Limnological Surveys of Welsh Lakes: Llyn Helyg, Llyn Bedydd and Pant-yr-ochain Pools, Clwyd

E. M. Shilland & D. T. Monteith

CCW Contract Science Report No. 486

Report to the Countryside Council for Wales

CCW Nominated Officer: Dr Catherine Duigan

September 2001

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

http://www.geog.ucl.ac.uk/ecrc

Distribution List

Countryside Council for Wales
- Nominated officer, Freshwater ecologist (8 copies)
- Biological Sciences Registry (1 copy)
- The librarian (1 copy)
- CCW Areas (5 copies)

Joint Nature Conservation Committee
- The librarian (1 copy)

English Nature
- The librarian (1 copy)

Scottish Natural Heritage
- The librarian (1 copy)

Department of the Environment (Northern Ireland)
- The librarian (1 copy)

The National Library of Wales
- The librarian (1 copy)

Executive Summary

1. Water chemistry, lake physical characteristics and aquatic macrophyte data collected between July 2000 and May 2001 are presented for three study sites in Clwyd, North Wales; Llyn Helyg, Llyn Bedydd and three of the Pant-yr-ochain Pools.

2. The field survey and analytical methodology follow those of previous reports on Welsh lakes by the Environmental Change Research Centre.

3. The survey data collected are used to classify the lakes based on existing standard schemes.

4. All three lakes are shallow, low altitude, dominated by silty substrates and actively managed for angling. Whilst all have high alkalinity, Llyn Helyg and Pant-yr-ochain Pool 1 exhibit moderate phosphorous whereas Llyn Bedydd is considerably more eutrophic. The water chemistry of the three sites generally falls within the limits of the previous CCW lake classification studies.

5. Llyn Helyg has an extensive submerged and emergent aquatic macrophyte flora. It is however appreciably different from that found historically, though rare species are still present. Eutrophication would appear to present a significant threat to the current assemblage.

6. Llyn Bedydd and Pant-yr-ochain pools 1 and 2 are devoid of submerged aquatic macrophytes. It is difficult to explain this by water chemistry alone. However the light environment of littoral habitats is restricted by high concentrations of total organic carbon and by shading from overhanging trees. In addition the disturbance of sediments from benthivorous fish may also be a detrimental factor.

7. The baseline status of the aquatic flora of all three sites could be established by palaeo-ecological techniques.

Crynodeb Weithredol

1. Cyflwynir cemeg dwr, nodweddion ffisegol llyn a data dyfrol macroffyt a gasglwyd rhwng Gorffennaf 2000 a Mai 2001 ar gyfer tri safle astudiaeth yng Nghlwyd, Gogledd Cymru; Llyn Helyg, Llyn Bedydd a thri o Lynnoedd Pant-yr-ochain.

2. Mae'r arolwg maes a'r fethodoleg ddadansoddol yn dilyn patrwm adroddiadau cynharach ar lynnoedd Cymru gan Ganolfan Ymchwil Newid Amgylcheddol.

3. Defnyddir y data a gasglwyd yn ystod yr arolwg i ddosbarthu'r llynoedd yn ol cynlluniau safonol sy'n bodoli ar hyn o bryd.

4. Mae'r tri llyn yn fas, o uchder isel, wedi'u dominyddu gan swbstradau lleidiog ac yn cael eu rheloli'n weithredol ar gyfer pysgota. Tra'u bod i gyd o alcalinedd uchel, mae Llyn Helyg a Llyn 1 Pant–yr –ochain i'w gweld yn weddol ffosfforaidd tra bo Llyn Bedydd yn llawer mwy ewtroffaidd. Mae cemeg dwr y tri safle yn gyffredinol o fewn terfynau astudiaethau dosbarthiad llynnoedd blaenorol CCGC.

5. Mae gan Llyn Helyg fflora dyfrol macroffyt helaeth yn suddedig ac uwchben y dwr. Mae'n dra gwahanol,fodd bynnag, i'r hyn a geir yn hanesyddol er bod rhywogaethau prin yn parhau yno. Byddai ewtroffeiddio yn cael ei weld yn fygythiad arwyddocaol i'r cyfosodiad presennol.

6. Nid oes macroffytau dyfrol suddedig yn Llyn Bedydd a llynnoedd 1 a 2 Pant-yr–ochain. Mae'n anodd esbonio hyn trwy gemeg dwr yn unig. Mae amgylchedd golau cynefinoedd arfordirol yn cael ei gyfyngu gan grynodiad uchel o garbon organig cyflawn a chan gysgod coed sy'n crogi drosodd. Ar ben hyn gallai hefyd y ffaith fod pysgod dyfnforol yn chwalu'r gwaddodion fod yn ffactor niweidiol.

7. Gellid sefydlu statws sylfaenol y fflora dyfrol ar y tri safle trwy dechnegau paleoecolegol.

Table of Contents **Page**

List of Figures

List of tables

1. Project Introduction

This report, commissioned by the Countryside Council for Wales (CCW), presents the data from the study of three lake sites in Clwyd, North Wales. Lake physical characteristics, water chemistry and aquatic macrophytes were recorded at Llyn Helyg (SJ 115774), Llyn Bedydd (SJ 471392) and Pant-yr-ochain Pools (SJ 348533).

All results presented here, except those for water chemistry, are based on one-off sampling and surveys in July 2000. Recognized experts verified Charophyte and *Ranunculus* specimens from Llyn Helyg. Water samples were collected on four occasions (July 2000, Nov 2000, Feb 2001 and May 2001). Samples for TP, SRP, NO_3 and Chl *a* were frozen on site and analysed at the CEH laboratories, Penicuik.

2. Site Descriptions

2.1 Llyn Helyg Site Description

Lying at an altitude of 177m, Llyn Helyg, (SJ 115774) is situated 6 km west of Holywell in North Wales (Table 2.1). It is currently being considered for SSSI designation.

The lake is largely spring-fed and possesses a single main outflow at the western end. It has a shallow bathymetry, reaching 1.1m in the deepest flat area of the single gently sloping basin. At the time of the survey, aquatic macrophyte cover was high throughout the site. Artificially constructed around the 18th century (Figure 2.3) it is thought to be lined with puddled clay.

Catchment soils are dominated by cambic stagnogley of the Brickfield 2 association, which surround the lake. To the east of the catchment there is also some typical brown earth, East Keswick 3 association. The underlying geology is of the Dinantian "Carboniferous Limestone series" (Tournaisian and Viséan).

The A5151 runs through the eastern end of the catchment, which is predominantly arable land (Figure 2.1). The bulk of the catchment consists of the deciduous woodland that surrounds the lake. There is also a coniferous area South West of the lake.

The llyn is used for fishing and hosts a local angling club. In 1931 Ward described the lake as containing "a few trout and many pike, bream, roach and perch. The edges are shallow and reedy and it is only fishable from a boat." The woodland that surrounds the lake is managed for shooting. Public access to the site is restricted. The lake also provides a habitat for a wide variety of wildfowl.

Table 2.1 Llyn Helyg Physical Characteristics

Grid Reference	SJ 115774
Lake Altitude	177 m
Maximum Depth	1.1 m
Mean Depth	0.7 m
Volume	133.7 x $10^3 m^3$
Lake Surface Area	19.1 ha
Shoreline Development Index	1.6
Estimated Hydraulic Residence Time	100 Days
Secchi Disc Depth	>1.0 m
Catchment Area (including lake)	60 ha
Catchment: Lake Ratio	3.1

Figure 2.1 Catchment of Llyn Helyg

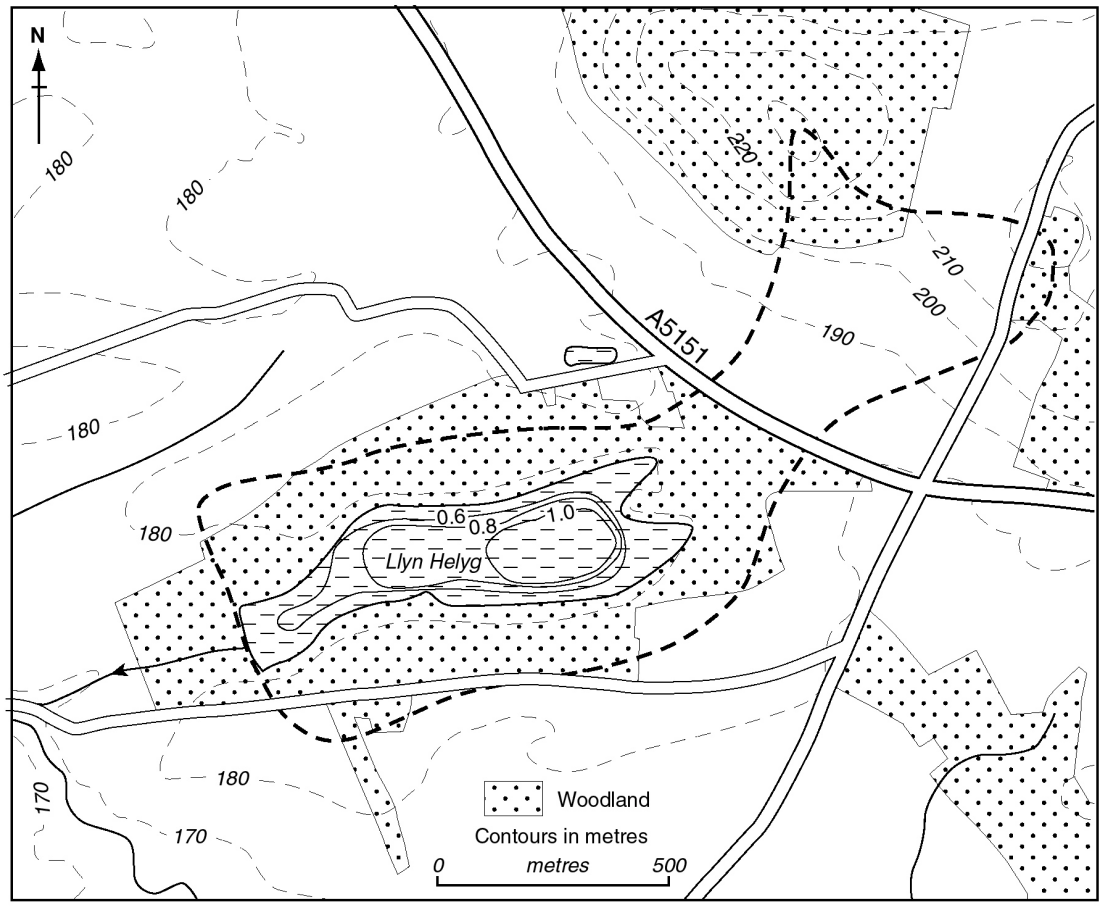
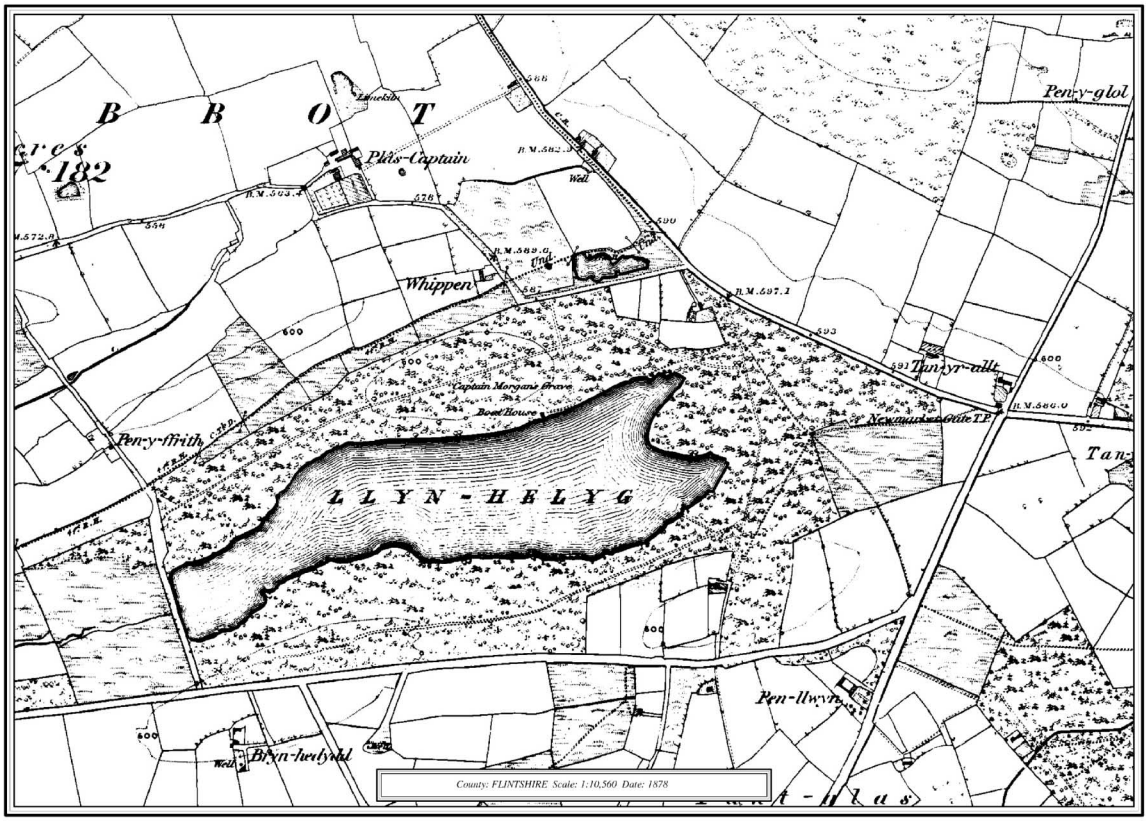


Figure 2.2 A View of Llyn Helyg

View from the northern shore looking southwest over a bed of *Nymphoides peltata*.

