including lake)	26 ha
Shoreline development index	1.1
Estimated hydraulic residence time	400 days
Catchment area	130 ha
Catchment:lake ratio	5
Net relief	10 m
Mean annual rainfall	1487 mm
Total S deposition	1.24 keq H^+ ha^{-1} yr
Total N deposition	1.59 keq H^+ ha^{-1} yr

Figure 2.3 Catchment of Llyn Alwen



2.4 Llyn Glasfryn

Llyn Glasfryn is a small and very shallow lake, lying in glacial drift deposits on the Lleyn Peninsula. The underlying geology of the site consists of Ordovician sedimentary rocks. The soils of the small surface catchment are of the East Keswick 1 series which are well drained fine loamy brown earths in drift with siliceous stones. The supply of water to Glasfryn is thought to extend beyond the boundaries of the surface catchment, due to the presence of underground springs and drains which converge on an artificial sluice, but the extent of this contribution is not clear and has not been taken into account here in the calculation of hydrological residence time.

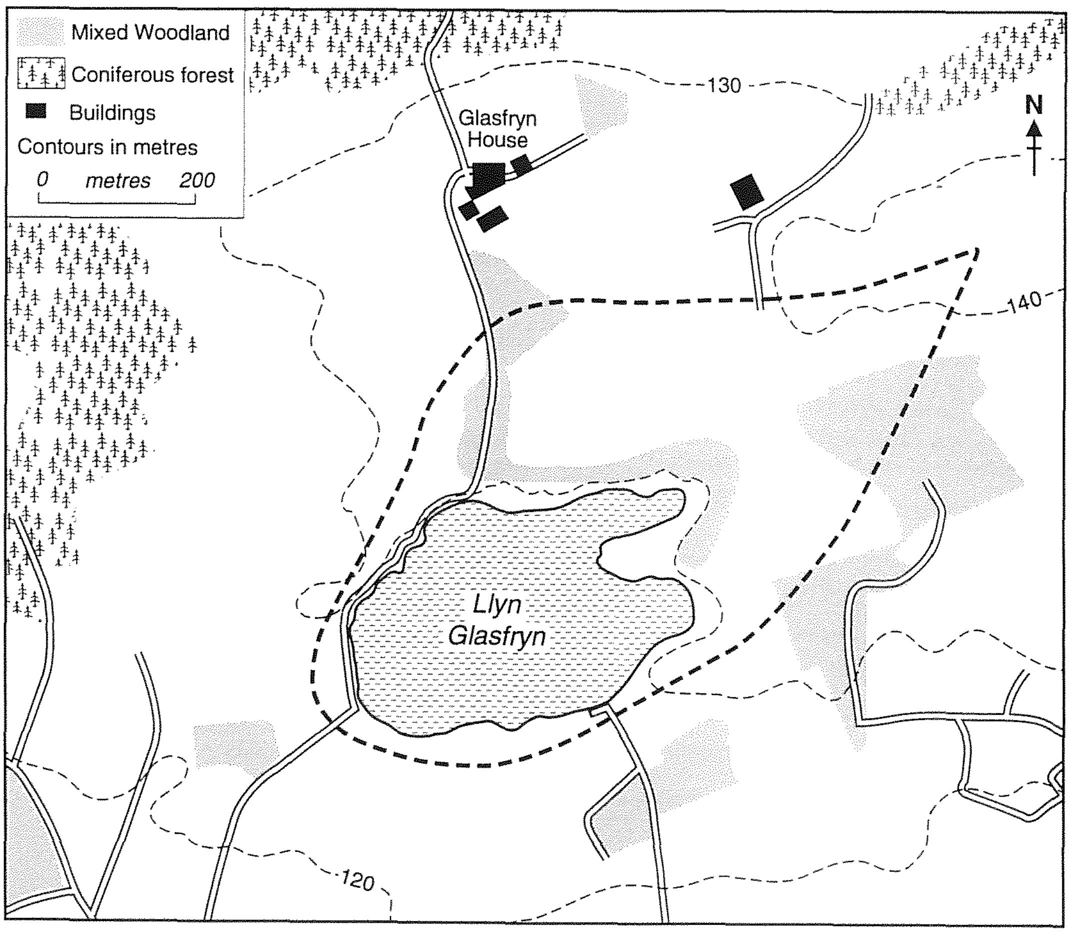
The east side of the lake is fringed by overhanging *Alnus* which grades into deciduous woodland while the west is open and extensively grazed farmland. The crenate shoreline and three small islands provide the lake with considerable habitat diversity.

One of few areas of standing water on the Peninsula, Llyn Glasfryn was notified as a SSSI in 1989, largely on account of its aquatic flora and due to the overwintering of birds such as Pochard, Teal, Tufted Duck, Goldeneye and Coot. Llyn Glasfryn is stocked with brown trout, and Mallard are reared for shooting at the site.

Table 2.4 Llyn Glasfryn: site characteristics

Grid reference	SH 404422
Lake altitude	130 m
Maximum depth	1.3 m
Mean depth	0.7 m
Volume	42 x 10^6 m^3
Lake area (including lake)	6 ha
Shoreline development index	2.0
Estimated hydraulic residence time	66 days
Catchment area	19 ha
Catchment:lake ratio	3.2
Net relief	10 m
Mean annual rainfall	1709 mm
Total S deposition	0.90 keq H^+ ha^{-1} yr
Total N deposition	0.92 keq H^+ ha^{-1} yr

Figure 2.4 Catchment of Llyn Glasfryn



2.5 Llyn Rhos Ddu

Llyn Rhos Ddu is a small, shallow and elongate lake which lies at the edge of the Newborough Warren dune system on the southern tip of Anglesey. The underlying geology of the site consists of ridges of Pre-Cambrian Hornblende Schists which run through the Warren, although and in most places this is overlain with a considerable thickness of sand. It seems likely that the lake occupies part of the former river channel of the Afon Braint which was later diverted by an incursion of wind blown sand (Robinson, 1980). The soils of the area chiefly comprise typical sand-pararendzinas of the Sandwich series, well drained calcareous and sometimes unstable soils at risk from wind erosion.

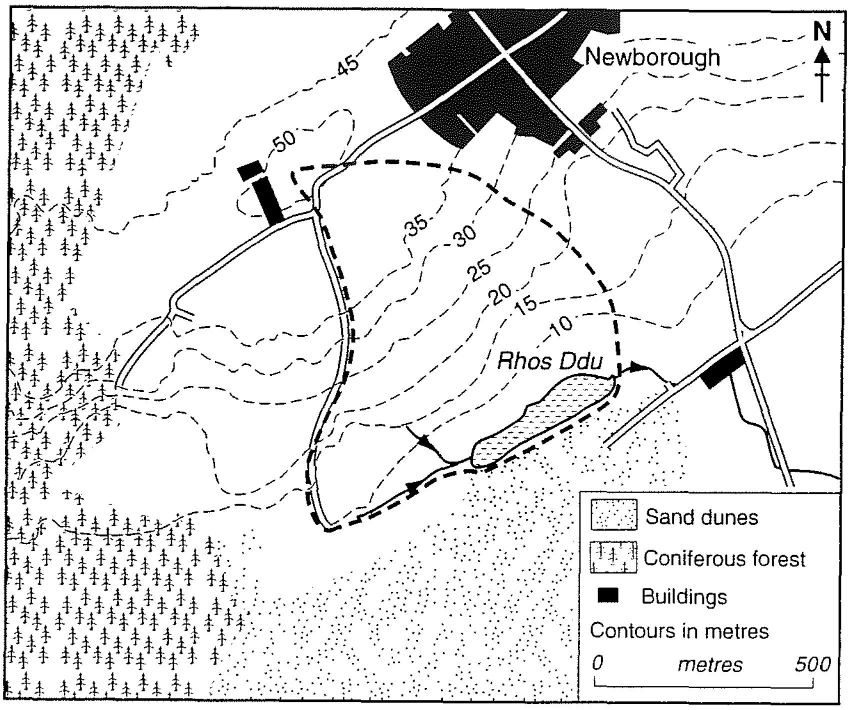
Today the hydrological catchment of the lake appears small although the extent of the contribution of a spring to the west of the lake is unclear. The lake drains via an outflow channel to the east into the lower stretch of the Afon Braint. The water level of the lake was accidentally lowered in 1994 during excavation work nearby when an old stone dam was removed. The history of this dam is not known but it is likely that it would have been used to increase storage capacity of what would have been an important freshwater resource for local agriculture.

Conservation interest lies in the lake's diverse biological assemblage, which includes the medicinal leech (*Hirudo medicinalis*) and a variety of bird-life. Llyn Rhos Ddu forms part of the Newborough Warren SSSI/NNR but it currently does not feature in the site citation.

Table 2.5 Llyn Rhos Ddu: site characteristics

Grid reference	SH 425648
Lake altitude	5 m
Maximum depth	1.1 m
Mean depth	0.6 m
Volume	12×10^6 m^3
Lake area (including lake)	2 ha
Shoreline development index	1.3
Estimated hydraulic residence time	20 days
Catchment area	40 ha
Catchment:lake ratio	20
Net relief	40 m
Mean annual rainfall	1073 mm
Total S deposition	0.68 keq H^+ ha^{-1} yr
Total N deposition	0.57 keq H^+ ha^{-1} yr

Figure 2.5 Catchment of Llyn Rhos Ddu



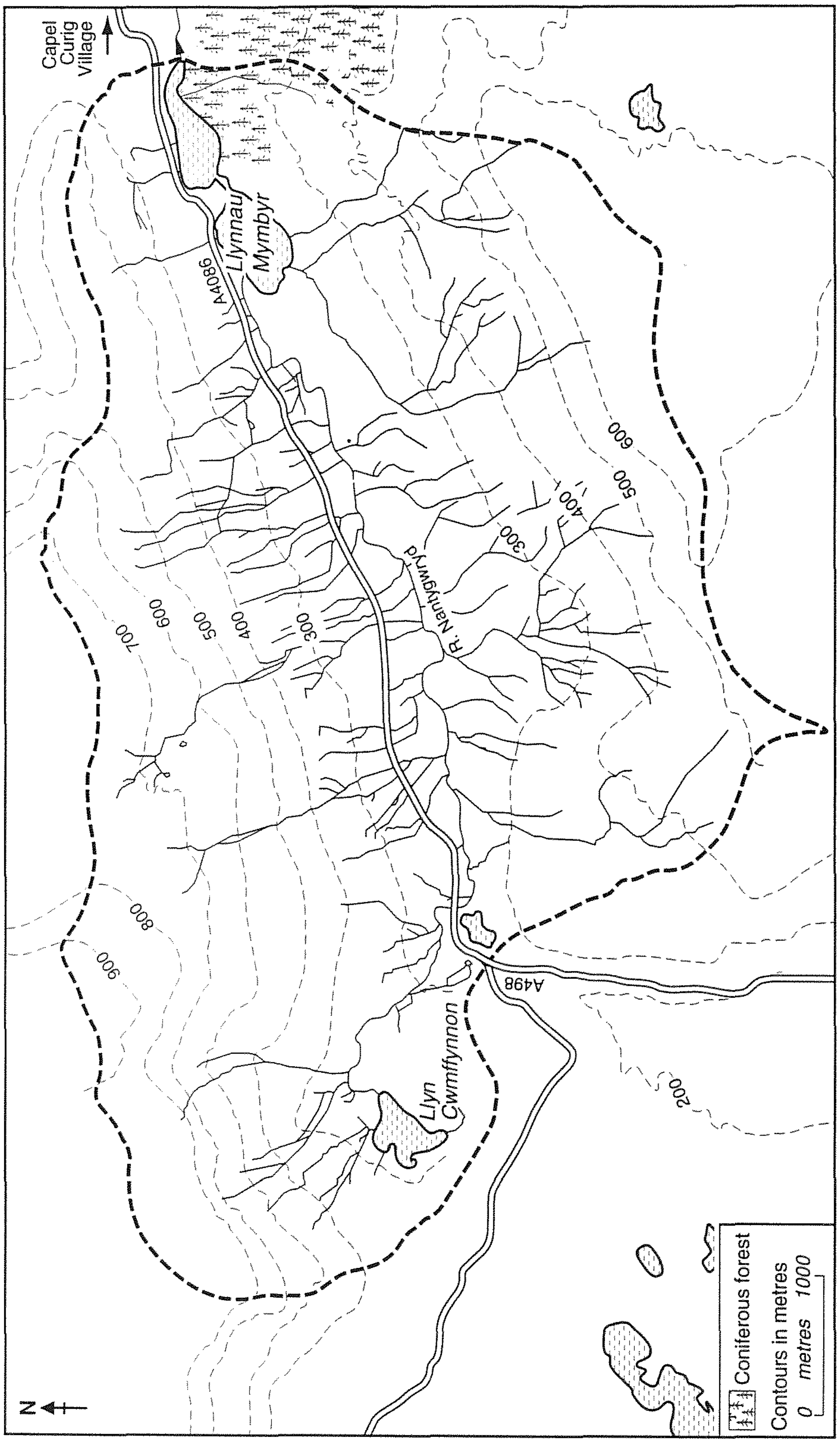
2.6 Llynnau Mymbyr

The Llynnau Mymbyr consist of two distinct basins, separated by a 100 m long rocky channel which was formed following a large rockfall, bisecting a once larger water body. The lakes, which are situated within a deeply cut glacial valley, are supplied chiefly by the Nantygwryd and the outflow forms a confluence with the Afon Llugwy in Capel Curig, 1 km to the east. A major trunk road, the A4086, runs parallel to the Nanygwryd along the north side of the valley. The underlying geology of the catchment is mainly of Ordovician origin although the lake itself lies on sandstone and is ringed by igneous intrusions of rhyolitic tuff. Soils in the lower lying parts of the catchment are mostly acidic raw oligo-amorphous peats of the Crowdy 1 series, while the upper slopes include very shallow humic rankers and ferric stagnopodzols of moderate grazing value.

Most of the catchment is used for the grazing of sheep and, to a lesser extent, cattle, although coniferous forest fringes the southern shore of the east basin. Llynnau Mymbyr is used by a local Outdoor Activity Centre for boating purposes. The site was first designated a SSSI in 1960.

Table 2.6 Llynnau Mymbyr: site characteristics	
Grid reference	SH 708574
Lake altitude	180 m
Maximum depth	7.8 m
Mean depth	4.5 m
Volume	1575 x 10^6 m^3
Lake area (including lake)	35 ha
Shoreline development index	1.9
Estimated hydraulic residence time	12 days
Catchment area	2470 ha
Catchment:lake ratio	70
Net relief	819 m
Mean annual rainfall	2437 mm
Total S deposition	1.53 keq H^+ ha^{-1} yr
Total N deposition	1.74 keq H^+ ha^{-1} yr

Figure 2.6 Catchment of Llynnau Mymbyr



2.7 Gloyw Lyn

Gloyw Lyn is a small, boulder dominated lake which lies in an area of hard, acidic Cambrian grits in the Harlech Dome, characterised by numerous cliffs and rocky outcrops. The soils are mostly humic rankers of the Revidge series, very shallow and acid peaty soils over rock, with bare rock and thick peat in places. The sparse vegetation is dominated by *Calluna vulgaris*, *Myrica gale* and *Trichophorum cespitosum* and grazing is largely restricted to a small number of feral goats.

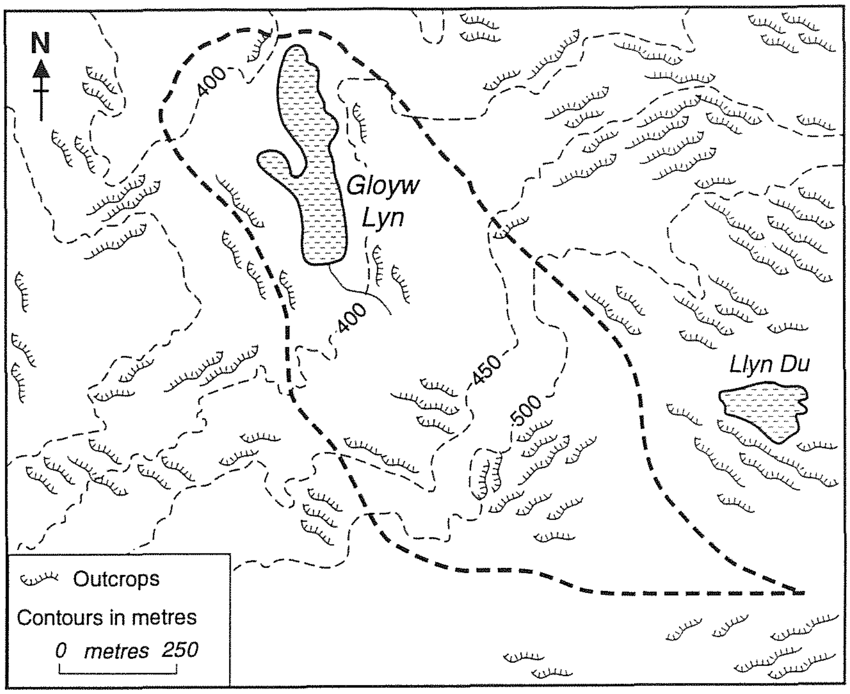
Gloyw Lyn is mostly shallow although two small basins in the north and south reach a depth of 7.2 m and 5.7 m respectively. The lake is fed by one steeply incised inflow which enters from the south and it drains via sub-surface channels to the north.

Together with several other lakes, Gloyw Lyn forms part of the extensive Rhinog SSSI which was first designated in 1955.

Table 2.7 Gloyw Lyn: site characteristics

Grid reference	SH 647298
Lake altitude	380 m
Maximum depth	7.2 m
Mean depth	3.0 m
Volume	90 x 10^6 m^3
Lake area (including lake)	3 ha
Shoreline development index	1.4
Estimated hydraulic residence time	34 days
Catchment area	63 ha
Catchment:lake ratio	21
Net relief	340 m
Mean annual rainfall	1974 mm
Total S deposition	1.17 keq H^+ ha^{-1} yr
Total N deposition	1.56 keq H^+ ha^{-1} yr

Figure 2.7 Catchment of Gloyw Lyn



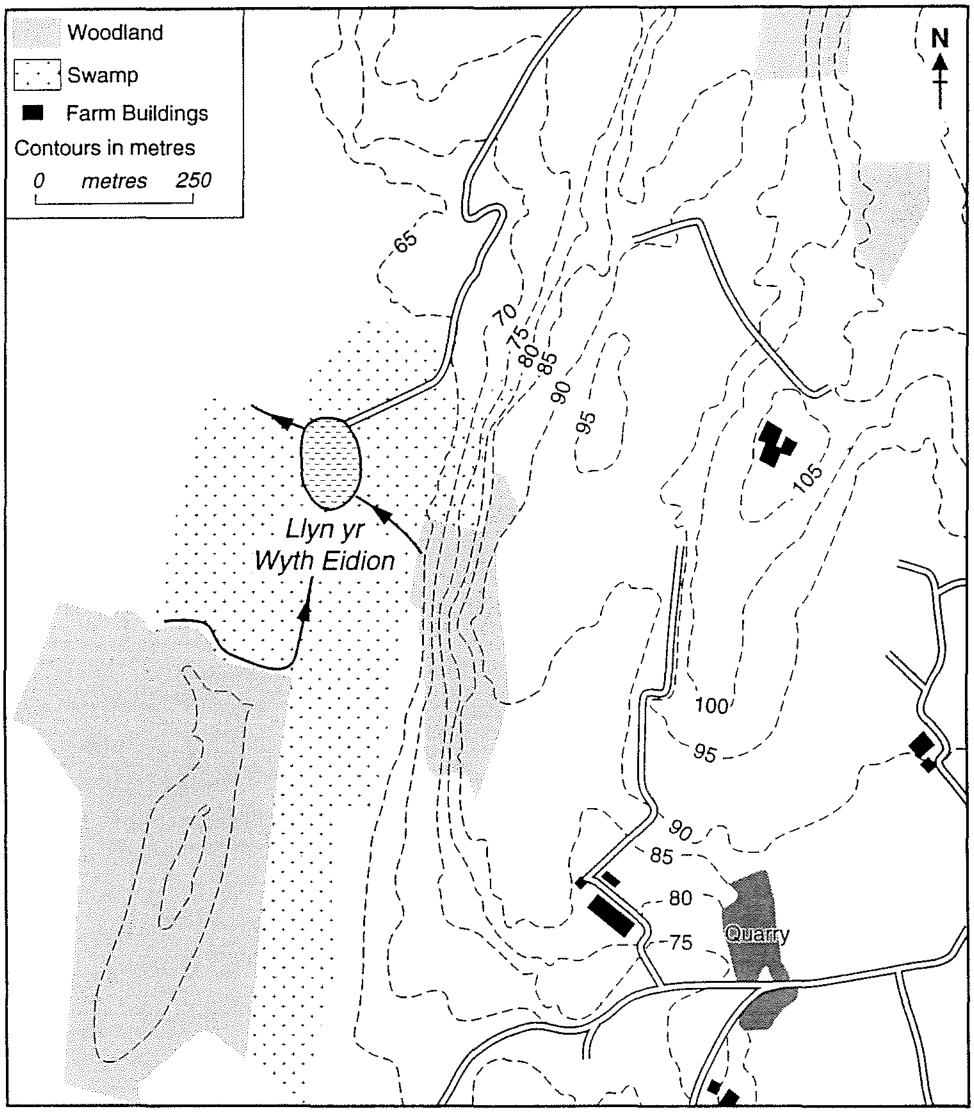
2.8 Llyn yr Wyth Eidion

Situated in a large calcareous valley mire on deposits of lacustrine shell mud, Llyn yr Wyth Eidion forms a small but deeply shelving circular water body with a maximum depth of 9 m. For a 'marl lake' this depth is unusual and leads to strong thermal stratification in summer. The area surrounding the lake mostly comprises *Cladium mariscus/Phragmites australis* dominated fen on deep fen peat of the Adventurers' 1 soil series. Llyn yr Wyth Eidion is listed as a Grade 1 site in Ratcliffe's 'Nature Conservation Review' (1977) and is managed by CCW as a National Nature Reserve, part of the Cors Erddreiniog SSSI. The site has been recognised for its conservation importance, partly because of its physical uniqueness and due to the diversity of certain biological groups, particularly gastropods and leeches

Llyn yr Wyth Eidion is fed by a number of base-rich springs which emerge from the foot of a carboniferous limestone escarpment, and it forms an integral part of the hydrologically managed Cors Erddreiniog system. The extent of the lake's catchment is therefore difficult to define and the catchment boundary has not been included in Figure 2.8.

Table 2.8 Llyn yr Wyth Eidion: site characteristics	
Grid reference	SH 470820
Lake altitude	64 m
Maximum depth	9.0 m
Mean depth	6.0 m
Volume	72×10^6 m^3
Lake area (including lake)	1.2 ha
Shoreline development index	1.1
Estimated hydraulic residence time	59 days
Catchment area	100 ha approx
Catchment:lake ratio	80 approx
Net relief	32 m
Mean annual rainfall	931 mm
Total S deposition	0.66 keq H^+ ha^{-1} yr
Total N deposition	0.51 keq H^+ ha^{-1} yr

Figure 2.8 Catchment of Llyn yr Wyth Eidion



2.9 Llyn Cau

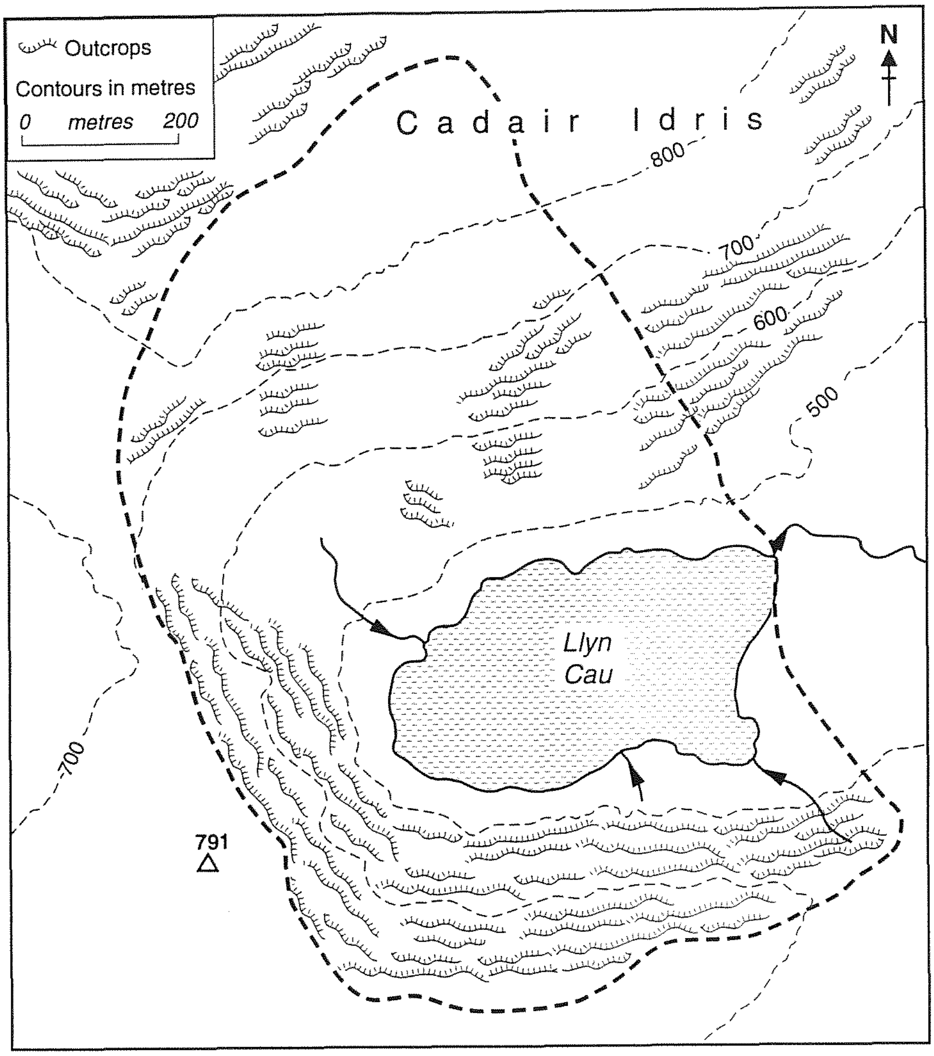
Llyn Cau, one of the deepest natural lakes in Wales, is situated in an upland cirque in the Cadair Idris National Nature Reserve and SSSI within the Snowdonia National Park in North Wales. The lake's conical basin (Howe and Yates, 1952) which reaches a water depth of almost 50 m, results from glacial scour of Ordivician volcanic and sedimentary rocks. The site is surrounded on three sides by steep rocky slopes which in places rise 300 m above the lake surface. According to Lewis (1938) the east and north facing walls consist predominantly of a sequence of silicified ashes and larvas of the Llandeilo series which are of moderate to acid composition, while the base of the cirque is dominated by grey-blue Llyn Cau mudstones. The north slopes are chiefly composed of pillow larvas of the Upper Basic Group. The thin soils on the steeper inclines are primarily very acid humic rankers of the Bangor series while the more gently sloping areas immediately encircling the lake are mostly dominated by humic brown podzols of the Moor Gate series which are well drained humose gritty loamy soils. The lake water is particularly transparent and the very low concentration of dissolved matter gives the lake a distinctively deep blue colour when viewed from the surrounding ridge.

Llyn Cau has long been recognised for the high quality of its brown trout. The lake was once designated as an upper storage pool for a pump storage power station planned for the area, with the intention of connecting it via a tunnel to Talyllyn lake in the valley below. However the scheme was shelved at the planning stage. The NNR was established in 1955 and is now owned by the Countryside Council for Wales.

Table 2.9 Llyn Cau: site characteristics

Grid reference	SH 715124
Lake altitude	470 m
Maximum depth	47 m
Mean depth	21 m
Volume	2940×10^6 m^3
Lake area (including lake)	14 ha
Shoreline development index	1.4
Estimated hydraulic residence time	777 days
Catchment area	99 ha
Catchment:lake ratio	7.1
Net relief	432 m
Mean annual rainfall	1759 mm
Total S deposition	1.03 keq H^+ ha^{-1} yr
Total N deposition	1.44 keq H^+ ha^{-1} yr

Figure 2.9 Catchment of Llyn Cau



2.10 Llyn Llagi

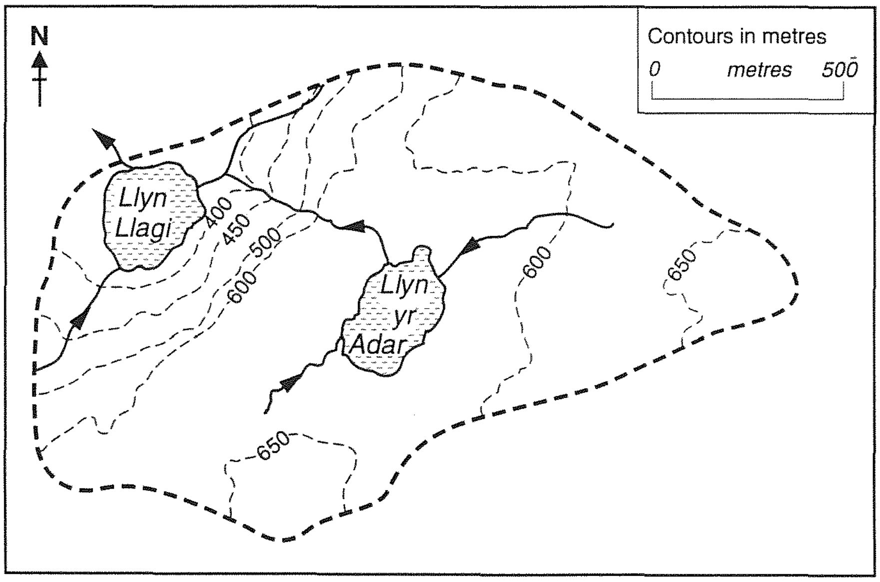
Llyn Llagi occupies a north-facing corrie at an altitude of 380 m in the central area of Snowdonia National Park in North Wales. The lake comprises an almost circular basin, reaching a maximum depth of approximately 16 m, and is fed by the outflow from Llyn yr Adar, which lies above the backwall, and several other small streams. Drainage is via a discreet outflow to the north-west. The geology consists primarily of Ordivician slates and shales of the Glanarfon series. The backwall is composed of a large doleritic intrusion with smaller intrusions of fine microgranites and volcanic tuff. Away from the bare rock backwall, the catchment soils are chiefly stagnopodzols and gleys, interspersed with blanket peats. These are dominated by moorland plant species such as *Calluna vulgaris*, *Molinia caerulea*, and *Eriophorum* sp. which are grazed at low intensity by sheep.

Llyn Llagi is part of the Llyn Llagi and Llyn yr Adar SSSI which was designated in 1959. It is a key site on the United Kingdom Acid Waters Monitoring Network and the Environmental Change Network; water samples have been analysed quarterly for chemistry and various aspects of the biology have been monitored annually for the past ten years. The site has also been the subject of palaeoecological investigation by the Environmental Change Research Centre (ie. Patrick *et al.*, 1987, Battarbee *et al.* 1988) which has shown that the lake has acidified from approximately pH 6.2 to 5.2 over the last 150 years as a consequence of atmospherically deposited pollution.

Table 2.9 Llyn Llagi: site characteristics

Grid reference	SH 649483
Lake altitude	380 m
Maximum depth	16.5 m
Mean depth	5.8 m
Volume	330×10^3 m^3
Lake area	6 ha
Shoreline development index	1.3
Estimated hydraulic residence time	39 days
Catchment area (including lake)	164 ha
Catchment:lake ratio	27
Net relief	298 m
Mean annual rainfall	2437 mm
Total S deposition	2.36 keq H^+ ha^{-1} yr
Total N deposition	1.84 keq H^+ ha^{-1} yr

Figure 2.10 Catchment of Llyn Llagi



3 Methods

The variables measured and recorded were determined by the Countryside Council for Wales in their tender document for this programme. The sampling methodologies have been adopted after consultation with relevant specialists, and where possible recognised standard field and analytical methods have been used. All methods are described in the Final Report for Phase I of the Integrated Classification and Assessment of Lakes in Wales (Allott *et al.* 1994). However following recommendations made in the Phase I report, minor modifications have been made to the sampling methodologies which have been applied in Phases II -IV; samples have not been taken for open water phytoplankton, littoral macroinvertebrates were sampled in the Autumn only, and littoral zooplankton samples were taken from five sampling stations from each lake only, in order to represent the dominant vegetation and substrate types. Llyn Llagi, a United Kingdom Acid Waters Monitoring Network site, was added to the current programme when it was realised that existing data was of a suitable format for inclusion. Data on a small sub-set of chemical determinands were not available for Llyn Llagi and the macroinvertebrate data is derived from a spring rather than autumn sample.

4 Results

Physio-chemical and biological data for each site are presented in a series of Appendices (A - J) and further notes on sampling locations for littoral Cladocera and macro-invertebrates are provided in Appendices K and L respectively.

4.1 Physio-chemical data

4.1.1 Hanmer Mere

The water chemistry of Hanmer Mere (Table A.1) is indicative of a nutrient rich, alkaline lake. The concentrations of phosphorus in all samples (most of which is in soluble reactive form) are the highest for any site in this project. A maximum of 2382 μg l^{-1} total phosphorus (TP) was recorded in the September sample. These levels are considerably higher than previous measurements for this site, made by the National Rivers Authority between 1992 and 1994, and more significantly, those made by the Environmental Change Research Centre (ECRC) during a survey of the Shropshire and Cheshire Meres between 1992 and 1993, when the same laboratory and methods were used. Generally, concentrations are approximately three times higher than those recorded for Hanmer Mere on the ECRC survey, during which 5 samples ranged from 160 - 871 μg P l^{-1}. The current concentrations are higher than any recorded on the ECRC survey which included many of the Meres of Cheshire and Shropshire, some of the most nutrient rich water bodies in the UK.

The apparently elevated concentrations of phosphorous at Hanmer Mere are unlikely to have resulted from changes in the hydrological balance, e.g. a reduction in rainfall or increase in evaporative losses, since the concentrations of other elements and conductivity are broadly similar to earlier results. Increased phosphorus loading from the sediments resulting from higher water temperatures and longer periods of anoxia cannot be ruled out as a mechanism; the July physical profile (Figure A.4) shows a marked temperature and oxygen gradient from the surface to the lake bottom, which is almost deoxygenated. However, it seems more likely that the site has recently undergone considerable enrichment, possibly due to the effect of overflow from cess-pits or septic tanks within the catchment.

Biological productivity is likely to be high although limited by nitrate concentration which was particularly low in the July sample (7 μg l^{-1}). Interestingly chlorophyll *a* concentration was low in all samples, and this probably reflects intense grazing activity of large bodied zooplankton in a lake where fish predation is apparently very low. The July secchi disc depth of 4.1 m is accordingly high for a nutrient rich site.

4.1.2 Llyn Tegid (Lake Bala)

Llyn Tegid is slightly acid lake (mean pH 6.36) and has relatively low alkalinity for a lowland site with a large and predominantly agricultural catchment (Table B.1). Although evidence from a recent palaeoecological study by Bennion *et al.*(1997) suggest that epilimnetic TP concentrations have increased over the last decade, phosphorus concentrations are low in all samples. However, nitrate and chlorophyll *a* levels are moderately high, with means of 453 μg N l^{-1} and 7.2 μg l^{-1}. Dissolved organic carbon levels are consistently high and, together with the significant phytoplankton crop, account for the limited depth penetration of aquatic macrophytes in the lake and the July secchi disc measurement of only 3.6 m. The July physical profile (Figure B.4) showed Llyn Tegid to be strongly thermally stratified, with a well developed thermocline at approximately 10 m depth, below which the water column was deoxygenated to a level which is likely to exclude fish at this time of year. The shape and absolute values for the temperature profile is very similar to previous profiles for Llyn Tegid recorded in July 1952 (Dunn 1961) and 1977 (Mills 1978) although in the latter, surface temperature was considerably warmer (20°c).

4.1.3 Llyn Alwen

In comparison with water chemistry of other sites on this project, Llyn Alwen (Table C.1) exhibits some extreme characteristics (see Table 1.2). It has the lowest mean pH and alkalinity of all sites, and accordingly, cation concentrations are low and aluminium concentrations high. Concentrations of both iron and manganese are particularly high (with means of 453 and 198 $\mu g\ l^{-1}$ respectively) and perhaps are indicative of some geological influence on water chemistry. Although the lake was thermally stratified in July with a well developed thermocline at about 6 m depth (Figure C.4), there was no evidence of significant deoxygenation of the hypolimnion, a factor which can result in the mobilisation of iron and manganese from the underlying sediments. Nitrate levels are also persistently high for an upland site and show no evidence of the seasonality commonly observed in upland systems as a result of the biological uptake of nitrogen during the growing season. Despite this, the low ratio of nitrate to sulphate suggests the former has a relatively low contribution to the total acidity of the site. Water transparency of Llyn Alwen is relatively poor, (July secchi disc depth = 2.3 m) and results from the significant concentration of dissolved organic carbon (mean = 3.9 mg l^{-1}).

4.1.4 Llyn Glasfryn

Despite its situation on the Lleyn Peninsula, the water chemistry of Llyn Glasfryn appears to be only moderately influenced by sea salts (Table D.1) . Chloride concentrations, conductivity and alkalinity are relatively high for the project as a whole but are considerably lower than those for sites on Anglesey and other more coastal locations. The lake's high productivity, apparent from the exceptionally high concentrations of chlorophyll *a* in all samples, may result in part from the shallow nature of the water body which will restrict the depth of epilimnetic circulation. The exceptionally high levels of iron and manganese probably arise from periods of deoxygenation of the lake sediments and such conditions are evident in the July physical profile (Figure D.4) which shows a decline in Oxygen concentration toward the sediment surface. The continued application of feed.for the purpose of duck rearing is likely to further elevate nutrient levels and exacerbate low oxygen conditions. Algal productivity is likely to be limited by the availability of nitrate, concentrations of which are low throughout the year and below the detection limit in the summer and autumn samples. Water transparency is poor throughout the year and in July a secchi disc depth of only 35 cm was recorded.

4.1.5 Llyn Rhos Ddu

Llyn Rhos Ddu exhibits water chemistry characteristics typical for a site in a coastal location influenced by underlying dune sand and sea-spray (Table E.1). The high values for alkalinity, conductivity and specific cation concentrations are very similar to those for other sites analysed during this project (ie. sites on Anglesey and Kenfig Pool on the coastline of South Wales). The lake has moderate levels of TP, ranging from 30 - 58 $\mu g\ l^{-1}$. Primary productivity is probably limited by the availability of nitrate. Concentrations of nitrate were only above the detection limit on one occasion, indicating that the lake chemistry is relatively unaffected by the limited agricultural activity within the catchment. High concentrations of iron and manganese are likely to result from periods of sediment anoxia at this extremely shallow site. The July physical profile (Figure E.4) shows a slight temperature gradient from the lake surface and a small decline in oxygen concentration toward the sediment. The secchi disc depth extended below the maximum depth of the lake of 0.8 m.

4.1.6 Llynnau Mymbyr

The chemistry of water samples taken from the outflow of the Llynnau Mymbyr is indicative of a nutrient poor system with a rapid flushing time (Table F.1). The site is moderately acid, but the sample taken in January (pH 4.96) demonstrates that the site is prone to severely acid episodes and these are likely to have biological importance. The remaining three samples have a mean pH of 6.20. Cation and alkalinity levels are low and the latter is negative in the January sample. The Llynnau Mymbyr are unproductive with low levels of chlorophyll *a*, TP and nitrate. There is no evidence for the 'unusually high nitrogen content' referred to in the SSSI citation of 1982. Dissolved organic carbon levels are relatively low throughout the year and the significant transparency observed in July (secchi disc depth of 6.5 m) is probably characteristic for the site. The July physical profile (Figure F.4) shows a significant temperature gradient from top to bottom and slight deoxygenation. However, given the very short residence time, it is unlikely that the lake ever thermally stratifies to a point where sediments will become anoxic.

4.1.7 Gloyw Lyn

Gloyw Lyn is a moderately acid site with a mean pH of 5.86 and low levels of alkalinity and base cations (Table G.1). The site is unproductive, as can be seen from the low concentrations of chlorophyll *a*, nitrate and TP. The dissolved organic carbon (DOC) concentration was relatively high on the day physical profile measurements were made and this is likely to account for the relatively poor secchi disc measurement of 3.8 m. DOC and absorbance values are considerably lower for the three later sampling dates and indicate that transparency is normally greater than the one secchi disc reading alone might suggest. In July the physical profile of the water column (Figure G.4) exhibited a declining temperature gradient from the surface to the lake bed and partial deoxygenation below 4 m water depth.

