Integrating Habitats Directive and Water Framework Directive Monitoring: Baseline Survey of Natura 2000 Standing Water Habitats in Wales.

Goldsmith, B., Bennion, H., Hughes, M., Jones, V., Rose, C. and Simpson, G.L.

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EXECUTIVE SUMMARY

This report was commissioned by the Environment Agency (EA) on behalf of the Countryside Council for Wales (CCW) in 2004. It brings together data collected in 2003 and 2004 from 28 Welsh lakes in 11 Special Areas of Conservation (SACs).

The report

- collates and presents limnological data collected for the Environment Agency in 2003 for the purposes of site condition assessment,
- presents limnological data collected for CCW in 2004 for the purposes of site condition assessment,
- provides a series of lake data reports on each of the 11 specifies SACs.

Sampling and analytical methods are described and the data presented in the report include;

- site information (catchment geology, land use and lake characteristics and bathymetries),
- water chemistry, temperature and oxygen profiles,
- macrophyte survey data presented as DAFOR rated species lists,
- short core analysis for diatoms (required for 19 of the 28 sites).

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1
PROJECT INTRODUCTION AND OBJECTIVES

1.1 Introduction

This report was commissioned by the Environment Agency (EA) on behalf of the Countryside Council for Wales (CCW) in 2004. The EA coordinated macrophyte and physico-chemical surveys on over 50 lake sites in England and Wales during 2003, including a number of lake sites within Welsh SACs (Special Areas of Conservation) and SSSIs (Sites of Special Scientific Interest). In an effort to update existing information on the site condition of these lakes and provide additional information on other Welsh lakes in SACs, CCW commissioned surveys on a further 19 lake sites in 2004. This report brings together data collected in 2003 and 2004 from 28 Welsh lakes in 11 SACs.

1.2 Project objectives

The principal objectives of this report are:

1. To collate and present limnological data collected for the Environment Agency in 2003 for the purposes of site condition assessment.
2. To present limnological data collected for CCW in 2004 for the purposes of site condition assessment.
3. To provide a series of lake data reports on each of the 11 specifies SACs.

2
METHODS

2.1 Aquatic Macrophyte Surveys

The methods used to collect macrophyte data were imposed by the Environment Agency as part of a wider survey in England and Wales for the establishment of a lake monitoring network to support the Water Framework Directive. The methods were chosen to be compatible with other surveys being conducted within Europe and formed the draft version of the methods since adopted by the Joint Nature Conservation Committee (see Common Standards Monitoring Guidance for Standing Waters, JNCC 2005a).

It should be stressed that these methods do not attempt to provide a complete species list for a lake site, but instead were devised to provide quantitative data of low subjectivity that can be obtained in a pragmatic and repeatable manner. The methods optimise the chance of recording those species most typical of a lake site and detecting marked changes in their abundance. While efforts were made to record additional species which did not occur in any of the survey sections, the absence of species expected or known to occur from a particular lake does not necessarily denote absence from the site.

The plant surveys consisted of four components; a strandline survey, emergent and marginal survey, shoreline wader survey and boat survey. These were carried out at each site on four discrete 100m sections of shoreline which were considered typical for the lake and gave good geographical coverage. In order to reduce disturbance, a maximum of 25% of the shoreline was surveyed, resulting in less than four sections being selected at smaller lakes (only one section was surveyed at Llyn Cadarn, Llyn yr Wyth Eidion and Llyn Coch). Where possible, surveying was performed using a bathyscope, but a double-headed rake was used in deeper water or where poor water clarity restricted visibility. All survey sections and boat transects were recorded using Global Positioning System (GPS), backed up with digital photographs where necessary. A full description of the methods is given in Appendix 1.

Table 2.1 Lakes surveyed in 2003 and 2004

SAC Name	Lake	WBID	Grid ref.	Survey date
Corsydd Môn / Anglesey Fens SAC				
	Llyn Cadarn	32792	SH492811	18/08/04
	Llyn yr Wyth Eidion	32761	SH474818	30/09/03
Y Twyni o Abermenai i Aberffraw / Abermenai to Aberffraw Dunes SAC				
	Llyn Coron	33337	SH378700	26/09/03
Llyn Dinam SAC				
	Llyn Dinam	32948	SH310775	27/09/03
Afon Gwyrfai a Llyn Cwellyn SAC				
	Llyn Cwellyn	34002	SH559549	01/10/03
Eryri / Snowdonia SAC				
	Llyn Coch	34051	SH598544	23/08/04
	Llyn Cwmffynnon	33974	SH649562	22/08/04
	Llyn Idwal	33836	SH645595	21/08/04
	Llyn Ogwen	33803	SH659604	20/08/04
Rhinog SAC				
	Gloyw Lyn	35233	SH646299	09/09/04
	Llyn Cwm Bychan	35180	SH640313	10/09/04
	Llyn Eiddew-mawr	35056	SH646337	11/09/04
	Llyn Perfeddau	35444	SH659264	12/09/04
Migneint-Arenig-Dduallt SAC				
	Llyn Hesgyn	34531	SH884442	05/09/04
	Llyn Conglog-Mawr	34845	SH759387	26/08/04
	Llyn Hiraethlyn	34928	SH743370	03/09/04
	Llyn y Garn	34895	SH761377	02/09/04
	Llyn Tryweryn	34854	SH788358	04/09/04
	Llyn y Dywarchen	34632	SH762420	25/08/04
Cadir Idris SAC				
	Llyn Cau	36267	SH715123	15/09/04
	Llyn Gafr	36159	SH711141	16/09/04
	Llyn Arran	36177	SH735139	17/09/04
Elenydd SAC				
	Llyn Gynon	38525	SN799646	07/09/03
	Llyn Cerrigllwydion Isaf	38282	SN843700	19/09/04
	Llyn Fyrddon Fawr	38240	SN800707	20/09/04
	Llyn Gwngu	38163	SN838729	21/09/04
Kenfig / Cynffig SAC				
	Kenfig Pool	41602	SS796815	21/09/03
Safleoedd Ystlum Sir Benfro a Llynnoedd Bosherston SAC				
	Bosherston Lily Ponds (Central Arm)	41602	SR977949	22/09/03

A total of 28 lake sites in 11 SACs were surveyed during the summers of 2003 and 2004 (Table 2.1). All *in-situ* macrophyte identifications were made by Ewan Shilland or Ben

Goldsmith. Specimens of charophytes, and *Utricularia* were preserved in IMS and sent to Nick Stewart for confirmation. Fine-leaved *Potamogeton* species were pressed and vouchers identified by Chris Preston (2003) and Ben Goldsmith (2004). Voucher specimens were collected for all taxonomically ambiguous species, if abundant, and identifications confirmed at a later date.

The specified survey methods only record presence/absence data for all but emergent and marginal species and therefore accurate plant abundance and cover scores can not be allocated for the lakes. Estimates of species abundance for each set of survey points at a site have been made from the total number of occurrences and these data have been converted to a DAFOR scale, where; D = Dominant, A = Abundant, F = Frequent, O = Occasional and R = Rare. Although efforts were made during the selection of sample sections to choose area typical of the site as a whole, these data do not apply to the entire site and should not be compared directly with any whole-site surveys.

2.2 Physico-Chemical Survey

Dissolved oxygen and temperature profiles and Secchi disk depth were recorded from the deepest point at all sites on the same dates as the macrophyte surveys in 2003 and 2004. Following the 2003 surveys, ENSIS was responsible for the monthly collection of water samples for chemical analysis between October 2003 and March 2004. These samples, collected from the outflow, were delivered to local Environment Agency offices and sent by the EA for analysis by the National Laboratory Service. After March 2004, local EA staff were responsible for water sample collection for the 2003 macrophyte sites and sampling intervals are irregular. At Llyn Coron, insufficient data were collected after March 2004 and therefore annual mean chemistry has been calculated using a 2004/5 data-set.

Water samples were collected from the 19 sites surveyed in 2004 on the same date as the macrophyte surveys. ENSIS then sampled these sites quarterly (December, March and June 2005). All ENSIS water samples were collected in acid-washed, polyethylene bottles which had been thoroughly rinsed with distilled, deionised water and further rinsed three times with lake water once on site. 500 ml of unfiltered water was collected and 100 ml of filtered water (Whatman GF/C filters -1.2 μm pore size). Additional water was filtered until the filter was visibly green and the filter disk retained for chlorophyll *a* analysis. All water samples were refrigerated and sent for analysis at the Macaulay Land Use Research Institute (MLURI), Aberdeen. Chlorophyll *a* samples were frozen and analysed within one week at University College London using cold acetone extraction on macerated samples followed by spectrophotometric determination. A list of determinands analyses by MLURI is given in Table 2.2. MLURI had problems with total phosphorus determination and were only able to accurately measure values over 50 μg P l^{-1}, which was insufficient for the majority of sites in this study. Additional analyses for TP and SRP were done by CEH Edinburgh and are presented.

Table 2.2 List of determinands analysed by MLURI

Chemical Variable	Record Code	Units
pH	pH	pH units
Conductivity	Cond	$\mu S\ cm^{-1}$
Alkalinity	Alk	μeq^{-1}
Dissolved organic carbon	DOC	mgl^{-1}
Soluble reactive phosphorus	SRP	$\mu gP\ l^{-1}$
Total phosphorus	TP	$\mu gP\ l^{-1}$
Chlorophyll *a*	Chl	$\mu g\ l^{-1}$
Total Nitrogen	TN	$mg\ l^{-1}$
Nitrate Nitrogen	NO_3^--N	$mg\ l^{-1}$
Soluble labile aluminium	LabAl	$\mu g\ l^{-1}$
Sulphate	SO4	μeql^{-1}
Total soluble iron	Fe	$\mu g\ l^{-1}$
Sodium	Na	μeql^{-1}
Potassium	K	μeql^{-1}
Magnesium	Mg	μeql^{-1}
Calcium	Ca	μeql^{-1}
Chloride	Cl	μeql^{-1}
Total soluble manganese	Mn	$\mu g\ l^{-1}$

Chemical determinands analysed under the EA contract varied but, no sites had data for labile aluminium, iron or manganese. All 2003 sites had limited data for certain variables (particularly DOC and the major cations and anions) and therefore calculation of annual mean chemistry and acid neutralising capacity was not possible.

Acid neutralising capacity (ANC) was calculated for all the 2004 ENSIS data using the major ions (as below) and expressed as annual means. Where full annual data were not available ANC values were calculated using the most complete data-sets available and expressed for that period.

ANC can be interpreted as the difference between buffering anions (bicarbonate, organic anions) that can react with H^+ to neutralise it, and acid cations (H^+), i.e. the capacity of anions in solution to buffer further inputs of H^+.

$ANC = [HCO_3^-] + [CO_3^{2-}] + [OH^-] - [OA^-] - [H^+] - [Al^{n+}]$

Where (all concentrations in $\mu eq\ l^{-1}$):

$[HCO_3^-]$ = bicarbonate anion
$[CO_3^{2-}]$ = carbonate anion (absent from acid sensitive waters)
$[OH^-]$ = hydroxyl anion (absent from acid sensitive waters)
$[OA^-]$ = organic anions

$[H^+]$ = hydrogen ion
$[Al^{n+}]$ = Σ positively charged Al species

According to the principle of electroneutrality, the sum of all positive ions in waters must equal the sum of all negative ions. Considering only the major ions in most natural, acid-sensitive waters:

$$[Ca^{2+}]+[Mg^{2+}]+[K^+]+[Na^+]+[H^+]+[Al^{n+}] = [SO_4^{2-}]+[NO_3^-]+[Cl^-]+[HCO_3^-]+[OA^-]+[CO_3^{2-}]+[OH^-]$$

Since $ANC = [HCO_3^-] + [CO_3^{2-}] + [OH^-] + [OA^-] - [H^+] - [Al^{n+}]$

this is numerically equivalent to

$$[Ca^{2+}] + [Mg^{2+}] + [K^+] + [Na^+] – [SO_4^{2-}] – [NO_3^-] – [Cl^-]$$

i.e.

$$ANC = \sum BC - \sum AA$$

This standard definition is used because base cations and acid anions are easy to measure and relatively conservative in waters, while HCO_3^-, CO_3^{2-}, OA^-, H^+ and Al^{n+} are very variable (reversible reactions) and difficult to measure.

2.3 Bathymetric Survey and Catchment Mapping

Where current information on lake depths and morphology did not exist, lake bathymetries were produced using a boat mounted Lowrance LMS-240, a combined GPS receiver and echo sounder. Many thousands of geo-referenced depths are recorded from a lake by rowing or motoring along evenly spaced transects across the entire lake surface. These data are stored electronically and can be used in various GIS packages to calculate lake volume and to produce high resolution contour maps (bathymetric maps) of the lake.

2.3.1 Lake Bathymetry Maps

Lake bathymetries were computed using data collected with a Lowrance LMS-240 combined echosounder/GPS unit. Point data were collected by the instrument which was suspended at the back of an inflatable boat at a rate of 1 data point per second. The typical speed of the boat during survey is about 3 knots. The data were thinned and converted to Ordnance Survey grid references (using Grid InQuest v6.0) before being imported into ArcGIS as a point layer. This layer was interpolated to create a depth grid using the inverse distance weighted (IDW) interpolation routine in Spatial Analyst (the parameters were: power = 2, search radius = variable, number of points = 12, maximum distance = 50m, cell size = 5-20m (depending on quality of point data and size of water body). A barrier polyline (lake outline) was used which was derived from the Ordnance Survey LandLine data and is shown on the maps as a thick blue line. This polyline was also used to derive an accurate surface area for the water body and this is the area shown on the map (in hectares). The maximum depth (metres, 1 decimal place) was obtained directly from measurements. The mean depth (metres, 1 decimal place) was computed from the interpolated depth grid. The volume was computed by multiplying surface area (m^2 = ha * 10000) by mean depth (m). The actual bathymetric data shown on the map is a

smoothed version of the interpolated grid (3x3 neighbourhood mean of the depth grid). The interpolation process can produce artefacts which result in unrealistic bathymetries, the smoothing process reduces the effects of these artefacts and better represents the uncertainty in the interpolation process. All other data on the map is derived directly from the GBLakes database (Hughes *et al*., 2004).

2.3.2 Catchment and Habitat Maps

The catchment and habitat maps show the lakes catchment outline (Hughes *et al*., 2004) overlaid on the CCW Habitats of Wales habitat classification (data supplied under licence from CCW). A key for the habitat classification is shown in Appendix 2. In two cases (Llyn Arran and Llyn Perfeddau) the catchment boundary was not available and an estimated boundary was hand-digitised from contours on the 1:25,000 Ordnance Survey raster data. Direction of outflow is indicated with a blue arrow. Catchment area is indicated on the map in hectares.

2.4 Diatom Analysis

2.4.1 Field and laboratory methods

A sediment core was taken in the summer of 2004 from the deepest part of each lake using a Glew gravity corer which collects short cores of typically 20-40 cm in length. All cores were extruded in the field at 1 cm intervals. A core could not be obtained from Llyn Cau in 2004 and, therefore, a core taken in 2002 was used.

Slides for diatom analysis were prepared from the top and bottom samples of each core using standard methods (Battarbee *et al*., 2001). At least 300 valves (siliceous component of the cell wall bearing the taxonomic features) were counted from each sample using a Leitz research microscope with a 100x oil immersion objective and phase contrast. Principal floras used in identification were Krammer & Lange-Bertalot (1986-1991). All slides are archived at the ECRC and the data are stored in the Amphora database.

2.4.2 Data analysis

All diatom data were expressed as percentage relative abundance, and were screened and harmonised prior to data analysis. Summary diagrams of the diatom changes (showing only those taxa present with a relative abundance of >2% in at least one sample) were produced for each site using C2 (Juggins, 2003).

The degree of floristic change between the bottom sample and the top sample was assessed using the squared chord distance dissimilarity coefficient (Overpeck *et al*. 1985) implemented in the statistical software R (R Development Core Team 2004). This is preferred to other dissimilarity measures as it maximises the signal to noise ratio, it performs well with percentage data and has sound mathematical properties (Overpeck *et al*. 1985). The scores range from 0 to 2 whereby 0 indicates that two samples are exactly the same and 2 that they are completely different. Scores less than 0.29, 0.39, 0.48 and 0.58 indicate insignificant floristic change at the 1st, 2.5th, 5th and 10th percentile, respectively (Simpson 2005). It is advised that the 2.5th percentile (score <0.39) is used to define sites with low floristic change between the bottom and top sample. This is more

stringent than the 5th percentile (score <0.48) used in previous similar studies (e.g. Bennion *et al*., 2004) and reflects revised thinking on the use of the chord distance statistic. This revision follows closer examination of sediment sample data from over 200 UK lake cores held in the ECRCs in-house AMPHORA database whereby unimpacted sites typically have chord distance values of <0.4 (in many cases <0.3) between core top and bottom samples (e.g. Bennion, 2004). The original selection of the 5th percentile to indicate low floristic change was developed based on between site comparisons where one has to account for natural variability (background noise) in the dataset – the result of natural differences between sites - and to reflect that no two sites will ever be perfectly similar in practise (Simpson, 2005; Simpson *et al*., 2005).

Weighted averaging (WA) regression and calibration (ter Braak & van Dam, 1989) has become a standard technique in palaeolimnology for reconstructing past environmental variables. A predictive equation known as a transfer function is generated that enables the inference of a selected environmental variable from fossil diatom assemblages, based on the relationship between modern surface-sediment diatom assemblages and contemporary environmental data for a large training (or calibration) set of lakes. This approach has been successfully employed to infer lake pH and total phosphorus (TP) concentrations whereby modern diatom optima and tolerances are calculated for each taxon based on their distribution in the training set, and then past pH or TP concentrations are derived from the weighted average of the optima of all diatoms present in a given fossil sample. The methodology and the advantages of WA over other methods of regression and calibration are well documented (e.g. ter Braak & van Dam, 1989).

Given that acidification was thought to be the key pressure at the study lakes, a diatom-pH transfer function was applied to the diatom data for each core, with the exception of Llyn Cadarn, following taxonomic harmonisation between the training sets and the fossil data. All taxa were included in the analysis. Reconstructions of diatom-inferred pH (DI-pH) were produced using the Surface Water Acidification Programme (SWAP) training set of 167 lakes from largely acid-sensitive, upland regions of the UK, Norway and Sweden (Stevenson *et al*., 1991). The model is based on simple WA with classical deshrinking (Line *et al*., 1994). The median value for the training set is pH 5.3 and the model has a root mean squared error of prediction (RMSEP) of 0.32 pH units. All reconstructions were implemented using C^2 (Juggins, 2003). The DI-pH values and the percentage of the taxa in each fossil sample that are present in the training set are given for each site. The DI-pH value for the core top sample is compared with the current measured annual mean pH calculated from the 2004-5 quarterly water chemistry dataset. The main pressure at Llyn Cadarn is expected to be eutrophication. However, owing to poor diatom preservation, a transfer function was not applied to this core.

The diatom results are presented on a site by site basis. For each site, the major species shifts are described, the degree of floristic change is given and the changes in pH as inferred by the diatom-pH transfer function are discussed.

3
RESULTS

3.1 Corsydd Môn/ Anglesey Fens SAC Llyn Cadarn & Llyn yr Wyth-Eidion

Location of SAC

SAC Details	
Grid Ref. (approx. centre)	SH470820
SAC EU Code	UK0012884
Total Area	467 ha
Total area of Freshwater	9.3 ha

General site character:
Inland water bodies (standing water, running water) (2%)
Bogs. Marshes. Water fringed vegetation. Fens (85%)
Heath. Scrub. Maquis and garrigue. Phygrana (5%)
Dry grassland. Steppes (1%)
Humid grassland. Mesophile grassland (5%)
Mixed woodland (2%)

Annex I habitats that are a primary reason for selection of this site:
3140 Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp.
Within Anglesey Fens, Llyn Yr Wyth Eidion is a small active marl-producing lake in north Wales and is an example of a lake on limestone. It is surrounded by the extensive calcareous valley mire of Cors Erddreiniog, which overlies limestone and protects the lake against nutrient enrichment, resulting in water of high quality. Hedgehog stonewort *Chara pedunculata* and the rare rugged stonewort *C. rudis* have been recorded at this site. Llyn Cadarn is not currently a notified feature within the SAC.
7210 Calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae*
The Anglesey Fens complex supports the second-largest area of calcareous fens in the UK. In some parts the low vigour of *Cladium* accounts for the species-richness of the vegetation, but elsewhere management prevents the development of monodominant stands, enabling the persistence of communities referable to the *Caricion davallianae*. The juxtaposition between species-poor stands of *Cladium* and areas with a more diverse floristic composition and structure is widespread, with characteristically species-rich contact zones between the two. Anthropogenic disturbance is believed to have been

instrumental in the development of various facies of a *Cladium – Molinia* community, a particular feature of the rich fens of north-west Wales.

7230 Alkaline fens

This composite site includes four component fen systems supporting a diverse range of short-sedge mires, including the best and most extensive Welsh examples of NVC type M13 *Schoenus nigricans – Juncus subnodulosus* mire and a range of communities referable to M9a *Carex rostrata – Calliergon cuspidatum/ giganteum* mire. These are considered to be of pre-eminent importance in the UK, owing to their extent, biogeographical significance and exceptionally rich assemblage of rich-fen species. The fens are strongly influenced by the underlying Carboniferous limestone and are fed by calcareous groundwater arising from discrete springs and more diffuse zones of seepage. The alkaline fen communities often occur within complex vegetation zonations, and typical contact communities include great fen-sedge *Cladium mariscus* swamp, fen carr, fen meadow communities dominated by blunt-flowered rush *Juncus subnodulosus* (M22 *Juncus subnodulosus – Cirsium dissectum* fen-meadow) and purple moor-grass *Molinia caerulea* (M25 *Molinia caerulea – Potentilla erecta* mire) as well as a range of vegetation types broadly referable to the *Cladio – Molinietum*. Gradations to unimproved calcicolous and neutral grasslands also occur. The characteristic mixture of southern and northern floristic elements includes a wide range of nationally or locally scarce species, including fly orchid *Ophrys insectifera*, narrow-leaved marsh orchid *Dactylorhiza traunsteineri*, marsh *helleborine Epipactis palustris*, lesser clubmoss, *Selaginella selaginoides* and slender sedge *Carex lasiocarpa*. Examples of M13 mire within Anglesey Fens which are strongly influenced by the discharge of calcareous groundwater provide the sole north Wales locus for the Annex II species 1044 Southern damselfly *Coenagrion mercuriale*.

The SAC also contains Annex I habitats 4010 Northern Atlantic wet heaths with *Erica tetralix* and 6410 *Molinia* meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*), but these are not primary reasons for designation.

(JNCC, 2005b)

3.1.1 Llyn Cadarn

3.1.1.1 Site Description

Llyn Cadarn is situated in the Cors Goch nature reserve owned by the North Wales Wildlife Trust and is designated as a Site of Special Scientific Interest. It is also a Special Area of Conservation under the EU Habitats Directive. The lake is fringed with reeds and shelves deeply beyond the outer edge of the reeds. Further site details can be found in Stewart (2004).

Information on the solid geology of the Llyn Cadarn catchment and land cover data are given in Tables 3.1.1 and 3.1.2 respectively. A catchment map is given in Figure 3.1.1.