Figure 2.3 Llyn Helyg and Surrounding Area in 1878



2.2 Llyn Bedydd Site Description

Llyn Bedydd (SJ 471392) is a 1.1 ha lake, 7 km south west of Whitchurch (Table 2.2). The lake and surrounding woodland form the Llyn Bedydd SSSI.

The lake is small, shallow and heavily shaded by Alder. A diminutive inflow stream feeds the lake from the southern end and drainage is through overflow pipes at the northwestern corner. It has existed in its current shape and size since at least 1878 (Figure 2.6)

Catchment soils include typical brown earth of the Wick 1 association surrounding the lake and an area of Salop association typical stagnogley to the south. These overlie a geology of Lower Jurassic Lower Lias.

The lake is surrounded by deciduous woodland while the wider catchment includes arable and grazing land, a small amount of woodland in the south, the A495 and several minor roads (Figure 2.4).

Further details on site history can be found in Wigginton's 1980 England Field Unit report on the Survey of Shropshire, Cheshire and Staffordshire Meres (site 24). For Llyn Bedydd, the "Use" section states "Limited amount of fishing, but very little of the margin is suitable". Today however, there are at least seven fishing platforms constructed all around the lake perimeter, with associated access routes through the woodland.

Table 2.2 Llyn Bedydd Physical Characteristics

Grid Reference	SJ 471392
Lake Altitude	86 m
Maximum Depth	1.5 m
Mean Depth	0.8 m
Volume	$8.8 \times 10^3 m^3$
Lake Surface Area	1.1 ha
Shoreline Development Index	1.2
Estimated Hydraulic Residence Time	2 Days*
Secchi Disc Depth	0.4 m
Catchment Area (including lake)	275 ha*
Catchment: Lake Ratio	250*

*Difficult to determine true catchment extent from topographic data.

Figure 2.4 Catchment of Llyn Bedydd

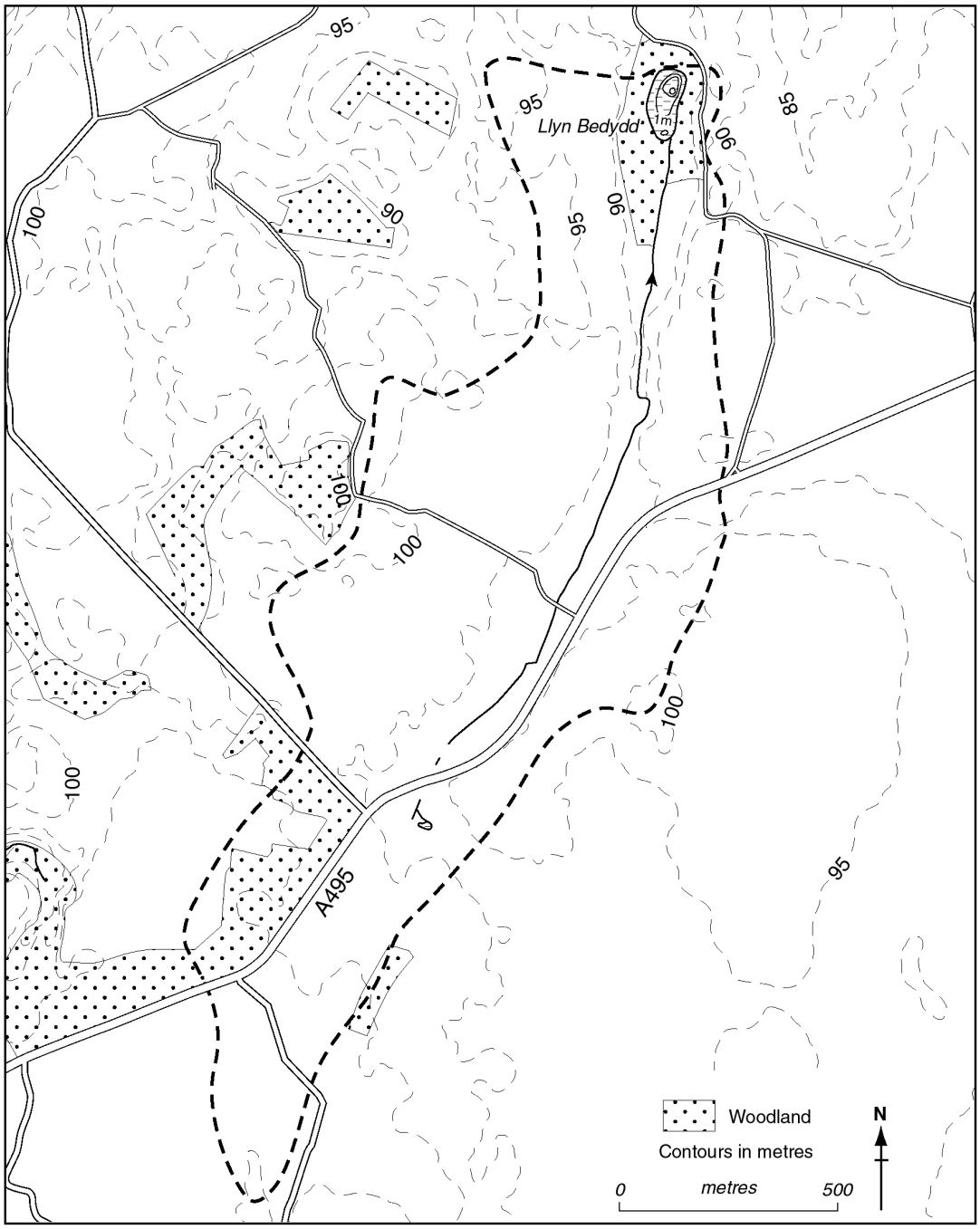
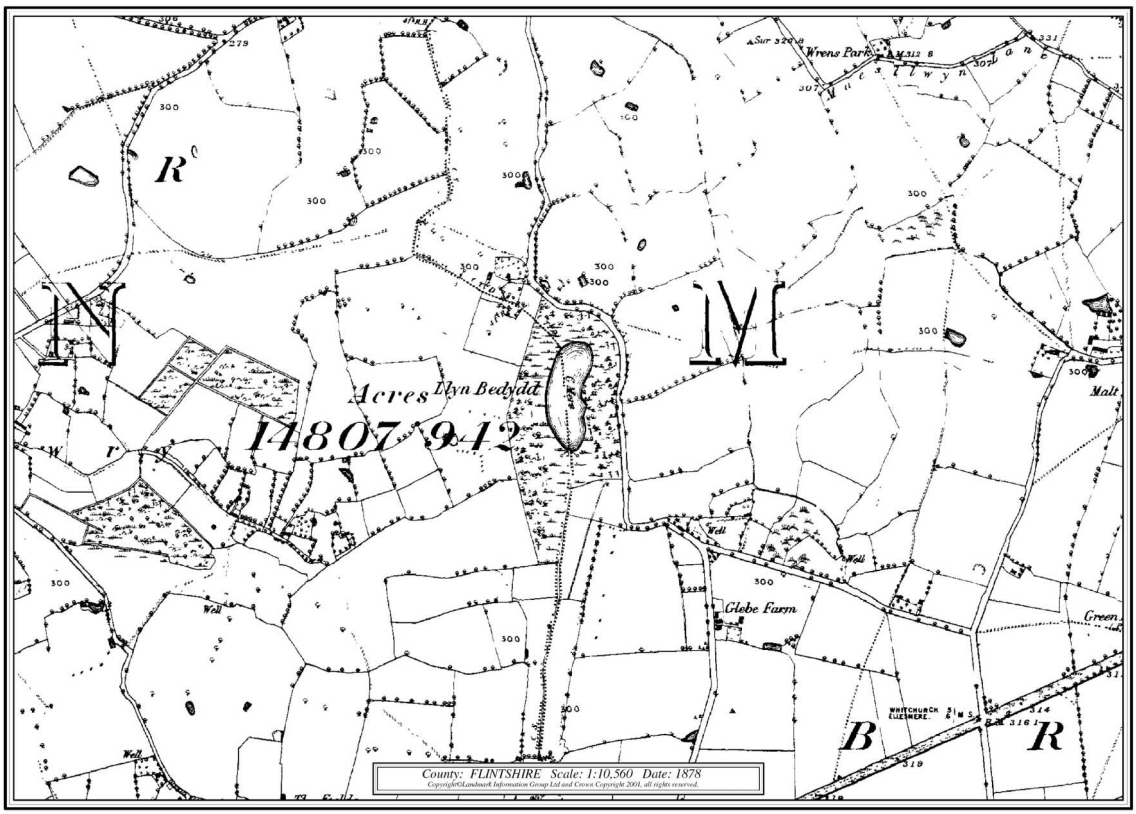


Figure 2.5 A View of Llyn Bedydd

View from the northern end of Llyn Bedydd looking south over some *Nuphar lutea.*

Figure 2.6 Llyn Bedydd and Surrounding Area in 1878



2.3 Pant-yr-ochain Pools Site Description

The Pant-yr-ochain Pools (SJ 348533), situated just North East of Wrexham, consist of a number of shallow pools of various sizes (Figure 2.7). In this project only the three most westerly were surveyed. The pools currently have no conservation designation.

The largest pool, pool 1, has two main basins, the deepest to the north, with a maximum depth of 2.3m (Table 2.3), and the other to the south with a maximum depth of 1.9m. Pool 2, immediately west of pool 1, consists of a single flat bottomed basin The northernmost pool, pool 3, shelves gently from the west, with the deepest 2.2m area by the eastern edge. When water levels are particularly high all three pools become connected. According to a conversation with the site owner, Mr. Jones, the pools are primarily ground-water fed systems, tightly linked to the water table, and levels fluctuate on an approximately 15 year cycle. Levels in these and other nearby pools were much lower when local coalmines were in operation. Though the pools have been present for some time at the site, historically they were less extensive (Figure 2.9).

Catchment geology is exclusively Westphalian and Stephanian from the Silesian Carboniferous. Soils are typical brown sands of the Newport 1 association.

The low relief catchment is difficult to define precisely, but includes the A5156 and parts of northeastern Wrexham. Both larger pools, pools 1 and 2, are heavily shaded by surrounding Alder forest whereas grazing land encircles pool 3.

Pools 1 and 3 are stocked and used for angling.

