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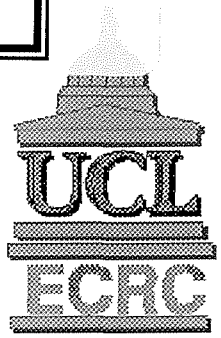

ENVIRONMENTAL CHANGE RESEARCH CENTRE

University College London

RESEARCH REPORT

No. 34

Integrated classification and assessment of lakes in Wales: Phase III

Editor: D.T. Monteith

A Report to the Countryside Council for Wales under Contract

No: FC-01-71

CCW Contract Science Report No.167

November 1996

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

Integrated Classification and Assessment of Lakes: Phase III - Final Report

Editor: D.T.Monteith

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A report to the Countryside Council for Wales by ENSIS Ltd.

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Executive Summary

1 This is the final report to the Countryside Council for Wales under contract FC 73-01-13: 'Integrated Classification and Assessment of Lakes: Phase III' and follows the format adopted in Phase I (Allott *et al.* 1994).

2 Data are presented for the six lakes surveyed in this phase of the study, all of which occur in South Wales. These are Kenfig Pool, Llyn Llech Owain, Llyn Fach, Llanbwchllyn, Llangorse Lake (Llyn Syfaddan) and Llyn y Fan Fawr.

3 The field survey and analytical methodology adopted 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, based on existing commonly employed schemes.

6 Further development of classification techniques outlined in the Phase I report require the incorporation of data from a further nine lakes, which have recently been surveyed under Phase IV.

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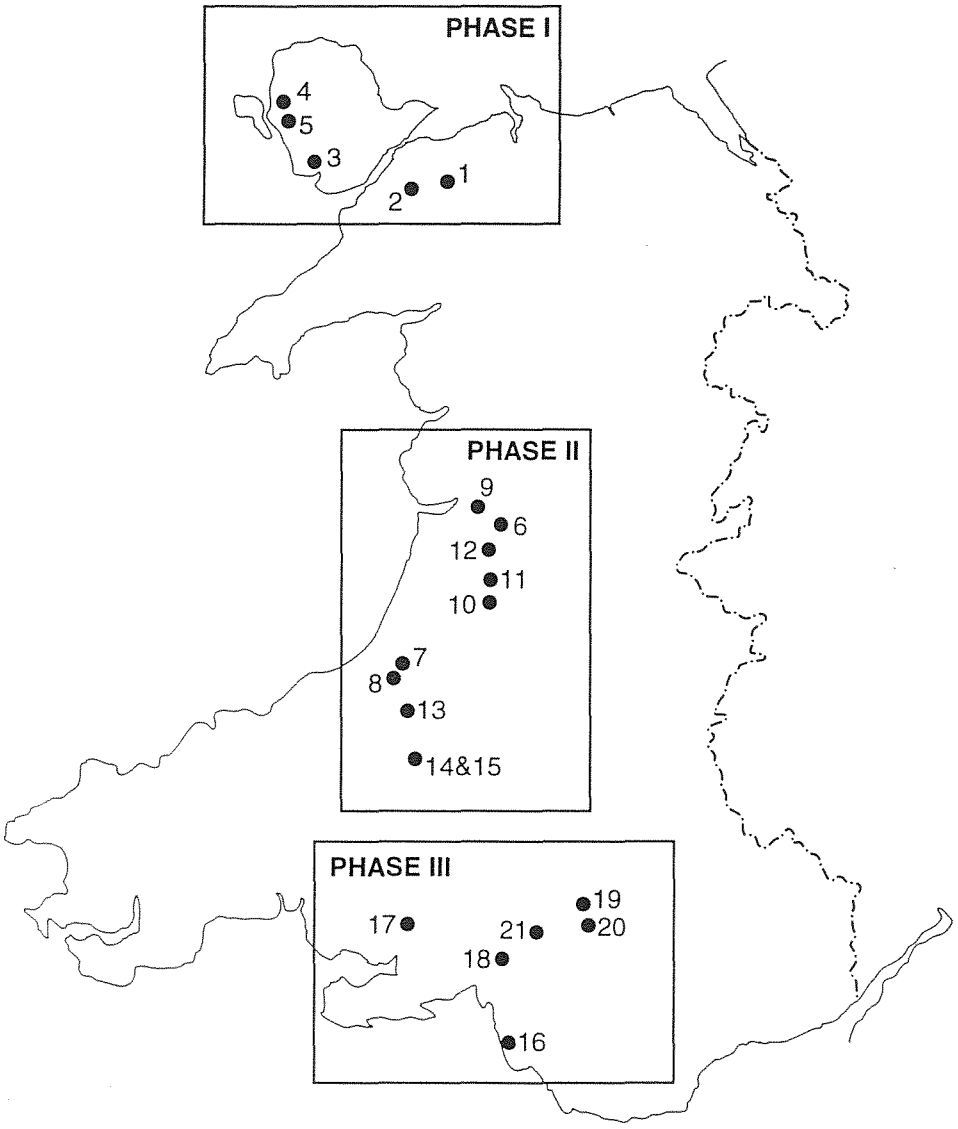
1 Introduction

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

Six lakes in South Wales, listed on the following page, have been assessed over the period 1995-1996. 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 classification schemes discussed in the first report. However, data from a further 9 lakes are required before multivariate statistical methods, also discussed in the first report, can be applied to develop a new integrated classification scheme for Welsh lakes.

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



PHASE I SITES		PHASE II SITES		PHASE III SITES	
1	Llyn Idwal	6	Bugeilyn	16	Kenfig Pool
2	Llyn Cwellyn	7	Llyn Eiddwen	17	Llyn Llech Owain
3	Llyn Coron	8	Llyn Fanod	18	Llyn Fach
4	Llyn Dinam	9	Llyn Glanmerin	19	Llan Bwchllyn
5	Llyn Penrhyn	10	Llyn Gynon	20	Llangorse Lake
		11	Llyn Hir	21	Llyn y Fan Fawr
		12	Llynnoedd Ieuan		
		13	Maes-Llyn		
		14&15	The Talley Lakes		

Table 1.1 Summary of physical parameters of lakes in Phases I, II and III

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 378380	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
RANGE		4 - 610	3 - 139	12 - 2091	1.7 - 36.0	1.4 - 22.6	48 - 19000

Table 1.2 Summary of mean water chemistry of sites in Phases I II and III (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*	<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 Summary of mean water chemistry of sites in Phases I II and III (continued)

Determinand		mean for site						
		Kenfig	Owain	Fach	Bwchllyn	Llangorse	Fan Fawr	Range
lab pH		7.90	4.95	6.28	7.51	8.00	6.56	4.92 - 8.61
Alkalinity 1**	µeq l^{-1}	2079	-8	99	1391	2446	86	-9 - 2446
Alkalinity 2**	µeq l^{-1}	2106	-8	92	1404	2476	78	-10 - 2476
lab Conductivity	µS cm^{-1}	345	78	63	217	312	37	28 - 442
Sodium	µeq l^{-1}	964	331	189	271	392	129	109 - 1846
Potassium	µeq l^{-1}	56	10	16	30	54	5	4 - 134
Magnesium	µeq l^{-1}	387	84	210	259	474	40	34 - 634
Calcium	µeq l^{-1}	2279	183	159	1837	2646	168	45 - 2646
Chloride	µeq l^{-1}	1058	387	209	319	485	145	105 - 1823
Aluminium total monomeric	µg l^{-1}	6	78	27	6	3	4	1 - 81
Aluminium non-labile	µg l^{-1}	5	57	20	2	3	3	1 - 59
Aluminium labile	µg l^{-1}	1	21	7	4	1	1	0 - 56
Absorbance	(250nm	0.125	0.447	0.052	0.147	0.135	0.046	0.027 - 0.447
Carbon total organic	mg l^{-1}	6.1	8.5	2.7	4.6	5.1	2.01	1.1 - 10.3
Phosphorus total	µgP l^{-1}	31.8	48.0	9.5	35.6	117.8	10.8	5 - 1085
Phosphorus total soluble	µgP l^{-1}	13.8	13.8	4.1	16.5	77.8	4.7	2.7 - 1038
Phosphorus soluble reactive	µgP l^{-1}	5.8	10.4	2.4	5.1	58.0	3.4	0.7 - 1016
Nitrate	µgN l^{-1}	86	99	116	859	602	86	54 - 859
Silica soluble reactive	mg l^{-1}	0.69	2.20	1.96	8.13	3.17	0.20	0.2 - 8.1
Chlorophyll a	µg l^{-1}	13.5	38.1	8.9	15.3	14.5	3.7	0.8 - 38.1
Sulphate	µeq l^{-1}	222	185	209	341	234	71.8	63 - 449
Copper total soluble	µg l^{-1}	0	0	0	0	0	0	0 - 39
Iron total soluble	µg l^{-1}	45	241	26	19	12.5	18.5	3 - 315
Lead total soluble	µg l^{-1}	0	1	0	0	0	1	0 - 4
Manganese total soluble	µg l^{-1}	10	37	21	3	20.5	5	-1 - 174
Zinc total soluble	µg l^{-1}	0	14	6	<1	0	5	0 - 38

** Alkalinity 1 = standard titration to 5.0 Alkalinity 2 = Gran titration

2 Site Descriptions

2.1 Kenfig Pool

Kenfig Pool is situated on the south-east shoreline of Swansea Bay, 10km to the south of the industrial connurbation of Port Talbot and 5km to the north-west of the seaside resort of Porthcawl. The Pool lies in the south-east quadrant of an extensive 600 ha hindshore type dune system, formally known as the Kenfig Burrows but now more generally known as the Kenfig National Nature Reserve. The dune system is composed on west-east trending ridges separated by seasonally flooded dune slacks. With a surface area of 24 ha and a maximum depth of 2.6m, the pool is the largest freshwater lake in the old county of Glamorgan.

The shoreline of Kenfig Pool is mostly composed of unconsolidated sand. However, the west side has well establised *Phragmites* beds and supports a layer (c. 0.2m) of autochthonous sediment, and the east and north-east sides are clayey with some cobbles. A well vegetated system of dune slacks and ridges surrounds the west side of the pool, while the east side supports better developed soils (not based on a sand substrate) and incorporates a caravan park and cattle grazed pasture.

The limits of the hydrological catchment are difficult to define given the very gradual slope of the vicinity and the unknown extent of drainage systems leading from the M4 motorway and the town of North Cornelly. However, it seems likely that most industrial and urban drainage bypasses the site. The following components of the hydrological budget have been identified (Dr Peter Jones pers. comm):

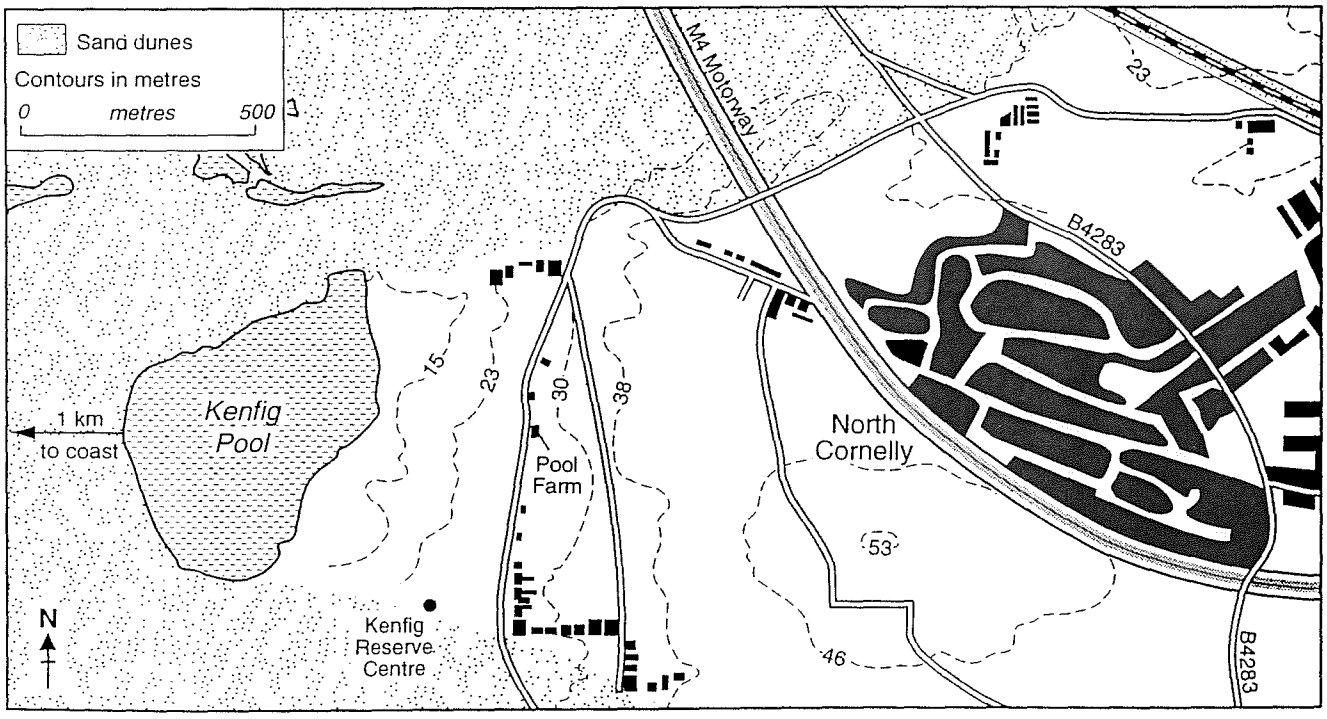
(i) the Pool acts as a sink for groundwater seeping out of the dune system water table to the north-west and discharges water into the dune system along the west and south sides;
(ii) surface runoff enters the Pool from Keupar Marl fields to the east, partly from ephemeral streams, which are subject to nitrogen application and (in 1994) waste paper sludge treatment;
(iii) locally perched water tables overlie boulder clay beneath sand to the north-east of the Pool, and these must contribute some inflow, at least during the winter;
(iv) there are concerns that some water may be entering the Pool from deep Carbonaceous Limestone sources beneath the pool, the catchment for which may be very extensive and may include local quarries used for landfill.

Kenfig Pool is noted for its aquatic plant communities and wintering wildfowl, and was notified as a Site of Special Scientific Interest in 1953 and a National Nature Reserve in 1989.

Table 2.1 Kenfig Pool: site characteristics	
Grid reference	SS 790820
Lake altitude	10 m
Maximum depth	2.6 m
Mean depth	1.8 m
Volume	414 x 10^3 m^3
Lake area	24 ha
Shoreline development index	2.1
Estimated hydraulic residence time	*
Catchment area (including lake)	*
Catchment:lake ratio	*
Net relief	*
Mean annual rainfall	1207 mm
Total S deposition	0.76 keq H^+ ha^{-1} yr^{-1}
Total N deposition	1.05 keq H^+ ha^{-1} yr^{-1}

* the lake catchment has not been defined as the nature and extent of the urban drainage network is not known

Figure 2.1 Catchment of Kenfig Pool



2.2 Llyn Llech Owain

Llyn Llech Owain lies on the western edge of the South Wales Coalfield at an altitude of 250m. The underlying geology is of acidic Carboniferous Namurian quartzite which has given rise to peats and acid, loamy soils of the Anglezarke series which have poor grazing value.

The catchment is largely covered by coniferous forestry plantation, while open land surrounding the lake is dominated by *Molinia caerulea*, *Deschampsia caespitosa* and *Erica tetralix*. Wetter areas contain sizeable stands of *Eriophorum angustifolium* amongst carpets of *Sphagnum* sp.

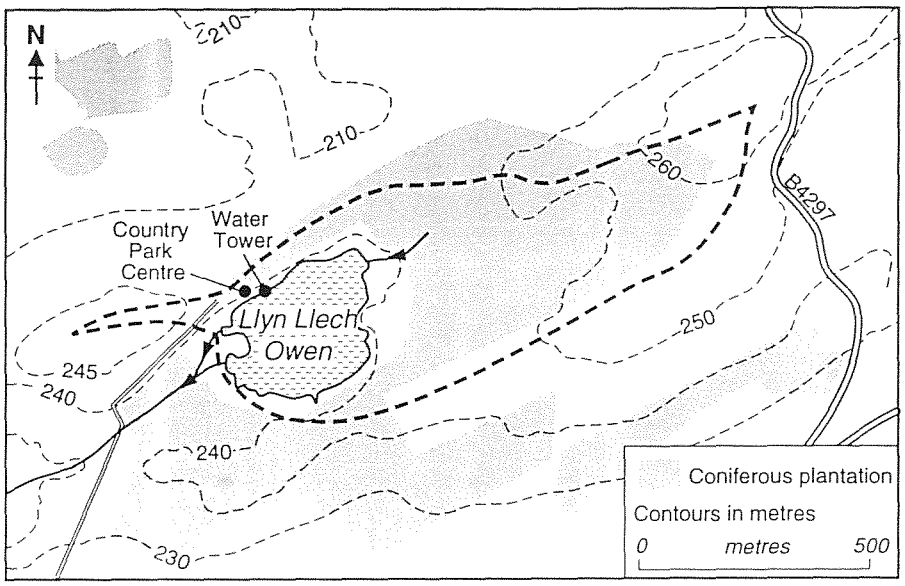
The lake was once used as a reservoir to supply the local village of Gorslas and surrounding area and was subject to considerable draw-down. However, extraction has now ceased and the water level has stabilised. The site has been developed by Camarthen District Council as a Country Park; a Visitor's Centre was opened two years ago and a footpath incorporating limestone chips has been built, encircling the lake. It was notified as a Site of Special Scientific Interest in 1993.

The main inflow is a channel from the forest plantation to the east of the lake. Drainage is through emergent swamp to the west.

Table 2.2 Llyn Llech Owain: site characteristics

Grid reference	SN 569151
Lake altitude	240 m
Maximum depth	1.7 m
Mean depth	1.2 m
Volume	67 x 10^3 m^3
Lake area (including lake)	6 ha
Shoreline development index	1.2
Estimated hydraulic residence time	88 days
Catchment area	32 ha
Catchment:lake ratio	5.3
Net relief	33 m
Mean annual rainfall	1350 mm
Total S deposition	0.78 keq H^+ ha^{-1} yr^{-1}
Total N deposition	1.04 keq H^+ ha^{-1} yr^{-1}

Figure 2.2 Catchment of Llyn Llech Owain



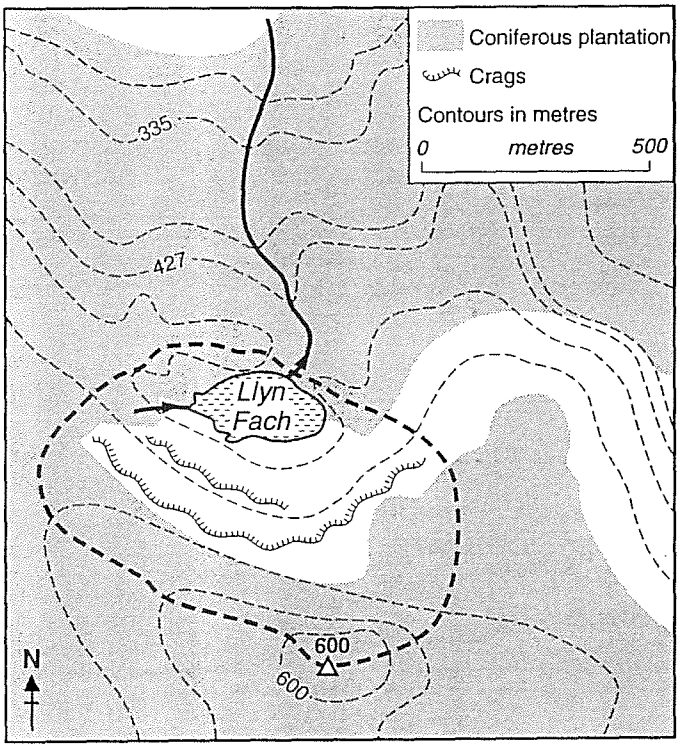
2.3 Llyn Fach

Llyn Fach is situated at an altitude of approximately 450m on the edge of the Pennant Sandstone Plateau in West Glamorgan within the Craig y Llyn SSSI (designated in 1962). Originating as an ice cut hollow at the base of Craig y Llyn cliff, Llyn Fach represents the most southerly corrie lake in the UK. The small catchment consists mainly of steep, poorly vegetated cliff walls although acidic Cambic stagnohumic gley soils (slowly permeable and seasonally waterlogged) have developed on the more gradual slopes. Patches of the Morgannwg coniferous forestry plantation lie within the boundary whilst the non-forested area of catchment surrounding the lake is dominated by *Molinia caerulea* and *Juncus effusus* with *Sphagnum* sp. in wetter reaches. The lake is relatively small with a surface area of 3ha, and its deepest point of 5m is located towards its east end. One discreet inflow feeds the lake via a forested slope to the west and the lake drains by an outflow to the north.

Table 2.3 Llyn Fach: site characteristics

Grid reference	SN 905037
Lake altitude	455 m
Maximum depth	5.0 m
Mean depth	1.7 m
Volume	54 x 10^3 m^3
Lake area	3 ha
Shoreline development index	1.2
Estimated hydraulic residence time	35 days
Catchment area (including lake)	46 ha
Catchment:lake ratio	15.3
Net relief	145 m
Mean annual rainfall	1653 mm
Total S deposition	1.22 keq H^+ ha^{-1} yr^{-1}
Total N deposition	1.82 keq H^+ ha^{-1} yr^{-1}

Figure 2.3 Catchment of Llyn Fach



2.4 Llanbwchllyn

Llanbwchllyn reservoir is situated approximately 10km south-east of Builth Wells, Powys, at an altitude of 295m. The underlying geology is sedimentary, of Silurian origin. The upper slopes of the lake catchment are characterised by soils of the Manod series (well drained, typical brown podzols) whereas those surrounding the lake are chiefly well drained, fine loamy brown earths of the Denbigh series, with some seasonally waterlogged silty cambic stagnogleys of the Cegin series to the south.

The catchment is predominantly sheep grazed moorland although the lower slopes contain quality arable land with some cattle grazed pasture. The lake is fed by an underground spring and two small streams which drain land to the north. Since the introduction of the dam, water is extracted via a submerged pipe.

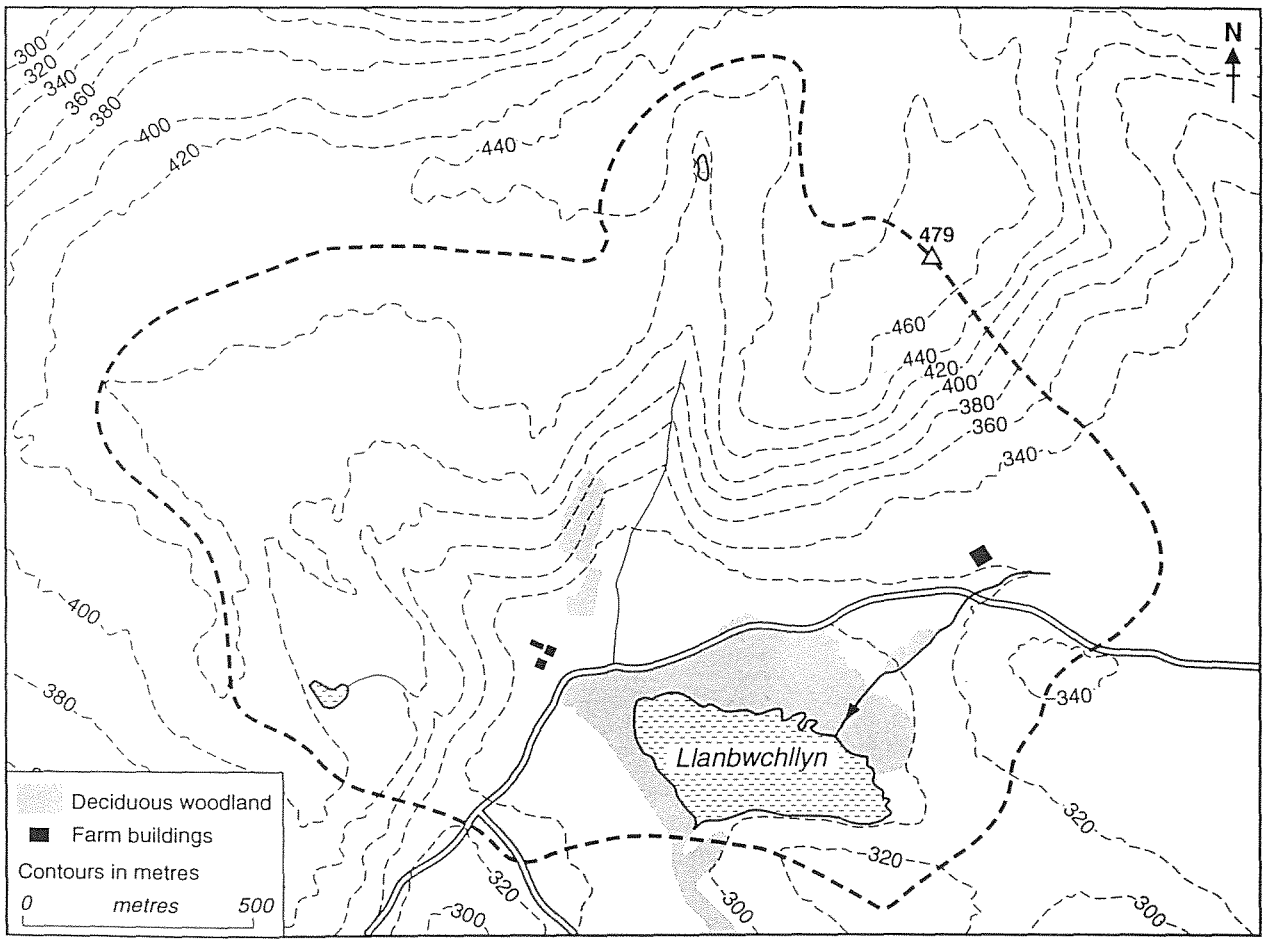
In 1957, before its development as a reservoir, Llanbwchllyn was notified as a Site of Special Scientific Interest (SSSI) by the Nature Conservancy Council due to its assessment as a "good example of an upland lake with a rich variety of aquatic vegetation and marsh flora round its margin, also notable for its bird life". Proposals to use the lake for water supply began in 1959 and this was enabled in 1964 by the Hay and Painscastle Water Order. In 1975 an earth dam was built, raising the water level by 1m and increasing the capacity by 50%.

A botanic survey by Thurley in 1977, following the creation of the reservoir, concluded that the aquatic macrophyte species assemblage had remained largely unchanged since a survey by Seddon in 1964, although several species had shown a quantitative decline in abundance. The site was renotified as a SSSI under the Wildlife and Countryside Act in 1981. More recently, a survey by Slater in 1985 for the Welsh Water Authority found major changes in the aquatic vegetation in comparison to the 1964 data and concluded that "the value of the open water as an SSSI must be threatened". In 1981 the lake was reported to have a fish population of roach, perch and pike only, but since then bream have been introduced by anglers who have argued that this would improve the quality of the fishery. In 1984 copper sulphate was applied to the lake in an attempt to control the blue green alga population which has become an increasing problem in recent years.