Table 3.1.1 Solid geology of the Llyn Cadarn catchment
(Data from British Geological Survey solid geology data at 1:62,500)

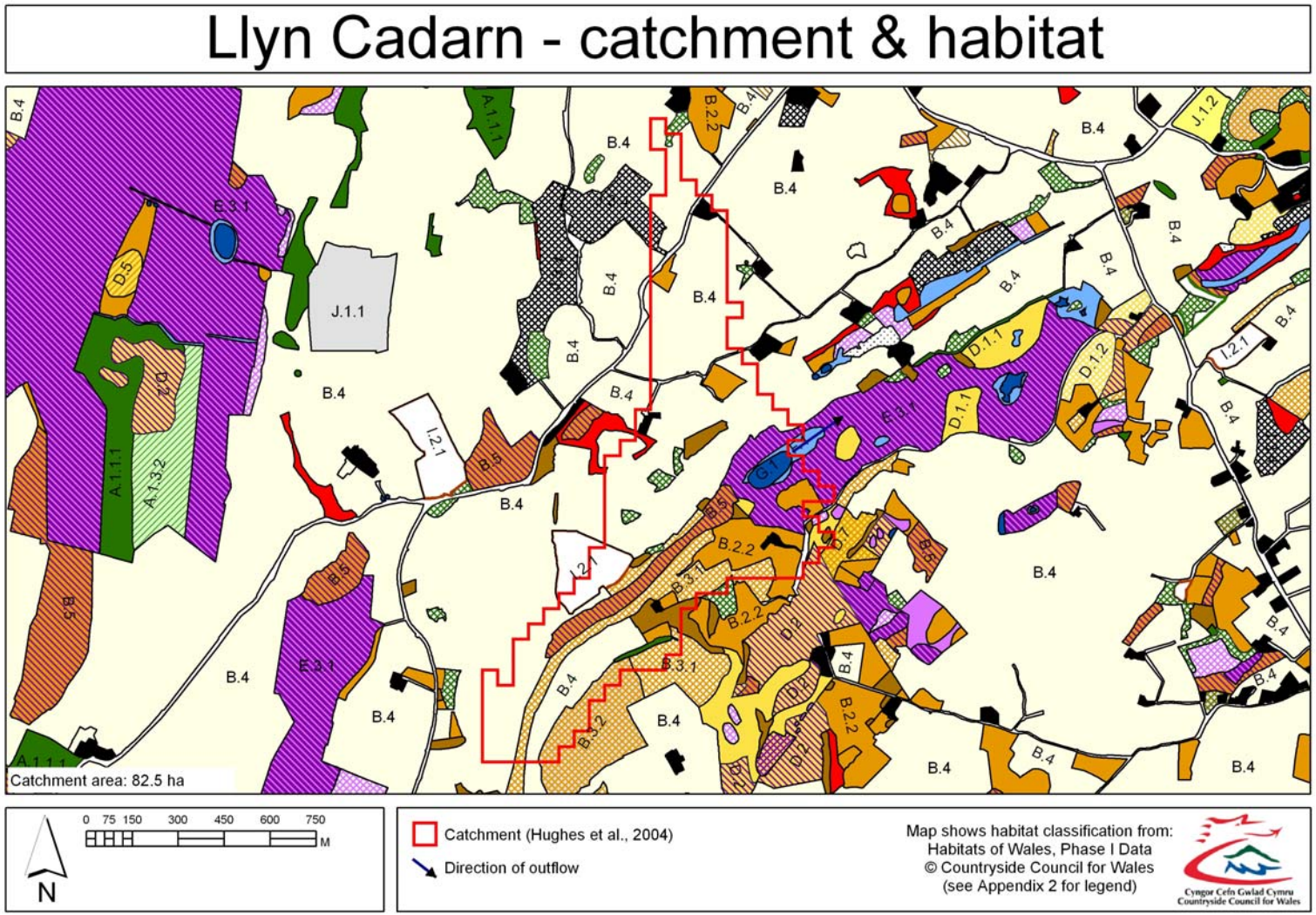
Name	Type	Percentage cover
Basal conglomerate (including possible Devonian)	Sedimentary	11.3
Tournaisian and Visean (Carboniferous Limestone Series)	Sedimentary	88.7

Table 3.1.2 Land cover data for the Llyn Cadarn catchment
(Data from CCW Phase 1 Habitat Survey)

Classification	Code	Percentage cover
Woodland and scrub		
Dense scrub	A.2.1	1.3
Grassland and marsh		
Semi-improved neutral grassland	B.2.2	8.5
Unimproved calcareous grassland	B.3.1	10.0
Semi-improved calcareous grassland	B.3.2	3.1
Improved grassland	B.4	54.0
Marshy grassland	B.5	4.9
Tall herb and fern		
Bracken	C.1.1	3.0
Mire		
Valley mire	E.3.1	5.9
Open water		
Standing water	G.1	1.2
Rock exposure and waste		
Quarry	I.2.1	2.8
*Other**		5.3

* Cover less than 1% and/or data not available

Figure 3.1.1 Llyn Cadarn catchment map



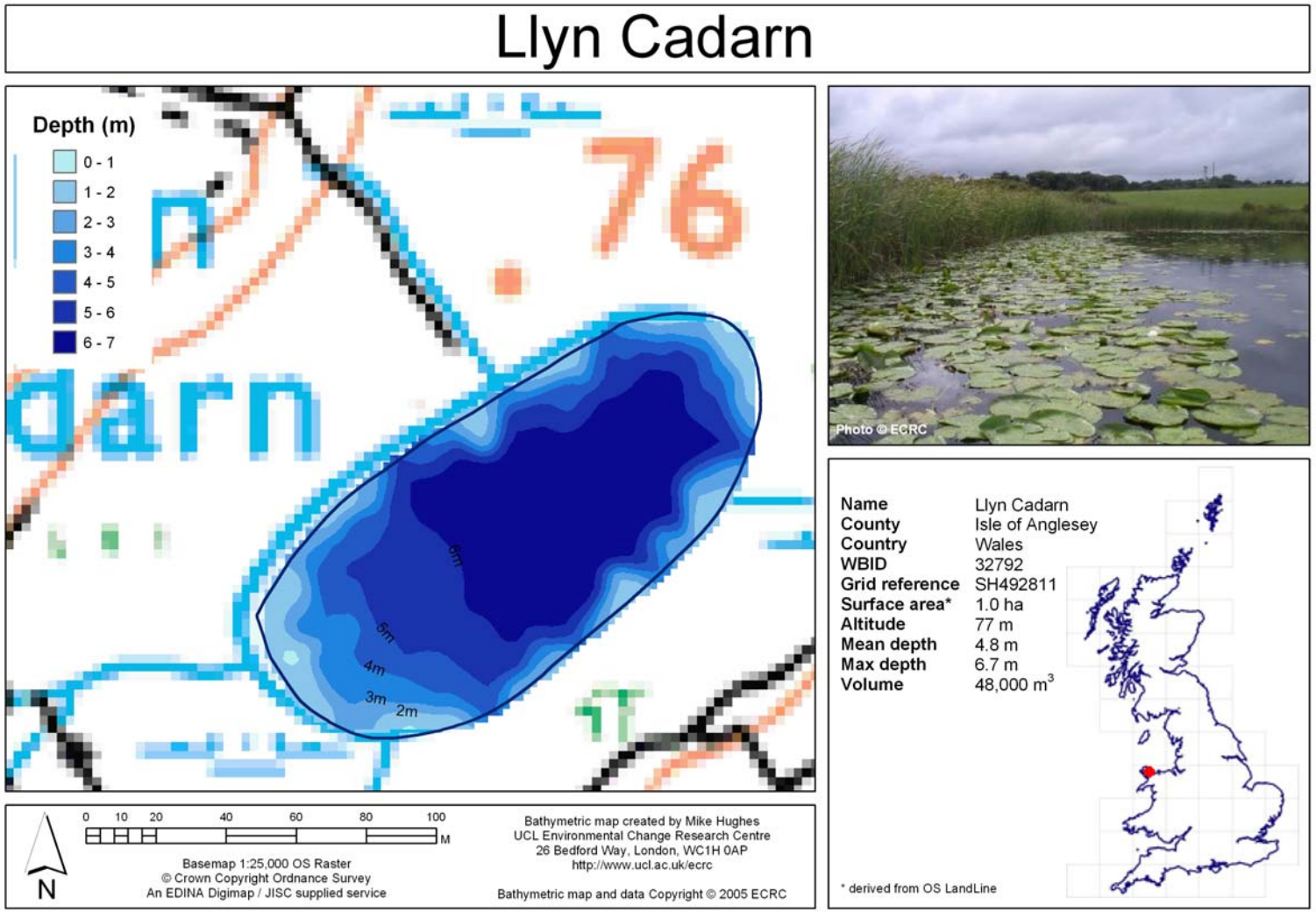
3.1.1.2 Bathymetry

The bathymetry of Llyn Cadarn is shown in Figure 3.1.2, physical and morphometric parameters are given in Table 3.1.3.

Table 3.1.3 Llyn Cadarn - physical and morphometric parameters

Lake altitude (m)	77
Maximum depth (m)	6.7
Mean depth (m)	4.8
Lake volume ($x10^3m^3$)	48.0
Area of lake surface (ha)	1
Perimeter of lake (km)	0.4
Shoreline development index	1.1
Estimated hydraulic residence time (days)	37
Secchi disc depth (m)	4.65
Catchment area including lake (ha)	82.5
Catchment to lake area ratio	82.5

Figure 3.1.2 Llyn Cadarn bathymetry map



3.1.1.3 Physico-chemical data

Temperature and oxygen profiles for Llyn Cadarn are given in Figure 3.1.3 and water chemistry data shown in Table 3.1.4.

Figure 3.1.3 Temperature and oxygen profiles for Llyn Cadarn

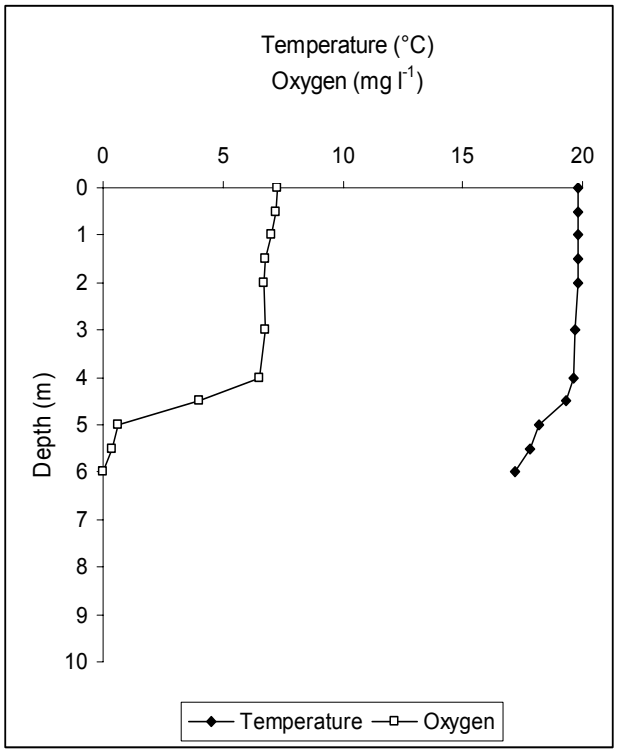


Table 3.1.4 Water chemistry data for Llyn Cadarn

	Sept 04	Dec 04	Mar 05	Jun 05	Annual mean
pH	7.9	7.9	8.3	8.3	8.0
Cond	431	499	497	497	481
Alk	2601	3156	3224	2997	n.c.
DOC	4.69	4.21	3.70	4.85	4.36
SRP	13	26	7	6	13
TP	<50	<50	<50	19.6	n.c.
Chl *a*	10.7	12.1	25.4	8.5	14.2
TN	0.40	0.83	0.90	0.53	0.67
NO_3^--N	0.03	3.08	2.97	0.47	1.64
Labile Al	<23	<23	<23	<23	n.c.
SO_4^{2-}	2211	1455	1405	1331	1600
Total Fe	<6	16	21	<6	n.c.
Na^+	674.3	607.3	662.5	650.8	648.7
K^+	66.8	69.0	55.8	48.7	60.1
Mg^{2+}	764.2	555.9	564.8	598.0	620.7
Ca^{2+}	4852.3	5039.9	4801.9	4738.5	4858.1
Cl^-	597.8	514.4	619.3	596.1	581.9
Total Mn	<2	<2	77.90	18.80	n.c.
ANC					3887.5

(n.c. – not calculated, one or more values below analytical detection)

3.1.1.4 Macrophyte survey

Results of the macrophyte survey are given in Tables 3.1.5 and 3.1.6.

Table 3.1.5 Macrophyte abundance for Llyn Cadarn – emergent and marginal survey

Taxon	DAFOR Abundance
Carex rostrata	**A**
Menyanthes trifoliata	**A**
Phragmites australis	**A**
Juncus acutiflorus	**A**
Potentilla palustris	**A**
Typha angustifolia	**D**
Myrica gale	**A**
Equisetum fluviatile	**F**
Angelica sylvestris	**F**
Cladium mariscus	**A**
Schoenoplectus lacustris	**A**
Ranunculus flammula	**F**
Galium palustre	**F**
Salix sp.	**F**
Epilobium palustre	**F**
Hydrocotyle vulgaris	**F**
Filipendula ulmaria	**F**
Stachys palustris	**F**
Juncus effusus	**A**
Lemna minor	**F**
Utricularia vulgaris agg. (*cf. australis*)	**F**
Carex acutiformis	**F**
Mentha aquatica	**F**
Epilobium hirsutum	**F**
Potentilla erecta	**F**
Lythrum salicaria	**F**
Juncus conglomeratus	**F**
Fontinalis antipyretica	**A**
Solanum dulcamara	**F**
Nuphar lutea	**A**
Carex riparia	**F**
Nymphaea alba	**A**

Table 3.1.6 Macrophyte abundance for Llyn Cadarn – wading and boat survey

Taxon	DAFOR Abundance
Carex rostrata	**F**
Cladium mariscus	**A**
Epilobium hirsutum	**R**
Equisetum fluviatile	**O**
Fontinalis antipyretica	**D**
Juncus acutiflorus	**F**
Lemna trisulca	**O**
Lycopus europaeus	**R**
Lythrum salicaria	**F**
Menyanthes trifoliata	**A**
Myrica gale	**R**
Nuphar lutea	**A**
Nymphaea alba	**F**
Phragmites australis	**A**
Potentilla palustris	**O**
Salix sp	**F**
Schoenoplectus lacustris	**F**
Solanum dulcamara	**F**
Typha angustifolia	**A**

No additional species were noted during a strandline survey (no Charaphytes found). Only one 100m shoreline transect was carried out in order to minimise disturbance on this small site (see Annex 1).

A vegetation survey by Stewart (2004) noted that much of the depths of the lake are unvegetated apart from the occasional strand of vegetation drifted from the perimeter zones. Around the edge is a band of water lilies, 5-10 metres wide corresponding with the zone where the bottom is more steeply sloping in 1-3 metres depth. The surrounding shelf is dominated by swamp communities comprising Reed *Phragmites australis*, Reedmace *Typha angustifolia*, Sedge *Cladium mariscus*, Bulrush *Schoenoplectus lacustris* and Lesser Pond Sedge *Carex acutiformis*. In one area at the north-eastern end the shelf lacks the swamp and the shallow open water is dominated by Water Moss *Fontinalis antipyretica*.

3.1.1.5 Short core analysis

A 25 cm Glew core, CADA2, was taken in a water depth of 6.1 m from Llyn Cadarn on 18-Aug-04. A summary diagram of the common taxa (>2%) is shown in Figure 3.1.4 and summary data are given in Table 3.1.7. The core top and bottom samples contained a total of 51 diatom taxa although in both cases the diatom frustules were very poorly preserved. In the bottom sample, few specimens were observed and only ~200 valves were counted. The assemblage of the bottom sample was dominated by non-planktonic

Fragilaria taxa, in particular *Fragilaria brevistriata*. Other notable taxa were the planktonic diatoms, *Cyclotella ocellata* and *Cyclotella* [*kuetzingiana* agg.], and central areas of *Gyrosigma* spp. were also relatively abundant. The top sample was very different being dominated by *Aulacoseira granulata* (57%) with occurrences of the planktonic diatoms, *Stephanodiscus parvus* and *Asterionella formosa,* and two *Nitzschia* taxa. None of these taxa were observed in the bottom sample. Consequently, the squared chord distance dissimilarity score between the two samples was very high (1.503).

Reconstructions of water chemistry were not carried out on the Llyn Cadarn core owing to the poor diatom preservation which would likely cause incorrect values to be inferred from the data.

In summary, there has been a significant degree of floristic change in the Llyn Cadarn core. The assemblage has shifted from one dominated by *Fragilaria* spp. commonly found attached to sediments, stones or plants of relatively productive, alkaline waters to one dominated by planktonic diatoms typical of lakes with high nutrient concentrations. The species changes suggest that the lake may have been less productive in the past, probably with better light conditions allowing *Fragilaria* spp. to grow attached to various substrates. However, given the poor preservation of diatom frustules, particularly in the lower sample, the data for this lake must be interpreted with caution.

Figure 3.1.4 Summary diagram of diatom assemblages in top and bottom samples from core CADA2

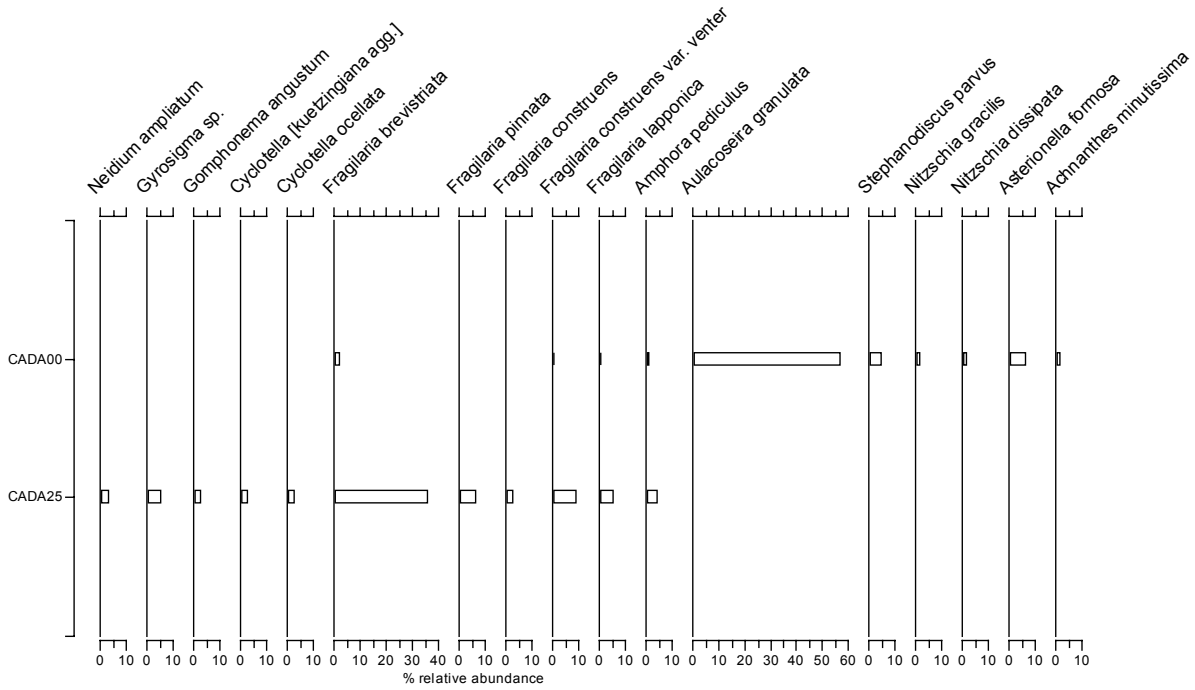


Table 3.1.7 Results of Llyn Cadarn short core analysis

Sample code	Depth (cm)	Annual mean current pH	DI-pH	No. taxa in fossil sample	% of taxa in fossil sample present in SWAP training set	Squared chord distance dissimilarity score between core top and bottom
CADA00	0	8.09	na	35	na	1.503
CADA25	25		na	27	na	

3.1.2 Llyn yr Wyth Eidion

3.1.2.1 Site Description

Llyn yr Wyth Eidion is a small, deeply shelving lake situated on deposits of lacustrine shell mud. Vegetation adjacent to the lake was predominantly *Carex*-dominated wet fen. A fuller site description is given in Monteith (1997).

Information on the solid geology of the Llyn yr Wyth Eidion catchment and land cover data are given in Tables 3.1.8 and 3.1.9 respectively. A catchment map is given in Figure 3.1.5.

Table 3.1.8 Solid geology of the Llyn yr Wyth Eidion catchment
(Data from British Geological Survey solid geology data at 1:62,500)

Name	Type	Percentage cover
Lower Old Red Sandstone, including Downtonian	Sedimentary	1.1
Basal Conglomerate (including possible Devonian)	Sedimentary	63.7
Tournaisian and Visean (Carboniferous Limestone Series)	Sedimentary	35.2

Table 3.1.9 Land cover data for the Llyn yr Wyth Eidion catchment
(Data from CCW Phase 1 Habitat Survey)

Classification	Code	Percentage cover
Woodland and scrub		
Semi-natural broadleaved woodland	A.1.1.1	6.0
Dense scrub	A.2.1	1.1
Grassland and marsh		
Semi-improved neutral grassland	B.2.2	2.5
Improved grassland	B.4	67.2
Marshy grassland	B.5	1.1
Mire		
Basic flush	E.2.2	1.4
Valley mire	E.3.1	15.7
Miscellaneous		
Arable	J.1.1	2.4
Other*		2.6

* Percentage cover >1% and /or data not available

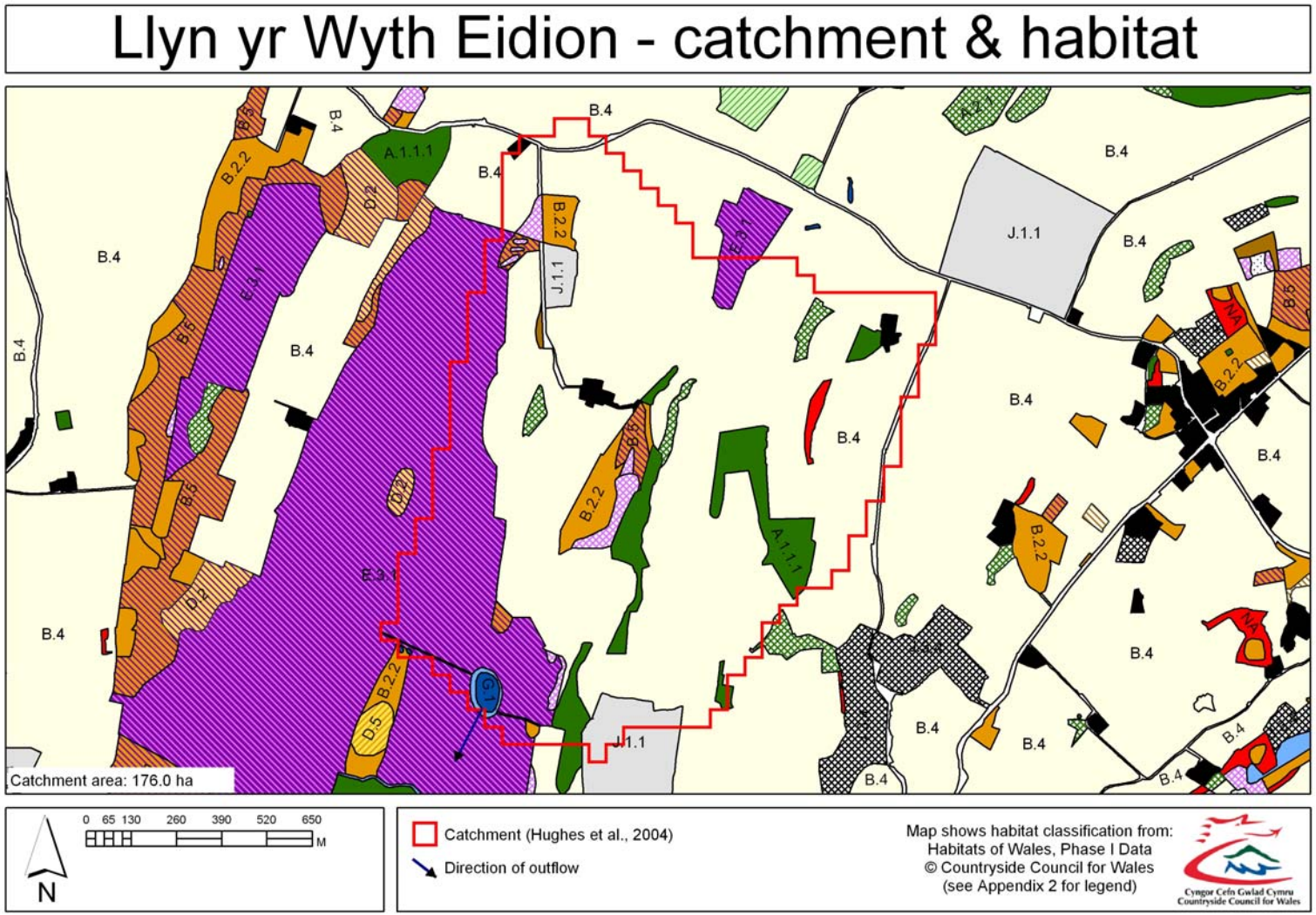
3.1.2.2 Bathymetry

A bathymetric map was not required as part of this study (a lake bathymetry is shown in Monteith (1997)). Physical and morphometric parameters are given in Table 3.1.10.

Table 3.1.10 Physical and morphometric parameters

Lake altitude (m)	68
Maximum depth (m)	9
Mean depth (m)	6.0
Lake volume ($x10^6m^3$)	78.9
Area of lake surface (ha)	1.31
Perimeter of lake (km)	0.4
Shoreline development index	1.05
Estimated hydraulic residence time (days)	28
Secchi disc depth (m)	4.18
Catchment area including lake (ha)	176
Catchment to lake area ratio	134.4

Figure 3.1.5 Llyn yr Wyth Eidion catchment map



3.1.2.3 Physico-chemical data

Temperature and oxygen profiles for Llyn yr Wyth Eidion are given in Figure 3.1.6 and water chemistry data shown in Table 3.1.11.