Table 2.3 Pant-yr-ochain Physical Characteristics

Grid Reference	SJ 348533
Lake Altitude	72 m
Maximum Depth	2.3 m
Mean Depth (pool 1)	1.0 m
Volume (excluding pool 3)	$57 \times 10^3 m^3$
Lake Surface Area (excluding pool 3)	5.7 ha
Shoreline Development Index (excluding pool 3)	2.1
Estimated Hydraulic Residence Time	44 Days
Secchi Disc Depth	0.65 m
Catchment Area (including all pools)	68 ha
Catchment: Lake Ratio	11.9

Figure 2.7 Catchment of Pant-yr-ochain Pools

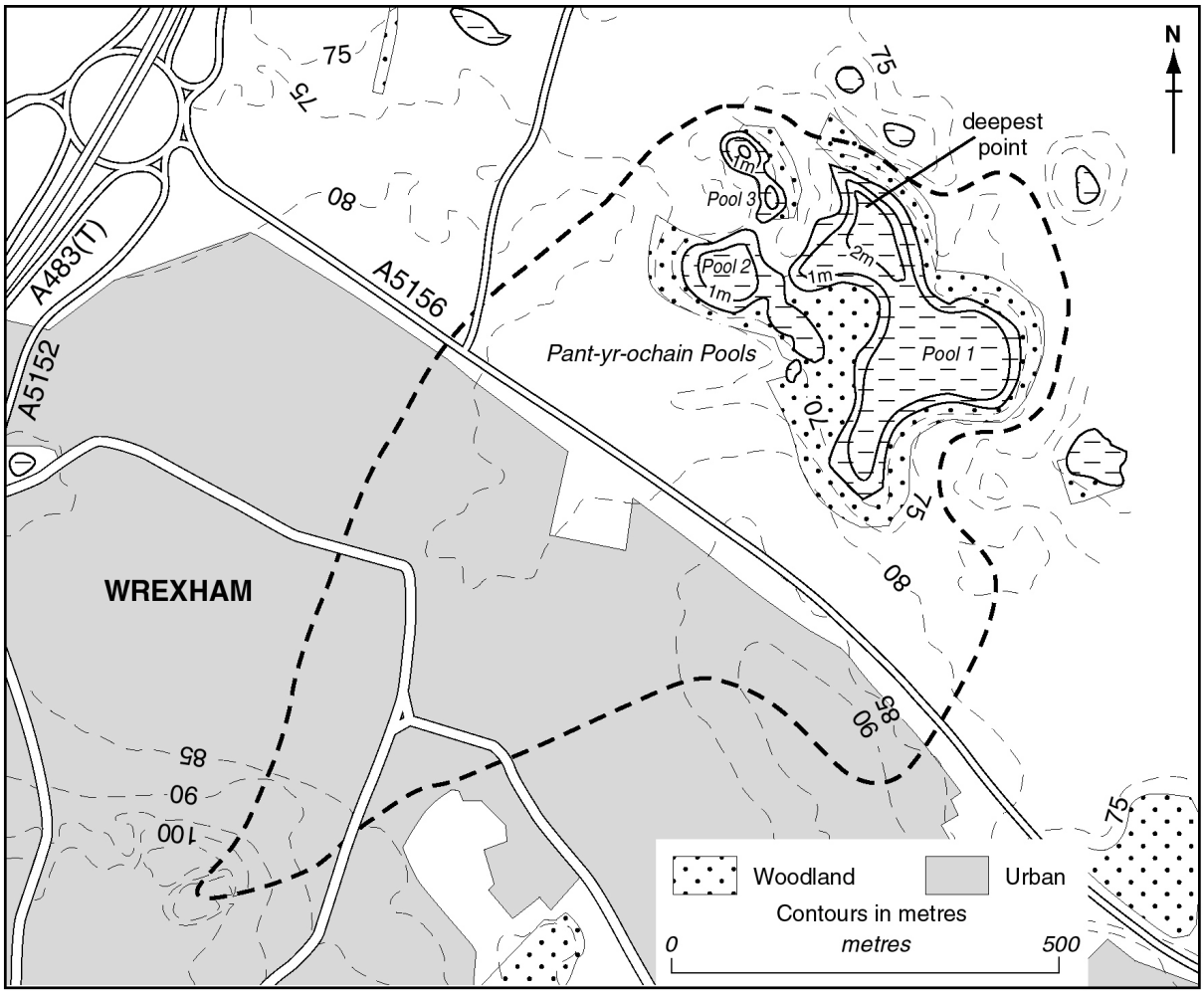


Figure 2.8 A View of Pant-yr-ochain Pool 1

View looking southeast from the northern end of Pant-yr-ochain Pool 1.

Figure 2.9 Pant-yr-ochain and Surrounding Area in 1900

3. Methods

Sampling methods for the project were set in the CCW tender document. These followed those of Allott *et al* (1994) where they are discussed in detail. Also incorporated were the methodological amendments reported in Monteith (1995). Particular effort was made with grab, grapnel and bathyscope techniques to find submerged vegetation in Llyn Bedydd and the Pant-yr-ochain pools. Voucher specimens of the charophyte species were sent to Nick Stewart and those of *Ranunculus* to Nigel Holmes.

4. Results

4.1 Chemistry

Chemical analysis was undertaken on water samples obtained on four visits to each site, July 2000, November 2000, February 2001 and again in May 2001. The last sampling was originally scheduled for early May but was slightly delayed by the Foot and Mouth disease outbreak. The analysis was performed at the Scottish Office Agriculture and Fisheries Department Freshwater Fisheries Laboratory with the exception of samples for TP, SRP. NO_3 and Chlorophyll *a,* which were frozen on site and subsequently sent to CEH Penicuik.

4.1.1 Llyn Helyg Water Chemistry

Water chemistry figures for Llyn Helyg (Table 4.1) are indicative of a relatively alkaline and nutrient rich lake. Total phosphorus values fluctuate throughout the year and reach a high of 91.4 µg l^{-1} in the February sample. Nitrate levels remain low however, being highest in November at only 5.2 µeq l^{-1}. pH remains at around 7.20 except for a high value in the May sample, which is likely to have been influenced by photosynthetic activity at the time of sampling. The physio-chemical profiles recorded during the July visit (Figures 4.1 and 4.2) demonstrate that Llyn Helyg was unstratified, relatively isothermic and only slightly deoxygenated at the bottom. Secchi depth on the same date was greater than the depth of the lake.

Both mean annual Chlorophyll *a* values and mean annual TP concentrations would classify Llyn Helyg as eutrophic according to the OECD classification (OECD 1982).

Table 4.1 Llyn Helyg Water Chemistry

	18-Jul-00	17-Nov-00	8-Feb-01	24-May -01	Mean
pH	7.20	7.17	7.28	9.89	7.89
Alkalinity (µeq l^{-1})	675	654	544	546	605
Conductivity (µS cm^{-1})	138	136	126	148	137
Sodium (µeq l^{-1})	460	414	379	384	409
Ammonium (µeq l^{-1})	<0.5	<0.5	<0.5	<0.5	<0.5
Potassium (µeq l^{-1})	8	21	25	6	15
Magnesium (µeq l^{-1})	230	203	188	183	201
Calcium (µeq l^{-1})	764	821	629	670	721
Chloride (µeq l^{-1})	505	434	393	399	433
Nitrate (µeq l^{-1})	1.1	5.2	2.4	1.4	2.5
Sulphate (µeq l^{-1})	86	157	138	117	125
Silicate (µg l^{-1})	120	1160	280	260	455
Total P (µg l^{-1})	37.4	18.6	91.4	39.7	46.8
TSP (µg l^{-1})	29.8	15.2	34.0	32.3	27.8
Soluble Reactive P (µg l^{-1})	7.2	5.6	16.0	11.6	10.1
Soluble Reactive SiO2 (mg l^{-1})	0.15	1.57	0.25	0.38	0.59
Aluminium - Total Monomeric (µg l^{-1})	<5	13	6	40	15
Aluminium - non-labile (µg l^{-1})	<5	11	6	13	8
Aluminium - labile (µg l^{-1})	<5	2	<5	27	7
Absorbance at 250 nm	0.274	0.412	0.315	0.395	0.349
Total Organic Carbon (mg l^{-1})	11.7	12.2	9.5	12.4	11.5
Chlorophyll *a* (µg l^{-1})	3.6	7.6	32.0	3.4	11.7

Figure 4.1 Llyn Helyg Oxygen Profile

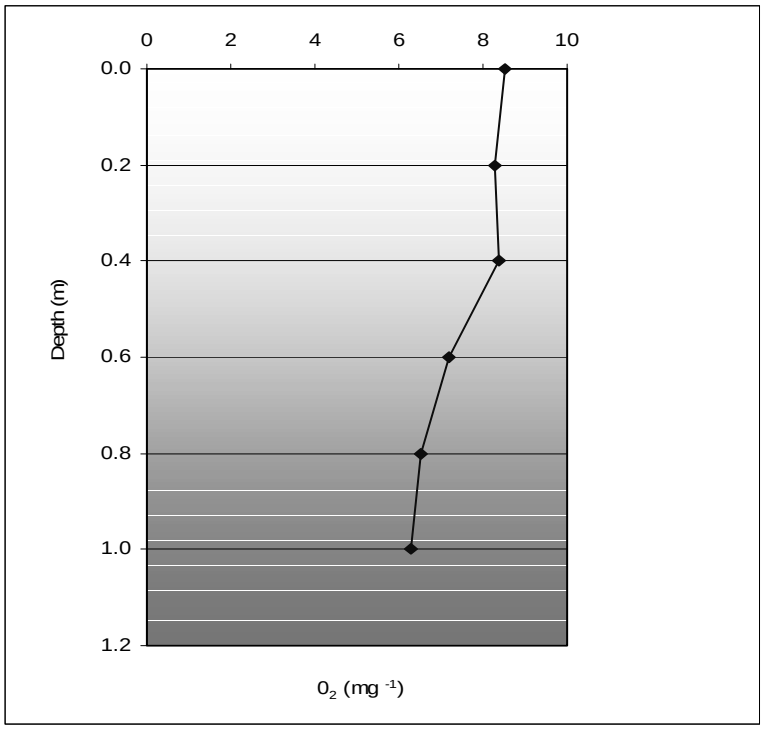
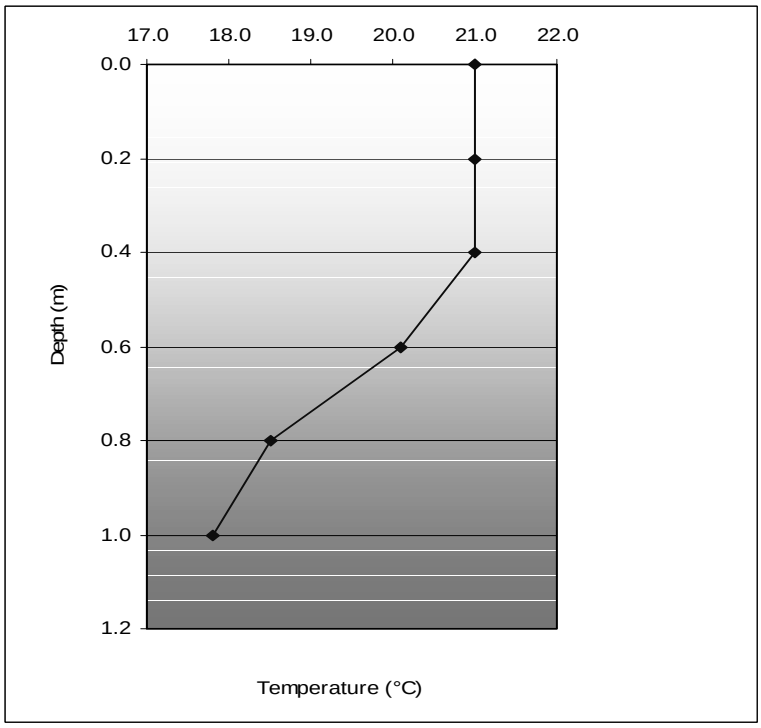


Figure 4.2 Llyn Helyg Temperature Profile



4.1.2 Llyn Bedydd Water Chemistry

The water chemistry of Llyn Bedydd is indicative of a highly alkaline and nutrient rich lake (Table 4.2). Alkalinity values only dip below 2000 µeq l^{-1} in the November sample. Total phosphorous values are also consistently high with the minimum recorded in the November sample of 231.5 µg l^{-1}. Nitrate values show distinct seasonality, exhibiting a high of 263 µeq l^{-1} in the February sample and a low of 1.25 µeq l^{-1} in July. As SRP levels remain high it is likely that productivity in Llyn Bedydd is N limited during the summer. Both Sodium and Chloride levels are variable, exhibiting a joint maximum in the February sample. TOC levels are consistently high and explain the very low Secchi transparency, 0.4m, recorded in July. The oxygen and temperature profiles recorded in the July visit (Figures 4.3 and 4.4) both gradually decline from the lake surface down though deoxygenation at the bottom of the lake is only partial.

According to the OECD classification of 1982 mean annual TP concentrations classify Llyn Bedydd as hyper-eutrophic, however mean annual Chlorophyll *a* is only at a eutrophic level.