Table 2.4 Llan Bwchllyn: site characteristics

Grid reference	SO 118464
Lake altitude	300 m
Maximum depth	8.0 m
Mean depth	3.0 m
Volume	303 x 10^3 m^3
Lake area	10 ha
Shoreline development index	1.5
Estimated hydraulic residence time	70 days
Catchment area (including lake)	260 ha
Catchment:lake ratio	26.0
Net relief	155 m
Mean annual rainfall	1031 mm
Total S deposition	0.92 keq H^+ ha^{-1} yr^{-1}
Total N deposition	1.53 keq H^+ ha^{-1} yr^{-1}

Figure 2.4 Catchment of Llanbwchllyn



2.5 Llangorse Lake (Llyn Syfaddan)

Situated in a lowland region (altitude of 155m) within the Brecon Beacons National Park, Llangorse Lake (or Llyn Syfaddan) is the largest lake in South Wales with a surface area of approximately 150 ha. Although its origins are uncertain, it seems likely that the lake basin results from the combined effects of ice scour and damming by drift material during the last glacial retreat. The underlying Old Red Sandstone drift determines the characteristic red colour of the shoreline soils and inflowing streams. The catchment soils are predominantly fine loamy brown earths, with an area of alluvial, Pelo-alluvial gleys to the south. The large catchment is mainly used for agriculture and contains several farms, Llangorse village, and a caravan site and other tourist developments.

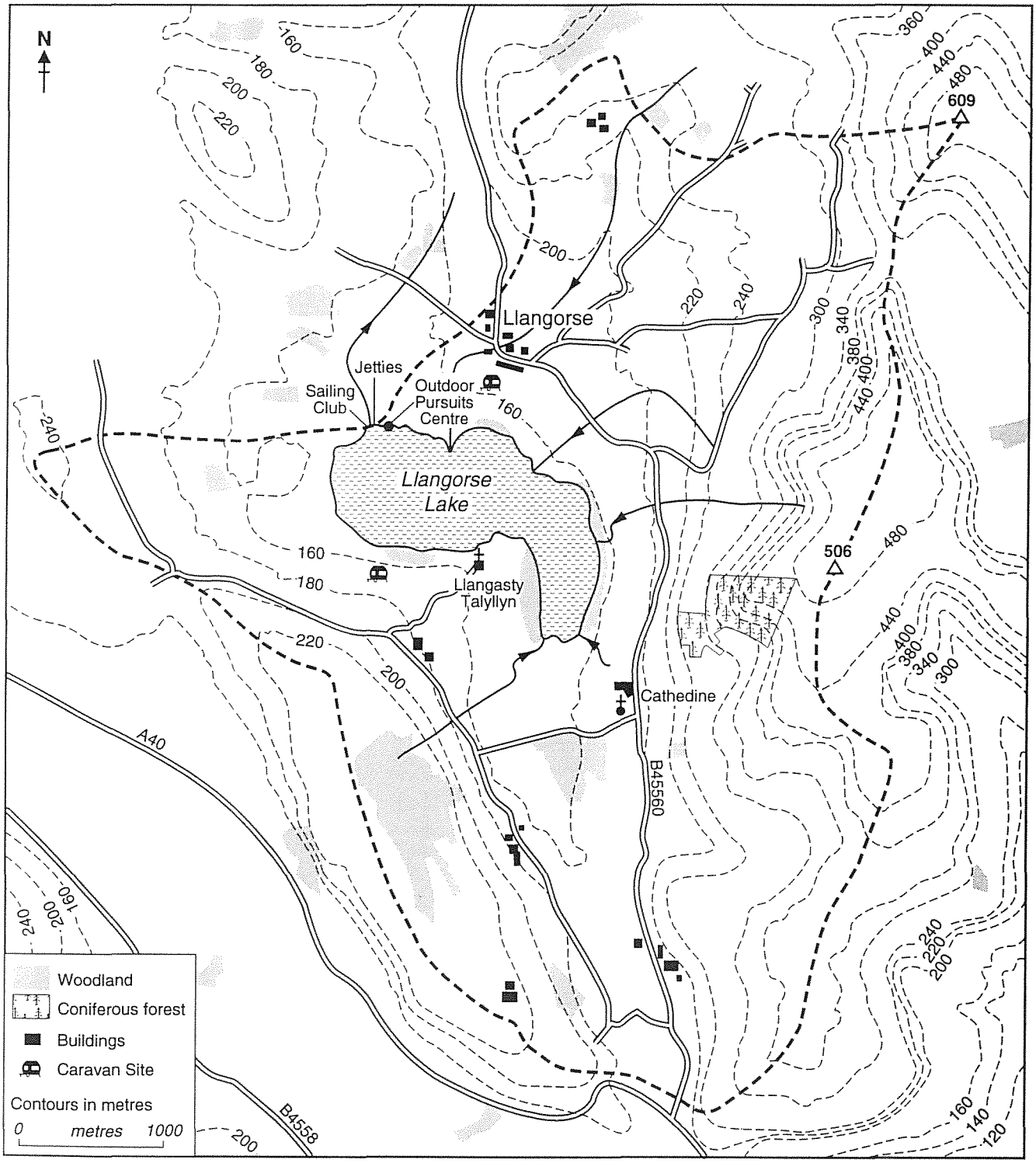
The lake is shallow, rich in nutrients and is renowned for its flora, on the basis of which it was declared a Site of Special Scientific Interest by the Nature Conservancy Council in 1954. It is also a Nature Conservation Review site and a potential Special Area for Conservation. The bio-diversity of the lake is widely recognised and the site is frequented by a variety of waterfowl. Until quite recently, Llangorse Lake received partially treated sewage effluent, which was thought to have increased the nutrient loading on the site and contributed to a decrease in water quality. A variety of water sports have also presented additional environmental pressures. The lake is currently the subject of a CCW funded palaeoecological study by the Environmental Change Research Centre, which seeks to determine the onset, timing and magnitude of nutrient enrichment.

Llangorse Lake receives water from the Afon Llynfi and from five small streams feeding its north and east shores. The Afon Llynfi also drains the lake at the north-west end to the River Wye.

Table 2.5 Llangorse Lake: site characteristics

Grid reference	SO 132265
Lake altitude	155 m
Maximum depth	7.5 m
Mean depth	2.0 m
Volume	2780 x 10^3 m^3
Lake area	139 ha
Shoreline development index	1.3
Estimated hydraulic residence time	70 days
Catchment area (including lake)	2091 ha
Catchment:lake ratio	15.0
Net relief	309 m
Mean annual rainfall	1167 mm
Total S deposition	1.0 keq H^+ ha^{-1} yr^{-1}
Total N deposition	1.5 keq H^+ ha^{-1} yr^{-1}

Figure 2.5 Catchment of Llangorse Lake



2.6 Llyn y Fan Fawr

Llyn y Fan Fawr lies at an altitude of 610m within the Mynydd Du SSSI in the Brecon Beacons, immediately beneath Fan Brycheiniog ridge. The geology of the catchment is predominantly of Old Red Sandstone with outcrops of Carboniferous Limestone and Millstone Grit. The overlying soils are predominantly ferric stagnopodzols, with a wet peaty surface horizon, bleached subsurface horizon and thin iron pan. The catchment vegetation is dominated by *Nardus stricta*, with patches of *Calluna vulgaris* and *Vaccinium myrtillus*. The cliffs of Bannau Brycheiniog are reported (from SSSI notification records) to support an interesting Arctic-alpine flora, including *Galium boreale*, *Salix herbacea* and *Sedum rosea*.

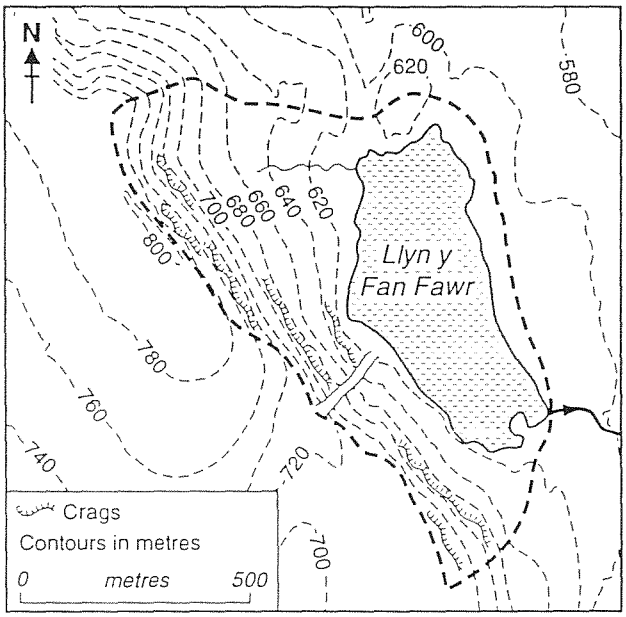
The main inflow to the lake is via a gulley which cuts through the ridge. The outflow is to the south-east and an old concrete dam, now ineffective, provides evidence of past attempts to raise the water level. Flow in the main inflow and outflow is highly dependent on antecedent rainfall and neither channel is permanent.

Llyn y Fan Fawr is included in Ratcliffe's 1977 Nature Conservation Review.

Table 2.6 Llyn y Fan Fawr: site characteristics

Grid reference	SN 831217
Lake altitude	610 m
Maximum depth	20.0 m
Mean depth	6.0 m
Volume	1020 x 10^3 m^3
Lake area (including lake)	17 ha
Shoreline development index	1.4
Estimated hydraulic residence time	588 days
Catchment area	49 ha
Catchment:lake ratio	2.9
Net relief	800 m
Mean annual rainfall	1653 mm
Total S deposition	1.22 keq H^+ ha^{-1} yr^{-1}
Total N deposition	1.82 keq H^+ ha^{-1} yr^{-1}

Figure 2.6 Catchment of Llyn y Fan Fawr



3 Methods

The variables recorded and measured 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; 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. At Llanbwchllyn reservoir, the large draw-down during the late summer made access to the normal littoral habitat impossible and therefore no macroinvertebrate samples were taken at this site.

4 Results

Physio-chemical and biological data for individual sites are presented in a series of Appendices (A - F) and further notes on the sampling locations for littoral Cladocera and macro-invertebrates are provided in Appendices G and H respectively.

4.1 Physio-chemical data

4.1.1 Kenfig Pool

The water chemistry of Kenfig Pool is indicative of a coastal, alkaline lake of moderate nutrient status. The high values for alkalinity (mean 2079 μeq^{-1}), conductivity (mean 345 $\mu S\ cm^{-1}$), sodium and chloride are similar to those recorded for the Anglesey sites during Phase I of this project, and reflect the influence of marine climate at this site. Most cations also occur at high concentrations, particularly calcium (mean 2279 $\mu g\ l^{-1}$) which may reflect the marine shell enriched dune sand and also inflow from a deep carbonate rich aquifer. The levels of phosphorus are moderate throughout the year and suggest that the lake is not heavily impacted by local agricultural or other land use practices. Chlorophyll *a* levels are relatively high throughout the year, with a maximum of 17.8 $\mu g\ l^{-1}$ recorded in the spring sample, and this probably accounts for the low secchi disc depth recorded in July of 1.2 m. This shallow lake was isothermal and well oxygenated on the July profiling date.

4.1.2 Llyn Llech Owain

The water chemistry data for Llyn Llech Owain is, in certain respects, unusual and difficult to explain. Given the underlying acid geology and soils, the acid and heavily peat stained nature of the lake is to be expected. Mean pH (4.95) and alkalinity (-8 $\mu eq\ l^{-1}$) values are lower than for all

other sites monitored to date with the exception of Llynoedd Ieuan. Water transparency is so low as to prevent the establishment of submergent macrophyte taxa typical of acid lakes. The high mean absorbance value for the site (0.447) is the highest recorded to date for this project and probably results from the high concentration of organic carbon (mean TOC 8.5 mg l^{-1}) derived from the peaty catchment. The July secchi disc depth was only 0.3 m. However, the relatively high levels of phosphorus and the exceptionally high levels of chlorophyll *a* appear contradictory to the properties described above, being more usually associated with biologically productive waters. These high levels most likely result from the products of decaying shoreline peat in the vicinity, close to the outflow, from where all samples were taken, and are unlikely to be representative of the lake water as a whole. An independent analysis of chlorophyll *a* in a water sample taken from the middle of the lake in July provided a value of 3.8 µg l^{-1}, as compared to a value of 65.2 µg l^{-1} for the outflow sample. It is also possible that the limestone chip footpath which circles the lake could have some localised effect on water chemistry as calcium levels also appear relatively high, although this is not reflected in sample pH. Further work is necessary before the apparent discrepancies in the chemistry data for this site can be properly understood. Moderate levels of sulphate and chloride probably reflect a marine influence on the water chemistry.

4.1.3 Llyn Fach

Llyn Fach is an acid (mean pH 6.28), nutrient poor lake, although relatively well buffered with mean values for alkalinity and calcium concentration of 99 and 159 µeq l^{-1} respectively. The lake water is relatively transparent with low absorbance at 250 nm (mean 0.052) and a July measured secchi disc depth which exceeded the 5 m maximum depth of the lake. Low levels of phosphorus and chlorophyll *a* were recorded throughout the year. Highest values for most chemical determinands were recorded in the January sample, however, this data should be treated cautiously as it was necessary to break through an ice layer (which covered the entire lake surface) to retrieve this water sample and the subsequent disturbance caused resuspension of some detrital material. The July profile measurements show slight evidence of the development of a thermocline in the upper half of the water column, although this is not reflected in the oxgen data which shows saturation throughout the profile.

4.1.4 Llanbwchllyn

The water chemistry of Llanbwchllyn is indicative of an alkaline lake of moderate nutrient status. Lake pH is always slightly above neutral and cation levels are high, particularly calcium (mean 1837 µeq l^{-1}). Phosphorus and chlorophyll *a* concentrations vary markedly throughout the year, with maximum values coinciding in the September sample. This could be accounted for by summer phosphorous release from the lake sediments following thermal stratification, as the July profiles show a well developed thermocline at approximately 2 m and complete deoxygenation beneath 5 m water depth. Secchi disc depth on the July sampling date was 0.8 m.

4.1.5 Llangorse Lake

Llangorse Lake is a particularly alkaline, nutrient rich and productive lake. The mean alkalinity of 2446 µeq l^{-1} is the highest recorded for any site monitored in this project to date, and all water

samples were close to pH 8.0. Total phosphorus and soluble reactive silica levels were generally high, although falling below 100 μg l^{-1} and almost zero respectively in the April sample. This feature could be explained by the occurrence of a springtime algal bloom, since the Chlorophyll a concentration peaks at this time at 31μg l^{-1}. Lake water transparency was poor at the time of profile measurements in July (secchi disc depth 1.1 m), thermal stratification was marked from the lake surface, and complete deoxygenation was evident below 5 m water depth. However there was no evidence of enhanced summer phosphorus levels resulting sediment release at this time.

4.1.6 Llyn y Fan Fawr

Llyn y Fan Fawr is a slightly acid lake, possessing significant buffering capacity with a mean alkalinity of 86μeq l^{-1}. This lake occurs at the highest altitude of all sites monitored in this project and therefore experiences one of the coldest environmental regimes. Despite moderate levels of most cations, the conductivity for the site is low throughout the year (mean 37 μS cm^{-1}), and exceptionally low values for chlorophyll *a*, soluble reactive silica, and absorbance (250 nm), are indicative of a biologically unproductive water body . Surprisingly, the July measured secchi disc depth was only 4.5 m, probably resulting from water staining from sources of catchment peat. Physical profiling in July revealed a well developed thermocline at approximately 6 m water depth, but with dissolved oxygen levels only slightly depleted below this.

4.2 Epilithic diatoms

4.2.1 Kenfig Pool

The epilithic flora of Kenfig Pool has low species diversity, with six taxa accounting for almost the whole assemblage. The major species are *Navicula cryptotenella, Achnanthes minutissima, Amphora pediculus, Cymbella microcephala, Achnanthes lanceolata* and *Epithemia sorex.* Many of these species are also present in the epilithic communities of Llangorse Lake and Llanbwchllyn but the notable difference here is the absence of the *Fragilaria* taxa despite their importance in the surface sediment assemblage. The reasons for this are unknown, but it may be due to the limited nature of the habitat or possibly the more brackish, sandy conditions at Kenfig Pool relative to the other lakes.

The epiphytic flora of Kenfig Pool has very low species diversity with a clear dominance by *Fragilaria intermedia* (approx 50% of the assemblage) and high relative abundance of *Achnanthes minutissima* (19-27%). The only other significant taxa are *Navicula cryptotenella* and *Cocconeis placentula. F. intermedia* is regarded as an alkaliphilous species with a pH optimum of 7-7.8, which is consistent with the observed water chemistry of the pool.

4.2.2 Llyn Llech Owain

The epilithic diatom flora of Llyn Llech Owain is characteristic of acidic, nutrient-poor waters. The assemblages are dominated by *Eunotia incisa* with *Eunotia rhomboidea* and *Achnanthes altaica*

also abundant. Other common species include *Fragilaria* [cf. *oldenburgiana* PIRLA], *Achnanthes austriaca* var. *minor* and *Frustulia rhomboides* var. *saxonica*.

4.2.3 Llyn Fach

The epilithic assemblages of Llyn Fach are relatively diverse, with a number of species acheiving high abundances. These include *Fragilaria virescens* var. *exigua*, *Brachysira vitrea*, *Nitzschia perminuta* and *Cymbella microcephela*. The flora is indicative of circumneutral to slightly acid waters with low nutrient status.

4.2.4 Llanbwchllyn

The epilithic flora of Llanbwchllyn has relatively low species diversity with dominance by the non-planktonic *Fragilaria* taxa, which comprise 40-60% of the whole assemblage, *Achnanthes minutissima* and *Cymbella microcephala*. These are cosmopolitan taxa, typical of alkaline freshwaters, although *C. microcephala* is reported to prefer well-aerated habitats.

4.2.5 Llangorse Lake (epilithic and epiphytic)

The epilithic diatom flora of Llangorse Lake is particularly diverse, with 23 species acheiving an abundance >1%. The most common taxa are *Fragilaria pinnata, F. brevistriata, Amphora pediculus, Cocconeis pediculus, Achnanthes minutissima, Navicula cryptotenella* and *Nitzschia dissipata*. All of these taxa are common in freshwaters but are generally indicative of alkaline conditions with a good supply of nutrients.

The epiphytic flora is much less diverse, with a marked dominance by *Cocconeis placentula* (57%) and *Achnanthes minutissima* also present in relatively high abundance (11%). These two taxa are amongst the most common of all freshwater diatoms and are widely distributed. However, *Cocconeis placentula* is most commonly found attached to plants in alkaline, nutrient-rich waters (e.g. Bennion (1994)).

4.2.6 Llyn y Fan Fawr

The epilithic assemblages have low species diversity and are dominated by the cosmopolitan taxon *Achnanthes minutissima (51%). Cyclotella microcephela*, *Nitzschia perminuta* and *Synedra miniscula* are also common, the latter species more usually associated with running waters than lakes. The assemblages are indicative of circumneutral conditions with low nutrient status.

4.3 Surface Sediment Diatoms

4.3.1 Kenfig Pool

The surface sediment assemblage is dominated by non-planktonic forms, typical of shallow, alkaline, nutrient-rich waters. The major species are *Fragilaria pinnata, Achnanthes minutissima* and *Amphora pediculus*. The shallow depth of Kenfig Pool (mean depth of 1.8 m) and abundance of submerged macrophytes across the lake bed suggest that the surface sediments lie within the normal photic zone, thus accounting for the dominance of attached forms in the surface sediment diatom assemblage. Similar assemblages have been observed in other shallow, alkaline waterbodies (Bennion 1994, 1995).

4.3.2 Llyn Llech Owain

The surface sediment diatom flora of Llyn Llech Owain is dominated by *Eunotia incisa*, a species common in nutrient-poor, acid waters. *Cymbella perpusilla* and *Navicula soehrensis* are also abundant, the latter species indicative of epipsammic (sandy) habitats. Several other species characteristic of slightly acid to acid waters are common in the sample, including *Frustulia rhomboides* var. *saxonica*, *Tabellaria flocculosa* and *Navicula* [sp. 1 Llyn Hir].

4.3.3 Llyn Fach

The surface sediment diatom assemblage of Llyn Fach is dominated by *Fragilaria virescens* var. *exigua* (22%). *Navicula globosa* and *Achnanthes minutissima* are also abundant and other common taxa include *Brachysira vitrea*, *Navicula jaarnfeltii* and *Cymbella microcephela*. These assemblages are indicative of nutrient-poor, circumneutral to slightly acid waters, although the ecology of *N. globosa* is poorly understood. Planktonic species are very poorly represented. The importance of small, attached forms such as *F. virescens* var. *exigua, N. jaarnfeltii* and *N. globosa* suggests that (as at Kenfig Pool) the surface sediments lie within the photic zone. This is consistent with the relatively shallow depth and high transparency of Llyn Fach.

4.3.4 Llanbwchllyn

The surface sediment assemblage is comprised of both planktonic taxa indicative of mesotrophic conditions and non-planktonic *Fragilaria* taxa (*F. pinnata* and *F. construens*), commonly observed in alkaline waters. The most abundant planktonic taxa are *Asterionella formosa* (17%) and *Aulacoseira granulata* (11%), species which can form large blooms in nutrient-rich lakes and are therefore often dominant in surface sediment assemblages of such waters. The small, centric planktonic species such as those of the genera *Stephanodiscus* and *Cyclostephanos* are not so common in the Llanbwchllyn surface sediments as in the surface sediments of Llangorse Lake. This is most likely due to the high silica (Si) concentrations and relatively low phosphorus (P) concentrations, and thus a high Si:P ratio at Llanbwchllyn which favours the growth of the larger planktonic forms, whereas the low Si:P ratio at Llangorse Lake favours the small, centric forms.

4.3.5 Llangorse Lake

The surface sediment diatom assemblage is dominated by planktonic taxa indicative of nutrient-rich, alkaline waters. *Aulacoseira subarctica*, generally found in mesotrophic waters is present in the highest abundance (31%) and *Cyclostephanos dubius* (17%), *Aulacoseira granulata* (6%) and *Stephanodiscus parvus* (5%) are also common. Diatom analysis undertaken on a sediment core from Llangorse Lake (Bennion, 1996) showed that the surface sediment assemblage indicated an improvement in water quality when compared with lower core samples. The centric taxa associated with highly nutrient-rich waters decreased in relative abundance, particularly *Stephanodiscus parvus, Aulacoseira ambigua, Cyclostephanos dubius* and *Stephanodiscus hantzschii*, whilst the relative abundance of *Aulacoseira subarctica* increased.

4.3.6 Llyn y Fan Fawr

The surface sediment diatom assemblage is dominated by the planktonic *Cyclotella comensis*, a species indicative of circumneutral, nutrient-poor conditions. Two other species are common; *Achnanthes minutissima* is cosmopolitan in circumneutral conditions, and *Cyclotella glomerata* is a planktonic species found in oligo-mesotrophic, circumneutral waters. Species diversity is very low, with these three taxa accounting for a very high proportion (65%) of the total count.

4.4 Aquatic macrophytes

4.4.1 Kenfig Pool

The sandy substrates which characterise the shoreline of Kenfig Pool support significant stands of *Phragmites australis* dominated swamp on the pool's seaward side, while the inland shoreline is cattle grazed and devoid of emergent vegetation. Other common components of the swamp vegetation include *Scirpus lacustris* ssp. *tabernaemontani*, *Scirpus maritimus*, and *Sparganium erectum*. The most diverse emergent assemblage occurs in the narrow neck at the far north end of the lake in which *Iris pseudacorus* is also present. Sheltered bays and small clearings within the larger stands contain significant floating leaved stands of *Polyganum amphibium*; *Potamogeton lucens* and *P. crispus* are occasional aquatic species here and *Eleocharis palustris*, *Hydrocotyle vulgaris*, and *Caltha palustris* occupy the margins. The open water provides a habitat for many aquatic species which together cover the entire lake bed. The fine leaved *Potamogeton trichoides* is locally dominant, particularly in the north of the lake, while the south end includes abundant *Ceratophyllum demersum*, *Elodea canadensis*, *Ranunculus circinatus*, *Myriophyllum spicatum* and the charophytes *Chara aspera* var. *aspera* (nationally scarce) and *Nitella flexilis* var. *flexilis*. The shallow open water (to 0.5m depth) habitat at the south end of the lake support swards of *Littorella uniflora* often growing in asssociation with *C. aspera* var. *aspera* and *Fontinalis antipyretica*. *C. aspera var. aspera* also dominates the substrate off the grazed landward shoreline, to a depth of approximately 1.5 m.

The NVC communities present at Kenfig Pool include the swamp communities S4 (*Phragmites australis*) and S20 (*Scirpus lacustris* ssp. *tabernaemontani*) and the aquatic communities A5

(*Ceratophyllum demersum*) and A10 (*Polyganum amphibium*). Other associations referred to above do not conform to NVC descriptions, so a summary of NVC communities clearly understates the community diversity of this site. Kenfig Pool is ranked 10A, a eutrophic category, according to Palmer (1992) and has a trophic ranking score of 8.39.

The aquatic flora of Kenfig Pool appears to have undergone significant change in the last few decades. The reedbeds, which are abundant today, only developed after 1945 when grazing declined (Dr Peter Jones pers. comm). Previously, when the shoreline was more open, *Limosella australis* was recorded in some abundance, having been recorded for the first time in Europe at the site in 1897. A description of the flora of Kenfig Pool was included in Ratcliffe's (1977) Nature Conservation Review. Although the species list recorded then has much in common with the current findings, *Isoetes echinospora* was reported to occur in deep water, and *P. pusillus* was described as the most abundant of four *Potamogeton* species. It seems most unlikely, given the dense beds of macrophytes which cover the lake and the current alkaline water chemistry, that *I.echinospora* could survive in the lake today. Although there is no direct evidence from water chemistry *P.trichoides* (unrecorded before 1982) may have increased recently to replace *P.pusillus* as the most abundant aquatic macrophyte as a result of trophic change (ie. nutrient enrichment). *P.pusillus* and *P. trichoides* (both fine leaved species) often grow in association and it is possible that the former is present at relatively low abundance but was not detected in the current survey.

4.4.2 Llyn Llech Owain

Llyn Llech Owain is characterised by emergent and floating leaved macrophyte species with low nutrient requirements. Submerged aquatic vascular plants are almost completely absent, a feature which may be explained by the highly stained water (total organic carbon concentration of 8 mg l^{-1}) which probably prevents enough photosynthetically active radiation reaching even the shallowest depths. One individual *Littorella uniflora* plant was found growing in less than 5 cm of water close to the old water tower. The most significant plant cover occurs towards the outflow where a sparce, floating leaved canopy of *Nuphar lutea* and, to a lesser extent, *Nymphaea alba* dominates. Stands of *Carex rostrata* and *Eleocharis palustris* along the south shoreline are flanked on the open water side by *Equisetum fluviatile. C.rostrata* is also present in the bay leading to the outflow where it grows in association with *Menyanthes trifoliata.* The only truely aquatic macrophyte present is the acidophilous moss *Sphagnum auriculatum* which grows in abundance in open water adjacent to the *E.fluviatile* beds around the south shoreline.