4.1.8 Llyn yr Wyth Eidion

The water chemistry of Llyn yr Wyth Eidion is the most alkaline of all sites in the project (Table H.1). Calcium and sulphate concentrations are approximately double those of the next most alkaline site (Llangorse Lake), and probably reflect a major contribution from calcium sulphate rich groundwater which feeds the lake via a system of springs. Nitrate concentrations are also exceptionally high, and, although falling below detection limit in the September sample, are greater than 3 mg l^{-1} in January and April. The source of nitrate is unclear but it seems most likely to result from agricultural contamination. TP concentrations are very low throughout the year and will restrict lake productivity. The July physical profile (Figure H.4) revealed a declining temperature gradient from top to bottom. The water column showed deoxygenation below 4 m water depth and anoxic conditions at the sediment surface. Chlorophyll *a* concentrations are moderately low throughout the year, but perhaps reflect the activity of zooplankton, rather than low primary productivity. The lake water had high transparency on all visits, and in July a secchi disc depth of 5.4 m was recorded.

4.1.9 Llyn Cau

Llyn Cau is a moderately acid lake and during the sampling year exhibited a relatively stable pH (mean of 5.84) which reflects the long water residence time of this site (Table I.1). Cation concentrations are low but not extreme for an upland acid lake. The water quality of Llyn Cau is striking for two reasons. Firstly, the dissolved organic carbon and absorbance values are particularly low, features which give rise to the distinctive blue colour of the water and the substantial secchi disc depth recorded in July of 15 m. Secondly, nitrate concentrations are relatively high for an upland lake, and provide no evidence of a seasonal fluctuation which is often observed in these systems as a result of summer uptake of nitrogen by soil and lake biota. Four samples over the course of one year are insufficient to properly understand the seasonal nitrogen dynamics of the Llyn Cau catchment. However, the data suggests that the limited soils within the catchment are nitrogen saturated throughout the year. High nitrate concentrations may also result in part from very low levels of lake water phosphorus which are likely to limit lake productivity . The nitrate concentrations are of a similar level to those recorded in October 1984 during an NCC survey. On the July sampling date, Llyn Cau was strongly thermally stratified and below the 12 m deep thermocline the water column showed slight deoxygenation (Figure I.4).

4.1.10 Llyn Llagi

Llyn Llagi (Table J.1) has a mean pH of 5.36 and a minimum of pH 5.04, typical of the more poorly buffered acid lakes on this survey. Alkalinity is particularly low and calcium concentrations appear to be lower than for all sites other than West Llynoedd Ieuan in the current project. Aluminium levels are correspondingly high. Like Llyn Cau, nitrate concentrations are relatively high for an upland site although perhaps showing slightly more seasonality (note the low September value), which is expected given the significant soil cover in the catchment. The July physical profile (Figure J.4) indicated the development of a weak thermocline at a water depth of 2 m, but the water column was well oxygenated throughout.

4.2 Epilithic / epiphytic diatoms

4.2.1 Hanmer Mere

The epiphytic samples from Hanmer Mere are extremely sparse with very few countable specimens. These data must therefore be interpreted with caution and may not provide a true representation of the epiphytic community of the lake. The taxa observed are cosmopolitan species (Table A.2) typically found in epiphytic habitats in circumneutral to alkaline waters, the most abundant taxon being *Cocconeis placentula*, a widespread epiphyte.

4.2.2 Llyn Tegid

The epilithic diatom flora of Llyn Tegid is diverse with a total of 55 taxa present in the three samples analysed (Table B.2). *Achnanthes minutissima*, however, was clearly the dominant taxon, comprising 43% of the whole assemblage. This species is widely distributed and extremely common in freshwaters. It appears, however, to prefer well aerated, weakly alkaline conditions and tends to perform badly in strongly acid or eutrophic waters, suggesting that Llyn Tegid is mildly nutrient-rich, and circumneutral to slightly alkaline. Another important taxon was *Asterionella formosa* (5%) which is the dominant taxon in the surface sediment assemblage. It appears to have been deposited from the plankton, as it is not a species typically associated with epilithic habitats. Other important taxa were *Fragilaria capucina*, *Synedra rumpens* and *Fragilaria intermedia*, which are all long, fine, araphidinate forms widely distributed in freshwaters but typically found in the littoral zones of circumneutral pH, weakly alkaline lakes.

4.2.3 Llyn Alwen

The epilithic diatom flora of Llyn Alwen is characterised by very low species diversity (Table C.2). The assemblages are dominated by *Eunotia incisa*, a species indicative of acid, nutrient-poor waters. Other species present include *Tabellaria flocculosa* and *Eunotia pectinalis*, both common in acid waters.

4.2.4 Llyn Glasfryn

The epilithic communities of Llyn Glasfryn (Table D.2) are co-dominated by *Nitzschia paleacea* (20%) and *Achnanthes minutissima* (22%), and *Navicula minima* (10%) is also important. *N. paleacea* is a cosmopolitan diatom typically found in epilithic habitats but is also associated with epiphytic, epipelic and planktonic communities. It is a freshwater, alkaliphilous species which tends to prefer low to circumneutral pH and alkalinity. *Navicula minima* is also a freshwater, alkaliphilous diatom with similar ecological preferences to *N. paleacea*. The findings, therefore, appears to be consistent with the water chemistry data for the lake.

4.2.5 Llyn Rhos Ddu

The epiphytic diatom samples from Llyn Rhos Ddu (Table E.2) are co-dominated by *Nitzschia paleacea* (32%) and *Cocconeis placentula* (32%), and *Epithemia adnata* is also important (16%).

C. placentula is a widespread epiphyte but is most common in circumneutral to alkaline waters such as Llyn Rhos Ddu. *E. adnata* prefers slight to moderately alkaline waters with moderate calcium content and thus performs well in conditions such as those found at Llyn Rhos Ddu.

4.2.6 Llynnau Mymbyr

The epilithic flora of Llynnau Mymbyr is relatively diverse (Table F.2). Common species include *Brachysira vitrea*, *Brachysira brebissonii*, *Achnanthes minutissima*, *Achnanthes altaica*, *Nitzschia frustulum* and *Achnanthes marginulata*. *Tabellaria flocculosa*, *Eunotia exigua*, *Cymbella lunata*, *Navicula leptostriata* and *Fragilaria virescens* var. *exigua* are also present. The assemblages are characteristic of nutrient poor, slightly acid surface waters.

4.2.7 Gloyw Lyn

The epilithic diatom flora of Gloyw Lyn is typical of nutrient-poor, acid waters (Table G.2). Common species include *Navicula leptostriata*, *Brachysira vitrea*, *Tabellaria flocculosa* and *Brachysira brebissonii*. *Peronia fibula*, *Frustulia rhomboides* var. *saxonica* and *Eunotia incisa* are also common.

4.2.8 Llyn yr Wyth Eidion

The epiphytic samples from Llyn yr Wyth Eidion are unusual in that they are strongly dominated by a single taxon *Achnanthes minutissima*, constituting 95% of the whole assemblage (Table H.2). No other taxon has a relative abundance greater than 1%. The exact reasons for this are unclear, although this species is a cosmopolitan one and is often abundant in epiphytic habitats, particularly in circumneutral waters that are neither strongly acid nor strongly nutrient-rich.

4.2.9 Llyn Cau

The epilithic diatom assemblages are indicative of nutrient-poor circumneutral to slightly acid waters (Table I.2). Abundant species include *Achnanthes marginulata*, *Tabellaria flocculosa* and the planktonic *Cyclotella comensis*. *Achnanthes minutissima*, *Eunotia exigua*, *Peronia fibula* and *Achnanthes altaica* are also common

4.2.10 Llyn Llagi

The epilithic diatom community of Llyn Llagi is typical of strongly acid water and is characterised by *Tabellaria quadriseptata*, *Tabellaria flocculosa*, *Eunotia* taxa, *E. incisa* and *E. rhomboidea* (Table J.2). *T. quadriseptata*, an indicator of particularly acid conditions has been one of the dominant taxa in the epilithon of Llyn Llagi since the beginning of the United Kingdom Acid Waters Monitoring Network in 1988.

4.3 Surface sediment diatoms

4.3.1 Hanmer Mere

The surface sediment assemblage of Hanmer Mere is dominated by *Stephanodiscus parvus* (80%), a small, centric, planktonic taxon commonly observed in strongly nutrient-rich, alkaline waters (Table A.3). This species is abundant in other eutrophic and hyper-eutrophic relatively small, shallow waters in Britain, e.g. ponds in south-east England (Bennion, 1994) and often dominates the planktonic community occurring in blooms, particularly in spring. *Stephanodiscus hantzschii* is also important in the assemblage (6%) and this is another centric, planktonic diatom indicative of strongly nutrient rich, alkaline waters.

4.3.2 Llyn Tegid

The surface sediment assemblage of Llyn Tegid (Table B.3) is dominated by *Asterionella formosa* (38%), a taxon commonly observed in the plankton of relatively deep, mildly nutrient-rich waters. The second most abundant taxon was *Aulacoseira subarctica* (16%), another planktonic species frequently recorded in oligo-mesotrophic lakes. *Achnanthes minutissima* comprised 10% of the assemblage reflecting its dominance in the littoral zone of the lake. *Cyclotella glomerata*, a small planktonic centric diatom, was also present (7%) and this taxon is normally associated with relatively nutrient-poor, circumneutral to alkaline freshwaters. Diatom analysis of a sediment core from Llyn Tegid (Bennion *et al.*, 1997) showed that the surface sediment and indeed the upper 15 cm of the core (representing the period 1975-1996) indicated a deterioration in water quality when compared with the lower core samples. *Cyclotella glomerata* and a number of other small *Cyclotella* species associated with oligotrophic conditions were dominant in the assemblages of the lower core section but were replaced by an expansion of *Asterionella formosa* in the mid-1970s.

4.3.3 Llyn Alwen

The surface sediment diatom assemblages of Llyn Alwen (Table C.3) are indicative of acid waters. The assemblages are dominated by *Eunotia incisa* and a group of problematic *Aulacoseira* taxa including *Aulacoseira* [cf. *lirata* var. *alpigena*]. These taxa would require detailed taxonomic examination to confirm identity. Other common taxa include *Tabellaria flocculosa*, *Cymbella perpusilla*, *Eunotia rhomboidea* and *Navicula soehrencis*.

4.3.4 Llyn Glasfryn

The surface sediment assemblage of Llyn Glasfryn (Table D.3) is dominated by *Fragilaria elliptica* (40%), a species typically associated with epilithic or benthic habitats of shallow, moderately nutrient-rich, circumneutral to weakly alkaline waters. *Cocconeis placentula* (10%) and *Achnanthes minutissima* (9%) are also important. These are cosmopolitan taxa found in a wide range of waters normally associated with epiphytic or epilithic habitats. *Achnanthes minutissima* tends to prefer well aerated, circumneutral waters with moderate nutrient concentrations. The assemblage is almost exclusively non-planktonic, reflecting the shallow water column at the site, and the importance of macrophytes, the lake bed and rocks as habitats for the diatoms.

4.3.5 Llyn Rhos Ddu

The surface sediment assemblage of Llyn Rhos Ddu (Table E.3) is diverse but preservation was poor with few specimens identifiable on the microscope slide. The most abundant taxon was *Stephanodiscus hantzschii* (12%) but a number of non-planktonic taxa were also important, namely *Navicula bacillum, Fragilaria pinnata, Navicula pupula, Amphora pediculus, Rhoicosphenia curvata, Fragilaria capucina* var. *mesolepta* and *Cocconeis placentula.* Many of these are indicative of strongly alkaline waters, which is consistent with the high measured mean alkalinity of 2500 $\mu eq\ l^{-1}$ and the high mean pH for the site. The presence of *Stephanodiscus hantzschii* suggests that the lake is also nutrient-rich.

4.3.6 Llynnau Mymbyr

The most common species in the surface sediment of Llynnau Mymbyr are *Brachysira vitrea* and *Fragilaria virescens* var. *exigua*, both characteristic of slightly acid, nutrient-poor waters (Table F.3). *Cymbella perpusilla*, *Navicula leptostriata*, *Achnanthes minutissima* and *Tabellaria flocculosa* are also common.

4.3.7 Gloyw Lyn

The surface sediment diatom assemblages of Gloyw Lyn are dominated by *Fragilaria virescens* var. *exigua* and *Navicula leptostriata*. Other common species include *Cymbella perpusilla*, *Eunotia naegelii* and *Tabellaria quadriseptata*. This latter species is indicative of strongly acid conditions, but the assemblages as a whole is characteristic of a nutrient-poor acid to strongly acid lake.

4.3.8 Llyn yr Wyth Eidion

The surface sediment diatom assemblage of Llyn yr Wyth Eidion (Table H.3) is dominated (55%) by a fine form of *Aulacoseira granulata*, a species commonly observed in the phytoplankton of moderately nutrient-rich waters. Other important taxa include *Fragilaria brevistriata, Fragilaria construens* var. *venter*, *Amphora pediculus* and *Achnanthes minutissima*, all species commonly found attached to either the sediments, stones or macrophyte surfaces of shallow, alkaline waters.

An earlier study of a core from Llyn yr Wyth Eidion (Bennion, 1996) indicated that there has been no clear species replacement since 1980, although the relative abundance of *Aulacoseira granulata* was only 20% in the 5 cm (1980) sample. The other notable changes were slight increases in *Asterionella formosa* and *Stephanodiscus parvus*, planktonic species commonly found in eutrophic lakes, between the 1980 and the 1995 sample (Bennion, 1994: Bennion, 1995). Diatom dissolution was extremely poor in the 5 cm sample, however, with presence of only very robust forms. The data may not therefore represent the true assemblage for this time and the observed changes in species composition may be more a reflection of the standard of preservation than any real species shifts. Diatom (silica) dissolution is not uncommon in lime-rich waters and has been observed in other calcareous lakes in Britain, e.g. Semer Water and Malham Tarn in Yorkshire.

4.3.9 Llyn Cau

The surface sediment assemblages of Llyn Cau (Table I.3) are dominated by *Cyclotella comensis*, a planktonic diatom indicative of nutrient-poor circumneutral waters. *Achnanthes marginulata* and *Achnanthes minutissima* are also present, but the assemblages are characterised by very low diversity and poor representation of periphytic diatoms.

4.3.10 Llyn Llagi

The surface sediment diatom assemblage at Llyn Llagi (Table J.3) is particularly species poor and dominated by *Tabellaria quadriseptata* and *Eunotia incisa,* taxa characteristic of very acid water. Sediment core analysis by the Environmental Change Research Centre (Patrick et al. 1995) demonstrates that *T.quadriseptata* was a relatively rare component of the sediment aasemblage until approximately 1960 since when its abundance has increased markedly, indicating significant acidification of this site.

4.4 Aquatic macrophytes

4.4.1 Hanmer Mere

Hanmer Mere (Table A.4, Figures A.2 - A.3) is largely fringed by overhanging *Alnus glutinosa* and occasional *Salix*. A large stand of *Typha angustifolia* dominates the north end of the lake, and is flanked on the open water side by an association of *Nuphar lutea* and *Nymphaea alba* which also ring the west side and south end. Extending out from the floating leaved canopy, submerged vegetation is abundant along most of the perimeter and dominated by *Potamogeton berchtoldii* and *Ceratophyllum demersum*, the latter being most abundant at about 3.0 m water depth where it grows in association with *Cladophora* sp. *Potamogeton crispus* occurs frequently between 1.0 and 2.0 m water depth. *Zannichelia palustris* is locally abundant in shallow water in the north end of lake where *Lemna trisulca* is also occasional. Small stands of *Typha latifolia*, *Sparganium erectum* and *Iris pseudacorus* occupy small sheltered bays along the west side. At the time of the survey, the Mere was covered by a dense bloom of the blue-green alga *Aphanizomenon flos-aquae*, and the filamentous alga *Hydrodictyon* sp. was also common and covering *P. berchtoldii* in shallow water.

Applying the scheme of Palmer (1992) Hanmer Mere is classified as Type 9, a eutrophic category. The Mere was described as 'mesotrophic' in the SSSI notification document of 1994, when a system for the Midland Meres, based on a combined aquatic macrophyte and water chemistry data-set, was applied. Hanmer Mere was surveyed by the England Field Unit in 1979 (Table N.1) and their species list largely conforms with results from the current survey. However they reported the occurrence of the emergent taxa *Menyanthes trifoliata* and *Carex rostrata*, neither of which were found this time. These species may have been lost as a result of increased grazing pressure but *C. rostrata* is usually associated with more meso- to oligotrophic environments. In addition there was no record in the earlier document *of C. demersum*, a species characteristic of nutrient enriched waters which is now abundant. Therefore the possibility of a nutrient enrichment impact on the macrophyte community of this site cannot be ruled out. The trophic ranking score is 8.75.

The NVC aquatic communities which can be identified include a species poor *Ceratophyllum demersum* community (A5) and the *Nymphaea alba* sub-community of the *Nuphar lutea* community (A8), while the only well defined swamp community is that of *Typha angustifolia* (S13).

4.4.2 Llyn Tegid (Lake Bala)

Much of the shoreline of the Llyn Tegid is encircled by a marginal association in which *Phalaris arundinacea* and *Oenanthe crocata* are dominant. The aquatic macroflora communities of Llyn Tegid form two main types which appear to be delimited by the extent of habitat exposure (Table B.4, Figures B.2 - B.3).

The perimeter of the site is largely composed of exposed, boulder dominated littoral substrates which are unsuitable for the development of sediments and the establishment of much aquatic vegetation. These parts of the lake are characterised by the moss *Fontinalis antipyretica*, which is attached to rocks, and very occasional patches of *Isoetes lacustris* which exploits pockets of sediment in deeper water.

The more sheltered bays in the south of the lake support a significantly more diverse aquatic flora, in which there is marked vertical zonation. *Littorella uniflora*, *Elatine hexandra* and *Eleocharis acicularis* tend to dominate the shallow zone which, as a result of the annual drawdown, is likely to become dry over the winter. The shallow water form of the nationally scarce *Luronium natans* and the charophyte *Nitella opaca* are common from about 0.6 m water depth and from about 1.5 m to 1.8 m *I. lacustris* and *L.natans* become co-dominant. No vascular aquatic species were found growing at more than 2.0 m water depth, which perhaps reflects the turbid nature of the site. *Callitriche hamulata* is also locally abundant in these parts of the lake. A second charophyte *Nitella translucens*, a new record for this site (Stewart pers. comm), was found at two locations in the south of the lake, and *Sparganium emersum* was locally abundant in the main bay in the south-west.

Llyn Tegid has been the subject of considerable scientific interest over the past few decades, and aquatic macrophyte species lists are available from previous surveys. A summary of past surveys is presented in a report by Eaton *et al.* (1984) (Table N.2) in which they compare their findings (from 1975 - 1984) with data from Dann (1952), Ratcliffe (1977) and the SSSI notification document of 1982. Although the lists are generally very similar to each other and to the list from this survey, there are some interesting exceptions. It is surprising that *Luronium natans*, which is abundant in the littoral of much of the south end of the lake is only mentioned in the SSSI notification, and this suggests that other surveys have not employed underwater viewing devices which are often necessary for the detection of this species. Other notable differences concern *Potamogeton natans*, which is listed by Dann, Ratcliffe and the SSSI notification, but was not found by Eaton *et al.* or during this survey, and *Nuphar lutea* which was listed by Dann, Ratcliffe and Eaton *et al.* although the latter record is for one site only at the south end. It is possible that *P. natans* and *N. lutea*, both of which depend on floating leaves, may have been adversely affected by fluctuations in water level, brought about by recent hydrological management.

Applying the scheme of Palmer (1992), Llyn Tegid is classified as Type 3, a boulder dominated oligotrophic category, and the trophic ranking score is 7.1 which is suggestive of more 'mesotrophic' conditions. It is not possible to allocate any of the aquatic communities of Llyn Tegid to NVC categories.

4.4.3 Llyn Alwen

Llyn Alwen is characterised by an aquatic macrophyte flora indicative of nutrient poor conditions (Table C.4, figures C.2 - C.3). Diversity is particularly low although two NVC communities can be identified. Shallow water around the west of the lake is represented by a *Littorella uniflora* - *Lobelia dortmanna* community (A22) in which a shallow water form of *Isoetes lacustris* is frequent. Below approximately 0.5 m to 2.0 m water depth, this is replaced by a patchy and virtually monospecific *Isoetes lacustris* community (A23). The coarser, cobble substrates on the east side of the lake provide fewer littoral habitats and shallow water tends to be dominated by *Isoetes lacustris* while the liverwort *Nardia compressa* grows abundantly on rock surfaces. *N.compressa* and other acidophilous bryophytes, *Fontinalis antipyretica* and *Sphagnum auriculatum* all occur in submerged locations down to a depth of approximately 2.0 m which appears to be the depth limit for all aquatic vegetation.

Llyn Alwen is classified as Type 3, a boulder dominated oligotrophic category, according to the scheme of Palmer (1992). The trophic ranking score for the species list is 5.17.

4.4.4 Llyn Glasfryn

Llyn Glasfryn is a shallow and sheltered lake and supports a diverse aquatic macroflora (Table D.4, Figures D.2 - D.3). The north side of the lake is well protected by surrounding deciduous woodland and this has allowed the establishment of emergent stands of *Menyanthes trifoliata* behind which *Iris pseudacorus*, *Mentha aquatica*, *Juncus effusus* and *Potentilla palustris* are all locally abundant. A floating leaved association of *Nuphar lutea* and *Nymphaea alba* extends out into the open water on this side, beyond which, the charophyte *Nitella flexilis* agg. (Stewart, pers. comm) is the dominant submerged taxa throughout. *Potamogeton obtusifolius* is also locally abundant in submerged habitats in the west of the lake and limited stands of *Potamogeton perfoliatus* occur off the south-west shore.

Littorella uniflora forms a shallow water sward around the more exposed east corner of the site, often in association with *Eleocharis acicularis* and *Elatine hydropiper*. *Eleocharis hexandra* is also present in a few shallow water locations.

Llyn Glasfryn has been the subject of occasional botanical surveys over the last century (Table N.4) although it seems that more detailed work on submerged taxa has only been carried out since a survey by Seddon in 1960 (Seddon 1964). There was no evidence on this survey of *Potamogeton berchtoldii*, *Ceratophyllum demersum* or *Myriophyllum alterniflorum* which were listed by Seddon and which Palmer (1987) ranked as locally dominant, frequent and occasional respectively. These species all favour submerged, open water habitats and it seems unlikely that they can have been overlooked, especially when one considers their former relative abundances. It seems more likely that this site has undergone recent environmental change which has lead to a change in the competitive balance of submerged species. Conditions at present seem to favour the dominance of *N. flexilis* which was recorded by Palmer, but is absent from earlier records.

Using the current species list Llyn Glasfryn classifies as Type 9, a mainly eutrophic category, according to Palmer (1992) and has a trophic ranking score of 7.5.

4.4.5 Llyn Rhos Ddu

Llyn Rhos Ddu (Table E.4, Figure E.2)is encircled by a dense perimeter of wetland vegetation, protected from grazing by fencing provided by the Reserve. The water level of the site was accidentally lowered two years ago and subsequently an inner perimeter has developed, consisting of a terrace 3 - 4 metres wide, and dominated on the open water side by emergent stands of *Menyanthes trifoliata*. Other abundant constituent taxa of this terrace include *Iris pseudacorus*, *Hippuris vulgaris*, *Sparganium erectum* and in drier reaches *Ranunculus lingua*. Stands of *Equisetum fluviatile* occur at both ends of the lake, and a small stand of *Carex rostrata* surrounds the outflow.

With the exception of a few small patches, the entire area of open water is covered in submerged macrophytes. Most of this consists of dense beds of *Potamogeton pusillus* with zones of locally abundant *Myriophyllum spicatum*, *Elodea canadensis*, occasional *Potamogeton perfoliatus* and, rarely, *Elodea nuttallii*. Shallow water on the north side of the lake is dominated by *Chara virgata*.

The submerged habitat in the west end of the lake is dominated by a particularly thick bed of *Elodea canadensis*, within which *Ranunculus circinatus* and *Myriophyllum spicatum* are occasional and *Ceratophyllum demersum* rare. In shallower water at the extreme end of the site *Zanichellia palustris*, at its only location in the lake, is locally abundant.

There appear to be few historical botanical survey records with which to compare the current one. Llyn Rhos Ddu is classified as Type 8 according to Palmer (1992), a eutrophic and often 'marl' category. The trophic ranking score is 8.76.

4.4.6 Llynnau Mymbyr

The aquatic macroflora of the Llynnau Mymbyr (Table F.4, Figure F.2) is generally typical of slightly acid and nutrient poor lakes of the north and west of Britain, although interestingly the site contains the nationally scarce charophyte *Nitella gracilis* (the first record of the species at this site (Stewart per. comm)). The lake shoreline is ringed by *Molinia caerulea*, *Juncus articulatus*, *Carex nigra* and *Ranunculus flammula*.

Shallow water vegetation is dominated by an association of *Littorella uniflora*, *Lobelia dortmanna* and *Juncus bulbosus* var. *fluitans*, while more sheltered parts support emergent assemblages which include *Carex rostrata*, *Equisetum fluviatile* and *Phragmites australis*. The west end of the west basin is dominated by the floating leaved species, *Potamogeton natans* and to a lesser extent *Nuphar lutea*.

Large areas of open water in both basins are shallow and rocky and dominated by *Isoetes lacustris*, which grows to a maximum depth of approximately 2.4 m, and locally abundant patches of *Myriophyllum alterniflorum* and occasional *Utricularia* sp.. *Potamogeton obtusifolius* appears to be the only plant able to colonise the more steeply shelving parts of both basins and grows to a maximum depth of 3.8 m. *Nitella gracilis* occurs in association with *P. obtusifolius* in the west basin.

In NVC terms the following communities are represented: the *Myriophyllum alterniflorum* sub-community of the *Littorella uniflora - Lobelia* community (A22), the *Isoetes lacustris* community (A23), the species poor sub-community of the *Potamogeton natans* community (A9), the *Carex rostrata* community (S9), and the *Equisetum fluviatile* community (S10).

The species list from the current survey is similar to those produced from earlier surveys, including a survey by Wade (1978) and White (1980) (Table N.6). However, there does not appear to be a previous record for *Potamogeton obtusifolius*, while White recorded *Potamogeton berchtoldii* which was not observed on this survey.

Applying the currently species list to the classification scheme of Palmer (1992), the Llynnau Mymbyr are ranked as Type 3, an oligotrophic, boulder dominated category. The trophic ranking score is 5.60.

4.4.7 Gloyw Lyn

The aquatic macroflora of Gloyw Lyn (Table G.4, Figures G.2 - G.3) is represented by three main assemblages, largely determined by the extent of habitat exposure, which are indicative of an acid and nutrient poor water body.

The shoreline around the north end of the lake is boulder dominated and very exposed to the action of wind and waves, and as a result there are few locations where suitable substrates have developed which can support higher plants. However in some relatively sheltered locations, a shallow water association of *Littorella uniflora* and *Lobelia dortmanna* forms a dense cover, occasionally in association with *Ranunculus flammula* and *Sphagnum auriculatum*. Likewise, the main basin of the lake is also boulder strewn and here only *Isoetes lacustris* is present in limited patches. In the far north end of the lake, *I. lacustris* grows to a maximum depth of 3.8 m. Individual plants resembling *Isoetes echinospora* were also recovered from Gloyw Lyn but were not positively verified due to the absence of diagnostic megaspores.

The south end of the lake is more sheltered and occupied by emergent vegetation growing on muddy substrates. The far south end is dominated by *Carex rostrata* swamp, while the shoreline which is fringed by *Sphagnum* sp., *Juncus effusus* and *Myrica gale*. *Menyanthes trifoliata* is also present in one location. In deeper water toward the centre of the lake, this swamp community grades into another dominated by *Equisetum fluviatile*, within which there are small areas of *Potamogeton natans* and *Sparganium angustifolium*. At the boundary of the swamp and open water, *Utricularia* sp. is locally abundant.

The apparent absence of *Juncus bulbosus* var. *fluitans* at Gloyw Lyn is perhaps surprising in the context of the other species recorded. Applying the species list to the scheme of Palmer (1992) Gloyw Lyn is classified as Type 3, a boulder dominated oligotrophic category. The trophic ranking score is 5.28. The NVC communities represented include the *Littorella* *uniflora - Lobelia dortmanna* and *Isoetes lacustris* aquatic communities (A23 and A24) and the *Carex rostrata* and *Equisetum fluviatile* swamp communities (S9 and S10).

4.4.8 Llyn yr Wyth Eidion

Llyn yr Wyth Eidion (Table H.4, Figure H.2) is fringed by a fen association of *Phragmites australis*, *Cladium mariscus* and *Carex elata*. *Scirpus lacustris* var. *lacustris* is locally abundant and part of the shoreline is ringed by *Salix* trees, many of which have died since a recent increase in water level at the site. Dense growth of a species of red alga, *Batrachospermum* sp. were found attached to the submerged stems of the *Carex elata* stands A band of *Nuphar lutea* and to a lesser extent *Nymphaea alba* ring the open water perimeter of the lake and at the time of visit the outer limit of aquatic macrophyte colonisation was dominated by large submerged basal leaves of *N.lutea*. *Hippuris vulgaris* and the charophyte *Chara virgata* occur in very limited patches between 1-2 m water depth. Given the clarity of the water (secchi disc depth = 5.7 m) the absence of any macrophyte development below the depth of *N.lutea* colonisation of approximately 3 m is surprising. However the sides of the lake basin shelve steeply and therefore plant colonisation may be restricted by the lack of substrate stability. Llyn yr Wyth Eidion was included in a recent survey of Welsh Stoneworts for the Countryside Council for Wales (Stewart, 1997) (Table N.8) when *Chara virgata* was the only charophyte recorded. Stewart refers to records for *Chara rudis* and *Chara pedunculata* from the 1880s and 1890s and suggests they have been lost due to eutrophication. In 'a Nature Conservation Review' (Ratcliffe, 1977) the site was reported to contain *Chara rudis* and *Chara acculeolata* but otherwise the species list is in close agreement with that provided by the current survey.

According to the current species list the site is classed as Type 9, a 'mainly eutrophic, sometimes marl' category according to Palmer (1992). The trophic ranking score is 7.38.

4.4.9 Llyn Cau

Llyn Cau is characterised by a species poor aquatic macrophyte flora typical of cold, nutrient poor acid lakes in the north and west of Britain (Table I.4, Figures I.2 - I.3). Despite the exceptional transparency of the water, vascular macrophytes are restricted to a maximum depth of approximately 3.0 m although some aquatic moss and liverwort species are present in deeper water locations.

Shallow water of this boulder dominated lake is mainly occupied by liverworts and mosses, including *Sphagnum auriculatum* and *Rhytidiadelphus squarrosus,* although *Littorella uniflora* is locally abundant in places where finer substrate is present. The more gradual slopes, between a water depth of 0.5 m and 3.0 m are covered in an association of *Isoetes lacustris*, *Callitriche hamulata* and *Juncus bulbosus* var. *fluitans*, the latter being most abundant adjacent to inflow streams.

The macrophyte flora of Llyn Cau was recorded during an NCC survey in 1989 (Table N.9), however it appears that this was confined to shoreline surveillance only as there is no record of *I.lacustris.* Interestingly, there is also no record of *Juncus bulbosus* var. *fluitans* from the 1989 work while this species is locally abundant in some littoral locations today. There are no records of species which were not found on the current survey. Application of the scheme of

Palmer (1992) to the species list classifies Llyn Cau as Type 1, a boulder dominated oligotrophic category. The trophic ranking score is 5.16.

4.4.10 Llyn Llagi

Llyn Llagi is characterised by a flora typical of moderately acid, nutrient poor lakes in upland parts of Britain (Table J.4, Figures J.2 - J.3). The lake is ringed by moorland vegetation dominated at the shoreline by *Juncus effusus*. *Lobelia dortmanna* is the dominant macrophyte in gently sloping areas of shallow water on the outflow side of the lake and on the west side it grows in association with *Juncus bulbosus* var. *fluitans*. Deeper water is dominated by *Isoetes lacustris* which reaches a maximum water depth of approximately 2.8 m, with occasional *Sphagnum auriculatum* and *Myriophyllum alterniflorum*. *Sparganium angustifolium* forms considerable floating leaved stands close to the north-east shore.

Llyn Llagi has been subject to bi-annual macrophyte surveys by the United Kingdom Acid Waters Network (UKAWMN) since 1988, and during this time there has been no change observed in species presence / absence or abundance, with the possible exception of a slight increase in the extent of *J. bulbosus* var. *fluitans*, a species which favours enhanced levels of Nitrogen. An earlier survey of Wade (1980) (Table N.10) also recorded the presence of *Callitriche hamulata* which has not been recorded by the UKAWMN.

Llyn Llagi is classified as Type 3, a boulder dominated oligotrophic category according to the scheme of Palmer (1992), and has a trophic ranking score of 5.02.

4.5 Littoral Cladocera

A total of 40 taxa were identified from the 51 samples collected from the ten study sites. Only 4 taxa were recorded from Llyn Llagi, with one sample containing only a single specimen of *Alonopsis elongata*. In contrast, a total of 14 taxa were recorded from Hanmer Mere, Llyn Tegid and Llynnau Mymbyr. These results reflect the tendency for the most diverse assemblages to occur in lowland sites, as noticed in earlier project phases. The results are given in full in Appendices A - J, Table 5.

As in previous phases of this project, *Chydorus sphaericus* and *Alona affinis* were the most frequently occurring taxa but they were not found in the high altitude, oligotrophic systems of Llyn Cau and Llyn Llagi. Notable species recorded during this project phase include *Daphnia magna* in Hanmer Mere, *Bythotrephes longimanus* in Llyn Alwen, *Simocephalus serrulatus* in Llyn Rhos Ddu, *Macrothrix laticornis* and *Streblocerus serricaudatus* in Llynnau Mymbyr, and *Lathonura rectirostris* in Llyn Yr Wyth Eidion. Of these species, only *S. serricaudatus* was recorded in earlier phases of the project from Llyn Eiddwen and Llyn Idwal.

The relatively large bodied *Daphnia magna* is known to occur in small, alkaline, chemically 'rich' ponds and the littoral regions of larger waterbodies (Potts and Fryer, 1979; Fryer, 1993) and it has been recorded from other meres on the Shropshire-Cheshire Plain. It was described as "rather rare" by Scourfield and Harding (1966). It is likely to play an important role in phytoplankton control in Hanmer Mere where it was abundant in some samples.

Bythotrephes longimanus is usually a component of the open water plankton but a small number were present in the samples taken from the littoral near the outflow of Llyn Alwen. *Simocephalus serrulatus* is also considered rare (Scourfield and Harding, 1966) but it has been recorded from another site on Anglesey (J. Bratton, pers. comm.). *Macrothrix laticornis* is an uncommon but widely distributed cladoceran in Britain (Scourfield and Harding, 1966). It usually frequents sites with sandy substrates (Scourfield and Harding, 1966) and its occurrence in Llynnau Mymbyr is therefore consistent with this ecological requirement. In Britain, *Streblocerus serricaudatus* usually occurs amongst vegetation, especially *Sphagnum*, in swamps, pools, and margins of lakes (Scourfield and Harding, 1966). It is considered rare but widely distributed (Scourfield and Harding, 1966). It was recorded from only one site in Llynnau Mymbyr (No. 4) which had relatively diverse vegetation structure. *Lathonura rectirostris* is also rare in Britain (Scourfield and Harding, 1966; Fryer, 1993). A single specimen was found associated with *Nuphar lutea* and *Carex* sp. in Llyn Yr Wyth Eidion.

Previous Cladocera records exist for a number of the sites including Hanmer Mere (see appendix in Goldspink et al., 1997), Llyn Tegid (e.g. Galliford, 1953; Pugh-Thomas, 1959, Scourfield, 1895; Williams, 1949), Llyn Llagi and Llyn Cau (Green, 1996).

4.6 Open water zooplankton

29 crustacean species, 6 species of rotifer and 1 insect species (Chaoboridae) were found in 10 Welsh lakes investigated during the Phase IV survey. Most species had been found at sites in earlier phases of the project; 4 species of crustacean were recorded for the first time but of these only *Daphnia magna* are truly planktonic, and their distribution amongst sites appears

random. The complete species list for each site is presented in Appendices A - J Table 6, while some sample characteristics are presented in Table 7.

Eudiaptomus gracilis was once more the most common species. There is no clear explanation for its absence from Llyn Cau and Gloyw Lyn (cf. niche characteristics in the Phase III report), although seasonality or low calcium/pH levels may be important factors. *E. gracilis* is clearly the most widespread species in context of the entire project, being one of the dominant species in 27 out of 31 lakes.

The second most common species, *Diaphanosoma brachyurum*, was recorded in 8 of the Phase IV sites. Its absence in the Anglesey lakes is consistent with its considered preference for slightly acid conditions (cf . niche characteristics in the Phase III report). *D. brachyurum* was found in 22 lakes in total.

Daphnia spp. can be considered the third most common 'group', having been found in a total of 18 lakes. Some large-sized species have significant value as indicators of alkaline conditions and reduced fish populations. The occurrence of the large bodied *D. magna* and *D. pulicaria* in Hanmer Mere probably account for the maintenance of relatively clear water (i.e. low algal concentration) at this site despite the high concentration of nutrients. The reduced population of planktivorous fish is an inevitable assumption for these species to survive. A similar example is provided by Llyn yr wyth Eidion where the zooplankton is dominated by *D. pulicaria*.

4.7 Littoral macroinvertebrates

A list of the macroinvertebrate species found and their abundances are presented in the Appendices A - J Table 5. Abundances have been standardised to mean numbers per minute. The macroinvertebrate species list for Llyn Llagi is taken from the 1996 spring sample from the United Kingdom Acid Waters Monitoring Network. The standard kick sampling methodology could not be applied at Gloyw Lyn because the littoral habitat was boulder dominated. At this site, the sampling net was scraped on the under surface of raised boulders, and in some cases boulders were turned over to disturb the substratum.

Macroinvertebrates were reasonably abundant in the littoral zones of all lakes other than Gloyw Lyn and Llyn Cau. The greatest numbers of individual invertebrates were recorded at Llyn Glasfryn and Hanmer Mere, whereas the highest values for 'minimum species richness' (ie. the total number of species recorded) were recorded at the two Anglesey lakes, Llyn yr Wyth Eidion (37) and Llyn Rhos Ddu (35).

Lowest 'minimum species richness' was recorded at Llyn Cau (7) Gloyw Lyn (8) and Llyn Alwen (9). Gloyw Lyn and Llyn Cau both yielded small numbers of individuals but macroinvertebrates were reasonably abundant in Llyn Alwen. No leeches or gastropod molluscs were found at these sites. The dominant group was the Chironomidae. Oligochaetes and the acid tolerant, net spinning caddis *Polycentropus flavomaculatus* were also found. Oulimnius species were abundant in Alwen, leptophlebid mayflies typical of acid waters were represented in Llyn Alwen and Gloyw Lyn and the acid tolerant Plectrocnemia species was recorded for Llyn Cau. The species assemblage at these lakes, all of which are upland sites, are therefore generally characteristic of lakes of low pH.

'Minimum species richness' was notably higher for Llynnau Mymbyr than for the latter three sites. The acid tolerant leptophlebid mayflies formed the most abundant group. No gastropod molluscs and relatively few leeches were recorded but a range of predatory insects was represented, including *Polycentropus flavomaculatus.* The species assemblage of Llynnau Mymbyr are thus indicative of a less acid environment then the sites mentioned above.

The dominant species recorded from Llyn Tegid was the mayfly *Caenis luctuosa*. Many of the species represented at this site, such as the caenid, leptophlebid and emphemerid mayflies, live in mud and silt and many feed on detritus and periphyton. Malacostraca and the bivalve *Pisidium* species feed on detritus while the caddis *Tinodes waerneri* is a grazer. The food web in Llyn Tegid is likely to be strongly dependent on detritus and attached algae.

The highest number of individuals was recorded at Llyn Glasfryn, the dominant taxon comprising the Oligochaeta which accounted for more than 70 % of the total. The majority of oligochaetes are deposit feeders although some can be carnivorous. Leeches were well represented and the gastropod mollusc *Potamopyrgus jenkinsi* was also recorded. The second most abundant taxon was the detrivore *Asellus meridianus*. *Pisidium*, which is a filter feeder on detritus were also relatively abundant. In comparison with the other sites form Phase IV, the assemblage present in this lake appears to reflect an intermediate nutrient-richness.

The two lakes with the highest minimum species richness were the two Anglesey sites, Llyn Rhos Ddu and Llyn yr Wyth Eidion. The most numerous groups represented were the Oligochaeta in Llyn Rhos Ddu and the Chironomidae in Llyn yr wyth Eidion. A diverse assemblage of molluscs, leeches, Malacostraca and insects, characteristic of a productive lake, was recorded at both sites. The lepidoptera found in Llyn Rhos Ddu probably reflect the extensive and diverse macrophytes at this site as does the variety of gastropod molluscs which graze periphyton growing on plants. Llyn Rhos Ddu also had a diverse assemblage of the mainly predatory Corixidae (Hemiptera). During the macrophyte sampling exercise at this site in July, the medicinal leech (*Hirudo medicinalis*) was observed in abundance but it was not recorded during the macroinvertebrate survey.