Table 4.2 Llyn Bedydd Water Chemistry

	19-Jul-00	17-Nov-00	8-Feb-01	24-May -01	Mean
pH	7.67	6.89	7.46	7.37	7.35
Alkalinity (µeq l^{-1})	2984	1713	2095	2508	2325
Conductivity (µS cm^{-1})	430	292	463	444	407
Sodium (µeq l^{-1})	707	493	1324	837	840
Ammonium (µeq l^{-1})	22	57	44	82	51
Potassium (µeq l^{-1})	462	337	330	368	374
Magnesium (µeq l^{-1})	1054	692	881	974	900
Calcium (µeq l^{-1})	2758	1761	2275	2656	2363
Chloride (µeq l^{-1})	947	580	1586	1070	1046
Nitrate (µeq l^{-1})	1.25	39.00	263.00	181.00	121.06
Sulphate (µeq l^{-1})	337	383	488	623	458
Silicate (µg l^{-1})	9210	4400	5980	4620	6053
Total P (µg l^{-1})	777.2	581.9	231.5	385.6	494.1
TSP (µg l^{-1})	589.5	499.4	171.3	366.0	406.6
Soluble Reactive P (µg l^{-1})	545.2	437.5	135.5	304.8	355.8
Soluble Reactive SiO2 (mg l^{-1})	7.98	5.82	5.45	4.88	6.033
Aluminium - Total Monomeric (µg l^{-1})	6	47	32	26	28
Aluminium - non-labile (µg l^{-1})	6	26	9	5	12
Aluminium - labile (µg l^{-1})	<5	21	23	21	16
Absorbance at 250 nm	1.371	1.302	0.876	1.152	1.175
Total Organic Carbon (mg l^{-1})	16.0	28.6	22.8	47.0	28.6
Chlorophyll *a* (µg l^{-1})	53.9	1.2	4.5	4.1	15.9

Figure 4.3 Llyn Bedydd Oxygen Profile

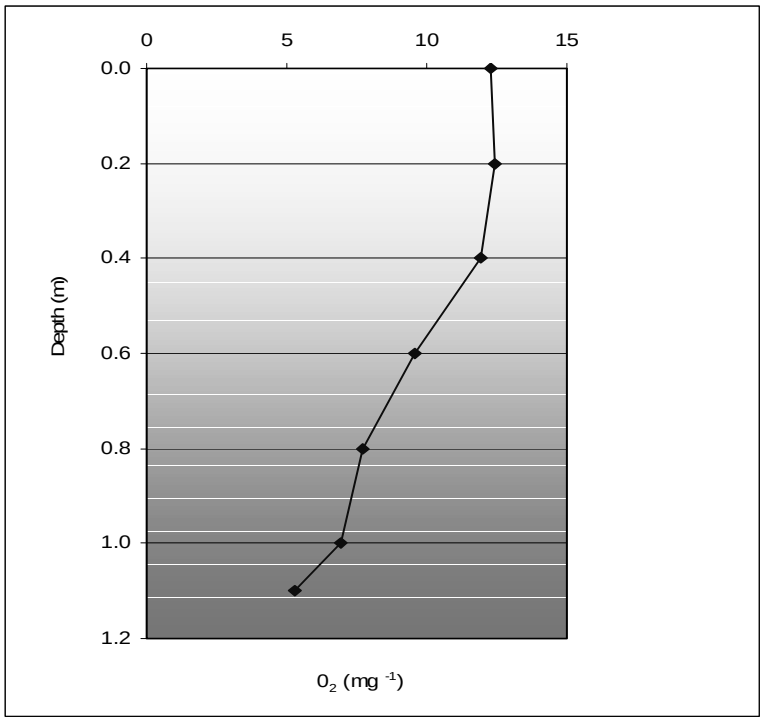
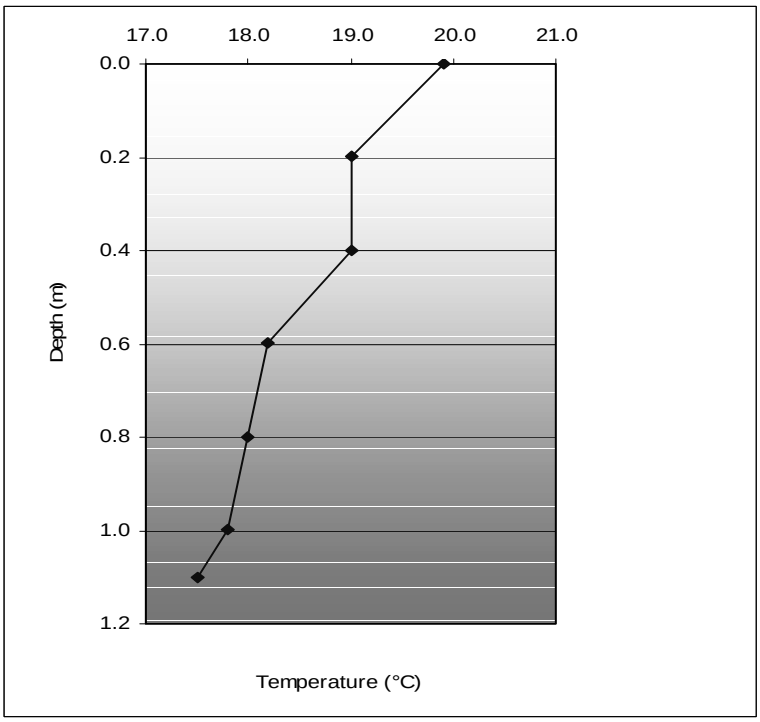


Figure 4.4 Llyn Bedydd Temperature Profile



4.1.3 Pant-yr-ochain Water Chemistry

Pant-yr-ochain Pool 1 is highly alkaline, with an average value in excess of 4000 µeq l^{-1}, and high pH, which reaches 8.00 in the July sample (Table 4.3). Conductivity values are also very high at >500 µS cm^{-1} for all samples. TP values are moderately high and remain consistent at around 60 µg l^{-1} all year whereas nitrate values peak in the February sample at 51 µeq l^{-1}. Chlorophyll *a* peaks at high levels in the two winter samples. Secchi depth for Pool 1, measured in July, was low at only 0.65 m. The oxygen and temperature profiles recorded on the same day (Figures 4.5 and 4.6) revealed deoxygenation at the lake bottom. Deoxygenation in Pool 3 (Figures 4.7 and 4.8) is even more severe.

Mean annual TP concentrations classify Pant-yr-ochain Pool 1 as eutrophic according to the OECD classification (OECD 1982), whereas the site is classified hyper-eutrophic according to its mean annual Chlorophyll *a* concentrations.

Table 4.3 Pant-yr-ochain Pool 1 Water Chemistry

	20-Jul-00	17-Nov-00	8-Feb-01	24-May -01	Mean
pH	8.00	7.69	7.90	7.83	7.86
Alkalinity (µeq l^{-1})	4110	4000	4270	3677	4014
Conductivity (µS cm^{-1})	547	507	554	551	540
Sodium (µeq l^{-1})	851	764	766	804	796
Ammonium (µeq l^{-1})	6	24	11	17	15
Potassium (µeq l^{-1})	67	66	62	63	65
Magnesium (µeq l^{-1})	840	765	808	810	806
Calcium (µeq l^{-1})	4765	4165	4289	4669	4472
Chloride (µeq l^{-1})	969	895	864	948	919
Nitrate (µeq l^{-1})	1.00	15.00	51.00	46.00	28.25
Sulphate (µeq l^{-1})	683	587	835	1010	779
Silicate (µg l^{-1})	10630	5930	12550	4570	8420
Total P (µg l^{-1})	60.3	59.1	61.2	60.5	60.3
TSP (µg l^{-1})	22.5	25.3	12.2	34.0	23.5
Soluble Reactive P (µg l^{-1})	4.1	8.0	5.2	17.2	8.6
Soluble Reactive SiO2 (mg l^{-1})	9.01	7.20	8.92	5.27	7.60
Aluminium - Total Monomeric (µg l^{-1})	<5	8	3	<5	3
Aluminium - non-labile (µg l^{-1})	<5	8	3	<5	3
Aluminium - labile (µg l^{-1})	<5	<5	<5	<5	<5
Absorbance at 250 nm	0.285	0.224	0.199	0.259	0.242
Total Organic Carbon (mg l^{-1})	6.3	8.5	6.8	8.1	7.4
Chlorophyll *a* (µg l^{-1})	25.8	44.2	65.9	14.3	37.6