The NVC communities present include the *Menyanthes trifoliata - Equisetum fluviatile* sub-community of S9 (*Carex rostrata*) and the *Nymphaea alba* sub-community of A8 (*Nuphar lutea*). Llyn Llech Owain is classed as Type 2 according to Palmer (1992), an oligotrophic, peat influenced category. Had the single individual of *L. uniflora* not been detected the site would have been classed as Type 1 (Dystrophic). The trophic ranking score for this site is 5.61.

The species list is similar to the list of aquatic species recorded for this site in 1963 by R.F.May and therefore provides no evidence of a changes in water quality over this period.

4.4.3 Llyn Fach

Llyn Fach supports a flora typical of an upland, nutrient poor lake. The firm substrates of the north

shoreline are dominated by *Lobelia dortmanna* (its southernmost occurrence in Britain) often in association with mats of *Sphagnum auriculatum* and sparse *Isoetes echinospora*. This community is replaced in deeper water, first by a dense growth of *Juncus bulbosus* var. *fluitans* and then by a monospecific sward of *I.echinospora* which is limited to a water depth of 3.8m. *Potamogeton polygonifolius* is locally abundant and the charophyte *Nitella flexilis* var. *flexilis* and *Myriophyllum alterniflorum* are occasional between 1.5 -2.5 m water depth. The vegetation surrounding the main inflow at the west end of the lake consists mainly of swamp communities of *Carex rostrata*, and *Equisetum fluviatile* grading into a mixed stand of *J. bulbosus* var. *fluitans* and *Scirpus fluitans*. *Sparganium angustifolium* (also at its southerly limit for Britain) forms significant floating leaved mats in this area. The south side of the lake is more influenced by the surrounding peat and a strip of *Sphagnum* bog flanks the shoreline. *C.rostrata* occurs in several small stands and *P.polygonifolius* and *Ranunculus flammula* are occasional along this side. *Potamogeton berchtoldii* is present amongst a littoral association of *S.auriculatum*, *J.bulbosus* var. *fluitans* and *L.dortmanna* at the east end of the lake.

The macrophyte communities present at Llyn Fach are inadequately described by the current NVC community descriptions. For example the NVC community which most closely matches the *Lobelia dortmanna* dominated littoral association in this lake, (A22) includes *Littorella uniflora* as a constant species and is therefore inappropriate. The communities which can be described are the swamp communities S9 (*Carex rostrata*), S10 (*Equisetum fluviatile*) and S19 (*Eleocharis palustris*) and the aquatic community A23 (*Isoetes setacea*). Llyn Fach is classed as Type 2 according to Palmer (1992), an oligotrophic category, influenced by peat, and has a trophic ranking score of 5.18.

There is little evidence of recent change in the macrophyte flora of Llyn Fach according to available survey data. However, records by Trow from 1911 note the occurence of *Littorella uniflora*, *I. lacustris* (in addition to *I.echinospora*) and *Utricularia minor*, none of which were recorded during the current survey.

4.4.4 Llanbwchllyn

The aquatic macrophyte flora of Llanbwchllyn reservoir has clearly been affected by reservoir use over the past two decades. The species list is generally restricted to emergent and floating leaved taxa which are able to tolerate large fluctuations in water level and aquatic species which are relatively tolerant of turbid conditions.

The most significant macrophyte cover consists of floating leaved stands of *Nymphaea alba*, *Nuphar lutea* and *Polyganum amphibium* which occupy the west end of the lake. The west shoreline is flanked by *Phragmites australis* swamp, while *Salix* sp. dominates in places. On the north-east shore stands of *P.australis* are interspersed with *Alnus* sp. The open water habitat is largely free of macrophytes, despite a sizeable area of the lake being less than 2 m deep. Small patches of the charophyte *Nitella flexilis* var. *flexilis* and *Potamogeton praelongus* occur towards the east end and in the south-west corner of the lake respectively. Small quantities of *Potamogeton crispus*, *Myriophyllum alterniflorum* and *Lemna trisulca* grow at the fringe of the *N.alba* canopy. In addition, specimens of *Potamogeton berchtoldii*, *P.praelongus* and *Myriophyllum spicatum* were found in shoreline strand material in the north-west corner. On a water sampling visit to the site in September 1995 the water level was approximately 1.5 m lower than on the date of the macrophyte survey and the rooting zone of the major floating leaved stands was exposed.

The NVC communities represented at this site are the swamp community S4 (Phragmites australis) and the aquatic communities A8 (*Nuphar lutea*), A7 (*Nymphaea alba*) and A10 (*Polyganum amphibium*). Llanbwchllyn is classed as type 5A, a mesotrophic category, according to Palmer (1992) and has a trophic ranking score of 7.78. Although, with reference to previous records, it appears that the total species list for aquatic plants has changed little over the past few decades, it is clear that development of Llanbwchllyn as a reservoir has had a marked effect on species abundance to an extent that many aquatic species are now ranked as rare and could be on the verge of extinction at this site.

4.4.5 Llangorse Lake

Llangorse Lake is fringed partly by emergent stands of vegetation, of which *Phragmites australis* and *Typha latifolia* are most dominant, and partly by more open grazed shorelines. *Sparganium erectum* occurs frequently amongst these emergent species while *Scirpus lacustris* ssp. *tabernaemontani* forms smaller isolated stands, most notably in the southern arm of the lake. The emergent stands are often flanked on the open water side by floating leaved canopies of *Nuphar lutea, Nymphoides peltata, Nymphaea alba and Polyganum amphibium.* The lake also contains a diverse submerged flora of which *Myriophyllum spicatum* and *Potamogeton perfoliatus* are most widespread (to a depth of approximately 1.8 m), often growing in association with *Elodea canadensis*, *Potamogeton pectinatus,* and *Lemna trisculca. P.lucens* forms significant stands in sheltered shallow water particularly along the south west shoreline, *P. crispus* is less common and mostly found in association with stands of floating leaved vegetation. *P. pusillus* is apparent in patches in shallow water and on occasion in association with *P. pectinatus* where it can be easily overlooked. The charophyte *Chara globularis* var. *globularis* is locally abundant in the eastern half of the lake. One individual *P. natans* plant was found in shallow water on the north shore. *Zannichellia palustris* was recorded at very low abundance in a few locations, along the north shoreline.

The presence of *Potamogeton perfoliatus*, *P. lucens* and *P. crispus* confirms the site's importance as an example of a eutrophic lake with Magnopotamion - type vegetation for which it is proposed as a Special Area for Conservation (pSAC) under the EU Habitats and Species Directive.

The aquatic plant communities can be described using the NVC classification system. Those represented at Llangorse Lake include the swamp communities S4 (*Phragmites australis*), S23 (*Typha latifolia*) and S20 (*Scirpus lacustris* var. *tabernaemontani*) and the aquatic communities A5 (*Ceratophyllum demersum*), A7 (*Nymphaea alba*), A8 (*Nuphar lutea*), A10 (*Polyganum amphibium*), A11 (*Potamogeton pectinatus - Myriophyllum spicatum*) and A12 (*Potamogeton pectinatus*). The site is typed as 10A, a eutrophic category, according to Palmer (1992) and the trophic ranking score is 8.36.

Llangorse Lake has been the subject of several botanic surveys over the past few decades and the data from these have been summarised in a report by the International Centre of Landscape Ecology (1993). Since 1977, several surveys have been based on the same transect lines, allowing a more objective monitoring of biological change. This methodology was deemed inappropriate for the current survey, given the constraints of time and the primary objective of producing a species summary for the site as a whole rather than one of monitoring change at specific locations. However some broad conclusions can be drawn on changes in the aquatic flora of the site.

The current species list has much in common with the species list of Philips and Sparke from 1961, with the main exceptions that *P. pectinatus* and *Z. palustris*, both characteristic of eutrophic conditions, were not recorded then. During the 1970s the lake apparently became inundated by these two species which appear to have thrived on the input of treated sewage effluent from Llangorse village. In 1977, Bacchus reported *Zannichelia palustris,* which is also noted for its ability to withstand conditions of high turbidity, to be the only submergent macrophyte in the lake. Since then, and the cessation of effluent input, several species have become re-established, *Z. palustris* has declined in abundance and results from surveys conducted between 1985 and 1992 suggest what Wade has described as a "period of stability". During this time *Myriophyllum spicatum* has been recorded as the most abundant species while intermediate abundances have been recorded for *Potamogeton perfoliatus*, *Elodea canadensis*, *P. pectinatus* and *Ceratophyllum demersum*. The current list departs only slightly from the 1985-1992 data, with the major exceptions being that *P. pusillus* has again been found (the first record since 1973), *Ranunculus circinatus* (only one record in 1992) is more frequent and that there has been an increase in the abundance of *P.lucens* which cannot now be described as "rare". In 1992, *P.lucens* was picked up on only one rake haul and was found at a total of five locations (this being its first record since 1973), and it seems likely that although the number of locations is still limited, its local abundance has much improved. *P. crispus* (only found on one survey since 1989) has again been found in a few locations.

A review of the floating leaved and emergent flora of the lake by Colquhoun (see ICOLE report (1993)) concluded that there had been little change since since the survey of 1961. Colquhoun's 1992 survey found all of the species recorded in 1961 with the exception of *Scirpus lacustris*, however this was found in abundance at several locations during the current survey. There is evidence from aerial surveys that there has been a decline in the cover of *Phragmites australis* in recent years but these may be localised losses (S.Reid pers. comm) and verification is beyond the scope of this survey.

4.4.6 Llyn y Fan Fawr

Llyn y Fan Fawr is almost entirely devoid of aquatic macrophytes. The reasons for this are unclear although the steeply shelving shoreline dominated by sandstone boulders, which characterises much of the lake, is unsuitable for the colonisation of most species. A shallow sandy area, close to the lake outflow is colonised by *Littorella uniflora* to a depth of 0.1m while a shallow water form of *Isoetes lacustris* extends to approximately 1m. The only other aquatic macrophyte at the site is the moss *Fontinalis antipyretica* which occurs rarely on boulders around the water line.

The only clearly definable NVC community at Llyn y Fan Fawr is A23, the *Isoetes lacustris* community, although the shallow water monospecific *L. uniflora* sward could be described as a *Littorella uniflora* sub-community of A22. The site is classed as type 3 according to Palmer (1992), an oligotrophic, coarse substrate category and has a trophic ranking score of 6.0.

Llyn y Fan Fawr is described in the Nature Conservation Review (Ratcliffe, 1977), which seems to indicate that *L.uniflora* and *I.lacustris* were once more widespread along the east side of the lake. However, no other species were mentioned to those listed here.

4.5 Littoral Cladocera

A total of 25 Cladocera taxa were recorded from 31 samples collected from the 6 study sites. The samples taken at Llanbwchllyn were relatively sparse, with one sample lacking any Cladocera and only small numbers of four taxa (*Alona* sp., *A. affinis*, *Chydorus sphaericus*, *Pleuroxus uncinatus*) being recorded from the remainder. Four Cladocera taxa only were recorded from Llyn Y Fan Fawr, but higher numbers of specimens were found. The most diverse assemblages were recorded in Llyn Llech Owain and Kenfig Pool, where 13 taxa were recorded at each site. The results are given in Appendices A-F, Tables 6 and 7.

No taxon was common to all six sites, although *A. affinis* and *C. sphaericus* were recorded at five. The most frequently occurring taxa, *C. sphaericus,* was present in 13 of the samples analyzed. A fish-louse was identified as *Argulus foliaceus*, with reference to Gurney (1948).

Most of the recorded taxa were previously recorded in Phases 1 and II of this project, with the exception of *Alona* sp., *Pleuroxus denticulatus*, *Pleuroxus uncinatus*, *Rhynchotalona falcata*. The reporting of the small *Alona* at Llanbwchllyn as "*Alona* sp." was necessary because only shells were found and species level identification was not possible. Observations on the ecology of *Pleuroxus denticulatus* in the literature are limited, with Scourfield and Harding (1966) reporting it from "among weeds". It may be significant that, during this survey, it was only found amongst vegetation at two lowland sites (Kenfig Pool and Llangorse Lake).

P. uncinatus is a specialised bottom dweller, which frequents muddy sites and hard substrata that have a covering of detritus; it often occurs where vegetation is absent (Fryer 1993). It has been previously recorded from locations which experience fluctuations in water level (Duigan 1992) and this may explain its presence in Llanbwchllyn only. *R. falcata* is known to occur frequently on *Chara* and sandy substrata (Duigan 1992; Fryer 1993). These observations are consistent with its occurrence at sampling sites in Kenfig Pool and Llyn Llech Owain.

Differences in the species assemblages found in upland and lowland sites, and noticed in previous phases of this project were not as clearly evident in phase III. In 1995, the most diverse assemblages were recorded from the lowland sites, not mountain lakes as in phases I and II. *Alonopsis elongata*, a typical upland oligotrophic species, is noticeably absent from Llyn Y Fan Fawr.

No previous records for zooplankton for these survey sites were found, with the exception of some unpublished data for Llangorse Lake (Britton 1973, see bibliography). Further survey and a collation of all previous records for Cladocera in Wales is required before a complete assessment of the conservation importance of the species recorded can be carried out.

4.6 Open water zooplankton

18 crustacean species, 7 species of rotifers and 1 species of insect (larvae) were found in the six lakes investigated during July 1996 (Phase III). Three of the crustacean species and two of the rotifer species had not been recorded during Phases I and II.

Eudiaptomus gracilis was the only species found in all six Phase III sites. This species is the most

widespread calanoid in the project to date, having been recorded as one of the dominant species in the open water zooplankton community in 19 of 21 lakes. The pattern of occurence of *E. gracilis* in Yorkshire has been reported by Fryer (1993) where it appears to prefer alkaline conditions but is found in standing waters with a pH and calcium concentration range of 5.3 - 10.2 and 8 - 180 mg l^{-1}. The data from this survey suggest that the tolerance of *E. gracilis* of acidic conditions is not so exceptional, dense populations having, for example, been found in Llyn Llech Owen, Llynoedd Ieuan and Llyn Hir.

The second most common crustacean species recorded in the survey to date is *Diaphanosoma brachyurum* which has occured at 14 sites. The tolerance of this species to acid conditions has previously been documented by Fryer and Forshaw (1979) who, in the Inner Hebrides, found it occuring in sites with a pH as low as 4.4. Within the Welsh dataset it appears the the pH preference of this species is slightly acid, since the more alkaline sites such as Llanbwchllyn, Kenfig Pool and Llangorse lake contain either reduced densities, a more random occurrence or a total absence of the species.

The genus *Daphnia* spp., has occurred in 13 of the lakes to date and there is some evidence that it shows a preference (in comparison to *Diaphanosoma* sp.) for more alkaline conditions, as is illustrated in the difference between the zooplankton communities of Llynnau Fach, Fan Fawr and Llech Owain and the other Phase III sites. Moreover, the data set suggests that, within the *Daphnia* genus, *D. galeata* is particularly sensitive to acidity.

4.7 Littoral macroinvertebrates

A list of the macroinvertebrate species found and their abundances are presented in the Appendices A-F Table 5. Llanbwchllyn was not sampled, due to reservoir draw-down making the normal littoral zone inaccessible. With the exception of Llyn y Fan Fawr the remaining Phase III sites contained reasonable abundances of macroinvertebrates. Both the total number of individuals and the minimum species richness increased in the following sequence: Llyn y Fan Fawr, Llyn Fach, Llyn Llech Owain, Kenfig Pool, Llangorse Lake.

Low numbers were recorded for Llyn y Fan Fawr which was also particularly species poor. Oligochaetes, the majority of which are deposit feeders, were the most numerously represented group at this site. The evidence suggests that this lake is nutrient poor and it is likely that the littoral food web is based on fine detritus and/or attached algae. No leeches were recorded from this lake and, with the exception of the mollusc *Ancylus fluviatilis*, the only other taxa represented were insects. The caddisfly larva *Polycentropus flavomaculatus* and the cased caddis fly larva *Sericostoma personatum* are associated with lakes with a stony substratum. One further reason for the the low abundance of macroinvertebrates at this site may be the insuitable nature of the habitat, the surveyed stretch composed largely of loose and not readily colonizable gravel. Much of the shoreline of this site is composed of large boulders which are impossible to sample adequately using conventional kick sampling techniques.

Macroinvertebrates in the littoral samples from Llyn Fach were reasonably abundant, but as for Llyn y Fan Fawr, most were oligochaetes. No leeches or molluscs were recorded for this lake and, with the exception of Hydracarina, all other species were insects, including such predators as the larva of Odonata and Megaloptera. The domination of the macroinvertebrate fauna by insect taxa is

characteristic of relatively nutrient poor lakes.

Llyn Llech Owain was similarly dominated by insect taxa. The most numerous taxon was the mayfly species *Leptophlebia* sp., which feeds on periphyton and detritus and in silty habitats between stones. Other species which feed on periphyton and / or detritus and which were recorded in low numbers from this lake included the caddisflies *Agrypnia* spp., caenid mayflies and *Pisidium* sp.. The alderfly larva *Sialis lutaria* is an active predator with biting mouthparts and is usually found where there is an abundance of silt. No molluscs were found, which perhaps reflects the acid nature of the site. Other evidence for low pH may be derived from the poorly decomposed terrestrial leaf litter which was collected in all samples.

Macroinvertebrates were more abundant in Kenfig Pool; the most numerous taxon being caenid mayflies which inhabit areas of silt between stones and feed on periphyton and detritus. Other groups and taxa which were relatively abundant included Oligochaetes, *Pisidium* spp. and predatory triclads. In addition the samples from Kenfig Pool contained several taxa which had not been found at the sites mentioned above. These included the Tricladida, gastropod molluscs, Malacostraca and Lepidoptera, while the leech *Helobdella stagnalis* was more abundant than in Llyn Llech Owain. The species assemblage is indicative of a less acid, more nutrient rich site than those mentioned above.

The greatest number of invertebrates and the highest minimum species richness were found in samples from Llangorse Lake. Oligochaetes were the most numerous group, but there was also a diverse assemblage of molluscs, leeches, Malacostraca and insects. This assemblage of species is characteristic of productive lakes. The molluscs graze periphyton and *Asellus aquaticus* (the second most numerous taxon) is a shredder of vegetative material and a detritivore. Of the leeches, *Helobdella stagnalis* and *Glossiphonia* spp. are predators on other macroinvertebrates such as molluscs, insects and worms, while *Theromyzon tessulatum* and *Piscicola geometra* are parasitic on birds and fish respectively. When not attached to its host, *P. geometra* lives free among water plants. Lepidoptera, which are relatively abundant in samples from this lake, are also associated with water plants.

Hemiptera were found in four of the lakes sampled. Although present in the samples in numbers too low for any conclusions to be drawn, some interesting observations were made concerning this group. The following species-environment relationships are drawn from the work of Savage (1989). *Sigara scotti* occurs most frequently in waters of less than 100 $\mu S\ cm^{-1}$ conductivity, pH less than 6.0 and often in habitats containing little organic matter or plant cover. *Sigara distincta and S. dorsalis*, on the other hand, most frequently occur at conductivities of between 100 - 1000 $\mu S\ cm^{-1}$ and appear to require more abundant organic matter or plant cover. *S. distincta* is usually only found where the pH is greater than 6.0, although *S. dorsalis* occurs over a wider pH range. In this survey *Sigara scotti* was the only Hemipteran species recorded in Llyn Fach and Llyn Llech Owain and was not recorded at any other site. *S. distincta* and *S. dorsalis* were only found in samples from Kenfig Pool. *Corixa dentipes*, *C. punctata* and *S. falleni* were only present in samples from Llangorse Lake. *C. punctata* has a requirement for relatively high quantities of organic matter and plant cover and is usually found at sites with conductivities between 100 - 1000 $\mu S\ cm^{-1}$ and a pH greater than 6.0. *S. falleni* is also most usually found in the 100 - 1000 $\mu S\ cm^{-1}$ conductivity range, and although ocassionally occuring above this has not been recorded below 100$\mu S\ cm^{-1}$. Similarly, it has never been recorded from waters of less than pH 6.0. *C. dentipes* appears to have a more cosmopolitan distribution. Generally therefore, the distribution patterns of these species in the

current study appear to be consistent with those of previous studies reviewed by Savage.

In the Phase II report, the lakes were tentatively classified in four groups based on their invertebrate fauna and species richness (species richness values in square brackets):

1. upland, relatively species poor lakes [12 -19]
2 lakes with intermediate species richness, but no Malacostraca [26, 28]
3 lakes with intermediate species richness, dominated by Malacostraca [32]
4 lakes with very high species richness [49 (30)]

It is possible to fit the Phase III lakes into the same categories with varying success:

Llyn y Fan Fawr is an upland lake which fits Category 1 but with lower species richness [6] than any of those in the previous study. Llyn Fach [12] and Llyn Llech Owain [15] also meet the requirements for Category 1. Kenfig Pool [19] is a lowland site and contained some Malacostraca, but was relatively species poor and therefore fits the system poorly. Llangorse Lake fits Category 3 reasonably although Malacostraca were only the second most dominant taxon (after the Oligochaeta). Further development of classification systems will proceed following the collection of data or the remaining 9 sites in this project

5 Summary and discussion

The six South Wales lakes studied in this phase of the Integrated Classification and Assessment of Lakes project display a diverse range of physical, chemical and biological characteristics.

Preliminary analysis of the water chemistry data show Llyn Fach and Llyn y Fan Fawr to be nutrient poor, slightly acid sites. However, these sites are physically very different in terms of underlying geology, morphometry, land-use etc., and despite having similar catchment areas the latter is approximately 20 times greater in volume and thus has a considerably greater residence time. These two sites also have distinctly differing biologies, and although *Isoetes lacustris* is a common macrophyte to both, and both are characterised by an oligochaete and chironomid dominated invertebrate fauna, Llyn Fach demonstrates markedly greater species richness and abundance. Llyn Llech Owain is significantly more acid than the two sites mentioned above, and so heavily influenced by catchment peat that its photic zone is negligible. The high levels of phosphorus and chlorophyll *a* measured at this site are difficult to explain and further investigation is necessary before confidence can be placed on an assessment of its trophic status.

Despite major differences in location and underlying geology there are certain similarities in the water chemistry of Llangorse Lake, Llanbwchllyn and Kenfig Pool. All three sites are strongly alkaline (in the context of the 21 sites surveyed to date they are comparable in this respect with the 3 Anglesey sites only) and have similar base cation status and water transparency. Importantly, however Llangorse Lake exhibits notably higher levels of phosphorus, while both Llangorse Lake and Llanbwchllyn show seasonally higher levels of Nitrate. Physically, these sites have little in

Table 5.1 Site classifications based on existing schemes

Classification scheme	Kenfig	Owain	Fach	Llanbwchllyn	Llangorse	Fan Fawr
Thermal mixing (Lewis 1983)	continuous warm polymictic	continuous warm polymictic	discontinuous warm polymictic	warm monomictic	warm monomictic	warm monomictic
Dillon and Rigler (1975)	Class III	Class IV	Class I	Class IV	Class IV	Class II
OECD (1982)	eutrophic	eutrophic	oligotrophic	eutrophic	hyper-eutrophic	mesotrophic
UKAWRG (1989)	never acid	permanently acid	never acid	never acid	never acid	never acid
Critical load for total acidity (Henriksen model) (keq H^+ ha^{-1} yr^{-1})	29.4	1.4	4.1	18.5	34.0	2.3
Critical load exceedance for total acidity (Henriksen model) (keq H^+ ha^{-1} yr^{-1})	not exceeded	not exceeded	not exceeded	not exceeded	not exceeded	not exceeded
Critical load for total acidity (diatom model) (keq H^+ ha^{-1} yr^{-1})	28.6	1.2	0.9	20.8	33.0	1.7
Critical load exceedance for total acidity (Diatom model) (keq H^+ ha^{-1} yr^{-1})	not exceeded	not exceeded	0.7	not exceeded	not exceeded	not exceeded
Palmer *et al.* (1992) Site type	10A	2	2	5A	10A	3
Category	eutrophic	oligotrophic	oligotrophic	mesotrophic	eutrophic	oligotrophic
Trophic Ranking Score	8.39	5.61	5.18	7.78	8.36	6.0
National Vegetation Classification (Rodwell 1995) Community types	A5,A10,S4,S20	A8,S9	A23,S9,S10, S19	A7,A8,A10	A5,A7,A8,A10,A11,A12,S4,S20,S23	A22

common: for example, the surface area and lake volume of Llangorse Lake is an order of magnitude greater than the other two; the fluctuating water levels of Llanbwchllyn, resulting from reservoir management has had a serious impact on shoreline macrophyte development; and Kenfig Pool is unusual in that it is a coastal site lying within a sand dune system. Biologically the sites show some similarities, for example in the representation of epilithic diatom taxa and locally dominant patches of *Phragmites* swamp and floating leaved stands of *Polyganum amphibium*. However the littoral cladoceran and open water zooplankton communities differ distinctly, Kenfig Pool showing the greatest diversity. Llangorse Lake is richest in aquatic macrophyte taxa and this is at least in part a reflection of the large habitat diversity of this large lake. Interestingly, Llangorse Lake also demonstrates a particularly diverse macroinvertebrate community per length of shoreline (all macroinvertebrate surveys are conducted over the same length of shoreline).

There is documentary evidence that Llangorse Lake and Llanbwchllyn have both experienced recent, anthropogenically driven environmental change which has impacted on their biology, and most notably on their aquatic macrophyte flora. Species abundance and habitat diversity have been deleteriously affected by reservoir management at Llanbwchllyn, while there is botanical evidence that there has been some recent recovery towards pre- nutrient enrichment conditions at Llangorse Lake, following the cessation of partly treated sewage influx at the site.

Application of existing classification schemes, reviewed in the Phase I report, to the Phase III sites (see Table 5.1) produces a variety of groupings some of which are surprising. The thermal mixing scheme of Lewis (1983) which groups sites according to the extent of ice cover and duration of thermal stratification, is largely dependent on lake depth, since seasonal ice cover can be ruled out as a factor. This results in the unlikely groupings of Llyn y Fan Fawr with Llangorse Lake and Llanbwchllyn as warm monomictic sites and Kenfig Pool and Llyn Llech Owain as continuous warm polymictic sites.

The Dillon and Rigler system which is based solely on summer chlorophyll *a* levels classes Llyn Fach as Class I, Llyn y Fan Fawr as Class II, Kenfig Pool as Class III and Llangorse Lake and Llanbwchllyn as Class IV. The classification of Llyn Llech Owain as Class IV must be treated with caution given doubts over the representivity of the data for this site.

The OECD trophic scheme, which classifies sites by their chlorophyll *a* and phosphorus levels, also produces some unexpected classifications. Although Llyn Fach falls easily into the oligotrophic category, Llyn y Fan Fawr, which appears to be relatively biologically unproductive, is classed mesotrophic, on the basis of slightly elevated chlorophyll *a* and phosphorus levels, and a secchi disc depth of only 4.5m. Kenfig Pool and Llanbwchllyn are both classed as eutrophic and Llangorse Lake hyper-eutrophic on the basis of secchi depth and phosphorus level, but only eutrophic according to chlorophyll *a* concentration. Llyn Llech Owain seems to be mis-classified as a eutrophic site for reasons already discussed.