Adult Hemiptera were found at five sites, Gloyw Lyn, Llyn Glasfryn, Hanmer Mere, Llyn Rhos Ddu and Llyn yr Wyth Eidion, while immature specimens which could not be identified to species level were recorded in Llyn Tegid. As noted in the Phase III report, the distribution of certain Hemipteran species is worth comment although some caution is required in the interpretation of results. The distribution data quoted are from Savage (1989).

Two species were only recorded from Gloyw Lyn: *Sigara scoti* and *Callicorixa wollastoni*. Both species are most frequently found in waters with a conductivity of < 100 $\mu S\ cm^{-1}$ and at a pH of < 6.0. *Callicorixa praeusta* and *Corixa punctata* are more frequently found in waters with a pH > 6.0 while *Sigara concinna*, *S. falleni* and *S. dorsalis* were not listed by Savage as occurring in waters with a pH < 6.0. Savage does not record *S. concinna* or *S. falleni* in lakes with a conductivity of < 100 $\mu S\ cm^{-1}$ and *C. praeusta* and *C. punctata* are more frequently found in waters with a conductivity above this level. The distribution patterns for Hemipterans with regard to pH and conductivity are therefore generally consistent with the findings of Savage although *S. dorsalis* was found in the relatively acid Gloyw Lyn. It is possible that this species is at the very edge of its environmental niche.

In the Phase II study, lakes were divided into groups according to their macroinvertebrate fauna:

ie. 1 upland, species poor lakes
2 intermediate species richness but no Malacostraca
3 intermediate species richness, dominated by Malacostraca
4 very high species richness

Few of the Phase IV sites fall easily into these categories:

- Gloyw Lyn [8], Llyn Cau [7] and Llyn Alwen [9] are all upland sites with very poor species richness so clearly fit group 1.
- Llynnau Mymbyr [20] is relatively species poor, although more diverse than the above sites, with no Malacostraca, so could be considered on the lower borderline of Category 2.
- The remaining sites could probably be included in Category 3 based on their minimum species richness, although Malacostraca did not form the dominant group at any of these sites. A similar observation was made for Llangorse Lake in Phase III.

The current system is difficult to apply for a large number of the 31 sites in this project. It is therefore clear that further consideration of the macroinvertebrate data from all four Phases in relation to physico-chemistry is necessary so that a more appropriate classification can be established.

5 Summary and discussion

The ten lakes included in Phase IV of the Integrated Classification and Assessment of Lakes project exhibit a broad range of physical and chemical characteristics. For example: lake volume (Llyn Tegid 85,000 x 10^6 m^3 - Llyn Rhos Ddu 12 x 10^6 m^3); altitude (Llyn Cau 470m - Llyn Rhos Ddu 5m); lake water residence time (Llyn Cau 777 days - Llynnau Mymbyr 12 days); mean alkalinity (Llyn yr Wyth Eidion 3997 μeq l^{-1} - Llyn Alwen--19 μeq l^{-1}); mean Nitrate (Llyn yr Wyth Eidion 1937 μN l^{-1} - Gloyw Lyn 30 μgN l^{-1}) and mean TP (Hanmer Mere 1806 μg P l^{-1} - Llyn Llagi 3 μg P l^{-1}). The sites also show a wide range of biological assemblages, ranging from species poor sites, often characterised by an Isoetid dominated macroflora, e.g. Llyn Llagi, to species rich sites often with a variety of emergent, floating leaved and submerged macrophyte such as Llyn Glasfryn.

Application of a variety of existing lake classification schemes (described in the Phase I report) to the Phase IV data-set leads to a variety of site groupings (see Table 5.1). The majority of the upland, nutrient poor sites group together using several schemes. For example, Llynnau Mymbyr, Gloyw Lyn and Llyn Cau are all Class I (Dillon and Rigler 1975), occasionally acid (UKAWRG 1989), and oligotrophic (Palmer 1992), and all three highlight an apparent discrepancy between Critical Load exceedance models for Total Acidity, being 'not exceeded 'according to the Henriksen Model but 'exceeded' according to the Diatom Model. Llyn Alwen and Llyn Llagi are also oligotrophic according to Palmer. However, both these sites are permanently acid (UKAWRG) and exceeded according to both Critical Load exceedance models. Llyn Llagi is placed in Class II of the Dillon and Rigler scheme on account of relatively elevated levels of chlorophyll *a*.

The OECD scheme highlights some differences in the physico-chemical characteristics of the five sites discussed above. Llynnau Mymbyr, Gloyw Lyn and Llyn Llagi class as oligotrophic, but Llyn Alwen does not fit well into any of the classes due to relatively high TP and low secchi disc measurement, while Llyn Cau is classed as ultra-oligotrophic on the grounds of exceptionally low chlorophyll *a* and TP concentration and large secchi disc depth.

The Dillon and Rigler Class I grouping, which is solely based on chlorophyll *a* concentration, is not restricted to the broadly 'oligotrophic' set of sites discussed so far, but includes Llyn yr Wyth Eidion, a reed fringed calcareous mire with exceptionally high levels of nitrate. This site probably has high primary productivity, but phytoplankton levels are kept low by grazing of a diverse and abundant zooplankton population. The macrophyte typing scheme of Palmer includes Llyn Tegid as oligotrophic (Type 3), despite the presence of species such as *Elatine hexandra* and *Eleocharis acicularis* which favour moderate levels of nutrients. This typing appears at odds with a relatively high Trophic Ranking Score of 7.1, also derived from the macrophyte species list. The prediction of an exceedance of the Critical Load for Acidity (Diatom Model) at this site can be discounted, since the Model was developed for upland systems and assumes no catchment sources of nitrogen. It is interesting to note that while the Palmer scheme places Llyn yr Wyth Eidion and Llyn Tegid at either end of the trophic spectrum both sites are classed as mesotrophic according to the OECD scheme.

Hanmer Mere, Llyn Glasfryn and Llyn yr Wyth Eidion are classed as Type 9 and Llyn Rhos Ddu Type 8, both eutrophic categories according to Palmer. All sites are, unsurprisingly, 'never acid' (UKAWRG), have high Critical Loads and are 'not exceeded' according to Critical Loads Models. However these lakes differ markedly in their chlorophyll *a* concentrations and according to Dillon and Rigler, are classed II, IV, I and III respectively. According to the OECD classification Llyn Glasfryn is classed hyper-eutrophic, Llyn yr Wyth Eidion mesotrophic and Llyn Rhos Ddu eutrophic. Hanmer Mere is probably best placed in the hyper-eutrophic category on the basis of its particularly high TP concentrations. However chlorophyll *a* concentrations are low, probably as a result of intense zooplankton grazing at this site where fish predation is very restricted. This again highlights the problem of using chlorophyll *a* as a means of classifying lake trophic status.

A number of interesting species observations were made during the Phase IV survey. The recording of the nationally scarce *Luronium natans* in relative abundance in Llyn Tegid is noteworthy, as is what appears to be the first record for *Nitella translucens* at this site (Stewart pers. comm). Although fish surveys have not been included in this project, Llyn Tegid is also home to the endemic sub-species *Coregonus laveratus.* Another nationally scarce macrophyte species, the charophyte *Nitella gracilis* was recorded for the first time in Llynnau Mymbyr, whilst the medicinal leech *Hirudo medicinalis* was observed (although not detected during the macro-invertebrate survey) at Llyn Rhos Ddu.

The Integrated Classification and Assessment of Lakes in Wales project has now completed surveys of 31 lakes. Water chemistry, physical details and species lists have been compiled, screened and entered on the project database. The next stage of the project will be to apply the data in the development of a new integrated classification system following statistical techniques outlined in the Phase I report.

Table 5.1 Site classification based on existing schemes

Classification scheme	Hanmer	Tegid	Alwen	Glasfryn	Rhos Ddu	Mymbyr	Gloyw	Eidion	Cau	Llagi
Thermal mixing (Lewis 1983)	discontinuous warm polymictic	warm monomictic	warm monomictic	continuous warm polymictic	continuous warm polymictic	discontinuous warm polymictic	warm monomictic	warm monomictic	warm monomictic	warm monomictic
Dillon and Rigler (1975)	Class II	Class II	Class I	Class IV	Class III	Class I	Class I	Class I	Class I	Class II
OECD (1982)	problematic	mesotrophic	problematic	hypereutrophic	eutrophic	oligotrophic	oligotrophic	mesotrophic	ultra-oligotrophic	oligotrophic
UKAWRG (1989)	never acid	never acid	permanently acid	never acid	never acid	occasionally acid	occasionally acid	never acid	occasionally acid	permanently acid
Critical load for total acidity (Henriksen model) (keq H^+ ha^{-1} yr^{-1})	6.1	2.0	0.8	7.1	13.8	3.2	1.5	32.0	1.8	0.8
Critical load exceedance for total acidity (Henriksen model) (keq H^+ ha^{-1} yr^{-1})	not exceeded	not exceeded	0.6	not exceeded	not exceeded	not exceeded	not exceeded	not exceeded	not exceeded	0.8
Critical load for total acidity (diatom model) (keq H^+ ha^{-1} yr^{-1})	18.9	1.6	0.4	6.2	31.9	0.9	0.8	65.0	0.8	0.5
Critical load exceedance for total acidity (diatom model) (keq H^+ ha^{-1} yr^{-1})	not exceeded	0.4	1.0	not exceeded	not exceeded	0.8	0.4	not exceeded	0.5	1.3
Palmer *et al.* (1992) Site type	9	3	3	9	8	3	3	9	1	3
Category	eutrophic	oligotrophic	oligotrophic	eutrophic	eutrophic	oligotrophic	oligotrophic	eutrophic	oligotrophic	oligotrophic
Trophic Ranking Score	8.8	7.1	5.2	7.5	8.8	5.6	5.3	7.4	5.2	5.0
National Vegetation Classification (Rodwell 1995) Community types	A5,A8,S13	no classes	A22,A23	A8,A10,A13	A13,A5,S14	A9,A22,A23, S9,S10	A23,A24,S9, S10	A8, S1, S4,S8	A22, A23, A24	A22,A23

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Table A.1 Hanmer Mere water chemistry

Determinand	Sample				
	11/07/96	23/09/96	14/01/97	03/04/97	mean
lab pH	7.68	7.57	7.63	7.79	7.66
field pH		7.78	7.80		
Alkalinity 1 (μeq l^{-1})	1633	1753	1705	1650	1685
Alkalinity 2 (μeq l^{-1})	1652	1778	1725	1675	1708
lab conductivity (μS cm^{-1})	350	362	363	357	358
field conductivity (μS cm^{-1})	350	420	455	315	385
Sodium (μeq l^{-1})	1088	1123	1098	1112	1105
Potassium (μeq l^{-1})	311	333	337	333	329
Magnesium (μeq l^{-1})	751	775	759	785	768
Calcium (μeq l^{-1})	1513	1458	1495	1556	1506
Chloride (μeq l^{-1})	1288	1342	1320	1366	1329
Aluminium total monomeric (μg l^{-1})	3	4	4	4	4
Aluminium non-labile (μg l^{-1})	3	3	4	4	4
Aluminium labile (μg l^{-1})	0	1	0	0	0.3
Absorbance (250nm)	0.344	0.345	0.340	0.329	0.340
Carbon total organic (mg l^{-1})	14.0	15.9	14.1	14.3	14.6
Phosphorous total (μg P l^{-1})	1394	2382	1798	1652	1806
Phosphorous total soluble (μg P l^{-1})	1308	2313	1438	1455	1628
Phosphorous soluble reactive (μg P l^{-1})	1220	2248	1403	1445	1579
Nitrate (μg N l^{-1})	7	75	521	321	231
Silica soluble reactive (mg l^{-1})	2.7	3.4	5.9	0.9	3.2
Chlorophyll *a* (μg l^{-1})	4.8	7.5	1.4	1.8	3.9
Sulphate (μeq l^{-1})	285	220	273	323	275
Copper total soluble (μg l^{-1})	0	0	0	0	0
Iron total soluble (μg l^{-1})	40	50	60	110	65
Lead total soluble (μg l^{-1})	0	0	0	0	0
Manganese total soluble (μg l^{-1})	5	29	15	31	20
Zinc total soluble (μg l^{-1})	0	0	0	0	0

Table A.2 Hanmer Mere epilithic diatom taxon

TAXON	Relative frequency (%)
Achnanthes minutissima	9.5
Aulacoseira granulata	9.5
Cocconeis placentula	23.8
Gomphonema parvulum	4.8
Gomphonema sp.	9.5
Navicula cryptotenella [var. 1]	9.5
Nitzschia palea var.*palea*	9.5
Nitzschia paleacea	9.5
Stephanodiscus parvus	4.8
Synedra tabulata (Ag.)	9.5

Table A.3 Hanmer Mere surface sediment diatom taxon list (including taxa >1%)

TAXON	Relative frequency (%)
Achnanthes conspicua	1.1
Aulacoseira granulata	2.5
Cyclostephanos [cf. *tholioformis*]	1.1
Fragilaria pinnata var.*pinnata*	1.4
Stephanodiscus hantzschii	6.5
Stephanodiscus parvus	81.2

Table A.4 Hanmer Mere aquatic macrophyte abundance summary: 11-7-96

Taxon	code	Abundance
Emergent taxa		
Eleocharis palustris	382004	O
Iris pseudacorus	382901	O
Sparganium erectum	384603	O
Typha angustifolia	384901	F
Typha latifolia	384902	R
Floating leaved taxa		
Nuphar lutea	365501	A
Nymphaea alba	365601	O
Polyganum amphibium	366501	O
Submerged taxa		
Cladophora sp.	170099	F
Ceratophyllum demersum	361401	A
Lemna trisulca	383304	O
Potamogeton berchtoldii	384003	A
Potamogeton crispus	384006	F
Zannichelia palustris	385201	R

Table A.5 Hanmer Mere littoral Cladocera taxon list: 11-7-96

Taxa	Sample number				
	1	2	3	4	5
	number of individuals				
Acroperus harpae		1			1
Alona affinis				1	+
Chydorus sphaericus		80		1	+
Daphnia hyalina		21	495	36	44
Daphnia magna	50	3		115	1054
Daphnia pulex				45	
Eurycercus lamellatus		599		8	
Monospilus dispar				2	
Pleuroxus aduncus		73		1	4
Pleuroxus trigonellus			1		
Pleuroxus truncatus	26	3			
Scapholeberis mucronata					42
Simocephalus vetulus		5			
Total count	76	785	496	994	1145

Table A.6 Hanmer Mere zooplankton abundance summary: 11-7-96

Taxon	Count
Ceriodaphnia dubia	x
Daphnia galeata	50
Daphnia magna	170
Daphnia pulex	220
Eudiaptomus gracilis	840
Eurycercus lamellatus	x
Macrocyclops albidus	x
Mesocyclops leuckarti	50
Simocephalus exspinosus	x
other planktonic organisms (not quantitatively sampled)	
Volvox	4070
Chaoborus sp.	20

X = rare species with relative abundance below 1%
x = very rare species found only at one site

Table A.7 Hanmer Mere zooplankton characteristics

Site depth (m)	5.5
Total zooplankton biomass excluding Chaoborus larvae(g DW m^{-2})	1.17
Chaoborus biomass (g DW m^{-2})	0.25
Net algal biomass (g DW m^{-2})	1.6
Cladoceran biomass as proportion of total zooplankton biomass (%)	69
Large cladoceran (>710µm) as proportion of total zooplankton biomass	43
Large Copepoda (>420µm) as proportion of total zooplankton biomass	6

Table A.8 Hanmer Mere littoral macroinvertebrate summary: 23-9-96
Mean numbers of individuals per one minute kick/sweep sample.

code	Taxon	Mean count/sample
	TURBELLARIA	
03120000	Tricladida	27.6
	MOLLUSCA	
13070107	*Lymnaea peregra*	0.8
	BIVALVIA	
14030200	*Pisidium* sp.	32.0
16000000	OLIGOCHAETA	182.8
	HIRUDINEA	
17020101	*Theromyzon tessalatum*	1.6
17020301	*Glossiphonia heteroclita*	2.0
17020302	*Glossiphonia complanata*	0.8
17020401	*Bratrachobdella paludosa*	1.6
17020501	*Helobdella stagnalis*	45.6
17040102	*Erpobdella octoculata*	10.8
19000000	HYDRACARINA	2.4
	MALACOSTRACA	
28030101	*Asellus aquaticus*	276.0
	EPHEMEROPTERA	
30020301	*Cloeon dipterum*	96.4
30080204	*Caenis horaria*	315.2
	HEMIPTERA	
33110000	Corixidae sp. - immatures	84.0
33110401	*Callicorixa praeusta*	0.8
33110702	*Arctocorisa germari*	2.0
33110810	*Sigara concinna*	9.6
	COLEOPTERA	
35010000	Haliplidae sp. - larvae	2.4
35110600	Oulimnius sp. - larvae	1.2
	TRICHOPTERA	
38040201	*Tinodes waeneri*	0.4
38120000	Leptoceridae sp.	0.8
	DIPTERA	
40080000	Ceratopogonidae	174.4
40090000	Chironomidae	69.6

Figure A.1 Hanmer Mere: sample location and substrate map

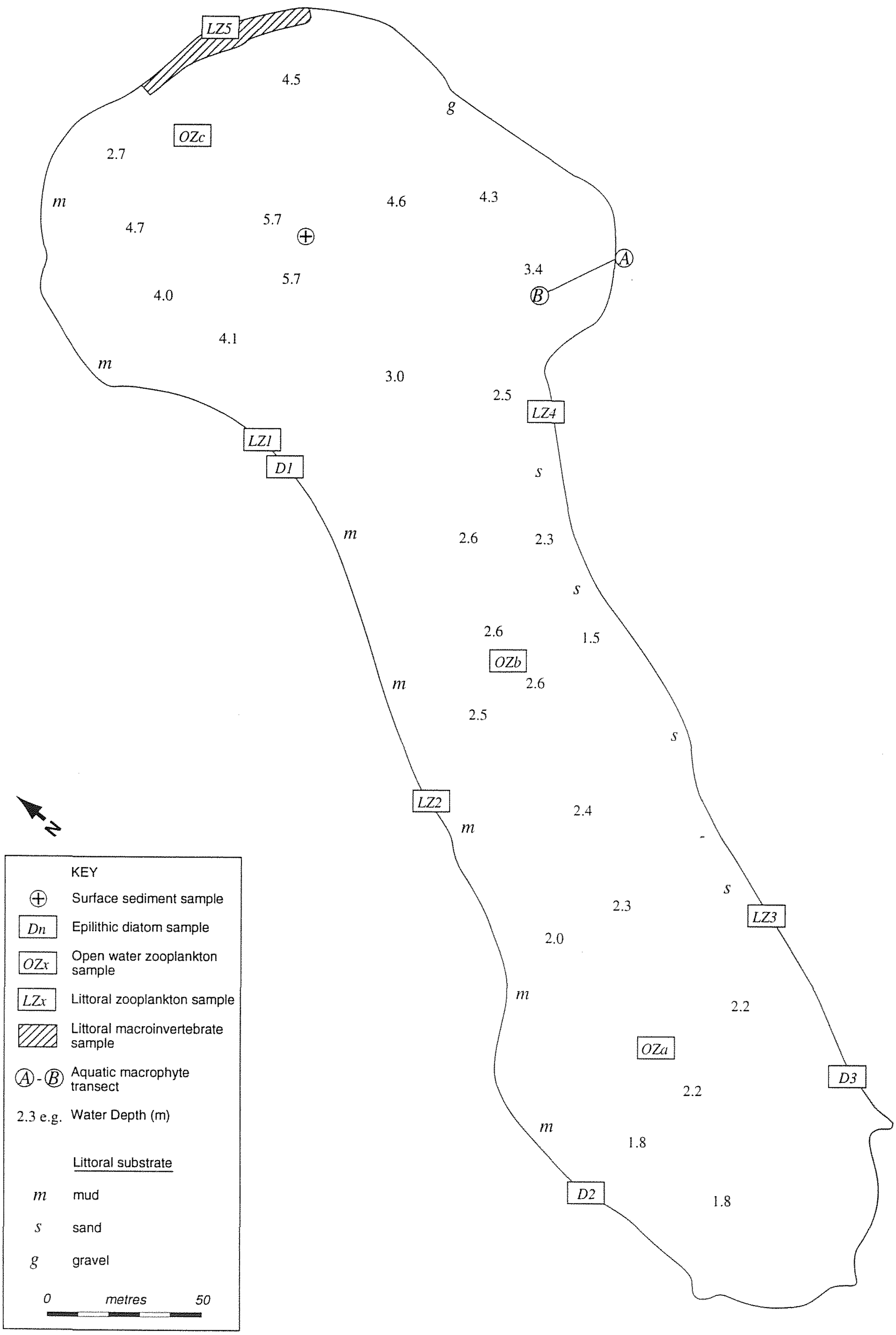
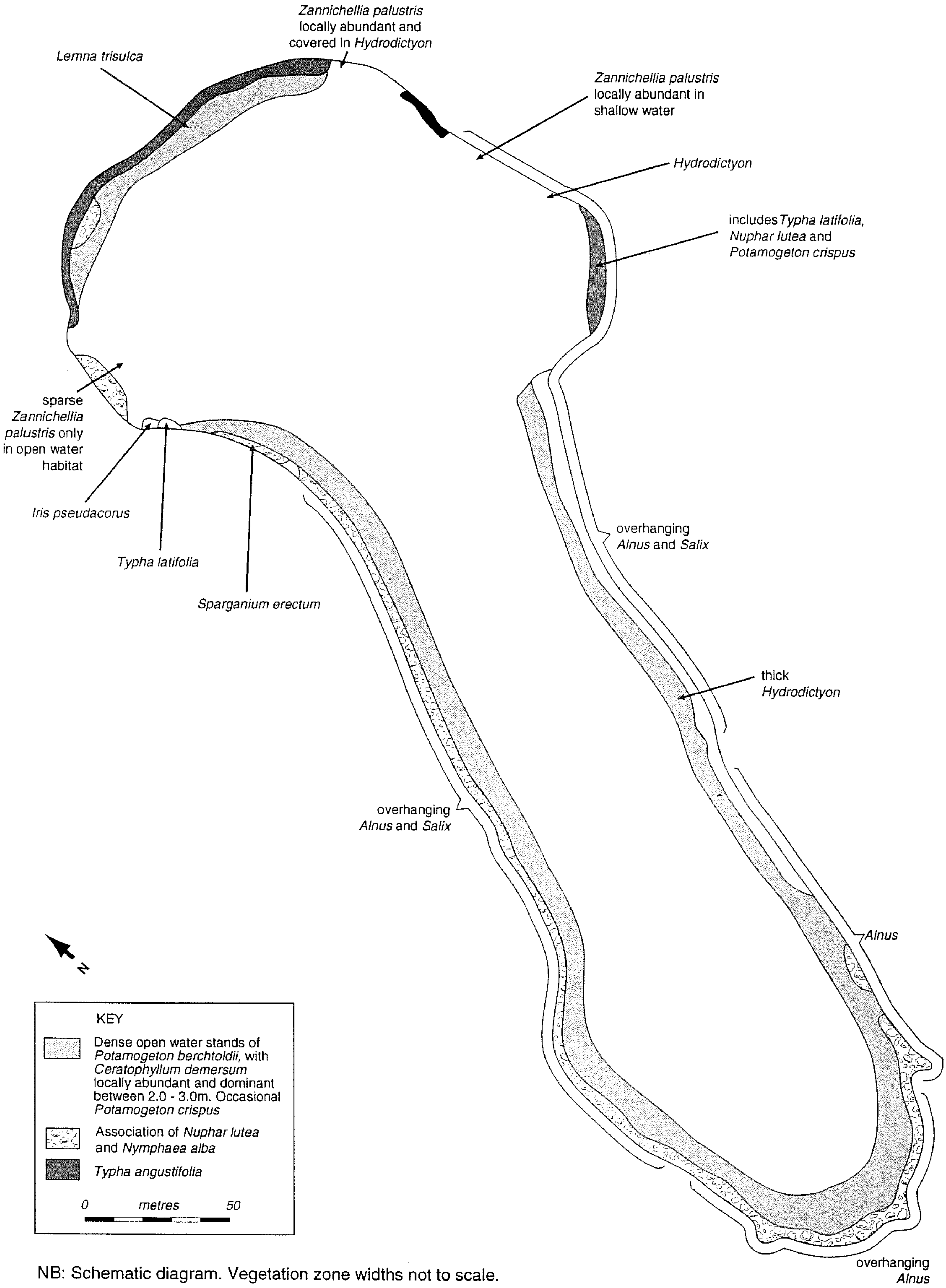


Figure A.2 Hanmer Mere: aquatic macrophyte distribution map: 11-7-96



NB: Schematic diagram. Vegetation zone widths not to scale.

Figure A.3 Hanmer Mere: aquatic macrophyte transect profile

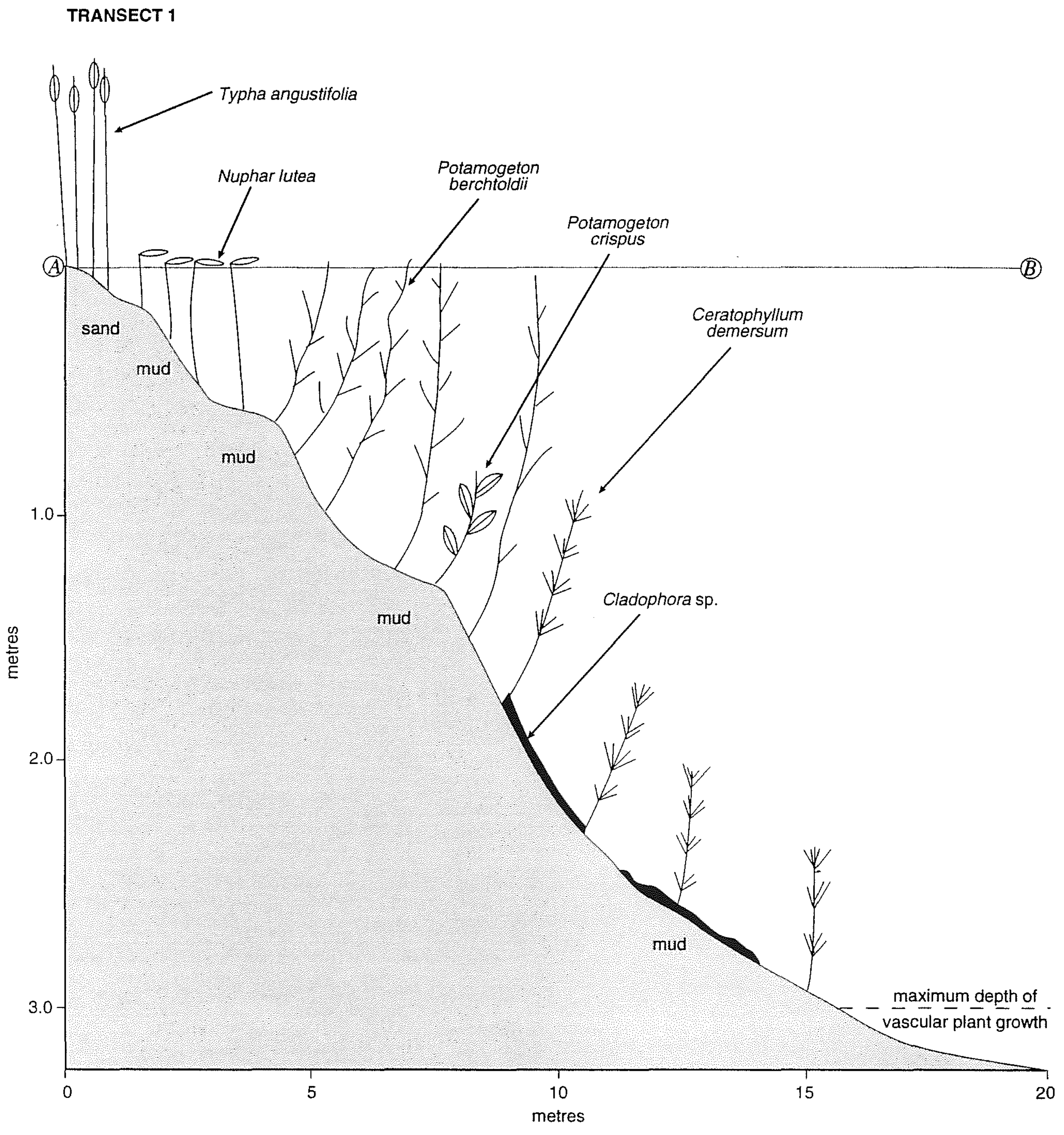


Figure A.4 Hanmer Mere: Temperature and dissolved oxygen profiles 11-7-96 (Temperature °c- solid circles, Oxygen mg l^{-1}- empty boxes)

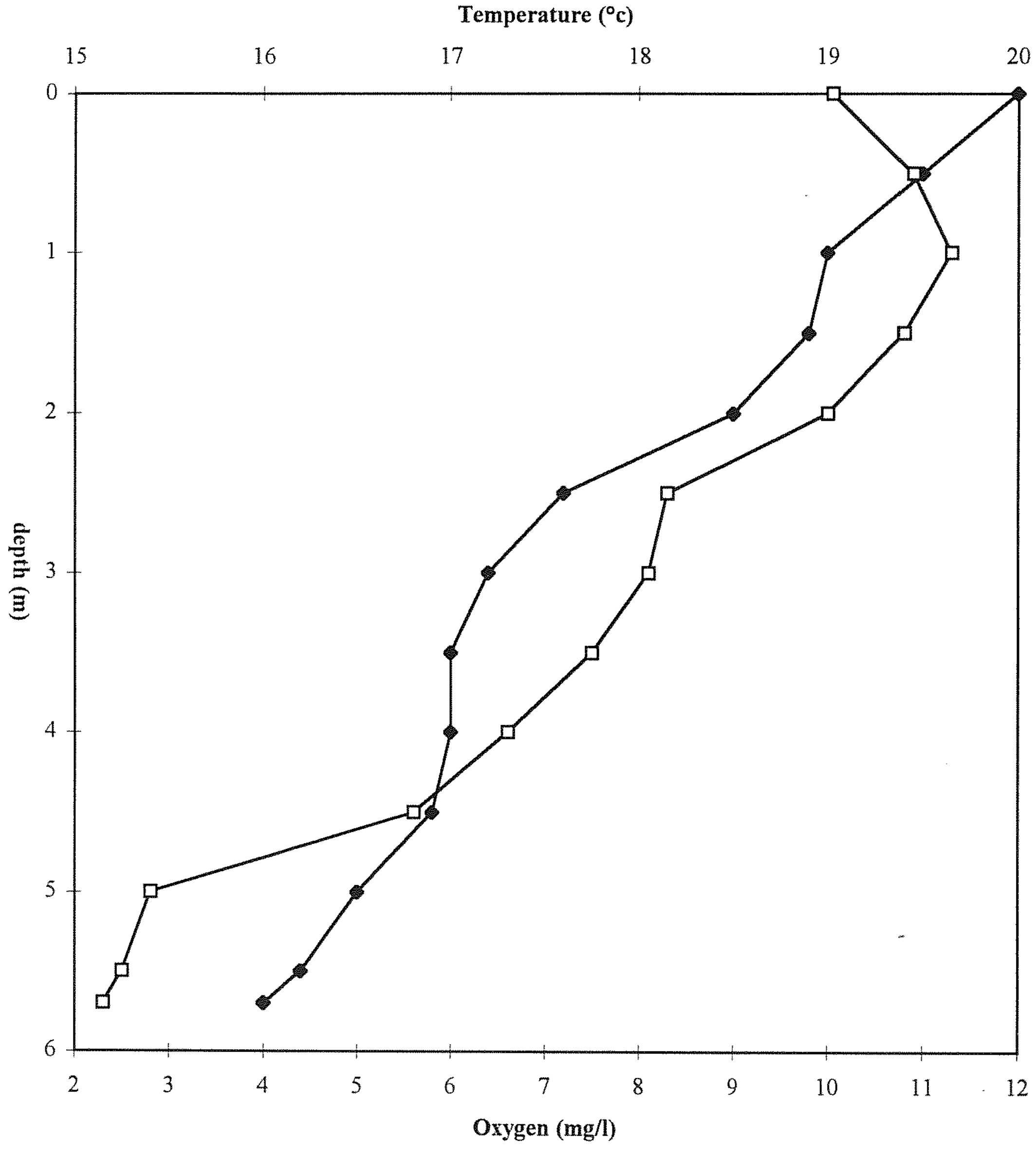


Table B.1 Llyn Tegid water chemistry

Determinand	Sample				
	13/07/96	23/09/96	14/01/97	03/04/97	mean
lab pH	6.35	6.68	6.65	6.06	6.36
field pH		7.44	6.63		
Alkalinity 1 (μeq l^{-1})	87	102	81	29	75
Alkalinity 2 (μeq l^{-1})	80	96	70	24	68
lab conductivity (μS cm^{-1})	56	56	53	64	57
field conductivity (μS cm^{-1})	60	64	50	53	57
Sodium (μeq l^{-1})	228	222	202	242	224
Potassium (μeq l^{-1})	15	16	16	20	17
Magnesium (μeq l^{-1})	92	93	87	94	92
Calcium (μeq l^{-1})	189	189	176	209	191
Chloride (μeq l^{-1})	233	222	217	344	254
Aluminium total monomeric (μg l^{-1})	6	5	17	41	17
Aluminium non-labile (μg l^{-1})	6	5	16	30	14
Aluminium labile (μg l^{-1})	0	3	1	11	4
Absorbance (250nm)	0.145	0.137	0.190	0.158	0.158
Carbon total organic (mg l^{-1})	4.2	4.0	4.5	4.1	4.2
Phosphorous total (μg P l^{-1})	14	8	12	19	13
Phosphorous total soluble (μg P l^{-1})	9	6	9	7	8
Phosphorous soluble reactive (μg P l^{-1})	7	2	7	5	5
Nitrate (μg N l^{-1})	441	376	568	427	453
Silica soluble reactive (mg l^{-1})	0.5	1.2	2.1	1.4	1.3
Chlorophyll a (μg l^{-1})	8.3	7.2	1.0	12.3	7.2
Sulphate (μeq l^{-1})	112	109	97	100	105
Copper total soluble (μg l^{-1})	0	0	0	0	0
Iron total soluble (μg l^{-1})	50	20	110	70	63
Lead total soluble (μg l^{-1})	0	0	0	0	0
Manganese total soluble (μg l^{-1})	7	4	0	12	6
Zinc total soluble (μg l^{-1})	0	0	0	6	2

Table B.2 Llyn Tegid epilithic diatom taxon list (including taxa >1%)

Taxon	Relative frequency (%)
Achnanthes minutissima	42.6
Achnanthes subatomoides	1.6
Asterionella formosa	5.4
Aulacoseira subarctica	2.2
Cymbella minuta	1.5
Cymbella silesiaca	2.8
Fragilaria capucina	4.2
Fragilaria capucina var.*gracilis*	3.9
Fragilaria intermedia	3.9
Nitzschia palea	1.4
Nitzschia dissipata	1.2
Nitzschia gracilis	3.0
Nitzschia lacuum	1.4
Synedra rumpens	5.6
Tabellaria flocculosa	1.7
Synedra [cf. *pulcella*]	2.6

Table B.3 Llyn Tegid surface sediment diatom taxon list (including taxa >1%)

TAXON	Relative frequency (>1%)
Achnanthes minutissima	9.8
Asterionella formosa	38.3
Aulacoseira subarctica	15.6
Cyclotella comensis	1.2
Cyclotella glomerata	7.2
Cymbella silesiaca	1.2
Fragilaria capucina	3.5
Fragilaria crotonensis	1.7
Fragilaria intermedia	2.6
Gomphonema parvulum	1.7
Synedra acus	1.4
Synedra minuscula	3.2
Tabellaria flocculosa	2.3

Table B.4 Llyn Tegid aquatic macrophyte abundance summary: 12-7-96

Taxon	code	Abundance
Emergent taxa		
Carex rostrata	381129	R
Submerged taxa		
Nitella translucens	220000	R
Nitella opaca var. *attenuata*	220000	O
Fontinalis antipyretica	323401	F
Isoetes lacustris	350302	F
Callitriche hamulata	361103	F
Callitriche stagnalis	361108	R
Elatine hexandra	362401	A
Littorella uniflora	363901	F
*Eleocharis acicularis**	382001	O
*Luronium natans**	383401	F
Sparganium emersum	384602	R
Common fringing taxa		
Mentha aquatica	364601	O
Oenanthe crocata	365802	A
Ranunculus flammula	366904	O
Salix sp.	367500	O
Juncus effusus	383010	F
Phalaris arundinacea	383701	A

* = Taxon regionally rare for NRA Welsh Region

Table B.5 Llyn Tegid littoral Cladocera taxon list: 12-7-96

Taxa	Sample number				
	1	2	3	4	5
	number of individuals				
Alona affinis	13	36			
Alonopsis elongata	2	8	2	1	1
Camptocercus rectirostris	2	1			
Chydorus sphaericus		+			
Daphnia galeata		2			
Diaphanosoma brachyurum					6
Eubosmina longispina	7	636	293	1055	284
Eurycercus lamellatus	142	12		1	18
Pleuroxus truncatus		8			
Polyphemus pediculus	3	510	15	5	4
Rhynchotalona falcata		1			
Scapholeberis mucronata		2			
Sida crystallina		1			
Total count	169	1217	310	1062	313

Table B.6 Llyn Tegid zooplankton abundance summary: 12-7-96

Taxon	Count
Diaphanosoma brachyurum	X
Daphnia galeata	450
Daphnia longispina	20
Leptodora kindti	20
Eubosmina longispina	90
Eudiaptomus gracilis	160
Paracyclops fimbriatus	x
Cyclops abyssorum	180
Megacyclops gigas	X
other planktonic organisms (not quantitatively sampled)	
Kellicottia longispina	50

X = rare species with relative abundance below 1%
x = very rare species found only at one site

Table B.7 Llyn Tegid zooplankton characteristics

Site depth (m)	40.0
Total zooplankton biomass excluding Chaoborus larvae(g DW m^{-2})	1.06
Chaoborus biomass (g DW m^{-2})	0.0
Net algal biomass (g DW m^{-2})	0.0
Cladoceran biomass as proportion of total zooplankton biomass (%)	54
Large cladoceran (>710µm) as proportion of total zooplankton biomass	8
Large Copepoda (>420µm) as proportion of total zooplankton biomass	20

Table B.8 **Llyn Tegid littoral macroinvertebrate summary: 23-9-96**
Mean numbers of individuals per one minute kick/sweep sample.

code	Taxon	Mean count / sample
	MOLLUSCA	
13090310	*Planorbis contortus*	1.6
13100201	*Ancylus fluviatilis*	0.4
	BIVALVIA	
14030200	*Pisidium* spp.	136.8
16000000	OLIGOCHAETA	51.2
	HIRUDINEA	
17020501	*Helobdella stagnalis*	1.2
19000000	HYDRACARINA	12.0
	MALACOSTRACA	
28030101	*Asellus aquaticus*	1.6
28070305	*Gammarus pulex*	34.8
	EPHEMEROPTERA	
30020000	Baetidae species - immatures	0.4
30020301	*Cloeon dipterum*	0.4
30040000	Leptophlebiidae - immatures	7.6
30070102	*Ephemera danica*	3.2
30080206	*Caenis luctuosa*	296.0
31000000	PLECOPTERA - immatures	0.8
	HEMIPTERA	
33110000	Corixidae sp. - immatures	60.0
	COLEOPTERA	
35030703	*Potamonectes depressus*	1.2
35110600	Oulimnius sp. - larvae	8.4
35110602	*Oulimnius troglodytes*	3.2
	TRICHOPTERA	
38030301	*Polycentropus flavomaculatus*	1.2
38040201	*Tinodes waeneri*	33.6
38060101	*Agraylea multipunctata*	0.4
38120107	*Athripsodes cinereus*	14.0
38120203	*Mystacides longicornis*	0.8
38120600	*Oecetis* sp.	1.6
38130101	*Goera pilosa*	2.0
38140201	*Lepidostoma hirtum*	2.4
	DIPTERA	
40080000	Ceratopogonidae	27.6
40090000	Chironomidae	14.0