Figure 3.1.6 Temperature and oxygen profiles for Llyn yr Wyth Eidion

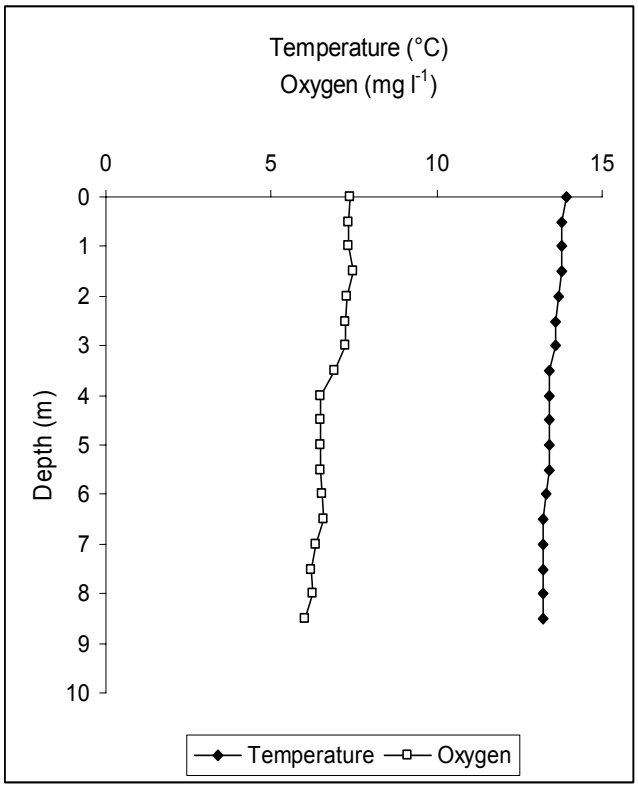


Table 3.1.11 Water chemistry data for Llyn yr Wyth Eidion

	Dec 03	Mar 04	Jul 04	Sept 04	Annual mean
pH	7.7	7.9	7.7	7.6	7.7
Cond	464	494	488	524	493
Alk	3083.2	3444.0	3444.0	3755.6	3431.7
DOC	-	-	7.90	12.60	n.c.
SRP	8	2	5	2	4
TP	34	15	35	14	24.5
Chl *a*	0.6	5.4	6.8	3.1	4.0
TN	4.63	4.71	0.49	3.00	3.21
NO_3^--N	3.07	3.21	0.22	2.32	2.21
Labile Al	-	-	-	-	-
SO_4^{2-}	-	-	732	865	n.c.
Total Fe	-	-	-	-	-
Na^+	-	-	-	613.4	n.c.
K^+	-	-	-	68.1	n.c.
Mg^{2+}	-	-	-	376.1	n.c.
Ca^{2+}	-	-	4835.3	5089.8	n.c.
Cl^-	-	-	792.4	640.1	n.c.
Total Mn	-	-	-	-	-
ANC	-	-	-	-	-

(n.c. – not calculated, one or more values below analytical detection)
(- denotes data not collected or analysed)

3.1.2.4 Macrophyte survey

Results of the macrophyte survey are given in Tables 3.1.12 and 3.1.13.

Table 3.1.12 Macrophyte abundance for Llyn yr Wyth Eidion – emergent and marginal survey

Taxon	DAFOR Abundance
Mentha aquatica	**F**
Epilobium palustris	**F**
Phragmites australis	**A**
Cladium mariscus	**A**
Carex elata	**D**
Typha latifolia	**A**
Salix sp.	**A**
Alnus glutinosa	**F**
Galium palustre agg.	**F**
Juncus effusus	**F**
Scutellaria galericulata	**F**
Hypuris vulgaris	**F**

Table 3.1.13 Macrophyte abundance for Llyn yr Wyth Eidion – wading and boat survey

Taxon	DAFOR Abundance
Alnus glutinosa	**R**
Carex elata	**D**
Cladium mariscus	**F**
Epilobium palustris	**R**
Chara virgata	**A**
Chara vulgaris	**A**
Fontinalis antipyretica	**F**
Hippuris vulgaris	**R**
Lemna minor	**F**
Nymphaea alba	**F**
Nuphar lutea	**A**
Phragmites australis	**F**
Potamogeton crispus	**R**
Salix sp	**R**
Sparganium natans	**R**
Typha latifolia	**F**

As this is a small lake site, only one transect completed to minimise disturbance. A thorough visual search of the entire site was performed and a strandline survey found the presence of *Callitriche* species, *Potamogeton berchtoldii*, *Sparganium erectum*, *Schoenoplectus lacustris* and *Potamogeton perfoliatus*. *Hottonia palustris* was found to be frequent in abundance in the outflow close to the lake. Following overnight rain, the water level was 10-15 cm above normal.

3.1.2.5 Short core analysis

Short core analysis was not required as part of this study. Epilithon and surface diatom taxon lists are given in Monteith (1997).

3.2 Y Twyni o Abermenai i Aberffraw/ Abermenai to Aberffraw Dunes SAC
Llyn Coron

Location of SAC

SAC Details	
Grid Ref. (approx. centre)	SH413642
SAC EU Code	UK0020021
Total Area	1871 ha
Total area of Freshwater	48.6 ha

General site character:
Coastal sand dunes. Sand beaches. Machair (55%)
Shingle. Sea cliffs. Islets (2.9%)
Inland water bodies (standing water, running water) (2.6%)
Bogs. Marshes. Water fringed vegetation. Fens (0.3%)
Heath. Scrub. Maquis and garrigue. Phygrana (1.4%)
Coniferous woodland (37.8%)

Annex I habitats that are a primary reason for selection of this site
2110 Embryonic shifting dunes
Abermenai to Aberffraw Dunes is one of two sites selected to represent Embryonic shifting dunes in north Wales. Embryonic dunes form a zone across a broad part of the beach/dune interface, making this site one of the most extensive examples of this habitat type in the UK. It is a site where, in contrast to some others in north Wales, recreational damage is minimal.
2120 Shifting dunes along the shoreline with *Ammophila arenaria* (`white dunes`)
Abermenai to Aberffraw Dunes is one of two sites selected in north Wales. It contains one of the largest areas of lyme-grass *Leymus arenarius* shifting dune community in Wales. The mobile dunes at the southern end of the site support an abundance of sea-holly *Eryngium maritimum*, and there is well-developed zonation of dune types, including both seaward transitions between mobile dune and foredune, and landward transitions to fixed dune and dune slack.
2130 Fixed dunes with herbaceous vegetation (`grey dunes`)
Within this dune complex in north Wales are extensive areas of both fixed dune vegetation with red fescue *Festuca rubra* and lady's bedstraw *Galium verum* and semi-fixed dune grassland with marram *Ammophila arenaria* and red fescue. Despite the fact

that a large proportion of the open vegetation has been afforested, the remaining communities retain considerable interest. Notable species of the site include early sand-grass *Mibora minima*. On the south side of Menai Strait, the dunes at Morfa Dinlle include a lichen-rich community with *Coelocaulon aculeatum* (SD11), a type of vegetation which is very rare in Wales.

2170 Dunes with *Salix repens* ssp. *argentea* (*Salicion arenariae*)

Abermenai to Aberffraw Dunes in north Wales comprises an extensive area of dunes with a complete range of dune vegetation, including substantial areas of slack vegetation dominated by creeping willow *Salix repens* ssp. *argentea*. Despite the extent of afforestation, the dune aquifer retains its overall integrity, although changes in water table, partly attributable to the growth of the forest, have influenced the development of the dune slacks. There is long-term potential for further improvement.

2190 Humid dune slacks

Abermenai to Aberffraw Dunes represents Humid dune slacks in north Wales. There are large areas of open dune vegetation and many Humid dune slacks remain, although there have been changes in the water table that are partly attributable to the growth of the commercial forest. The changes have influenced the development of humid dune slacks, which nonetheless retain most the essential features of the habitat type.

The SAC also contains 3150 Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation, but this is not primary reasons for designation.

(JNCC, 2005b)

3.2.1 Llyn Coron

3.2.1.1 Site Description

Llyn Coron lies at 9 m above sea level just 2 km from the coast in south-west Anglesey. The lake and its outflow the Afon Ffraw form the Tywyn Aberffraw SSSI. A full site description is given in Allott *et al.* (1994). At the time of sampling, the east side of lake was extensively grazed by livestock.

Information on the solid geology of the Llyn Coron catchment and land cover data are given in Tables 3.2.1 and 3.2.2 respectively. A catchment map is given in Figure 3.2.1.

Table 3.2.1 Solid geology of the Llyn Coron catchment
(Data from British Geological Survey solid geology data at 1:62,500)

Name	Type	Percentage cover
Gneiss, mica schists	Metamorphic	10.4
Basalt dolerite, camptonite and allied types	Igneous	1.1
Andesitic lava and tuff	Igneous	18.2
Rocks of Anglesey, Lleyn Peninsular, Charnwood, Longmynd etc	Sedimentary	70.3

Table 3.2.2 Land cover data for the Llyn Coron catchment
(Data from CCW Phase 1 Habitat Survey)

Classification	Code	Percentage cover
Grassland and marsh		
Semi-improved neutral grassland	B.2.2	3.1
Improved grassland	B.4	84.9
Marshy grassland	B.5	1.8
Open water		
Standing water	G.1	1.3
Miscellaneous		
Arable	J.1.1	1.1
Buildings	J.3.6	1.9
Other*		5.9

* Percentage cover >1% and /or data not available

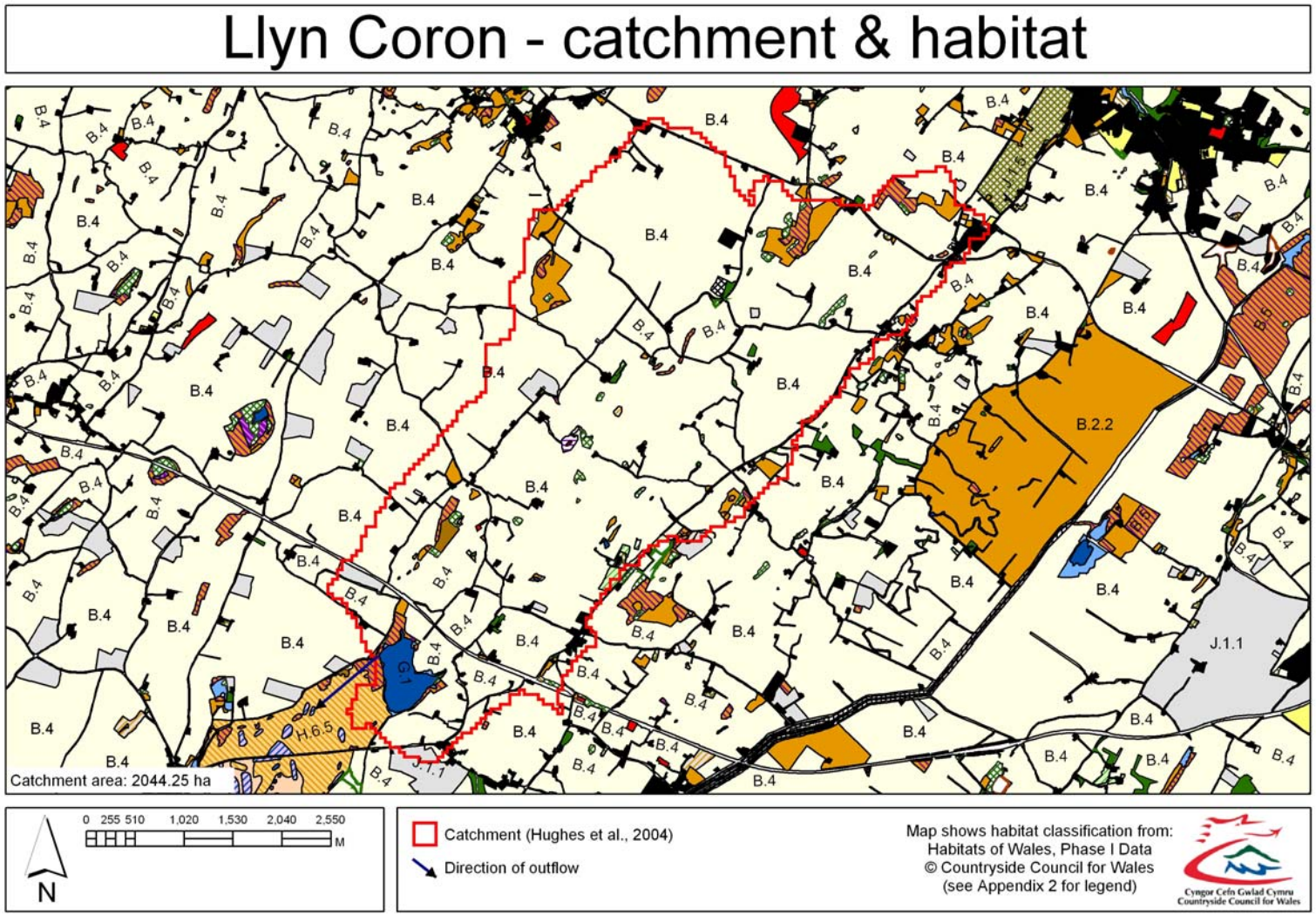
3.2.1.2 Bathymetry

A bathymetric map was not required as part of this study (bathymetric information is given in Allott *et al* (1994)). Physical and morphometric parameters are given in Table 3.2.3.

Table 3.2.3 Llyn Coron - physical and morphometric parameters

Lake altitude (m)	9
Maximum depth (m)	2.8
Mean depth (m)	1.8
Lake volume ($x10^3m^3$)	504
Area of lake surface (ha)	28
Perimeter of lake (km)	2.5
Shoreline development index	1.35
Estimated hydraulic residence time (days)	20.3
Secchi disc depth (m)	1.08
Catchment area (ha)	2044
Catchment to lake area ratio	73

Figure 3.2.1 Llyn Coron catchment map



3.2.1.3 Physico-chemical data

Temperature and oxygen profiles for Llyn Coron are given in Figure 3.2.2 and water chemistry data shown in Table 3.2.4.

Figure 3.2.2 Temperature and oxygen profiles for Llyn Coron

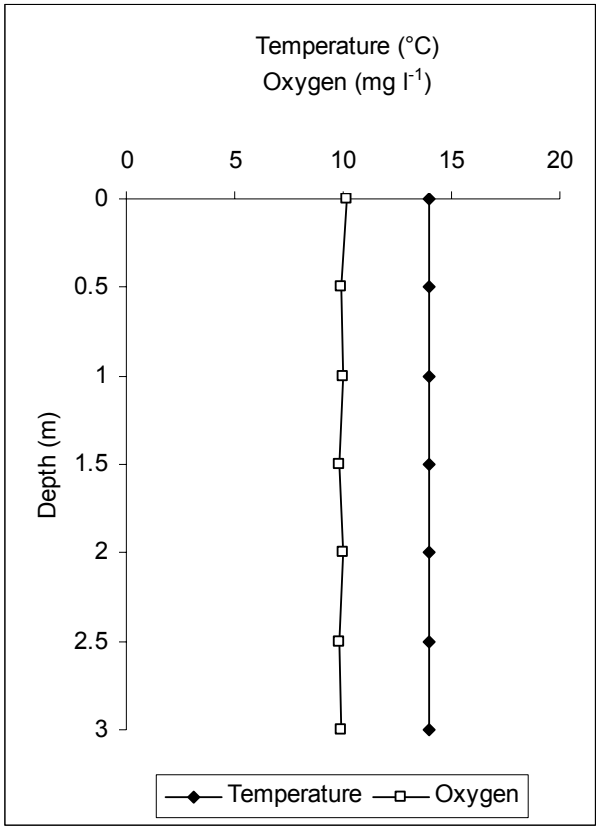


Table 3.2.4 Water chemistry data for Llyn Coron

	Aug 03	Nov 03	Mar 04	Jun 04	Annual mean
pH	8.2	7.5	7.4	8.3	7.8
Cond	332	317	299	347	324
Alk	1771.2	1574.4	1230.0	1738.4	1578.5
DOC	7.39	12.80	7.15	5.71	8.26
SRP	15	39	42	19	29
TP	45	76	<50	31	n.c.
Chl *a*	10.3	2.6	2.6	9.7	6.3
TN	0.49	2.90	4.67	2.57	2.66
NO_3^--N	0.14	2.10	3.11	1.98	1.83
Labile Al	-	-	-	-	-
SO_4^{2-}	310	395	316	435	364
Total Fe	-	-	-	-	-
Na^+	-	878.7	952.7	1078.8	n.c.
K^+	-	101.4	107.3	84.2	n.c.
Mg^{2+}	-	651.0	576.9	768.7	n.c.
Ca^{2+}	1721.6	1786.4	1517.0	2150.7	1793.9
Cl^-	1238.0	798.1	1159.0	1139.3	1083.6
Total Mn	-	-	-	-	-
ANC					1946.07

(n.c. – not calculated, one or more values below analytical detection)
(- denotes data not collected or analysed)

3.2.1.4 Macrophyte survey

Results of the macrophyte survey are given in Tables 3.2.5 and 3.2.6.

Table 3.2.5 Macrophyte abundance for Llyn Coron – emergent and marginal survey

Taxon	DAFOR Abundance
Phragmites australis	**R**
Iris pseudacorus	**D**
Schoenoplectus tabernaemontani	**A**
Sparganium erectum	**O**
Hydrocotyle vulgaris	**F**
Persicaria amphibia	**F**
Filipendula ulmaria	**A**
Potentilla anserina	**A**
Eleocharis palustris	**F**
Persicaria hydropiper	**R**
Potentilla palustris	**R**
Juncus articulatus/acutiflorus	**O**
Juncus effusus	**R**
Carex cf. disticha	**R**
Solanum dulcamara	**A**
Phalaris arundinacea	**F**
Equisetum fluviatile	**R**
Persicaria maculosa	**R**
Sagina procumbens	**R**
Cerastium glomeratum	**R**
Carex caryophyllea	**R**
Elatine hydropiper	**R**
Lycopus europaeus	**R**
Eleocharis multicaulis	**R**
Littorella uniflora	**R**
Mentha aquatica	**R**
Lythrum portula	**R**

Table 3.2.6 Macrophyte abundance for Llyn Coron – wading and boat survey

Taxon	DAFOR Abundance
Callitriche truncata	**D**
Elatine hydropiper	**F**
Eleocharis acicularis	**F**
Chara vulgaris	**R**
Equisetum fluviatile	**R**
Elodea canadensis	**O**
Iris pseudacorus	**O**
Lemna minor	**R**
Myriophyllum spicatum	**D**
Phalaris arundinacea	**R**
Phragmites australis	**R**
Potamogeton cf. berchtoldii	**R**
Potamogeton pectinatus	**R**
Solanum dulcamara	**R**
Sparganium erectum	**R**
Schoenoplectus tabernaemontani	**O**
Zannichellia palustris	**A**

A strandline survey recorded no additional species. *Impatiens glandulifera* was observed growing in the anglers car park to the north west side of the lake.

3.2.1.5 Short core analysis

Short core analysis was not required as part of this study. Epilithon and surface diatom taxon lists are given in Allott *et al.* (1994).

3.3 Llyn Dinam SAC
Llyn Dinam

Location of SAC

SAC Details	
Grid Ref. (approx. centre)	SH310774
SAC EU Code	UK0030186
Total Area	36.7 ha
Total area of Freshwater	10.5 ha

General site character:
Inland water bodies (standing water, running water) (28.6%)
Bogs. Marshes. Water fringed vegetation. Fens (31%)
Dry grassland. Steppes (20.4%)
Humid grassland. Mesophile grassland (14%)
Broad-leaved deciduous woodland (6%)

Annex I habitats that are a primary reason for selection of this site
3150 Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation
Llyn Dinam is a coastal eutrophic lake in north Wales. Common reed *Phragmites australis*, and to a lesser extent common club-rush *Scheonoplectus lacustris*, dominate the shoreline. Rigid hornwort *Ceratophyllum demersum* is abundant in shallow open water, often in association with autumnal starwort *Callitriche hermaphroditica* and ivy-leaved duckweed *Lemna trisulca*. The white and yellow water-lilies *Nymphaea alba* and *Nuphar lutea* dominate in a sheltered arm on the west side. Fennel-leaved pondweed *Potamogeton pectinatus*, perfoliate pondweed *P. perfoliatus* and lesser pondweed *P. pusillus* have been recorded. Stoneworts *Chara* spp. are present. Water chemistry characteristics are consistent with those expected in eutrophic lakes, including relatively high pH, alkalinity and phosphorus levels. Llyn Dinam is the least-enriched of a series of Anglesey Lakes which have been subjected to sediment diatom analysis.

(JNCC, 2005b)

3.3.1 Llyn Dinam

3.3.1.1 Site Description
Llyn Dinam lies some 1.5 km from the coast of western Anglesey within the Llynnau y Fali: Valley Lakes SSSI. A site description can be found in Allott *et al.* (1994*).*

Vegetation types adjacent to the lake include dense *Phragmites* marsh, *Salix* scrub, *Juncus*-dominated marsh and rough grazing to the shore. A farm house is situated close to one sample site with some old farm implements close to the shore. Llyn Dinam is an RSPB Reserve but is used locally for wildfowling. There appears to be relatively low human disturbance to the site.

Information on the solid geology of the Llyn Dinam catchment and land cover data are given in Tables 3.3.1 and 3.3.2 respectively. A catchment map is given in Figure 3.3.1.

Table 3.3.1 Solid geology of the Llyn Dinam catchment
(Data from British Geological Survey solid geology data at 1:62,500)

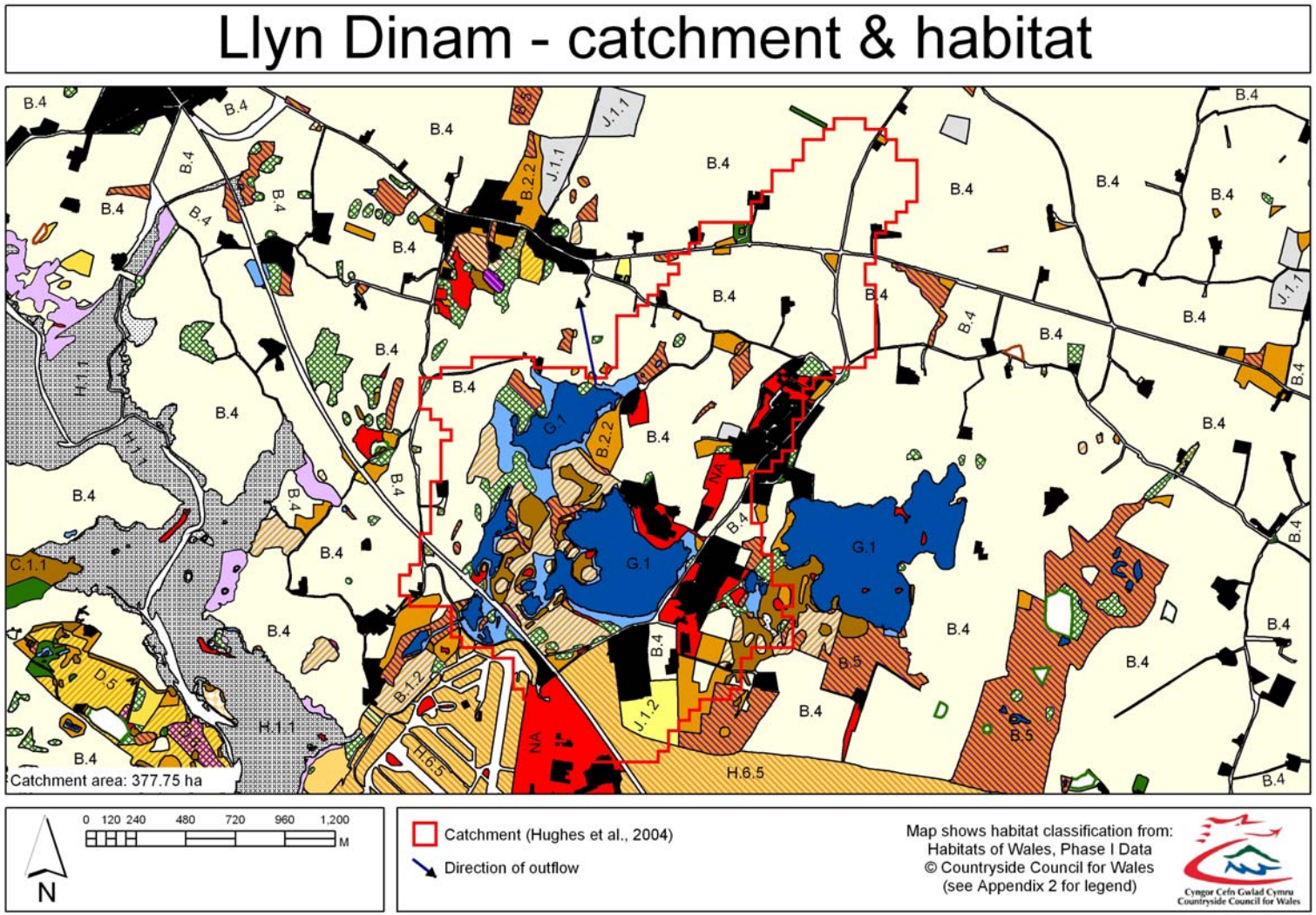
Name	Type	Percentage cover
Gabbro and allied types	Igneous	15.9
Rocks of Anglesey, Lleyn Peninsular, Charnwood, Longmynd etc	Sedimentary	84.1

Table 3.3.2 Land cover data for the Llyn Dinam catchment
(Data from CCW Phase 1 Habitat Survey)

Classification	Code	Percentage cover
Woodland and scrub		
Dense scrub	A.2.1	2.9
Grassland and marsh		
Semi-improved acidic grassland	B.1.2	5.3
Semi-improved neutral grassland	B.2.2	4.0
Improved grassland	B.4	43.6
Marshy grassland	B.5	2.9
Tall herb and fern		
Bracken	C.1.1	3.0
Swamp, marginal and inundation		
Swamp	F.1	5.1
Open water		
Standing water	G.1	9.8
Coastland		
Dune grassland	H.6.5	3.5
Miscellaneous		
Amenity grassland	J.1.2	1.6
Buildings	J.3.6	7.7
Other*		10.6

* Percentage cover >1% and /or data not available

Figure 3.3.1 Llyn Dinam catchment map



3.3.1.2 Bathymetry

A bathymetric map was not required as part of this study (bathymetric information is given in Allott *et al.* (1994)). Physical and morphometric parameters are given in Table 3.3.3.