Application of the United Kingdom Acid Waters Review Group scheme, designed to enable the classification of waters susceptible to acidification, classes all sites other than Llyn Llech Owain as "never acid" while the latter is "permanently acid". The Henriksen Critical Loads model predicts that no site is exceeded for total acidity while the Diatom Critical Loads model predicts that Llyn Fach is an exception, being slightly exceeded.

The aquatic macrophyte typing scheme of Palmer (1992) classes Llyn Llech Owain, Llyn Fach and

Llyn y Fan Fawr as oligotrophic lakes. The scheme successfully distinguishes between the former two as Type 2 (sites with peat dominated substrate) and the latter as Type 3 (sites with boulder dominated substrate). Llyn Llech Owain would have been classed as Type I (the dystrophic category) which is probably more appropriate, had it not been for one record of *Littorella uniflora.* Despite its moderate nutrient status, Kenfig Pool is classed with Llangorse Lake as Type 10A (a lowland eutrophic category with well developed submergent communities) while Llanbwchllyn is classed as Type 5A (an uncommon, mesotrophic category). Of the six sites Llangorse Lake contains by far the highest number of NVC defined aquatic and swamp community types, while Llyn y Fan Fawr is clearly the most impoverished.

A comprehensive chemical, physical and biological data-set has now been compiled for 21 Welsh lakes in this project and data for a final group of nine lakes are currently being collected. Analytical techniques discussed in the Phase I report, will be applied to a full data-set of 30 lakes during 1997.

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Appendix A Data Tables and Figures: Kenfig Pool

Table A.1 Kenfig Pool water chemistry

Determinand		Sample				
		5-7-95	25-9-95	31-1-96	16-4-96	mean
lab pH		7.67	8.07	7.88	8.14	7.90
field pH		8.43	----	7.97	7.28	----
Alkalinity 1	$\mu eq\ l^{-1}$	1990	1746	2270	2311	2079
Alkalinity 2	$\mu eq\ l^{-1}$	2011	1763	2296	2353	2106
lab Conductivity	$\mu S\ cm^{-1}$	339	315	360	365	345
field conductivity	$\mu S\ cm^{-1}$	365	----	280	370	----
Sodium	$\mu eq\ l^{-1}$	1024	1087	898	847	964
Potassium	$\mu eq\ l^{-1}$	55	52	60	57	56
Magnesium	$\mu eq\ l^{-1}$	390	381	398	379	387
Calcium	$\mu eq\ l^{-1}$	2074	1751	2629	2663	2279
Chloride	$\mu eq\ l^{-1}$	1116	1204	975	936	1058
Aluminium total monomeric	$\mu g\ l^{-1}$	2	13	4	4	6
Aluminium non-labile	$\mu g\ l^{-1}$	0	13	3	4	5
Aluminium labile	$\mu g\ l^{-1}$	2	0	1	0	1
Absorbance	(250nm)	0.121	0.128	0.120	0.130	0.125
Carbon total organic	$mg\ l^{-1}$	5.9	6.9	6	5.7	6.1
Phosphorus total	$\mu gP\ l^{-1}$	35.2	37.8	33	21	32
Phosphorus total soluble	$\mu gP\ l^{-1}$	15.4	10.9	13.7	15.2	13.8
Phosphorus soluble reactive	$\mu gP\ l^{-1}$	5.6	4.7	5.3	7.6	5.8
Nitrate	$\mu gN\ l^{-1}$	52	<10	215	71	86
Silica soluble reactive	$mg\ l^{-1}$	1.47	0.68	0.39	0.22	0.69
Chlorophyll a	$\mu g\ l^{-1}$	7.2	15.9	13.1	17.8	13.5
Sulphate	$\mu eq\ l^{-1}$	200	161	261	266	222
Copper total soluble	$\mu g\ l^{-1}$	0	0	0	0	0
Iron total soluble	$\mu g\ l^{-1}$	70	70	33	7	45
Lead total soluble	$\mu g\ l^{-1}$	0	0	0	0	0
Manganese total soluble	$\mu g\ l^{-1}$	0	0	31	9	10
Zinc	$\mu g\ l^{-1}$	0	0	0	0	0

Table A.2a Kenfig Pool epilithic diatom taxon list (including taxa >1.0%)

Taxon	Relative frequency (%)
Achnanthes lanceolata	5.6
Achnanthes clevei	3.2
Achnanthes minutissima	18.1
Achnanthes minuscula	1.4
Amphora pediculus	16.3
Cymbella microcephala	7.3
Cocconeis thumensis	6.2
Epithemia sorex	9.3
Fragilaria intermedia	2.9
Navicula cryptotenella	14.4
Nitzschia fonticola	1.2

Table A.2b Kenfig Pool epiphytic diatom taxon list (including taxa >1.0%)

Taxon	Relative frequency (%)
Achnanthes minutissima	23.1
Cymbella microcephala	1.7
Cocconeis placentula	3.9
Cocconeis pediculus	1.4
Epithemia sorex	3.3
Fragilaria intermedia	52.2
Gomphonema angustatum	1.1
Navicula cryptotenella	5.7

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

Taxon	Relative frequency (%)
Achnanthes lanceolata	1.4
Achnanthes minutissima	12.4
Amphora pediculus	11.3
Asterionella formosa	3.5
Cocconeis placentula	3.9
Cocconeis thumensis	3.5
Cymbella microcephala	1.8
Epithemia adnata	1.4
Fragilaria construens var. *venter*	3.2
Fragilaria intermedia	2.8
Fragilaria pinnata	17.0
Gomphonema minutum	1.4
Gyrosigma acuminatum	1.8
Navicula cryptocephala	1.4
Navicula cryptotenella	5.3
Navicula gregaria	3.5
Navicula porifera	1.1
Navicula pupula	1.1
Navicula radiosa	1.4
Navicula rhyncocephala	2.5
Nitzschia dissipata	2.1
Nitzschia recta	2.1
Stephanodiscus hantzschii	2.1

Table A.4 Kenfig Pool aquatic macrophyte abundance summary: 5-7-95

Taxon	code	Abun
Emergent taxa		
Caltha palustris	361201	F
Oenanthe fistulosa *	365803	R
Scirpus maritimus	384505	O
Scirpus lacustris spp. tabernaemontani *	384504	F
Equisetum palustre	350299	O
Hydrocotyle vulgaris	363401	F
Mentha aquatica	364601	O
Alisma plantago-aquatica	380303	F
Baldellia ranunculoides	380601	R
Eleocharis palustris	382004	O
Iris pseudacorus	382901	O
Phragmites australis	383801	A
Floating leaved taxa		
Polyganum amphibium	366501	O
Submergent taxa		
Chara aspera var. *aspera* **	220000	F
Nitella flexilis var. *flexilis*	220000	O
Ceratophyllum demersum *	361401	O
Littorella uniflora	363901	F
Myriophyllum spicatum *	365403	O
Ranunculus circinatus *	366970	F
Potamogeton crispus *	384006	O
Potamogeton lucens *	384011	O
Potamogeton pectinatus	384015	R
Potamogeton trichoides *	384021	A

* = taxon regionally rare for NRA Welsh Region
** = nationally scarce taxon

Table A.5 Kenfig Pool littoral Cladocera taxon list: 5-7-95

Taxa	Sample number				
	1	2	3	4	5
Acroperus harpae		15		46	9
Alona affinis	1	4		4	
Alona costata	2	1	13	63	1
Ceriodaphnia pulchella	11	37	30	11	
Chydorus sphaericus				6	1
Daphnia longispina			9	4	
Eurycercus lamellatus	1	14	19	39	
Monospilus dispar	s				s
Pleuroxus aduncus			9	39	5
Pleuroxus denticulatus			1		
Rhynchotalona falcata				2	
Scapholeberis mucronata			128	5	
Simocephalus vetulus		7		13	30
Total Count	15	78	209	232	46

s = shell fragment only

Table A.6 Kenfig Pool zooplankton abundance summary: 5-7-95 Abundance in vertical net hauls (number of individuals 0.01 m^{-2})

Taxon	Abun
Ceriodaphnia pulchella	10
Daphnia galeata	x
Simocephalus vetulus	X
Bosmina longirostris	X
Acroperus harpae	X
Chydorus sphaericus	X
Pleuroxus aduncus	X
Eudiaptomus gracilis	10
Macrocyclops albidus	X
Eucyclops macruroides	X
Other planktonic organisms (not quantitatively sampled)	
Volvox sp.	
Asplanchna sp.	
Kellicottia longispina	
Filinia sp.	
Keratella cochlearis	
Euchlanis triquetra	

X = rare species with relative abundance < 1%
x = rare species recorded only at one of two investigated sites

Table A.7 Kenfig Pool zooplankton characteristics

Site depth (m)	2.1
Total zooplankton biomass (g DW m^{-2})	0.02
Net algal biomass (g DW m^{-2})	0.01
Cladoceran biomass as proportion of total zooplankton biomass (%)	~20
Large cladoceran (>710µm) as proportion of total zooplankton biomass (%)	0
Large Copepoda (>420µm) as proportion of total zooplankton biomass (%)	0

Table A.8 Kenfig Pool littoral macroinvertebrate summary. Mean number of individuals per one minute kick/sweep sample.

code	Taxon	mean count / sample
	TURBELLARIA	
03120000	Tricladida	239.6
	MOLLUSCA	
13070107	*Lymnaea peregra*	3.6
	BIVALVIA	
14030200	*Pisidium* sp.	181.6
16000000	OLIGOCHAETA	232.4
	HIRUDINEA	
17020501	*Helobdella stagnalis*	15.6
19000000	HYDRACARINA	1.6
	MALACOSTRACA	
28030104	*Asellus meridianus*	36
	EPHEMEROPTERA	
30020000	Baetidae	1.2
30020302	*Cloeon simile*	2.4
30080206	*Caenis luctuosa*	494
	ODONATA	
32020000	Coenagriidae species - immatures	2
32020301	*Enallagma cyathigerum*	0.4
32090000	Libellulidae species - immatures	0.4
	HEMIPTERA	
33110801	*Sigara dorsalis*	0.8
33110803	*Sigara distincta*	0.4
	COLEOPTERA	
35010000	Haliplidae species - larvae	7.6
35110600	*Oulimnius* sp.	2
39000000	LEPIDOPTERA	0.8
40080000	CERATOPOGONIDAE	2.8
40090000	CHIRONOMIDAE	168.4

Figure A.1 Kenfig Pool: sample location and substrate map

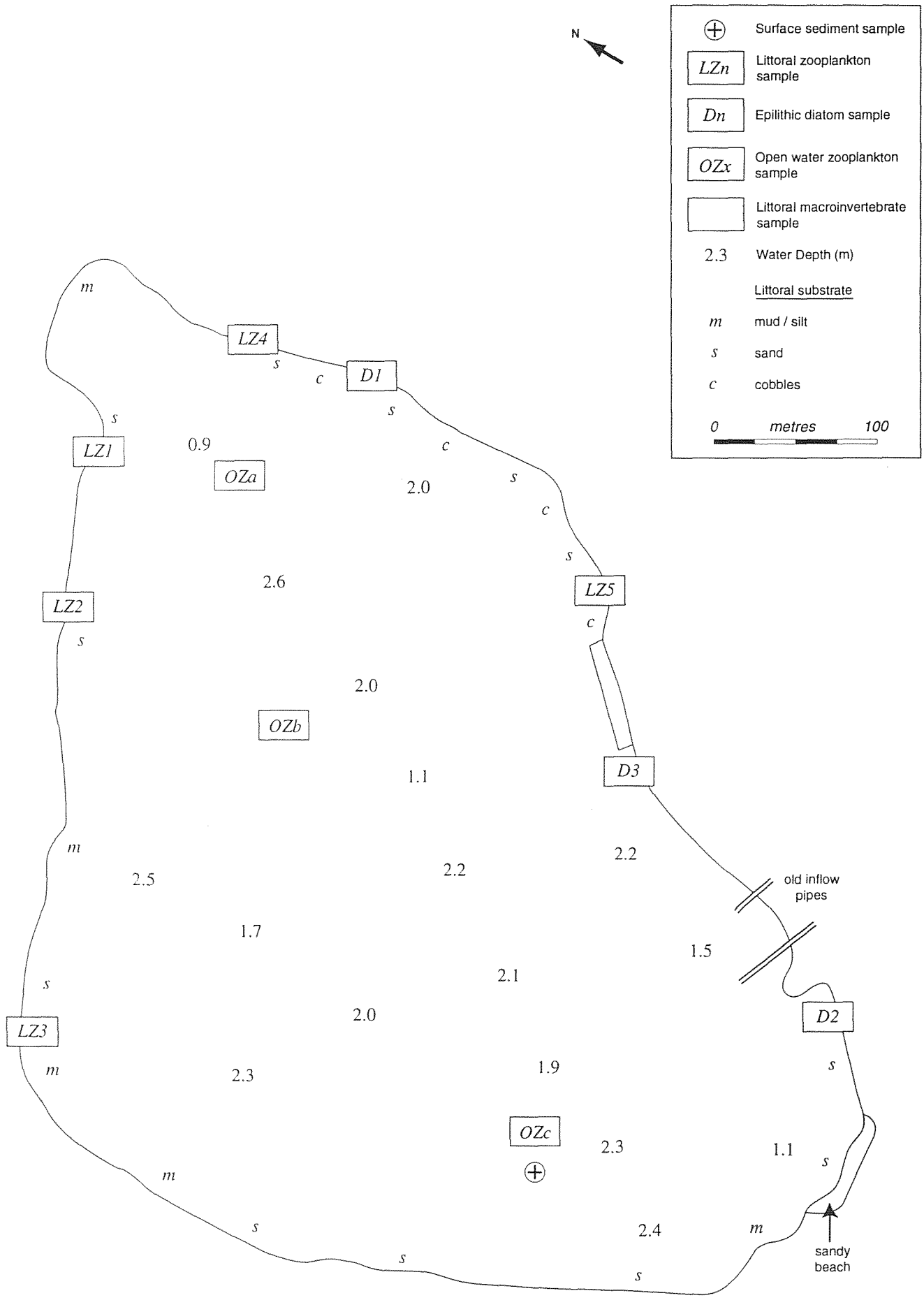


Figure A.2 Kenfig Pool: aquatic macrophyte distribution map 5-7-95

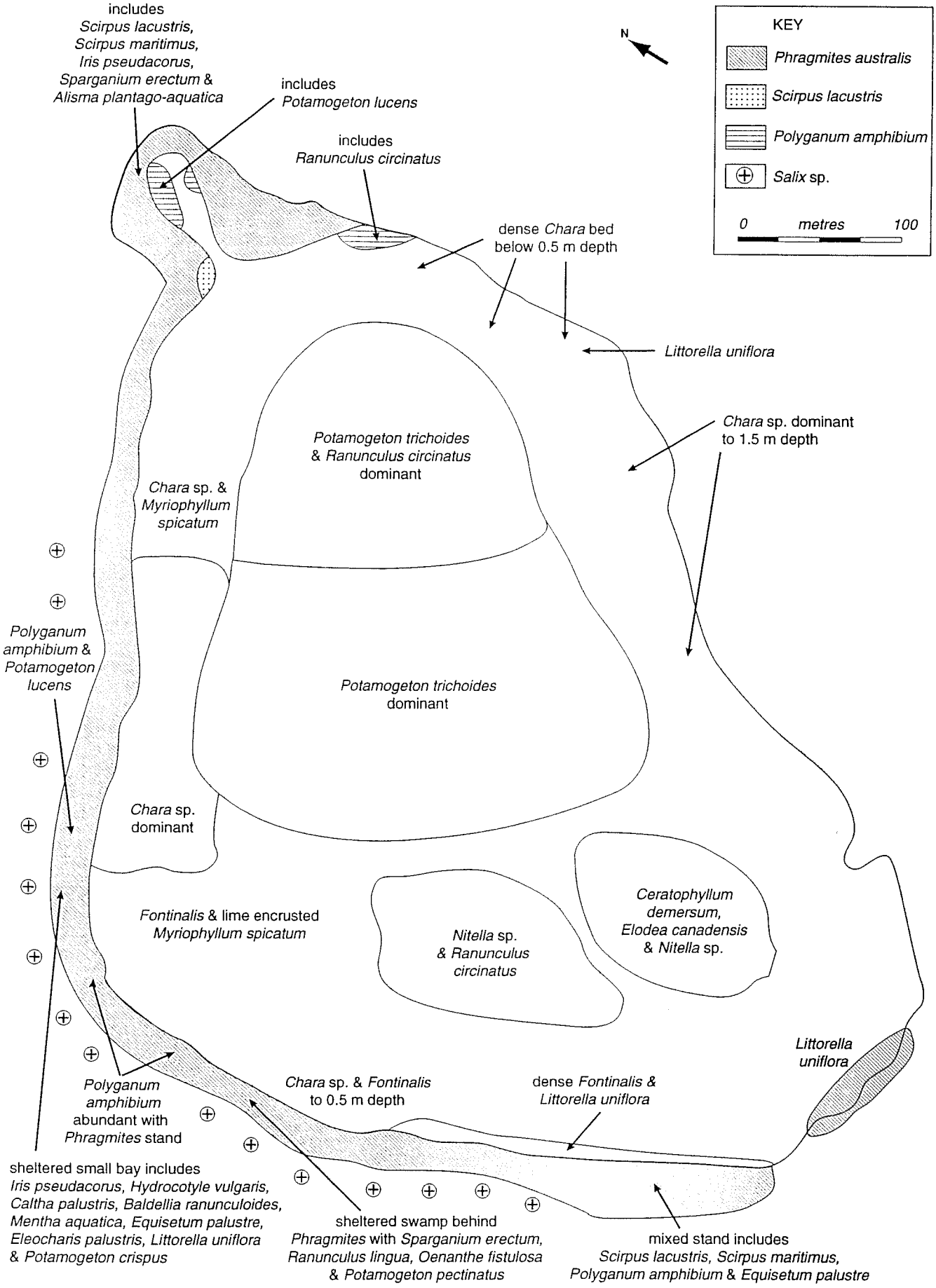
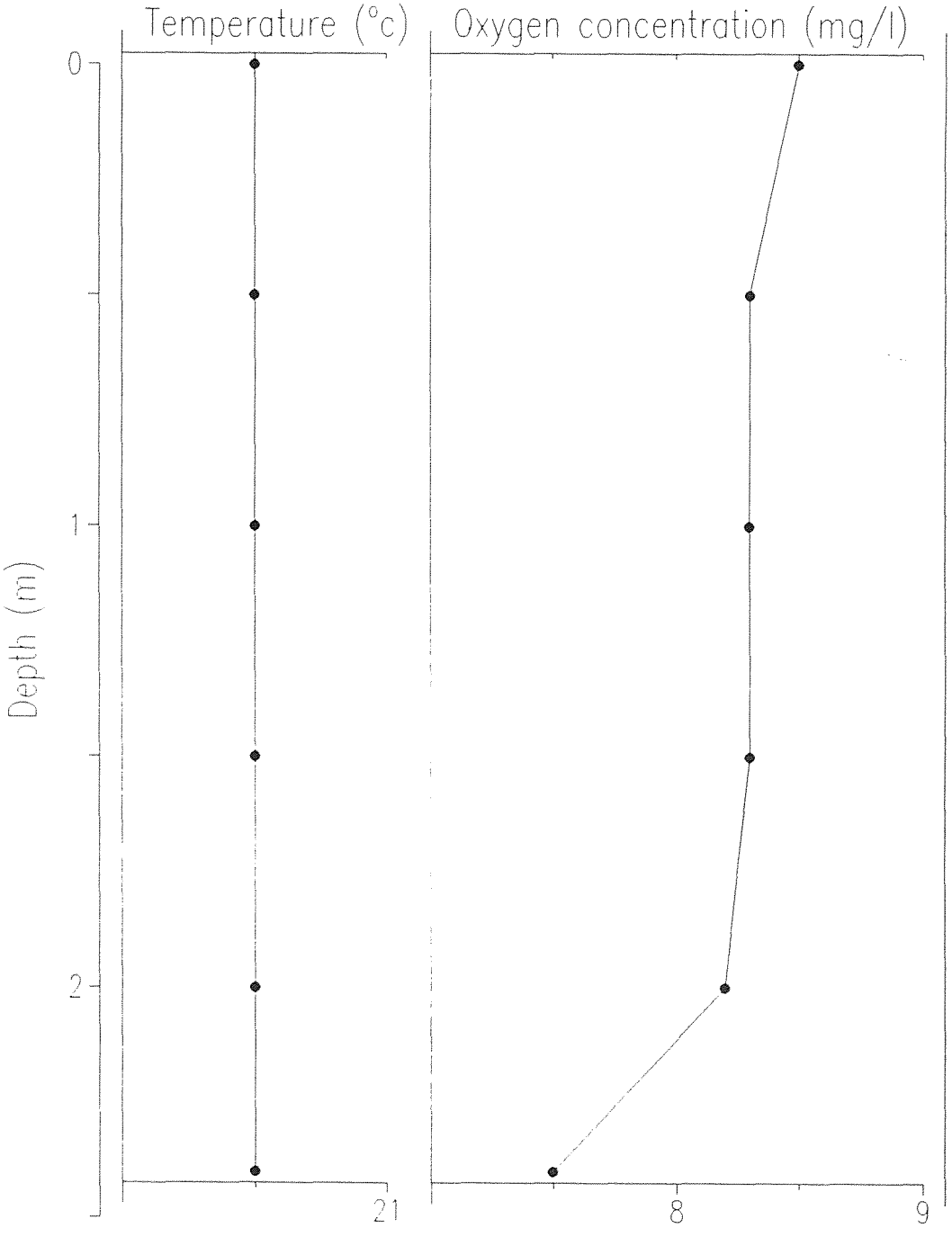


Figure A.4 Kenfig Pool: Temperature and dissolved oxygen profiles 5-7-95



Appendix B Data Tables and Figures: Llyn Llech Owain

Table B.1 Llyn Llech Owain water chemistry

Determinand		Sample				
		12-7-95	25-9-95	30-1-96	16-4-96	mean
lab pH		5.10	4.98	4.87	4.90	4.95
field pH		----	----	4.76	4.83	----
Alkalinity 1	$\mu eq\ l^{-1}$	5	-11	-13	-13	-8
Alkalinity 2	$\mu eq\ l^{-1}$	-4	-8	-6	-13	-8
lab Conductivity	$\mu S\ cm^{-1}$	78	80	81	71	78
field conductivity	$\mu S\ cm^{-1}$	----	----	72	90	----
Sodium	$\mu eq\ l^{-1}$	359	382	309	273	331
Potassium	$\mu eq\ l^{-1}$	10	8	10	11	10
Magnesium	$\mu eq\ l^{-1}$	80	82	92	83	84
Calcium	$\mu eq\ l^{-1}$	189	175	196	171	183
Chloride	$\mu eq\ l^{-1}$	449	478	335	286	387
Aluminium total monomeric	$\mu g\ l^{-1}$	79	11	124	99	78.3
Aluminium non-labile	$\mu g\ l^{-1}$	67	11	79	71	57
Aluminium labile	$\mu g\ l^{-1}$	12	0	45	28	21
Absorbance	(250nm)	0.490	0.338	0.52	0.440	0.447
Carbon total organic	$mg\ l^{-1}$	8.1	7	10	8.7	8.5
Phosphorus total	$\mu gP\ l^{-1}$	55.4	64.5	42.0	30.0	48.0
Phosphorus total soluble	$\mu gP\ l^{-1}$	17.2	*	14.7	9.4	13.8
Phosphorus soluble reactive	$\mu gP\ l^{-1}$	12.5	*	10.5	8.3	10.4
Nitrate	$\mu gN\ l^{-1}$	15	16	188	175	99
Silica soluble reactive	$mg\ l^{-1}$	1.44	3.38	2.39	1.75	2.24
Chlorophyll a	$\mu g\ l^{-1}$	65.2	33.6	33.7	19.9	38.1
Sulphate	$\mu eq\ l^{-1}$	140	151	229	221	185
Copper total soluble	$\mu g\ l^{-1}$	0	0	0	0	0
Iron total soluble	$\mu g\ l^{-1}$	750	125	48	39	241
Lead total soluble	$\mu g\ l^{-1}$	0	0	2	0	1
Manganese total soluble	$\mu g\ l^{-1}$	25	41	45	35	37
Zinc total soluble	$\mu g\ l^{-1}$	13	10	18	16	14

* = data failed quality control procedure

Table B.2 Llyn Llech Owain epilithic diatom taxon list (including taxa >1.0%)

TAXON	Relative frequency (%)
Achnanthes austriaca var. *minor*	3.9
Achnanthes austriaca var. *helvetica*	3.2
Achnanthes altaica	9.1
Cymbella perpusilla	2.6
Eunotia rhomboidea	12.5
Eunotia incisa	32.2
Eunotia minutissima	2.2
Eunotia [*vanheurckii* var. *intermedia*]	1.0
Eunotia sp.	1.0
Fragilaria [cf. *oldenburgiana*]	6.5
Frustulia rhomboides var. *saxonica*	6.9
Frustulia rhomboides var. *viridula*	3.0
Neidium densestriatum	1.6
Tabellaria flocculosa	2.2

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

Taxon	Relative frequency (%)
Cymbella perpusilla	13.0
Eunotia incisa	25.0
Eunotia rhomboidea	3.2
Eunotia sp.	1.3
Eunotia vanheurckii var. *intermedia*	1.3
Fragilaria [cf. *oldenburgiana*]	3.2
Frustulia rhomboides var. *saxonica*	6.9
Navicula difficillima	5.0
Navicula hassiaca	1.9
Navicula minima	1.5
Navicula soehrensis	8.7
Navicula sp.	1.1
Navicula [sp. 1]	6.3
Nitzschia angustata var. *acuta*	1.5
Pinnularia irrorata	3.0
Surirella delicatissima	1.3
Tabellaria flocculosa	4.5

Table B.4 Llyn Llech Owain aquatic macrophyte abundance summary: 12-7-95

Taxon	code	Abun
Emergent taxa		
Equisetum fluviatile	350202	F
Hydrocotyle vulgaris	363401	O
Menyanthes trifoliata	364701	O
Carex rostrata	381129	F
Eleocharis palustris	382004	O
Floating leaved taxa		
Nuphar lutea	365501	A
Nymphaea alba	365601	F
Potamogeton polygonifolius	384017	R
Submergent taxa		
Sphagnum auriculatum	327401	O
Littorella uniflora	363901	R
Juncus bulbosus var. *fluitans*	383006	R
Fringing taxa		
Molinia caerulea		
Deschampsia cespitosa		
Eriophorum angustifolium		
Drosera rotundiflora		

* = taxon regionally rare for NRA Welsh Region

Table B.5 Llyn Llech Owain littoral Cladocera taxon list: 12-7-95

Taxa	Sample number				
	1	2	3	4	5
Acantholeberis curvirostris				1	
Alona affinis			+		
Alona guttata				1	2
Alona quadrangularis					1
Alona rustica		1	1		
Alonella excisa			1		3
Chydorus piger		+		+	2
Chydorus sphaericus	3	2	2	1	18
Diaphanosoma brachyurum	7	121	994	754	571
Graptoleberis testudinaria	1				
Monospilus dispar	3	1			
Pleuroxus truncatus		1	+	+	5
Rhynchotalona falcata	2				1
Total Count	16	126.	998	757	603