Figure 4.5 Pant-yr-ochain Pool 1 Oxygen Profile

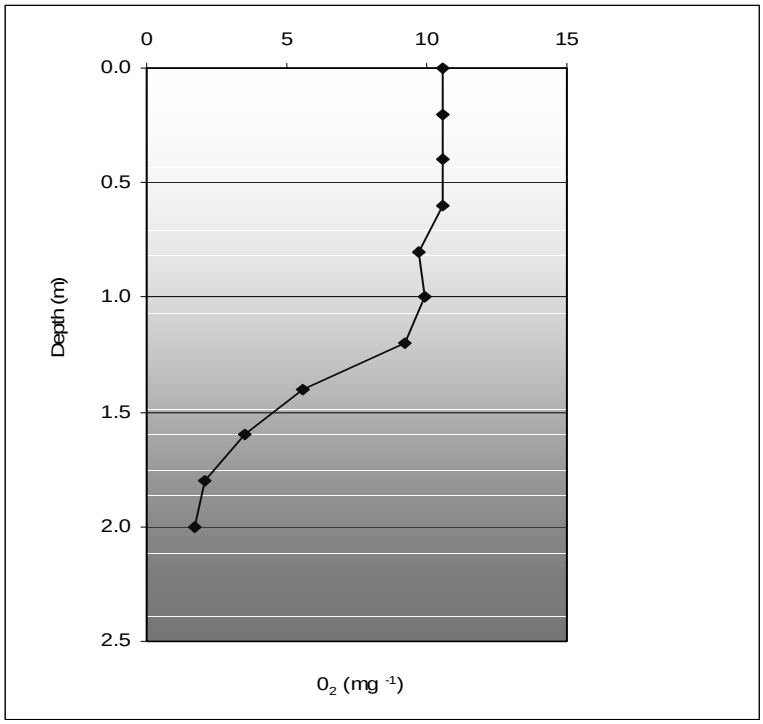


Figure 4.6 Pant-yr-ochain Pool 1 Temperature Profile

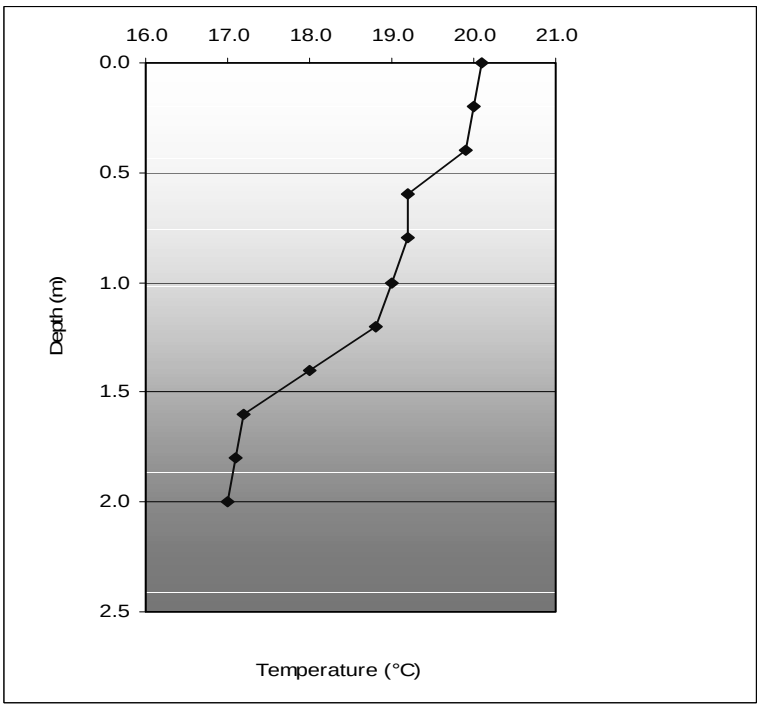


Figure 4.7 Pant-yr-ochain Pool 3 Oxygen Profile

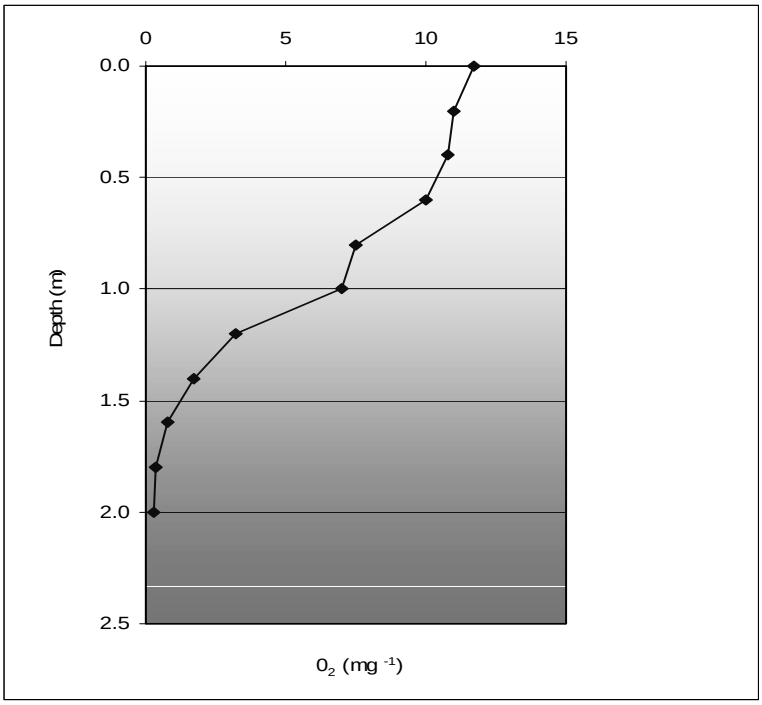
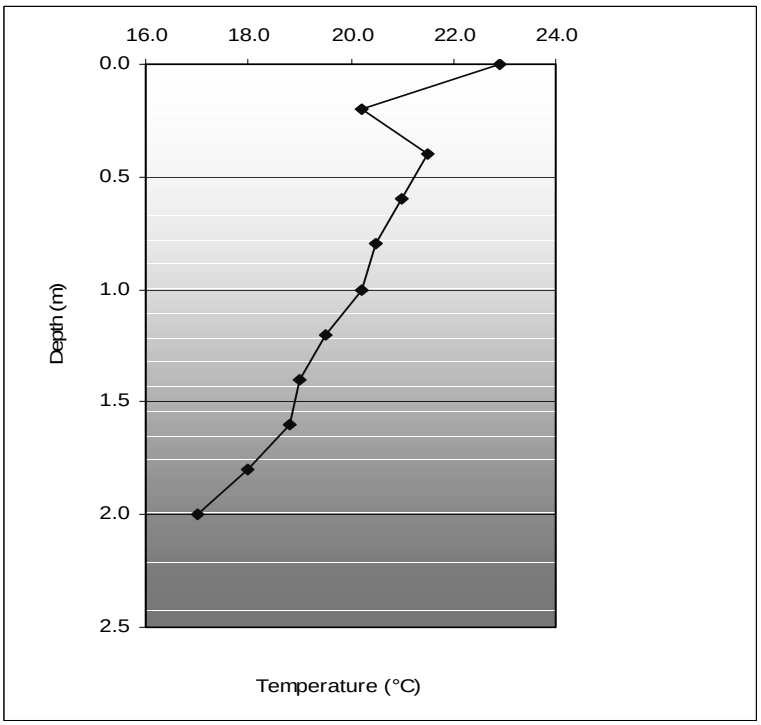


Figure 4.8 Pant-yr-ochain Pool 3 Temperature Profile



4.2 Aquatic Macrophyte communities

Figure 4.9 Llyn Helyg Aquatic Macrophyte Distributions

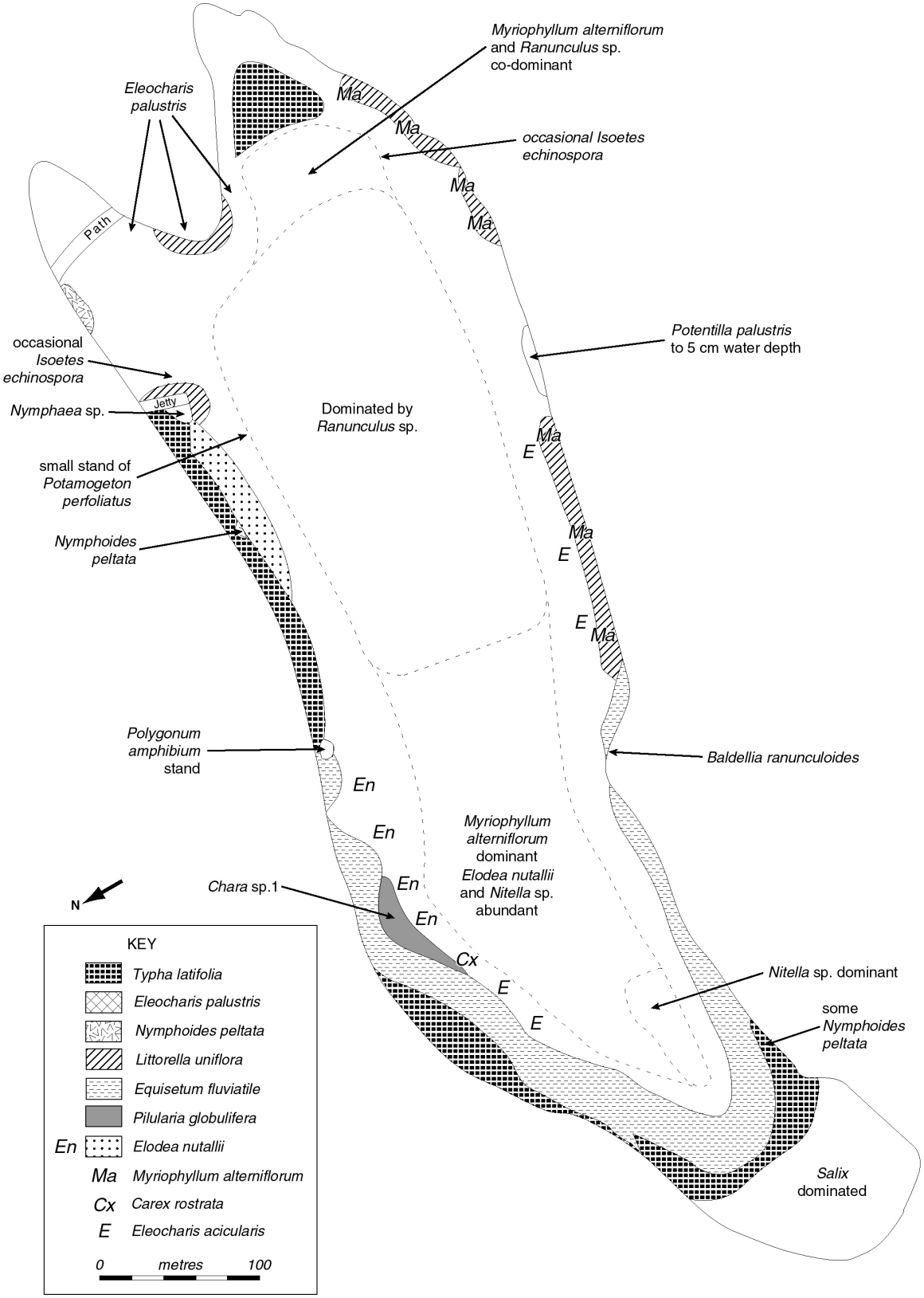


Table 4.4 Llyn Helyg Aquatic Macrophyte Relative Abundance

Taxon	Code	Abundance
Submerged		
Nitella flexilis var *flexilis*	NBNSYS0000101615	F
Chara virgata	NBNSYS0000039858	O
Isoetes echinospora	NBNSYS0000002009	R
Pilularia globulifera	NBNSYS0000002089	O
Crassula helmsii	NBNSYS0000004639	R
Littorella uniflora	NBNSYS0000004280	F
Myriophyllum alterniflorum	NBNSYS0000003610	A
Eleocharis acicularis	NBNSYS0000002394	F
Elodea nuttallii	NBNSYS0000002115	F
Potamogeton perfoliatus	NBNSYS0000002134	R
Floating leaved		
Nymphaea sp.	NBNSYS0000135676	O
Nymphoides peltata	NBNSYS0000003977	O
Polygonum amphibium	NBNSYS0000003752	O
Emergent		
Equisetum fluviatile	NBNSYS0000002016	F
* *cf. Ranunculus peltatus* x *omiophyllus*		A
Baldellia ranunculoides	NBNSYS0000002099	R
Carex rostrata	NBNSYS0000002426	O
Mentha aquatica	NBNSYS0000004198	O
Typha latifolia	NBNSYS0000002369	O
Other marginal wetland taxa		
Carex pseudocyperus	NBNSYS0000002425	R
Eleocharis palustris	NBNSYS0000002397	O
Lycopus europaeus	NBNSYS0000004206	F
Potentilla palustris	NBNSYS0000003338	F

* Ranunculus ID from Dr Nigel Holmes, pers comm.

4.2.1 Llyn Helyg Aquatic Macrophytes

Llyn Helyg is extremely shallow, reaching a maximum depth of only 1 m, and aquatic macrophytes occur in abundance throughout the lake (Figure 4.9 and Table 4.4). At the time of our survey the eastern side of the central area of the lake was dominated by an aquatic *Ranunculus* hybrid, possibly *Ranunculus peltatus* x *omiophyllus* (NVC Community A20), whilst the western side was dominated by *Myriophyllum alterniflorum* (A13). The western end also hosted abundant *Elodea nuttallii* and *Nitella flexilis* var *flexilis*, with the *Nitella* the predominate species in a small area at the far western end of the open water. In a small section of the eastern end of the lake *Myriophyllum alterniflorum* and the *Ranunculus* species were co-dominant. In the slightly shallower water towards the shores these mid-lake assemblages were replaced by other species. *Eleocharis acicularis* occurred in this zone on the southern and northwestern sides of the lake. Adjacent to the *Eleocharis acicularis* beds in the northwest was an area of *Pilularia globulifera* intermixed with some *Chara virgata*. The non-native *Elodea nuttallii* was also found in this area but was spread along the bulk of the northern edge of the site as well, forming areas of NVC community A15. Fringing the southern shore, the jetty and in between the two eastern bays were large strips of *Littorella uniflora* (A22). A few specimens of *Isoetes echinospora* were found in the southeastern corner of the lake and off the small jetty in the northeast. A similarly diminutive stand of *Potamogeton perfoliatus* (A13a) was found growing just to the west of the same jetty. *Crassula helmsii*, an introduced species, appeared in limited amounts in the southeastern bay.

Floating leaved species were less well represented in the site than the submerged species, both in terms of number of species and abundance of those present. A single small area of *Polygonum amphibium*, (NVC community A10), occurred approximately half way along the site's northern edge. The sole stand of water lily, a *Nymphaea alba* garden cultivar, was recorded next to the jetty in the northeast. Another introduced species, *Nymphoides peltata*, was found in small colonies both near the jetty and in the southwest corner of the lake and a somewhat larger colony in the northeastern bay.

The emergent aquatic vegetation at Llyn Helyg was dominated by two main species, *Typha latifolia* and *Equisetum fluviatile*. The NVC S12 *Typha latifolia* community formed a fringe round the western, and much of the northern, edges of the site and also occurred in a stand in the southeastern bay. *Equisetum fluviatile* (S10), however, was abundant only in the western half of the lake, forming a continuous fringe over much of that area. Where it shared shoreline with *Typha latifolia*, it tended to grow in the slightly deeper water. *Carex rostrata* (S9) grew in a small area near the *Pilularia globulifera* in the northeast of the llyn. In between the two bays at the eastern end of the site was a restricted stand of *Eleocharis palustris* (S19) Finally, a small area of another garden cultivar, *Glyceria maxima*, was growing next to the jetty.

For this survey Llyn Helyg has a trophic ranking score of 7.3 (Palmer *et al* 1992) and is characterised as site type 5A, a mesotrophic category, by Palmer (1992).

An extremely large Swan Mussel, *Anodonta cygnea* was observed during the surveying.