Figure B.1 Llyn Tegid: sample location and substrate map

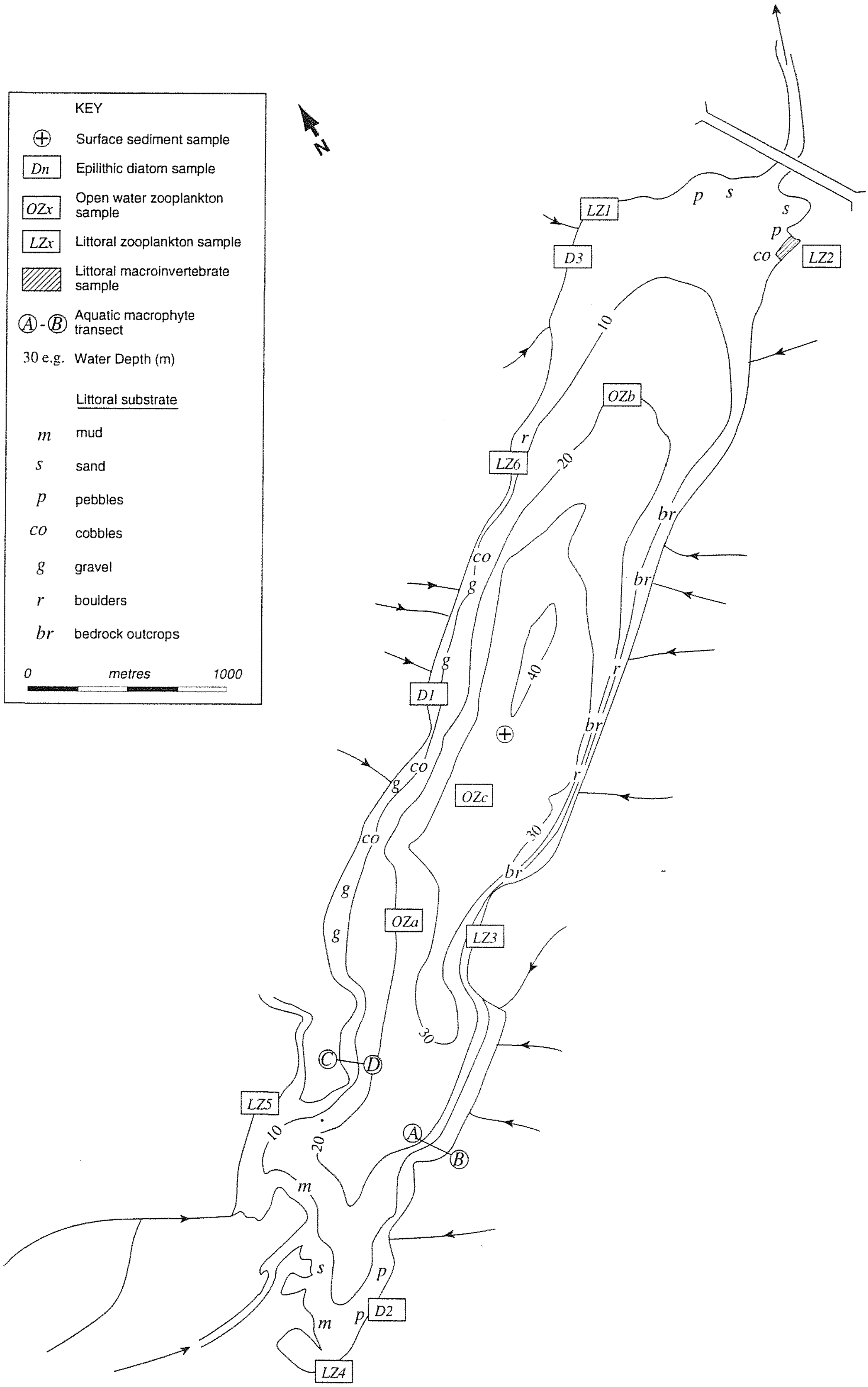
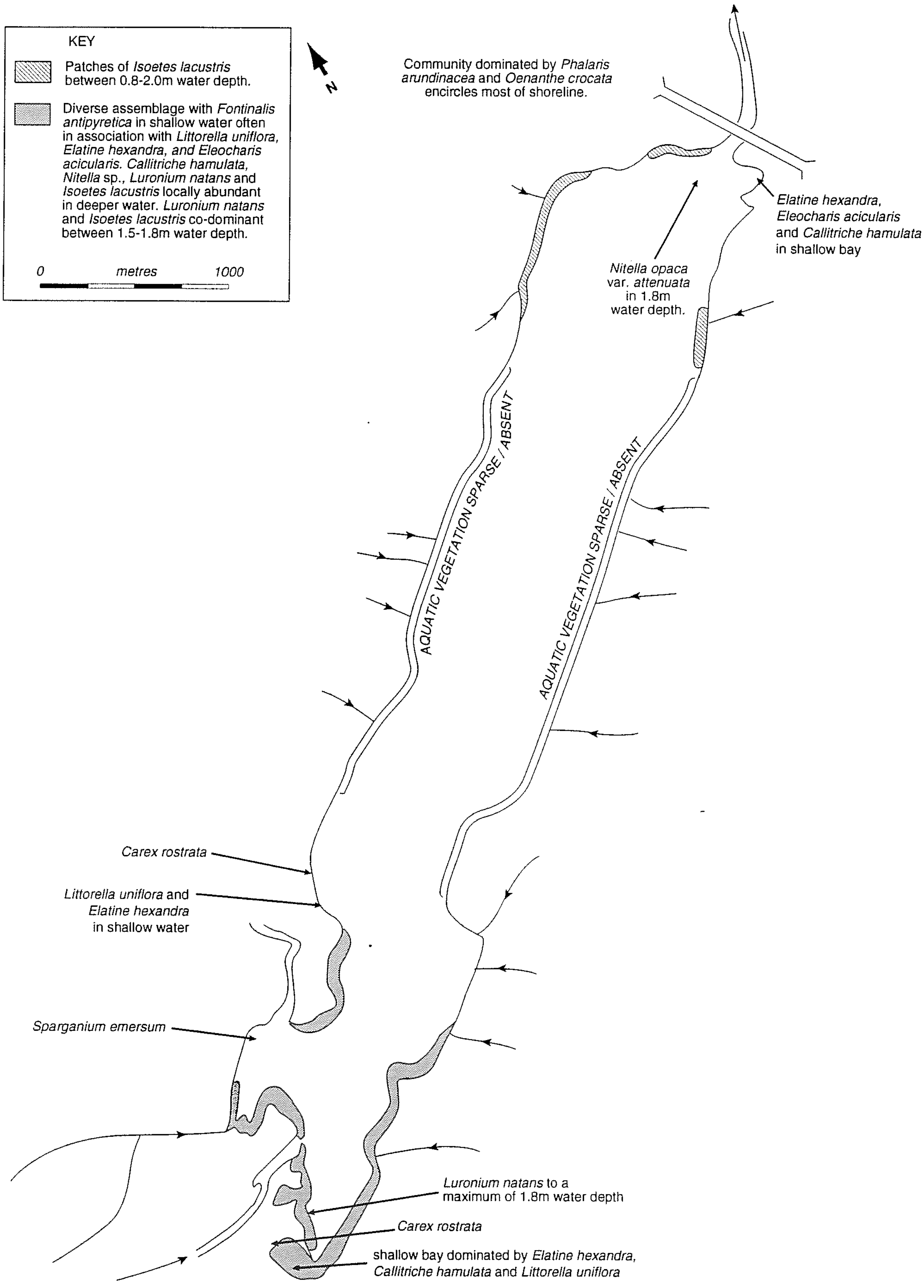
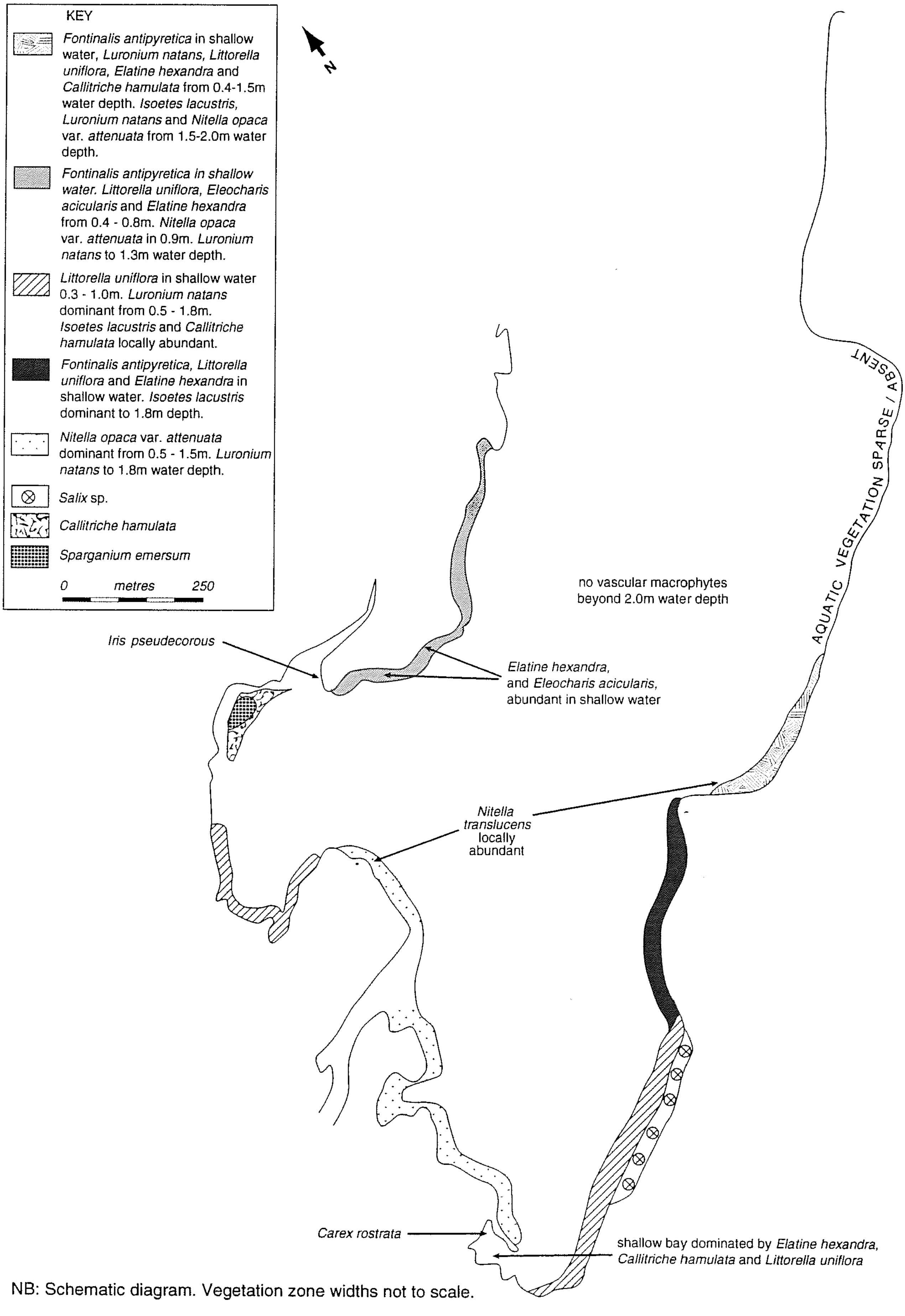


Figure B.2a Llyn Tegid: aquatic macrophyte distribution map (entire) : 12-7-96



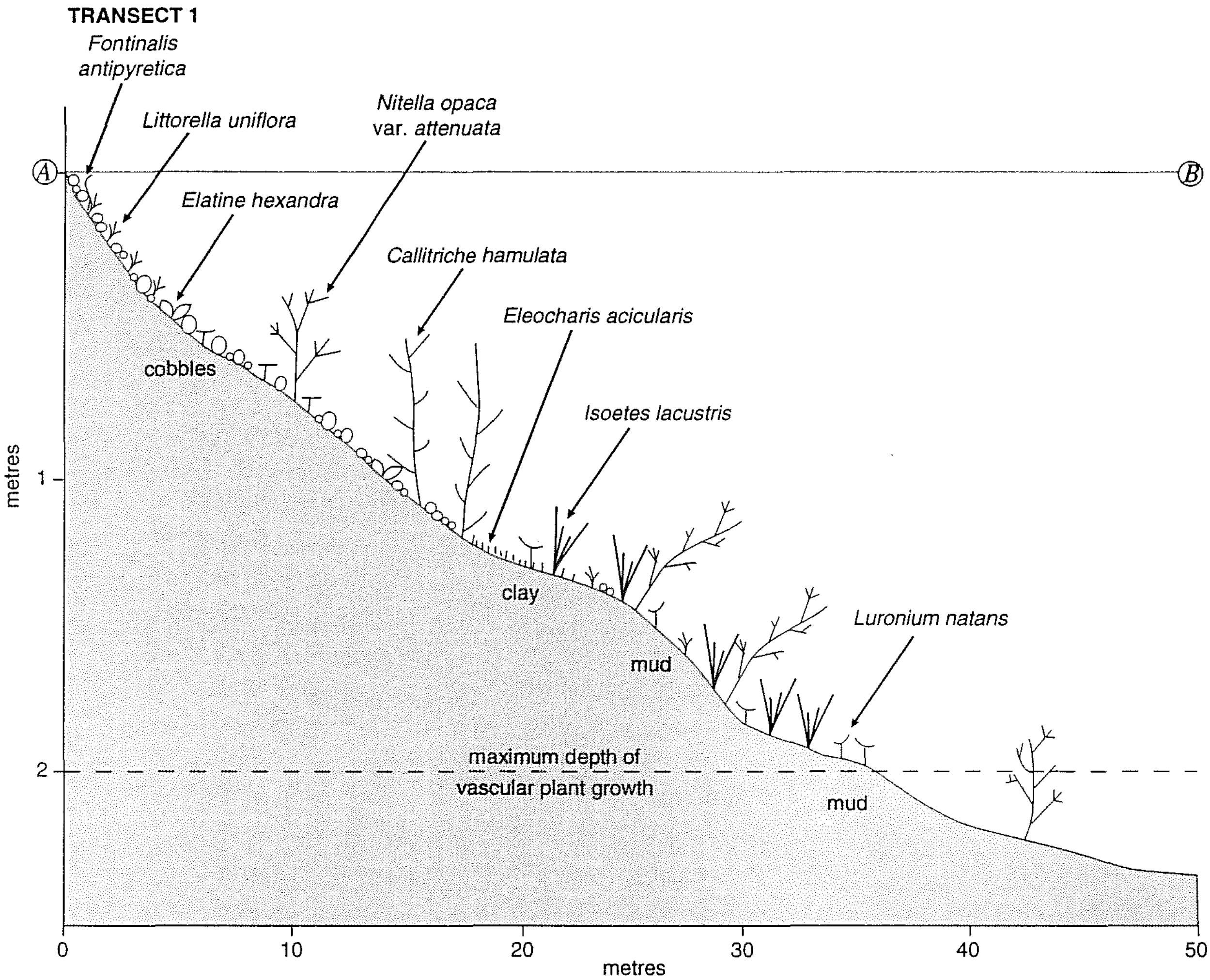
NB: Schematic diagram. Vegetation zone widths not to scale.

Figure B.2b Llyn Tegid: aquatic macrophyte distribution map (south end): 12-7-96



NB: Schematic diagram. Vegetation zone widths not to scale.

Figure B.3 Llyn Tegid: aquatic macrophyte transect profiles



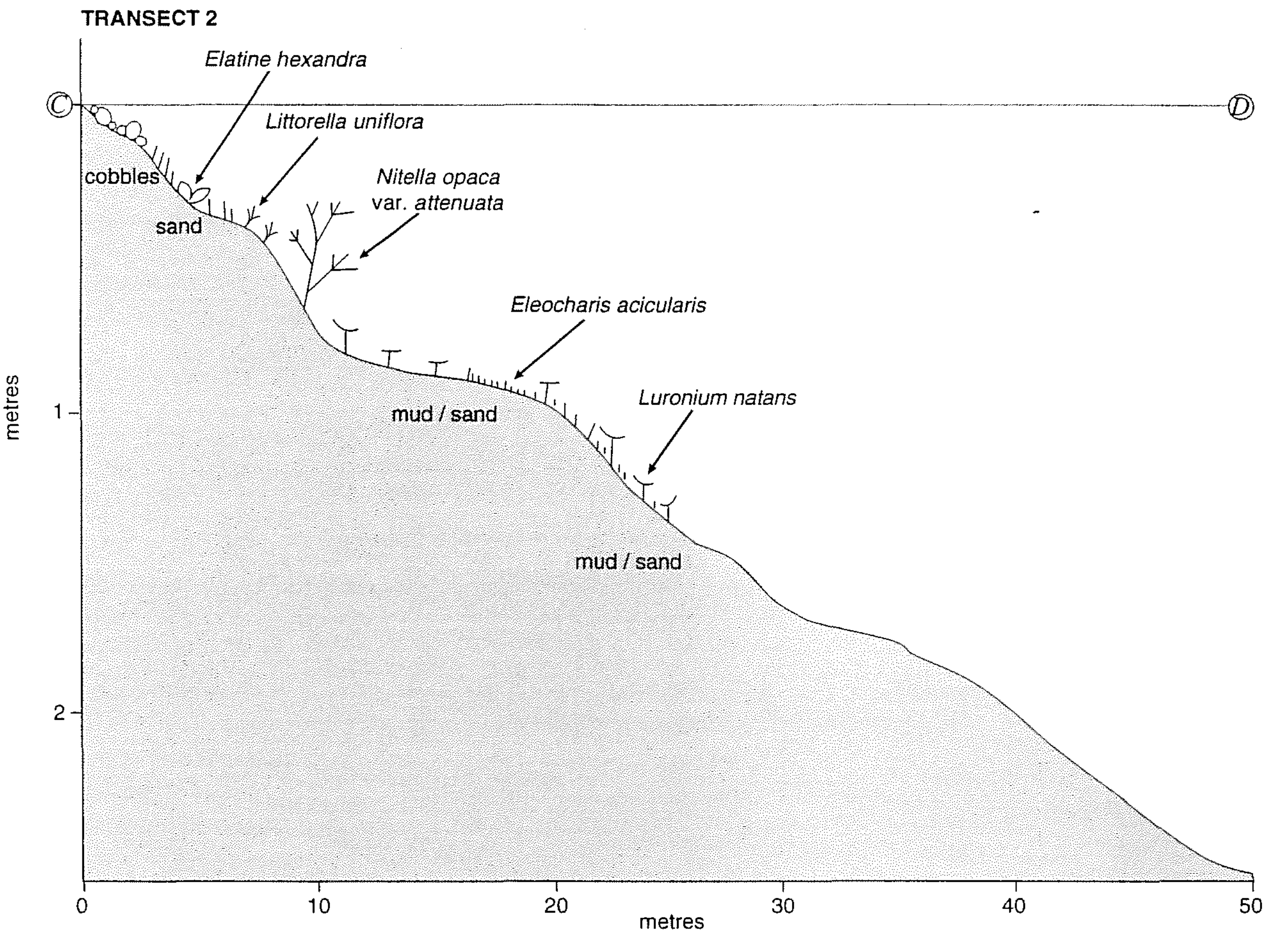


Figure B.4 **Llyn Tegid: Temperature and dissolved oxygen profiles 12-7-96 (Temperature °c- solid circles, Oxygen mg l^{-1}- empty boxes)**

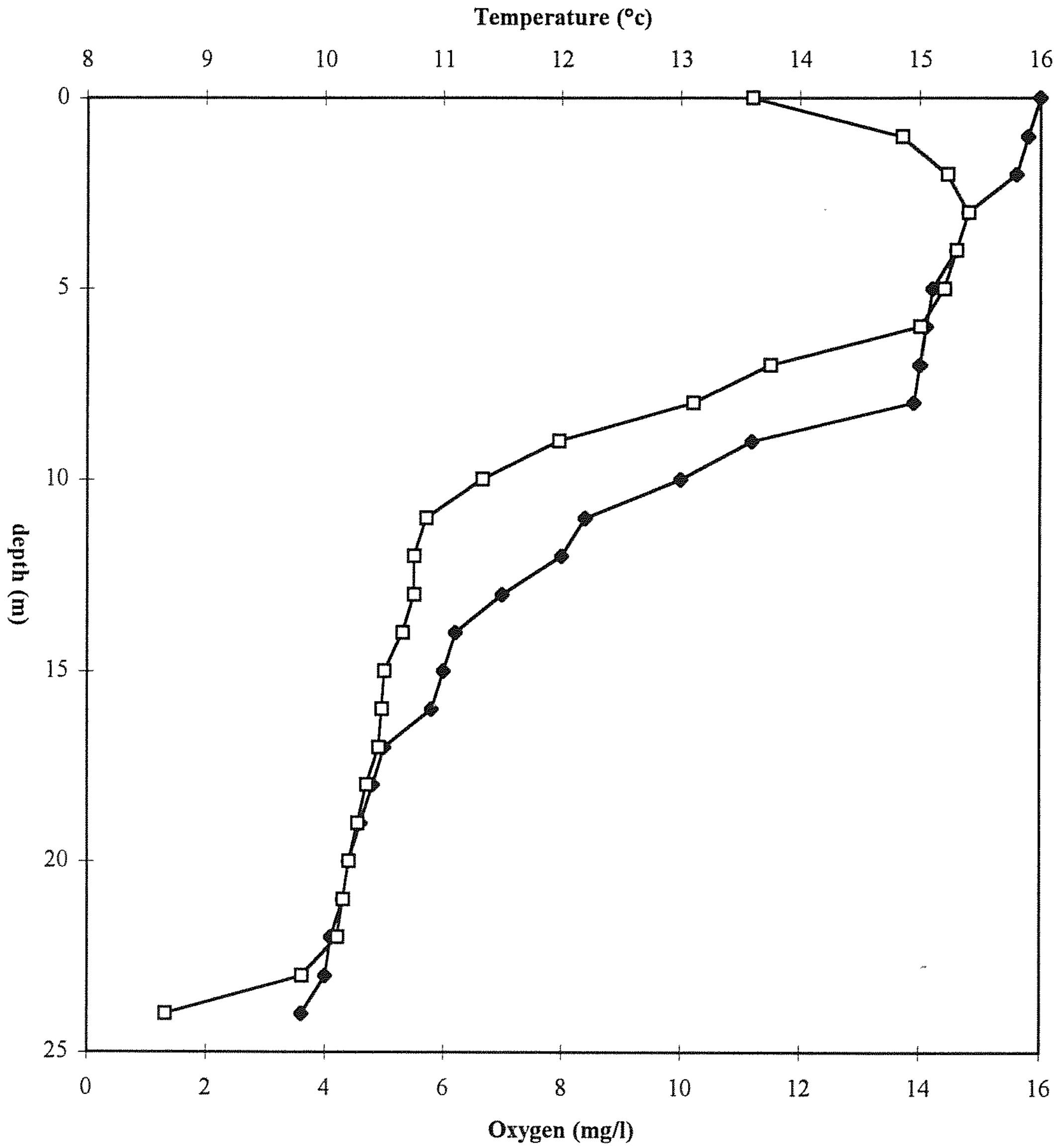


Table C.1 Llyn Alwen water chemistry

Determinand	Sample				
	14/07/96	23/09/96	14/01/97	03/04/97	mean
lab pH	4.98	4.82	4.78	4.50	4.74
field pH		5.12	4.30	4.40	
Alkalinity 1 (μeq l^{-1})	-11	-15	-17	-32	-19
Alkalinity 2 (μeq l^{-1})	-9	-16	-22	-34	-20
lab conductivity (μS cm^{-1})	50	50	52	55	52
field conductivity (μS cm^{-1})	49	49	47	49	49
Sodium (μeq l^{-1})	230	226	230	222	227
Potassium (μeq l^{-1})	14	11	14	12	13
Magnesium (μeq l^{-1})	97	90	94	75	89
Calcium (μeq l^{-1})	69	56	68	41	59
Chloride (μeq l^{-1})	248	236	249	256	247
Aluminium total monomeric (μg l^{-1})	51	40	62	70	56
Aluminium non-labile (μg l^{-1})	25	16	36	30	27
Aluminium labile (μg l^{-1})	26	24	26	40	29
Absorbance (250nm)	0.144	0.128	0.210	0.208	0.173
Carbon total organic (mg l^{-1})	3.7	3.2	4.4	4.3	3.9
Phosphorous total (μg P l^{-1})	30	10	12	14	16
Phosphorous total soluble (μg P l^{-1})	5	5	7	10	7
Phosphorous soluble reactive (μg P l^{-1})	3	3	6	7	5
Nitrate (μg N l^{-1})	140	139	132	116	132
Silica soluble reactive (mg l^{-1})	1.4	1.5	1.7	1.5	1.5
Chlorophyll a (μg l^{-1})	0.9	7.9	0.9	1.8	2.9
Sulphate (μeq l^{-1})	103	103	98	94	100
Copper total soluble (μg l^{-1})	0	0	0	0	0
Iron total soluble (μg l^{-1})	430	450	560	370	453
Lead total soluble (μg l^{-1})	0	0	0	0	0
Manganese total soluble (μg l^{-1})	211	260	162	158	198
Zinc total soluble (μg l^{-1})	0	0	0	13	3

Table C.2 Llyn Alwen epilithic diatom taxon list (including taxa >1%)

TAXON	Relative frequency (%)
Achnanthes sp.	1.1
Eunotia incisa	68.4
Eunotia pectinalis	5.6
Eunotia rhomboidea	3.3
Tabellaria flocculosa	12.9

Table C.3 Llyn Alwen surface sediment diatom taxon list (including taxa >1%)

TAXON	Relative frequency (%)
Aulacoseira perglabra	3.9
Aulacoseira sp.	3.3
Aulacoseira [cf. *lirata* var. *alpigena*]	12.6
Aulacoseira [sp. 1]	5.7
Aulacoseira [sp. 2]	3.7
Brachysira brebissonii	1.2
Cymbella perpusilla	5.7
Eunotia incisa	26.3
Eunotia pectinalis	1.8
Eunotia pectinalis var.*ventralis*	1.4
Eunotia rhomboidea	4.5
Fragilaria virescens var.*exigua*	1.6
Fragilaria [cf. *oldenburgiana*]	2.0
Frustulia rhomboides var.*viridula*	3.5
Navicula hassiaca	2.6
Navicula soehrensis	3.5
Tabellaria flocculosa	5.9

Table C.4 Llyn Alwen aquatic macrophyte abundance summary: 14-7-96

Taxon	code	Abundance
Emergent taxa		
Juncus effusus	383010	A
Submerged taxa		
Fontinalis antipyretica	323401	O
Sphagnum auriculatum	327401	O
Nardia compressa	343701	F
Scapania undulata	345410	O
Isoetes lacustris	350302	A
Littorella uniflora	363901	O
Lobelia dortmanna	364001	F

Table C.5 Llyn Alwen littoral Cladocera taxon list: 14-7-96

Taxa	Sample number				
	1	2	3	4	5
	number of individuals				
Alona affinis			1		
Alona rustica		2	3		
Alonella excisa				3	1
Alonopsis elongata	4	96	585	60	83
Bythotrephes longimanus	+				
Chydorus piger			1		
Chydorus sphaericus	+		1		
Diaphanosoma brachyurum					2
Eubosmina longispina	2210	1243	667	219	193
Graptoleberis testudinaria	1				2
Rhynchotalona falcata				1	
Total count	2215	1341	1258	283	281

Table C.6 Llyn Alwen zooplankton abundance summary: 14-7-96

Taxon	Count
Diaphanosoma brachyurum	2600
Bythotrephes longimanus	X
Leptodora kindti	20
Eubosmina longispina	200
Eudiaptomus gracilis	2580

X = rare species with relative abundance below 1%
x = very rare species found only at one site

Table C.7 Llyn Alwen zooplankton characteristics

Site depth (m)	12.0
Total zooplankton biomass excluding Chaoborus larvae(g DW m^{-2})	1.67
Chaoborus biomass (g DW m^{-2})	0.0
Net algal biomass (g DW m^{-2})	0.0
Cladoceran biomass as proportion of total zooplankton biomass (%)	63
Large cladoceran (>710µm) as proportion of total zooplankton biomass	1
Large Copepoda (>420µm) as proportion of total zooplankton biomass	1

Table C.8 Llyn Alwen littoral macroinvertebrate summary: 23-9-96
Mean numbers of individuals per one minute kick/sweep sample.

code	Taxon	Mean count/sample
	TURBELLARIA	
03120000	Tricladida	2.0
16000000	OLIGOCHAETA	78.4
	EPHEMEROPTERA	
30040000	Leptophlebiidae species	26.8
	COLEOPTERA	
35030703	*Potamonectes depressus*	0.4
35110600	*Oulimnius* species - larvae	70.8
35110602	*Oulimnius troglodytes*	4.0
	TRICHOPTERA	
38030301	*Polycentropus flavomaculatus*	91.2
38040201	*Tinodes waeneri*	14.8
	DIPTERA	
40080000	Ceratopogonidae	0.4
40090000	Chironomidae	252.0

Figure C.1 Llyn Alwen: sample location and substrate map

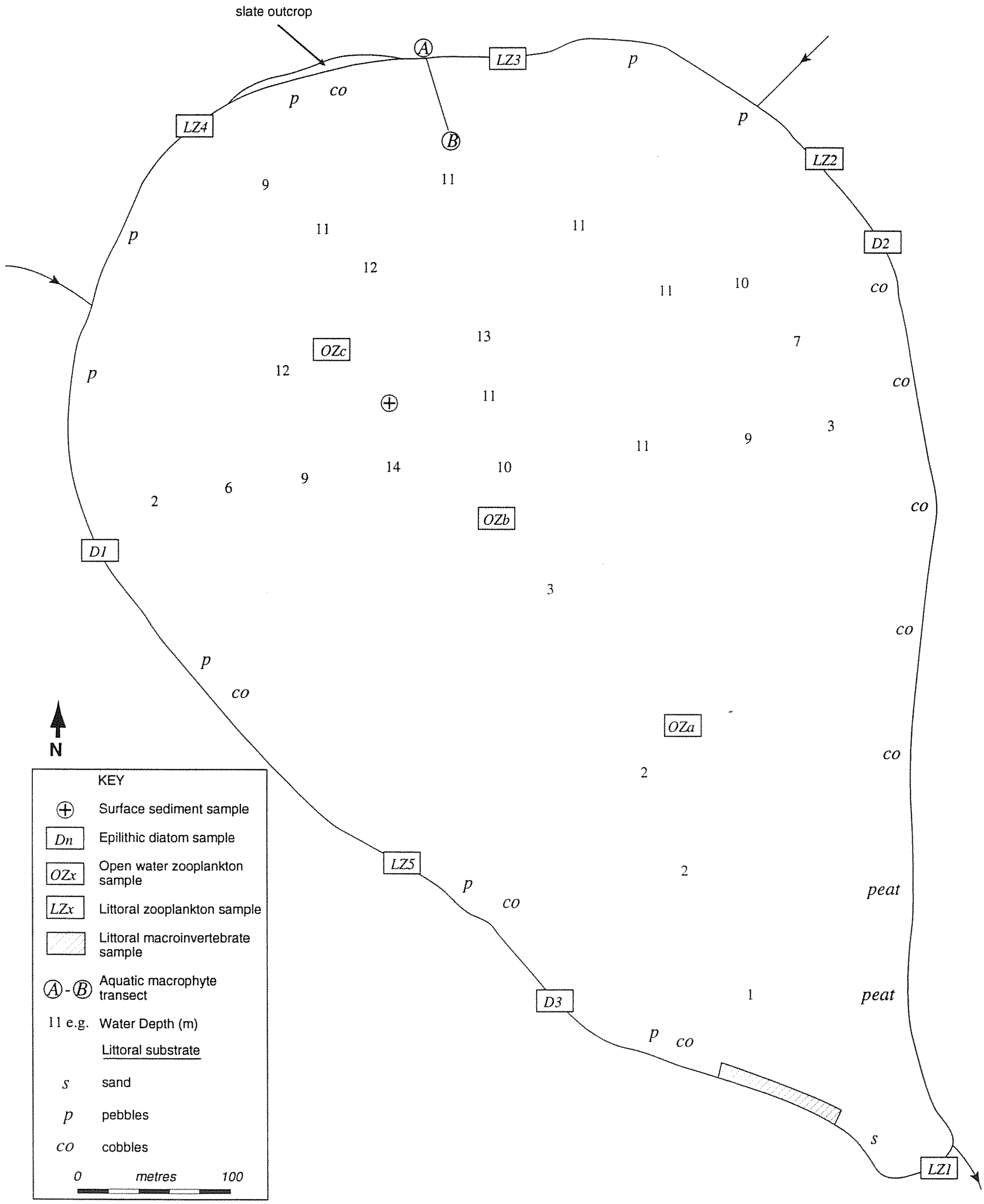
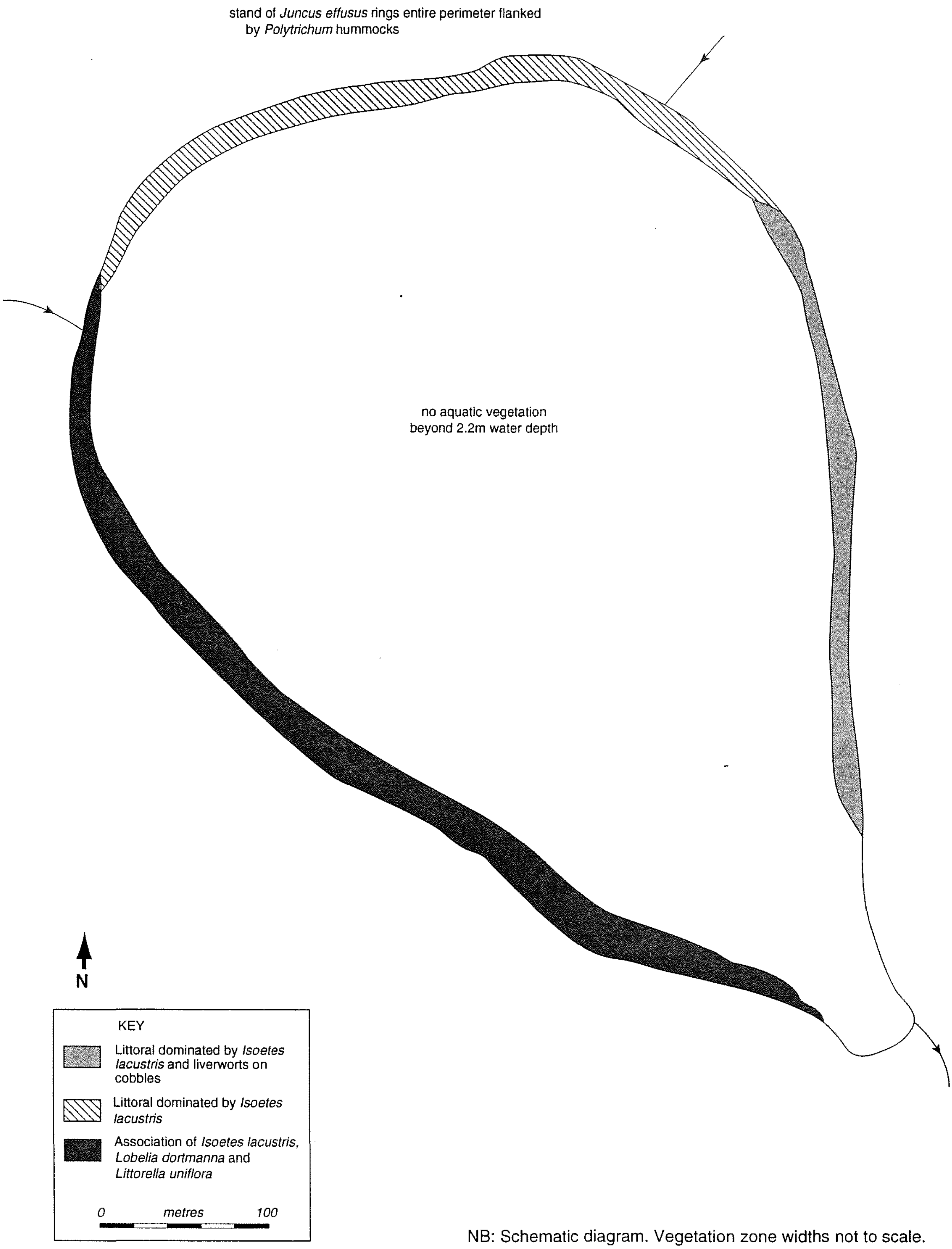


Figure C.2 Llyn Alwen: aquatic macrophyte distribution map: 14-7-96



NB: Schematic diagram. Vegetation zone widths not to scale.