+ = taxon present

Table B.6 Llyn Llech Owain zooplankton abundance summary: 12-7-95 Abundance in vertical net hauls (number of individuals 0.01 m^{-2})

Taxon	Count
Diaphanosoma brachyurum	1200
Chydorus sphaericus	0.01
Eudiaptomus gracilis	1160
Macrocyclops albidus	0.01

Table B.7 Llyn Llech Owain zooplankton characteristics

Site depth (m)	1.5
Total zooplankton biomass (g DW m^{-2})	0.67
Net algal biomass (g DW m^{-2})	0
Cladoceran biomass as proportion of total zooplankton biomass (%)	44
Large cladoceran (>710µm) as proportion of total zooplankton biomass (%)	0
Large Copepoda (>420µm) as proportion of total zooplankton biomass (%)	1

Table B.8 Llyn Llech Owain littoral macroinvertebrate summary. Mean number of individuals per one minute kick/sweep sample.

code	Taxon	Mean count / sample
	BIVALVIA	
14030200	*Pisidium* sp.	181.6
16000000	OLIGOCHAETA	68.4
	HIRUDINEA	
17020501	*Helobdella stagnalis*	1.6
	EPHEMEROPTERA	
30040100	*Leptophlebia* sp.	122
30080206	*Caenis luctuosa*	1.2
	HEMIPTERA	
33110000	Corixidae sp.	5.2
33110807	*Sigara scotti*	0.4
	COLEOPTERA	
35030706	*Stictotarsus duodecimpustulatus*	0.4
35030905	*Hydroporus lepidus*	1.2
35110602	*Oulimnius troglodytes*	0.8
	MEGALOPTERA	
36010101	*Sialis lutaria*	2.8
	TRICHOPTERA	
38030402	*Holocentropus picicornis*	3.2
38070000	Phryganeidae	0.8
38070400	*Agrypnia* sp.	1.2
38120203	*Mystacides longicornis*	0.4
	DIPTERA	
40010000	Tipulidae	0.4
40080000	Ceratapogonidae	1.2
40090000	Chironomidae	51.2

Figure B.1 Llyn Llech Owain: sample location and substrate map

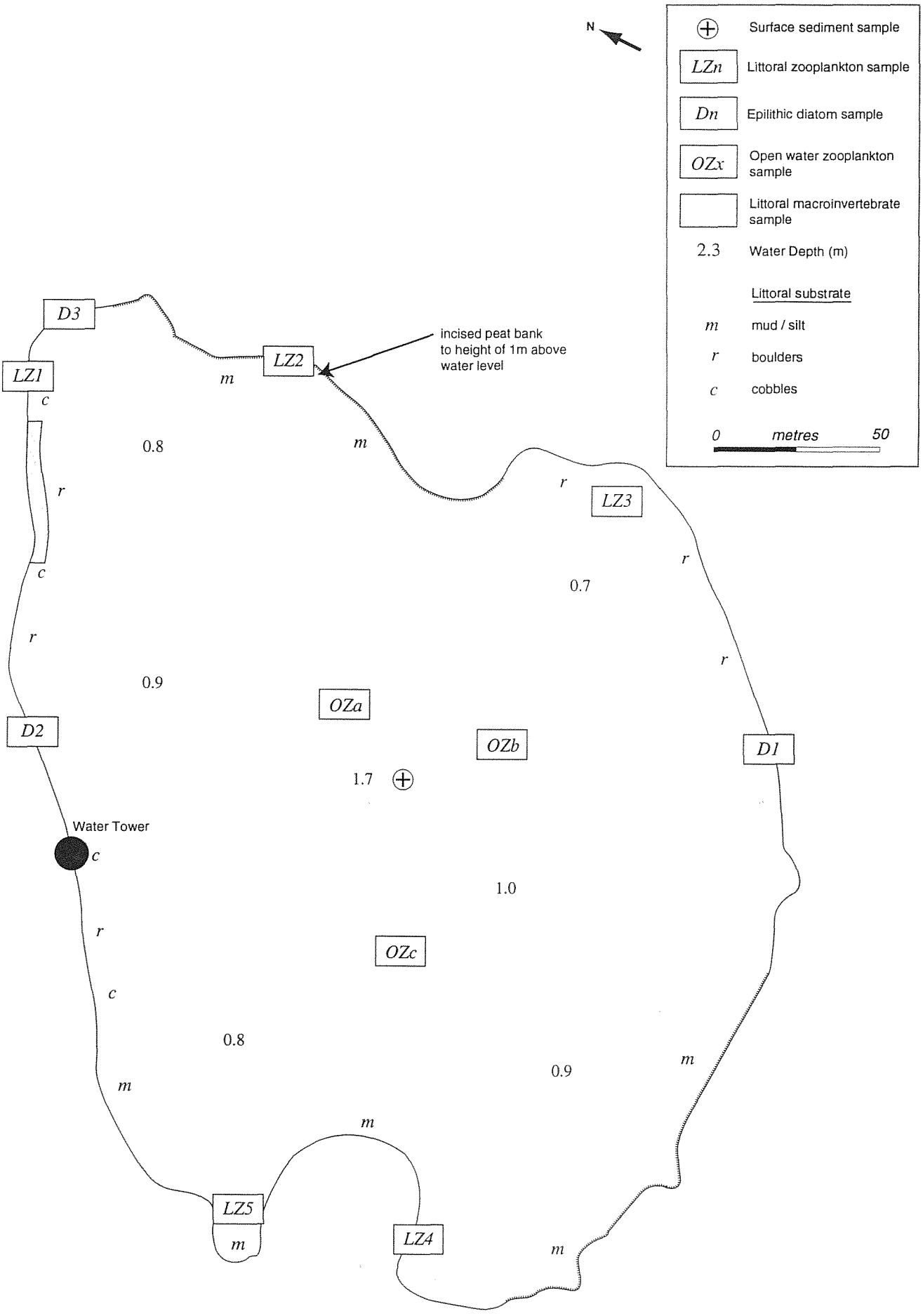


Figure B.2 Llyn Llech Owain: aquatic macrophyte distribution map 12-7-95

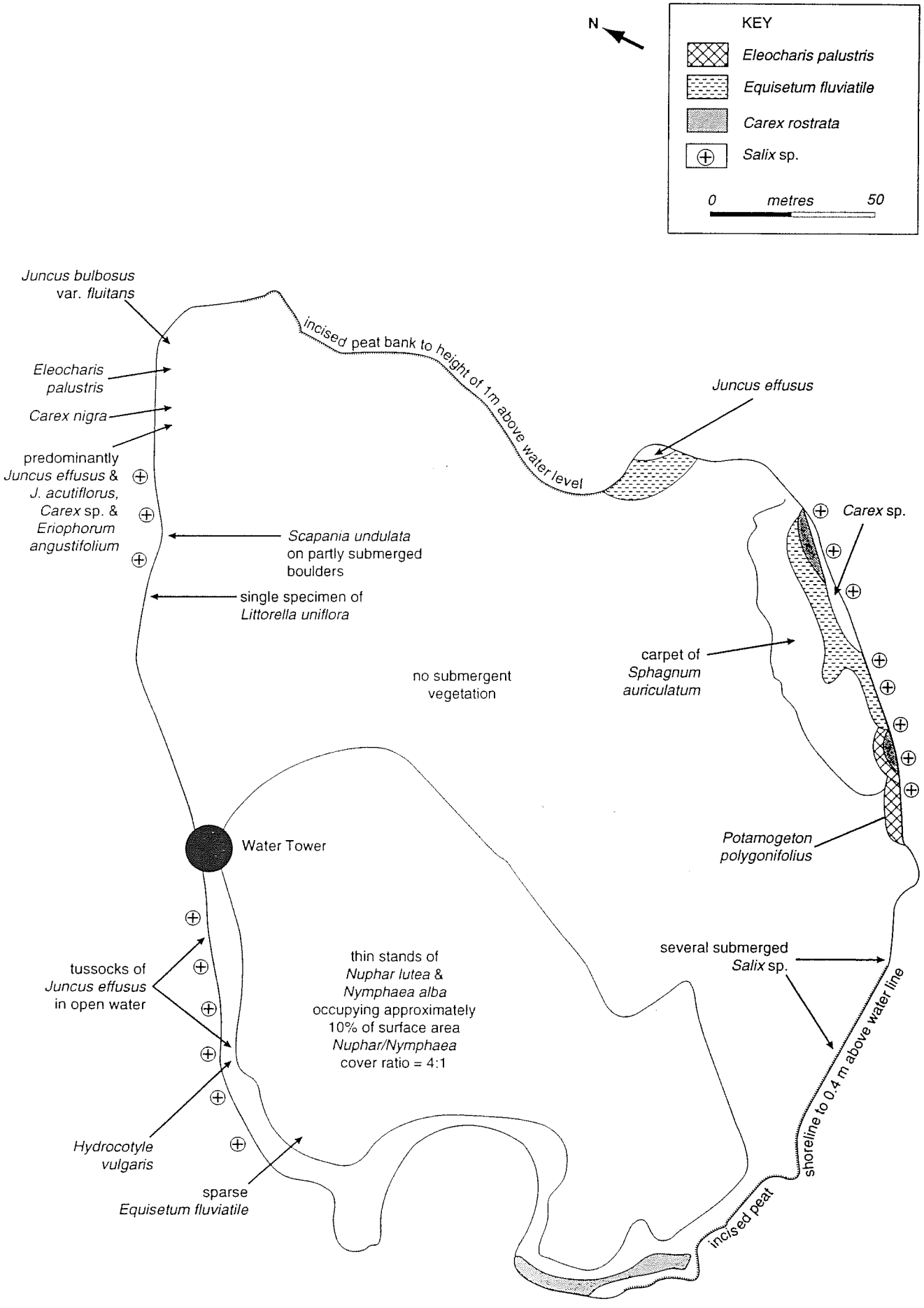
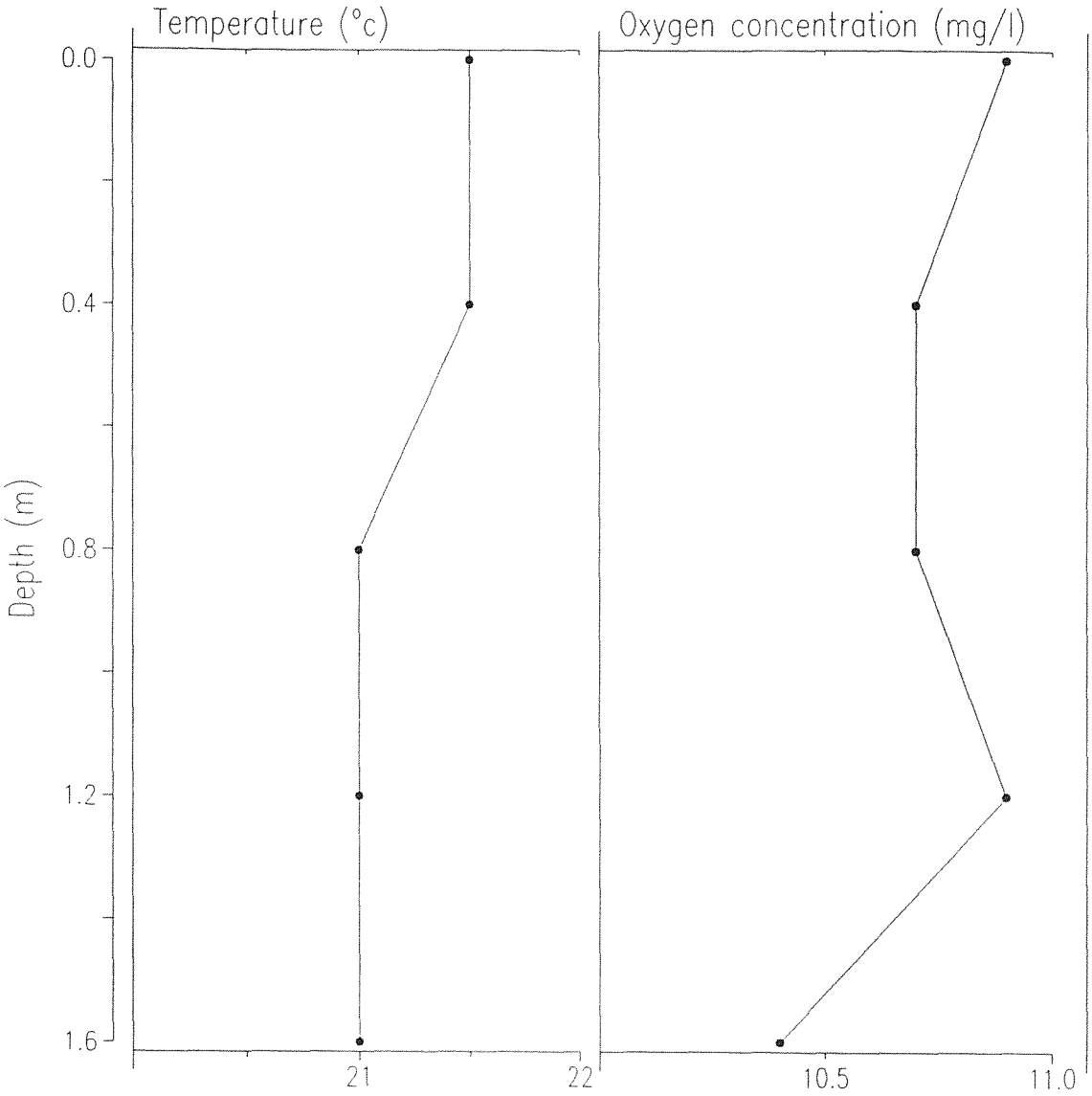


Figure B.4 Llyn Llech Owain: Temperature and dissolved oxygen profiles 12-7-95



Appendix C Data Tables and Figures: Llyn Fach

Table C.1 Llyn Fach water chemistry

Determinand		Sample				
		8-7-95	25-9-95	31-1-96	16-4-96	mean
lab pH		6.58	6.63	5.93	6.37	6.28
field pH		6.83	----	5.64	7.20	----
Alkalinity 1	$\mu eq\ l^{-1}$	88	107	129	70	99
Alkalinity 2	$\mu eq\ l^{-1}$	80	99	127	61	92
lab Conductivity	$\mu S\ cm^{-1}$	54	55	90	52	63
field conductivity	$\mu S\ cm^{-1}$	45	----	82	65	----
Sodium	$\mu eq\ l^{-1}$	183	182	238	154	189
Potassium	$\mu eq\ l^{-1}$	12	12	23	17	16
Magnesium	$\mu eq\ l^{-1}$	182	193	296	169	210
Calcium	$\mu eq\ l^{-1}$	137	139	241	119	159
Chloride	$\mu eq\ l^{-1}$	211	209	256	161	209
Aluminium total monomeric	$\mu g\ l^{-1}$	5	65	22	17	27
Aluminium non-labile	$\mu g\ l^{-1}$	4	50	11	15	20
Aluminium labile	$\mu g\ l^{-1}$	1	15	11	2	7
Absorbance	(250nm)	0.050	0.056	0.070	0.030	0.052
Carbon total organic	$mg\ l^{-1}$	3.2	3.4	2.6	1.4	2.7
Phosphorus total	$\mu gP\ l^{-1}$	8.7	7.1	13.4	8.9	9.5
Phosphorus total soluble	$\mu gP\ l^{-1}$	5.7	2.5	2.7	5.3	4.1
Phosphorus soluble reactive	$\mu gP\ l^{-1}$	2.2	1.4	2.5	3.4	2.4
Nitrate	$\mu gN\ l^{-1}$	16	10	171	265	116
Silica soluble reactive	$mg\ l^{-1}$	0.13	1.27	4.34	2.09	1.96
Chlorophyll a	$\mu g\ l^{-1}$	0.9	1.7	31.6	1.40	8.9
Sulphate	$\mu eq\ l^{-1}$	162	164	336	175	209
Copper total soluble	$\mu g\ l^{-1}$	0	0	0	0	0
Iron total soluble	$\mu g\ l^{-1}$	2	15	46	39	26
Lead total soluble	$\mu g\ l^{-1}$	0	0	0	0	0
Manganese total soluble	$\mu g\ l^{-1}$	0	0	47	35	21
Zinc total soluble	$\mu g\ l^{-1}$	0	0	8	16	6

Table C.2 Llyn Fach epilithic diatom taxon list (including taxa >1.0%)

Taxon	Relative frequency (%)
Achnanthes minutissima	6.5
Achnanthes marginulata	1.6
Achnanthes altaica	2.1
Brachysira vitrea	14.0
Brachysira brebissonii	7.8
Cymbella microcephala	12.8
Cymbella lunata	6.2
Fragilaria virescens var. *exigua*	17.6
Frustulia rhomboides var. *saxonica*	1.0
Navicula subtilissima	1.6
Navicula angusta	1.0
Nitzschia perminuta	11.6
Nitzschia frustulum	2.2
Peronia fibula	4.0

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

Taxon	Relative frequency (%)
Achnanthes minutissima	12.1
Brachysira vitrea	5.6
Cymbella lunata	1.2
Cymbella microcephala	3.0
Fragilaria virescens var. *exigua*	21.8
Navicula globosa	14.5
Navicula jaernefeltii	4.2
Navicula pupula	1.4
Navicula radiosa var. *tenella*	5.8
Navicula subrotundata	1.8
Nitzschia perminuta	1.6
Peronia fibula	3.2
Stauroneis anceps f. *gracilis*	1.2

Table C.4 Llyn Fach aquatic macrophyte abundance summary: 8-7-95

Taxon	code	Abun
Emergent taxa		
Lythrum portula	364599	R
Menyanthes trifoliata	364701	O
Eleocharis palustris	382004	O
Floating leaved taxa		
Potamogeton natans	384012	O
Potamogeton polygonifolius	384017	F
Sparganium angustifolium *	384601	F
Submergent taxa		
Nitella flexilis var. *flexilis*	220000	O
Sphagnum auriculatum	327401	A
Isoetes echinospora	350301	A
Lobelia dortmanna	364001	A
Myriophyllum alterniflorum	365401	O
Juncus bulbosus var. *fluitans*	383006	A
Potamogeton berchtoldii	384003	O
Scirpus fluitans	384502	F
Fringing taxa		
Juncus articulatus		
Juncus effusus		
Galium palustre		
Carex sp.		
Viola palustris		

* = taxon regionally rare for NRA Welsh Region

Table C.5 Llyn Fach littoral Cladocera taxon list: 8-7-95

Taxa	Sample number				
	1	2	3	4	5
Alona affinis			+	1	
Alonella excisa		7			+
Chydorus piger					1
Chydorus sphaericus			+	1	s
Diaphanosoma brachyurum		1		2	
Eubosmina longispina	45	182	278	22	2745
Graptoleberis testudinaria	1		s	6	
Monospilus dispar			s		
Sida crystallina	28	2	11	63	2
Total Count	74	192	289	95	2748

s = shell fragment

Table C.6 Llyn Fach zooplankton abundance summary: 8-7-95 Abundance in vertical net hauls (number of individuals 0.01 m^{-2})

Taxon	Count
Diaphanosoma brachyurum	130
Ceriodaphnia quadrangula	X
Eubosmina longispina	1100
Eudiaptomus gracilis	210
Macrocyclops albidus	x

X = rare species with relative abundance < 1%
x = rare species recorded only at one of two investigated sites

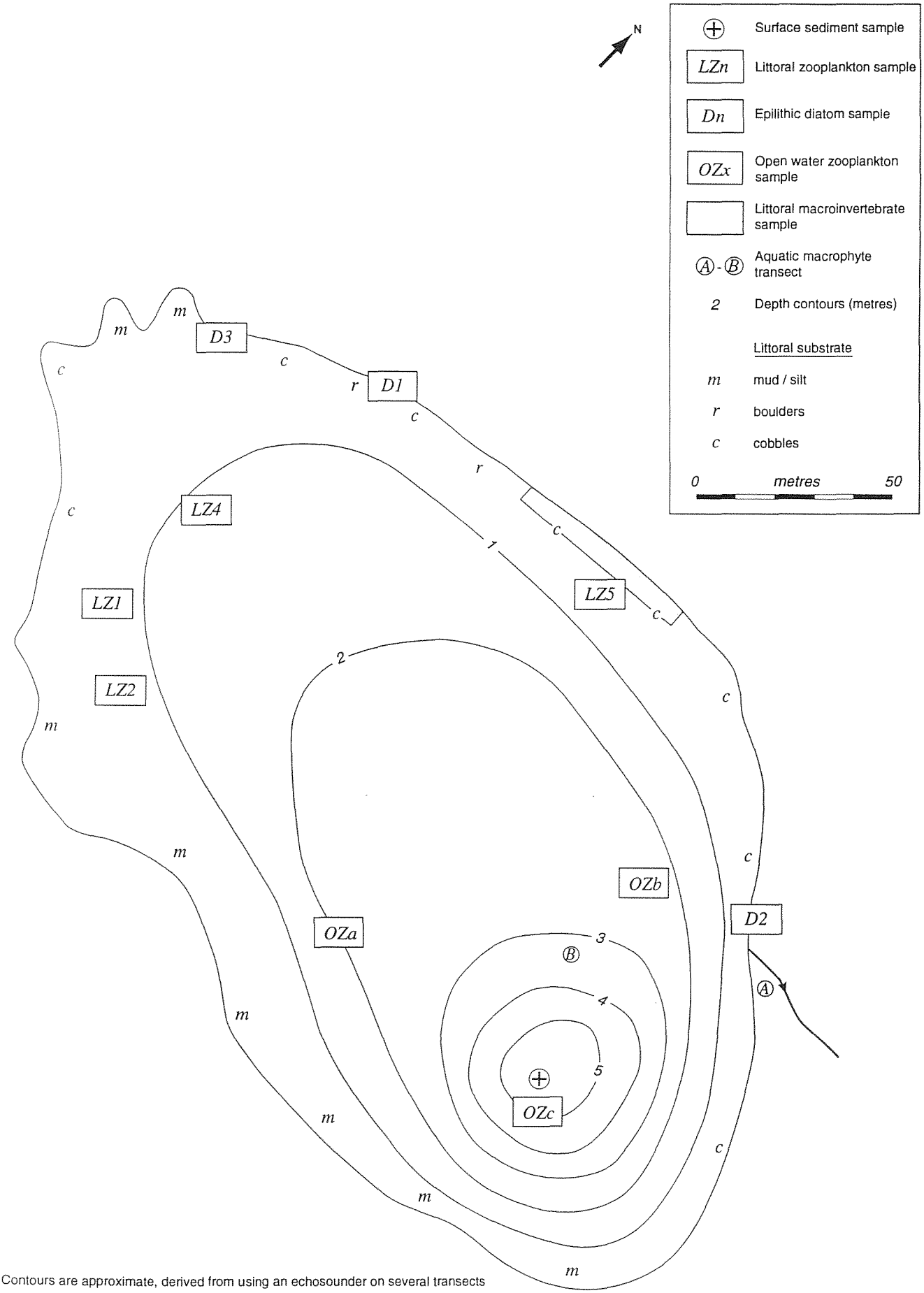
Table C.7 Llyn Fach zooplankton characteristics

Site depth (m)	4.8
Total zooplankton biomass (g DW m^{-2})	0.48
Net algal biomass (g DW m^{-2})	0
Cladoceran biomass as proportion of total zooplankton biomass (%)	80
Large cladoceran (>710µm) as proportion of total zooplankton biomass (%)	0
Large Copepoda (>420µm) as proportion of total zooplankton biomass (%)	3

Table C.8 Llyn Fach littoral macroinvertebrate summary. Mean number of individuals per one minute kick/sweep sample.

code	Taxon	Mean count / sample
16000000	OLIGOCHAETA	181.6
19000000	HYDRACARINA	0.4
	EPHEMEROPTERA	
30020302	*Cloeon simile*	0.4
	ODONATA	
32010101	*Platycnemis pennipes*	0.4
32020000	Coenagriidae	9.2
32020101	*Pyrrhosoma nymphula*	0.8
32070205	*Aeshna juncea*	0.8
	HEMIPTERA	
33110807	*Sigara scotti*	5.2
	MEGALOPTERA	
36010101	*Sialis lutaria*	2.4
	TRICHOPTERA	
38120203	*Mystacides longicornis*	0.4
38120301	*Triaenodes bicolor*	0.4
	DIPTERA	
40080000	Ceratapogonidae	10
40090000	Chironomidae	19.6