Figure 4.10 Llyn Bedydd Aquatic Macrophyte Distribution

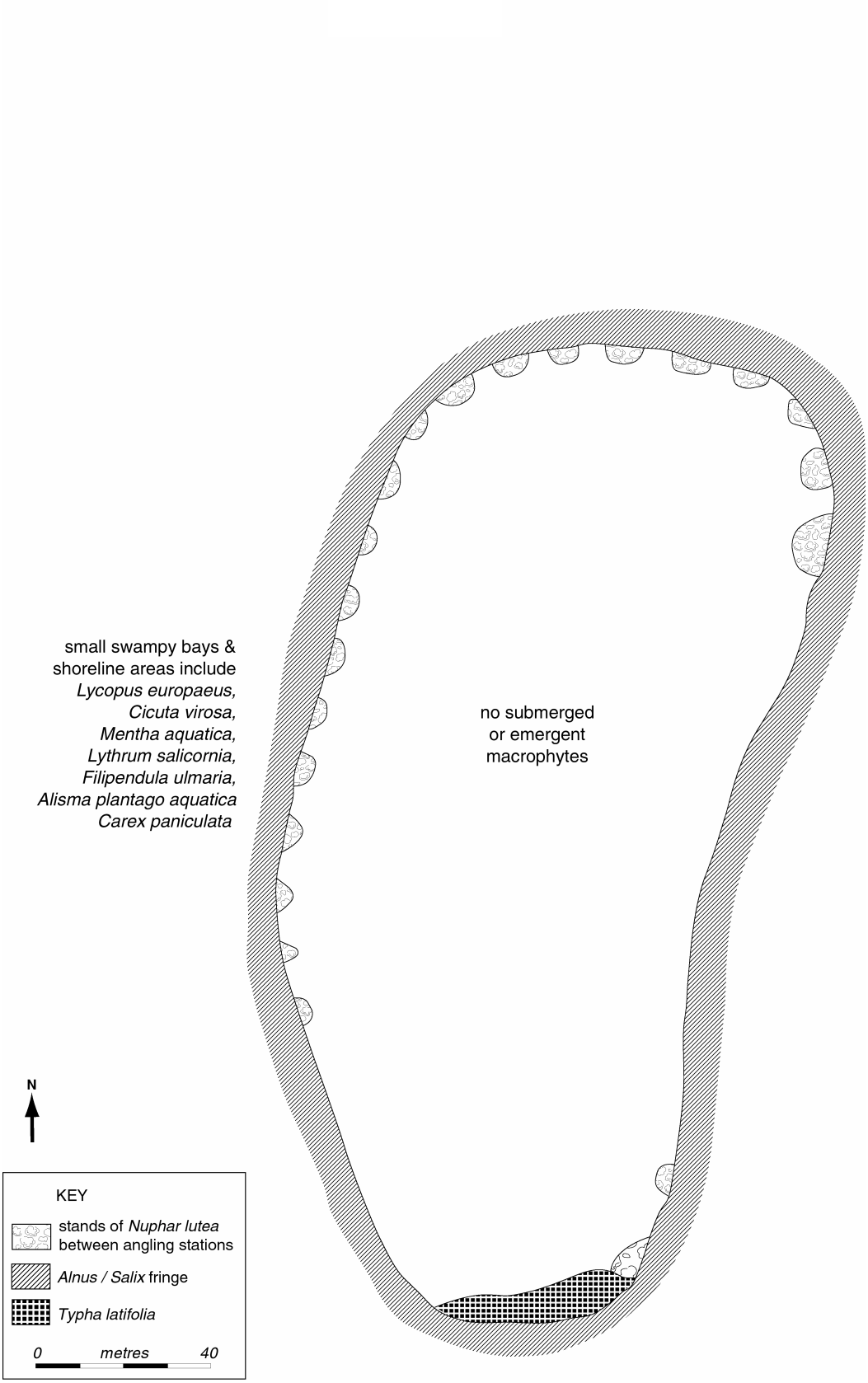


Table 4.5 Llyn Bedydd Aquatic Macrophyte Relative Abundance

Taxon	Code	Abundance
Floating leaved		
Nuphar lutea	NBNSYS0000002758	A
Emergent		
Alisma plantago aquatica	NBNSYS0000002101	R
Iris pseudacorus	NBNSYS0000002269	R
Typha latifolia	NBNSYS0000002369	O
Other marginal wetland taxa		
Carex paniculata	NBNSYS0000002464	F
Carex acutiformis	NBNSYS0000002431	O
Cicuta virosa	NBNSYS0000003674	O
Lythrum salicaria	NBNSYS0000003524	O
Mentha aquatica	NBNSYS0000004198	O
Filipendula ulmaria	NBNSYS0000003316	R
Lysimachia vulgaris	NBNSYS0000003936	R

4.2.2 Llyn Bedydd Aquatic Macrophytes

Aquatic macrophyte data for Llyn Bedydd is presented in Table 4.5 and Figure 4.10. Submerged vegetation is completely absent from the lake. *Nuphar lutea* represents the sole floating leaved species present (NVC community A8). It mainly occurs in stands between the fishing stations that are positioned around the northern and western shores of the lake and is presumably prevented from forming a continuous fringe by physical disturbance. Some smaller stands also occur at the southeastern end of the lake.

Emergent vegetation is limited to the southernmost margin of the site and consists of a single stand of *Typha latifolia*, NVC community S12. Within this stand occasional specimens of *Iris pseudacorus* and *Alisma plantago aquatica* were found. An overhanging *Alnus* and *Salix* fringe surrounds the rest of the lake.

The trophic ranking score for the species list above is 8.5. (Palmer *et al* 1992) and the site is typed as 9, a floating leaved dominated eutrophic category, by Palmer (1992).

Figure 4.11 Pant-yr-ochain Pool 1 Aquatic Macrophyte Distribution

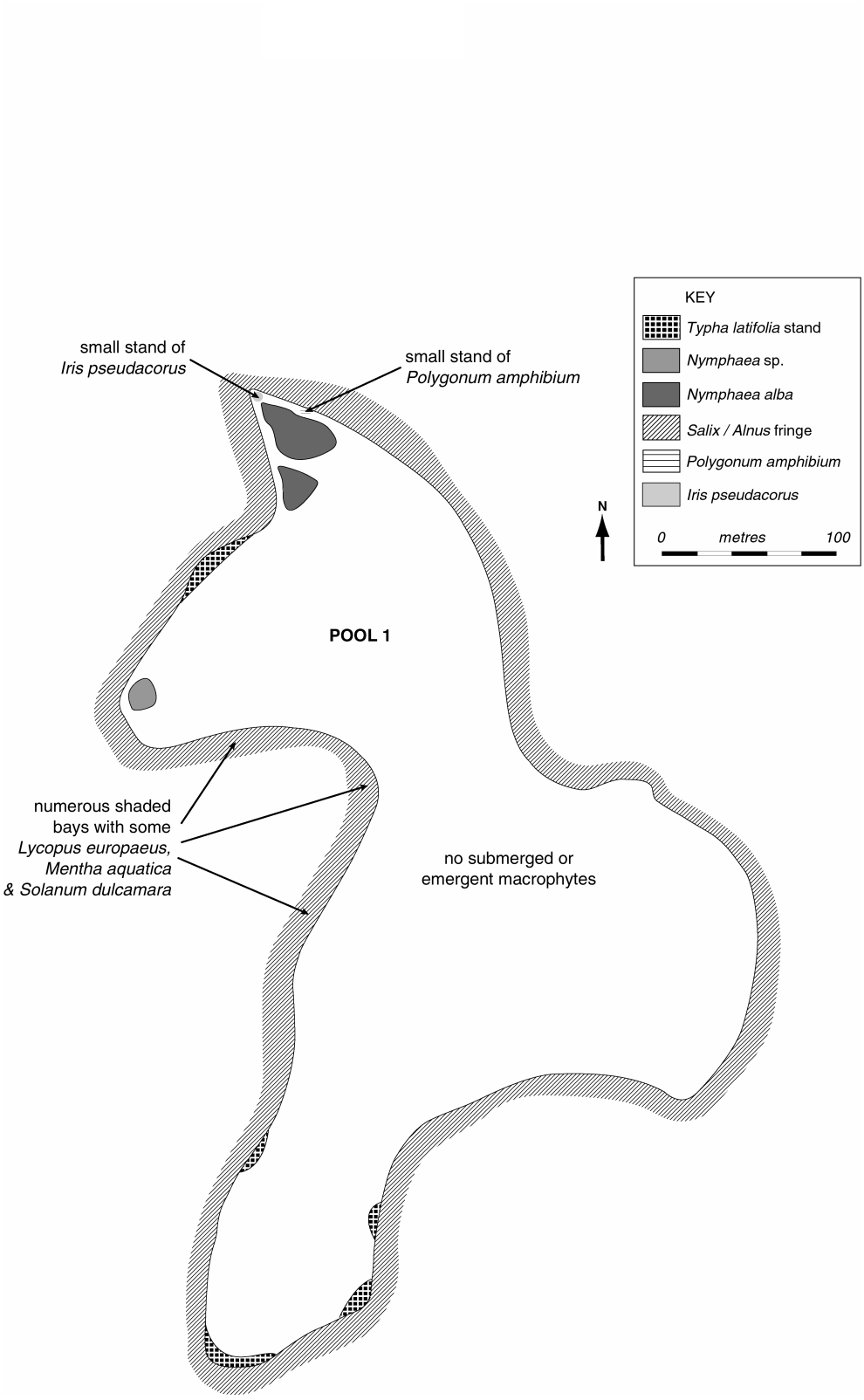


Table 4.6 Pant-yr-ochain Pool 1 Aquatic Macrophyte Relative Abundance

Taxon	Code	Abundance
Floating leaved		
Nymphaea alba	NBNSYS0000002757	F
Nymphaea sp.	NBNSYS0000135676	O
Polygonum amphibium	NBNSYS0000003752	R
Emergent		
Mentha aquatica	NBNSYS0000004198	R
Iris pseudacorus	NBNSYS0000002269	O
Typha latifolia	NBNSYS0000002369	O

4.2.3.1 Pant-yr-ochain Pool 1 Aquatic Macrophytes

Pool 1 at Pant-yr-ochain is devoid of any submerged macrophyte species (Table 4.6 and Figure 4.11). Representing floating leaved plants are *Nymphaea alba*, an undetermined *Nymphaea* cultivar and *Polygonum amphibium.* Of these *Nymphaea alba* is the most abundant, situated in two stands at the northern end of the lake forming NVC community A7a. On one side of this, closer to shore, is a very small area of *Polygonum amphibium* (A10). The *Nymphaea* cultivar forms a single small stand in a bay on the west of the site.

Emergent macrophytes are also limited in both numbers and space in Pool 1. One bed of *Typha latifolia* (NVC community S12) was found at the northern end of the site and four more fringing small areas of the far southern bay. *Iris pseudacorus* forms a small stand at the extreme northern tip of the lake and very occasional specimens of *Mentha aquatica* grow on the lake fringes, under the overhanging *Salix* and *Alnus* that surrounds the entire pool.

Using Palmer *et al* (1992) Pool 1 has a trophic index score of 8.75. Palmer (1992) classifies the site as type 8, a category that includes eutrophic sites with species poor open water.

Of note is that the site landowner maintained that Water Soldier, *Stratiotes aloides* was formerly present in Pool 1 and that an adult female Great Crested Newt, *Triturus cristatus* was found on the shore on the day of the survey.