Figure C.3 Llyn Alwen: aquatic macrophyte transect profile

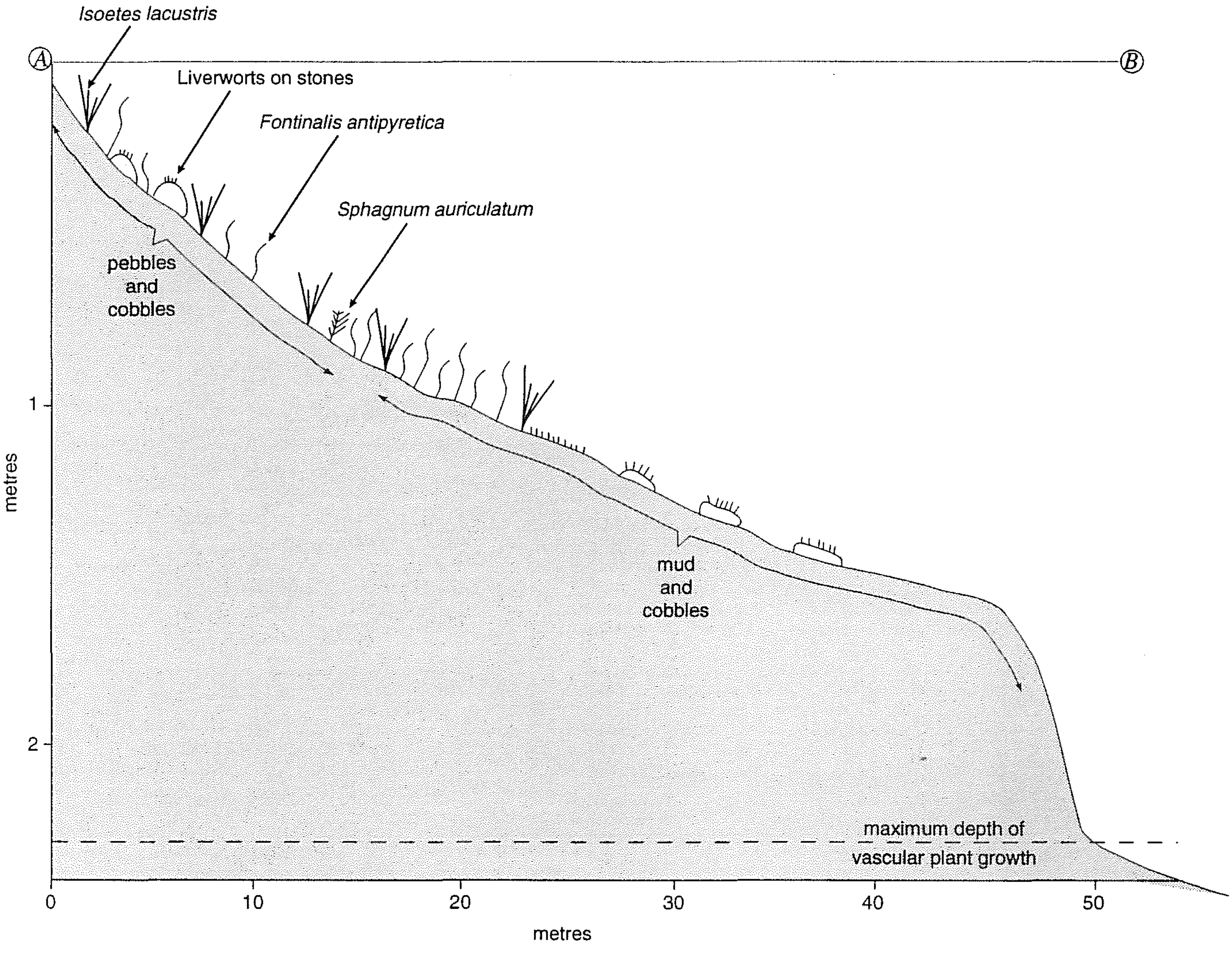


Figure C.4 Llyn Alwen: Temperature and dissolved oxygen profiles 14-7-96 (Temperature °c- solid circles, Oxygen mg l^{-1}- empty boxes)

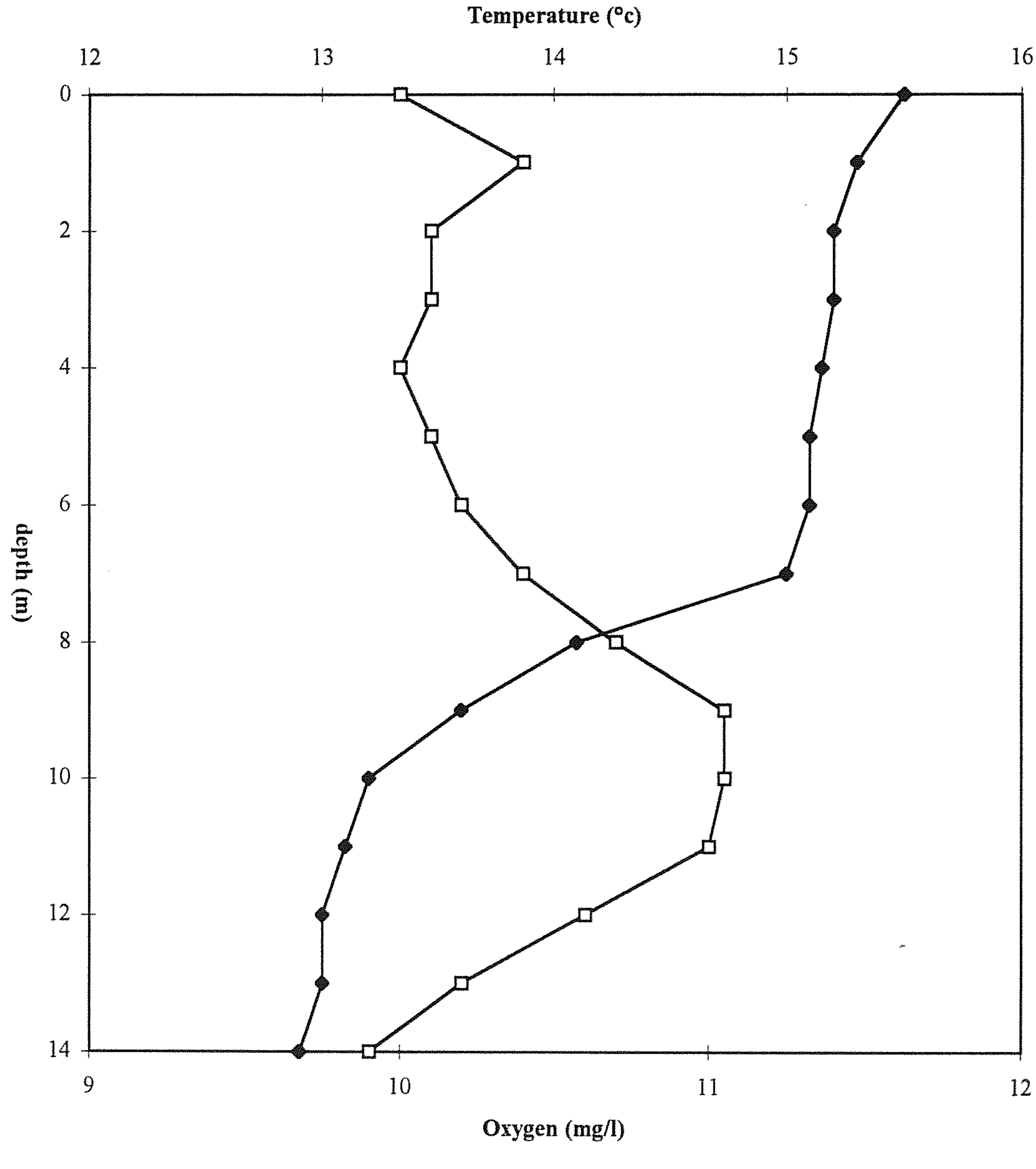


Table D.1 Llyn Glasfryn water chemistry

Determinand	Sample				
	15/07/96	25/09/96	16/01/97	04/04/97	mean
lab pH	6.65	6.57	7.03	6.86	6.74
field pH		6.81			
Alkalinity 1 ($\mu eq\ l^{-1}$)	430	521	437	368	439
Alkalinity 2 ($\mu eq\ l^{-1}$)	436	528	437	368	442
lab conductivity ($\mu S\ cm^{-1}$)	113	126	139	137	129
field conductivity ($\mu S\ cm^{-1}$)	125	130	135	135	131
Sodium ($\mu eq\ l^{-1}$)	413	481	507	550	488
Potassium ($\mu eq\ l^{-1}$)	17	56	66	58	49
Magnesium ($\mu eq\ l^{-1}$)	203	217	209	210	210
Calcium ($\mu eq\ l^{-1}$)	448	461	492	475	469
Chloride ($\mu eq\ l^{-1}$)	501	561	653	756	618
Aluminium total monomeric ($\mu g\ l^{-1}$)	17	5	9	9	10
Aluminium non-labile ($\mu g\ l^{-1}$)	3	4	8	9	6
Aluminium labile ($\mu g\ l^{-1}$)	14	1	1	0	4
Absorbance (250nm)	0.170	0.193	0.180	0.192	0.184
Carbon total organic ($mg\ l^{-1}$)	9.5	24.0	7.8	12.0	13.3
Phosphorous total ($\mu g\ P\ l^{-1}$)	98	296	79	113	146
Phosphorous total soluble ($\mu g\ P\ l^{-1}$)	25	40	35	70	43
Phosphorous soluble reactive ($\mu g\ P\ l^{-1}$)	9	7	12	27	14
Nitrate ($\mu g\ N\ l^{-1}$)	7	7	144	31	47
Silica soluble reactive ($mg\ l^{-1}$)	0.9	1.7	0.9	0.2	0.9
Chlorophyll a ($\mu g\ l^{-1}$)	72.6	162.4	63.3	106.7	101.3
Sulphate ($\mu eq\ l^{-1}$)	53	12	97	90	63
Copper total soluble ($\mu g\ l^{-1}$)	0	0	9	0	2
Iron total soluble ($\mu g\ l^{-1}$)	580	1950	680	240	863
Lead total soluble ($\mu g\ l^{-1}$)	0	0	0	0	0
Manganese total soluble ($\mu g\ l^{-1}$)	468	793	10	413	421
Zinc total soluble ($\mu g\ l^{-1}$)	0	0	0	0	0

Table D.2 Llyn Glasfryn epilithic diatom taxon taxon list (including taxa >1%)

TAXON	Relative frequency (%)
Achnanthes minutissima	21.6
Cocconeis placentula	4.1
Fragilaria construens var.*venter*	3.0
Fragilaria elliptica	9.6
Fragilaria sp.	1.3
Gomphonema parvulum	1.9
Navicula agrestis	3.4
Navicula minima	10.4
Navicula porifera	1.2
Navicula seminulum	2.1
Navicula sp.	1.5
Navicula subrotundata	1.3
Navicula [cf. *seminulum*]	1.0
Nitzschia dissipata	1.5
Nitzschia frustulum	2.4
Nitzschia paleacea	20.3
Synedra nana	2.8

Table D.3 Llyn Glasfryn surface sediment diatom taxon list (including taxa >1%)

TAXON	Relative frequency (%)
Achnanthes minutissima	8.8
Cocconeis placentula	10.4
Fragilaria construens var.*venter*	4.3
Fragilaria elliptica	39.9
Fragilaria pinnata	1.2
Fragilaria virescens var.*exigua*	3.0
Gomphonema parvulum	2.7
Navicula atomus	1.5
Navicula cryptocephala	2.7
Navicula minima	1.2
Navicula rhyncocephala	2.7
Navicula seminulum	1.8
Navicula sp.	2.4
Navicula submuralis	1.2
Navicula [cf. *seminulum*]	1.2
Nitzschia dissipata	1.5
Synedra nana	1.5

Table D.4 Llyn Glasfryn aquatic macrophyte abundance summary: 15-7-96

Taxon	code	Abundance
Emergent taxa		
Caltha palustris	361201	O
Mentha aquatica	364601	O
Menyanthes trifoliata	364701	F
Potentilla palustris	366704	F
Ranunculus flammula	366904	O
Alisma plantago aquatica	380303	R
Carex rostrata	381129	R
Iris pseudocorus	382901	O
Juncus acutifloris/articulatus	383099	A
Phalaris arundinacea	383701	O
Floating leaved taxa		
Nuphar lutea	365501	F
Nymphaea alba	365601	R
Polyganum amphibium	366501	R
Submerged taxa		
Nitella flexilis agg.	220098	A
Elatine hexandra	362401	O
Elatine hydropiper	362402	R
Littorella uniflora	363901	O
Eleocharis acicularis *	382001	R
Potamogeton obtusifolius *	384014	O
Potamogeton perfoliatus *	384016	R

* = Taxon regionally rare for NRA Welsh Region

Table D.5 Llyn Glasfryn littoral Cladocera taxon list: 15-7-96

Taxa	Sample number				
	1	2	3	4	5
	number of individuals				
Acroperus harpae					+
Alona costata		2	1		
Ceriodaphnia reticulata	16	157	34	29	143
Chydorus sphaericus	110	394	164	720	543
Eubosmina longispina	1		0.1		
Eurycercus lamellatus				1	
Pleuroxus truncatus					1
Total count	127	553	199	750	687

Table D.6 Llyn Glasfryn zooplankton abundance summary: 15-7-96

Taxon	Count
Ceriodaphnia dubia	x
Ceriodaphnia reticulata	x
Chydorus sphaericus	50
Eudiaptomus gracilis	1330
Eucylops serrulatus	x
Cylops strenuus	290
other planktonic organisms (not quantitatively sampled)	
Chaoborus sp.	X
Conochilus sp.	420
Nauplia	30
Asplanchna sp.	220
Filinia sp.	50

X = rare species with relative abundance below 1%
x = very rare species found only at one site

Table D.7 Llyn Glasfryn zooplankton characteristics

Site depth (m)	1.3
Total zooplankton biomass excluding Chaoborus larvae(g DW m^{-2})	1.23
Chaoborus biomass (g DW m^{-2})	0.01
Net algal biomass (g DW m^{-2})	0.00
Cladoceran biomass as proportion of total zooplankton biomass (%)	5
Large cladoceran (>710μm) as proportion of total zooplankton biomass	0
Large Copepoda (>420μm) as proportion of total zooplankton biomass	36

Table D.8 Llyn Glasfryn littoral macroinvertebrate summary: 25-9-96
Mean numbers of individuals per one minute kick/sweep sample.

code	Taxon	Mean count/sample
	TURBELLARIA	
03120000	Tricladida	176.4
	MOLLUSCA	
13040301	*Potamopyrgus jenkinsi*	22.8
	BIVALVIA	
14030200	*Pisidium* sp.	42.4
16000000	OLIGOCHAETA	1083.2
	HIRUDINEA	
17020101	*Theromyzon tessalatum*	11.6
17020302	*Glossiphonia complanata*	4.8
17020501	*Helobdella stagnalis*	12.4
17040102	*Erpobdella octoculata*	0.4
19000000	HYDRACARINA	0.4
	MALACOSTRACA	
28030104	*Asellus meridianus*	103.2
	ODONATA	
32020000	COENAGRIIDAE	2.0
	HEMIPTERA	
33110000	Corixidae species - immatures	0.4
33110803	*Sigara distincta*	0.8
	COLEOPTERA	
35010000	Haliplidae sp.	3.6
35010304	*Haliplus ruficollis* group	2.0
35020101	*Hygrobia hermanni*	0.8
35030101	*Noterus clavicornis*	0.8
35030201	*Laccophilus minutus*	0.8
35030401	*Hyphydrus ovatus*	0.8
35110600	*Oulimnius* species - larvae	0.8
	MEGALOPTERA	
36010101	*Sialis lutaria*	0.4
38120203	*Mystacides longicornis*	0.4
39000000	LEPIDOPTERA	0.4
	DIPTERA	
40080000	Ceratopogonidae	0.4
40090000	Chironomidae	58.4

Figure D.1 Llyn Glasfryn: sample location and substrate map

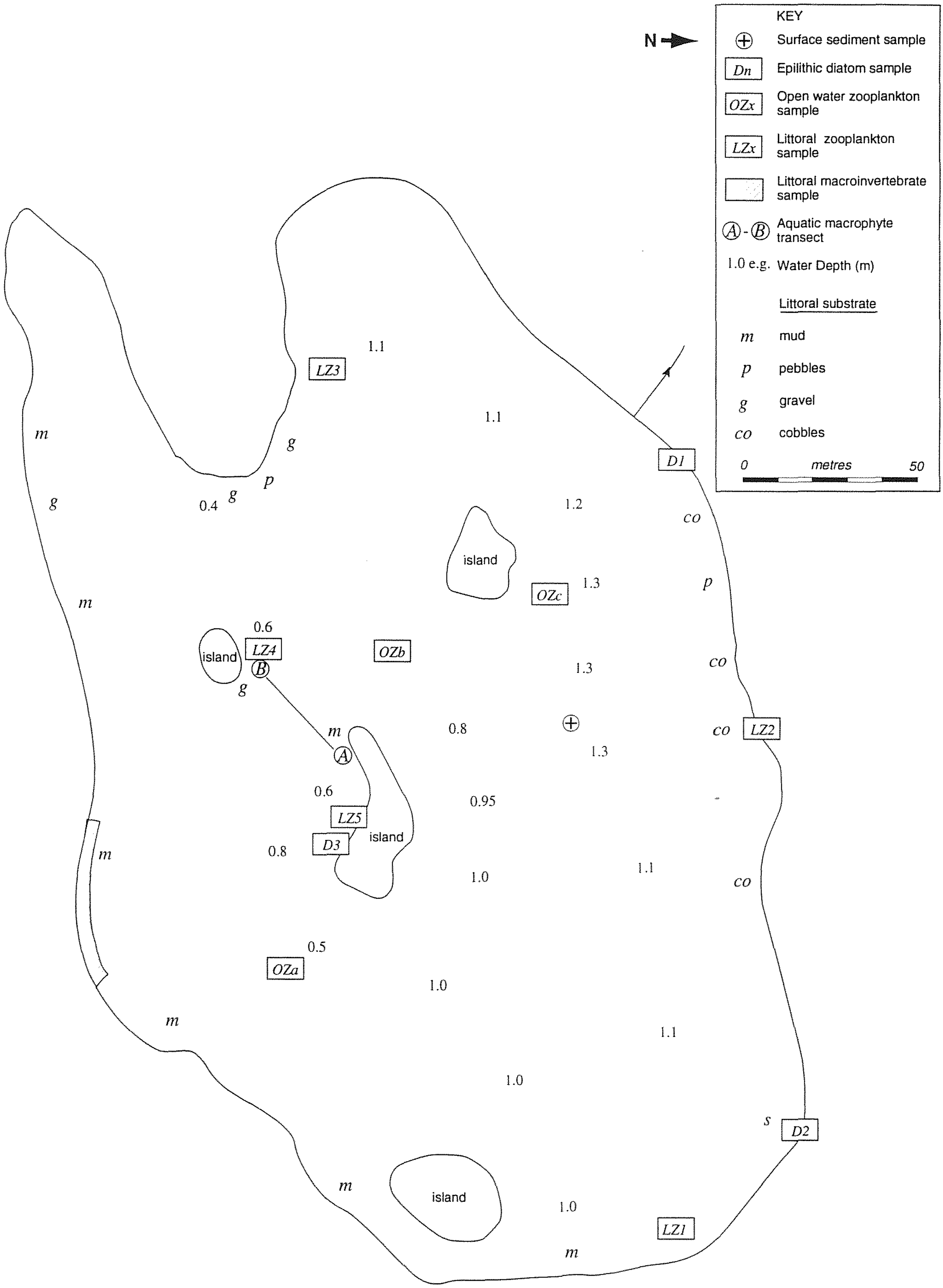
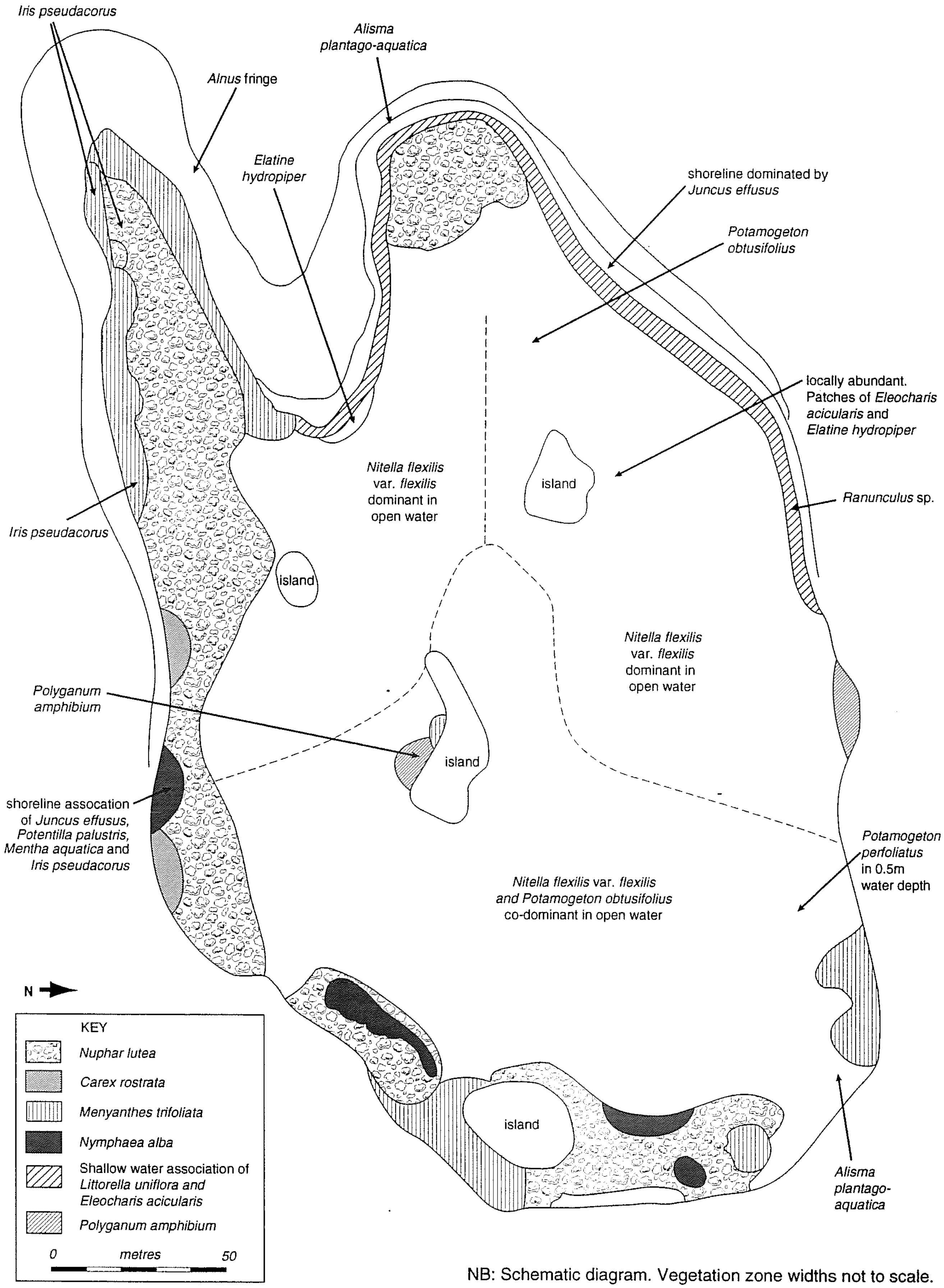


Figure D.2 Llyn Glasfryn: aquatic macrophyte distribution map: 15-7-96



NB: Schematic diagram. Vegetation zone widths not to scale.

Figure D.3 Llyn Glasfryn: aquatic macrophyte transect profile

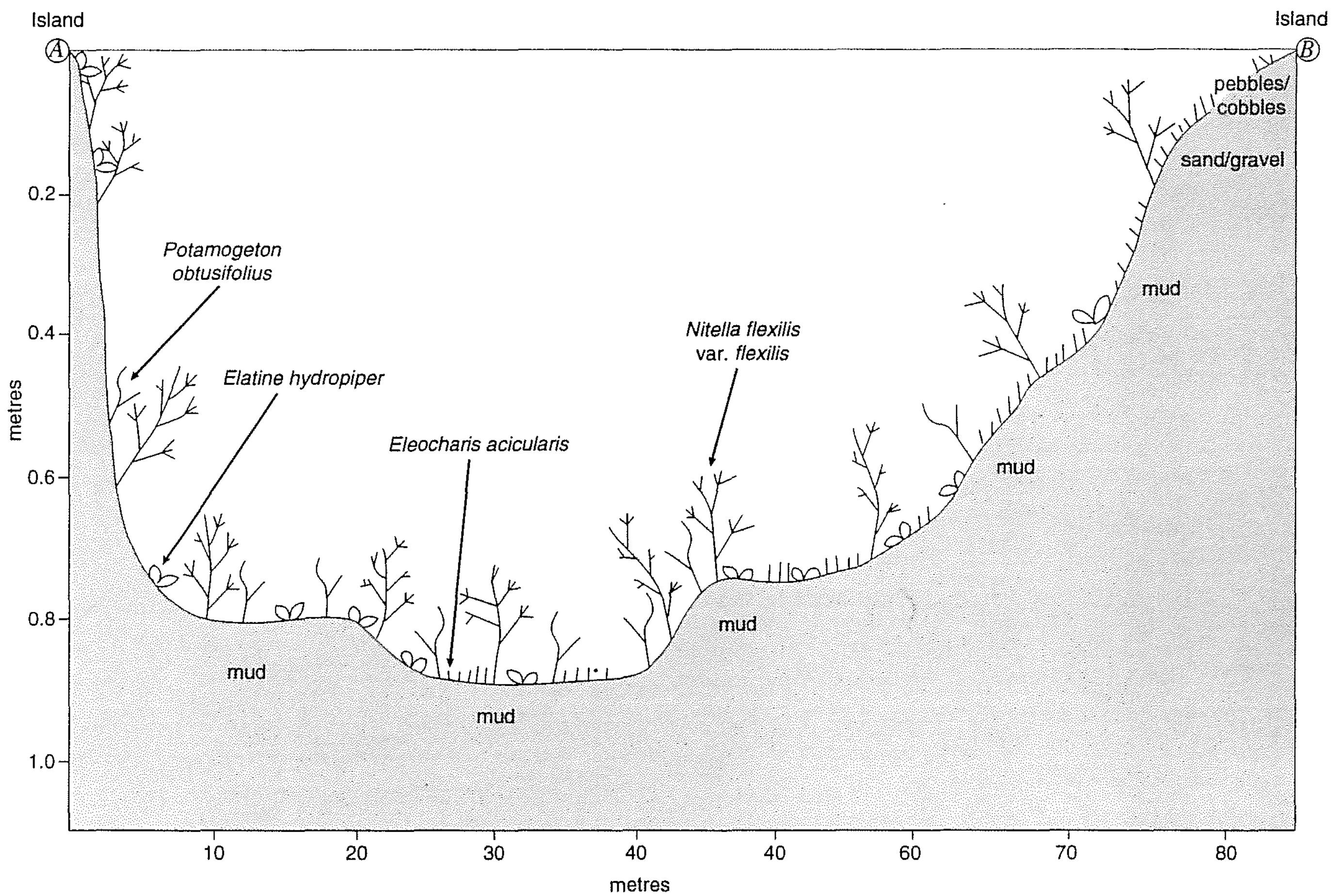


Figure D.4 **Llyn Glasfryn: Temperature and dissolved oxygen profiles 15-7-96 (Temperature °c- solid circles, Oxygen mg l^{-1}- empty boxes)**

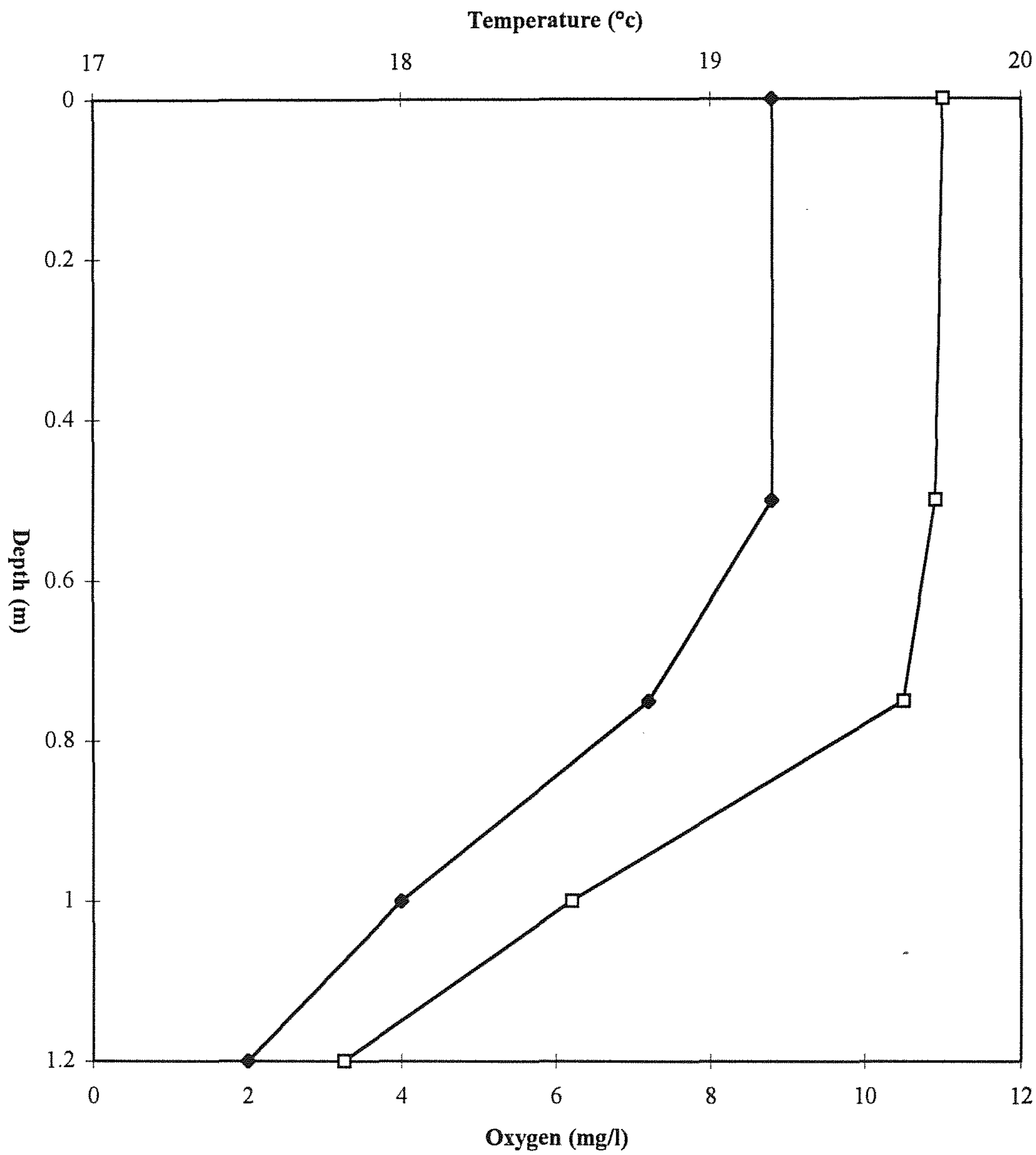


Table E.1 Llyn Rhos Ddu water chemistry

Determinand	Sample				
	16/07/96	25/09/96	16/01/97	04/04/97	mean
lab pH	9.63	8.08	8.06	8.26	8.24
field pH		8.05	8.10		
Alkalinity 1 (μeq l^{-1})	1285	2485	3183	2979	2483
Alkalinity 2 (μeq l^{-1})	1298	2514	3219	3024	2514
lab conductivity (μS cm^{-1})	266	388	473	451	395
field conductivity (μS cm^{-1})	260	385	460	470	394
Sodium (μeq l^{-1})	1014	1155	977	1106	1063
Potassium (μeq l^{-1})	7	33	72	70	46
Magnesium (μeq l^{-1})	624	733	679	716	688
Calcium (μeq l^{-1})	1245	2166	3326	3150	2472
Chloride (μeq l^{-1})	1181	1200	1208	1365	1239
Aluminium total monomeric (μg l^{-1})	7	4	7	41	15
Aluminium non-labile (μg l^{-1})	1	4	4	7	4
Aluminium labile (μg l^{-1})	6	0	3	34	11
Absorbance (250nm)	0.273	0.286	0.190	0.220	0.242
Carbon total organic (mg l^{-1})	9.4	11.3	6.5	7.4	8.7
Phosphorous total (μg P l^{-1})	58	41	30	40	42
Phosphorous total soluble (μg P l^{-1})	17	29	8	8	15
Phosphorous soluble reactive (μg P l^{-1})	10	9	3	4	7
Nitrate (μg N l^{-1})	7	7	126	-7	37
Silica soluble reactive (mg l^{-1})	1.2	9.2	7.1	1.9	4.9
Chlorophyll a (μg l^{-1})	6.7	3.6	25.5	14.3	12.5
Sulphate (μeq l^{-1})	82	21	346	327	194
Copper total soluble (μg l^{-1})	0	2	0	0	1
Iron total soluble (μg l^{-1})	370	390	390	180	333
Lead total soluble (μg l^{-1})	0	0	0	0	0
Manganese total soluble (μg l^{-1})	121	59	124	78	96
Zinc total soluble (μg l^{-1})	0	0	0	2	1

Table E.2 Llyn Rhos Ddu epiphytic diatom taxon taxon list (including taxa >1%)

TAXON	Relative frequency (%)
Cocconeis placentula var.*placentula*	32.8
Epithemia adnata	15.9
Gomphonema constrictum	4.5
Gomphonema minutum	2.2
Gomphonema parvulum	3.0
Navicula cryptotenella	1.2
Nitzschia paleacea	32.3
Nitzschia sp.	1.4
Rhoicosphenia curvata	2.4

Table E.3 Llyn Rhos Ddu surface sediment diatom taxon list (including taxa >1%)

TAXON	Relative frequency (%)
Amphora pediculus	5.3
Cocconeis placentula	5.3
Cocconeis thumensis	1.2
Epithemia adnata	1.8
Fragilaria intermedia var.*continua*	5.3
Fragilaria parasitica	2.4
Fragilaria pinnata	6.5
Fragilaria sp.	1.2
Gomphonema constrictum	1.8
Gomphonema gracile	1.2
Gomphonema intricatum var.*pumilum*	1.8
Gomphonema minutum	1.2
Gomphonema parvulum	2.4
Gomphonema sp.	4.1
Navicula bacillum	7.1
Navicula pupula	5.9
Navicula sp.	1.8
Navicula trivialis	4.7
Nitzschia dissipata	1.2
Nitzschia paleacea	3.5
Nitzschia vermicularis	1.8
Rhoicosphenia curvata	5.3
Stephanodiscus hantzschii	11.2
Surirella sp.	1.2
Synedra tabulata	1.2
Synedra ulna var. *ulna*	2.9

Table E.4 Llyn Rhos Ddu aquatic macrophyte abundance summary: 16-7-96

Taxon	code	Abundance
Emergent taxa		
Equisetum fluviatile	350202	O
Mentha aquatica	364601	O
Menyanthes trifoliata	364701	A
Veronica beccabunga	369802	R
Carex rostrata	3811129	R
Eleocharis palustris	382004	O
Iris pseudocorus	382901	A
Scirpus lacustris ssp. *lacustris* *	384504	R
Sparganium erectum	384603	A
Floating leaved taxa		
Polyganum amphibium	366501	O
Lemna minor	383302	R
Submerged taxa		
Chara virgata	220000	F
Ceratophyllum demersum	361401	O
Hippuris vulgaris *	363201	F
Ranunculus circinatus *	366970	O
Elodea canadensis	382101	F
Potamogeton pusillus	384003	A
Potamogeton perfoliatus *	384016	O
Zannichelia palustris *	385201	R
common fringing taxa		
Lysimachia vulgaris	364404	O
Filipendula ulmaria	362701	O
Potentilla palustris	366704	O
Ranunculus lingua *	366908	O

* = Taxon regionally rare for NRA Welsh Region

Table E.5 Llyn Rhos Ddu littoral Cladocera taxon list: 16-7-96

Taxa	Sample number				
	1	2	3	4	5
	number of individuals				
Acroperus harpae	37	5	31	3	2
Alona affinis	28	5	44	30	17
Alona costata			24		
Alona rectangula	+				
Bosmina longirostris					57
Ceriodaphnia dubia	242			11	11
Chydorus sphaericus	48	21	126	58	149
Daphnia hyalina				9	14
Eurycercus lamellatus	115	6	95	178	547
Monospilus dispar					2
Simocephalus serrulatus	12				
Simocephalus vetulus	23				
Total count	505	37	320	289	799

Table E.6 Llyn Rhos Ddu zooplankton abundance summary: 16-96

Taxon	Count
Diaphanosoma brachyurum	X
Ceriodaphnia dubia	X
Daphnia galeata	200
Bosmina longirostris	1000
Acroperus harpae	x
Alona affinis	x
Eurycercus lamellatus	X
Eudiaptomus gracilis	100
Macrocyclops albidus	X
Eucyclops macruroides	X
Paracyclops fimbriatus	x
Cylops strenuus	20
Megacylops viridis	X

X = rare species with relative abundance below 1%
x = very rare species found only at one site

Table E.7 Llyn Rhos Ddu zooplankton characteristics

Site depth (m)	0.8
Total zooplankton biomass excluding Chaoborus larvae(g DW m^{-2})	0.52
Chaoborus biomass (g DW m^{-2})	0.00
Net algal biomass (g DW m^{-2})	0.00
Cladoceran biomass as proportion of total zooplankton biomass (%)	46
Large cladoceran (>710µm) as proportion of total zooplankton biomass	5
Large Copepoda (>420µm) as proportion of total zooplankton biomass	13

Table E.8 Llyn Rhos Ddu littoral macroinvertebrate summary: 25-9-96
Mean numbers of individuals per one minute kick/sweep sample.

code	Taxon	Mean count/sample
	TURBELLARIA	
03120000	Tricladida	11.2
	MOLLUSCA	
13030103	*Valvata piscinalis*	2.0
13040301	*Potamopyrgus jenkinsi*	50.0
13070105	*Lymnaea stagnalis*	0.4
13070107	*Lymnaea peregra*	16.8
13080201	*Physa fontinalis*	11.2
13090307	*Planorbis albus*	28.0
	BIVALVIA	
14030200	*Pisidium* sp.	17.6
16000000	OLIGOCHAETA	258
	HIRUDINEA	
17020101	*Theromyzon tessalatum*	6.4
17020302	*Glossiphonia complanata*	6.4
17020501	*Helobdella stagnalis*	14.0
17040102	*Erpobdella octoculata*	19.6
19000000	HYDRACARINA	4.4
	MALACOSTRACA	
28030101	*Asellus aquaticus*	9.2
	EPHEMEROPTERA	
30020000	Baetidae species - immatures	28.8
30020301	*Cloeon dipterum*	29.6
30080206	*Caenis luctuosa*	3.2
	ODONATA	
32020000	Coenagriidae species -immatures	59.2
32020201	*Ischnura elegans*	0.4
	HEMIPTERA	
33100101	*Plea leachi*	54.0
33110000	Corixidae species - immatures	0.4
33110401	*Callicorixa praeusta*	30.0
33110502	*Corixa punctata*	0.8
33110504	*Corixa panzeri*	11.6
33110702	*Arctocorisa germari*	5.6
33110801	*Sigara dorsalis*	85.2
33110803	*Sigara distincta*	16.4
33110804	*Sigara falleni*	24.4
33110810	*Sigara concinna*	39.2
	COLEOPTERA	
35010000	Haliplidae sp.	13.6
35010301	*Haliplus confinis*	8.0
35030000	Dytiscidae undet. (larvae	0.4
35030101	*Noterus clavicornis*	4.4
35030401	*Hyphydrus ovatus*	0.8
35040601	*Hygrotius inaequalis*	1.2
	TRICHOPTERA	
38120106	*Athripsodes aterrimus*	11.6
39000000	LEPIDOPTERA	36.0
	DIPTERA	
40090000	Chironomidae	62.4
40200000	Tabanidae	2.8

Figure E.1 Llyn Rhos Ddu: sample location and substrate map

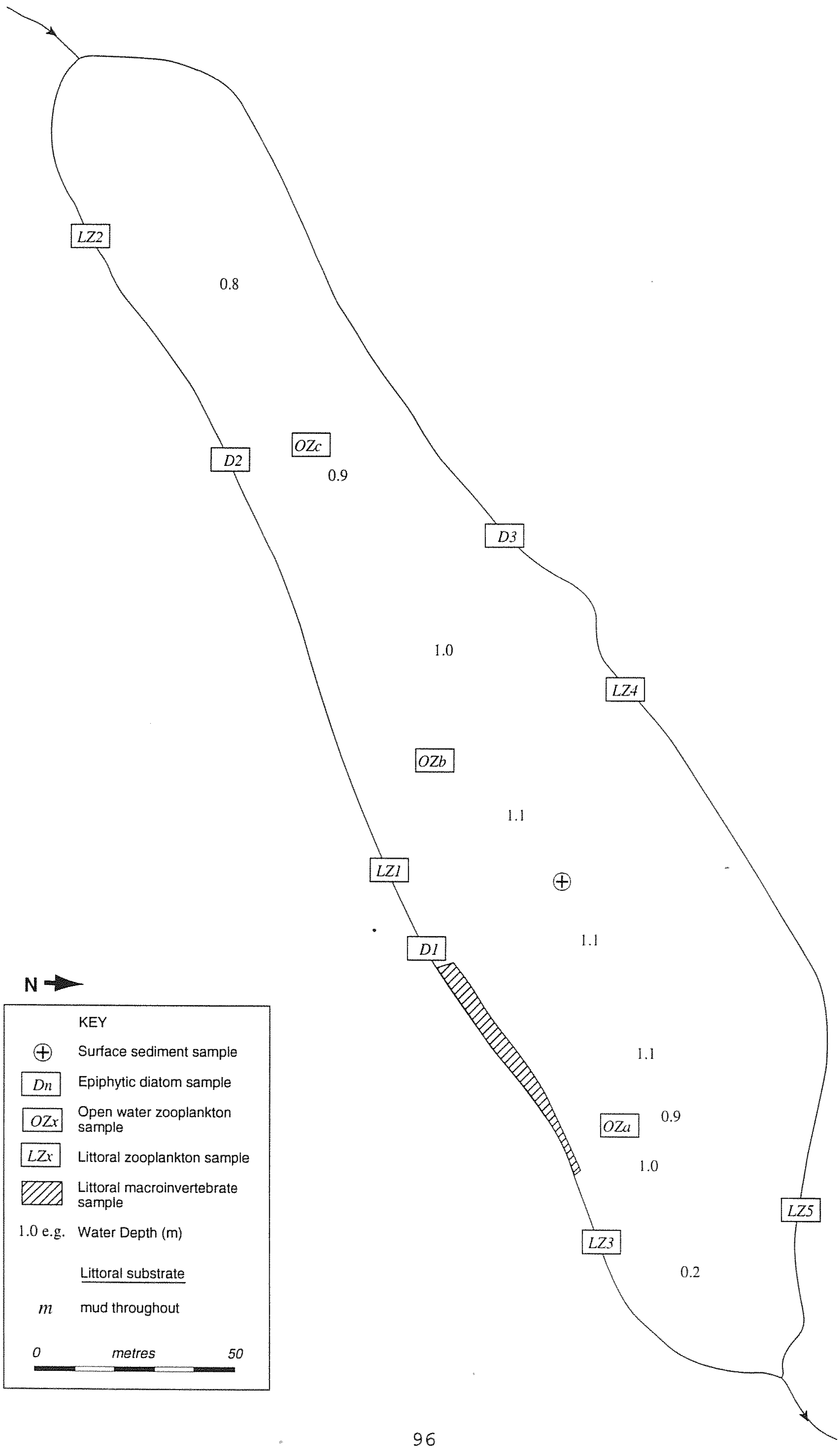
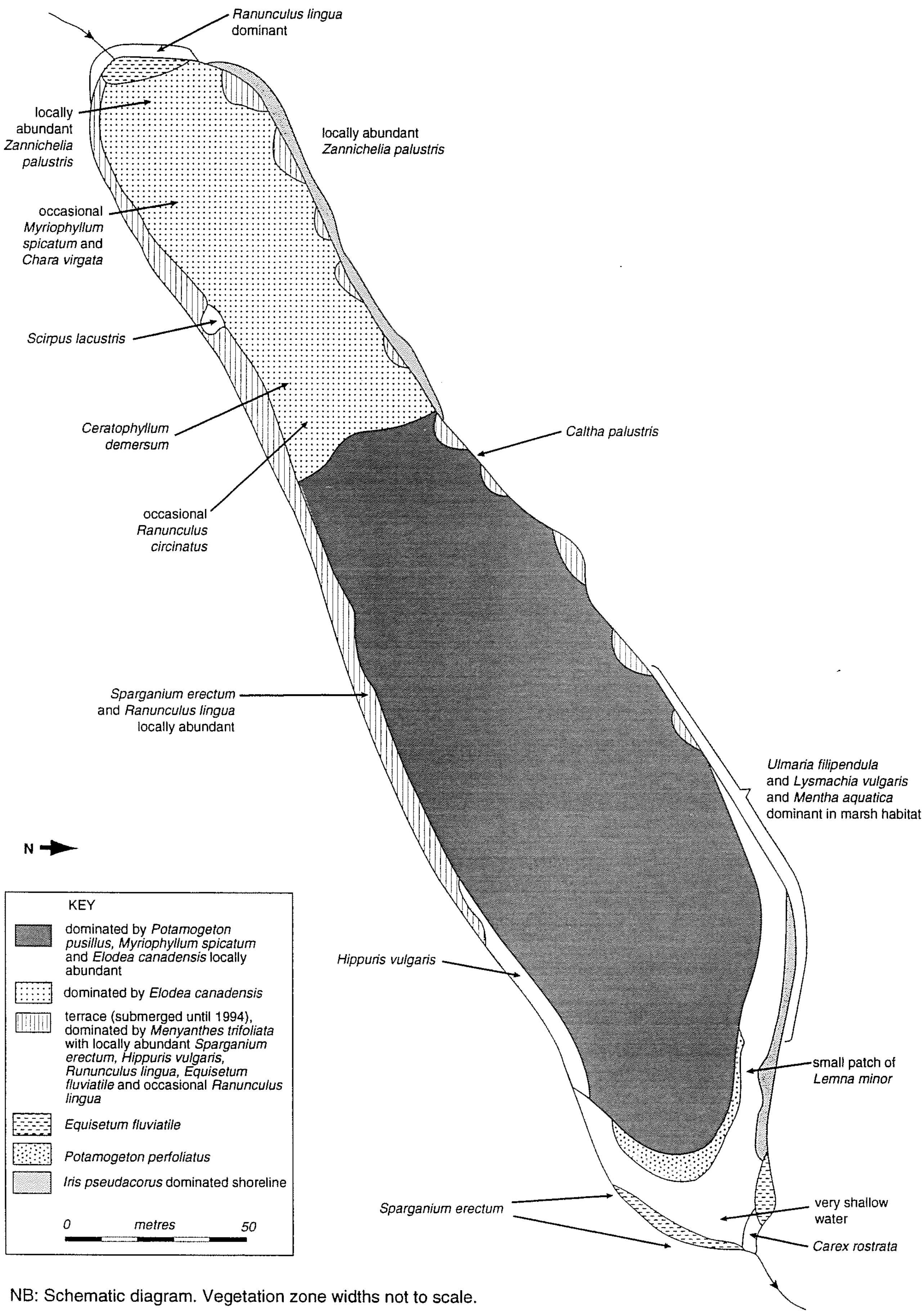


Figure E.2 Llyn Rhos Ddu: aquatic macrophyte distribution map: 16-7-96



NB: Schematic diagram. Vegetation zone widths not to scale.