Table 3.3.3 Llyn Dinam - physical and morphometric parameters

Lake altitude (m)	8
Maximum depth (m)	1.8
Mean depth (m)	1.4
Lake volume ($x10^3m^3$)	136.3
Area of lake surface (ha)	9.7
Perimeter of lake (km)	1.9
Shoreline development index	1.67
Estimated hydraulic residence time (days)	36
Secchi disc depth (m)	1.5
Catchment area including lake (ha)	377
Catchment to lake area ratio	38.9

3.3.1.3 Physico-chemical data

Temperature and oxygen profiles for Llyn Dinam are given in Figure 3.3.2 and water chemistry data shown in Table 3.3.4.

Fig. 3.3.2 Temperature and oxygen profiles for Llyn Dinam

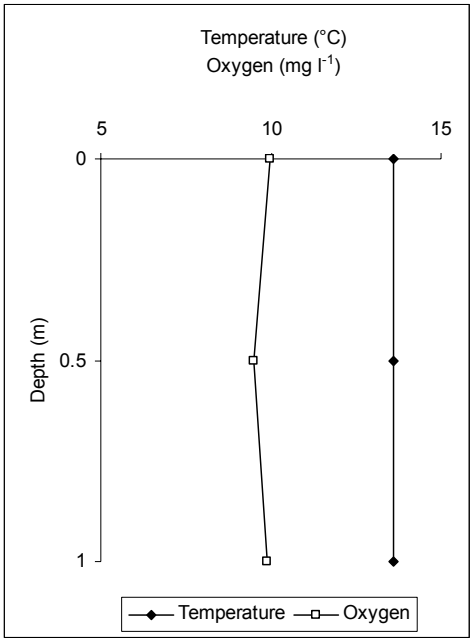


Table 3.3.4 Water chemistry data for Llyn Dinam

	Dec 03	Mar 04	Aug 04	Oct 04	Annual mean
pH	7.4	8.5	8.0	7.6	7.7
Cond	347	348	390	405	373
Alk	1164.4	1098.8	1394.0	1443.2	1275.1
DOC	-	-	9.28	11.90	n.c.
SRP	-	2	36	22	n.c.
TP	80	34	78	41	58.25
Chl *a*	3.6	20.8	26.9	13.6	16.2
TN	1.98	1.63	1.28	1.10	1.50
NO_3^--N	1.35	0.29	0.04	0.19	0.47
Labile Al	-	-	-	-	-
SO_4^{2-}	-	-	218	314	n.c.
Total Fe	-	-	-	-	-
Na^+	-	-	-	1870.5	n.c.
K^+	-	-	-	98.6	n.c.
Mg^{2+}	-	-	-	740.7	n.c.
Ca^{2+}	-	-	1581.8	1472.1	n.c.
Cl^-	-	-	2185.5	2061.4	n.c.
Total Mn	-	-	-	-	-
ANC – October 04 only			-		1790

(n.c. – not calculated, one or more values below analytical detection)
(- denotes data not collected or analysed)

3.3.1.4 Macrophyte survey

Results of the macrophyte survey are given in Tables 3.3.5 and 3.3.6.

Table 3.3.5 Macrophyte abundance for Llyn Dinam – emergent and marginal survey

Taxon	DAFOR Abundance
Phragmites australis	**F**
Schoenoplectus lacustris	**A**
Solanum dulcamara	**A**
Menyanthes trifoliata	**A**
Veronica beccabunga	**O**
Sparganium erectum	**A**
Epilobium hirsutum	**F**
Berula erecta	**F**
Carex paniculata	**F**
Lycopus europaeus	**F**
Mentha aquatica	**F**
Filipendula ulmaria	**O**
Hydrocotyle vulgaris	**F**
Bidens cernua	**O**
Lythrum salicaria	**O**
Myosotis laxa	**O**
Galium palustre agg.	**O**
Ranunculus lingua	**O**
Salix sp.	**O**
Iris pseudacorus	**O**
Rumex hydrolapathum	**O**
Potentilla palustris	**O**
Alisma plantago-aquatica	**R**
Angelica sylvestris	**R**
Veronica anagallis-aquatica	**R**
Persicaria amphibia	**O**
Persicaria hydropiper	**O**
Persicaria maculosa	**O**
Ranunculus flammula	**O**
Carex panicea	**R**
Juncus effusus	**O**
Juncus articulatus/acutiflorus	**O**
Sagina procumbens	**R**
Chenopodium album agg.	**R**
Bidens tripartita	**O**
Caltha palustris	**R**
Eleocharis multicaulis	**O**

Table 3.3.5 continued

Taxon	DAFOR Abundance
Eleocharis palustris	**O**
Phalaris arundinacea	**R**
Typha angustifolia	**R**
Ranunculus aquatilis agg.	**O**
Callitriche cf hermaphroditica	**R**
Ranunculus hederaceus	**R**
Lotus corniculatus	**R**
Potentilla anserina	**O**

Table 3.3.6 Macrophyte abundance for Llyn Dinam – wading and boat survey

Taxon	DAFOR Abundance
Alisma plantago-aquatica	**R**
Berula erecta	**R**
Callitriche sp	**F**
Carex paniculata	**R**
Ceratophyllum demersum	**D**
Chara vulgaris	**R**
Elatine hydropiper	**O**
Elodea canadensis	**R**
Epilobium hirsutum	**R**
Eleocharis acicularis	**R**
Eleocharis palustris	**R**
Fontinalis antipyretica	**D**
Lemna minor	**F**
Lemna trisulca	**D**
Littorella uniflora	**R**
Lycopus europaeus	**R**
Iris pseudacorus	**O**
Mentha aquatica	**O**
Menyanthes trifoliata	**O**
Myosotis laxa	**R**
Myriophyllum spicatum	**F**
Nitella flexilis agg.	**F**
Nuphar lutea	**F**
Nymphaea alba	**F**
Persicaria amphibia	**R**
Phragmites australis	**F**
Potamogeton berchtoldii	**O**

Table 3.3.6 continued

Taxon	DAFOR Abundance
Potamogeton pectinatus	**R**
Potentilla palustris	**O**
Ranunculus lingua	**R**
Schoenoplectus lacustris	**F**
Solanum dulcamara	**F**
Sparganium erectum	**A**
Typha latifolia	**R**
Veronica beccabunga	**O**
Zannichellia palustris	**O**

No additional species were recorded in a strandline survey.

3.3.1.5 Short core analysis

Short core analysis was not required as part of this study. Epilithon and surface diatom taxon lists are given in Allott *et al.* (1994).

3.4 Afon Gwyrfai a Llyn Cwellyn SAC
Llyn Cwellyn

Location of SAC

SAC Details	
Grid Ref. (approx. centre)	SH547561
SAC EU Code	UK0030046
Total Area	114 ha
Total area of Freshwater	114 ha

General site character:
Inland water bodies (standing water, running water) (100%)

Annex I habitats that are a primary reason for selection of this site
3130 Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*
Llyn Cwellyn, north Wales, is an oligotrophic glacial lake (Type 3) representative of oligotrophic lakes found in the mountains of Snowdonia. It is a relatively large, deep lake, in contrast to Llyn Idwal, also in Snowdonia. Because of its depth the lake stratifies during the summer, with a thermocline developing at 10-15 m depth that has a marked effect upon the ecology of the site. Although the site has acidified since the late 19th century, water quality remains high and Llyn Cwellyn supports one of the few native Welsh populations of Arctic char *Salvelinus alpinus* ('Torgoch' in Welsh). The macrophyte flora of Llyn Cwellyn is characterised by abundant shoreweed *Littorella uniflora,* water lobelia *Lobelia dortmanna*, quillwort *Isoetes lacustris*, bulbous rush *Juncus bulbosus* and alternate water-milfoil *Myriophyllum alterniflorum*. The rare awlwort *Subularia aquatica* is abundant in places and 1831 Floating water-plantain *Luronium natans* occurs at this site. Six-stamened waterwort *Elatine hexandra* has been recorded in shallow water off the north shore and bog pondweed *Potamogeton polygonifolius* occurs in stream inflows in the south.

3260 Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation
The Gwyrfai is a good example of the small, steep rivers that occur in north-west Wales. It is dominated by base-poor rock and contains extensive beds of the most oligotrophic end of sub-type 3 of this habitat, dominated by stream water-crowfoot *Ranunculus penicillatus* ssp. *penicillatus*, intermediate water-starwort *Callitriche hamulata*, aquatic mosses *Fontinalis* spp. and bulbous rush *Juncus bulbosus*. The conservation value of the site is enhanced by the presence of good adjacent river corridor habitat, and by the

presence of Llyn Cwellyn, a good example of *a Littorella – Lobelia – Isoetes* oligotrophic lake.

(JNCC, 2005b)

3.4.1 Llyn Cwellyn

3.4.1.1 Site Description

Llyn Cwellyn is situated at an altitude of 142 m in the Nant y Betws valley within the Snowdonia National Park. The lake level is maintained by a concrete weir on the outflow and water is abstracted for raw drinking supply. There is a mature coniferous forest plantation to the southern shore, with a hotel at the western end near the outflow. Vegetation types adjacent to the lake include rough grassland, some improved pasture and a wetland area. A road runs along the northern shore. In terms of recreational use, angling is limited to hotel guests and permit holders. Further site details are given in Allott *et al* (1994).

Information on the solid geology of the Llyn Cwellyn catchment and land cover data are given in Tables 3.4.1 and 3.4.2 respectively. A catchment map is given in Figure 3.4.1.

Table 3.4.1 Solid geology of the Llyn Cwellyn catchment
(Data from British Geological Survey solid geology data at 1:62,500)

Name	Type	Percentage cover
Granite, syenite, granophyre and allied types	Igneous	4.5
Basalt dolerite, camptonite and allied types	Igneous	12.6
Rhyolite, trachyte, felsite, elvans and allied types	Igneous	0.1
Basalt, spilite, hyaloclastic and related tuffs	Igneous	0.8
Ryolitic tuff, including ignimbrite	Igneous	7.7
Upper Cambrian, including Tremadoc	Sedimentary	8.9
Llanvern and Arenig	Sedimentary	26.7
Caradoc	Sedimentary	38.7

Table 3.4.2 Land cover data for the Llyn Cwellyn catchment
(Data from CCW Phase 1 Habitat Survey)

Classification	Code	Percentage cover
Woodland and scrub		
Planted coniferous woodland	A.1.2.2	5.7
Felled coniferous woodland	A.4.2	1.8
Grassland and marsh		
Unimproved acid grassland	B.1.1	51.2
Semi-improved acidic grassland	B.1.2	6.8
Improved grassland	B.4	5.3
Marshy grassland	B.5	6.6
Tall herb and fern		
Bracken	C.1.1	1.0
Heathland		
Dry acid heath	D.1.1	3.5
Dry heath/acid grassland mosaic	D.5	1.5
Mire		
Blanket bog	E.1.6.1	1.5
Acid/neutral flush	E.2.1	2.4
Open water		
Standing water	G.1	6.2
Other*		6.5

* Percentage cover >1% and /or data not available

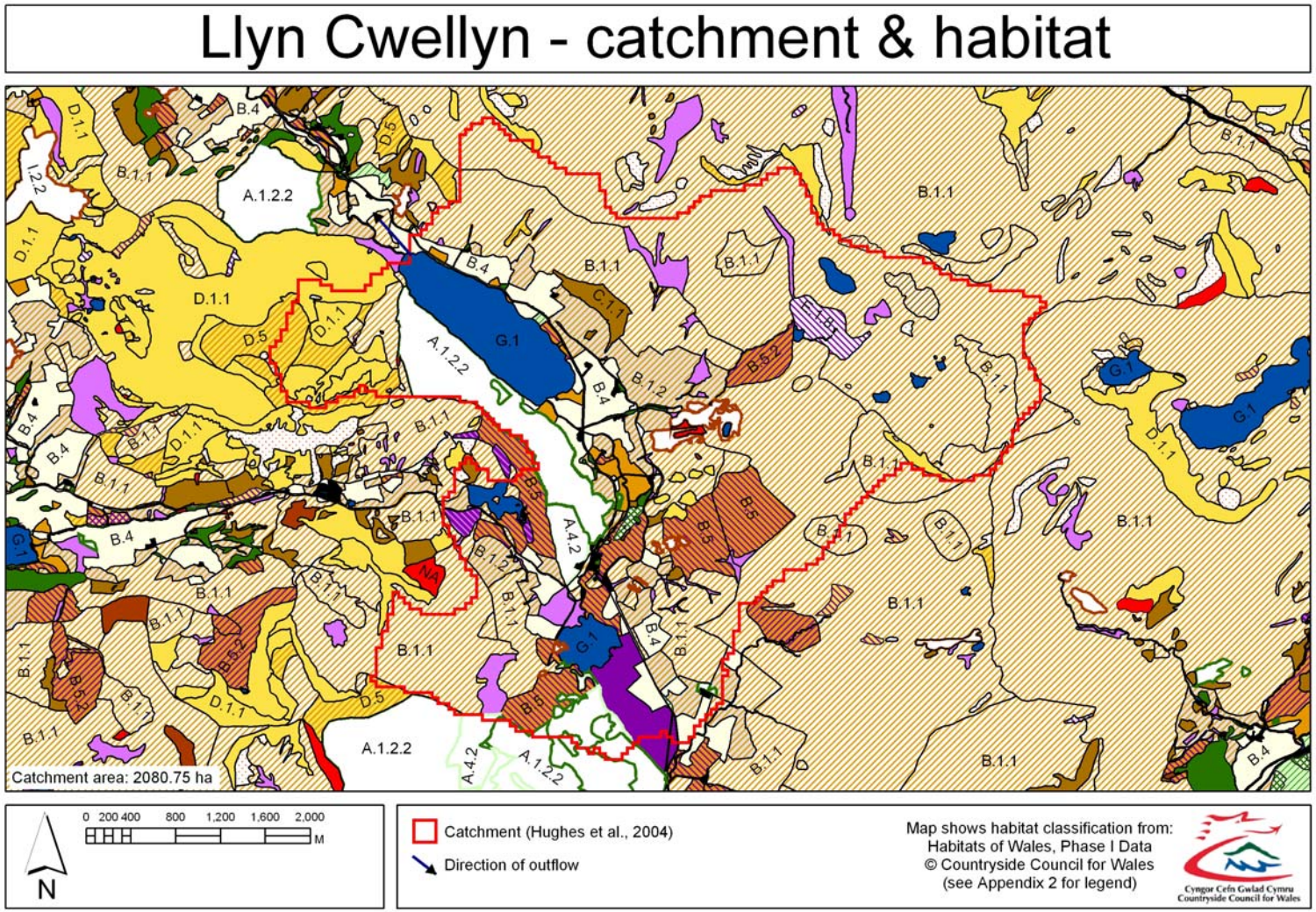
3.4.1.2 Bathymetry

A bathymetric map was not required as part of this study (a lake bathymetry is given in Allott *et al* (1994)). Physical and morphometric parameters are given in Table 3.4.3.

Table 3.4.3 Llyn Cwellyn - physical and morphometric parameters

Lake altitude (m)	142
Maximum depth (m)	36
Mean depth (m)	22.6
Lake volume ($x10^3m^3$)	20,360
Area of lake surface (ha)	90.1
Perimeter of lake (km)	4.5
Shoreline development index	1.32
Estimated hydraulic residence time (days)	136.1
Secchi disc depth (m)	7.25
Catchment area including lake (ha)	2081
Catchment to lake area ratio	23.1

Figure 3.4.1 Llyn Cwellyn catchment map



3.4.1.3 Physico-chemical data

Temperature and oxygen profiles for Llyn Cwellyn are given in Figure 3.4.2 and water chemistry data shown in Table 3.4.4.

Figure 3.4.2 Temperature and oxygen profiles for Llyn Cwellyn

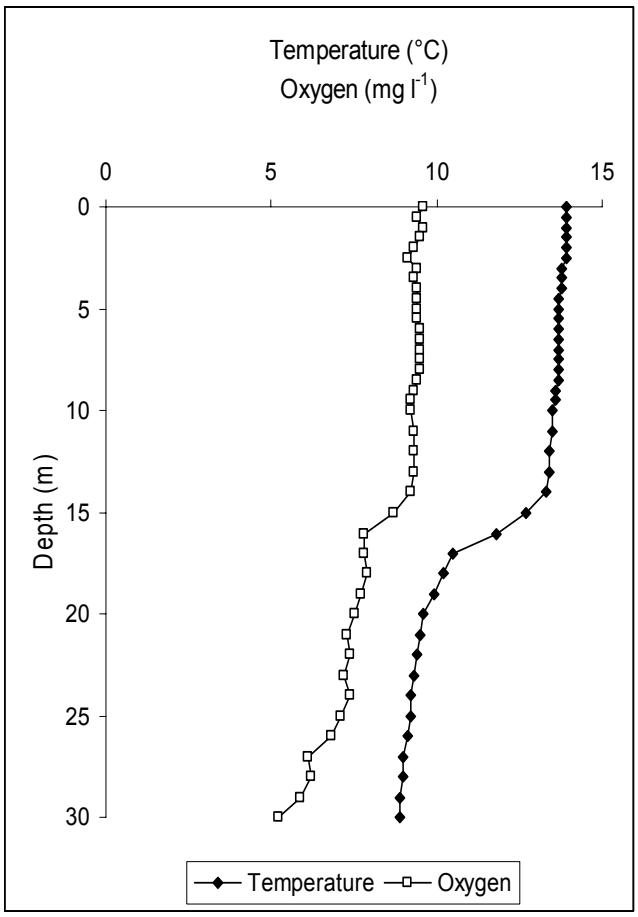


Table 3.4.4 Water chemistry data for Llyn Cwellyn

	Dec 03	Mar 04	Jun 04	Sept 04	Annual mean
pH	7.6	7.6	7.1	6.8	6.9
Cond	37	34	36	33	35
Alk	60.7	82.0	-	58.1	n.c.
DOC	-	-	1.34	1.81	n.c.
SRP	-	4	10	4	n.c.
TP	10	4	17	6	9
Chl *a*	1.4	1.5	2.5	5.5	2.7
TN	0.39	0.38	0.41	0.37	0.39
NO_3^--N	0.25	0.36	0.13	0.18	0.00
Labile Al	-	-	-	-	-
SO_4^{2-}	-	-	70	73	n.c.
Total Fe	-	-	-	-	-
Na^+	-	-	-	-	-
K^+	-	-	-	-	-
Mg^{2+}	-	-	-	-	-
Ca^{2+}	-	-	79.8	101.8	n.c.
Cl^-	-	-	197.4	190.9	n.c.
Total Mn	-	-	-	-	-
ANC	-	-	-	-	-

(n.c. – not calculated, one or more values below analytical detection)
(- denotes data not collected or analysed)

3.4.1.4 Macrophyte survey

Results of the macrophyte survey are given in Tables 3.4.5 and 3.4.6.

Table 3.4.5 Macrophyte abundance for Llyn Cwellyn – emergent and marginal survey

Taxon	DAFOR Abundance
Phalaris arundinacea	**A**
Lotus pedunculatus	**R**
Fontinalis antipyretica	**O**
Juncus effusus	**A**
Salix sp.	**R**
Oenanthe crocata	**R**
Angelica sylvestris	**R**
Crocosmia aurea x C. pottsii	**R**
Juncus articulatus/acutiflorus	**D**
Potentilla erecta	**R**
Viola palustris	**O**
Galium palustre agg.	**F**
Racomitrium sp.	**O**
Apium nodiflorum	**R**
Ranunculus flammula	**R**
Mentha aquatica	**R**
Caltha palustris	**R**

Table 3.4.6 Macrophyte abundance for Llyn Cwellyn – wading and boat survey

Taxon	DAFOR Abundance
Callitriche hamulata	**F**
Fontinalis antipyretica	**F**
Isoetes lacustris	**A**
Juncus bulbosus	**A**
Juncus articulatus/acutiflorus	**R**
Juncus effusus	**R**
*Luronium natans**	**R**
Littorella uniflora	**A**
Lobelia dortmanna	**A**
Myriophyllum alterniflorum	**O**
Nitella flexilis agg.	**O**
*Nitella gracilis**	**R**
Phalaris arundinacea	**R**
Potamogeton berchtoldii	**R**
Ranunculus flammula	**O**
Scapania undulata	**R**
Sphagnum auriculatum	**O**
Subularia aquatica	**R**

* RDB species

A strandline survey recorded the presence of *Potamogeton polygonifolius* and *Elatine hexandra.*

3.4.1.5 Short core analysis

Short core analysis was not required as part of this study. Epilithon and surface diatom taxon lists are given in Allott *et al.* (1994).

3.5 Eryri/ Snowdonia SAC
Llyn Coch, Llyn Cwmffynnon, Llyn Idwal & Llyn Ogwen

Location of SAC

SAC Details	
Grid Ref. (approx. centre)	SH695658
SAC EU Code	UK0012946
Total Area	19738 ha
Total area of Freshwater	395 ha

General site character:
Inland water bodies (standing water, running water) (2%)
Bogs. Marshes. Water fringed vegetation. Fens (15%)
Heath. Scrub. Maquis and garrigue. Phygrana (19.7%)
Dry grassland. Steppes (34%)
Alpine and sub-alpine grassland (1%)
Broad-leaved deciduous woodland (0.3%)
Inland rocks. Screes. Sands. Permanent snow and ice (27%)
Other land (including towns, villages, roads, waste places, mines, industrial sites) (1%)

Annex I habitats that are a primary reason for selection of this site
3130 Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*
Llyn Idwal, in the mountains of Snowdonia, represents oligotrophic waters (Type 3) in north Wales. It is a relatively small, shallow, upland corrie, in contrast to Llyn Cwellyn, also in Snowdonia, and complete ice cover has been recorded in winter. No overall change in the lake's water chemistry has been found since the mid-19th century, and the water quality is considered to be high. The site has a good representation of typical plant species, including quillwort *Isoetes lacustris*, water lobelia *Lobelia dortmanna*, shoreweed *Littorella uniflora*, bulbous rush *Juncus bulbosus*, alternate water-milfoil *Myriophyllum alterniflorum* and intermediate water-starwort *Callitriche hamulata*. Bog pondweed *Potamogeton polygonifolius* has been recorded from stream inlets, and pillwort *Pilularia globulifera* is reported from this site. Emergent and floating vegetation is mainly confined to the shallow sub-basin at the south end of the site, where floating bur-reed *Sparganium angustifolium* forms extensive mats, alongside stands of common reed *Phragmites australis*, water horsetail *Equisetum fluviatile* and bottle sedge *Carex rostrata.*
6150 Siliceous alpine and boreal grasslands
Snowdonia has the best-developed and most extensive areas of Siliceous alpine and boreal grasslands in Wales and is the largest example of the habitat type south of

Scotland. The principal sub-type present is U10 *Carex bigelowii – Racomitrium lanuginosum* moss-heath, but there are also fragments of U7 *Nardus stricta – Carex bigelowii* grass-heath. This site is representative of the more impoverished southern variants of the habitat type.

6430 Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels

Snowdonia is the most southerly site selected and contains the most extensive and diverse examples of hydrophilous tall herb fringe communities in Wales. Fragmentary stands of the habitat type occur on pumice tuff and other base-enriched igneous rocks at a range of altitudes throughout the site. The vegetation is floristically somewhat impoverished compared with Scottish examples but includes many of the species found further north, such as globe-flower *Trollius europaeus*, wild angelica *Angelica sylvestris* and holly-fern *Polystichum lonchitis*. It is important as a southern outlier for arctic-alpines such as alpine saw-wort *Saussurea alpina* and black alpine-sedge *Carex atrata*. There are also some southern species, which are absent further north, for example Welsh poppy *Meconopsis cambrica*.

8110 Siliceous scree of the montane to snow levels (*Androsacetalia alpinae* and *Galeopsietalia ladani*)

Snowdonia is the largest site in Wales representative of siliceous scree. The site has extensive screes of igneous rocks with large stands of U21 *Cryptogramma crispa – Deschampsia flexuosa* vegetation; associated species include fir clubmoss *Huperzia selago.* Bryophyte and lichen-dominated screes are also well-represented and include important populations of rare and local montane and oceanic species, such as *Marsupella adusta, Marsupella stableri* and *Cornicularia narmoerica*.

8210 Calcareous rocky slopes with chasmophytic vegetation

Snowdonia is representative of Calcareous rocky slopes with chasmophytic vegetation at one of its most southerly outposts in the UK, and contains the most extensive and diverse examples of these communities in Wales. Crevices in base-rich igneous rocks support a characteristic assemblage of plants, with a large number of arctic-alpine species. These include a number of nationally rare species, such as alpine saxifrage *Saxifraga nivalis*, tufted saxifrage *S. cespitosa*, alpine meadow-grass *Poa alpina* and alpine woodsia *Woodsia alpina*. A species of particular interest is the Snowdon lily *Lloydia serotina*, which in the UK occurs only in Snowdonia, in rock cracks and crevices on calcareous and more siliceous substrates, and is here at its northern limit in western Europe.