Figure 4.12 Pant-yr-ochain Pools 2 and 3 Aquatic Macrophyte Distribution

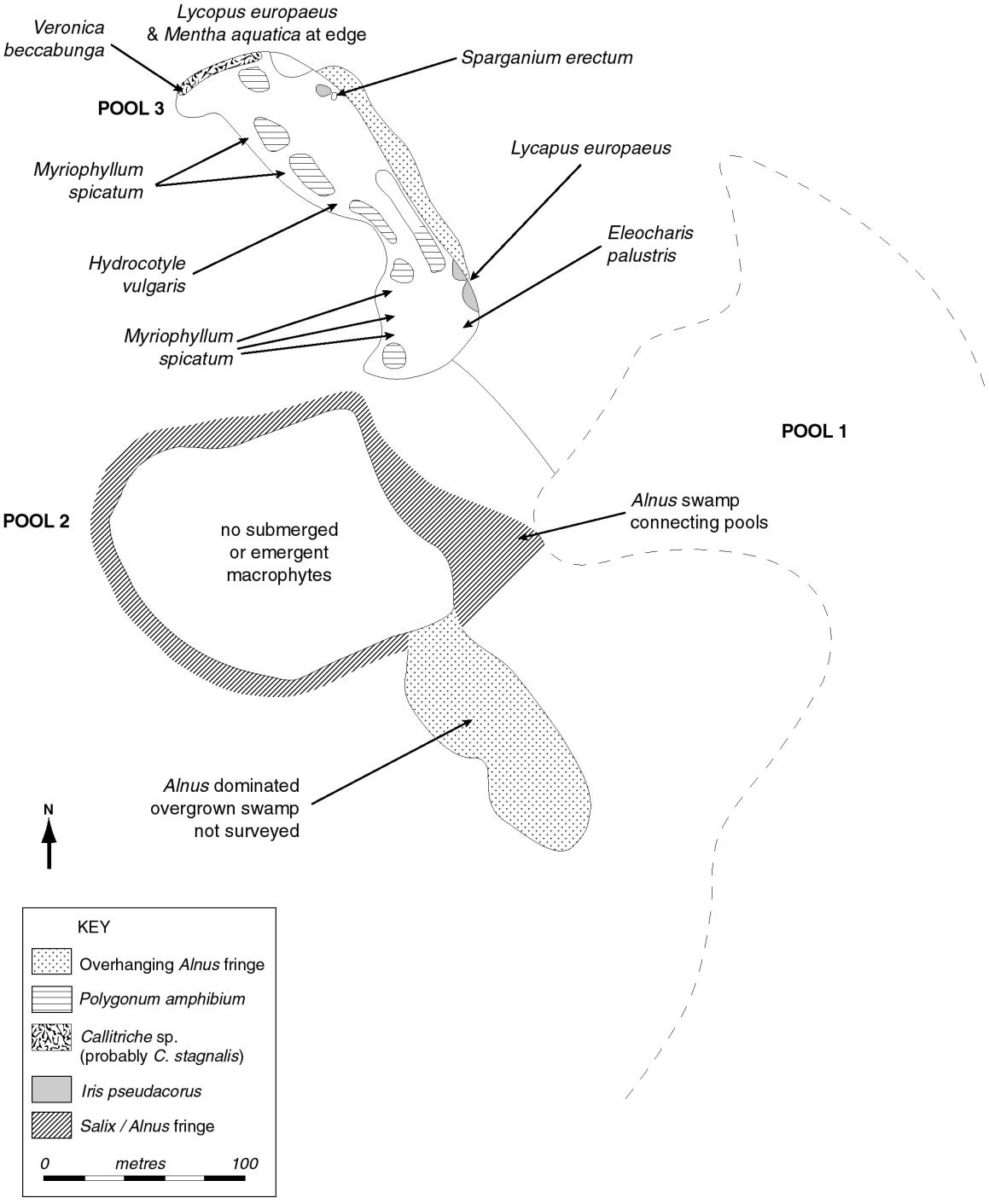


Table 4.7 Pant-yr-ochain Pool 3 Aquatic Macrophyte Relative Abundance

Taxon	Code	Abundance
Submerged		
Callitriche stagnalis	NBNSYS0000143455	O
Myriophyllum spicatum	NBNSYS0000003608	F
Floating leaved		
Polygonum amphibium	NBNSYS0000003752	A
Emergent		
Hydrocotyle vulgaris	NBNSYS0000003633	O
Veronica beccabunga	NBNSYS0000004096	R
Iris pseudacorus	NBNSYS0000002269	O
Phalaris arundinacea	NBNSYS0000002669	O
Sparganium erectum	NBNSYS0000002361	R
Typha latifolia	NBNSYS0000002369	R

4.2.3.2 Pant-yr-ochain Pool 2 Aquatic Macrophytes

No submerged, floating leaved or emergent species were present in Pool 2 (Figure 4.12). The pool margin was heavily shaded by overhanging *Alnus* sp.

4.2.3.3 Pant-yr-ochain Pool 3 Aquatic Macrophytes

Pool 3 has the richest aquatic macrophyte assemblage of the Pant-yr-ochain sites studied, possesses the least amount of fringing *Alnus* around its bank and is the only pool that has any submerged species (Table 4.7 and Figure 4.12). *Myriophyllum spicatum*, of NVC community type A11 occurs down much of the western side of the pool whilst a bed of *Callitriche stagnalis* (A16a) grows along the shallow northern fringe. The only floating leaved species that occurs is *Polygonum amphibium* (A10). It is abundant however, with several distinct stands covering much of the pool, interspaced on the western side with *M. spicatum* and some *Hydrocotyle vulgaris*. *Iris pseudacorus* was found at the south eastern edge of the site and also in a small stand in the north east, right next to a very small area of *Sparganium erectum,* S14d.

According to the species list above this pool has a trophic ranking score of 8.9 (Palmer *et al* 1992) and is typed as 8 after Palmer (1992), the same category as Pool 1.

Figure 4.13 PCA of the physio-chemical determinands for 31 Welsh Lakes (From Allott & Monteith 1999) also Incorporating Data for the Three Study Lakes

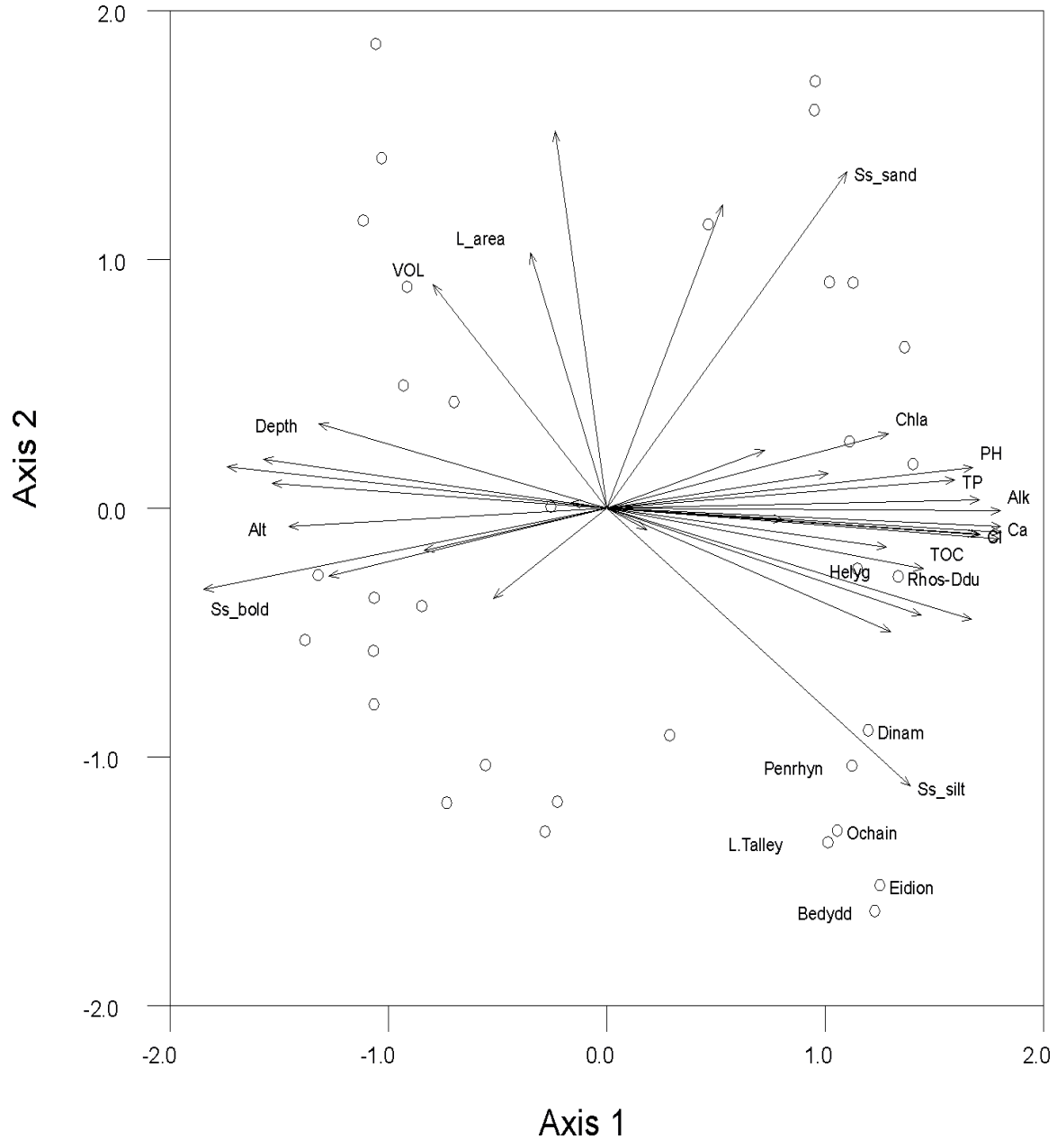
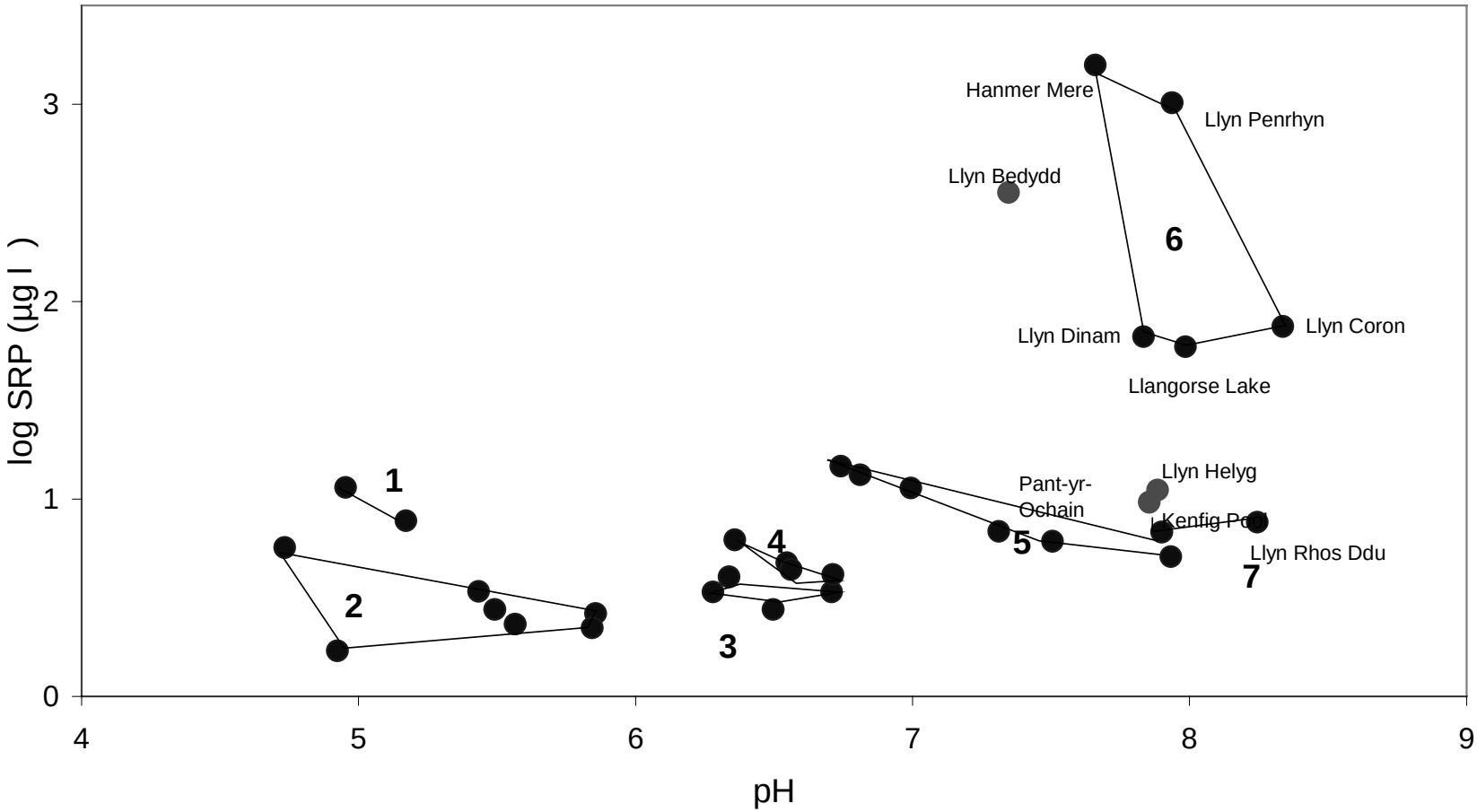


Figure 4.14 Mean Soluble Reactive Phosphorous-pH plot for 31 Welsh Lakes (From Allott & Monteith 1999) also Incorporating Data for the Three Study Lakes (Groupings Defined by Integrated Biological TWINSPAN Classification).