Figure E.4 Llyn Rhos Ddu: Temperature and dissolved oxygen profiles 16-7-96 (Temperature °c- solid circles, Oxygen mg l^{-1}- empty boxes)

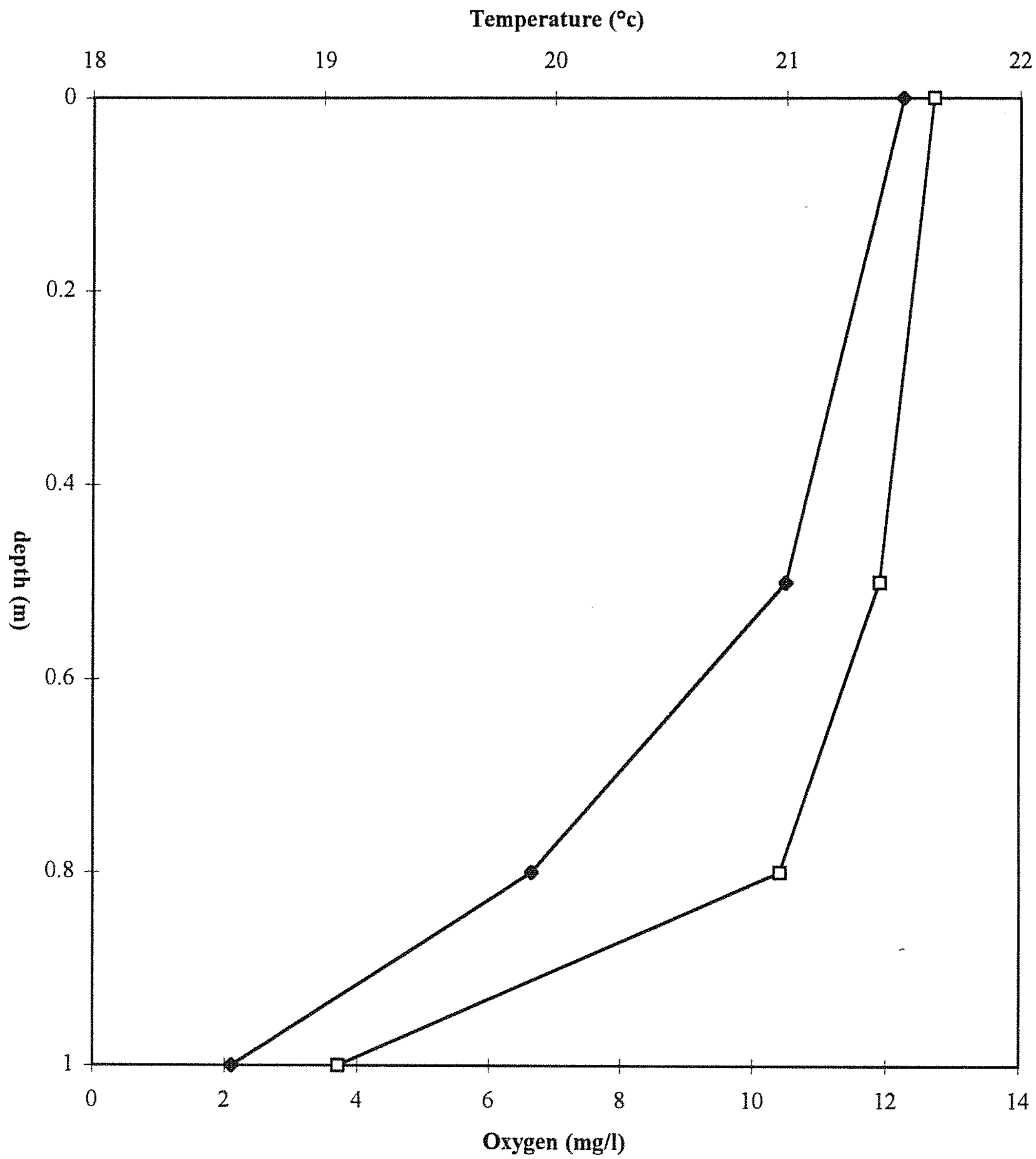


Table F.1 Llynnau Mymbyr water chemistry

Determinand	Sample				
	17/07/96	23/09/96	15/01/97	03/04/97	mean
lab pH	6.21	6.35	4.96	6.07	5.49
field pH		5.85			
Alkalinity 1 (μeq l^{-1})	42	45	-11	23	25
Alkalinity 2 (μeq l^{-1})	33	37	-9	14	19
lab conductivity (μS cm^{-1})	26	29	47	33	34
field conductivity (μS cm^{-1})	22	29	57	45	38
Sodium (μeq l^{-1})	122	143	203	173	160
Potassium (μeq l^{-1})	5	5	10	6	7
Magnesium (μeq l^{-1})	45	40	58	50	48
Calcium (μeq l^{-1})	96	75	100	78	87
Chloride (μeq l^{-1})	108	126	250	184	167
Aluminium total monomeric (μg l^{-1})	4	5	17	16	11
Aluminium non-labile (μg l^{-1})	3	3	9	14	7
Aluminium labile (μg l^{-1})	1	2	8	2	3
Absorbance (250nm)	0.061	0.056	0.040	0.066	0.056
Carbon total organic (mg l^{-1})	2.6	2.5	1.6	1.7	2.1
Phosphorous total (μg P l^{-1})	3	6	5	5	5
Phosphorous total soluble (μg P l^{-1})	3	4	3	3	3
Phosphorous soluble reactive (μg P l^{-1})	2	1	3	2	2
Nitrate (μg N l^{-1})	7	7	114	57	46
Silica soluble reactive (mg l^{-1})	0.4	0.5	1.8	0.7	0.8
Chlorophyll a (μg l^{-1})	1.5	1.8	1.4	1.2	1.5
Sulphate (μeq l^{-1})	58	60	73	53	61
Copper total soluble (μg l^{-1})	0	0	0	0	0
Iron total soluble (μg l^{-1})	60	60	0	0	30
Lead total soluble (μg l^{-1})	0	0	0	0	0
Manganese total soluble (μg l^{-1})	21	13	19	34	22
Zinc total soluble (μg l^{-1})	0	0	0	18	5

Table F.2 Llynnau Mymbyr epilithic diatom taxon taxon list (including taxa >1%)

TAXON	Relative frequency (%)
Achnanthes sp.	1.7
Achnanthes altaica	6.5
Achnanthes marginulata	5.1
Achnanthes minutissima	11.4
Brachysira brebissonii	11.1
Brachysira vitrea	11.1
Cymbella lunata	4.7
Cymbella perpusilla	1.3
Eunotia exigua	3.3
Eunotia incisa	1.6
Eunotia rhomboidea	1.1
Fragilaria virescens var.*exigua*	3.4
Frustulia rhomboides var.*saxonica*	2.5
Navicula mediocris	1.3
Navicula angusta	2.4
Navicula leptostriata	3.2
Navicula radiosa var.*tenella*	1.5
Nitzschia frustulum	6.9
Nitzschia perminuta	1.5
Peronia fibula	1.4
Tabellaria flocculosa	3.7

Table F.3 Llynnau Mymbyr surface sediment diatom taxon list (including taxa >1%)

TAXON	Relative frequency (%)
Achnanthes marginulata	1.4
Achnanthes minutissima	6.0
Brachysira brebissonii	3.7
Brachysira vitrea	17.7
Cymbella lunata	2.3
Cymbella perpusilla	6.3
Eunotia exigua	2.1
Eunotia incisa	3.3
Eunotia naegelii	1.6
Eunotia tenella	1.2
Fragilaria virescens var.*exigua*	12.8
Frustulia rhomboides var.*saxonica*	2.6
Navicula angusta	2.1
Navicula leptostriata	4.7
Navicula mediocris	1.2
Navicula radiosa var.*tenella*	1.4
Navicula [sp. 1]	1.2
Nitzschia frustulum	2.8
Peronia fibula	2.3
Tabellaria flocculosa	3.7

Table F.4 Llynnau Mymbyr aquatic macrophyte abundance summary: 17-7-96

Taxon	code	Abundance
Emergent taxa		
Polytrichum commune	326201	O
Equisetum fluviatile	350202	O
Ranunculus flammula	366904	O
Carex nigra	381119	O
Carex rostrata	381129	O
Eleocharis palustris	382004	O
Phragmites australis	383801	O
Floating leaved taxa		
Nuphar lutea	365501	R
Potamogeton natans	384012	O
Potamogeton polygonifolius	384017	O
Sparganium angustifolium	384601	R
Submerged taxa		
Nitella gracilis	220096	R
Sphagnum auriculatum	327401	F
Isoetes lacustris	350302	A
Littorella uniflora	363901	F
Lobelia dortmanna	364001	F
Myriophyllum alterniflorum	365401	F
Utricularia sp.	369600	O
Juncus bulbosus var. *fluitans*	383006	F
Potamogeton obtusifolius *	384014	O

* = Taxon regionally rare for NRA Welsh Region

Table F.5 Llynnau Mymbyr littoral Cladocera taxon list: 17-7-96

Taxa	Sample number				
	1	2	3	4	5
	number of individuals				
Acroperus harpae					1
Alona affinis	1	1			
Alonella excisa		2	13	1	5
Alonopsis elongata		2	2		19
Chydorus piger	1	1		3	1
Chydorus sphaericus				1	1
Drepanothrix dentata		1		1	
Eubosmina longispina			1	+	
Eurycercus lamellatus	2	11		2	2
Graptoleberis testudinaria		2			
Macrothrix laticornis	1				
Pleuroxus truncatus	2	4		87	1
Streblocerus serricaudatus				1	
Total count	7	24	16	96	30

Table F.6 Llynnau Mymbyr zooplankton abundance summary: 17-7-96

Taxon	Count
Diaphanosoma brachyurum	1000
Polyphemus pediculus	x
Eubosmina longispina	60
Eudiaptomus gracilis	1300
Eucyclops macruroides	x
Thermocyclops dybowskii	x
other planktonic organisms (not quantitatively sampled)	
Nauplia sp.	40
Rotifera sp.	120

X = rare species with relative abundance below 1%
x = very rare species found only at one site

Table F.7 Llynnau Mymbyr zooplankton characteristics

Site depth (m)	6.7
Total zooplankton biomass excluding Chaoborus larvae(g DW m^{-2})	1.06
Chaoborus biomass (g DW m^{-2})	0.00
Net algal biomass (g DW m^{-2})	0.0
Cladoceran biomass as proportion of total zooplankton biomass (%)	28
Large cladoceran (>710µm) as proportion of total zooplankton biomass	0
Large Copepoda (>420µm) as proportion of total zooplankton biomass	9

Table F.8 Llynnau Mymbyr littoral macroinvertebrate summary: 23-9-96
Mean numbers of individuals per one minute kick/sweep sample.

code	Taxon	Mean count/sample
	BIVALVIA	
14030200	*Pisidium* spp.	23.2
16000000	OLIGOCHAETA	64.8
	HIRUDINEA	
17020302	*Glossiphonia complanata*	0.4
17040102	*Erpobdella octoculata*	4.8
19000000	HYDRACARINA	8.0
	EPHEMEROPTERA	
30040000	Leptophlebiidae species	76.8
30080204	*Caenis horaria*	14.4
30080206	*Caenis luctuosa*	4.0
31000000	PLECOPTERA	4.8
	COLEOPTERA	
35110301	*Limnius volckmari*	2.4
35110600	*Oulimnius* species - larvae	0.8
35110602	*Oulimnius troglodytes*	0.8
	TRICHOPTERA	
38030301	*Polycentropus flavomaculatus*	1.2
38030501	*Cyrnus trimaculatus*	- 0.8
38060600	*Oxyethira* species	0.4
38120000	Leptoceridae species	7.6
38120107	*Athripsodes cinereus*	1.2
38150101	*Sericostoma personatum*	0.4
	DIPTERA	
40010000	Tipulidae	2.8
40080000	Ceratopogonidae	0.4
40090000	Chironomidae	64.4

Figure F.1 Llynnau Mymbyr: sample location and substrate map

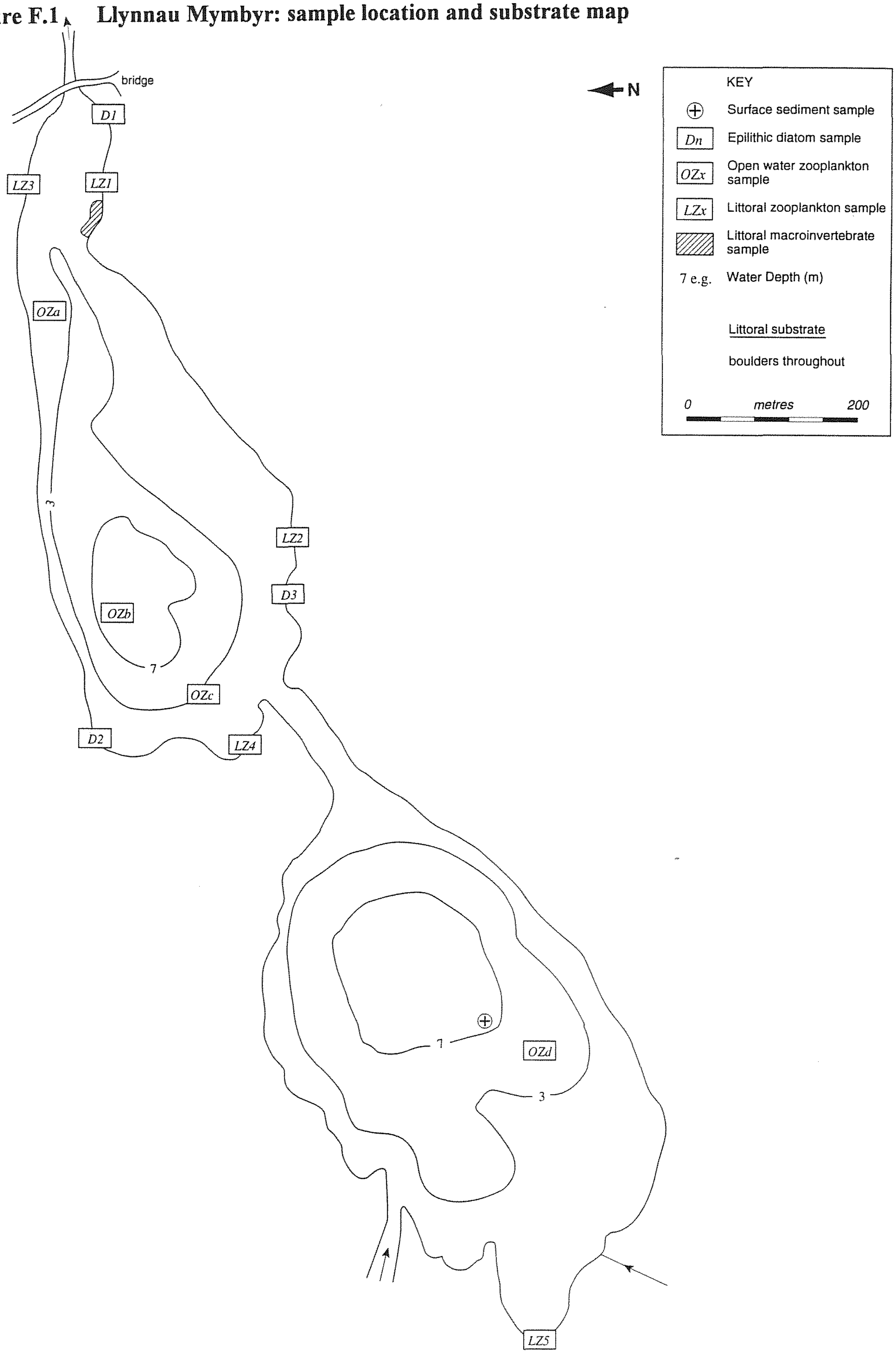
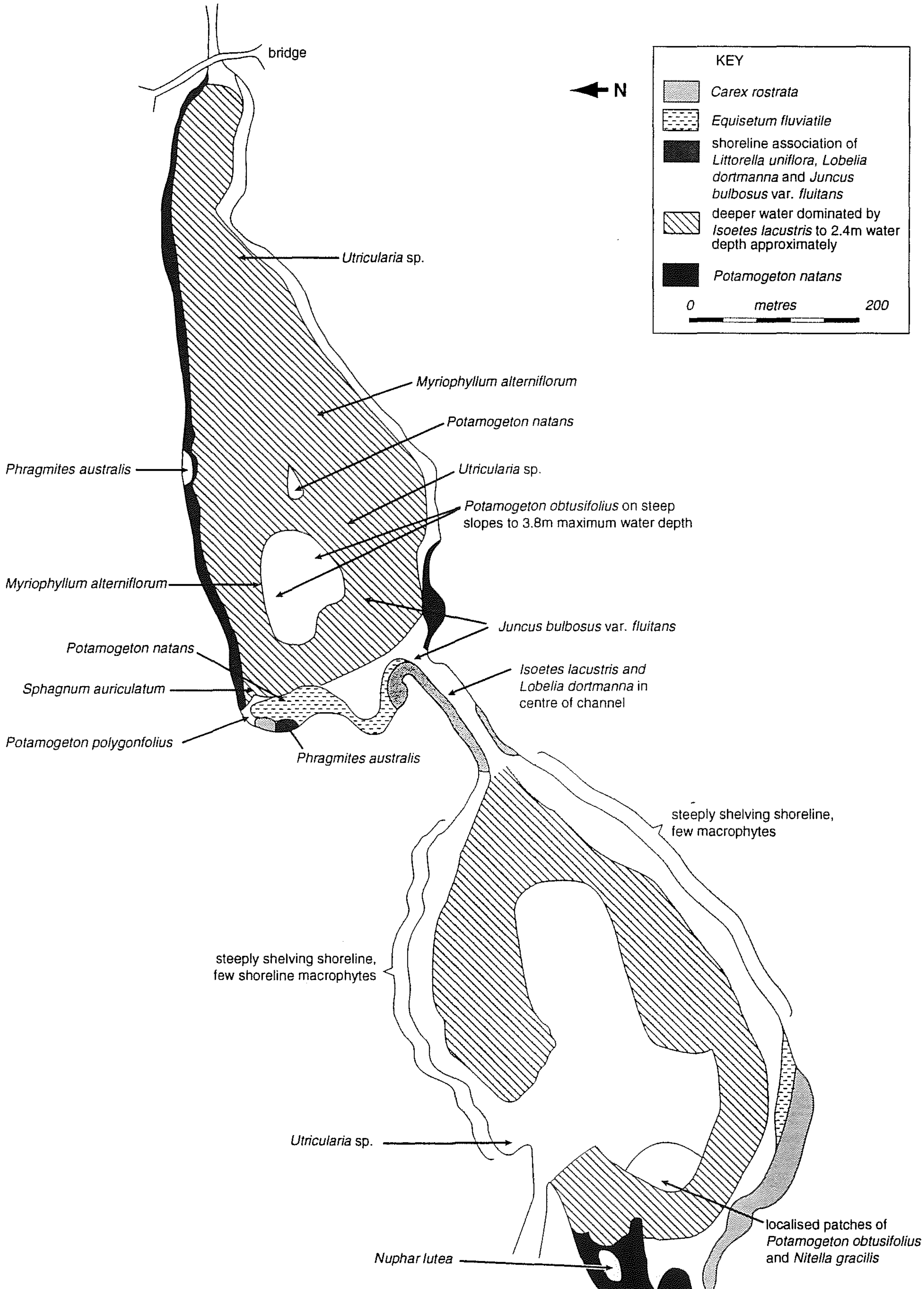


Figure F.2 Llynnau Mymbyr: aquatic macrophyte distribution map: 17-7-96



NB: Schematic diagram. Vegetation zone widths not to scale.

Figure F.4 Llynnau Mymbyr: Temperature and dissolved oxygen profiles 17-7-96 (Temperature °c- solid circles, Oxygen mg l^{-1}- empty boxes)

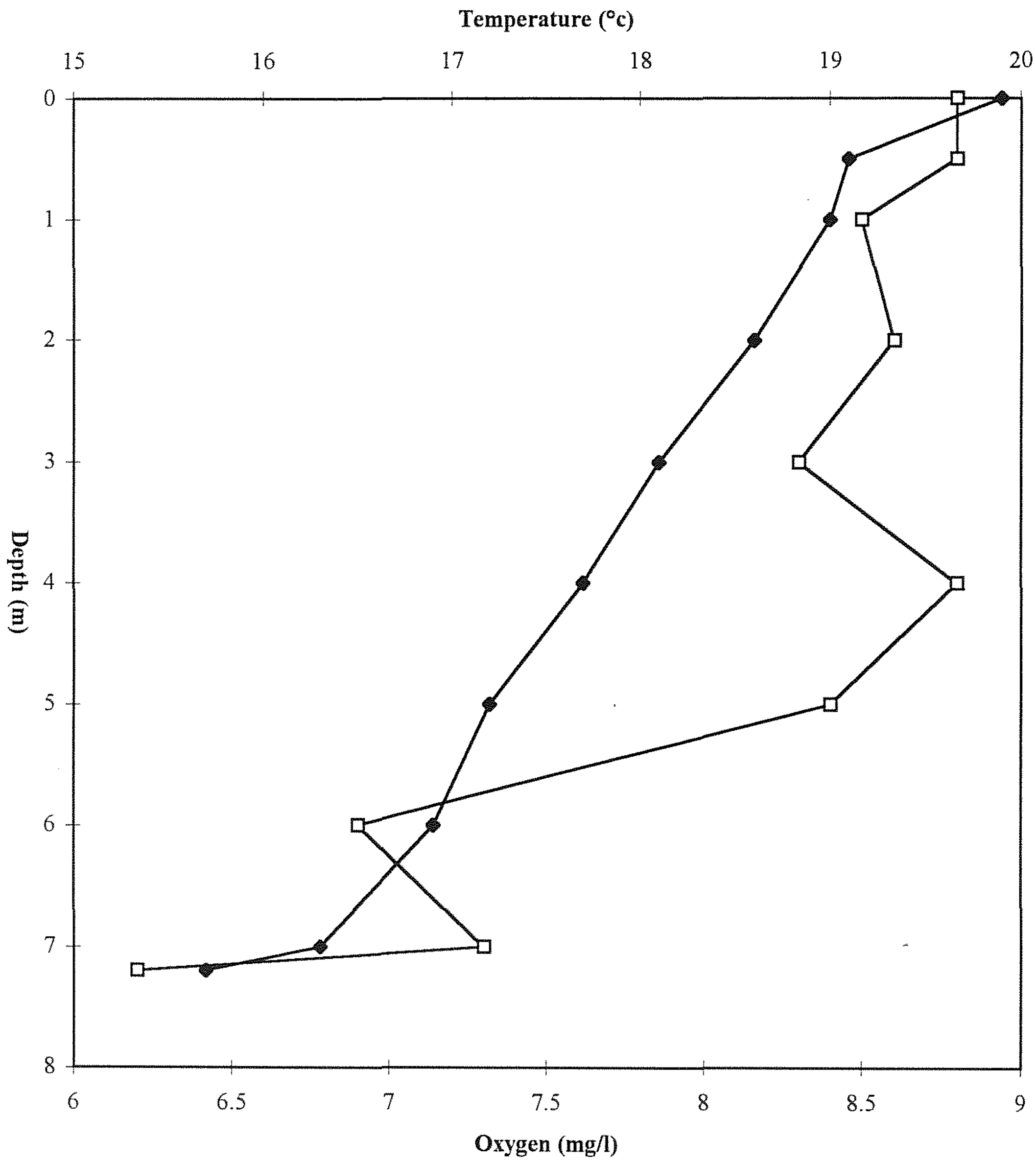


Table G.1 Gloyw Lyn water chemistry

Determinand	Sample				
	19/07/96	24/09/96	15/01/97	04/04/97	mean
lab pH	6.03	6.00	5.93	5.61	5.86
field pH		5.12			
Alkalinity 1 (μeq l^{-1})	33	27	25	13	25
Alkalinity 2 (μeq l^{-1})	24	18	15	4	15
lab conductivity (μS cm^{-1})	37	38	44	55	44
field conductivity (μS cm^{-1})	37	41	45	58	45
Sodium (μeq l^{-1})	182	194	216	276	217
Potassium (μeq l^{-1})	6	5	7	8	7
Magnesium (μeq l^{-1})	66	64	75	93	75
Calcium (μeq l^{-1})	92	78	84	96	88
Chloride (μeq l^{-1})	165	180	239	343	232
Aluminium total monomeric (μg l^{-1})	20	9	24	32	21
Aluminium non-labile (μg l^{-1})	20	8	22	7	14
Aluminium labile (μg l^{-1})	0	1	2	25	7
Absorbance (250nm)	0.110	0.066	0.060	0.063	0.075
Carbon total organic (mg l^{-1})	4.2	2.9	1.9	2.2	2.8
Phosphorous total (μg P l^{-1})	6	6	4	5	5
Phosphorous total soluble (μg P l^{-1})	4	2	2	2	3
Phosphorous soluble reactive (μg P l^{-1})	2	1	2	2	2
Nitrate (μg N l^{-1})	7	7	72	34	30
Silica soluble reactive (mg l^{-1})	0.4	0.2	1.7	0.6	0.7
Chlorophyll a (μg l^{-1})	0.7	2.4	2.9	2.2	2.1
Sulphate (μeq l^{-1})	88	92	86	84	88
Copper total soluble (μg l^{-1})	0	0	0	0	0
Iron total soluble (μg l^{-1})	90	70	70	50	70
Lead total soluble (μg l^{-1})	0	0	0	0	0
Manganese total soluble (μg l^{-1})	14	2	3	23	11
Zinc total soluble (μg l^{-1})	0	0	0	0	0

Table G.2 Gloyw Lyn epilithic diatom taxon taxon list (including taxa >1%)

TAXON	Relative frequency (%)
Achnanthes marginulata	1.3
Brachysira vitrea	28.9
Brachysira brebissonii	12.2
Eunotia rhomboidea	1.8
Eunotia incisa	1.9
Eunotia naegelii	2.7
Frustulia rhomboides var.*saxonica*	3.62
Navicula leptostriata	25.7
Nitzschia perminuta	1.5
Peronia fibula	3.6
Tabellaria flocculosa	8.4
Tabellaria quadriseptata	1.3

Table G.3 Gloyw Lyn surface sediment diatom taxon list (including taxa >1%)

TAXON	Relative frequency (%)
Achnanthes marginulata	1.6
Achnanthes minutissima	2.2
Aulacoseira perglabra	2.2
Brachysira brebissonii	2.2
Brachysira vitrea	3.4
Cymbella hebridica	1.5
Cymbella lunata	1.6
Cymbella perpusilla	3.8
Eunotia incisa	2.4
Eunotia naegelii	3.3
Eunotia rhomboidea	1.8
Fragilaria sp.	1.1
Fragilaria virescens var.*exigua*	16.3
Fragilaria [cf. *oldenburgiana*]	1.1
Frustulia rhomboides	1.3
Frustulia rhomboides var.*saxonica*	2.9
Gomphonema acuminatum	1.6
Navicula bremensis	1.8
Navicula leptostriata	21.1
Navicula madumensis	1.1
Navicula mediocris	2.2
Tabellaria flocculosa	1.8
Tabellaria quadriseptata	4.9

Table G.4 Gloyw Lyn aquatic macrophyte abundance summary: 19-7-96

Taxon	code	Abundance
Emergent taxa		
Equisetum fluviatile	350202	F
Caltha palustris	361201	R
Hydrocotyle vulgaris	363401	O
Menyanthes trifoliata	364701	R
Ranunculus flammula	366904	R
Carex rostrata	381129	F
Floating leaved taxa		
Potamogeton natans	384012	R
Submerged taxa		
Batrachospermum sp.	200000	O
Sphagnum auriculatum	327401	R
Isoetes lacustris	350302	O
Littorella uniflora	363901	O
Lobelia dortmanna	364001	O
Utricularia sp.	369600	R

Table G.5 Gloyw Lyn littoral Cladocera taxon list: 19-7-96

Taxa	Sample number				
	1	2	3	4	5
Acantholeberis curvirostris	1			4	
Acroperus harpae	4				5
Alona affinis	7	10	116	1	221
Alona rustica				1	
Alonella excisa	1	1			1
Alonella nana	1				
Alonopsis elongata	5	14	12	7	1
Chydorus sphaericus	3			4	
Drepanothrix dentata	5	1	1		
Eubosmina longispina	8		116		2
Eurycercus lamellatus	4			4	
Graptoleberis testudinaria					2
Sida crystallina					1
Total count	78	65	284	60	272

Table G.6 Gloyw Lyn zooplankton abundance summary: 19-7-96

Taxon	Count
Diaphanosoma brachyurum	X
Alona affinis	X
Eubosmina longispina	400
Cyclops abyssorum	400

X = rare species with relative abundance below 1%
x = very rare species found only at one site

Table G.7 Gloyw Lyn zooplankton characteristics

Site depth (m)	7.2
Total zooplankton biomass excluding Chaoborus larvae(g DW m^{-2})	0.68
Chaoborus biomass (g DW m^{-2})	0.00
Net algal biomass (g DW m^{-2})	0.0
Cladoceran biomass as proportion of total zooplankton biomass (%)	35
Large cladoceran (>710µm) as proportion of total zooplankton biomass	0
Large Copepoda (>420µm) as proportion of total zooplankton biomass	10

Table G.8 Gloyw Lyn littoral macroinvertebrate summary: 24-9-96
Mean numbers of individuals per one minute kick/sweep sample.

code	Taxon	Mean count/sample
	BIVALVIA	
14030200	*Pisidium* spp.	0.4
16000000	OLIGOCHAETA	6.8
	EPHEMEROPTERA	
30040000	Leptophlebiidae species	3.6
	HEMIPTERA	
33110000	Corixidae species - immatures	6.4
33110402	*Callicorixa wollastoni*	0.4
33110807	*Sigara scotti*	9.6
33110801	*Sigara dorsalis*	3.2
	TRICHOPTERA	
38030301	*Polycentropus flavomaculatus*	3.2
	DIPTERA	
40090000	Chironomidae	13.6

Figure G.1 Gloyw Lyn: sample location and substrate map

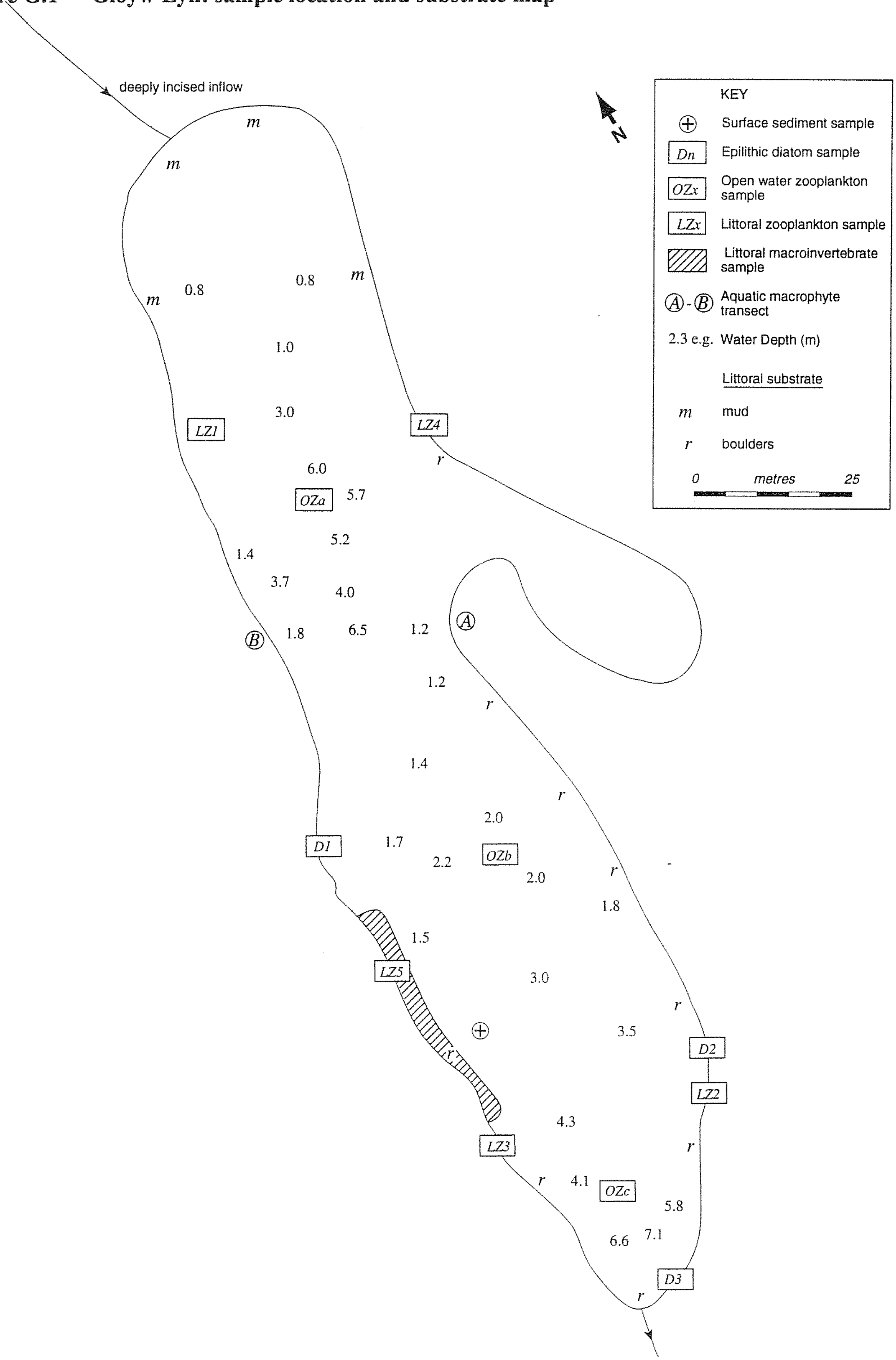
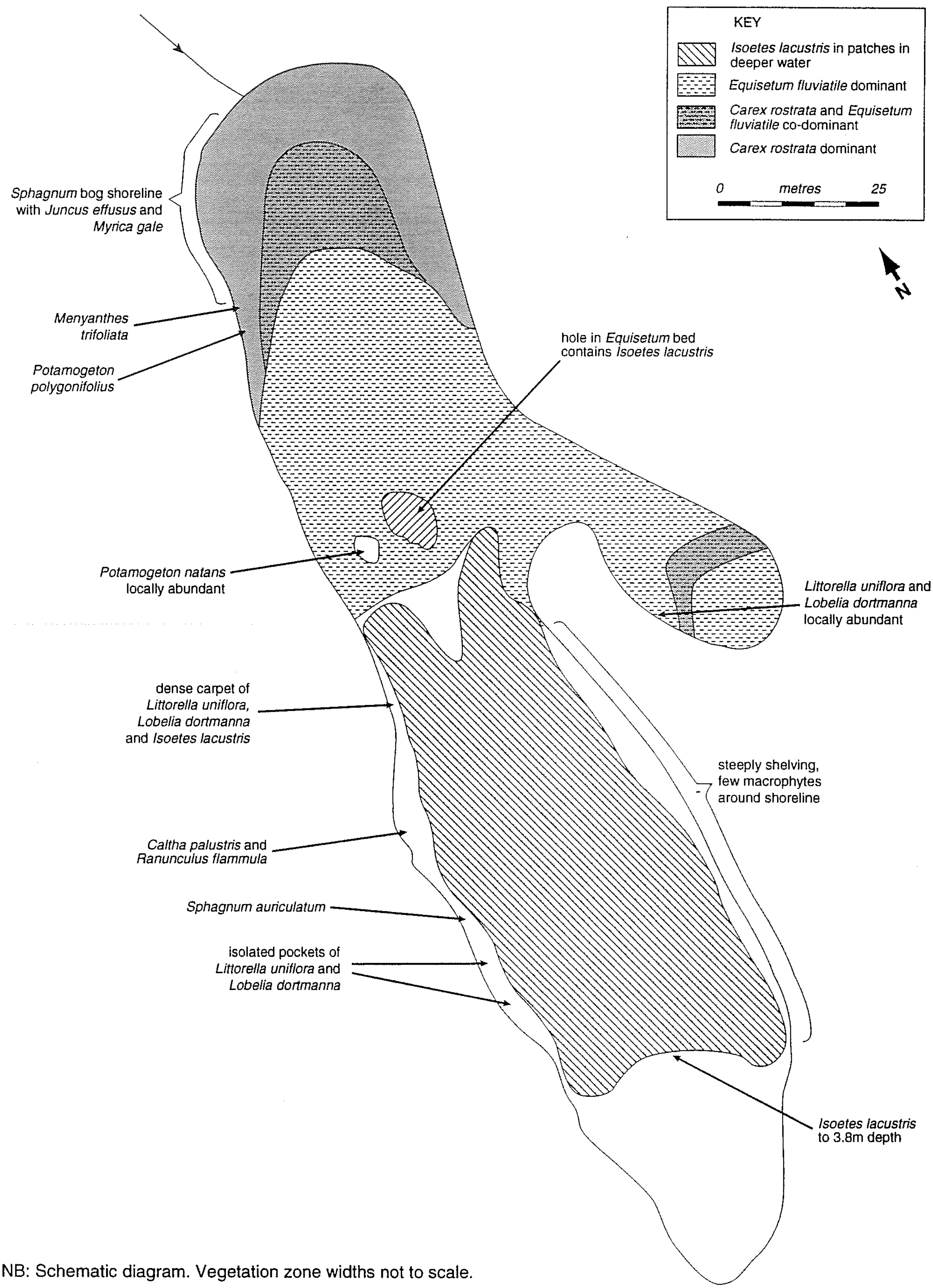


Figure G.2 Gloyw Lyn: aquatic macrophyte distribution map: 19-7-96



NB: Schematic diagram. Vegetation zone widths not to scale.