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



Contours are approximate, derived from using an echosounder on several transects

Figure C.2 Llyn Fach: aquatic macrophyte distribution map 8-7-95

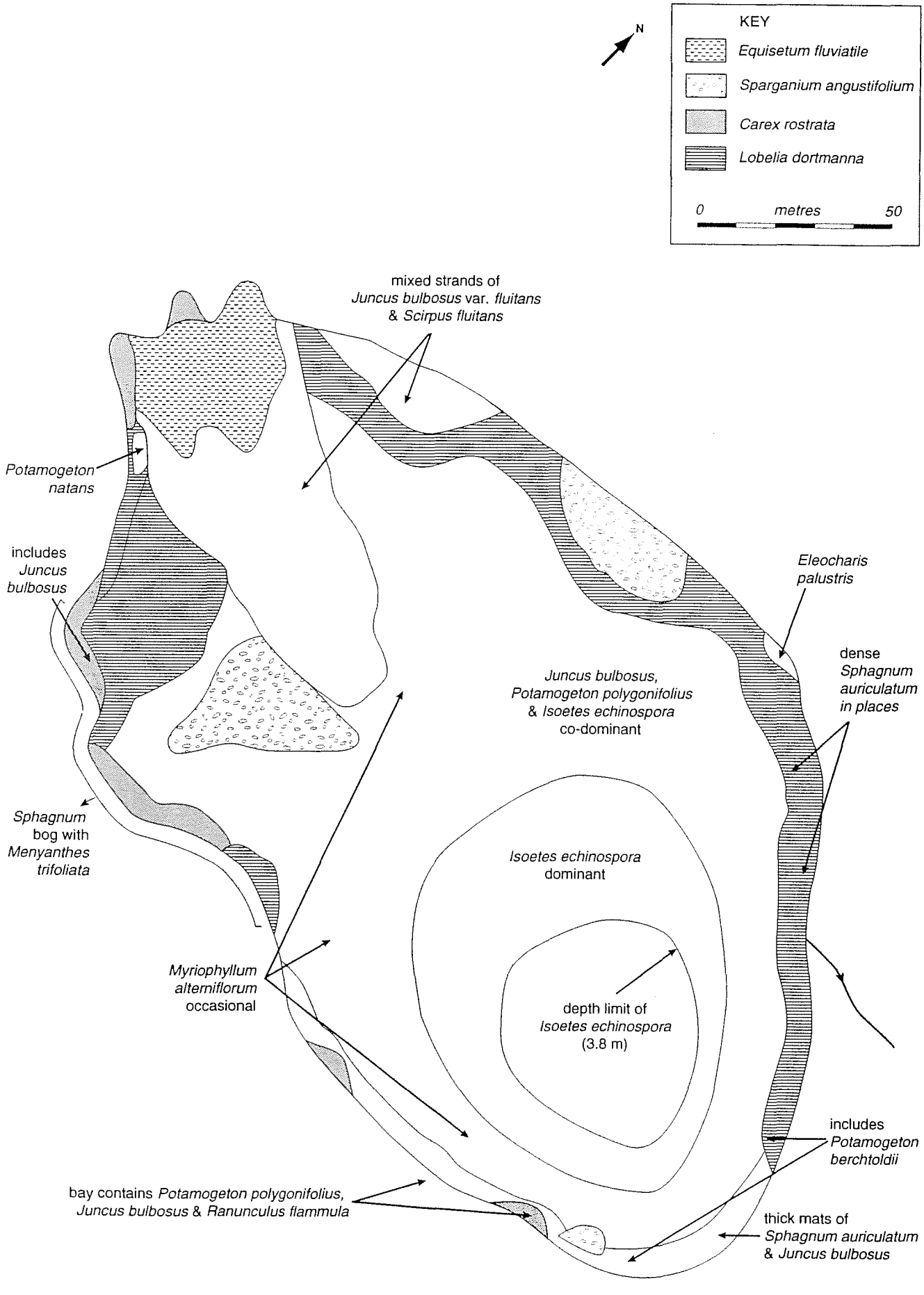


Figure C.3 Llyn Fach: aquatic macrophyte transect profile 8-7-95

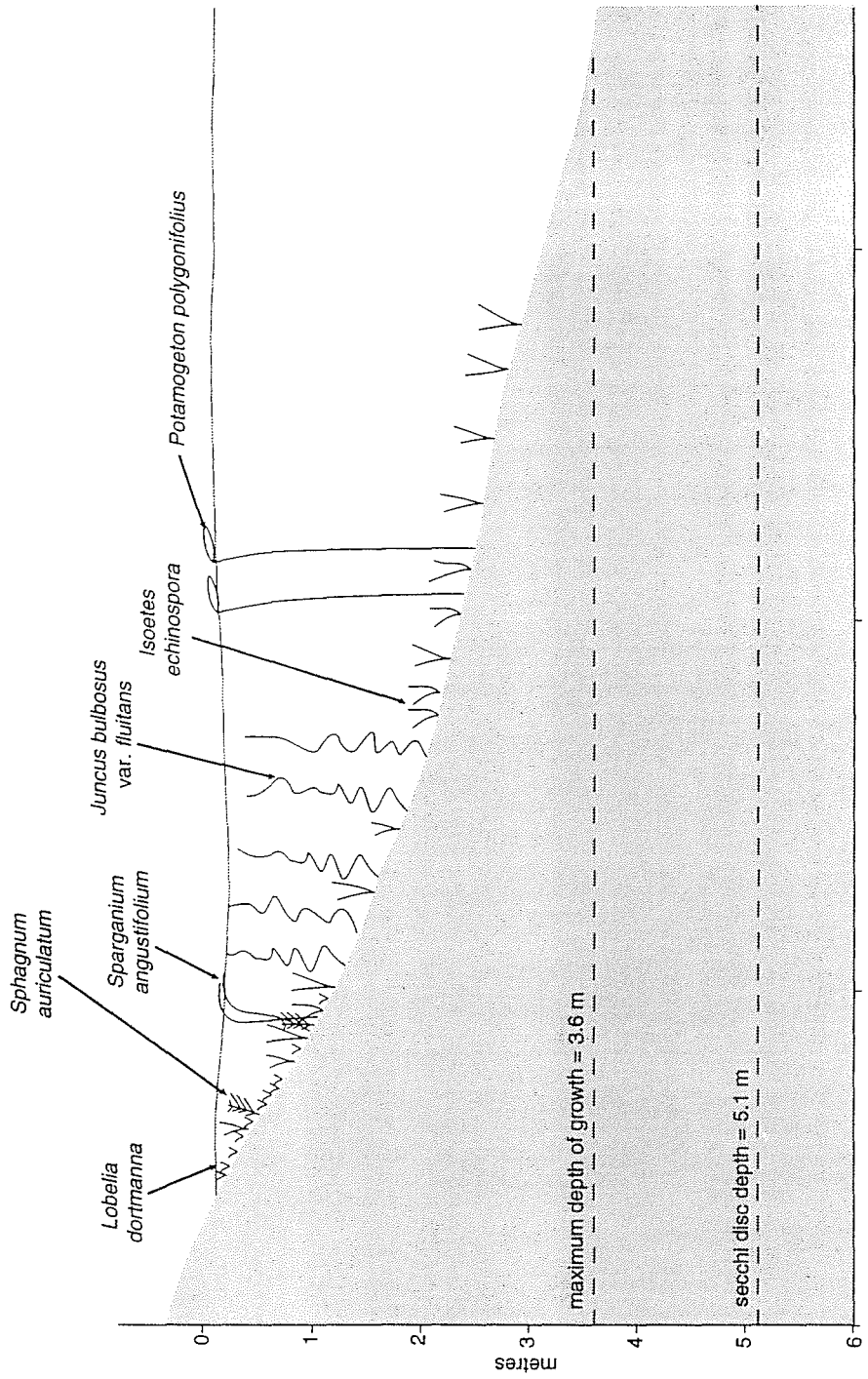
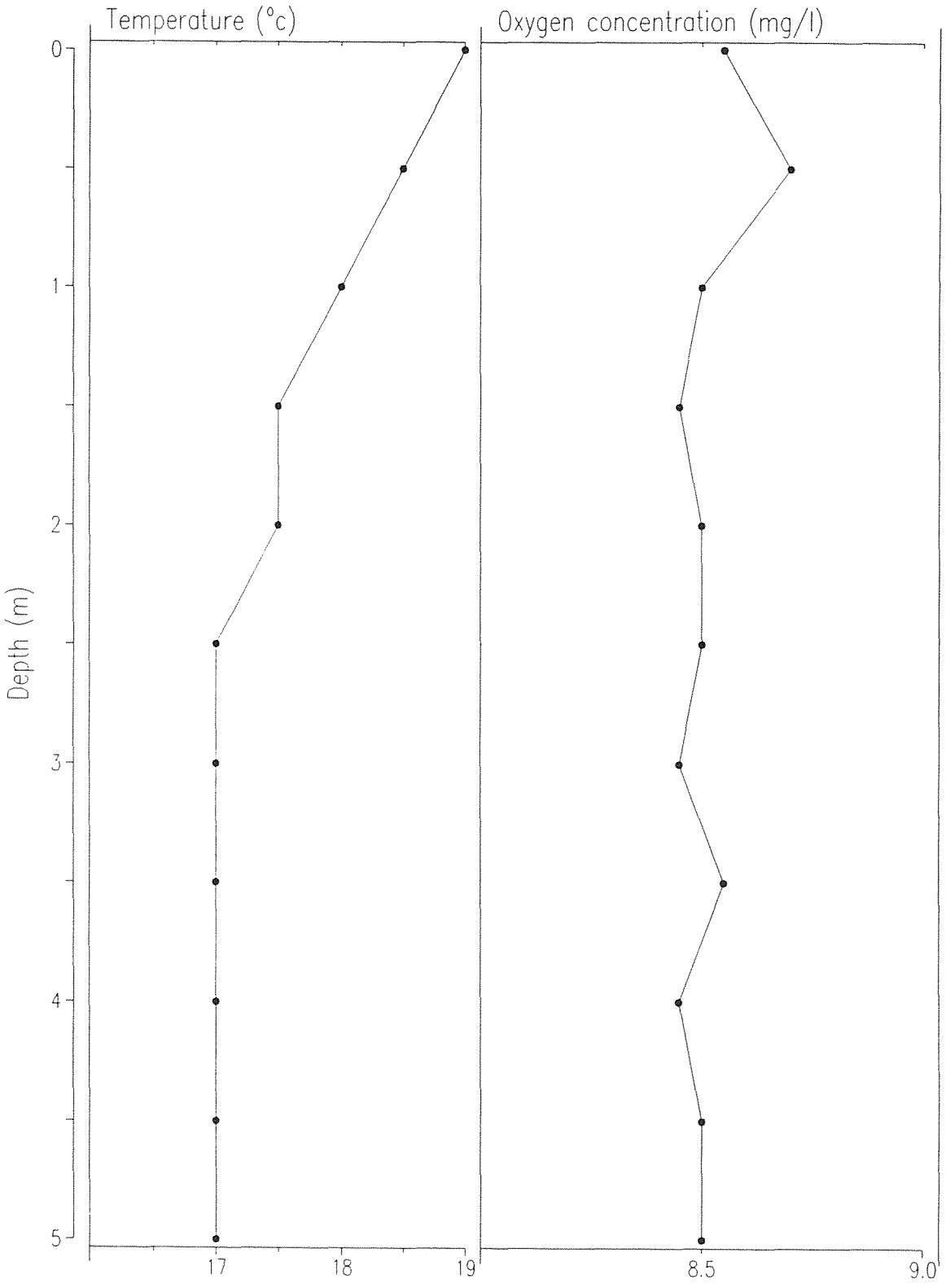


Figure C.4 Llyn Fach: Temperature and dissolved oxygen profiles 8-7-95



Appendix D Data Tables and Figures: Llanbwchllyn

Table A.1 Llanbwchllyn water chemistry

Determinand		Sample				
		9-7-95	26-9-95	31-1-96	17-4-96	mean
lab pH		7.63	7.72	7.38	7.39	7.51
field pH		8.64	----	7.35	6.38	----
Alkalinity 1	$\mu eq\ l^{-1}$	1473	1954	1102	1038	1391
Alkalinity 2	$\mu eq\ l^{-1}$	1490	1974	1110	1041	1404
lab Conductivity	$\mu S\ cm^{-1}$	203	239	222	203	217
field conductivity	$\mu S\ cm^{-1}$	197	239	210	250	224
Sodium	$\mu eq\ l^{-1}$	260	275	286	264	271
Potassium	$\mu eq\ l^{-1}$	26	26	34	32	30
Magnesium	$\mu eq\ l^{-1}$	247	243	278	268	259
Calcium	$\mu eq\ l^{-1}$	1614	2063	1924	1747	1837
Chloride	$\mu eq\ l^{-1}$	294	296	353	334	319
Aluminium total monomeric	$\mu g\ l^{-1}$	1	4	4	15	6
Aluminium non-labile	$\mu g\ l^{-1}$	1	4	0	4	2
Aluminium labile	$\mu g\ l^{-1}$	0	0	4	11	4
Absorbance	(250nm)	0.156	0.153	0.150	0.130	0.147
Carbon total organic	$mg\ l^{-1}$	4.7	5.2	4.7	3.7	4.6
Phosphorus total	$\mu gP\ l^{-1}$	50.3	53.3	21.8	17	36
Phosphorus total soluble	$\mu gP\ l^{-1}$	17.9	21.6	17.1	9.3	16.5
Phosphorus soluble reactive	$\mu gP\ l^{-1}$	3.4	6.2	7	3.8	5.1
Nitrate	$\mu gN\ l^{-1}$	10	<10	1963	1456	859
Silica soluble reactive	$mg\ l^{-1}$	3.54	20.90	7.20	0.88	8.13
Chlorophyll a	$\mu g\ l^{-1}$	18.6	28.9	8.8	4.9	15.3
Sulphate	$\mu eq\ l^{-1}$	240	246	480	396	341
Copper total soluble	$\mu g\ l^{-1}$	0	0	0	0	0
Iron total soluble	$\mu g\ l^{-1}$	40	10	19	7	19
Lead total soluble	$\mu g\ l^{-1}$	0	0	0	0	0
Manganese total soluble	$\mu g\ l^{-1}$	0	6	3	3	3
Zinc total soluble	$\mu g\ l^{-1}$	0	1	0	0	0

Table D.2 Llanbwchllyn epilithic diatom taxon list (including taxa >1.0%)

Taxon	Relative frequency (%)
Achnanthes minutissima	24.7
Amphora pediculus	2.7
Aulacoseira granulata	1.9
Cymbella microcephala	6.0
Cymbella reinhardtii	1.8
Fragilaria pinnata	15.9
Fragilaria construens	10.8
Fragilaria construens var. *binodis*	1.4
Fragilaria construens var. *venter*	11.6
Fragilaria brevistriata	7.7
Gomphonema minutum	1.4
Nitzschia amphibia	6.4
Stephanodiscus hantzschii	1.5

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

Taxon	Relative frequency (%)
Achnanthes minutissima	2.9
Asterionella formosa	17.2
Aulacoseira ambigua	1.8
Aulacoseira granulata	10.7
Cyclostephanos invisitatus	2.3
Fragilaria brevistriata	5.9
Fragilaria construens	13.8
Fragilaria construens var. *venter*	7.7
Fragilaria pinnata	16.1
Stephanodiscus hantzschii	7.5

Table D.4 Llanbwchllyn aquatic macrophyte abundance summary: 10-7-95

Taxon	code	Abun
Emergent taxa		
Equisetum palustre	350299	O
Menyanthes trifoliata	364701	O
Phragmites australis	383801	A
Juncus acutiflorus / articulatus	383099	F
Typha latifolia	384902	O
Floating leaved taxa		
Nuphar lutea	365501	O
Nymphaea alba	365601	F
Polyganum amphibium	366501	F
Submergent taxa		
Nitella flexilis var. *flexilis*	220000	R
Littorella uniflora	363901	O
Myriophyllum alterniflorum	365401	R
Myriophyllum spicatum *	365403	R
Lemna trisulca *	383304	R
Potamogeton berchtoldii	384003	R
Potamogeton crispus *	384006	R
Potamogeton praelongus *	384018	R
Fringing taxa		
Filipendula ulmaria		
Achillea ptarmica		
Epilobium spp.		
Galium palustre		
Lotus uliginosus		
Lycopus europaeus		
Oenanthe crocata		
Solanum dulcamara		
Alnus glutinosa		
Salix sp.		

* = taxon regionally rare for NRA Welsh Region

Table D.5 Llanbwchllyn littoral Cladocera taxon list: 10-7-95

Taxa	Sample number				
	1	2	3	4	5
Alona affinis			1	10	
Alona sp		s			
Argulus sp.	1				1
Chydorus sphaericus		s			
Pleuroxus uncinatus					3
Total Count	0	0	1	10	3

Table D.6 Llanbwchllyn zooplankton abundance summary: 10-7-95 Abundance in vertical net hauls (number of individuals 0.01 m^{-2})

Taxon	Count
Daphnia galeata	x
Bosmina longirostris	570
Eudiaptomus gracilis	30
Mesocyclops leuckarti	X
Chaoborus sp.	x

X = rare species with relative abundance < 1%
x = rare species recorded only at one of two investigated sites

Table D.7 Llanbwchllyn zooplankton characteristics

Site depth (m)	6.7
Total zooplankton biomass (g DW m^{-2})	0.38
Net algal biomass (g DW m^{-2})	0.70
Cladoceran biomass as proportion of total zooplankton biomass (%)	25
Large cladoceran (>710µm) as proportion of total zooplankton biomass (%)	0
Large Copepoda (>420µm) as proportion of total zooplankton biomass (%)	5

Figure D.1 Llanbwchllyn: sample location and substrate map

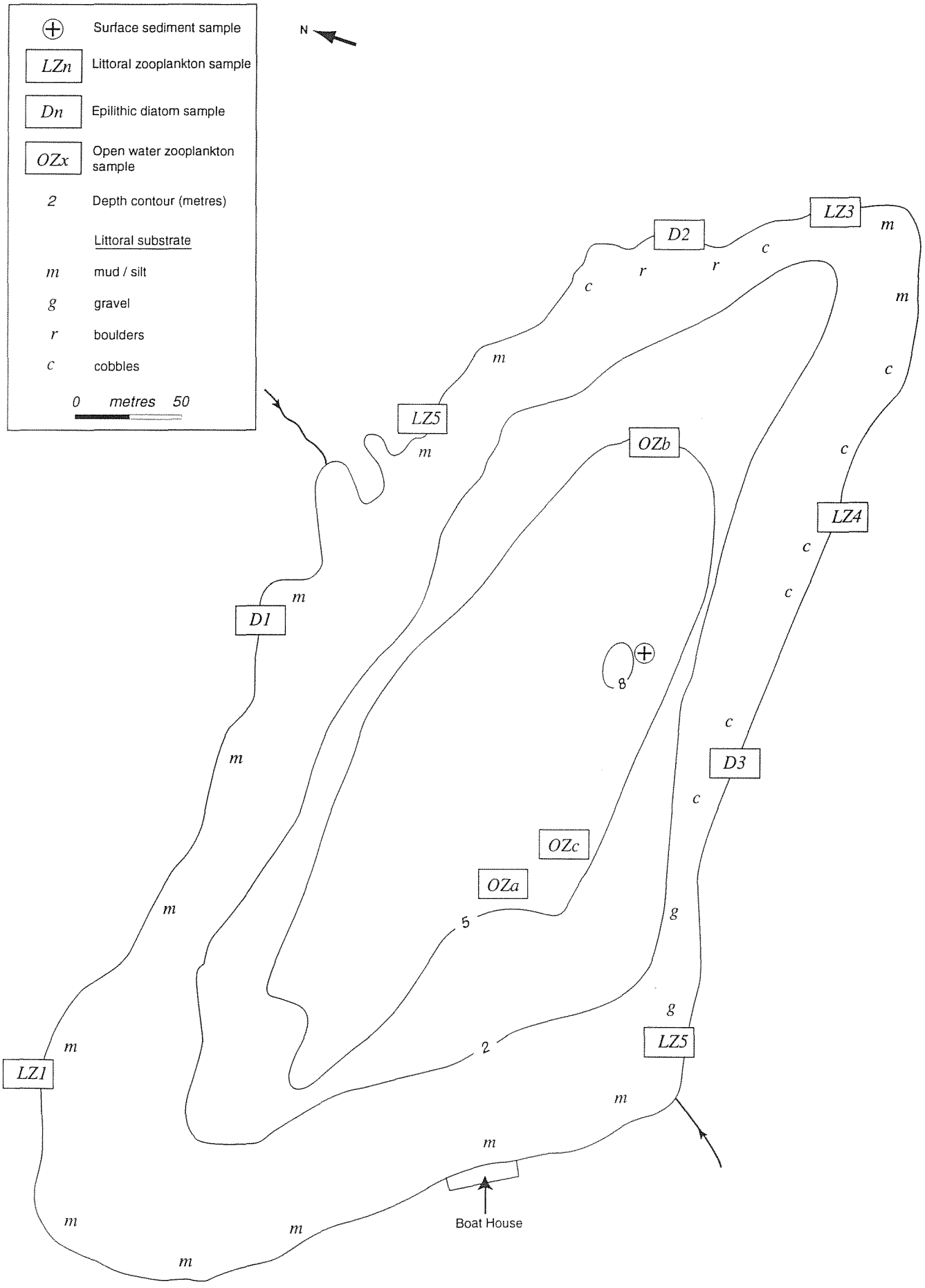


Figure D.2 Llanbwchllyn: aquatic macrophyte distribution map 10-7-95

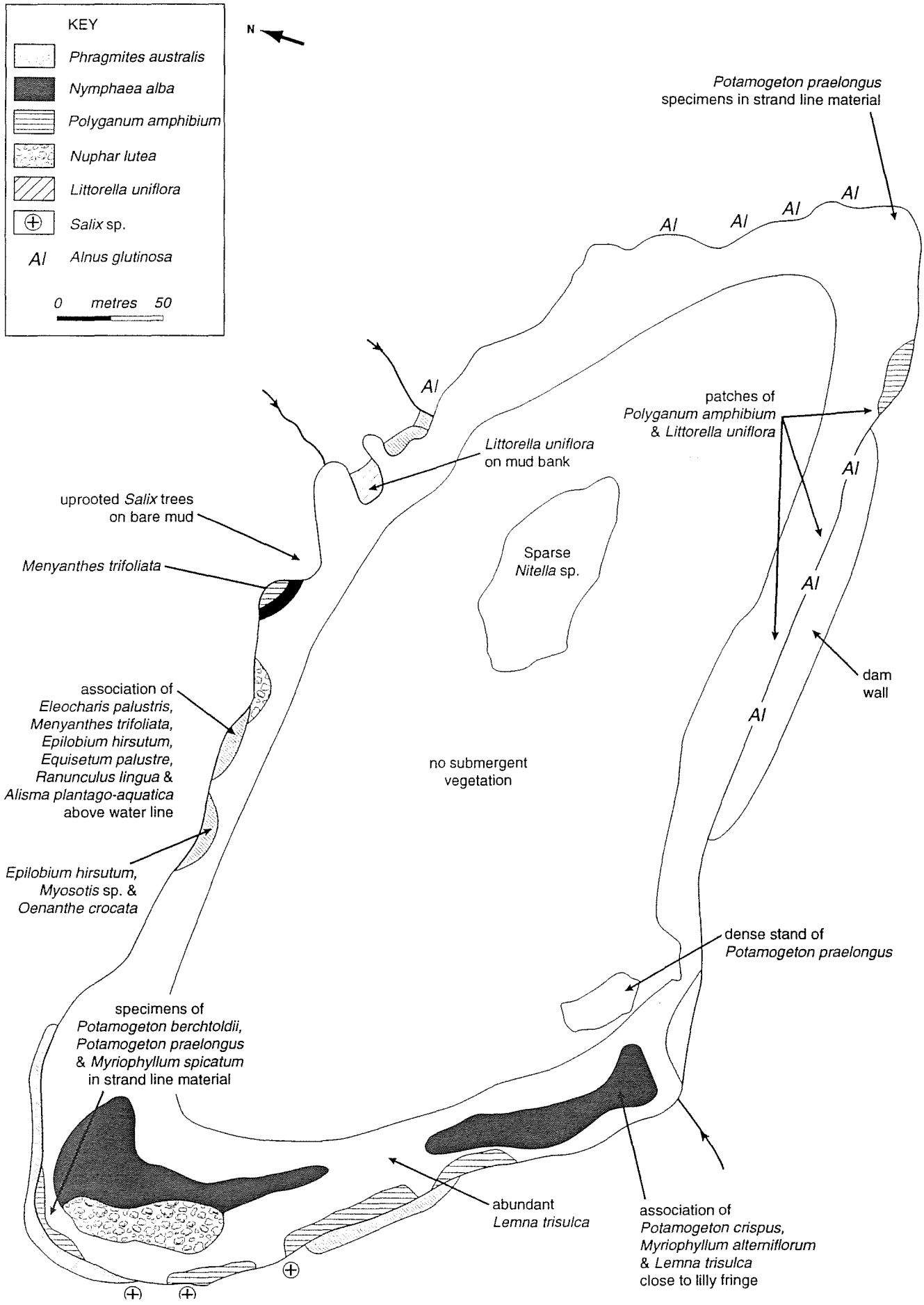
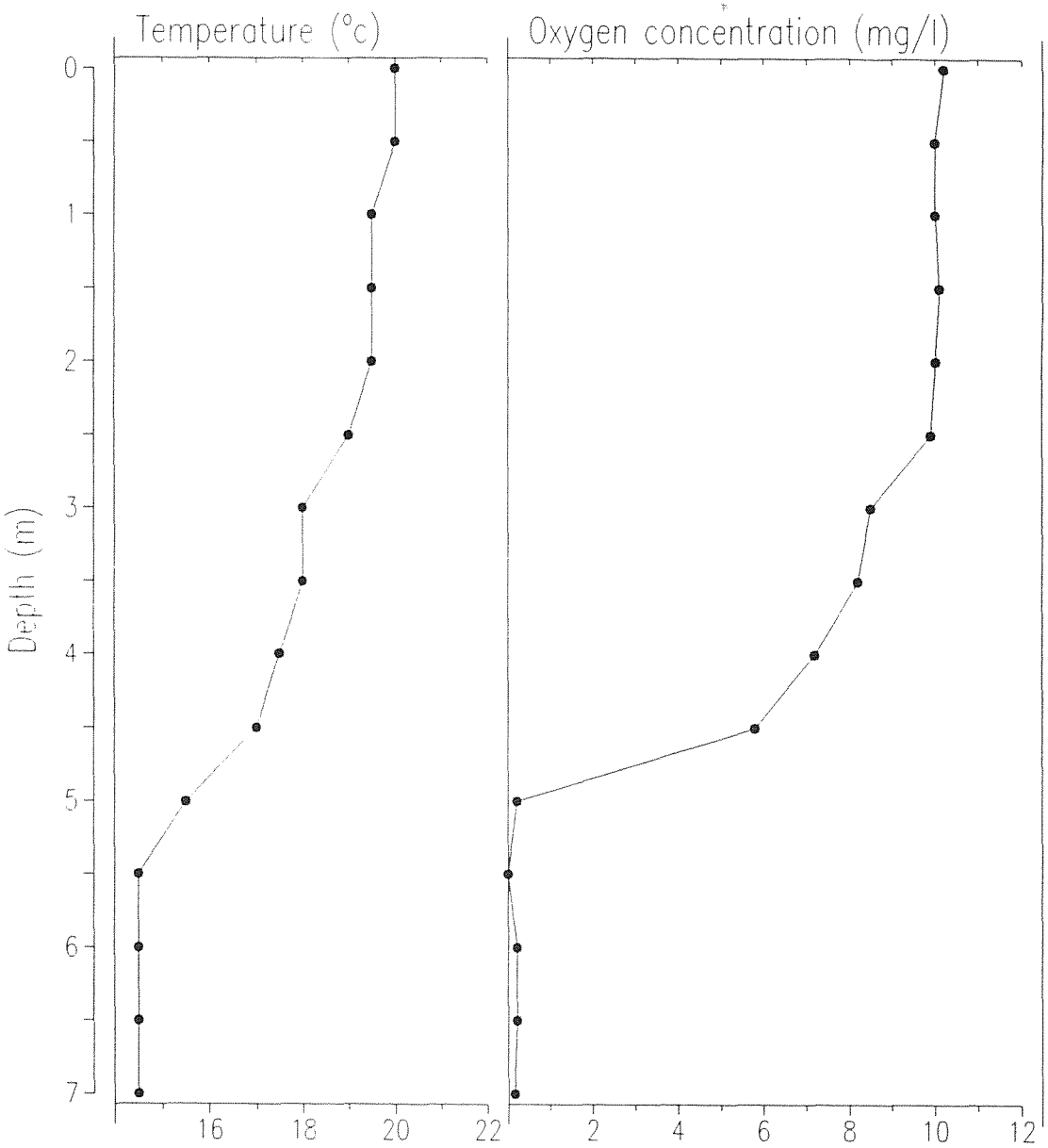