5. Discussion

This report provides summaries of the water chemistry, physical characteristics and aquatic macrophytes of Llyn Helyg, Llyn Bedydd and three of the Pant-yr-ochain pools surveyed over the period July 2000 to May 2001. Situated in north east Wales all three sites are shallow, alkaline, lowland lakes surrounded wholly or in part by deciduous woodland and are subject to angling pressures.

With respect to the chemistry of the lakes Llyn Bedydd has the highest nutrient loads, demonstrating very high nitrate and TP concentrations. However in relation to the 31 other sites forming an earlier part of this study (Allott & Monteith, 1999) all three can be considered at the eutrophic end of the nutrient gradient.

Using the same physio-chemical variables as Allott *et al* (1999) the three study sites in this report were added passively to the 1999 data set in a PCA (Principle Components Analysis). Figure 4.13 shows the positions of Llyn Helyg, Llyn Bedydd and Pant-yr-ochain within this 31-lake ordination. The three sites fall on the right hand side of the plot, the principle environmental gradient described by Allott & Monteith (1999), indicating their enriched, alkaline status. In a similar ordination of welsh lake chemistry and aquatic macrophytes Seddon (1972) also found that Llyn Helyg plotted as a biologically productive, hard water site. Llyn Helyg Pant-yr-ochain and Llyn Bedydd cluster together and their positioning on the second axis can be seen to be influenced largely by their small size and the silty nature of their substrates. The closest sites to these two lakes from the original study are, respectively, Lower Talley Lake in Dyfed and Llyn yr Wyth Eidion on Anglesey, both small, nutrient rich lakes. Llyn Helyg plots close to Llyn Rhos-ddu, which is another Anglesey lake. Similar to Llyn Helyg, Llyn Rhos-Ddu is shallow, alkaline and highly vegetated but with slightly lower nutrient levels.

In Figure 4.14 the three study sites are plotted within the SRP-pH matrix, used by Allot & Monteith (1999, Figure 5.5) to discriminate between the integrated biology site classifications. The plot indicates chemical similarity between Llyn Bedydd and those sites in group six, all high in alkalinity and phosphorous. It is interesting to note however the very close relationship to the nearby site, Hanmer Mere. In contrast to Llyn Beddyd, all of the group six sites exhibited abundant submerged flora. Pant-yr-ochain and Llyn Helyg are located between groups five and seven and particularly close to the maritime influenced sites such as Llyn Rhos-Ddu. Whilst Llyn Helyg is indeed relatively close to the coast and therefore susceptible to sea spray, the Pant-yr-ochain Pools are a considerable distance from the sea. In this case, it is possible that the highly alkaline chemistry is primarily a result of a saline ground-water influence. As with Llyn Bedydd the impoverished aquatic macrophyte flora cannot easily be explained by water chemistry alone. A poor light environment resulting from low transparency and the overhanging tree fringes that shade the littoral zones in both lakes is likely to be a major contributing factor, in addition to the action of bottom feeding fish. The steeply shelving shoreline bathymetry of Llyn Bedydd may also help inhibit the establishment of aquatic plant growth.

In botanical terms Llyn Helyg is clearly the most diverse and exhibits a wide assemblage of submerged and emergent aquatic macrophytes. It also hosts species of special interest. *Pilularia globulifera* is threatened internationally, classified as *Vulnerable* in the United Kingdom and subject to a Species Action Plan (UK Biodiversity Group, 1998). *Isoetes echinospora* occurs in less than 100 10km grid squares in the United Kingdom and is rare

in non-oligotrophic sites. Although yet to be confirmed taxonomically, the record of *Ranunculus peltatus* x *omiophyllus* would be extremely noteworthy. A very rare cross, it has not been recorded for 75 years, and never at Llyn Helyg (Dr Nigel Holmes, pers comm.). The flora is rich, a common occurrence in mesotrophic assemblages, and reflects the more moderate alkalinity and nutrient levels in the lake. There are clear threats, however, to the current flora and despite a thorough survey in the summer of 2000 several species previously recorded in the site were not found. (Stewart, 1998, Day, 1997). These include *Subularia aquatica*, *Potamogeton polygonifolius*, *Potamogeton pusillus*, *Potamogeton crispus*, *Potamogeton berchtoldii*, *Juncus bulbosus* and *Myriophyllum spicatum.* A previous report from the lake (Day, 1997) stated: "Quillwort and littorella together form a vast carpet covering acres of the bed of the Llyn"- clearly no longer the case with only a few specimens of *Isoetes echinospora* remaining in the site in 2000. Indeed the dominance of the potentially unusual *Ranunculus* cross may be a response to recent eutrophication of the site and its expansion may have been at the expense of some of the species listed above. However it is becoming clear from studies involving the monitoring of lowland lake systems that submerged floral assemblages can show considerable inter-annual variation (Dr Carl Sayer, pers comm.). Caution therefore should be exercised in taking the results of this most recent survey as representative of the current state. We would recommend that CCW consider a repeat aquatic macrophyte survey of the site to confirm our results. Eutrophication is singled out in a United Kingdom Habitat Action Plan for mesotrophic lakes (1995) as the most significant threat to this habitat type.

Also of concern in Llyn Helyg is the presence of several introduced aquatic macrophyte species. *Elodea nuttallii* was abundant in much of the lake and is probably too well established to eradicate. Garden varieties of *Glyceria maxima* and *Nymphaea alba* appear to have been planted near the jetty on the northeastern shore. *Crassula helmsii* and *Nymphoides peltata* were also recorded in the site and may present problems for the *Pilularia globulifera* through direct competition and shading respectively (Stewart 1998). We did not find *Lemna minuscula,* an alien duckweed previously recorded in the lake (Leslie and Walters 1983). According to CCW sources the site has already been subject to direct anthropogenic interference through use of aquatic herbicides, additions of straw bales, sediment dredging and fish stocking but we do not have specific details of the extent of these activities.

Whilst Llyn Bedydd is surrounded by species rich woodland and has SSSI status, the lake itself currently presents little of conservation interest with respect to the submerged, floating leaved or emergent aquatic macrophyte flora. Pant-yr-ochain Pools 1 and 2 present a similar case. Both sites are hyper-eutrophic, according to OECD classifications, and transparency was very poor, especially in Llyn Bedydd, at the time of the July surveys. Alongside the overhanging shoreline trees and reported presence of bottom feeding carp these factors would suggest that the establishment of any submerged aquatic vegetation is unlikely unless alternative management of the site is forthcoming. Prior to any remediation it would be necessary to determine the nutrient status of the inflow sources for each lake. Subsequent steps could include removal of the carp or introduction of piscivorous fish species. Various courses of action may be effective to ameliorate the high nutrient levels. These could include pursuing alternative sources of inflow such as groundwater, protecting the sources of current runoff flowing into the lake, applying restrictions to upstream water abstraction or dredging of the sediments, which are likely to hold a reservoir of nutrients.

As the lakes are currently managed for fishing interests any major changes to the species composition may face implementation difficulties. Similarly with the number of different landowners in the sometimes extensive catchments, source water protection may prove arduous.

Sediment cores taken from Llyn Bedydd and Pant-yr-ochain and subsequently analysed for aquatic macrofossils could help to establish any historical aquatic macrophyte assemblages that were present in the lakes and provide an ecological baseline for any future restoration plans.

6. References

Allott, T. E. H., Monteith, D. T., Patrick, S. T., Duigan, C. A., Lancaster, J., Seda, M., Kirika, A., Bennion, H. & Harriman, R. (1994) Integrated classification and assessment of lakes in Wales: Phase I. Countryside Council for Wales Contract Science Report No. 85, 150pp.

Allott, T. E. H., Monteith. D. T. (1999) Classification of Lakes in Wales for Conservation using Integrated Biological Data. Countryside Council for Wales Contract Science Report No. 314, 154pp.

Biodiversity: The UK Steering Group Report – Volume II: **Action Plans (December 1995)** Mesotrophic Lakes. Page 265.

Day, P. (1997) Llyn Helyg. Records from Flora of Flintshire. CCW.

Monteith, D. T. (Ed) (1995) Integrated classification and assessment of lakes in Wales: Phase II. Countryside Council for Wales Contract Science Report No. 128, 171pp.

Organisation for Economic Cooperation and Development (OECD). (1982). *Eutrophication of Waters: Monitoring, Assessment and Control*. OECD, Paris

Palmer, M. (1992) A botanical classification of standing waters in Britain and a method for the use of macrophyte flora in assessing changes in water quality. Research and survey in nature conservation, No 19, Joint Nature Conservation Committee.

Palmer, M., Bell, S. L., Butterfield, I. (1992) A botanical classification of standing waters in Britain: applications for conservation and monitoring. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 2, 125-143

Leslie, A. C., Walters, S. M. (1983) The occurrence of *Lemna miniscula* Herter in the British Isles. *Watsonia*, 14, 243-248

Seddon, B. (1972) Aquatic macrophytes as limnological indicators. *Freshwater Biology* 2, 107-130

Stewart, N. (1998) Aquatic Flora of Llyn Helyg – Interim Report to CCW.

UK Biodiversity Group Tranche 2 Action Plans – Volume I: Vertebrates and vascular plants. (June 1998) *Pilularia globulifera*. Page 213.

Ward, F. (1931) The Lakes of Wales. A guide for anglers and others. The fishing, scenery, legends and place names, with some mention of river fishing. Herbert Jenkins publishers. 264pp.

Wigginton, M., J. (1980) England Field Unit report on the Survey of Shropshire, Cheshire and Staffordshire Meres (site 24). Nature Conservancy Council.

7. Acknowledgements

The authors would like to thank the local landowners at each site for allowing access, the drawing office at UCL Geography Department for the maps, Nick Stewart for charophyte identifications and Nigel Holmes for *Ranunculus* identifications.

Appendix 1 Bibliographies for the study sites

Llyn Helyg

Day, R.H. (1924-25) Some plants, worthy of notice, in North-west Flintshire, Llandudno, Colwyn Bay and District Field Club.1924-25: XI, 106-115

Galliford, A.L. (1953) Notes on the Distribution and Ecology of the Rotifera and Cladocera of North Wales. *North Western Naturalist*, 1, 513-529

Leslie, A.C.; Walters, S. M. (1983) The occurrence of *Lemna minuscula* Herter in the British Isles. *Watsonia*, 14, 243-248

Seddon, B. (1972) Aquatic macrophytes as limnological indicators. *Freshwater Biology* 2, 107-130

Shilland, E. M., Monteith, D. T. (2001) Limnological Surveys of Welsh lakes: Llyn Helyg, Llyn Bedydd and Pant-yr-ochain Pools, Clwyd - Progress Report. January 2001. CCW Contract Science Report No. 423

Ward, F. (1931) The Lakes of Wales. A guide for anglers and others. The fishing, scenery, legends and place names, with some mention of river fishing. Herbert Jenkins publishers. 264pp.

Llyn Bedydd

Figgis, N. P. (1995) Dead Men's Boats - The Early Medieval Canoe from Llan-gors and the Sunken Dug-outs of Wales and the Marches. Atelier Productions. 54

Savage, A. A.; Pratt, M. M. (1976) Corixidae (water boatmen) of the North-West Midland Meres. *Field Studies*, 4, 463-476

Shilland, E. M.; Monteith, D. T. (2001) Limnological Surveys of Welsh lakes: Llyn Helyg, Llyn Bedydd and Pant-yr-ochain Pools, Clwyd - Progress Report. January 2001. CCW Contract Science Report No. 423

Wigginton, M., J. (1980) England Field Unit Report on the Survey of Shropshire, Cheshire and Staffordshire Meres Project No 1. Part 2 (site 24). Nature Conservancy Council

Pant Yr Ochain Pools

Shilland, E. M.; Monteith, D.T. (2001) Limnological Surveys of Welsh lakes: Llyn Helyg, Llyn Bedydd and Pant-yr-ochain Pools, Clwyd - Progress Report. January 2001. CCW Contract Science Report No. 423