8220 Siliceous rocky slopes with chasmophytic vegetation

Snowdonia, north Wales, is representative of Siliceous rocky slopes with chasmophytic vegetation at the southern edge of the range of the habitat type. Acidic crevice communities occur throughout the site on igneous outcrops and include populations of stiff sedge *Carex bigelowii*, fir clubmoss *Huperzia selago* and forked spleenwort *Asplenium septentrionale*. Atlantic species, including Wilson's filmy-fern *Hymenophyllum wilsonii* and a wide range of bryophytes, are also well-represented.

This large SAC also includes contains the following Annex I habitats 4010 Northern Atlantic wet heaths with *Erica tetralix*, 4030 European dry heaths, 4060 Alpine and Boreal heaths, 6170 Alpine and subalpine calcareous grasslands, 6230 Species-rich *Nardus* grassland, on siliceous substrates in mountain areas (and submountain areas in

continental Europe), 7130 Blanket bogs, 7150 Depressions on peat substrates of the *Rhynchosporion*, 7220 Petrifying springs with tufa formation (*Cratoneurion*), 7230 Alkaline fens, 7240 Alpine pioneer formations of the *Caricion bicoloris-atrofuscae*, 91A0 Old sessile oak woods with *Ilex* and *Blechnum* in the British Isles

(JNCC, 2005b)

3.5.1 Llyn Coch

3.5.1.1 Site Description

Llyn Coch is a small, shallow upland lake, having a surface area of 1.2 ha and a mean depth 0.5 m. Vegetation in the catchment consists entirely of unimproved acid grassland. Information on the solid geology of the Llyn Coch catchment and land cover data are given in Tables 3.5.1 and 3.5.2 respectively. A catchment map is given in Figure 3.5.1 .

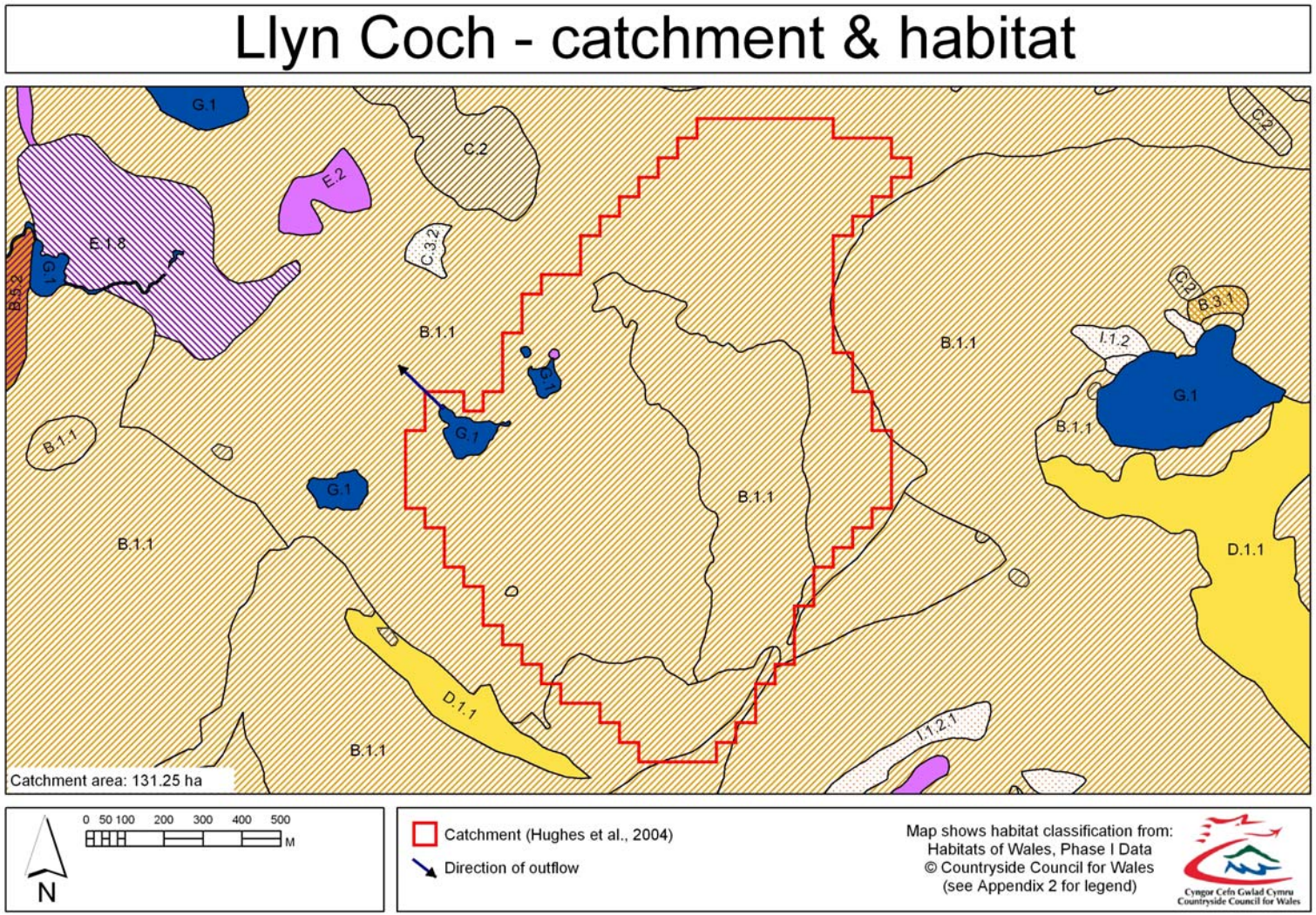
Table 3.5.1 Solid geology of the Llyn Coch catchment
(Data from British Geological Survey solid geology data at 1:62,500)

Name	Type	Percentage cover
Basalt dolerite, camptonite and allied types	Igneous	13.0
Basalt, spilite, hyaloclastic and related tuffs	Igneous	12.5
Ryolitic tuff, including ignimbrite	Igneous	74.5

Table 3.5.2 Land cover data for the Llyn Coch catchment
(Data from CCW Phase 1 Habitat Survey)

Classification	Code	Percentage cover
Grassland and marsh		
Unimproved acid grassland	B.1.1	98.7
Open water		
Standing water	G.1	1.3

Figure 3.5.1 Llyn Coch catchment map



3.5.1.2 Bathymetry

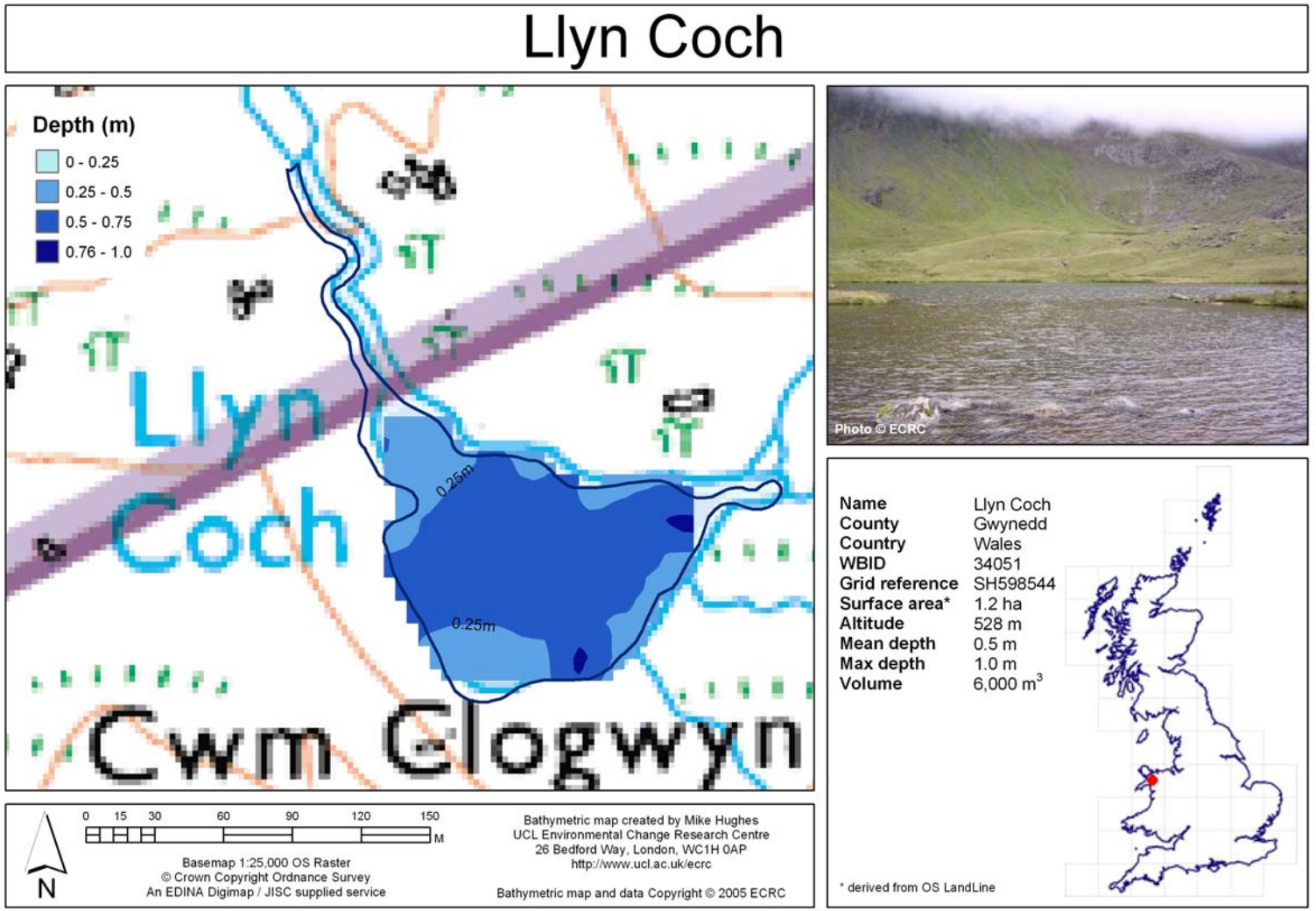
The bathymetry of Llyn Coch is shown in Figure 3.5.2, physical and morphometric parameters are given in Table 3.5.3.

Table 3.5.3 Llyn Coch - physical and morphometric parameters

Lake altitude (m)	528
Maximum depth (m)	1
Mean depth (m)	0.5
Lake volume ($x10^3m^3$)	6
Area of lake surface (ha)	1.2
Perimeter of lake (km)	0.4
Shoreline development index	1.21
Estimated hydraulic residence time (days)	0.45
Secchi disc depth (m)	na
Catchment area (ha)	131.3
Catchment to lake area ratio	109.4

na – not available

Figure 3.5.2 Llyn Coch bathymetry map



3.5.1.3 Physico-chemical data

Temperature and oxygen profiles for Llyn Coch are given in Figure 3.5.3 and water chemistry data shown in Table 3.5.4.

Figure 3.5.3 Temperature and oxygen profiles for Llyn Coch

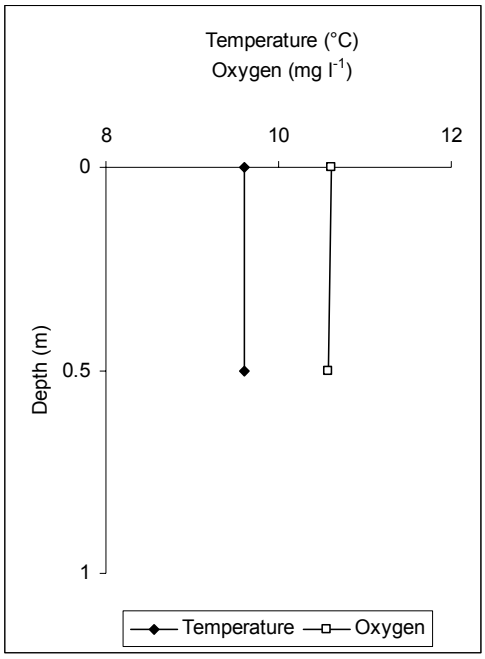


Table 3.5.4 Water chemistry data for Llyn Coch

	Sept 04	Dec 04	Mar 05	Jun 05	Annual mean
pH	7.2	6.8	6.9	7.0	7.0
Cond	26	37	39	39	35
Alk	<114	229.5	205.0	111.6	n.c.
DOC	1.03	0.13	0.32	0.57	0.51
SRP	7	8	7	7	7
TP	<50	<50	<50	3.2	n.c.
Chl *a*	0.7	0.5	0.2	1.1	0.6
TN	0.28	0.29	0.37	0.35	0.32
NO_3^--N	0.91	1.44	1.30	1.03	1.17
Labile Al	<23	<23	18.6	<23	n.c.
SO_4^{2-}	94	82	79	74	82
Total Fe	7	8	<6	<6	n.c.
Na^+	123.9	135.7	155.9	142.3	139.5
K^+	3.1	3.1	2.2	3.4	3.0
Mg^{2+}	44.9	63.3	70.1	63.4	60.4
Ca^{2+}	116.7	153.9	145.6	154.9	142.8
Cl^-	129.6	137.1	166.2	159.9	148.2
Total Mn	2.2	3.6	<2.0	3.4	n.c.
ANC					31.07

(n.c. – not calculated, one or more values below analytical detection)

3.5.1.4 Macrophyte survey

Results of the macrophyte survey are given in Tables 3.5.5 and 3.5.6.

Table 3.5.5 Macrophyte abundance for Llyn Coch – emergent and marginal survey

Taxon	DAFOR Abundance
Carex panicea	**F**
Carex echinata	**A**
Viola palustris	**A**
Carex binervis	**F**
Sparganium angustifolium	**F**
Juncus bulbosus	**A**
Juncus squarrosus	**F**
Potentilla erecta	**F**
Galium saxatile	**F**
Juncus effusus	**A**
Carex demissa	**F**
Epilobium brunnescens	**F**

Table 3.5.6 Macrophyte abundance for Llyn Coch – wading and boat survey

Taxon	DAFOR Abundance
Isoetes lacustris	**D**
Littorella uniflora	**D**
Myriophyllum alterniflorum	**R**

A strandline survey recorded the presence of *Callitriche hamulata*. Only one 100 m shoreline transect was carried out in order to minimize the disturbance to this small site (as per method, Appendix 1). At the time of sampling the water level was approximately 5 cm above normal after heavy rain.

3.5.1.5 Short core analysis

A 10 cm Glew core, COCH1 (also known as VH5501_1), was taken in a water depth of 1.1 m from Llyn Coch on 23-Aug-04. A summary diagram of the common taxa (>2%) is shown in Figure 3.5.4 and summary data are given in Table 3.5.7. The core top and bottom samples contained a total of 69 diatom taxa although there was a high mineral content and many frustules were badly broken. The assemblage of the bottom sample was comprised of numerous non-planktonic species typical of circumneutral waters, the most abundant being *Achnanthes* spp. *(e.g. minutissima, didyma, levanderi, daonensis), Nitzschia fonticola,* and benthic *Fragilaria* spp. *(e.g. virescens* var. *exigua, pinnata, construens* var. *venter)*. The top sample also contained high amounts of *Achnanthes minutissima* and the benthic *Fragilaria* taxa but the other *Achnanthes* spp. declined and a

number of taxa, namely *Cocconeis placentula*, *Fragilaria pseudoconstruens*, *Gomphonema* spp. and *Synedra* spp. increased in relative abundance. The squared chord distance dissimilarity score between the two samples was 0.676.

Reconstructions of diatom-inferred pH (DI-pH) were produced using the SWAP training set. A relatively low percentage of the taxa in the fossil samples were present in the SWAP training set. The analogues were especially poor for the top sample where a number of important taxa (e.g. *Fragilaria pseudoconstruens, Synedra ulna*, *Synedra rumpens* var. *familiaris*) were absent from the training set (Table 3.5.7). The DI-pH values are ~6.6 for both the bottom and the top samples, indicating no change in acidity status. The annual mean current pH based on quarterly water samples collected during 2004-2005 is 6.98 and therefore the diatom model appears to slightly under-estimate current pH by ~0.4 pH units.

In summary, there has been a moderate degree of floristic change in the Llyn Coch core but the assemblages of both the bottom and top samples are comprised of non-planktonic taxa typically associated with the substrates of circumneutral waters. There is no evidence of acidification although the reconstructed diatom-pH values must be viewed with caution owing to the poor analogues. The observed species shifts are more likely to be explained by alterations in habitat availability such as changes in the host plant community.

Figure 3.5.4 Summary diagram of diatom assemblages in top and bottom samples from core COCH1 (alias VSH5501_1)

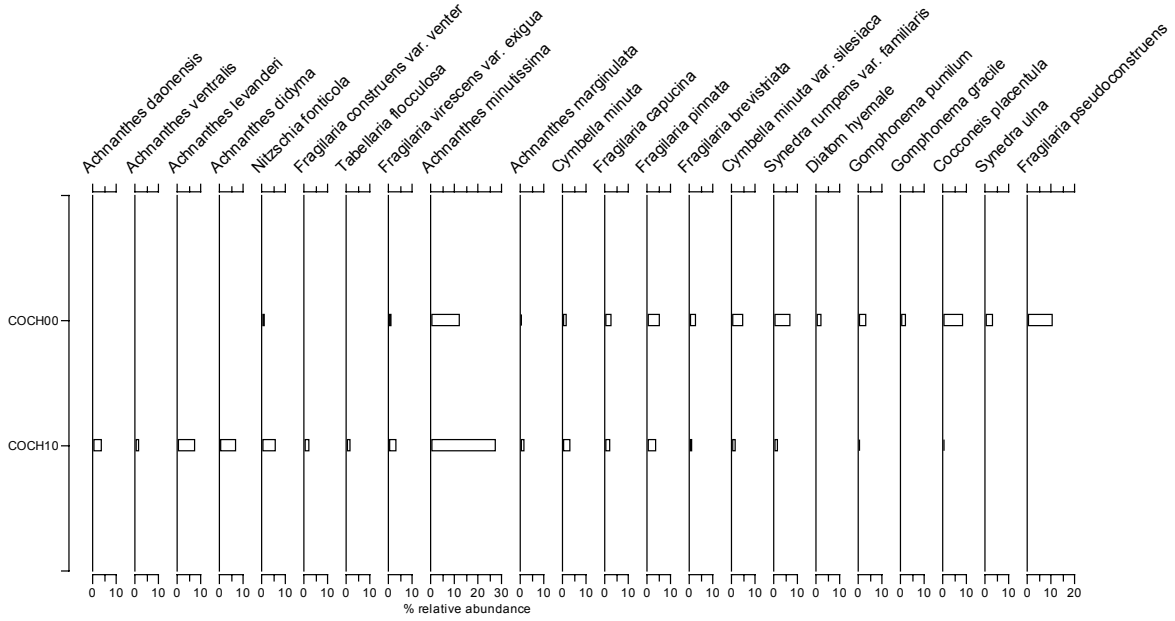


Table 3.5.7 Results of Llyn Coch short core analysis

Sample code	Depth (cm)	Annual mean current pH	DI-pH	No. taxa in fossil sample	% of taxa in fossil sample present in SWAP training set	Squared chord distance dissimilarity score between core top and bottom
COCH00	0	6.98	6.66	55	58	0.676
COCH10	10		6.61	49	79	

3.5.2 Llyn Cwmffynnon

3.5.2.1 Site Description

Llyn Cwmffynnon lies at an altitude of 385 m. Vegetation surrounding the lake is dominated by rough upland grazing. Information on the solid geology of the Llyn Cwmffynnon catchment and land cover data are given in Tables 3.5.8 and 3.5.9 respectively. A catchment map is given in Figure 3.5.5.

Table 3.5.8 Solid geology of the Llyn Cwmffynnon catchment
(Data from British Geological Survey solid geology data at 1:62,500)

Name	Type	Percentage cover
Rhyolite, trachyte, felsite, elvans and allied types	Igneous	12.3
Ryolitic tuff, including ignimbrite	Igneous	1.2
Caradoc	Sedimentary	86.5

Table 3.5.9 Land cover data for the Llyn Cwmffynnon catchment
(Data from CCW Phase 1 Habitat Survey)

Classification	Code	Percentage cover
Grassland and marsh		
Unimproved acid grassland	B.1.1	67.4
Heathland		
Dry acid heath	D.1.1	12.3
Lichen/bryophyte heath	D.3	1.6
Mire		
Blanket bog	E.1.6.1	4.4
Acid/neutral flush	E.2.1	1.9
Open water		
Standing water	G.1	11.0
Other*		1.4

* Percentage cover >1% and /or data not available

3.5.2.2 Bathymetry

The bathymetry of Llyn Cwmffynnon is shown in Figure 3.5.6, physical and morphometric parameters are given in Table 3.5.10.

Table 3.5.10 Llyn Cwmffynnon - physical and morphometric parameters

Lake altitude (m)	385
Maximum depth (m)	11.2
Mean depth (m)	2.7
Lake volume ($x10^3m^3$)	267.3
Area of lake surface (ha)	9.9
Perimeter of lake (km)	1.5
Shoreline development index	1.29
Estimated hydraulic residence time (days)	36.4
Secchi disc depth (m)	3.6
Catchment area including lake (ha)	79.5
Catchment to lake area ratio	8.0