Figure D.4 Llanbwchllyn: Temperature and dissolved oxygen profiles 10-7-95



Appendix E Data Tables and Figures: Llangorse Lake

Table E.1 Llangorse Lake water chemistry

Determinand		Sample				
		11-7-95	26-9-95	31-1-96	17-4-96	mean
lab pH		7.88	8.05	7.96	8.08	8.00
field pH		8.23	----	7.93	7.30	----
Alkalinity 1	$\mu eq\ l^{-1}$	2404	2535	2331	2513	2446
Alkalinity 2	$\mu eq\ l^{-1}$	2437	2560	2366	2542	2476
lab Conductivity	$\mu S\ cm^{-1}$	296	300	312	340	312
field conductivity	$\mu S\ cm^{-1}$	295	----	295	410	---
Sodium	$\mu eq\ l^{-1}$	394	403	372	399	392
Potassium	$\mu eq\ l^{-1}$	47	49	63	58	54
Magnesium	$\mu eq\ l^{-1}$	467	501	460	467	474
Calcium	$\mu eq\ l^{-1}$	2326	2569	2776	2913	2646
Chloride	$\mu eq\ l^{-1}$	474	480	479	506	485
Aluminium total monomeric	$\mu g\ l^{-1}$	0	5	3	5	3
Aluminium non-labile	$\mu g\ l^{-1}$	0	5	3	3	3
Aluminium labile	$\mu g\ l^{-1}$	0	0	0	2	1
Absorbance	(250nm)	0.129	0.142	0.150	0.120	0.135
Carbon total organic	$mg\ l^{-1}$	4.8	5.7	5.3	4.4	5.1
Phosphorus total	$\mu gP\ l^{-1}$	133.4	149.7	118.2	69.7	117.8
Phosphorus total soluble	$\mu gP\ l^{-1}$	93.4	106	93.8	17.8	77.8
Phosphorus soluble reactive	$\mu gP\ l^{-1}$	79.7	81.8	64.5	5.8	58.0
Nitrate	$\mu gN\ l^{-1}$	<10	10	18.6	585	602
Silica soluble reactive	$mg\ l^{-1}$	5.92	2.43	4.24	0.09	3.17
Chlorophyll a	$\mu g\ l^{-1}$	12.9	4.1	10.1	31	14.5
Sulphate	$\mu eq\ l^{-1}$	186	168	291	289	234
Copper total soluble	$\mu g\ l^{-1}$	0	0	0	0	0
Iron total soluble	$\mu g\ l^{-1}$	30	4	11	5	13
Lead total soluble	$\mu g\ l^{-1}$	0	0	0	0	0
Manganese total soluble	$\mu g\ l^{-1}$	0	5	26	51	21
Zinc total soluble	$\mu g\ l^{-1}$	0	0	0	0	0

Table E.2a Llangorse Lake epilithic diatom taxon list (including taxa >1.0%)

Taxon	Relative frequency (%)
Achnanthes lanceolata	1.3
Achnanthes minutissima	5.3
Amphora pediculus	9.9
Cyclostephanos dubius	2.4
Cocconeis placentula	1.1
Cocconeis pediculus	7.6
Cocconeis thumensis	1.3
Epithemia sorex	2.9
Fragilaria pinnata	12.6
Fragilaria brevistriata	9.2
Fragilaria intermedia	2.2
Fragilaria sp.	1.1
Gomphonema constrictum	1.3
Gomphonema minutum	1.4
Navicula cryptocephala var .*veneta*	1.4
Navicula capitoradiata	1.8
Navicula radiosa var. *tenella*	6.9
Nitzschia fonticola	1.5
Nitzschia dissipata	7.0
Nitzschia paleacea	2.7
Nitzschia lacuum	1.5
Nitzschia sp.	1.4
Rhoicosphenia curvata	2.9

Table E.2b Llangorse Lake epiphytic diatom taxon list (including taxa >1.0%)

Taxon	Relative frequency (%)
Achnanthes minutissima	11.4
Cocconeis placentula	56.7
Fragilaria intermedia	3.5
Gomphonema angustatum	4.7
Gomphonema parvulum	6.1
Navicula minima	3.8
Navicula tripunctata	1.2
Nitzschia frustulum	1.2
Nitzschia palaea var.*debilis*	6.4

Table E.3 Llangorse Lake surface sediment diatom taxon list (including taxa >1%)

Taxon	Relative frequency (%)
Asterionella formosa	1.5
Aulacoseira ambigua	3.3
Aulacoseira granulata	0.7
Aulacoseira subarctica	31.0
Cyclostephanos dubius	16.7
Cyclotella pseudostelligera	1.2
Cyclotella radiosa	4.8
Fragilaria pinnata	4.5
Fragilaria construens	2.1
Fragilaria construens var.*venter*	2.1
Fragilaria brevistriata	6.3
Stephanodiscus hantzschii	3.3
Stephanodiscus parvus	5.1

Table E.4 Llangorse Lake aquatic macrophyte abundance summary: 9-7-95

Taxon	code	Abun
Emergent taxa		
Mentha aquatica	364601	O
Menyanthes trifoliata	364701	O
Alisma plantago-aquatica	380303	R
Eleocharis palustris	382004	O
Iris pseudacorus	382901	O
Phragmites australis	383801	A
Scirpus lacustris ssp. tabernaemontani *	384504	F
Sparganium erectum	384603	O
Typha latifolia	384902	F
Floating leaved taxa		
Nuphar lutea	365501	A
Nymphaea alba	365601	F
Nymphoides peltata	365701	F
Polyganum amphibium	366501	F
Lemna polyrhizza	383303	R
Lemna minor	383302	O
Potamogeton natans	384012	R
Submergent taxa		
filamentous green algae	170000	O
Cladophora sp.	220000	O
Chara globularis var. *globularis*	220000	O
Fontinalis antipyretica	323401	O
Ceratophyllum demersum	361401	O
Myriophyllum spicatum *	365403	A
Ranunculus circinatus *	366970	O
Elodea canadensis	382101	F
Lemna trisulca *	383304	F
Potamogeton crispus *	384006	R
Potamogeton lucens *	384011	O
Potamogeton pectinatus	384015	F
Potamogeton perfoliatus *	384016	F
Potamogeton pusillus *	384019	O
Zannichelia palustris	385201	R

* = taxon regionally rare for NRA Welsh Region

Table E.5 Llangorse Lake littoral Cladocera taxon list: 9-7-95

Taxa	Sample number					
	1	2	3	4	5	6
Alona affinis				1	1	
Chydorus sphaericus	1	1				
Daphnia hyalina	1			1		9
Eurycercus lamellatus						2
Pleuroxus denticulatus			1			
Sida crystallina	22	1	188	2		35
Total Count	24	2	189	4	1	46

Table E.6 Llangorse Lake zooplankton abundance summary: 9-7-95 Abundance in vertical net hauls (number of individuals 0.01 m^{-2})

Taxon	Count
Daphnia galeata	1300
Eudiaptomus gracilis	500
Macrocyclops albidus	x
Cylops strenuus	480
Cyclops vicinus	230
Acanthocyclops robustus	80

X = rare species with relative abundance < 1%
x = rare species recorded only at one of two investigated sites

Table E.7 Llangorse Lake zooplankton characteristics

Site depth (m)	7.2
Total zooplankton biomass (g DW m^{-2})	1.91
Net algal biomass (g DW m^{-2})	0
Cladoceran biomass as proportion of total zooplankton biomass (%)	42
Large cladoceran (>710µm) as proportion of total zooplankton biomass (%)	4
Large Copepoda (>420µm) as proportion of total zooplankton biomass (%)	16

Table E.8 Llangorse Lake littoral macroinvertebrate summary. 26-9-95 mean number of individuals per one minute kick/sweep sample.

code	Taxon	Mean count / sample
	TURBELLARIA	
03120000	Tricladida	222.8
	MOLLUSCA	
13030103	*Valvata piscinalis*	3.6
13040501	*Bithynia tentaculata*	0.4
13070105	*Lymnaea stagnalis*	0.4
13070106	*Lymnaea auricularia*	0.8
13070107	*Lymnaea peregra*	0.4
13090307	*Planorbis albus*	26.4
13100101	*Acroloxus lacustris*	2.4
	BIVALVIA	
14030200	*Pisidium* sp.	10.8
16000000	OLIGOCHAETA	1747.6
	HIRUDINEA	
17010101	*Piscicola geometra*	0.4
17020101	*Theromyzon tessalatum*	0.4
17020301	*Glossiphonia heteroclita*	0.8
17020302	*Glossiphonia complanata*	2.4
17020501	*Helobdella stagnalis*	25.6
19000000	HYDRACARINA	0.4
	MALACOSTRACA	
28030101	*Asellus aquaticus*	242.4
28070305	*Gammarus pulex*	5.2
	COLLEMBOLA	
29030000	Isotomidae	1.6
	EPHEMEROPTERA	
30020000	Baetidae	0.4
30020301	*Cloeon dipterum*	3.6
	ODONATA	
32020000	Coenagriidae	0.8

Table E.8	Llangorse Lake littoral macroinvertebrate summary (continued)	
	HEMIPTERA	
33090102	*Notonecta viridis*	0.4
33110000	Corixidae sp.	4.4
33110501	*Corixa dentipes*	0.4
33110502	*Corixa punctata*	0.8
33110804	*Sigara falleni*	0.4
	COLEOPTERA	
35010000	Haliplidae sp.	0.4
35110600	*Oulimnius* sp.	1.6
	MEGALOPTERA	
36010101	*Sialis lutaria*	0.4
39000000	LEPIDOPTERA	36.4
	DIPTERA	
40010000	Tipulidae	0.8
40090000	Chironomidae	142.4

Figure E.1 Llangorse Lake: sample location and substrate map 9-7-95

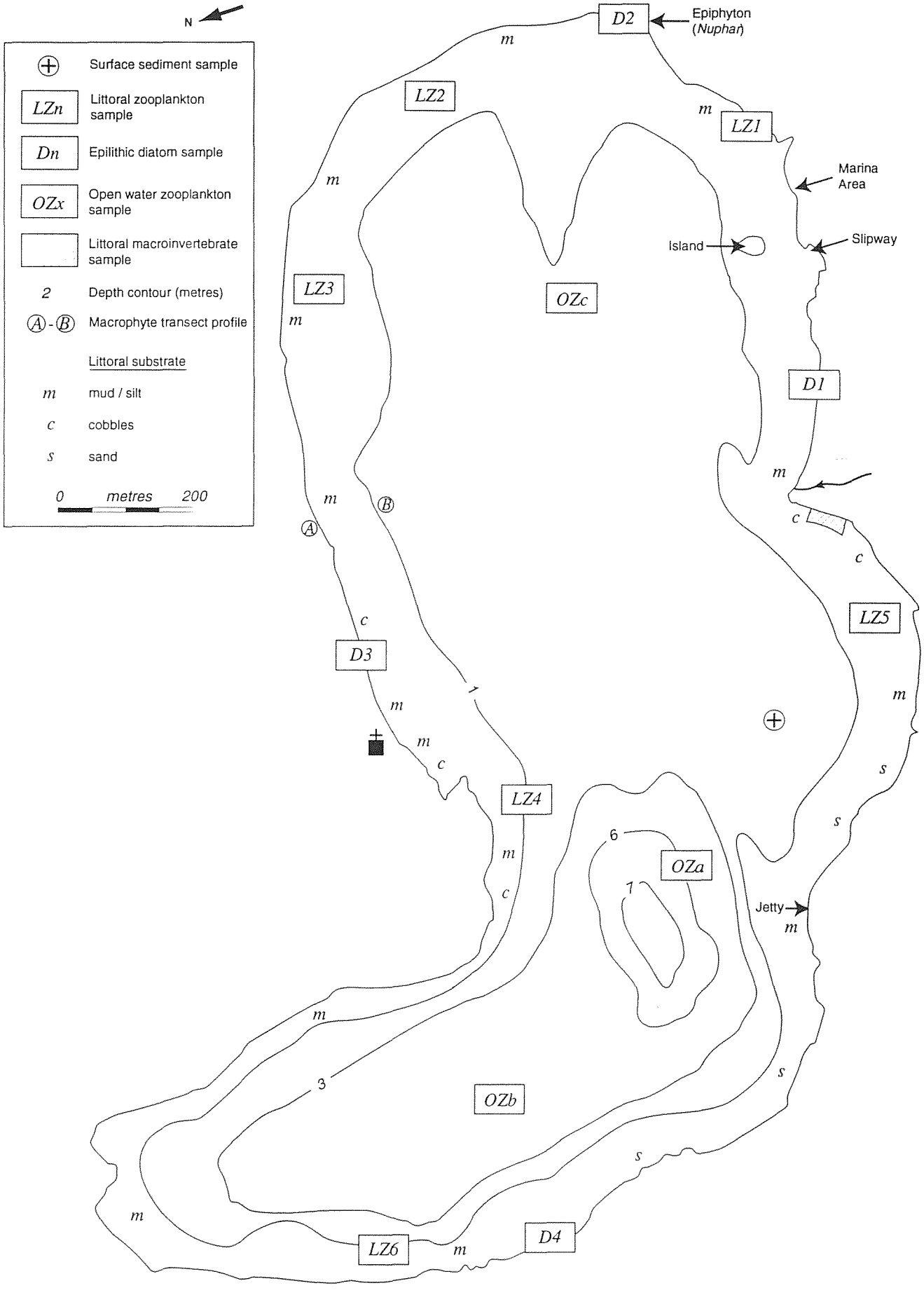


Figure E.2 Llangorse Lake: aquatic macrophyte distribution map 9-7-95

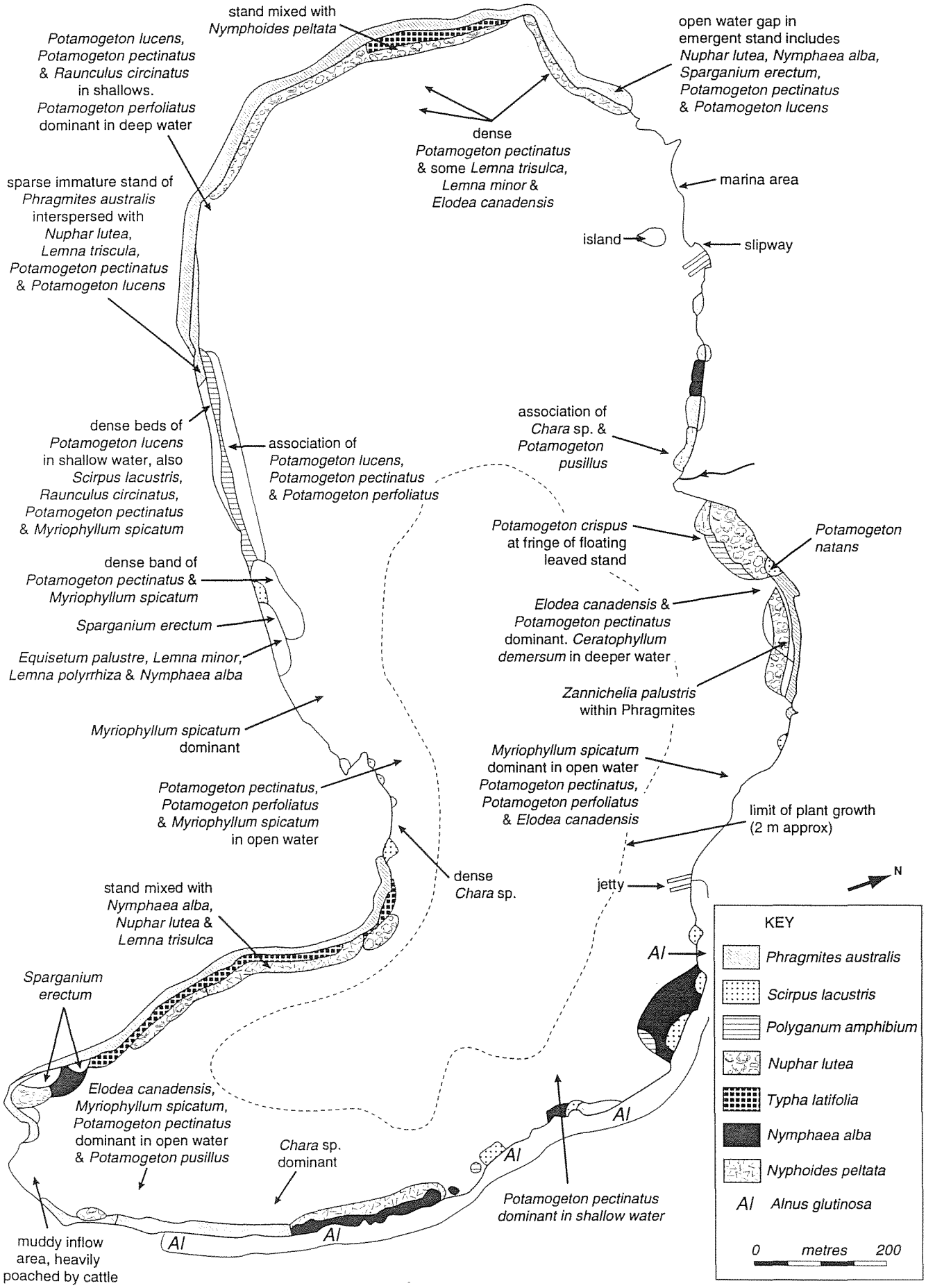


Figure E.3 Llangorse Lake: aquatic macrophyte transect profile 9-7-95

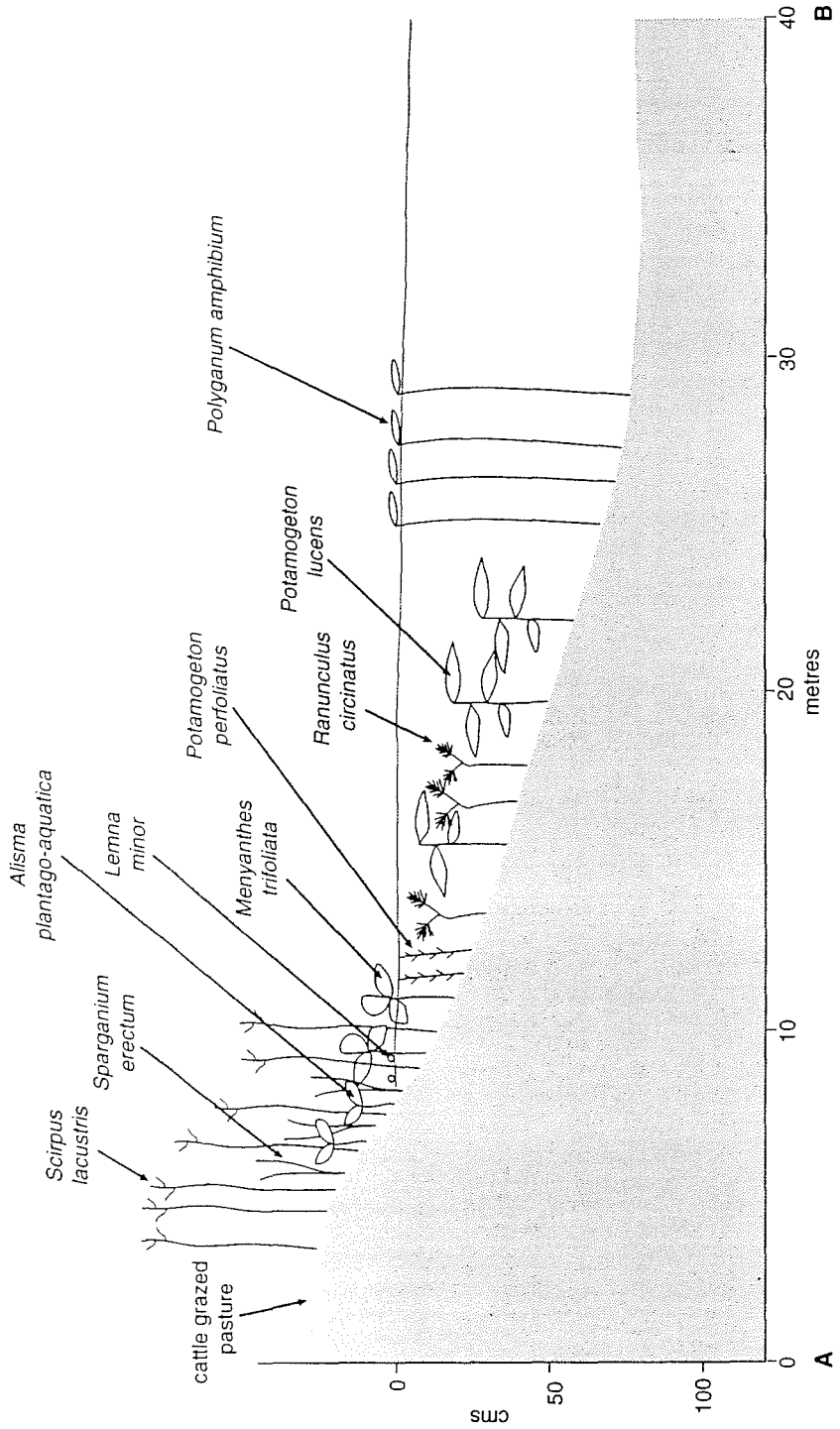
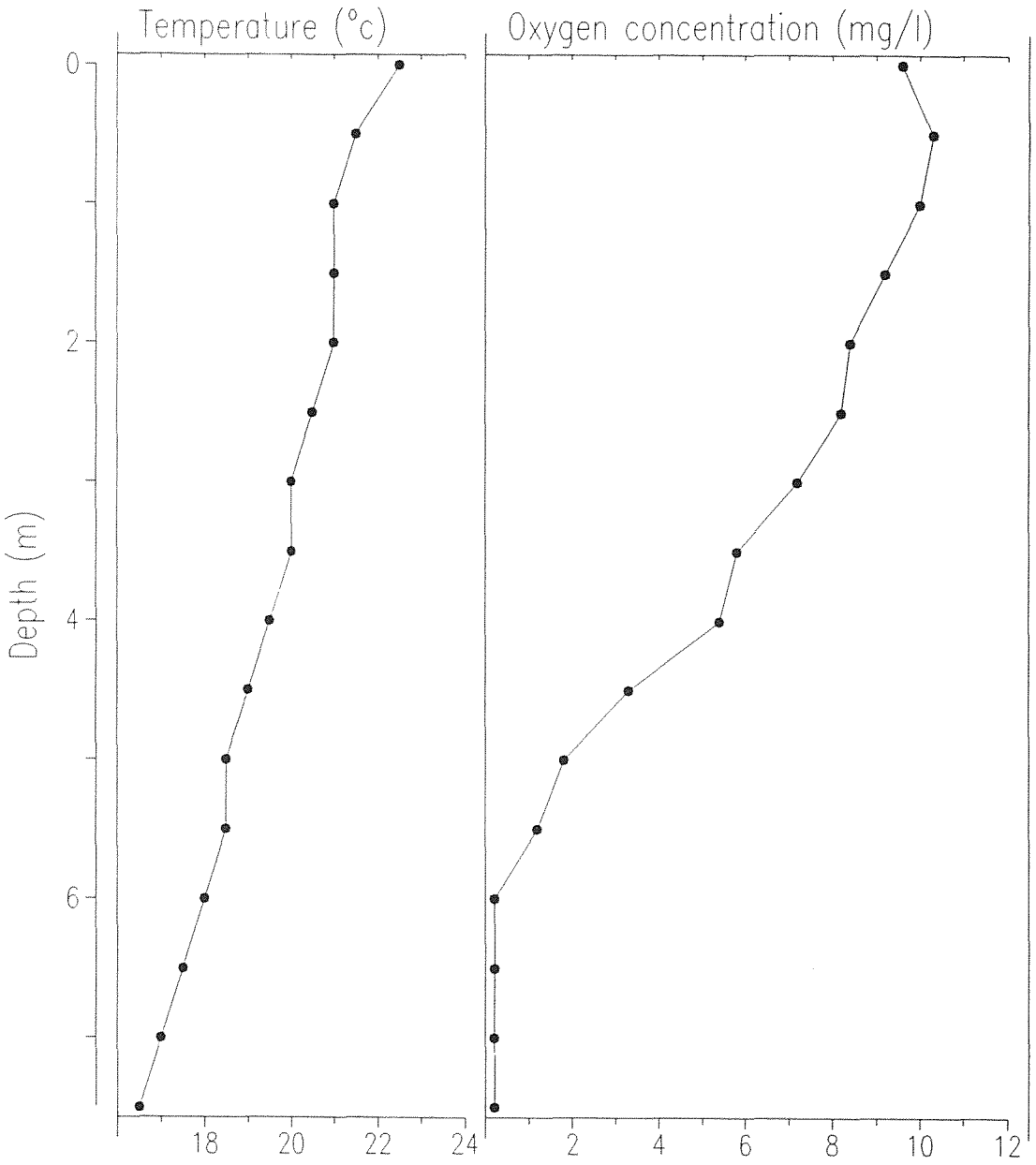


Figure E.4 Llangorse Lake: Temperature and dissolved oxygen profiles 9-7-95



Appendix F Data Tables and Figures: Llyn y Fan Fawr

Table F.1 Llyn y Fan Fawr water chemistry

Determinand		Sample				
		12-7-95	26-9-95	31-1-96	17-4-96	mean
lab pH		6.66	6.73	6.59	6.36	6.56
field pH		7.11	----	6.23	6.44	----
Alkalinity 1	$\mu eq\ l^{-1}$	87	94	85	76	86
Alkalinity 2	$\mu eq\ l^{-1}$	80	85	77	68	78
lab Conductivity	$\mu S\ cm^{-1}$	36	35	40	36	37
field conductivity	$\mu S\ cm^{-1}$	38		42	55	45
Sodium	$\mu eq\ l^{-1}$	133	128	130	125	129
Potassium	$\mu eq\ l^{-1}$	6	5	6	4	5
Magnesium	$\mu eq\ l^{-1}$	39	39	40	40	40
Calcium	$\mu eq\ l^{-1}$	161	153	176	182	168
Chloride	$\mu eq\ l^{-1}$	150	144	148	139	145
Aluminium total monomeric	$\mu g\ l^{-1}$	4	4	3	4	4
Aluminium non-labile	$\mu g\ l^{-1}$	1	4	1	4	3
Aluminium labile	$\mu g\ l^{-1}$	3	0	2	0	1
Absorbance	(250nm)	0.034	0.050	0.050	0.050	0.046
Carbon total organic	$mg\ l^{-1}$	1.9	2.6	1.8	1.8	2.0
Phosphorus total	$\mu gP\ l^{-1}$	15.5	9.3	6.2	12.1	10.8
Phosphorus total soluble	$\mu gP\ l^{-1}$	9.5	2.7	1.8	4.6	4.7
Phosphorus soluble reactive	$\mu gP\ l^{-1}$	6.2	1.3	1.7	4.4	3.4
Nitrate	$\mu gN\ l^{-1}$	22	16	111	195	86
Silica soluble reactive	$mg\ l^{-1}$	0.05	0.25	0.27	0.24	0.20
Chlorophyll a	$\mu g\ l^{-1}$	2.7	4.5	3.3	4.1	3.7
Sulphate	$\mu eq\ l^{-1}$	71	68	73	75	72
Copper total soluble	$\mu g\ l^{-1}$	0	0	0	0	0
Iron total soluble	$\mu g\ l^{-1}$	60	7	3	4	19
Lead total soluble	$\mu g\ l^{-1}$	5	0	0	0	1
Manganese total soluble	$\mu g\ l^{-1}$	0	11	3	4	5
Zinc total soluble	$\mu g\ l^{-1}$	8	1	10	0	5

Table F.2 Llyn y Fan Fawr epilithic diatom taxon list (including taxa >1.0%)

TAXON	Relative frequency (%)
Achnanthes minutissima	51.1
Achnanthes levanderi	1.5
Brachysira vitrea	3.9
Cymbella microcephala	10.4
Cymbella lunata	1.1
Denticula tenuis	2.4
Gomphonema intricatum	1.6
Nitzschia perminuta	2.7
Nitzschia angustata var.*acuta*	2.0
Nitzschia recta	1.0
Nitzschia sp.	1.4
Synedra minuscula	7.2
Tabellaria flocculosa	2.8

Table F.3 Llyn y Fan Fawr surface sediment diatom taxon list (including taxa >1%)