Figure G.3 Gloyw Lyn: aquatic macrophyte transect profile

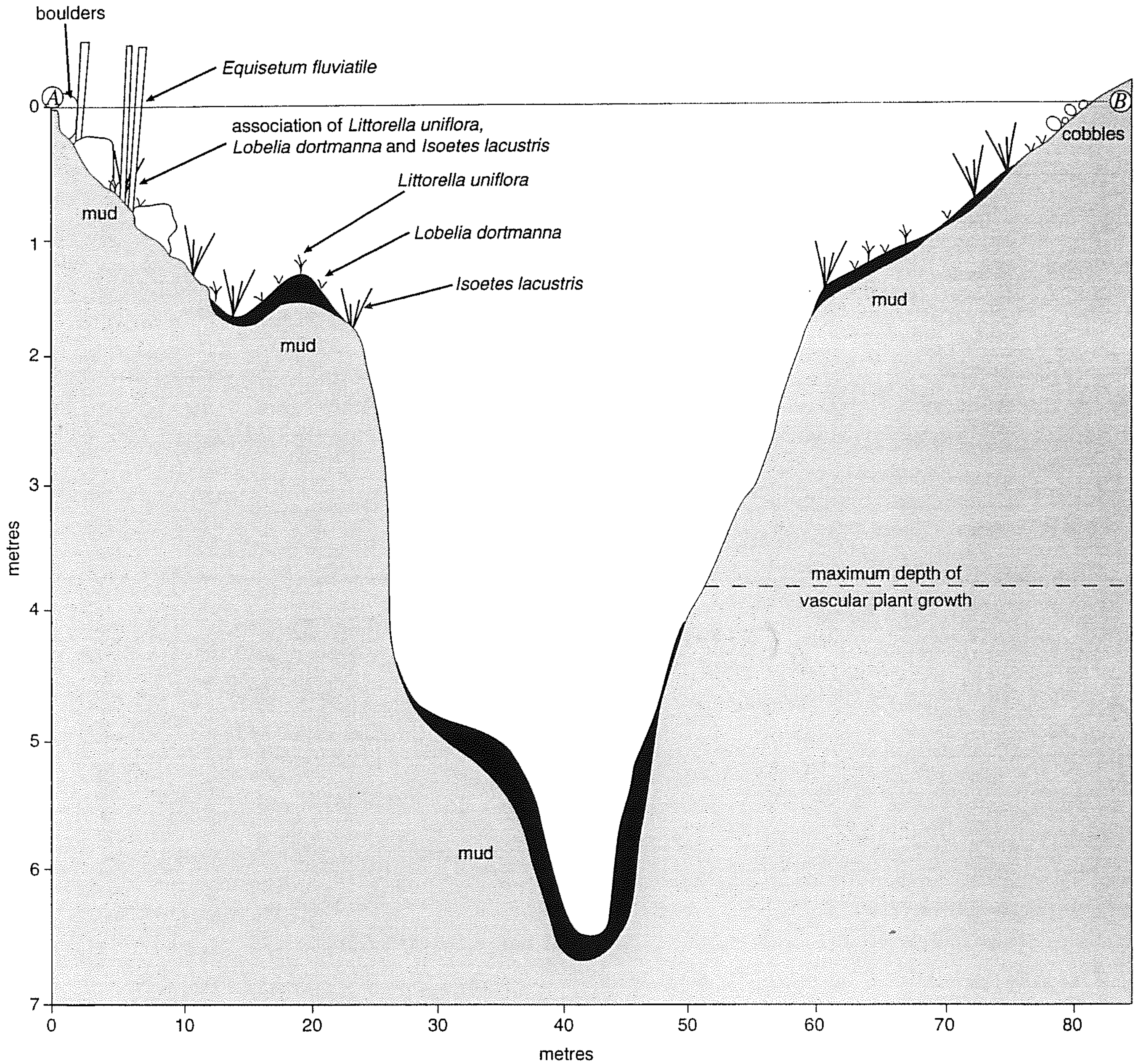


Figure G.4 Gloyw Lyn: Temperature and dissolved oxygen profiles 19-7-96 (Temperature °c- solid circles, Oxygen mg l^{-1}- empty boxes)

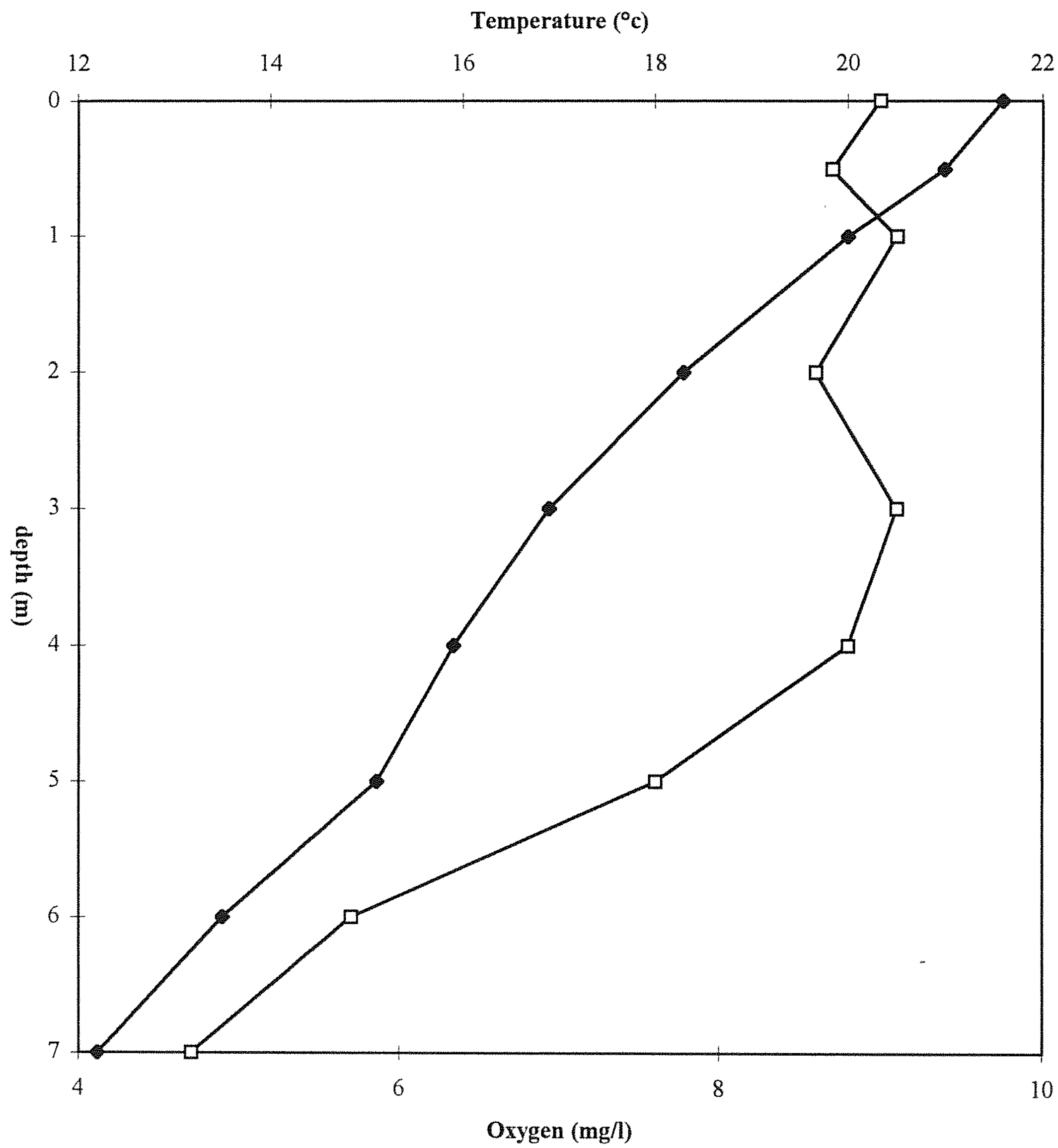


Table H.1 Llyn yr Wyth Eidion water chemistry

Determinand	Sample				
	20/07/96	26/09/96	16/01/97	05/04/97	mean
lab pH	7.95	7.88	7.86	8.07	7.93
field pH		7.81	7.65		
Alkalinity 1 (μeq l^{-1})	4034	4107	4022	3826	3997
Alkalinity 2 (μeq l^{-1})	4097	4185	4066	3874	4056
lab conductivity (μS cm^{-1})	576	570	621	571	585
field conductivity (μS cm^{-1})	545	570	550	580	561
Sodium (μeq l^{-1})	704	737	716	689	712
Potassium (μeq l^{-1})	35	34	48	43	40
Magnesium (μeq l^{-1})	404	433	360	358	389
Calcium (μeq l^{-1})	5947	5579	5883	5886	5824
Chloride (μeq l^{-1})	897	888	1039	990	954
Aluminium total monomeric (μg l^{-1})	4	7	5	7	6
Aluminium non-labile (μg l^{-1})	4	4	4	4	4
Aluminium labile (μg l^{-1})	0	3	1	3	2
Absorbance (250nm)	0.308	0.317	0.280	0.277	0.296
Carbon total organic (mg l^{-1})	8.4	9.7	7.3	7.3	8.2
Phosphorous total (μg P l^{-1})	16	25	16	10	17
Phosphorous total soluble (μg P l^{-1})	11	14	6	5	9
Phosphorous soluble reactive (μg P l^{-1})	4	5	4	3	4
Nitrate (μg N l^{-1})	553	7	3639	3549	1937
Silica soluble reactive (mg l^{-1})	2.6	4.8	4.5	1.7	3.4
Chlorophyll a (μg l^{-1})	2.2	9.1	2.3	2.9	4.1
Sulphate (μeq l^{-1})	1107	882	1049	989	1007
Copper total soluble (μg l^{-1})	0	0	0	0	0
Iron total soluble (μg l^{-1})	40	90	120	100	88
Lead total soluble (μg l^{-1})	0	0	0	0	0
Manganese total soluble (μg l^{-1})	73	39	15	9	34
Zinc total soluble (μg l^{-1})	0	0	0	2	1

Table H.2 Llyn yr Wyth Eidion epilithic diatom taxon (including taxa >0.1%)

TAXON	Relative frequency (%)
Achnanthes minutissima	95.2
Amphora pediculus	0.3
Cymbella microcephala	0.5
Eunotia sp.	0.9
Navicula cryptocephala	0.3
Navicula radiosa	0.2
Nitzschia fonticola	0.3
Nitzschia palea	0.3
Nitzschia sp.	0.4
Tabellaria flocculosa	0.3

Table H.3 Llyn yr Wyth Eidion surface sediment diatom taxon list (including taxa >1%)

TAXON	Relative frequency (%)
Achnanthes minutissima	5.2
Amphora pediculus	3.8
Asterionella formosa	1.9
Aulacoseira granulata	55.5
Cocconeis placentula	1.4
Fragilaria brevistriata	7.7
Fragilaria construens var.*venter*	6.3
Fragilaria leptostauron	1.6
Fragilaria pinnata	2.5
Fragilaria sp.	1.1
Navicula cryptocephala	1.6
Stephanodiscus parvus	1.4

Table H.4 Llyn yr Wyth Eidion aquatic macrophyte abundance summary: 20-7-96

Taxon	code	Abundance
Emergent taxa		
Carex elata	381111	O
Cladium mariscus	381301	O
Phragmites australis	383801	A
Scirpus lacustris ssp. *lacustris*	384504	O
Floating leaved taxa		
Nuphar lutea	365501	A
Nymphaea alba	365601	O
Submerged taxa		
Chara virgata	000000	O
Hippuris vulgaris	363201	R
Potamogeton pusillus	384019	R

Table H.5 Llyn yr Wyth Eidion littoral Cladocera taxon list: 20-7-96

Taxa	Sample number				
	1	2	3	4	5
	number of individuals				
Acroperus harpae	2	3	1	28	1
Alona affinis	5	11	10	32	7
Chydorus sphaericus	2	9	1		6
Daphnia hyalina					2062
Daphnia pulex	32	414	2		204
Diaphanosoma brachyurum			1		2
Eurycercus lamellatus	3	2	4	2	4
Lathonura rectirostris			1		
Pleuroxus aduncus	2	9			
Pleuroxus laevis			2	1	
Total count	46	448	22	63	2286

Table H.6 Llyn yr Wyth Eidion zooplankton abundance summary: 20-7-96

Taxon	Count
Diaphanosoma brachyurum	200
Daphnia galeata	200
Daphnia pulex	230
Eudiaptomus gracilis	270
Cyclops vicinus	x
Thermocyclops dybowskii	320
other planktonic organisms (not quantitatively sampled)	
Chaoborus sp.	X
Volvox	3300
Nauplia	20
Asplanchna sp.	90

X = rare species with relative abundance below 1%
x = very rare species found only at one site

Table H.7 Llyn yr Wyth Eidion zooplankton characteristics

Site depth (m)	6.7
Total zooplankton biomass excluding Chaoborus larvae(g DW m^{-2})	1.28
Chaoborus biomass (g DW m^{-2})	0.00
Net algal biomass (g DW m^{-2})	0.0
Cladoceran biomass as proportion of total zooplankton biomass (%)	28
Large cladoceran (>710µm) as proportion of total zooplankton biomass	0
Large Copepoda (>420µm) as proportion of total zooplankton biomass	9

Table H.8 Llyn yr Wyth Eidion littoral macroinvertebrate summary: 26-9-96 Mean numbers of individuals per one minute kick/sweep sample.

code	Taxon	Mean count/sample
	TURBELLARIA	
03120000	Tricladida	0.8
	MOLLUSCA	
13030103	*Valvata piscinalis*	0.8
13040301	*Potamopyrgus jenkinsi*	6.8
13070107	*Lymnaea peregra*	2.0
13080201	*Physa fontinalis*	1.2
13090307	*Planorbis albus*	1.2
	BIVALVIA	
14030200	*Pisidium* spp.	32.0
16000000	OLIGOCHAETA	46.8
	HIRUDINEA	
17020101	*Theromyzon tessalatum*	0.8
17020302	*Glossiphonia complanata*	0.8
17020501	*Helobdella stagnalis*	0.8
17040102	*Erpobdella octoculata*	18.0
19000000	HYDRACARINA	4.0
	MALACOSTRACA	
28030104	*Asellus meridianus*	32.4
28070305	*Gammarus pulex*	50.0
	EPHEMEROPTERA	
30020000	Baetidae species -immatures	60.4
30020301	*Cloeon dipterum*	1.6
30080204	*Caenis horaria*	9.2
	ODONATA	
32020000	Coenagriidae species - immatures	22.8
32020201	*Ischnura elegans*	0.4
32070101	*Brachytron pratense*	0.8
	HEMIPTERA	
33110801	*Sigara dorsalis*	1.2
33110804	*Sigara falleni*	1.2
33110806	*Sigara fossarum*	0.8
	COLEOPTERA	
35010000	Haliplidae species - larvae	0.4
35010301	*Haliplus confinis*	0.4
35030101	*Noterus clavicornis*	0.8
35030907	*Hydroporus lineatus*	0.4
35050500	*Helophorus* sp.	0.4
35110600	*Oulimnius* species - larvae	2.0
	MEGALOPTERA	
36010101	*Sialis lutaria*	1.2
	TRICHOPTERA	
38040301	*Lype phaeopa*	8.4
38070400	*Agrypnia varia / obselata*	4.0
38120106	*Athripsodes aterrimus*	23.2
38120301	*Triaenodes bicolor*	1.2
	DIPTERA	
40010000	Tipulidae	4.0
40040200	Dixella species	2.0
40080000	Ceratopogonidae	0.4
40090000	Chironomidae	356.0
40170000	Empididae	0.4

Figure H.1 Llyn yr Wyth Eidion: sample location and substrate map

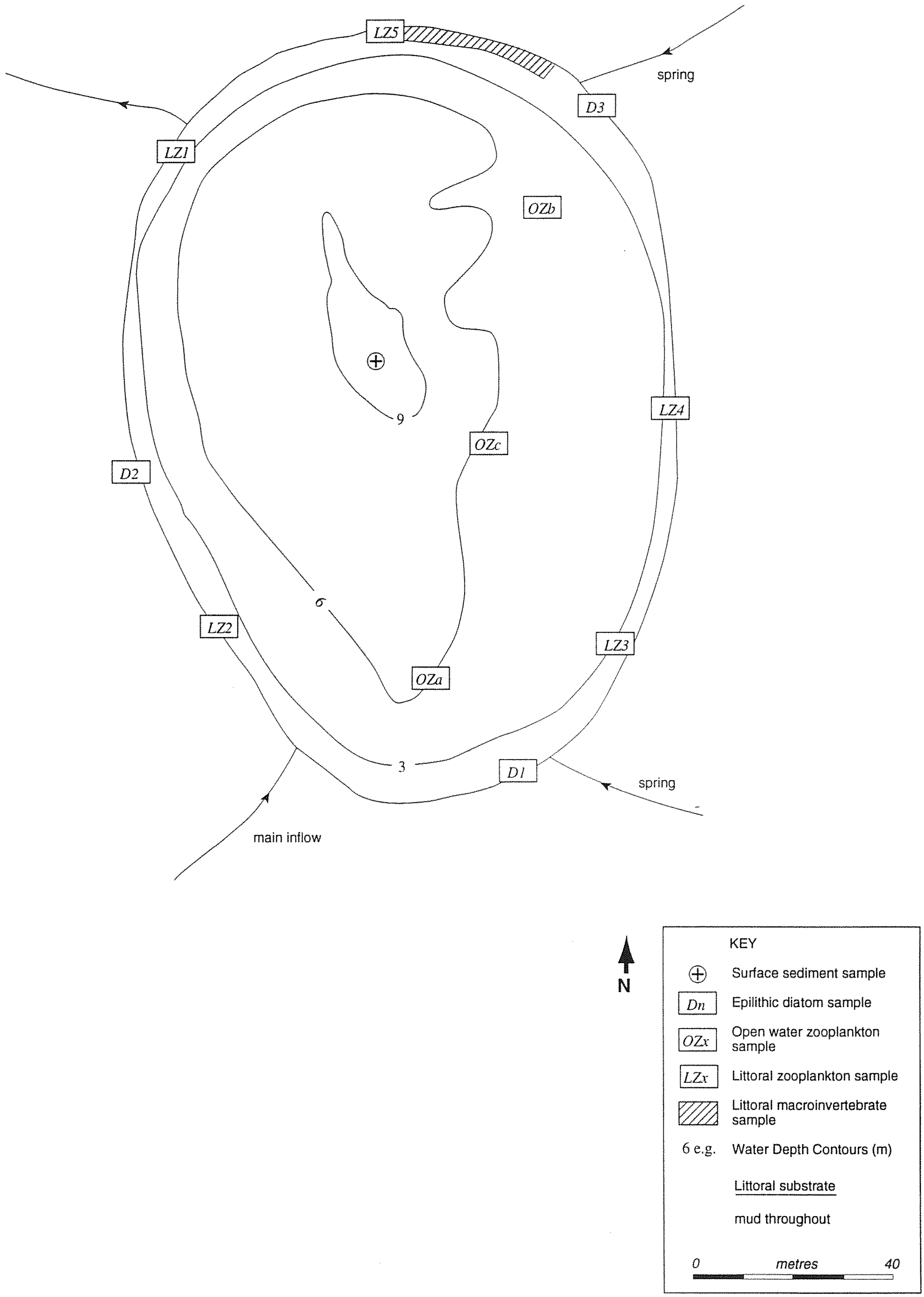


Figure H.2 Llyn yr Wyth Eidion: aquatic macrophyte distribution map: 19-7-96

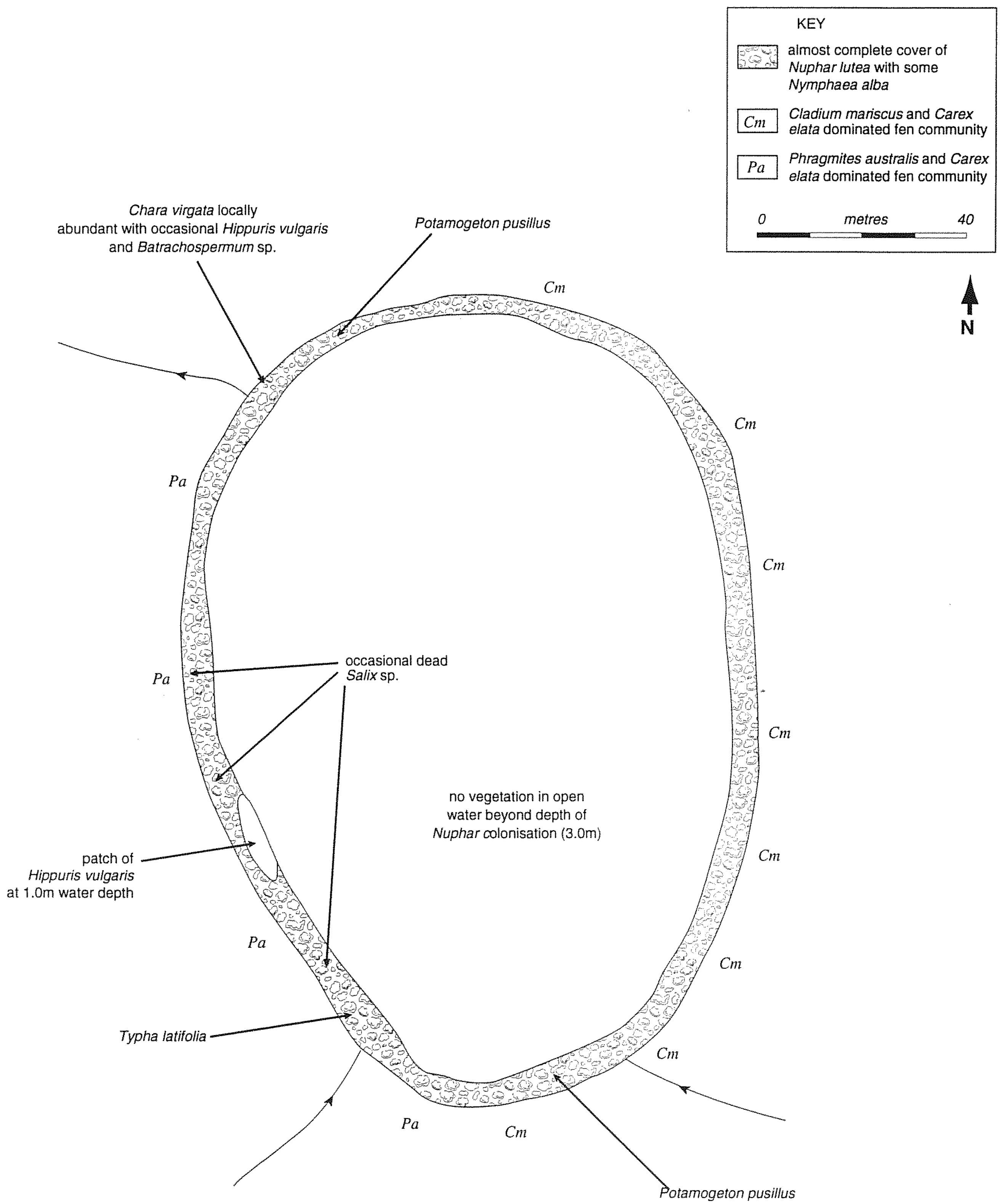


Figure H.4 Llyn yr Wyth Eidion: Temperature and dissolved oxygen profiles 20-7-96 (Temperature °c- solid circles, Oxygen mg l^{-1}- empty boxes)

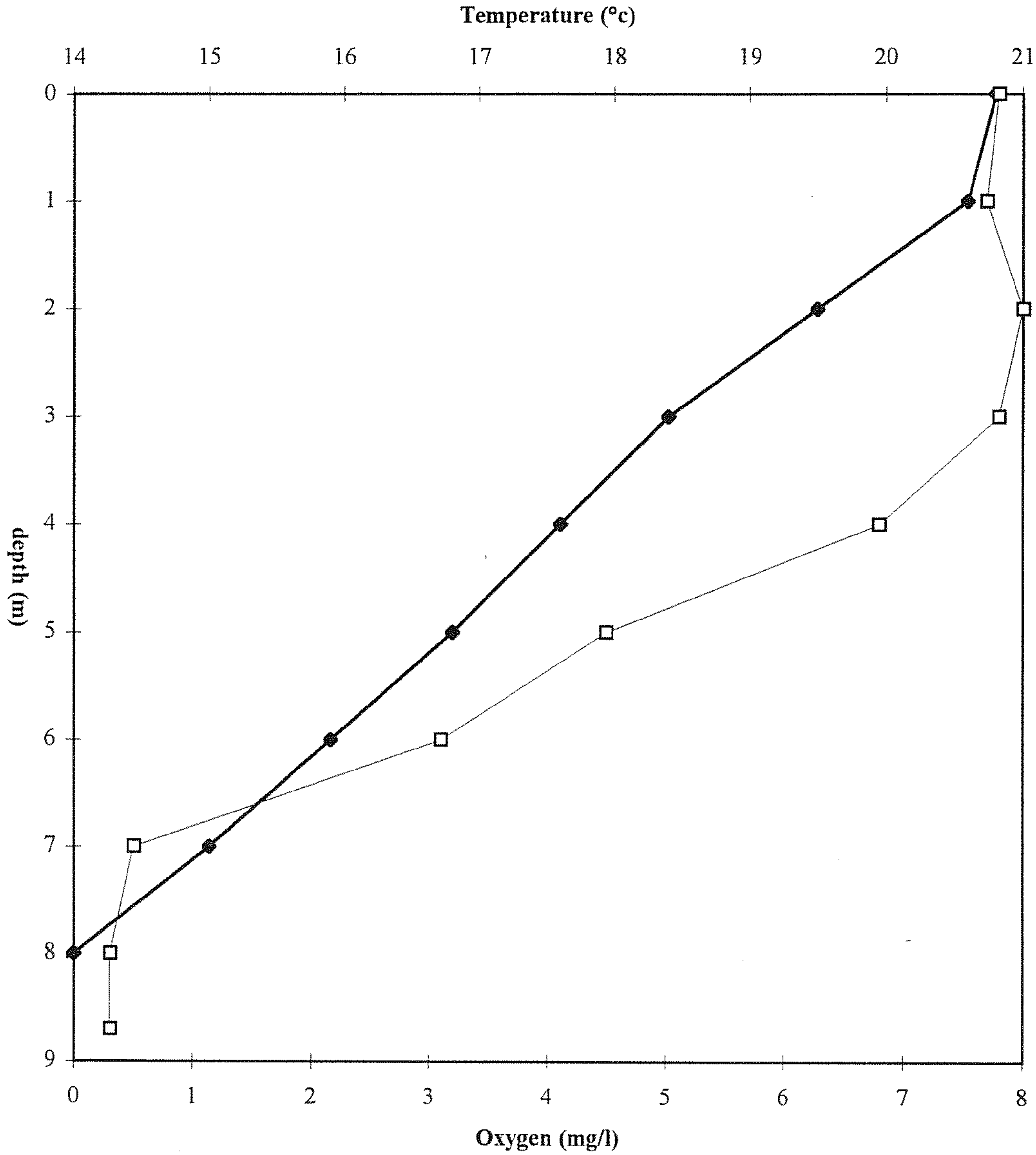


Table I.1 Llyn Cau water chemistry

Determinand	Sample				
	22/07/96	24/09/96	15/01/97	04/04/97	mean
lab pH	5.92	5.81	5.73	5.95	5.84
field pH		5.70			
Alkalinity 1 ($\mu eq\ l^{-1}$)	18	15	16	18	17
Alkalinity 2 ($\mu eq\ l^{-1}$)	8	5	6	9	7
lab conductivity ($\mu S\ cm^{-1}$)	32	32	31	32	32
field conductivity ($\mu S\ cm^{-1}$)	31	32	33	33	32
Sodium ($\mu eq\ l^{-1}$)	142	144	140	145	143
Potassium ($\mu eq\ l^{-1}$)	5	6	6	7	6
Magnesium ($\mu eq\ l^{-1}$)	63	62	60	59	61
Calcium ($\mu eq\ l^{-1}$)	112	80	70	81	86
Chloride ($\mu eq\ l^{-1}$)	145	147	146	155	148
Aluminium total monomeric ($\mu g\ l^{-1}$)	1	2	6	6	4
Aluminium non-labile ($\mu g\ l^{-1}$)	1	2	6	6	4
Aluminium labile ($\mu g\ l^{-1}$)	0	0	0	0	0
Absorbance (250nm)	0.007	0.028	0.010	0.021	0.017
Carbon total organic ($mg\ l^{-1}$)	1.0	0.7	0.6	0.9	0.8
Phosphorous total ($\mu g\ P\ l^{-1}$)	3	4	5	3	3.5
Phosphorous total soluble ($\mu g\ P\ l^{-1}$)	1	3	2	2	2
Phosphorous soluble reactive ($\mu g\ P\ l^{-1}$)	1	1	2	2	1
Nitrate ($\mu g\ N\ l^{-1}$)	244	163	141	210	190
Silica soluble reactive ($mg\ l^{-1}$)	1.3	1.3	1.3	1.3	1.3
Chlorophyll a ($\mu g\ l^{-1}$)	0.7	0.8	1.0	1.1	0.9
Sulphate ($\mu eq\ l^{-1}$)	73	71	70	69	71
Copper total soluble ($\mu g\ l^{-1}$)	0	0	0	0	0
Iron total soluble ($\mu g\ l^{-1}$)	10	0	0	60	18
Lead total soluble ($\mu g\ l^{-1}$)	0	0	0	0	0
Manganese total soluble ($\mu g\ l^{-1}$)	3	3	0	4	3
Zinc total soluble ($\mu g\ l^{-1}$)	0	0	0	4	1

Table I.2 **Llyn Cau epilithic diatom taxon taxon list (including taxa >1%)**

TAXON	Relative frequency (%)
Achnanthes altaica	5.0
Achnanthes marginulata	25.8
Achnanthes minutissima	4.9
Achnanthes [*altaica* var. *minor*]	1.4
Cyclotella comensis	16.3
Cyclotella rossii	1.1
Eunotia sp.	1.2
Eunotia denticulata	2.7
Eunotia exigua	6.1
Eunotia incisa	1.9
Eunotia pectinalis var. *minor*	1.2
Peronia fibula	4.3
Tabellaria flocculosa	14.0

Table I.3 **Llyn Cau surface sediment diatom taxon list (including taxa >1%)**

TAXON	Relative frequency (%)
Achnanthes altaica	1.4
Achnanthes austriaca	1.6
Achnanthes austriaca var.*helvetica*	1.6
Achnanthes marginulata	5.3
Achnanthes minutissima	3.1
Brachysira vitrea	1.9
Cyclotella comensis	72.8
Cyclotella rossii	1.8

Table I.4 Llyn Cau aquatic macrophyte abundance summary: 22-7-96

Taxon	code	Abundance
Submerged taxa		
Sphagnum auriculatum	327401	O
Rhytidiadelphus squarrosus	327001	O
Nardia compressa	343701	F
Isoetes lacustris	350302	A
Callitriche hamulata	361103	F
Littorella uniflora	363901	F
Juncus bulbosus var. *fluitans*	383006	F

Table I.5 Llyn Cau littoral Cladocera taxon list: 22-7-96

Taxa	Sample number				
	number of individuals				
	1	2	3	4	5
Acroperus harpae		4		8	1
Alonella excisa		2		3	3
Alonopsis elongata	9	26	38	152	83
Chydorus piger	1				
Eubosmina longispina				35	
Eurycercus lamellatus				1	
Monospilus dispar		1			
Total count	10	33	38	199	87

Table I.6 Llyn Cau zooplankton abundance summary: 22-7-96

Taxon	Count
Diaphanosoma brachyurum	40
Eurycercus lamellatus	x
Eubosmina longispina	4500
Cyclops abyssorum	1200

X = rare species with relative abundance below 1%
x = very rare species found only at one site

Table I.7 Llyn Cau zooplankton characteristics

Site depth (m)	46.5
Total zooplankton biomass excluding Chaoborus larvae(g DW m^{-2})	2.15
Chaoborus biomass (g DW m^{-2})	0.00
Net algal biomass (g DW m^{-2})	0.0
Cladoceran biomass as proportion of total zooplankton biomass (%)	70
Large cladoceran (>710μm) as proportion of total zooplankton biomass	0
Large Copepoda (>420μm) as proportion of total zooplankton biomass	3

Table I.8 Llyn Cau littoral macroinvertebrate summary: 24-9-96
Mean numbers of individuals per one minute kick/sweep sample.

code	Taxon	Mean count/sample
16000000	OLIGOCHAETA	60.4
	HIRUDINEA	
17020302	*Glossiphonia complanata*	0.4
17040102	*Erpobdella octoculata*	4.8
19000000	HYDRACARINA	8.0
	TRICHOPTERA	
38030200	*Plectrocnemia* species	4.0
38030301	*Polycentropus flavomaculatus*	32.4
38030501	*Cyrnus trimaculatus*	3.6
	DIPTERA	
40010000	Tipulidae	6.4
40090000	Chironomidae	69.6

Figure I.1 Llyn Cau: sample location and substrate map

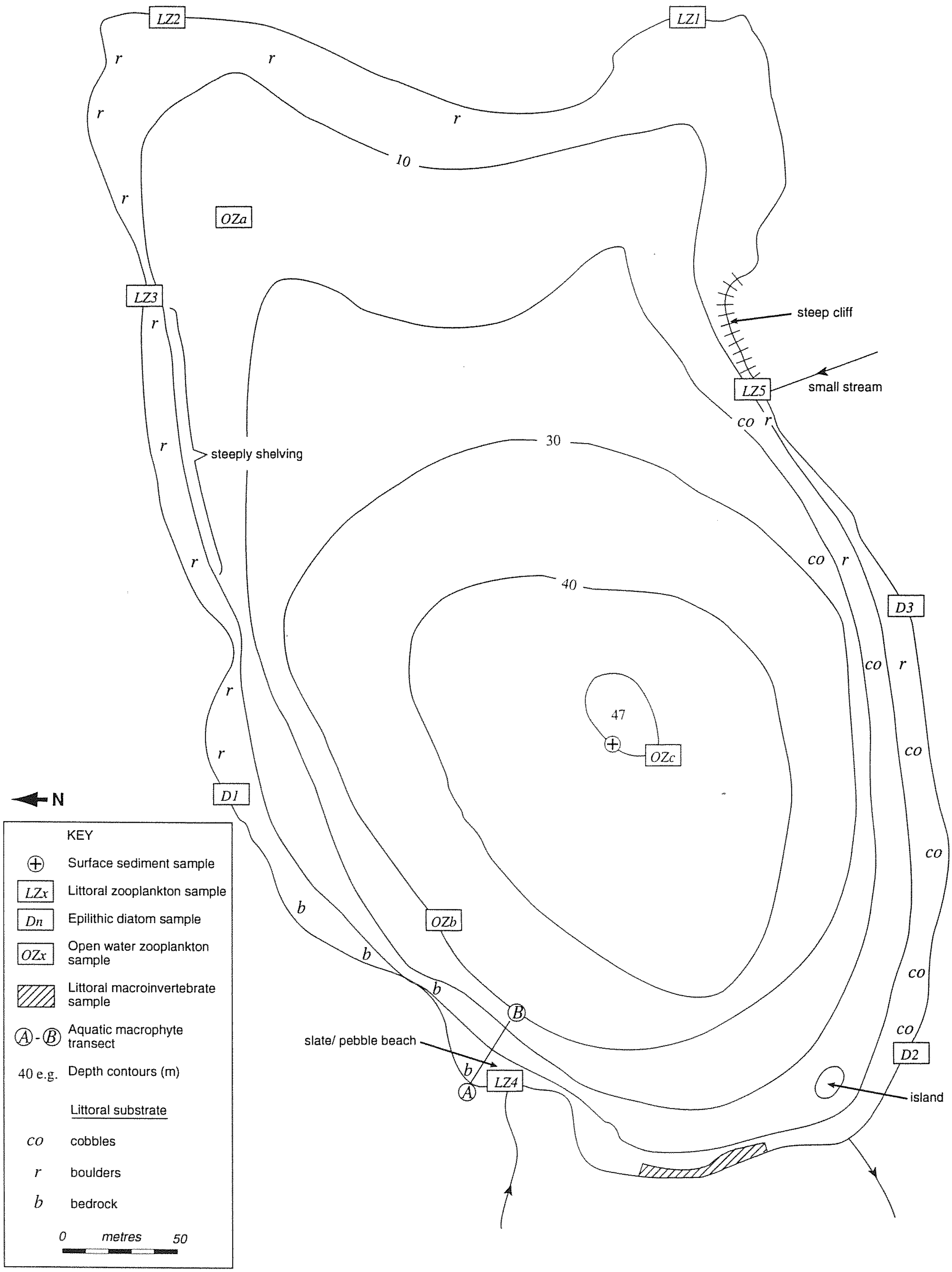
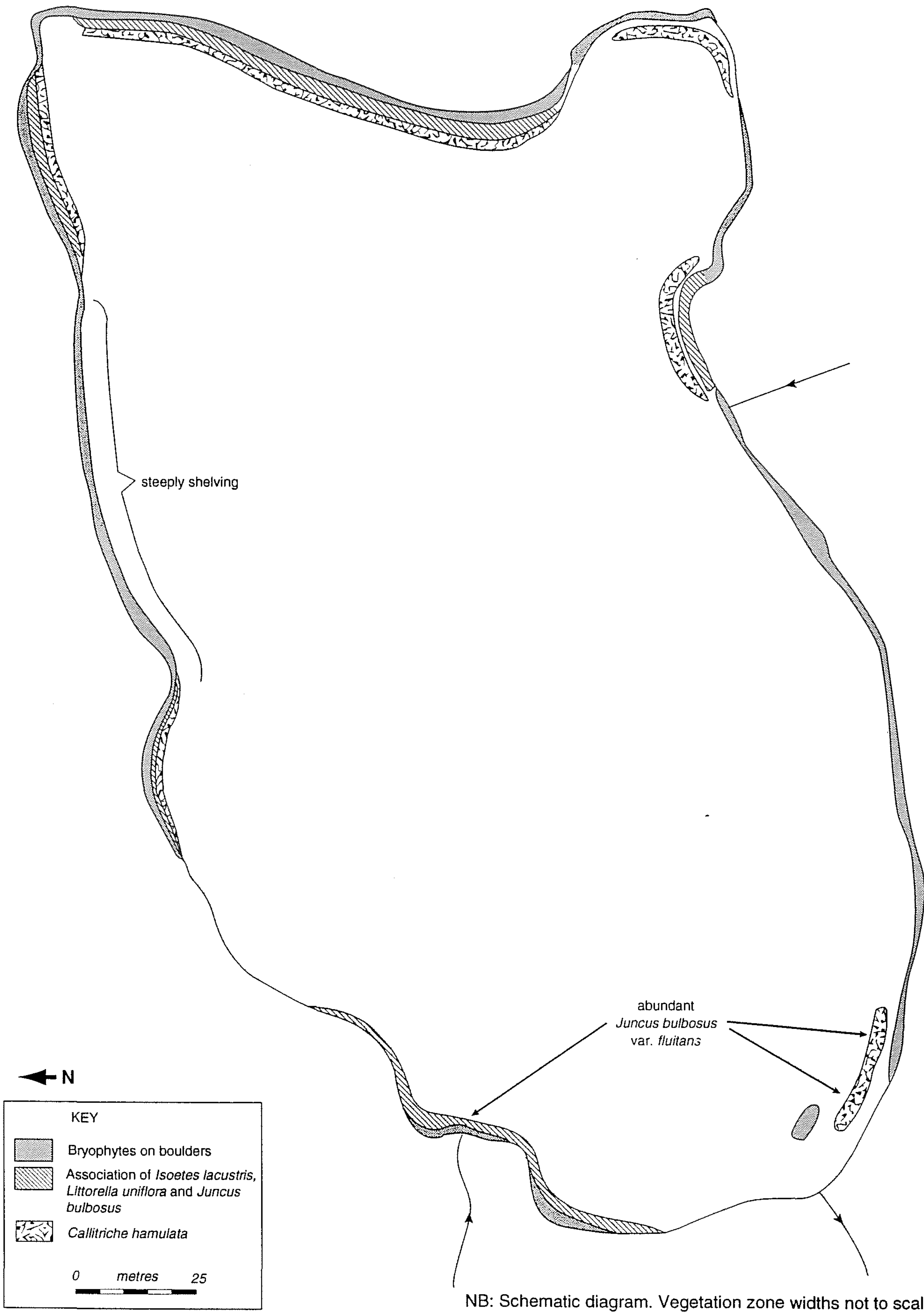


Figure I.2 Llyn Cau: aquatic macrophyte distribution map: 22-7-96



NB: Schematic diagram. Vegetation zone widths not to scale.