Figure 3.5.5 Llyn Cwmffynnon catchment map

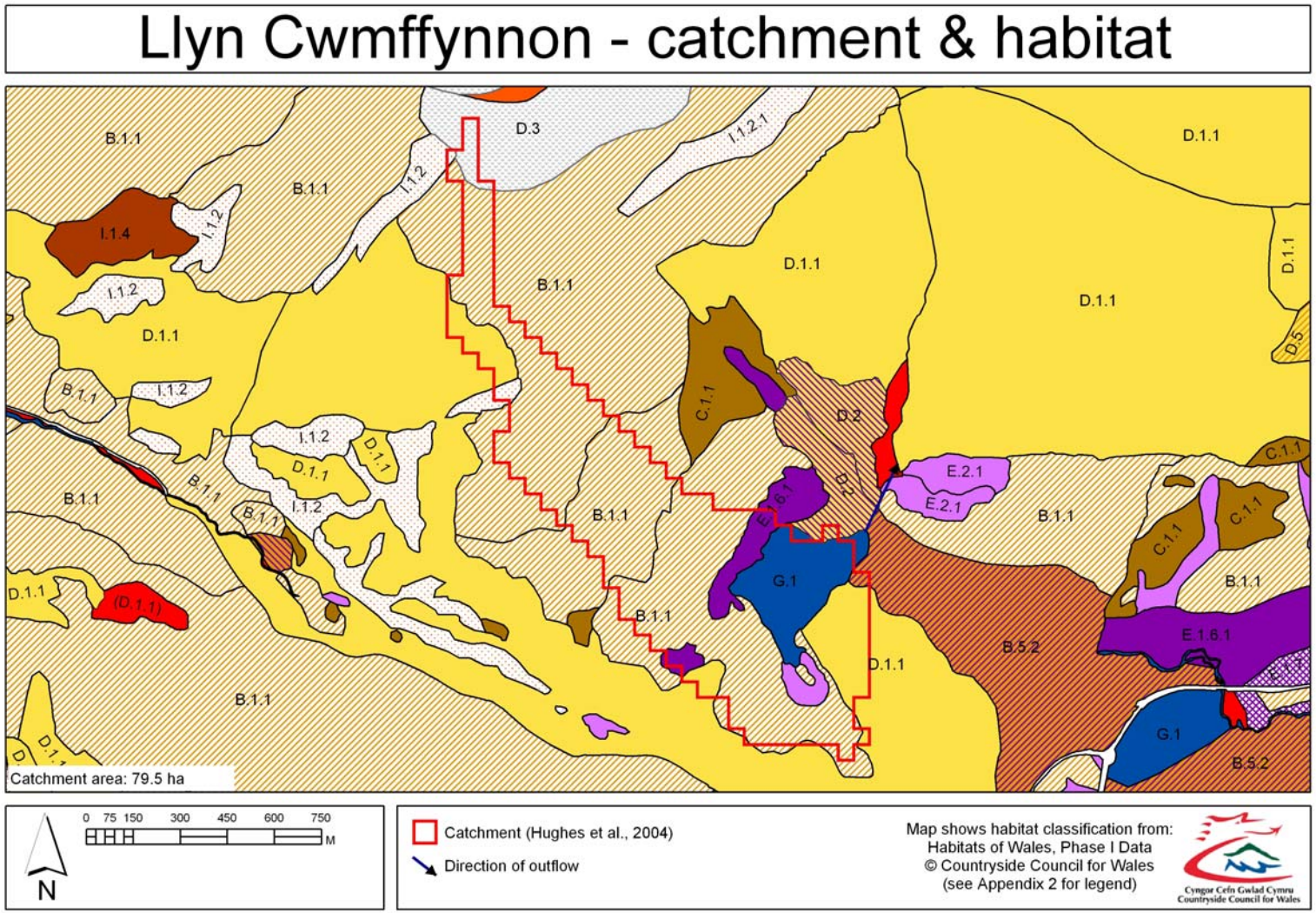
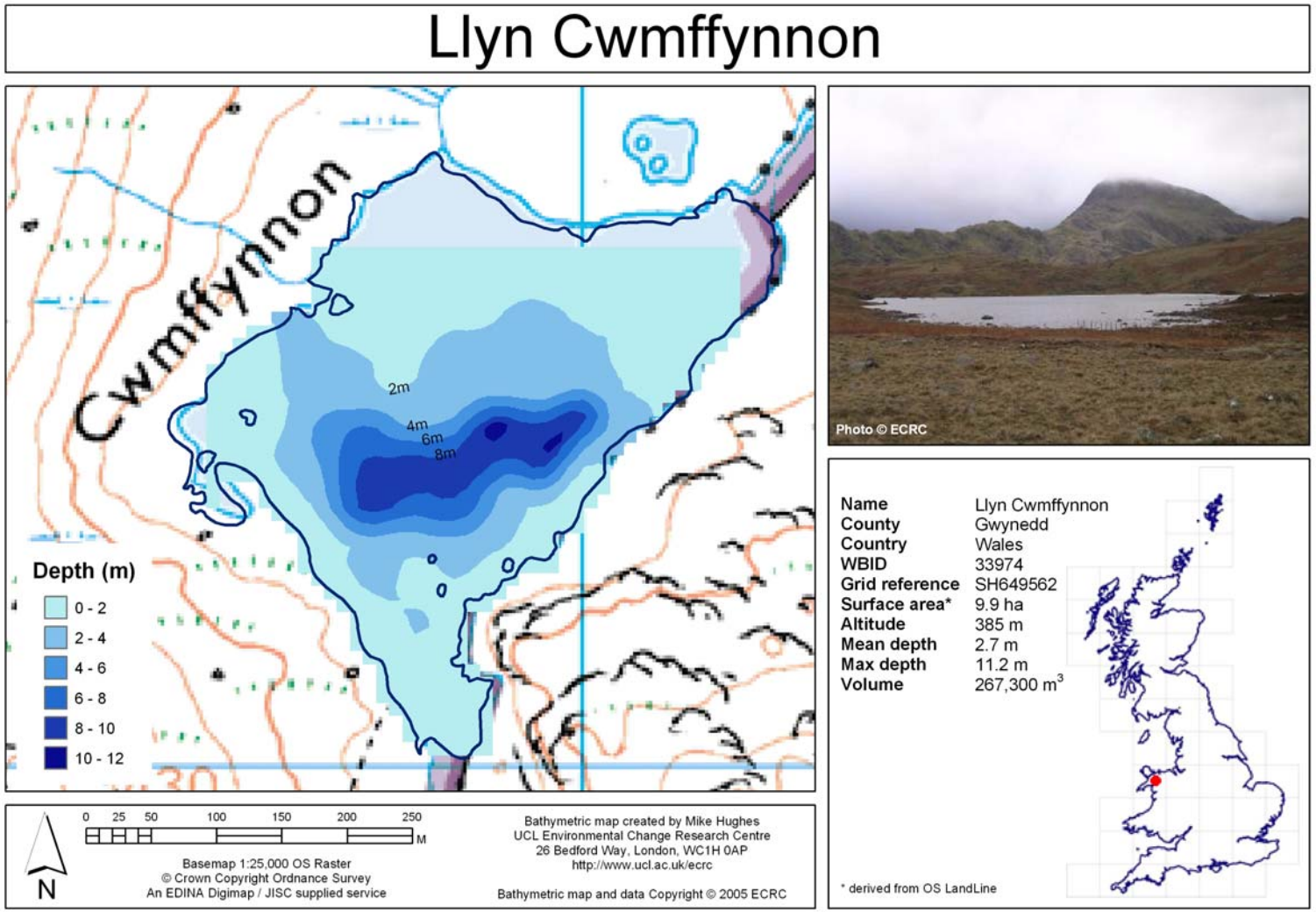


Figure 3.5.6 Llyn Cwmffynnon bathymetry map



3.5.2.3 Physico-chemical data

Temperature and oxygen profiles for Llyn Cwmffynnon are given in Figure 3.5.7 and water chemistry data shown in Table 3.5.11.

Figure 3.5.7 Temperature and oxygen profiles for Llyn Cwmffynnon

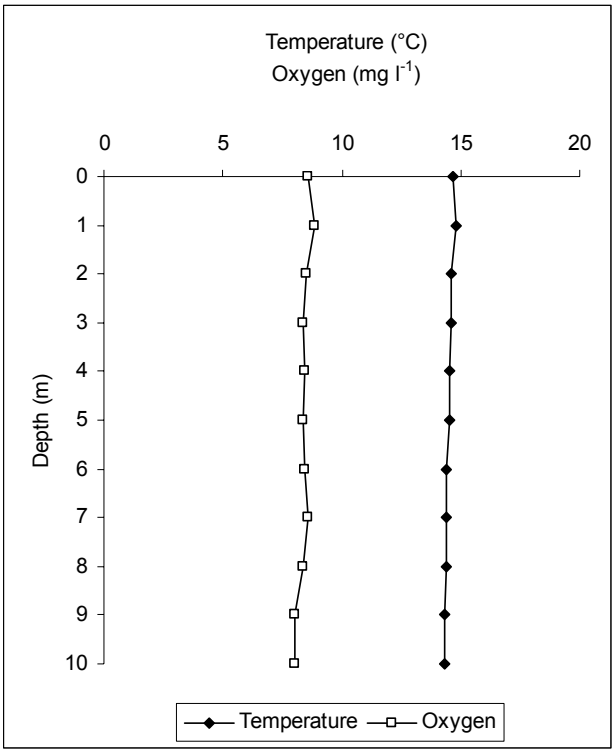


Table 3.5.11 Water chemistry data for Llyn Cwmffynnon

	Sept 04	Dec 04	Mar 05	Jun 05	Annual mean
pH	6.5	6.4	6.0	6.3	6.2
Cond	15	20	29	29	24
Alk	<114	<114	<114	31.3	n.c.
DOC	3.66	1.26	0.84	2.14	1.97
SRP	7	5	6	7	6
TP	56.8	<50	<50	4.1	n.c.
Chl *a*	5.6	1.9	1.1	3.2	3.0
TN	0.18	0.15	0.30	0.41	0.26
NO_3^--N	0.09	0.25	0.48	0.33	0.29
Labile Al	<23	<23	<23	<23	<23
SO_4^{2-}	34	36	41	40	38
Total Fe	22	22	12	13	17
Na^+	94.4	108.4	171.0	117.8	122.9
K^+	2.3	2.2	3.2	2.6	2.6
Mg^{2+}	27.1	28.0	48.0	28.6	32.9
Ca^{2+}	36.8	35.1	48.0	37.2	39.3
Cl^-	101.9	121.0	194.4	138.1	138.9
Total Mn	95.6	4.2	<2.0	8.3	n.c.
ANC					-0.04

(n.c. – not calculated, one or more values below analytical detection)

3.5.2.4 Macrophyte survey

Results of the macrophyte survey are given in Tables 3.5.12 and 3.5.13.

Table 3.5.12 Macrophyte abundance for Llyn Cwmffynnon – emergent and marginal survey

Taxon	DAFOR Abundance
Juncus effusus	**F**
Ranunculus flammula	**A**
Sphagnum sp.	**A**
Galium saxatile	**F**
Carex demissa	**A**
Carex panicea	**F**
Carex echinita	**F**
Potamogeton polygonifolius	**O**
Eriophorum angustifolium	**A**
Drosera rotundifolia	**F**
Littorella uniflora	**O**
Viola palustris	**F**
Carex rostrata	**O**
Phragmites australis	**R**
Menyanthes trifoliata	**R**
Juncus articulatus/acutiflorus	**O**
Equisetum fluviatile	**O**

Table 3.5.13 Macrophyte abundance for Llyn Cwmffynnon – wading and boat survey

Taxon	DAFOR Abundance
Carex rostrata	**R**
Equisetum fluviatile	**F**
Isoetes lacustris	**A**
Juncus bulbosus	**F**
Littorella uniflora	**A**
Lobelia dortmanna	**D**
Myriophyllum alterniflorum	**O**
Phragmites australis	**R**
Potamogeton natans	**F**
Sparganium angustifolium	**R**
Sphagnum (cf. *auriculatum*)	**R**
Utricularia vulgaris agg.	**R**

A strandline survey found no additional species present (no *Luronium natans* found).

3.5.2.5 Short core analysis

A 25 cm Glew core, CFYN1, was taken in a water depth of 10 m from Llyn Cwmffynnon on 22-Aug-04. A summary diagram of the common taxa (>2%) is shown in Figure 3.5.8 and summary data are given in Table 3.5.14. The core top and bottom samples contained a total of 91 diatom taxa. The assemblage of the bottom sample was comprised of numerous non-planktonic species typical of circumneutral, relatively nutrient-poor waters, the most abundant being *Achnanthes minutissima, Fragilaria brevistriata,* and *Navicula seminulum* var. *intermedia.* The top sample was also diverse but was markedly different with *Fragilaria virescens* var. *exigua*, *Navicula leptostriata* and *Brachysira vitrea,* diatoms more typically found in moderately acid waters, occurring in the highest abundances. Consequently, the squared chord distance dissimilarity score between the two samples was high (0.976).

Reconstructions of diatom-inferred pH (DI-pH) were produced using the SWAP training set. A high percentage of the taxa in the fossil samples were present in the SWAP training set and there were no major analogue problems (Table 3.5.14). The DI-pH values decline by approximately 1 pH unit from 6.57 at the core bottom to 5.49 at the top, indicating significant acidification. The annual mean current pH based on quarterly water samples collected during 2004-2005 is 6.3 and therefore the diatom model appears to under-estimate current pH by ~0.8 pH units.

In summary, there has been a significant degree of floristic change in the Llyn Cwmffynnon core indicating moderate acidification of the lake.

Figure 3.5.8 Summary diagram of diatom assemblages in top and bottom samples from core CFYN1

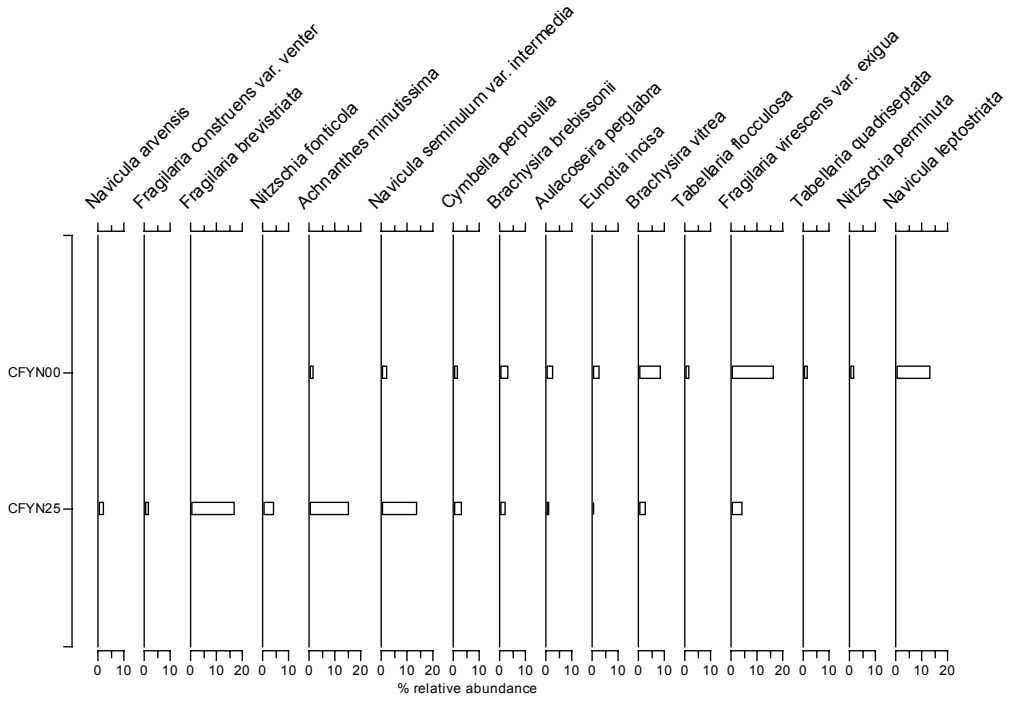


Table 3.5.14 Results of Llyn Cwmffynnon short core analysis

Sample code	Depth (cm)	Annual mean current pH	DI-pH	No. taxa in fossil sample	% of taxa in fossil sample present in SWAP training set	Squared chord distance dissimilarity score between core top and bottom
CFYN00	0	6.3	5.49	69	94	0.976
CFYN25	25		6.57	48	89	

3.5.3 Llyn Idwal

3.5.3.1 Site Description

Llyn Idwal lies at the head of the Nant Ffrancon Valley in the Snowdonia National Park, above Llyn Ogwen. The surrounding vegetation types include steep upland grazing, rough grazing and areas of *Juncus* dominated wetland. Further site details can be found in Allott *et al.* (1994).

Information on the solid geology of the Llyn Idwal catchment and land cover data are given in Tables 3.5.15 and 3.5.16 respectively. A catchment map is given in Figure 3.5.9.

Table 3.5.15 Solid geology of the Llyn Idwal catchment
(Data from British Geological Survey solid geology data at 1:62,500)

Name	Type	Percentage cover
Granite, syenite, granophyre and allied types	Igneous	0.3
Basalt, spilite, hyaloclastic and related tuffs	Igneous	6.5
Ryolitic tuff, including ignimbrite	Igneous	51.1
Caradoc	Sedimentary	42.1

Table 3.5.16 Land cover data for the Llyn Idwal catchment
(Data from CCW Phase 1 Habitat Survey)

Classification	Code	Percentage cover
Grassland and marsh		
Unimproved acid grassland	B.1.1	42.6
Heathland		
Dry acid heath	D.1.1	25.5
Lichen/bryophyte heath	D.3	8.2
Mire		
Acid/neutral flush	E.2.1	4.0
Open water		
Standing water	G.1	4.3
Rock exposure and waste		
Natural rock exposure	I.1	4.9
Acid/neutral scree	I.1.2.1	5.7
Other*		4.8

* Percentage cover >1% and /or data not available

3.5.3.2 Bathymetry

The bathymetry of Llyn Idwal is shown in Figure 3.5.10, physical and morphometric parameters are given in Table 3.5.17.

Table 3.5.17 Llyn Idwal - physical and morphometric parameters

Lake altitude (m)	370
Maximum depth (m)	13.0
Mean depth (m)	2.9
Lake volume ($x10^3m^3$)	394.4
Area of lake surface (ha)	13.6
Perimeter of lake (km)	2.0
Shoreline development index	1.55
Estimated hydraulic residence time (days)	13.3
Secchi disc depth (m)	5.4
Catchment area (ha)	335.8
Catchment to lake area ratio	24.7

Figure 3.5.9 Llyn Idwal catchment map

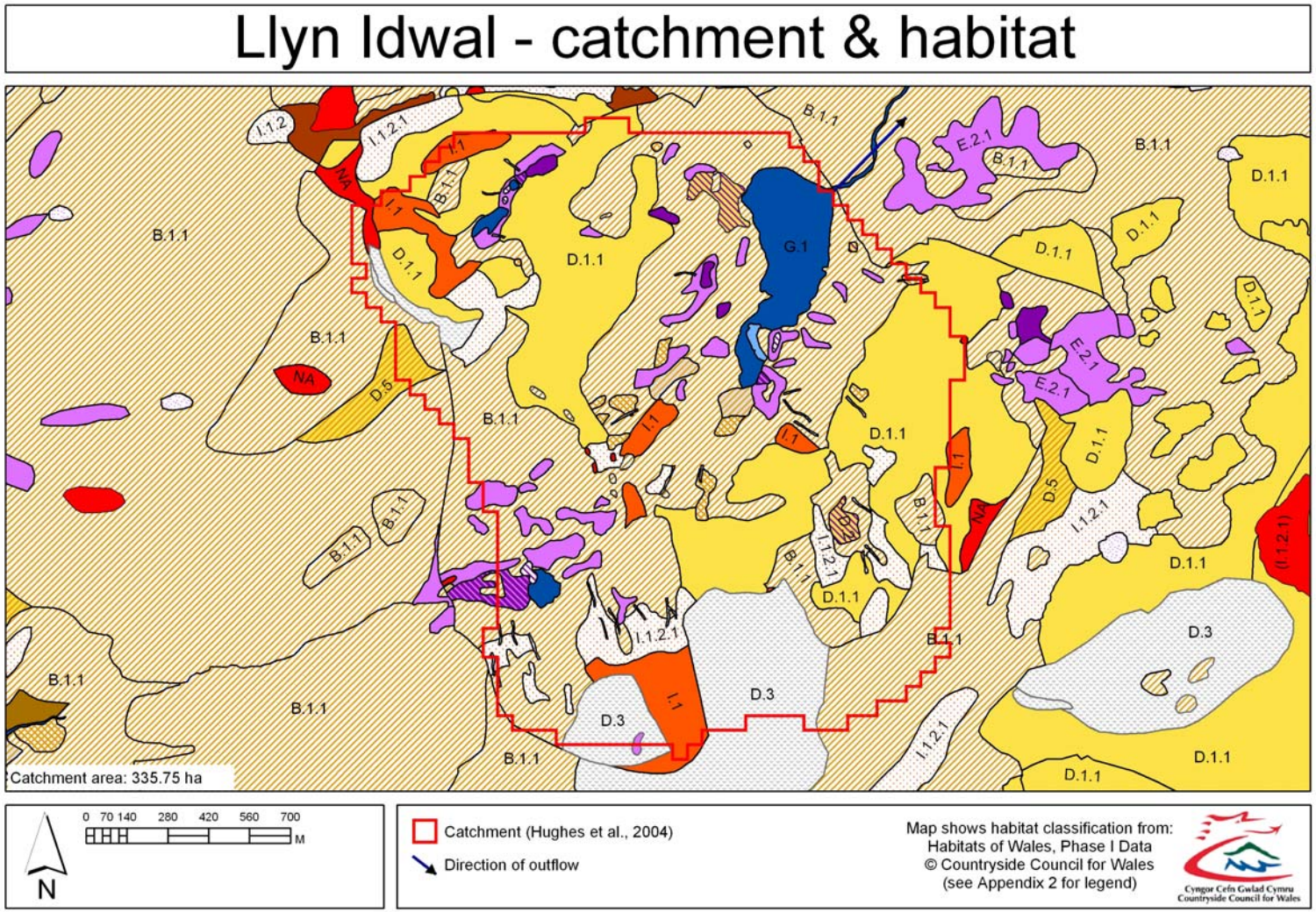
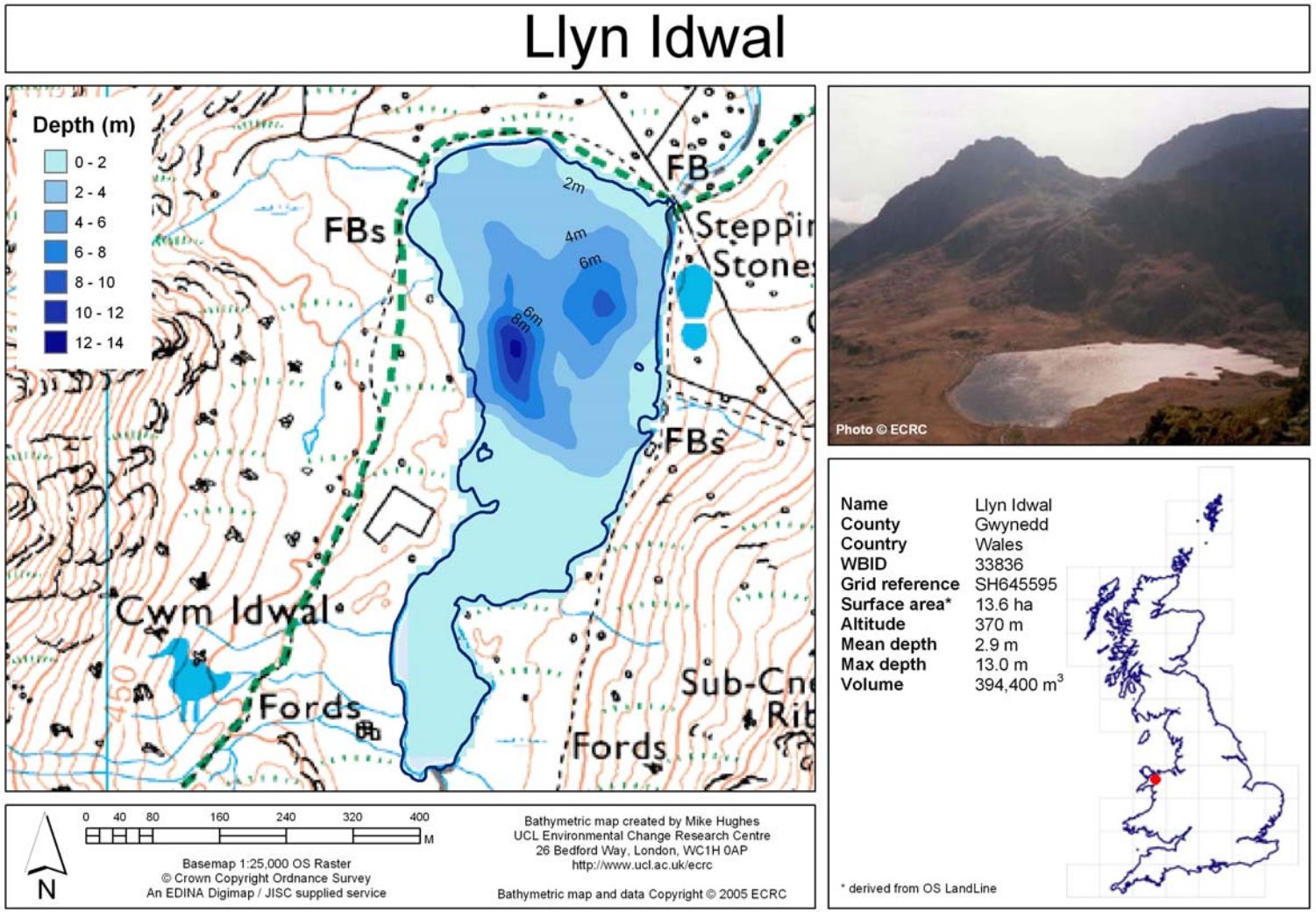


Figure 3.5.10 Llyn Idwal bathymetry map



3.5.3.3 Physico-chemical data

Temperature and oxygen profiles for Llyn Idwal are given in Figure 3.5.11 and water chemistry data shown in Table 3.5.18.

Figure 3.5.11 Temperature and oxygen profiles for Llyn Idwal

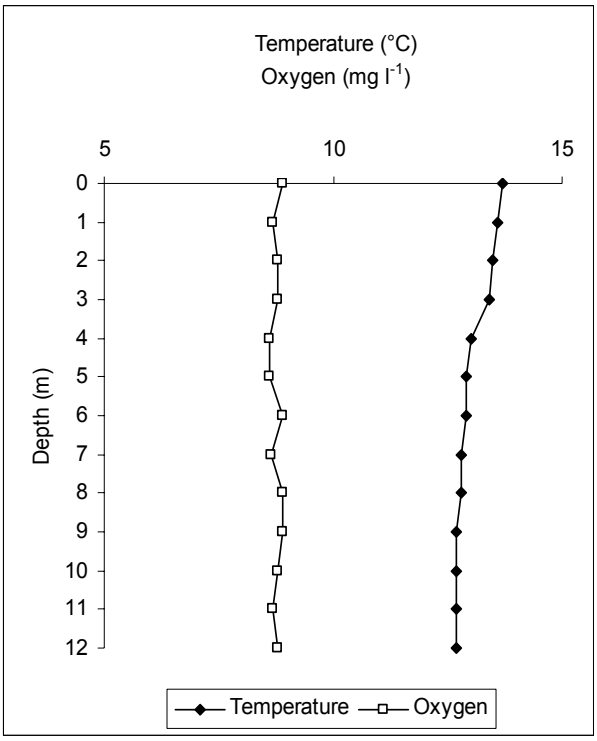


Table 3.5.18 Water chemistry data for Llyn Idwal

	Jul 04	Oct 04	Jan 05	Apr 05	Annual mean
pH	7.1	6.3	6.3	6.2	6.4
Cond	26	24	28	26	26
Alk	91.8	50.8	47.6	93.5	70.9
DOC	1.47	0.88	0.59	1.06	1.00
SRP	4	5	2	8	5
TP	7	19	8	14	12
Chl *a*	1.5	0.4	0.3	0.7	0.7
TN	0.20	0.39	0.20	0.43	0.31
NO_3^--N	0.02	0.10	0.11	0.15	0.10
Labile Al	-	-	-	-	-
SO_4^{2-}	46	34	47	39	41
Total Fe	-	-	-	-	-
Na^+	-	107.9	146.6	118.3	n.c.
K^+	-	5.1	4.4	5.1	n.c.
Mg^{2+}	-	31.3	38.7	37.0	n.c.
Ca^{2+}	96.3	58.9	69.9	76.8	75.5
Cl^-	121.3	138.2	184.4	152.8	149.2
Total Mn	-	-	-	-	-
ANC – October to April only					25.86

(n.c. – not calculated, one or more values below analytical detection)
(- denotes data not collected or analysed)

3.5.3.4 Macrophyte survey

Results of the macrophyte survey are given in Tables 3.5.19 and 3.5.20.