Taxon	Relative frequency (%)
Achnanthes levanderi	2.9
Achnanthes minutissima	20.3
Brachysira vitrea	1.3
Cyclotella comensis	32.3
Cyclotella glomerata	12.4
Cyclotella krammeri	2.5
Cymbella microcephala	2.1
Navicula pseudoscutiformis	1.7
Nitzschia fonticola	1.5
Nitzschia perminuta	2.3
Synedra minuscula	7.4
Temporary sp. 1	2.3

Table F.4 Llyn y Fan Fawr aquatic macrophyte abundance summary: 8-7-95

Taxon	code	Abun
Submergent taxa		
Fontinalis antipyretica	323401	R
Isoetes lacustris	350302	R
Littorella uniflora	363901	R

Table F.5 Llyn y Fan Fawr littoral Cladocera taxon list: 8-7-95

Taxa	Sample number				
	1	2	3	4	5
Chydorus piger	1				
Diaphanosoma brachyurum	4	32		7	4
Graptoleberis testudinaria			s		
Monospilus dispar					s
Total Count	5	32	0	7	4

s = shell fragment

Table F.6 Llyn y Fan Fawr zooplankton abundance summary: 8-7-95 Abundance in vertical net hauls (number of individuals 0.01 m^{-2})

Taxon	Count
Diaphanosoma brachyurum	590
Eudiaptomus gracilis	4500
Chydorus sphaericus	X
Cyclops abyssorum	850

X = rare species with relative abundance < 1%
x = rare species recorded only at one of two investigated sites

Table F.7 Llyn y Fan Fawr zooplankton characteristics

Site depth (m)	20.2
Total zooplankton biomass (g DW m^{-2})	3.57
Net algal biomass (g DW m^{-2})	0
Cladoceran biomass as proportion of total zooplankton biomass (%)	17
Large cladoceran (>710µm) as proportion of total zooplankton biomass (%)	0
Large Copepoda (>420µm) as proportion of total zooplankton biomass (%)	28

Table F.8 Llyn y Fan Fawr littoral macroinvertebrate summary. 26-9-95 mean number of individuals per one minute kick/sweep sample.

code	Taxon	Mean count / sample
	MOLLUSCA	
13100201	*Ancylus fluviatilis*	1.2
16000000	OLIGOCHAETA	57.6
	COLEOPTERA	
35110600	*Oulimnius* sp.	2.4
	TRICHOPTERA	
38030301	*Polycentropus flavomaculatus*	1.2
38150101	*Sericostoma personatum*	2.4
	DIPTERA	
40090000	Chironomidae	23.6

Figure F.1 Llyn y Fan Fawr: sample location and substrate map

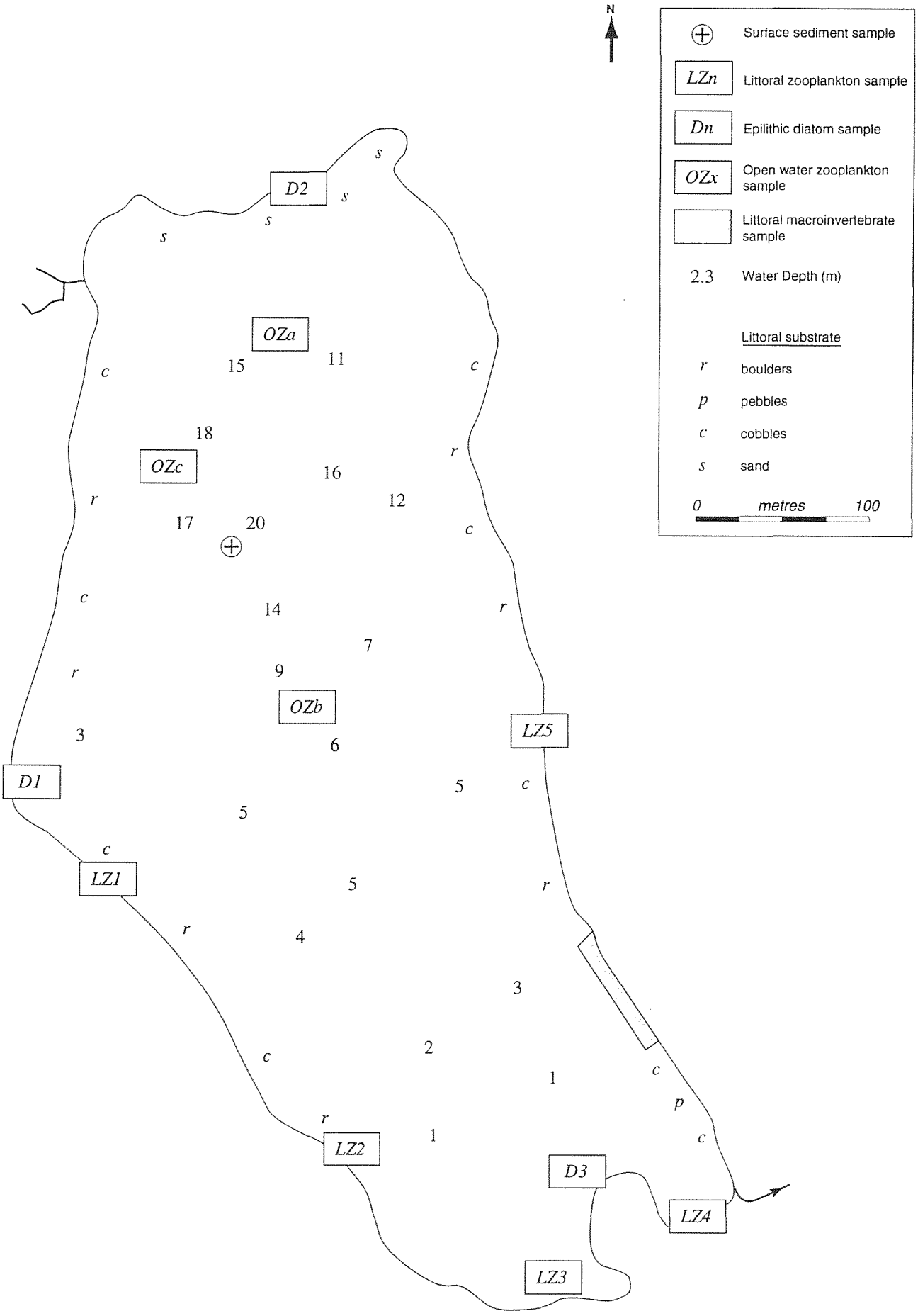


Figure F.2 Llyn y Fan Fawr: aquatic macrophyte distribution map 8-7-95

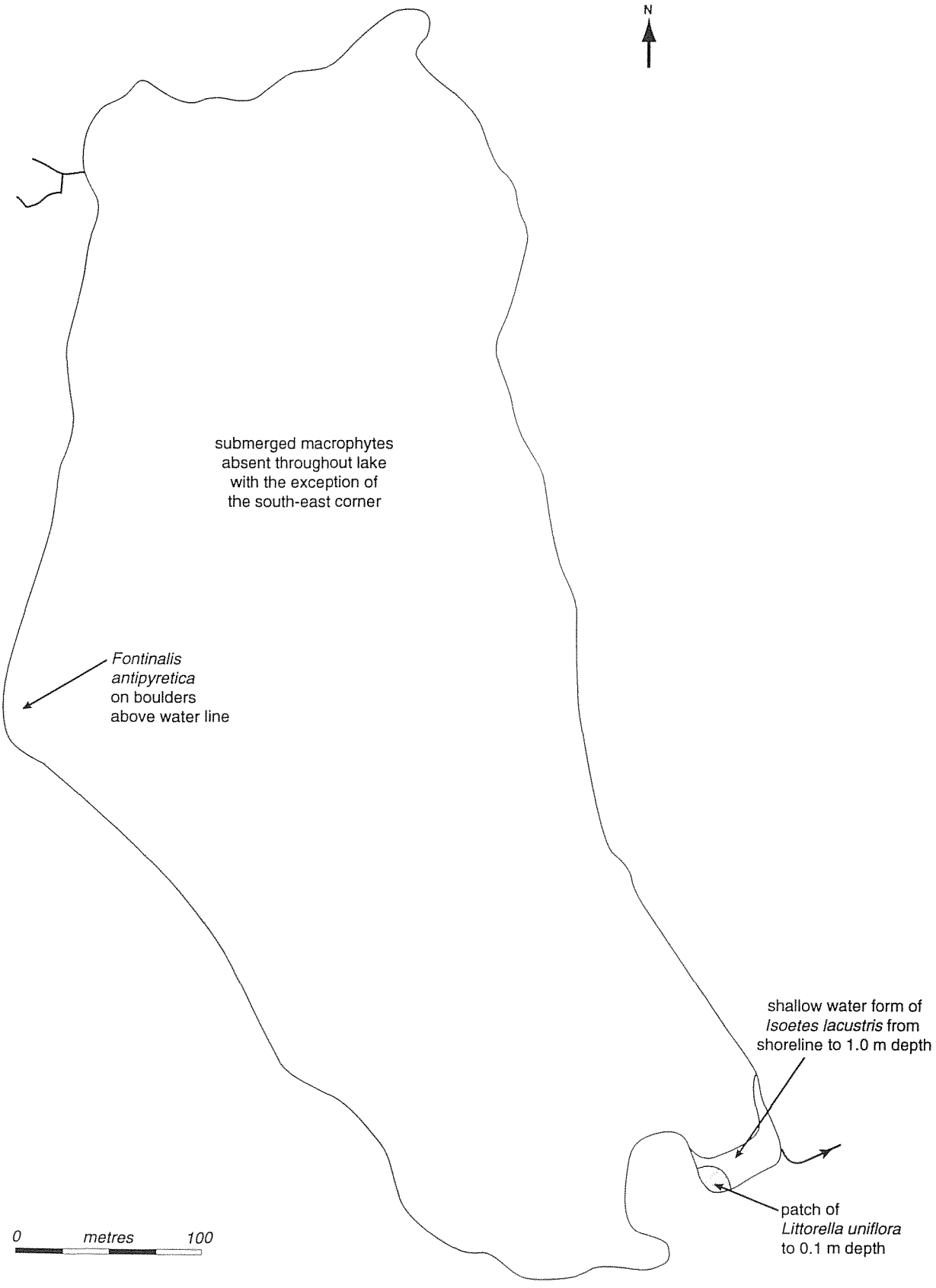
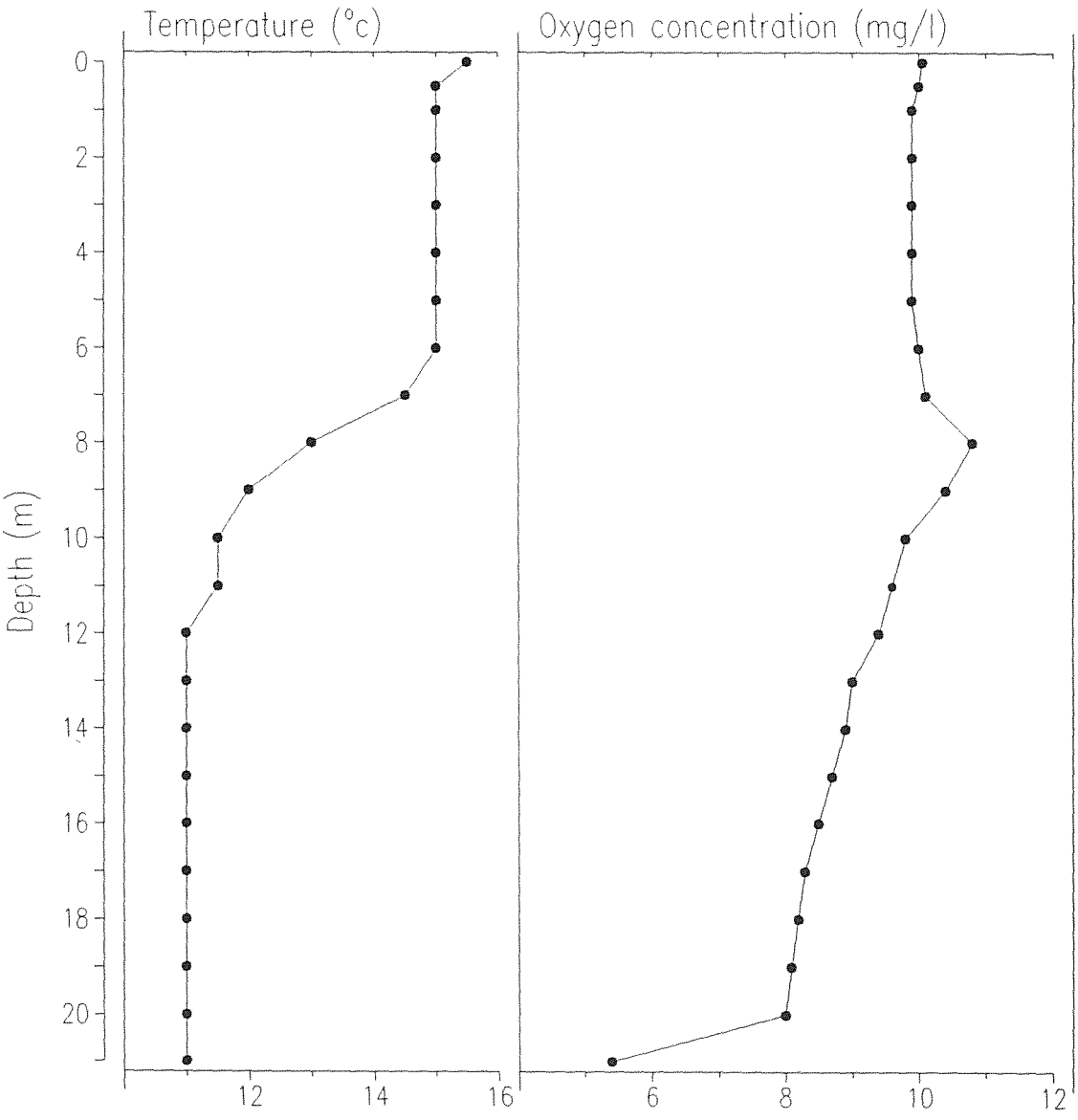


Figure F.4 Llyn y Fan Fawr: Temperature and dissolved oxygen profiles 5-7-95



Appendix G Notes on Cladocera sampling sites

G.1 Kenfig Pool, 5-7-95

Samples taken while walking around the shore

Site 1: Sandy beach, protected from the wind, almost no detritus

Site 2: Outer margin of *Phragmites*, depth ~50cm, dominated by *Chara* , *Myriophyllum*, rich in detritus, wind protected.

Site 3: Outer margin of *Phragmites*, within patch of *Polyganum*, *Chara* and detritus beneath, wind protected

Site 4: *Polyganum* bed, *Chara* and detritus beneath, wind exposed

Site 5: Sand/cobble beach, dominated by *Chara*

G.2 Llyn Llech Owain, 12-7-95

Samples taken while walking around the shore (s) or by boat (b)

Site 1: Rocky shore, 20-60cm depth (s)

Site 2: Eroded peat, no vegetation (b)

Site 3: Mud bottom, dominated by *Equisetum* and *Sphagnum*, 50cm depth (s)

Site 4: Eroded peat shoreline, *Nuphar* dominant (b)

Site 5: *Carex rostrata* bed (b), ~ 30cm depth

G.3 Llyn Fach, 8-7-95

Samples taken while walking around the shore (s) or by boat (b)

Site 1: Dense *Lobelia* bed, depth ~ 40cm depth (s)

Site 2: Sparse *Sparganium* bed, ~ 1m (b)

Site 3: *Lobelia* bed, ~ 10-40cm depth (s)

Site 4: *Juncus bulbosus* dominated, ~1m depth (b)

Site 5: *Lobelia* and *Isoetes* dominated, cobble substrate, 30-80 cm depth (s)

G.4 Llan Bwchllyn, 9-7-95

Samples taken while walking around the shore

Site 1: Outer margins of dense *Phragmites* bed, wind exposed

Site 2: Outer margins of *Phragmites* bed, wind protected

Site 3: Cobble substrate, wind protected, dense schools of fish fry

Site 4: Cobble substrate, wind exposed

Site 5: Within lilly bed, dense schools of fish fry

G.5 Llangorse Lake, 10-7-95

Samples taken while walking around the shore (s) or by boat (b)

Site 1: Dominated by *Nymphoides* and *Potamogeton pectinatus*, 80cm depth (b)

Site 2: Dominated by *Nuphar* and *Potamogeton pectinatus*, 80cm depth (b)

Site 3: Dominated by *Nuphar / Nymphaea* and *Potamogeton lucens*, dense schools of fish fry (b)

Site 4: Dominated by *Myriophyllum spicatum*, 40cm depth (s)

Site 5: Cobble /boulder substrate, *Myriophyllum spicatum* dominant (s)

Site 6: Sand substrate within mixed bed of *Polyganum* and *Scirpus* (s)

G.6 Llyn y Fan Fawr, 7-7-95

Samples taken while walking around the shore

Site 1: Rocky bottom, wind protected site

Site 2: Rocky bottom, protected bay

Site 3: Sand and cobbles, wind protected

Site 4: *Littorella* dominated bay

Site 5: Wind exposed shore, rocky bottom

Appendix H: Notes on littoral macroinvertebrate sampling sites

H.1 Kenfig Pool

-turbid water, sand/cobbles with silt between, *Littorella* along margin, macrophyte debris including *Potamogeton trichoides*, *Ranunculus circinatus* and *Elodea canadensis* in littoral.

H.2 Llyn Llech Owain

-brown water, large boulders with silt between, leaf litter, extensive stands of *Juncus effusus*, overhanging *Alnus*

H.3 Llyn Fach

-clear water, large cobbles under silt, abundant *Lobelia*, *Isoetes* and patches of *Juncus bulbosus.*

H.4 Llangorse Lake

-clear water, sand/gravel/silt, extensive stands of *Nymphoides peltata*, patches of *Myriophyllum spicatum*, some *Lemna minor* and *Lemna trisulca.*

H.5 Llyn y Fan Fawr

-clear water, large cobbles/boulders interspersed with patches of gravel and shingle, no macrophytes and no visible organic matter

Appendix I: A bibliography for the study sites

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Appendix J Previous macrophyte records for phase III sites

Kenfig Pool

Alisma plantago-aquatica (Seddon 1972)
Apium inundatum (Seddon 1972)
Baldellia ranunculoides (Seddon 1972) Newbold (1977)
Botumus umbellatus (Seddon 1972)
Caltha palustris (Seddon 1972)
Carex acuta (Seddon 1972)
Carex elata (Seddon 1972)
Carex nigra (Seddon 1972)
Carex otrubae (Seddon 1972)
Ceratophyllum demersum Vachell (1936) Seddon (1964) (Seddon 1972) Newbold (1977) Jones (1982)
Callitriche stagnalis (Seddon 1972)
Chara aspera var. *aspera* Chater (1995)
Chara sp. Newbold (1977)
Eleocharis palustris (Seddon 1972)
Epilobium hirsutum (Seddon 1972)
Elodea canadensis (Seddon 1972) Newbold (1977)
Epilobium palustre (Seddon 1972)
Equisetum fluviatile (Seddon 1972)
Equisetum palustre
Hippuris vulgaris (Seddon 1972)
Hydrocotyle vulgaris (Seddon 1972) Newbold (1977)
Iris pseudacorus (Seddon 1972)
Littorella uniflora (Seddon 1972) Newbold (1977)
Limosella australis Trow (1987) Marshall & Schoolbred (1901) Vachell (1933 & 1938) Guile (1943) Shanahan (1970)
Lycopus europaeus (Seddon 1972)
Lysmachia vulgaris (Seddon 1972)
Lythrum salicaria (Seddon 1972)
Menyanthes trifoliata (Seddon 1972)
Myosotis caespitosa (Seddon 1972)
Myriophyllum alterniflorum Vachell (1929) Kay (1972)
Myriophyllum spicatum (Seddon 1972) Newbold (1977)
Nymphaea alba (Seddon 1972)
Oenanthe fistulosa (Seddon 1972)
Oenanthe lachenalii (Seddon 1972)
Phragmites australis (Seddon 1972)
Polyganum amphibium (Seddon 1972) Newbold (1977)
Potamogeton crispus (Seddon 1972)
Potamogeton gramineus (Seddon 1972) Bowen (1982)
Potamogeton lucens Motley (1843) Trow (1908) Seddon (1964) (Seddon 1972)
Potamogeton natans (Seddon 1972)
Potamogeton pectinatus (Seddon 1972)
Potamogeton perfoliatus Newbold (1977)
Potamogeton pusillus Vachell (1930) Seddon (1964) (Seddon 1972) Newbold (1977)
Potamogeton trichoides Bowen (1982)
Ranunculus aquatilus (Seddon 1972)
Ranunculus circinatus (Seddon 1972)
Ranunculus trichophyllus (Seddon 1972)
Ranunculus flammula (Seddon 1972) Newbold (1977)
Scirpus lacustris (Seddon 1972)
Scirpus lacustris ssp.m *tabernaemontani* (Seddon 1972) Newbold (1977)
Scirpus maritimus Newbold (1977)
Zanichellia palustris Wade (1975)

Llyn Llech Owain

SSSI citation (1993) references to:

Carex rostrata
Equisetum fluviatile
Juncus bulbosus var. *fluitans*
Menyanthes trifoliata
Littorella uniflora
Nymphaea alba
Nuphar lutea
Potamogeton polygonifolius

Llyn Fach

Caltha palustris Palmer (1988)
Carex rostrata Trow (1911) (Seddon 1972) Newbold (1977) Palmer (1988)
Eleocharis palustris Palmer (1988)
Equisetum fluviatile Newbold (1977) Palmer (1988)
Eriophorum angustifolium Palmer (1988)
Glyceria fluitans Palmer (1988)
Isoetes echinospera Trow (1911) (Seddon 1972) Palmer (1988)
Isoetes lacustris Trow (1911) (Seddon 1972) Newbold (1977)
Juncus bulbosus Palmer (1988)
Juncus effusus Palmer (1988)
Littorella uniflora Trow (1911) (Seddon 1972)
Lobelia dortmanna Trow (1911) (Seddon 1972) Newbold (1977) Palmer (1988)
Lythrum portula Trow (1911) Palmer (1988)
Menyanthes trifoliata Trow (1911) (Seddon 1972)
Myriophyllum alterniflorum Trow (1911) (Seddon 1972) Newbold (1977)
Potamogeton polygonifolius (Seddon 1972) Newbold (1977) Palmer (1988)
Ranunculus flammula Palmer (1988)
Scirpus fluitans Trow (1911) (Seddon 1972) Newbold (1977) Palmer (1988)
Sparganium angustifolium Trow (1911) (Seddon 1972) Palmer (1988)
Sparganium minimum Newbold (1977)
Sphagnum sp. Palmer (1988)
Utricularia minor Trow (1911)

Llanbwchllyn

Agrostis stolonifera Thurley (1977)
Alisma plantago-aquatica Seddon (1972) Thurley (1977)
Callitriche sp. Thurley (1977) Cragg *et al.* (1981)
Caltha palustris Seddon (1972) Thurley (1977)
Carex acuta Thurley (1977)
Carex acutiformis Seddon (1972) Thurley (1977) Cragg *et al.* (1981)
Carex curta Seddon (1972)
Carex nigra Seddon (1972) Thurley (1977)
Carex riparia Seddon (1972) Thurley (1977)
Carex rostrata Seddon (1972) Thurley (1977) Cragg *et al.* (1981)
Carex vesicaria Seddon (1972) Thurley (1977)
Chara sp. Cragg *et al.* (1981)
Charophyta Thurley (1977)
Cladium mariscus Seddon (1972)
Eleocharis palustris Seddon (1972)
Epilobium hirsutum Seddon (1972)
Epilobium palustre Seddon (1972)
Equisetum fluviatile Seddon (1972)
Glyceria fluitans Seddon (1972)
Hydrocotyle vulgaris Seddon (1972) Thurley (1977)
Iris pseudacorus Thurley (1977)
Juncus effusus Thurley (1977) Cragg *et al.* (1981)

Lemna minor Seddon (1972)
Lemna trisulca Thurley (1977) Cragg *et al.* (1981)
Littorella uniflora Seddon (1972) Thurley (1977) Cragg *et al.* (1981)
Lycopus europaeus Seddon (1972)
Lysmachia vulgaris Seddon (1972)
Lythrum salicaria Seddon (1972)
Mentha aquatica Thurley (1977)
Menyanthes trifoliata Seddon (1972) Thurley (1977) Cragg *et al.* (1981)
Myriophyllum alterniflorum Seddon (1972) Thurley (1977) Cragg *et al.* (1981)
Myriophyllum spicatum Thurley (1977) Cragg *et al.* (1981)
Nuphar lutea Seddon (1972) Thurley (1977) Cragg *et al.* (1981)
Nymphaea alba Seddon (1972) Thurley (1977) Cragg *et al.* (1981)
Myosotis laxa Thurley (1977)
Myosotis scorpiodes Seddon (1972)
Myosotis secunda Seddon (1972)
Oenanthe crocata Seddon (1972)
Oenanthe fistulosa Seddon (1972)
Phragmites australis Seddon (1972) Thurley (1977) Cragg *et al.* (1981)
Polyganum amphibium Seddon (1972) Thurley (1977) Cragg *et al.* (1981)
Potamogeton berchtoldii Thurley (1977) Cragg *et al.* (1981)
Potamogeton crispus Seddon (1972) Thurley (1977) Cragg *et al.* (1981)
Potamogeton praelongus Thurley (1977)
Potentilla palustris Seddon (1972) Thurley (1977)
Ranunculus circinatus Cragg *et al.* (1981)
Ranunculus flammula Seddon (1972) Thurley (1977)
Ranunculus trichophyllus Thurley (1977)
Ranunculus lingua Seddon (1972)
Sparganium emersum Seddon (1972)
Sparganium erectum Seddon (1972) Thurley (1977)
Typha angustifolia Seddon (1972) Thurley (1977)
Typha latifolia Seddon (1972) Thurley (1977) Cragg *et al.* (1981)
Veronica anagallis-aquatica Seddon (1972)
Veronica beccabunga Seddon (1972) Thurley (1977)
Veronica scutellata Thurley (1977)

Llangorse Lake

See report by the International Centre of Landcape Ecology (1993).

Llyn y Fan Fawr

Nature Conservation Review (Ratcliffe, 1977) references to:

Fontinalis antipyretica
Isoetes lacustris
Littorella uniflora

Appendix K: 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 Assessmnet 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 Assessmnet 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.

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.

Duigan, C.A. (1995). Anglesey Lakes Symposium. Freshwater News -Special Issue, 8(1): 1-22.

Duigan, C.A. (1994). Llyn Cwellyn - recent survey work commissioned by the Countryside Council for Wales. Freshwater News 7(3): 10-14, Appendix I: 1-4.

Duigan, C.A., T.E.H. Allott, H. Bennion, J. Lancaster, D.T. Monteith, S.T. Patrick, J. Ratcliffe and J.M. Seda (1996). The Anglesey Lakes, Wales, UK - A Conservation Resource. Aquatic Conservation: Marine and Freshwater Ecosystems. 6, 31-55.

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.

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.

Media coverage related to the Anglesey Lakes Symposium included a series of radio and TV interviews by BBC Wales and press coverage.