Figure I.3 Llyn Cau: aquatic macrophyte transect profile

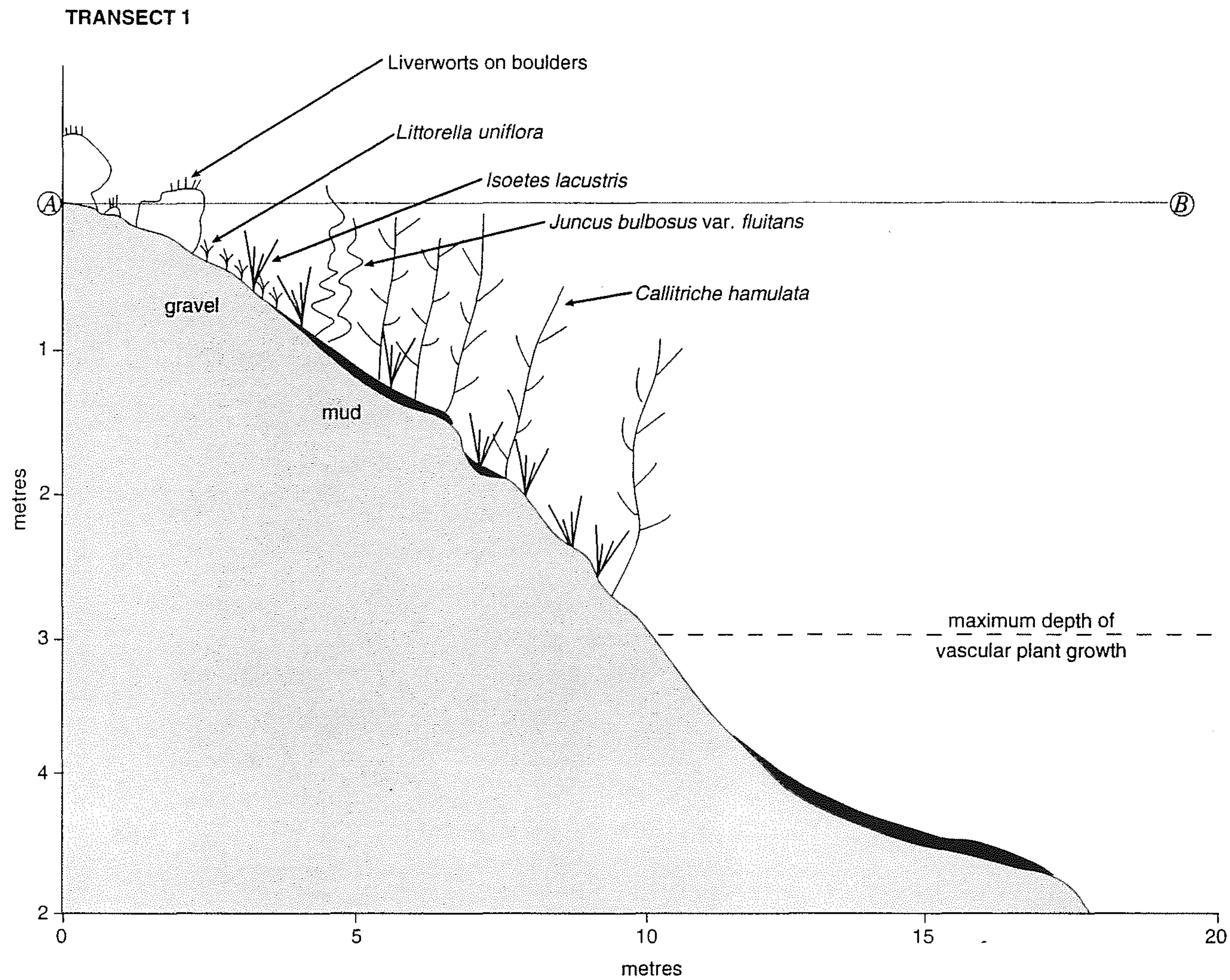


Figure I.4 **Llyn Cau: Temperature and dissolved oxygen profiles 22-7-96 (Temperature °c- solid circles, Oxygen mg l^{-1}- empty boxes)**

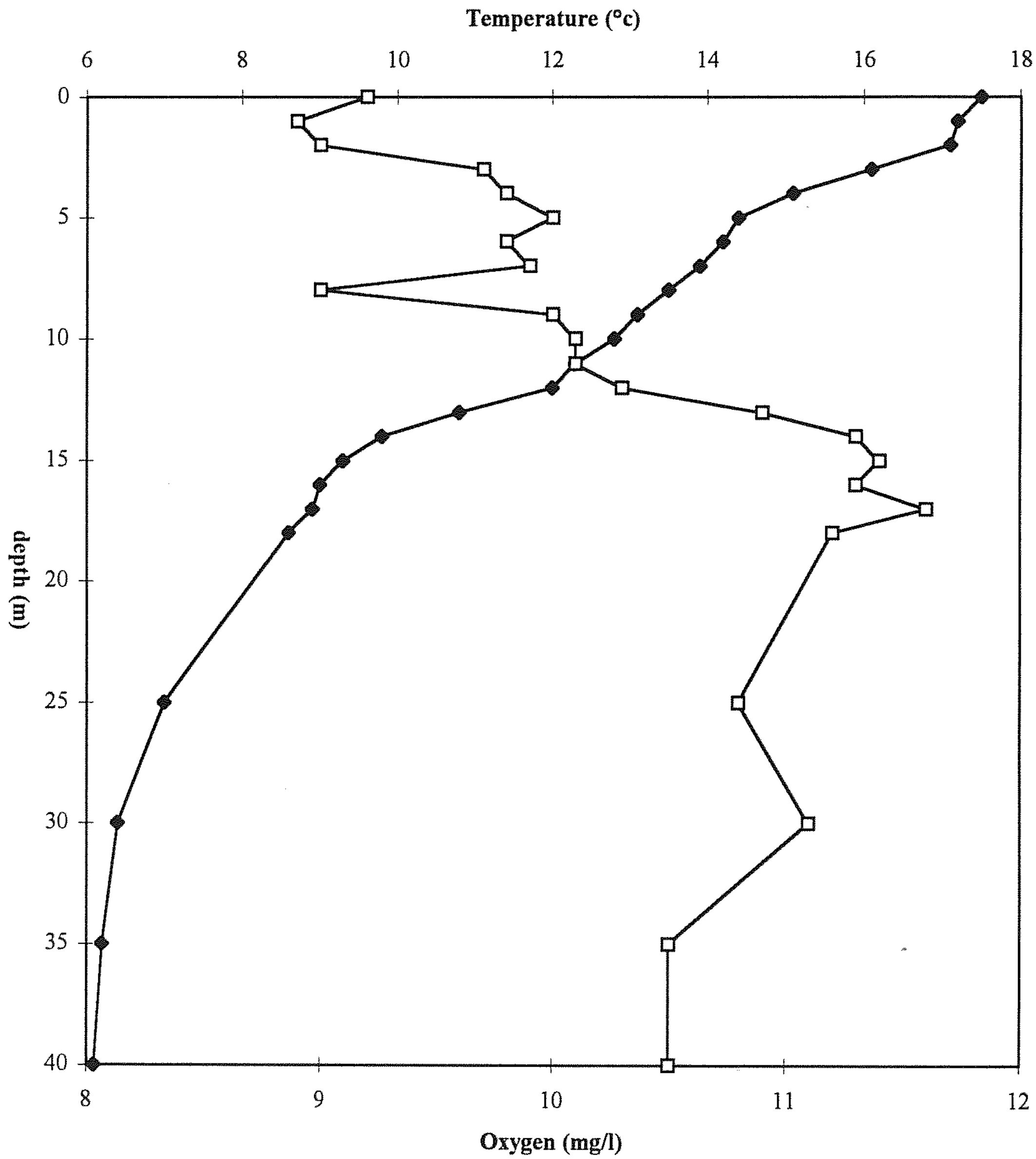


Table J.1 Llyn Llagi water chemistry

Determinand	Sample				
	04/06/96	03/09/96	03/12/96	04/03/97	mean
lab pH	5.51	5.83	5.42	5.04	
field pH	no data available				
Alkalinity 1 (μeq l^{-1})	no data available				
Alkalinity 2 (μeq l^{-1})	4	12	4.4	-8	3
lab conductivity (μS cm^{-1})	30	16	22	33	25
field conductivity (μS cm^{-1})	no data available				
Sodium (μeq l^{-1})	139	117	170	200	157
Potassium (μeq l^{-1})	3	3	5	5	4
Magnesium (μeq l^{-1})	41	41	49	58	47
Calcium (μeq l^{-1})	54	52	46	57	53
Chloride (μeq l^{-1})	127	118	206	257	177
Aluminium total monomeric (μg l^{-1})	70	66	63	67	67
Alumium non-labile (μg l^{-1})	52	45	no data	39	45
Aluminium labile (μg l^{-1})	18	21	no data	28	22
Absorbance (250nm)	no data available				
Carbon total organic (mg l^{-1})	0.7	5.5	1.9	1.7	2.5
Phosphorous total (μg P l^{-1})	0	7	1	3	3
Phosphorous total soluble (μg P l^{-1})	no data available				
Phosphorous soluble reactive (μg P l^{-1})	no data available				
Nitrate (μg N l^{-1})	140	30	110	130	103
Silica soluble reactive (mg l^{-1})	0.0	0.2	0.3	0.2	0.2
Chlorophyll a (μg l^{-1})	6.3	1.1	2.5	11.1	5.3
Sulphate (μeq l^{-1})	81	69	46	54	62
Copper total soluble (μg l^{-1})	0	0	0	0	0
Iron total soluble (μg l^{-1})	65	110	80	40	74
Lead total soluble (μg l^{-1})	no data available				
Manganese total soluble (μg l^{-1})	29	39	51	53	43
Zinc total soluble (μg l^{-1})	0	0	0	0	0

Table J.2 Llyn Llagi epilithic diatom taxon taxon list (including taxa >1%)

TAXON	Relative frequency (%)
Achnanthes marginulata	6.6
Achnanthes [*altaica* var. *minor*]	1.9
Brachysira brebissonii	5.2
Brachysira vitrea	4.3
Cymbella perpusilla	1.5
Eunotia exigua	2.3
Eunotia incisa	12.8
Eunotia naegelii	4.2
Eunotia rhomboidea	2.8
Frustulia rhomboides var. *viridula*	3.0
Frustulia rhomboides var. *saxonica*	3.8
Navicula leptostriata	7.6
Neidium alpinum	1.1
Nitzschia gracilis	1.3
Nitzschia perminuta	1.1
Peronia fibula	1.6
Tabellaria flocculosa	13.7
Tabellaria quadriseptata	12.8

Table J.3 Llyn Llagi surface sediment diatom taxon list (including taxa >1%)

TAXON	Relative frequency (%)
Achnanthes marginulata	1.2
Brachysira brebissonii	1.0
Brachysira vitrea	1.4
Eunotia incisa	16.0
Fragilaria virescens var.*exigua*	2.1
Frustulia rhomboides var.*saxonica*	1.2
Frustulia rhomboides var.*viridula*	2.1
Gomphonema angustatum	1.0
Navicula leptostriata	2.7
Peronia fibula	1.2
Tabellaria flocculosa	7.0
Tabellaria quadriseptata	50.4

Table J.4 Llyn Llagi aquatic macrophyte abundance summary: 22-7-95

Taxon	code	Abundance
Emergent taxa		
Juncus acutifloris	383001	A
Juncus effusus	383010	O
Floating leaved taxa		
Potamogeton polygonifolius	384017	R
Sparganium angustifolium	384601	O
Submerged taxa		
Batrachospermum sp.	020000	O
Filamentous green algae	170000	A
Fontinalis antipyretica	323402	O
Sphagnum auriculatum	327401	F
Marsupella emarginata	343402	R
Nardia compressa	343701	R
Isoetes echinospora	350301	O
Isoetes lacustris	350302	A
Littorella uniflora	363901	F
Lobelia dortmanna	364001	A
Myriophyllum alterniflorum	365401	R

Table J.5 Llyn Llagi littoral Cladocera taxon list: 21-7-96

Taxa	Sample number				
	1	2	3	4	5
	number of individuals				
Alonopsis elongata	8	24	1	1	1
Chydorus piger		1			
Diaphanosoma brachyurum				7	
Eurycercus lamellatus	3	5		1	1
Graptoleberis testudinaria		1			
Total count	11	31	1	9	2

Table J.6 Llyn Llagi zooplankton abundance summary: 21-7-96

Taxon	Count
Diaphanosoma brachyurum	510
Daphnia longispina	140
Eubosmina longispina	110
Eudiaptomus gracilis	690
Cyclops abyssorum	60

Table J.7 Llyn Llagi zooplankton characteristics

Site depth (m)	11.4
Total zooplankton biomass excluding Chaoborus larvae(g DW m^{-2})	0.74
Chaoborus biomass (g DW m^{-2})	0.00
Net algal biomass (g DW m^{-2})	0.0
Cladoceran biomass as proportion of total zooplankton biomass (%)	33
Large cladoceran (>710µm) as proportion of total zooplankton biomass	1
Large Copepoda (>420µm) as proportion of total zooplankton biomass	17

Table J.8 Llyn Llagi littoral macroinvertebrate summary: 18-4-96
Mean numbers of individuals per one minute kick/sweep sample.

code	Taxon	total no. individuals
16000000	OLIGOCHAETA	306
	HIRUDINEA	
17040102	*Erpobdella octoculata*	3
	EPHEMEROPTERA	
30040000	LEPTOPHLEBIIDAE	51
	PLECOPTERA	
31070101	*Siphonoperla torrentium*	1
	COLEOPTERA	
35030703	*Potamonectes depressus*	10
35110603	*Oulimnius tuberculatus*	15
	TRICHOPTERA	
38030200	*Plectrocnemia* sp.	1
38030300	*Polycentropus* sp.	19
38030500	*Cyrnus* sp.	11
38040201	*Tinodes waeneri*	2
38060600	*Oxyethira* sp.	125
38080500	*Limnephilus* sp.	1
	DIPTERA	
40090000	Chironomidae	751

Figure J.1 Llyn Llagi: sample location and substrate map

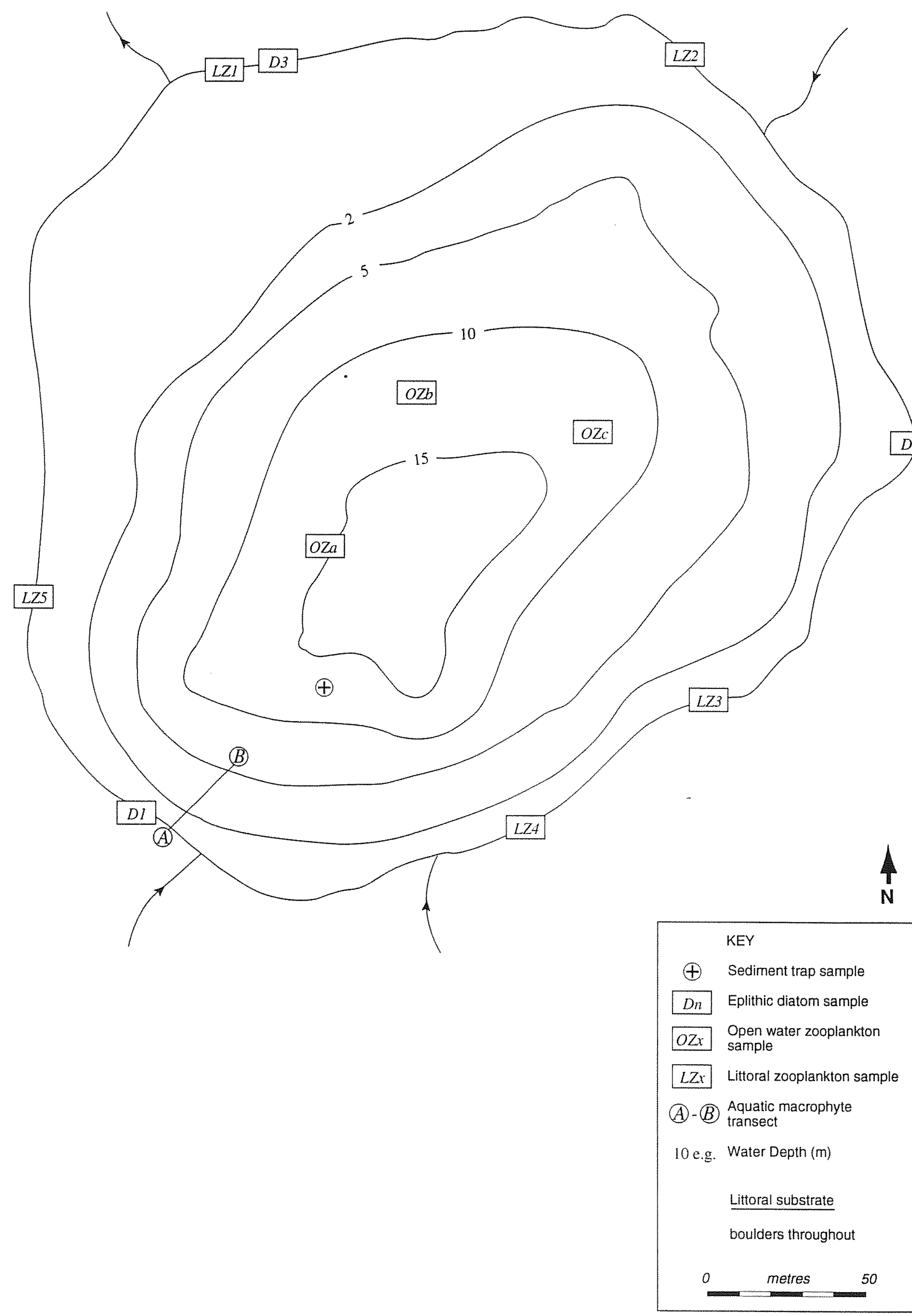


Figure J.2 Llyn Llagi: aquatic macrophyte distribution map: 22-7-95

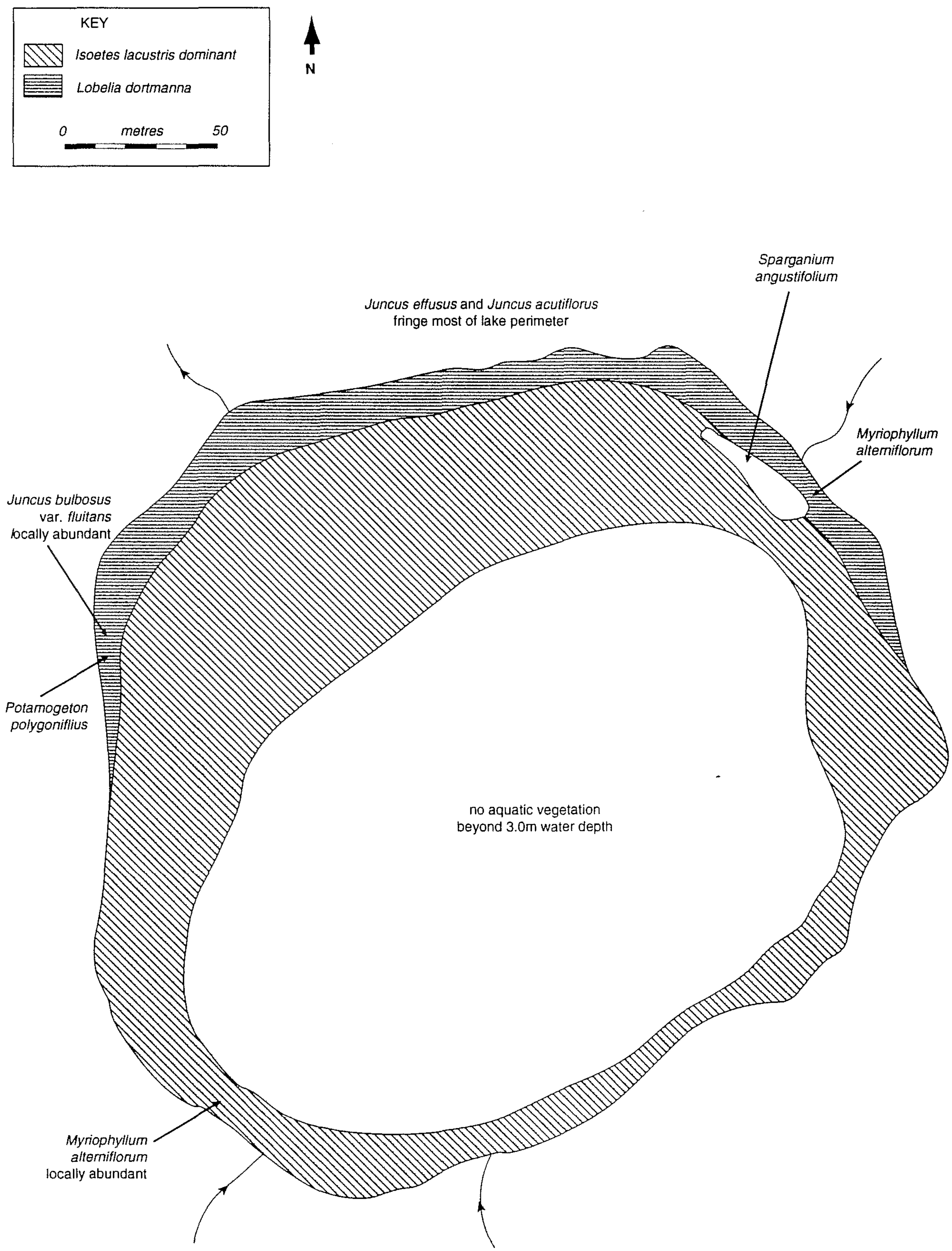


Figure J.3 Llyn Llagi: aquatic macrophyte transect profile

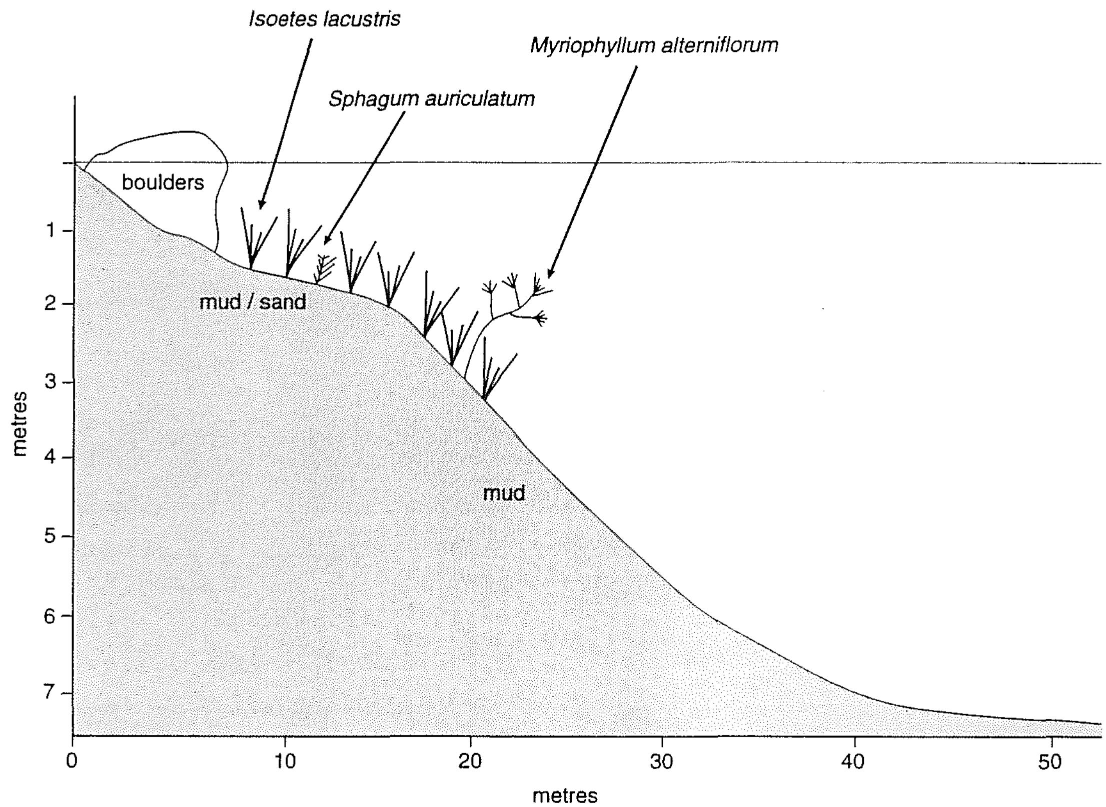
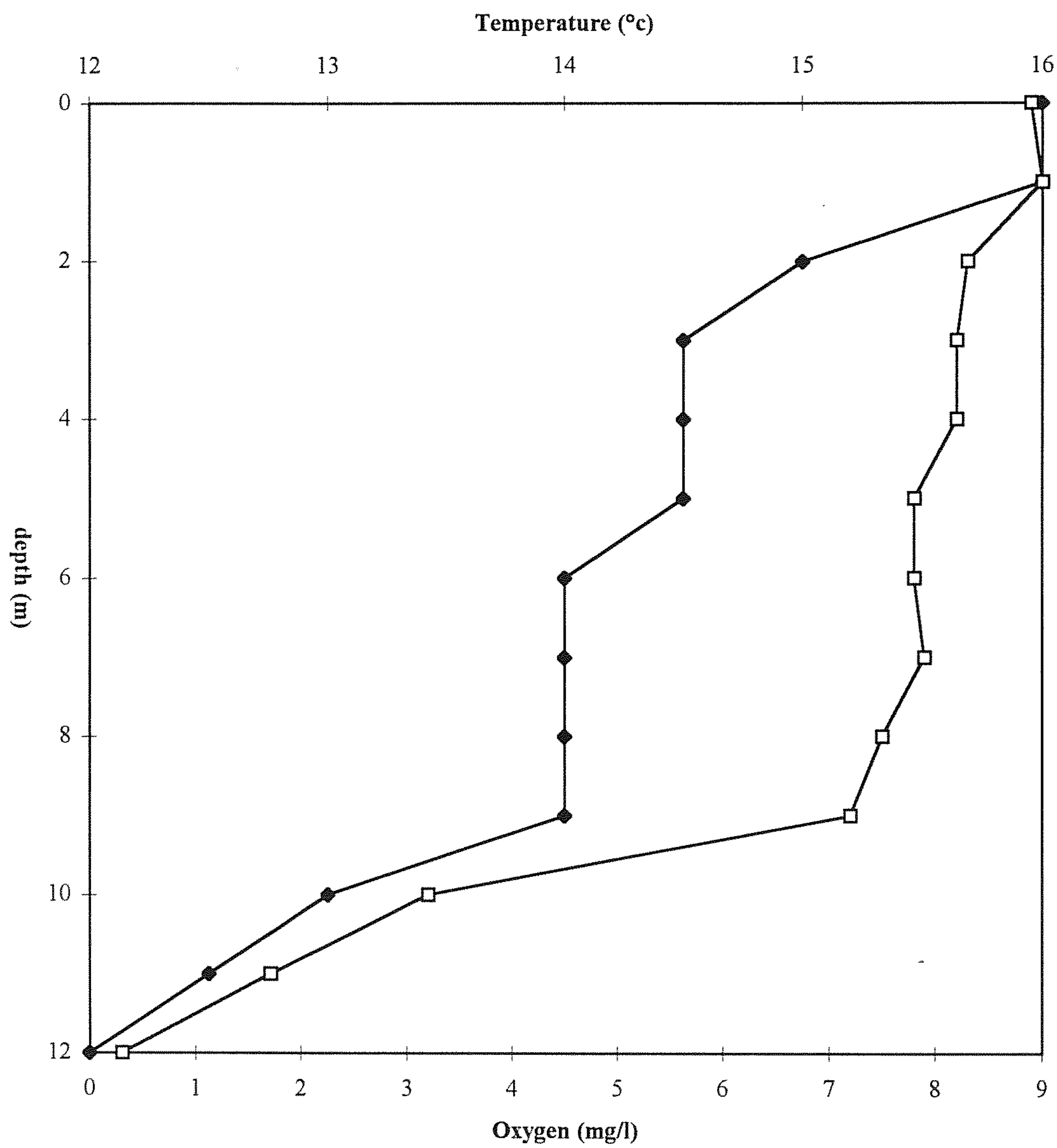


Figure J.4 **Llyn Llagi: Temperature and dissolved oxygen profiles 21-7-96 (Temperature °c- solid circles, Oxygen mg l^{-1}- empty boxes)**



Appendix K Notes on Cladocera sampling sites

K.1 Hanmer Mere: 11 July 1996

1. Water-lily bed; sample taken from boat.

2. *Potamogeton berchtoldii* bed; sample taken from boat.

3. Underneath trees; woody debris in water; sampling site between shore and margin of water-lily bed.

4. No aquatic vegetation; adjacent ground poached by cattle.

5. Sampled at base of *Sparganium* bed.

K.2 Llyn Tegid: 12 July 1996

1. Leisure Centre Launch Area; stoney substrate; no aquatic vegetation.

2. Adjacent to sailing club entrance; sandy substrate with *Littorella* and emergent grasses.

3. Rock/sand substrates with fine silt cover.

4. Silt substrate with filamentous alga growth; poached by cattle.

5. Stone/rock substrate; clear water; no aquatic vegetation.

6. Boulder/stone/gravel; clear water; no aquatic vegetation.

K.3 Llyn Alwen: 14 July 1996

1. Sand/stone shore with *Littorella* mat; clear water; area adjacent to outflow; onshore wind.

2. Rock/gravel substrate; no aquatic vegetation; clear water; onshore wind.

3. *Littorella* mat; rock/boulder substrate; site immediately in front of boat house.

4. Wind sheltered margin; gravel substrate devoid of vegetation.

5. Wave-washed shore; onshore wind; stone/rock/gravel substrate; no vegetation.

K.4 Llyn Glasfryn: 15 July 1996

1. Sample taken from boat in *Nuphar lutea* bed; onshore wind.

2. *Juncus* bed; sampled from boat; onshore wind.

3. *Nuphar lutea* bed; sampled from boat.

4. *Menyanthes* bed; sampled from boat in sheltered bay.

5. Island site; *Polygonum amphibium* bed.

K.5 Llyn Rhos Ddu, 16 July 1996

1. Sample at funnel into lake for stock access; sampled in *Potamogeton* bed in front of *Menyanthes* bed.

2. South end of lake on car park side; sampled in mass of *Elodea*.

3. *Equisetum* sp. with fine-leaved *Potamogeton* on edge of *Menyanthes* swamp.

4. Sandy bottom covered with *Ceratophyllum* and filamentous algae; sampling site directly opposite access point.

5. Outflow end; opposite sampling station 3; sandy bottom; fine leaved *Potamogeton* present; filamentous algae.

K.6 Llynnau Mymbyr: 17 July 1996

1. *Lobelia* mat with some *Equisetum*; silt covered boulders and vegetation; water clear; abundant small fish.

2. *Lobelia*, *Littorella* and *Juncus bulbosus*; boulders; water clear.

3. Boulder covered algae; small amount of *Isoetes.*

4. *Lobelia*, *Eleocharis* sp., *Carex* sp. Present.

5. Stoney substrate; *Juncus bulbosus* and *Littorella.*

K.7 Gloyw Lyn: 19 July 1996

1. *Equisetum* bed.

2. Boulders.

3. Bedrock slabs.

4. *Equisetum* and *Carex* bed.

5. *Lobelia* bed.

K.8 Llyn Yr Wyth Eidion: 20 July 1996

1. *Nymphaea alba* bed at outflow; sampled around floating leaves.

2. *Nymphaea alba* bed; sampled submerged leaves.

3. Small bay; sampled through *Nuphar lutea* and base of *Carex* sp.

4. Onshore wind; sampled through base of *Carex* sp. and small amount of *Nuphar lutea.*

5. *Phragmites/Carex* bed.

K.9 Llyn Cau: 22 July 1996

1. *Littorella* mat with algal growth; stone substrate.

2. Small embayment adjacent to outflow; small area sheltered by boulders with some moss covered rocks.

3. Rock/boulders with some moss and abundant algae.

4. Scree-like beach of small stones; some algae; some vegetation offshore in deeper water.

5. Boulders with alga and moss.

K.10 Llyn Llagi: 21 July 1996

1. *Lobelia* mat; some *Isoetes* and *Littorella*; filamentous algae present.

2. *Potamogeton* and *Lobelia* with algal growths.

3. Boulders covered in moss and algae.

4. *Littorella* and *Lobelia* dominant; some *Isoetes* in deeper water; stone substrate with algae.

5. *Littorella* and *Lobelia* dominant; sand/stone substrate.

Appendix L Notes on littoral macroinvertebrate sampling sites

L.1 Hanmer Mere

Turbid water, mud/silt with cobbles, stands of *Typha angustifolia* in vicinity

L.2 Llyn Tegid

Clear water, pebbles/cobbles + a few large boulders + silt, no vegetation at sample site, reed beds on shore 1 m above level of drawdown

L.3 Llyn Alwen

Clear water, gravel, pebbles, cobbles, *Juncus effusus* at margin

L.4 Llyn Glasfryn

Turbid water, pebbles, cobbles, extensive submerged, floating leaved (and emergent) macrophytes

L.5 Llyn Rhos Ddu

Clear water, sand/ silt, extensive *Menyanthes trifoliata*, with *Hippuris vulgaris*, *Polyganum amphibium*, *Lemna trisulca* and filamentous algae

L.6 Llynnau Mymbyr

Turbid water, silt/pebbles, cobbles and some boulders, sparse bryophytes

L.7 Gloyw Lyn

Slightly peaty water, large boulders, sparse brophytes

L.8 Llyn yr Wyth Eidion

Slightly turbid water, mud/silt, stands of *Phragmites australis* + *Scirpus lacustris*

L.9 Llyn Cau

Clear water, silt, gravel, cobbles, small boulders, *Littorella, Isoetes* + liverworts on boulders

L.10 Llyn Llagi

Slightly peaty water, pebbles, cobbles, boulders, *Lobelia dortmanna* and filamentous algae

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Appendix N Previous macrophyte records for Phase IV sites

Table N.1 Hanmer Mere

England Field Unit, NCC (1979) = 1
SSSI citation (1994) = 2

Carex rostrata	1	
Ceratophyllum demersum		
Cladophora sp.		
Eleocharis palustris		
Iris pseudacorus		
Lemna minor	1	
Lemna trisulca		
Menyanthes trifoliata		
Nuphar lutea	1	2
Nymphaea alba		
Polyganum amphibium	1	
Potamogeton berchtoldii	1	2
Potamogeton crispus	1	2
Sparganium erectum	1	2
Typha angustifolia	1	2
Typha latifolia		
Zannichelia palustris	1	2

Table N.2 Llyn Tegid

Dann (1952) = 1
P.M Benoit (plant records 1968-71) = 2
Ratcliffe (1977) = 3
SSSI citation = 4
J.W.Eaton (1975-84) = 5

Achillea ptarmica		2			
Alopecurus gericulatus		2			
Apium inundatum		2			
Callitriche sp.	1		3	4	
Callitriche hamulata					5
Callitriche intermedia		2			
Callitriche stagnalis					
Carex acuta		2			
Carex rostrata		2			
Carex vesicaria		2			
Elatine hexandra		2			
Elatine hydropiper					5
Eleocharis acicularis		2			
Elodea canadensis		2			5
Fontinalis antipyretica					5
Fontinalis sp.	1				
Glyceria sp.	1				
Iris pseudacorus					5
Isoetes sp.	1				
Isoetes lacustris			3		5

	1	2	3	4	5
Littorella uniflora	1		3	4	5
Luronium natans		2		4	
Mentha arvensis					
Myosotis cespitosa					
Myosotis palustris					
Myriophyllum alterniflorum					5
Nasturtium microphyllum					
Nitella opaca					5
Nitella translucens					
Nuphar sp.	1				
Nuphar lutea			3		5
Phalaris arundinacea		2			5
Polyganum minus					
Potamogeton natans	1		3	4	
Scirpus sp.					
Sparganium emersum		2			5
Sparganium erectum				4	

Table N.4 Llyn Glasfryn

J.E.Griffith (1894) = 1
Seddon (1960) = 2
Seddon (1977) = 3
Palmer (1987) = 4
SSSI citation (1989) = 5
CCW survey (1994) = 6

	1	2	3	4	5	6
Alisma plantago aquatica		2	3	4		6
Apium inundatum		2	3	4		
Caltha palustris		2	3	4		
Carex curta			3			
Carex nigra		2	3			
Carex rostrata		2		4		6
Ceratophyllum demersum		2	3	4		
Elatine hexandra		2	3	4	5	
Elatine hydropiper				4	5	6
Eleocharis acicularis		2	3	4	5	6
Eleocharis palustris		2		4		6
Glyceria fluitans		2	3			
Hypericum elodes			3			
Iris pseudacorus		2	3	4		6
Isoetes echinospora		2				
Lemna minor		2	3			
Littorella uniflora	1	2	3	4		6
Lobelia dortmanna	1					
Mentha aquatica				4		6
Menyanthes trifoliata		2	3	4		
Myriophyllum alterniflorum	1	2	3	4	5	6
Nitella flexilis					5	
Nuphar lutea	1	2	3	4		6
Nymphaea alba	1	2	3	4		6
Phalaris arundinacea		2	3	4		
Phalaris arundinacea			3			6
Polyganum amphibium		2		4		6
Potamogeton berchtoldii		2	3	4	5	

Potamogeton obtusifolius		2	3	4	5	
Potamogeton perfoliatus		2	3	4	5	6
Potentilla palustris		2		4		6
Potentilla palustris			3			
Ranunculus aquatilus		2	3			
Ranunculus circinatus	1	2	3			
Ranunculus flammula		2	3	4		
Ranunculus hederaceus				4		
Scirpus fluitans			3			
Subularia aquatica			3			

Table N.6 Llynnau Mymbyr

SSSI citation (1982) = 1
Andrews and McConnell (1977-78) = 2
Wade (1978) = 3
White (1980) = 4

Carex rostrata	1		3	
Carex nigra				4
Elatine hexandra				4
Equisetum fluviatile			3	
Isoetes echinospora		2		
Isoetes lacustris		2	3	4
Juncus bulbosus	1	2	3	4
Juncus articulatus				4
Littorella uniflora		2	3	4
Lobelia dortmanna	1	2	3	4
Myriophyllum alterniflorum		2	3	4
Nuphar lutea			3	4
Phragmites australis	1		3	
Potamogeton sp.		2		
Potamogeton berchtoldii				4
Ranunculus flammula				4
Sphagnum auriculatum			3	4
Utricularia sp.		2	3	4

Table N.8 Llyn yr Wyth Eidion

Stewart (1997) = 1

Carex elata	1
Chara virgata	1
Nuphar lutea	1
Nymphaea alba	1
Phragmites australis	1
Scirpus lacustris	1

Table N.9 Llyn Cau

Palmer (1984) = 1

Callitriche hamulata	1
Littorella uniflora	1
Solenostoma triste	1

Table N.10 Llyn Llagi

Seddon (1971) = 1
Wade (1980) = 2

Callitriche hamulata		2
Isoetes lacustris	1	2
Juncus bulbosus	1	2
Littorella uniflora	1	2
Lobelia dortmanna	1	2
Myriophyllum alterniflorum		2
Sparganium angustifolium	1	

Appendix O: Final Data Sets for Cladocera

A small amount of taxonomic harmonisation was carried out on the Cladocera data sets in preparation for the analyses. All records for *Daphnia pulex* and *Daphnia pulicaria* were combined into a *Daphnia pulex* species group. *Daphnia hyalina* s.s. and other vars. were amalgamated into a *Daphnia hyalina* group, with the exception of *Daphnia hyalina* var. *galeata*, which is referred to as *D. galeata*. Records for *Argulus* sp. and *Alona* sp. were removed.

Appendix P: Project Output to Date

Research Reports -

Environmental Change Research Centre (1994). Integrated Classification and Assessment of Lakes in Wales: Phase I. A preliminary data report to the Countryside Council for Wales under Contract No. FC 7301-71.

Environmental Change Research Centre (1994). Integrated Classification and Assesssment of Lakes in Wales: Phase I. A final report to the Countryside Council for Wales under Contract No. FC 73-01-71. CCW Contract science Report No. 85.

Environmental Change Research Centre (1995). Integrated Classification and Assessmnent of Lakes in Wales: Phase II. A preliminary data report to the Countryside Council for Wales under Contract No. FC 73-01-13. CCW Contract Science report No. 89.

Environmental Change Research Centre (1995). Integrated Classification and Assessmnent of Lakes in Wales: Phase II. A final data report to the Countryside Council for Wales under Contract No. FC 73-01-13. CCW Contract Science report No.128.

Environmental Change Research Centre (1996). Integrated Classification and Assessmnent of Lakes in Wales: Phase III. A final data report to the Countryside Council for Wales under Contract No. FC 73-01-71. CCW Contract Science report No.167.

Publications -

Allott, T. (1995). Recent Limnological Surveys of Llyn Coron, Llyn Dinam and Llyn Penrhyn. Freshwater News - Special Issue, 8(1): 10-13.

Bennion, H., Duigan, C.A., Haworth, E.Y., Allott, T.E.H., Anderson, N.J., Juggins, S., Monteith, D.T. (1996). The Anglesey lakes, Wales, UK - changes in trophic status of three standing waters as inferred from diatom transfer functions and their implications for conservation. Aquatic Conservation: Marine and Freshwater Ecosystems. 6, 81-92.

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Duigan, C.A., D.T. Monteith, L.Carvalho, H.Bennion, J.Hutchinson, J.M.Seda and F.Evans. The current ecological and conservation status of Llyn Tegid (Bala Lake), Snowdonia National Park, North Wales. Presentation at the Llyn Tegid Symposium, 20th November 1997. Proceedings to be published by Snowdonia National Park in 1998.

Other applications of information -

The results of the limnological surveys of the three Phase I Anglesey sites formed a contribution to the Anglesey Lakes Symposium, Beaumaris, Anglesey, November 1994, which was hosted by the Countryside Council for Wales. Media coverage related to the Anglesey Lakes Symposium included a series of radio and TV interviews by BBC Wales and press coverage.

The limnological survey data collected has been used by the Anglesey Wetland Strategy Group in its discussions on standing water management.

The data collected was used in the assessment of sites for inclusion as proposed SACs under the EC Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora. It is expected that the data collected will contribute to the development of management plans for the sites surveyed.