Table 3.5.19 Macrophyte abundance for Llyn Idwal – emergent and marginal survey

Taxon	DAFOR Abundance
Carex demissa	**F**
Carex panicea	**O**
Ranunculus flammula	**F**
Viola palustris	**F**
Galium saxatile	**F**
Euphrasia officinalis agg.	**O**
Juncus effusus	**A**
Juncus articulatus/acutiflorus	**A**
Phragmites australis	**R**
Menyanthes trifoliata	**R**
Carex rostrata	**R**
Potentilla palustris	**R**
Caltha palustre	**R**
Sphagnum sp.	**R**
Potentilla erecta	**F**
Carex echinita	**R**
Juncus squarrosus	**R**

Table 3.5.20 Macrophyte abundance for Llyn Idwal – wading and boat survey

Taxon	DAFOR Abundance
Callitriche hamulata	**O**
Carex rostrata	**O**
Elatine hexandra	**O**
Equisetum fluviatile	**F**
Isoetes lacustris	**D**
Juncus bulbosus	**F**
Juncus effusus	**R**
Littorella uniflora	**A**
Lobelia dortmanna	**A**
Menyanthes trifoliata	**F**
Myriophyllum alterniflorum	**O**
Potamogeton berchtoldii	**O**
Potamogeton polygonifolius	**R**
Phragmites australis	**R**
Subularia aquatica	**F**

A strandline survey recorded no additional species. *Isoetes echinospora* has been reported at this site. Many individual plants found at the site resembled *I. echinospora*, with rather flaccid leaves, but all specimens carrying megaspores were confirmed as *I. lacustris*. *Pilularia globulifera* reported in the 1998 (JNCC) survey was not found in the current survey.

3.5.3.5 Short core analysis

Short core analysis was not required as part of this study. Epilithon and surface diatom taxon lists are given in Allott *et al.* (1994).

3.5.4 Llyn Ogwen

3.5.4.1 Site Description

Llyn Ogwen lies at an altitude of 300 m. Catchment vegetation consists mainly of unimproved grassland and dry heath. Adjacent to the lake are areas of rough grazing, bare rock and *Juncus* marsh.

Information on the solid geology of the Llyn Ogwen catchment and land cover data are given in Tables 3.5.21 and 3.5.22 respectively. A catchment map is given in Figure 3.5.12.

Table 3.5.21 Solid geology of the Llyn Ogwen catchment
(Data from British Geological Survey solid geology data at 1:62,500)

Name	Type	Percentage cover
Granite, syenite, granophyre and allied types	Igneous	0.1
Basalt dolerite, camptonite and allied types	Igneous	5.4
Rhyolite, trachyte, felsite, elvans and allied types	Igneous	3.4
Basalt, spilite, hyaloclastic and related tuffs	Igneous	1.4
Ryolitic tuff, including ignimbrite	Igneous	33.6
Caradoc	Sedimentary	56.1

Table 3.5.22 Land cover data for the Llyn Ogwen catchment
(Data from CCW Phase 1 Habitat Survey)

Classification	Code	Percentage cover
Grassland and marsh		
Unimproved acid grassland	B.1.1	41.7
Marshy grassland *Molinia* dominated	B.5.2	1.1
Heathland		
Dry acid heath	D.1.1	30.8
Lichen/bryophyte heath	D.3	4.5
Dry heath/acid grassland mosaic	D.5	1.8
Mire		
Blanket bog	E.1.6.1	1.0
Dry modified bog	E.1.8	1.5
Acid/neutral flush	E.2.1	3.8
Open water		
Standing water	G.1	3.5
Rock exposure and waste		
Natural rock exposure	I.1	1.1
Acid/neutral scree	I.1.2.1	1.9
Other*		7.3

* Percentage cover >1% and /or data not available

3.5.4.2 Bathymetry

The bathymetry of Llyn Ogwen is shown in Figure 3.5.13, physical and morphometric parameters are given in Table 3.5.23.

Table 3.5.23 Llyn Ogwen - physical and morphometric parameters

Lake altitude (m)	300
Maximum depth (m)	3.1
Mean depth (m)	2.2
Lake volume ($x10^3m^3$)	855.8
Area of lake surface (ha)	38.9
Perimeter of lake (km)	3.8
Shoreline development index	1.75
Estimated hydraulic residence time (days)	6.1
Secchi disc depth (m)	2.1
Catchment area including lake (ha)	1600
Catchment to lake area ratio	41.1

Figure 3.5.12 Llyn Ogwen catchment map

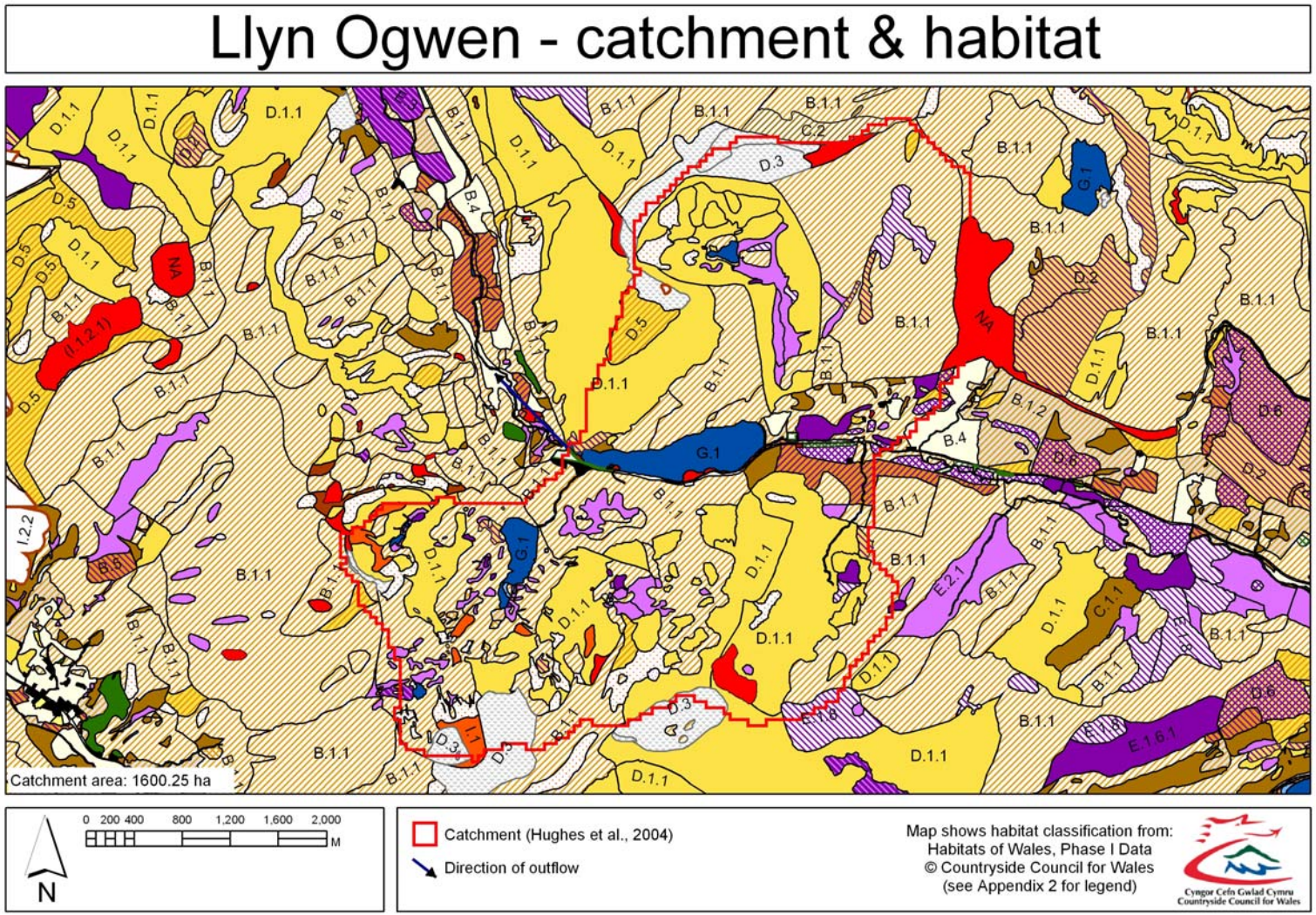
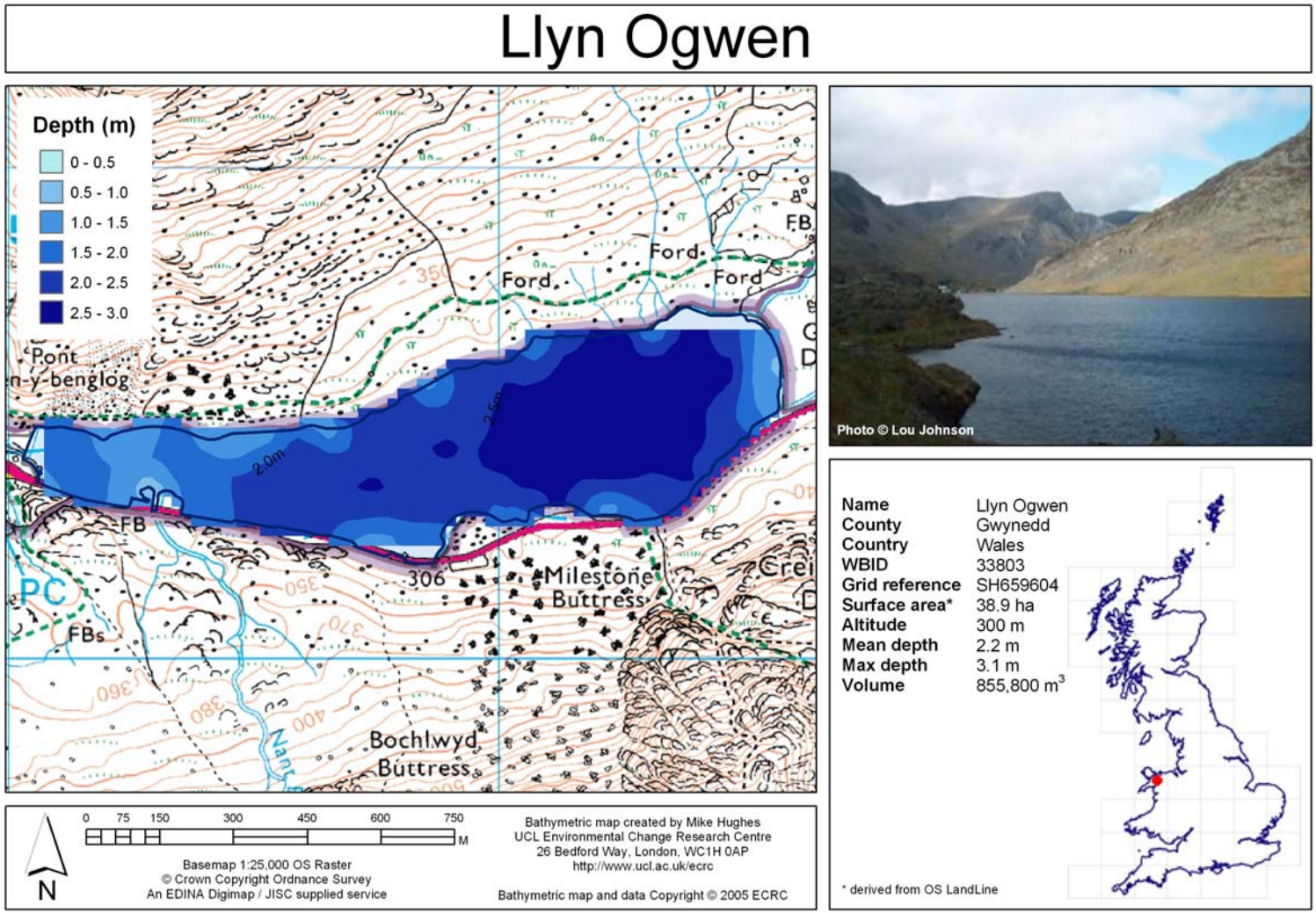


Figure 3.5.13 Llyn Ogwen bathymetry map



3.5.4.3 Physico-chemical data

Temperature and oxygen profiles for Llyn Ogwen are given in Figure 3.5.14 and water chemistry data shown in Table 3.5.24.

Figure 3.5.14 Temperature and oxygen profiles for Llyn Ogwen

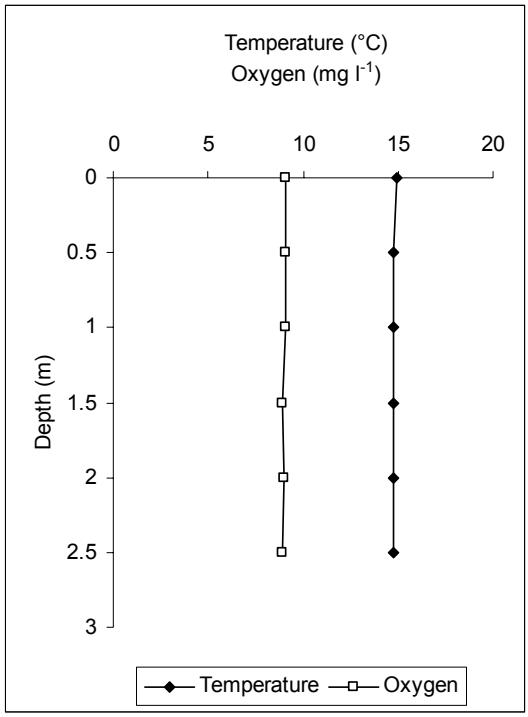


Table 3.5.24 Water chemistry data for Llyn Ogwen

	Jul 04	Oct 04	Jan 05	Apr 05	Annual mean
pH	6.9	6.6	6.5	6.0	6.6
Cond	23	25	29	25	25
Alk	60.7	59.0	31.2	70.5	55.4
DOC	2.50	1.28	0.84	1.19	1.45
SRP	4	4	2	5	4
TP	7	15	6	8	9
Chl *a*	4.4	1.0	0.8	1.3	1.9
TN	0.20	0.21	0.20	0.72	0.33
NO_3^--N	0.01	0.10	0.09	0.12	0.08
Labile Al	-	-	-	-	-
SO_4^{2-}	42	42	43	28	39
Total Fe	-	-	-	-	-
Na^+	-	147.9	158.3	118.3	n.c.
K^+	-	6.9	4.4	4.9	n.c.
Mg^{2+}	-	32.9	38.7	31.3	n.c.
Ca^{2+}	63.4	50.4	43.2	44.6	50.4
Cl^-	132.5	194.6	191.8	141.6	165.1
Total Mn	-	-	-	-	-
ANC – October to April only					5.77

(n.c. – not calculated, one or more values below analytical detection)
(- denotes data not collected or analysed)

3.5.4.4 Macrophyte survey

Results of the macrophyte survey are given in Tables 3.5.25 and 3.5.26.

Table 3.5.25 Macrophyte abundance for Llyn Ogwen – emergent and marginal survey

Taxon	DAFOR Abundance
Succisa pratensis	**O**
Juncus articulatus/acutiflorus	**A**
Juncus effusus	**F**
Ranunculus flammula	**F**
Galium saxatile	**F**
Caltha palustre	**O**
Scutellaria minor	**O**
Galium palustre	**F**
Hydrocotyle vulgaris	**R**
Cymbalaria muralis	**O**
Carex panicea	**F**
Carex echinita	**R**
Potentilla erecta	**F**
Juncus squarrosus	**O**
Glyceria fluitans	**R**
Sagina procumbens	**R**
Achillea ptarmica	**O**
Ranunculus omiophyllus	**R**
Juncus bulbosus	**R**
Juncus bufonius	**R**
Lotus pedunculatus	**O**
Rumex acetosa	**O**
Fontinalis antipyretica	**O**
Viola palustris	**O**
Filipendula ulmaria	**R**
Angelica sylvestris	**R**
Carex demissa	**O**

Table 3.5.26 Macrophyte abundance for Llyn Ogwen – wading and boat survey

Taxon	DAFOR Abundance
Callitriche hamulata	**R**
Elatine hexandra	**O**
Fontinalis antipyretica	**O**
Juncus articulatus/acutiflorus	**R**
Juncus bulbosus	**A**
Littorella uniflora	**D**
Lobelia dortmanna	**D**
Isoetes lacustris	**D**
Myriophyllum alterniflorum	**F**
Potamogeton natans	**R**
Ranunculus flammula	**R**
Sphagnum sp	**R**
Subularia aquatica	**R**
Sparganium angustifolium	**R**
Sphagnum auriculatum	**R**

No additional species were recorded in a strandline survey. The lake had a thick cover of *Isoetes lacustris* throughout the site from a water depth of 1 m.

3.5.4.5 Short core analysis

Short core analysis was not required as part of this study.

3.6 Rhinog SAC
Gloyw Lyn, Llyn Cwm Bychan, Llyn Eiddew-mawr, Llyn Perfeddau

Location of SAC

SAC Details	
Grid Ref. (approx. centre)	SH649297
SAC EU Code	UK0012945
Total Area	3145 ha
Total area of Freshwater	315 ha

General site character:
Inland water bodies (standing water, running water) (1%)
Bogs. Marshes. Water fringed vegetation. Fens (5%)
Heath. Scrub. Maquis and garrigue. Phygrana (75%)
Dry grassland. Steppes (8%)
Humid grassland. Mesophile grassland (3%)
Improved grassland (3%)
Broad-leaved deciduous woodland (4%)
Inland rocks. Screes. Sands. Permanent snow and ice (1%)

Annex I habitats that are a primary reason for selection of this site
4030 European dry heaths
Rhinog is representative of upland European dry heaths in Wales. On shady slopes, the site contains what is considered to be the best development of H21 *Calluna vulgaris – Vaccinium myrtillus – Sphagnum capillifolium* heath outside Scotland. Other NVC types represented include H8 *Calluna vulgaris – Ulex gallii*, H10 *Calluna vulgaris – Erica cinerea*, and H12 *Calluna vulgaris – Vaccinium myrtillus* heaths.
91A0 Old sessile oak woods with *Ilex* and *Blechnum* in the British Isles
Rhinog in north Wales contains high-quality examples of old sessile oak woods. This woodland is continuous with that in the adjacent Coedydd Derw a Safleoedd Ystlumod Meirion/ Meirionnydd Oakwoods and Bat Sites, and is best considered with that site.

Annex I habitats present as a qualifying feature, but not a primary reason for selection of this site

The Annex I habitats 3130 Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea,* 4010 Northern Atlantic

wet heaths with *Erica tetralix*, 4060 Alpine and Boreal heaths, 7130 Blanket bogs, 7150 Depressions on peat substrates of the *Rhynchosporion*, are also present, but not a primary reason for SAC selection

(JNCC, 2005b)

3.6.1 Gloyw Lyn

3.6.1.1 Site Description

Gloyw Lyn is a small, boulder dominated lake which lies in a sparsely vegetated catchment. A site description is given in Monteith (1997).

Information on the solid geology of the Gloyw Lyn catchment and land cover data are given in Tables 3.6.1 and 3.6.2 respectively. A catchment map is given in Figure 3.6.1.

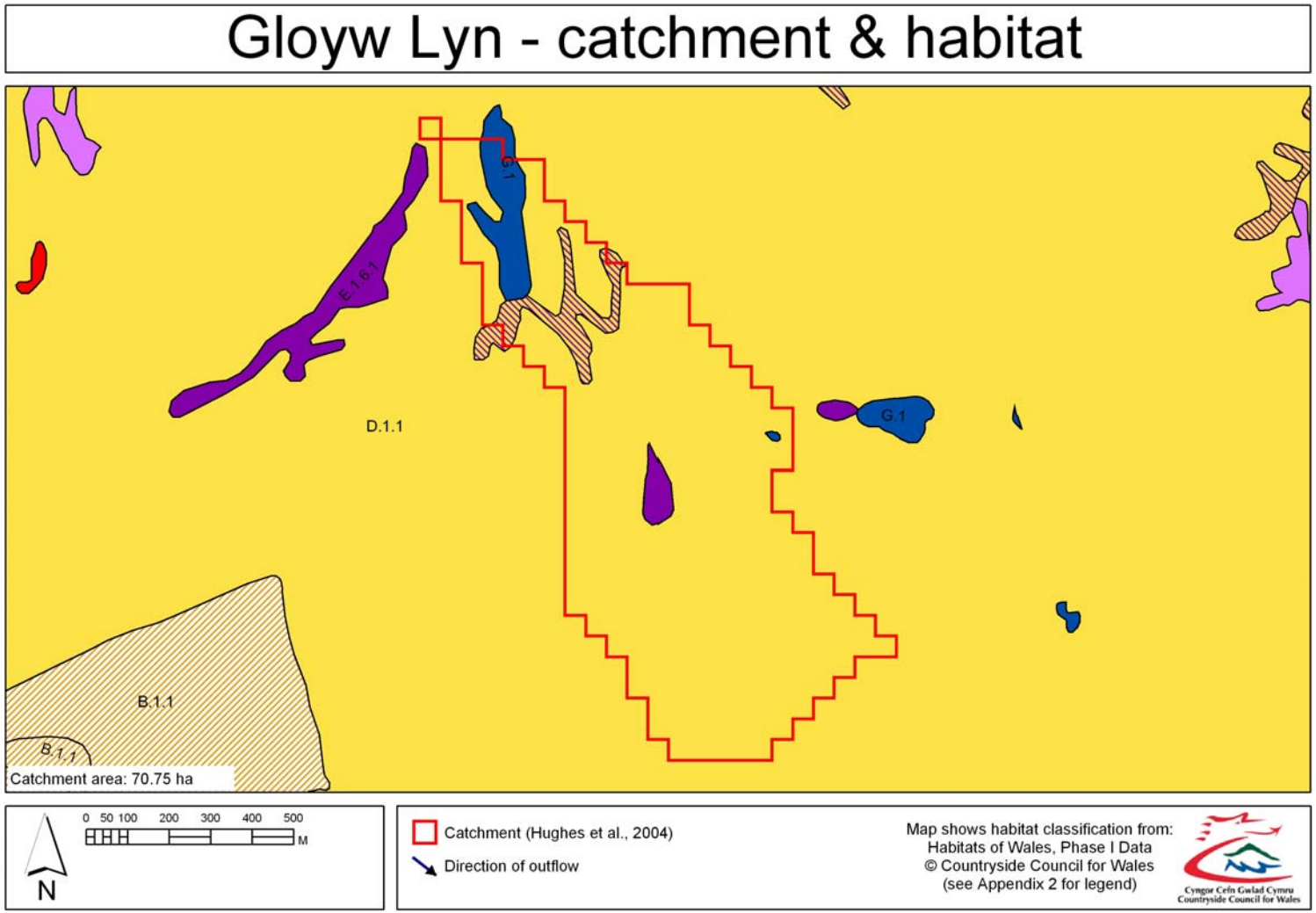
Table 3.6.1 Solid geology of the Gloyw Lyn catchment
(Data from British Geological Survey solid geology data at 1:62,500)

Name	Type	Percentage cover
Lower Cambrian	Sedimentary	100

Table 3.6.2 Land cover data for the Gloyw Lyn catchment
(Data from CCW Phase 1 Habitat Survey)

Classification	Code	Percentage cover
Heathland		
Dry acid heath	D.1.1	90.4
Wet heath	D.2	3.9
Mire		
Blanket bog	E.1.6.1	1.3
Open water		
Standing water	G.1	4.4

Figure 3.6.1 Gloyw Lyn catchment map



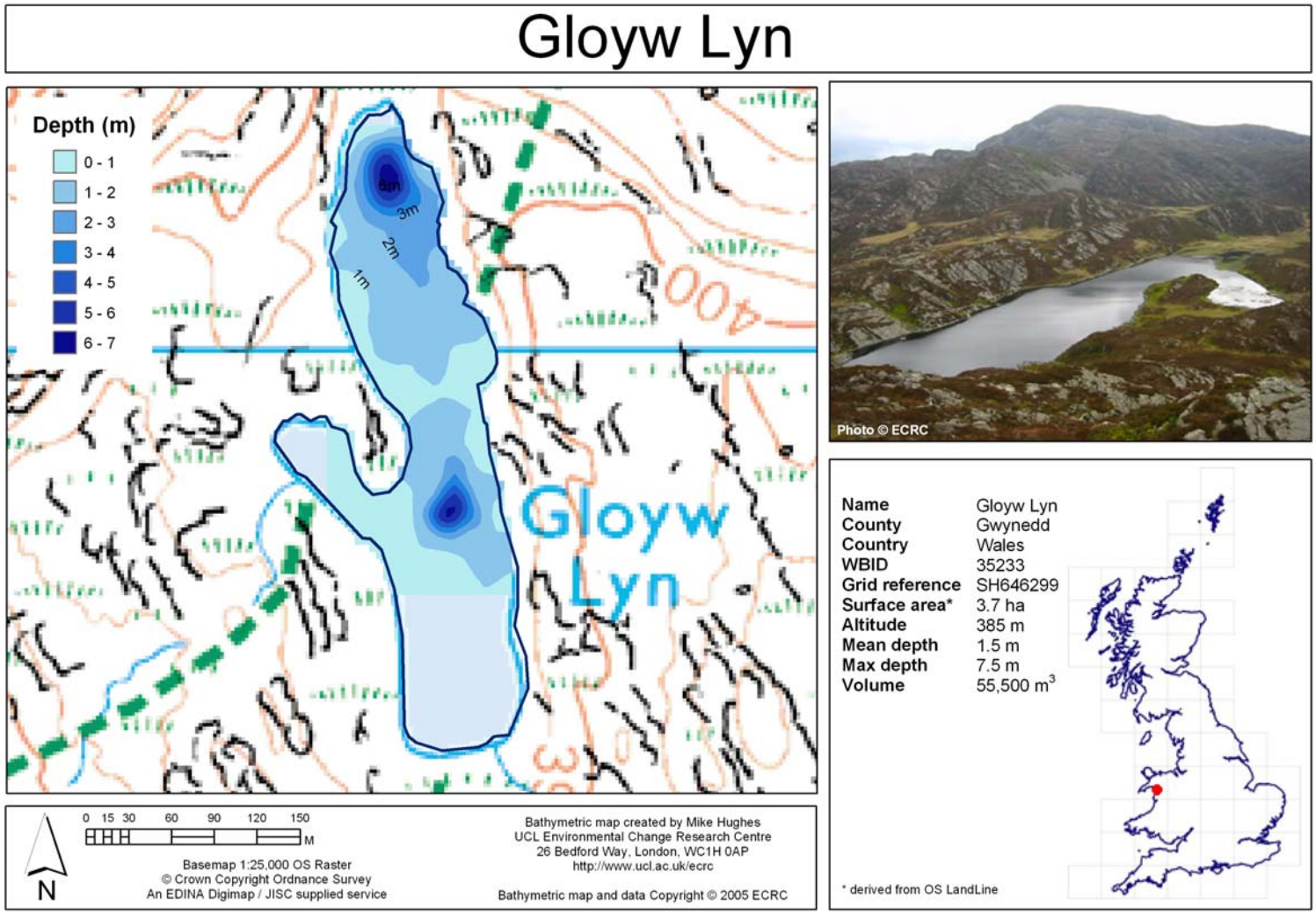
3.6.1.2 Bathymetry

The bathymetry of Gloyw Lyn is shown in Figure 3.6.2, physical and morphometric parameters are given in Table 3.6.3.

Table 3.6.3 Gloyw Lyn - physical and morphometric parameters

Lake altitude (m)	385
Maximum depth (m)	7.5
Mean depth (m)	1.5
Lake volume ($x10^6m^3$)	55.5
Area of lake surface (ha)	3.7
Perimeter of lake (km)	1.2
Shoreline development index	1.74
Estimated hydraulic residence time (days)	19.3
Secchi disc depth (m)	3.0
Catchment area (ha)	70.8
Catchment to lake area ratio	19.1

Figure 3.6.2 Gloyw Lyn bathymetry map



3.6.1.3 Physico-chemical data

Temperature and oxygen profiles for Gloyw Lyn are given in Figure 3.6.3 and water chemistry data shown in Table 3.6.4.

Figure 3.6.3 Temperature and oxygen profiles for Gloyw Lyn

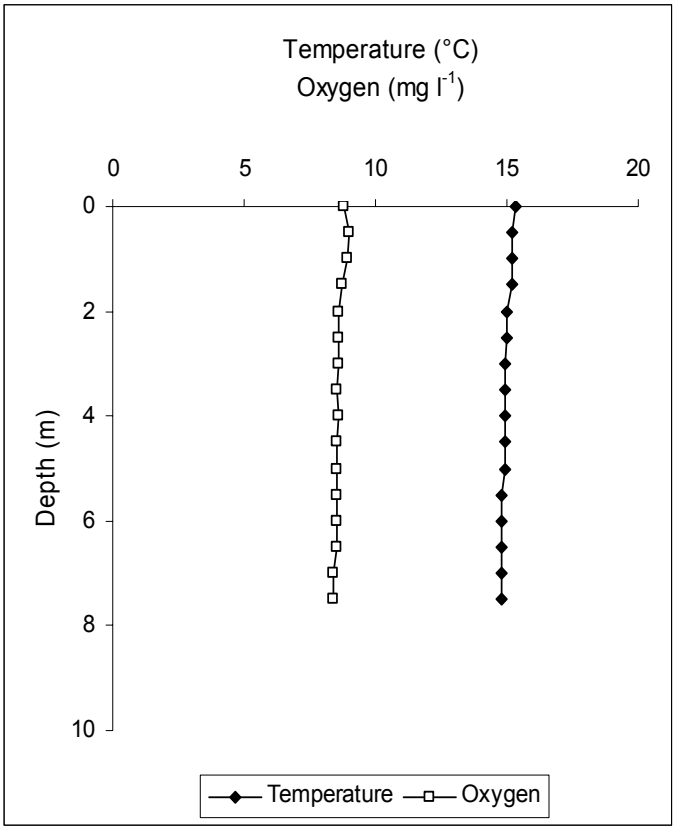


Table 3.6.4 Water chemistry data for Gloyw Lyn

	Sept 04	Dec 04	Mar 05	Jun 05	Annual mean
pH	6.0	5.8	5.9	6.2	5.9
Cond	26	33	51	39	37
Alk	<114	<114	<114	40.2	n.c.
DOC	5.94	3.39	2.00	4.49	3.96
SRP	7	5	2	6	5
TP	<50	<50	<50	9.1	n.c.
Chl *a*	3.5	3.2	4.3	6.2	4.3
TN	0.24	0.28	0.38	0.27	0.29
NO_3^--N	0.07	0.94	0.82	0.16	0.50
Labile Al	<23	35.9	23.4	28.3	n.c.
SO_4^{2-}	51	64	65	62	61
Total Fe	39	62	16	92	52
Na^+	181	195	290	221	222
K^+	3.2	6.8	8.0	5.7	5.9
Mg^{2+}	49.1	54.2	73.6	52.8	57.4
Ca^{2+}	50.7	53.3	error	52.9	n.c.
Cl^-	171.1	218.2	331.6	235.1	239.0
Total Mn	9.50	19.40	27.90	35.70	23.13
ANC					1.81

(n.c. – not calculated, one or more values below analytical detection)

3.6.1.4 Macrophyte survey

Results of the macrophyte survey are given in Tables 3.6.5 and 3.6.6.

Table 3.6.5 Macrophyte abundance for Gloyw Lyn – emergent and marginal survey

Taxon	DAFOR Abundance
Carex flacca	**O**
Juncus conglomeratus	**F**
Potentilla erecta	**F**
Sphagnum sp.	**F**
Carex demissa	**F**
Carex echinita	**F**
Juncus effusus	**F**
Galium saxatile	**F**
Viola palustris	**F**
Equisetum fluviatile	**F**
Carex rostrata	**O**
Trichophorum cespitosum	**O**
Potentilla palustris	**O**
Juncus articulatus/acutiflorus	**O**
Carex panicea	**O**

Table 3.6.6 Macrophyte abundance for Gloyw Lyn – wading and boat survey

Taxon	DAFOR Abundance
Carex rostrata	**O**
Equisetum fluviatile	**A**
Isoetes lacustris	**F**
Littorella uniflora	**A**
Lobelia dortmanna	**A**
Menyanthes trifoliata	**R**
Potamogeton natans	**R**
Sparganium angustifolium	**R**
Sphagnum auriculatum	**O**

A strandline survey recorded no additional species.

3.6.1.5 Short core analysis

A 26 cm Glew core, GYCW2, was taken in a water depth of 7 m from Gloyw Lyn on 08-Sep-04. A summary diagram of the common taxa (>2%) is shown in Figure 3.6.4 and summary data are given in Table 3.6.7. The core top and bottom samples contained a

total of 85 diatom taxa. The assemblage of the bottom sample was diverse with numerous non-planktonic species typical of mildly acid waters, the most abundant being *Achnanthes minutissima, Fragilaria virescens* var. *exigua* and *Brachysira vitrea*. The top sample had many taxa in common with the bottom sample, the only notable differences being an increase in *Eunotia incisa* and the appearance of a number of taxa associated with more acid conditions, albeit in low abundances. The squared chord distance dissimilarity score between the two samples was relatively low (0.468).

Reconstructions of diatom-inferred pH (DI-pH) were produced using the SWAP training set. A high percentage of the taxa in the fossil samples were present in the SWAP training set and there were no major analogue problems (Table 3.6.7). The DI-pH values decline slightly from 6.19 for the bottom sample to 5.83 for the top sample, indicating mild acidification. The annual mean current pH based on quarterly water samples collected during 2004-2005 is 5.96 and therefore the diatom model appears to provide a good estimate of current pH.

In summary, there has been a relatively small degree of floristic change in the Gloyw Lyn core. The species shifts appear to signify minor acidification of the lake.

Figure 3.6.4 Summary diagram of diatom assemblages in top and bottom samples from core GYCW2

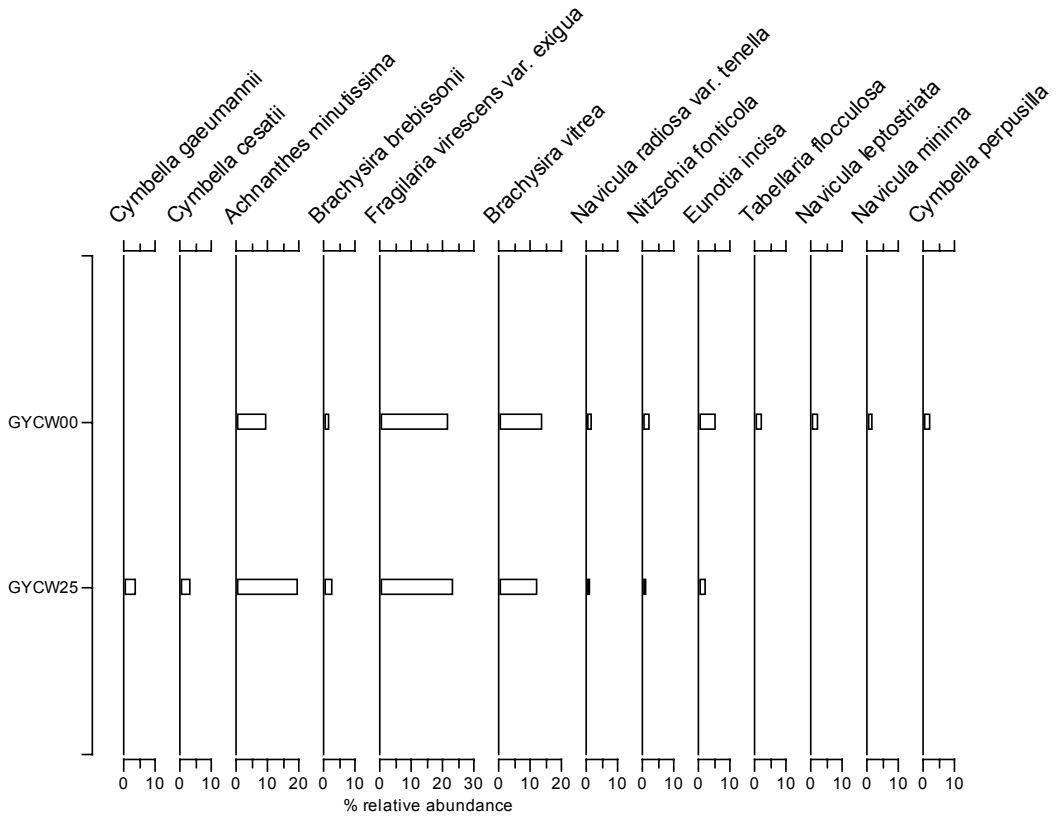


Table 3.6.7 Results of Gloyw Lyn short core analysis

Sample code	Depth (cm)	Annual mean current pH	DI-pH	No. taxa in fossil sample	% of taxa in fossil sample present in SWAP training set	Squared chord distance dissimilarity score between core top and bottom
GYCW00	0	5.96	5.83	57	94	0.468
GYCW25	25		6.19	53	92	

3.6.2 Llyn Cwm Bychan

3.6.2.1 Site Description

Llyn Cwm Bychan lies at an altitude of 158 m in a catchment dominated by dry acid heath. Adjacent to the lake itself are areas of bracken, deciduous woodland and steep bedrock. Information on the solid geology of the Llyn Cwm Bychan catchment and land cover data are given in Tables 3.6.8 and 3.6.9 respectively. A catchment map is given in Figure 3.6.5.

Table 3.6.8 Solid geology of the Llyn Cwm Bychan catchment
(Data from British Geological Survey solid geology data at 1:62,500)

Name	Type	Percentage cover
Basalt dolerite, camptonite and allied types	Igneous	2.1
Lower Cambrian	Sedimentary	97.9

Table 3.6.9 Land cover data for the Llyn Cwm Bychan catchment
(Data from CCW Phase 1 Habitat Survey)

Classification	Code	Percentage cover
Woodland and scrub		
Semi-natural broadleaved woodland	A.1.1.1	2.7
Tall herb and fern		
Bracken	C.1.1	5.8
Heathland		
Dry acid heath	D.1.1	85.7
Wet heath	D.2	1.6
Mire		
Blanket bog	E.1.6.1	1.4
Acid/neutral flush	E.2.1	1.5
Other*		1.3

* Percentage cover >1% and /or data not available

3.6.2.2 Bathymetry

The bathymetry of Llyn Cwm Bychan is shown in Figure 3.6.6, physical and morphometric parameters are given in Table 3.6.10.

Table 3.6.10 Llyn Cwm Bychan - physical and morphometric parameters

Lake altitude (m)	158
Maximum depth (m)	14.6
Mean depth (m)	4.9
Lake volume ($x10^3m^3$)	754.6
Area of lake surface (ha)	15.4
Perimeter of lake (km)	2.0
Shoreline development index	1.53
Estimated hydraulic residence time (days)	27.7
Secchi disc depth (m)	3.1
Catchment area (ha)	627
Catchment to lake area ratio	40.7

Figure 3.6.5 Llyn Cwm Bychan catchment map

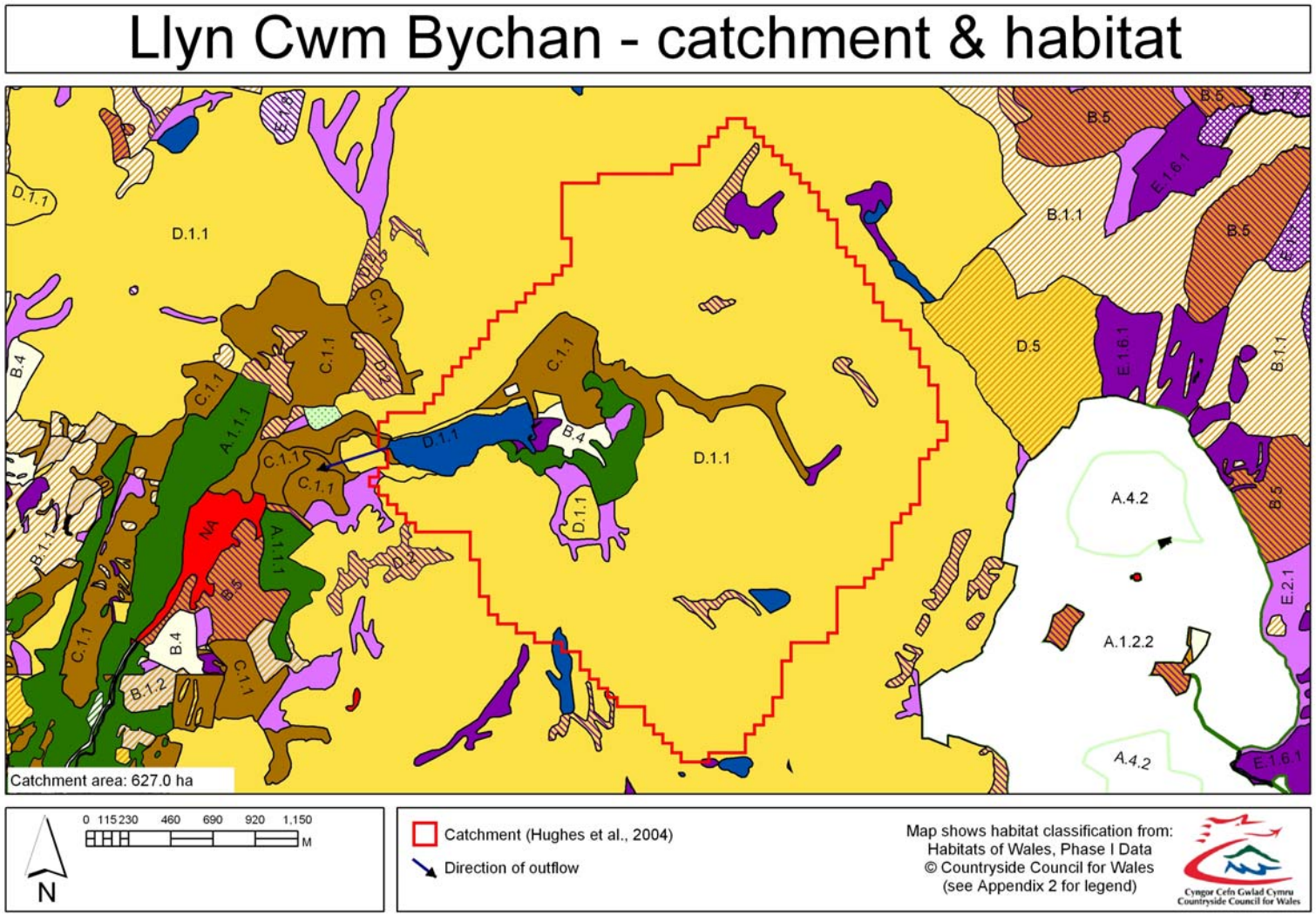
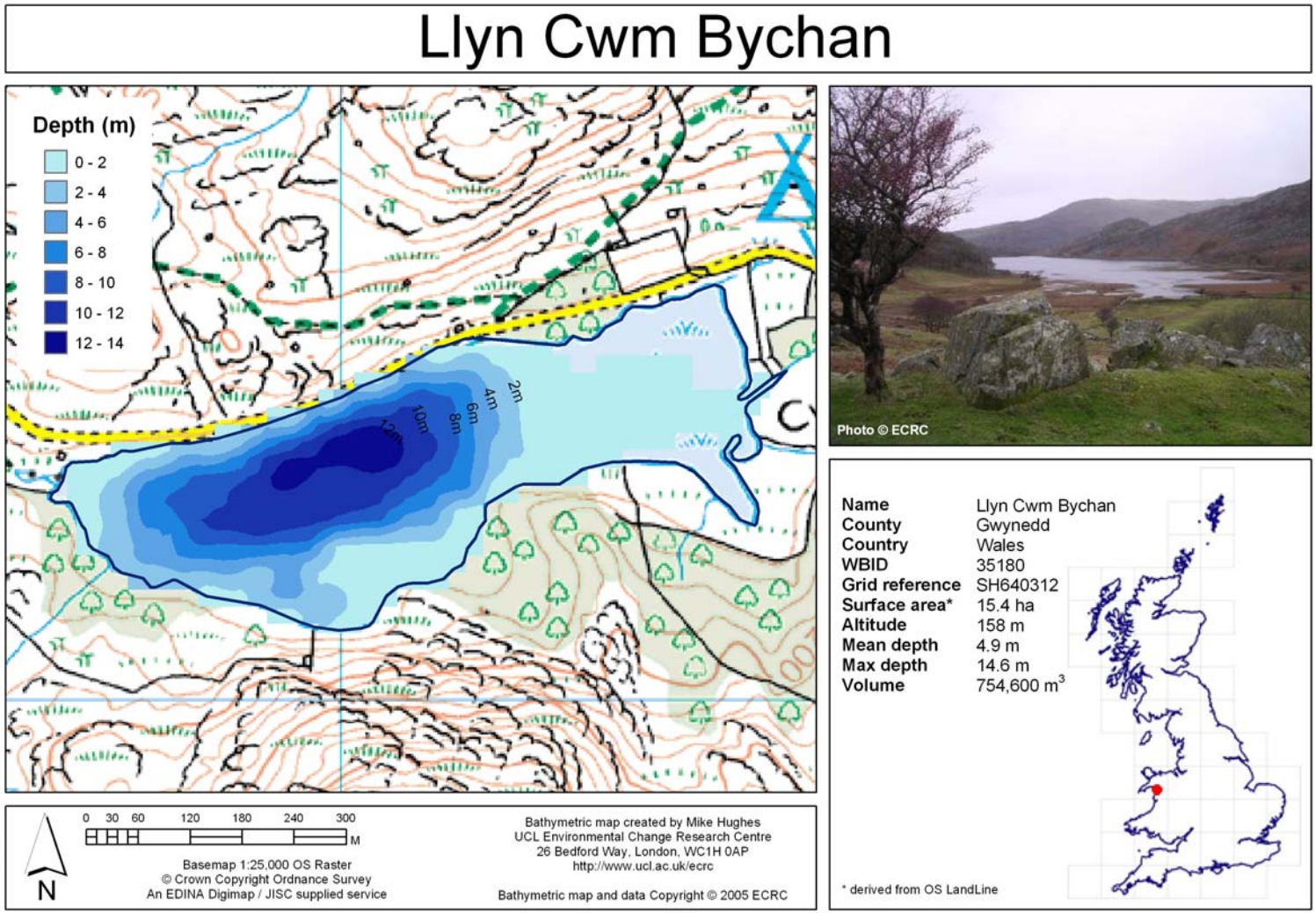


Figure 3.6.6 Llyn Cwm Bychan bathymetry map



3.6.2.3 Physico-chemical data

Temperature and oxygen profiles for Llyn Cwm Bychan are given in Figure 3.6.7 and water chemistry data shown in Table 3.6.11.

Figure 3.6.7 Temperature and oxygen profiles for Llyn Cwm Bychan

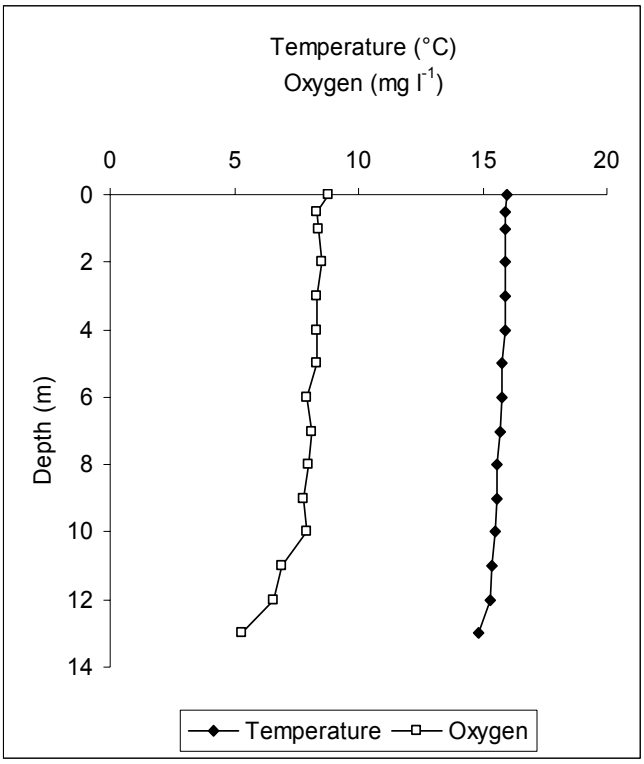


Table 3.6.11 Water chemistry data for Llyn Cwm Bychan

	Sept 04	Dec 04	Mar 05	Jun 05	Annual mean
pH	6.1	5.6	5.8	6.2	5.9
Cond	27	34	53	43	39
Alk	133.88	<114	<114	31.3	n.c.
DOC	4.12	2.44	2.00	2.98	2.88
SRP	7	4	2	6	5
TP	<50	52.1	<50	4.6	n.c.
Chl *a*	3.1	1.2	3.2	3.2	2.7
TN	0.24	0.26	0.57	0.22	0.32
NO_3^--N	0.22	0.68	0.81	0.45	0.54
Labile Al	15.6	20.4	42.0	19.9	24.5
SO_4^{2-}	59	63	59	68	62
Total Fe	171	40	16	34	65
Na^+	196.4	205.1	289.7	240.7	233.0
K^+	1.9	6.0	9.8	6.2	6.0
Mg^{2+}	43.1	53.0	65.5	56.5	54.5
Ca^{2+}	49.1	51.8	Error	55.5	n.c.
Cl^-	194.9	234.6	331.4	271.6	258.1
Total Mn	64.8	23.4	31.0	45.6	41.2
ANC					-13.30

(n.c. – not calculated, one or more values below analytical detection)

3.6.2.4 Macrophyte survey

Results of the macrophyte survey are given in Tables 3.6.12 and 3.6.13 respectively.

Table 3.6.12 Macrophyte abundance for Llyn Cwm Bychan – emergent and marginal survey

Taxon	DAFOR Abundance
Juncus effusus	**A**
Glyceria fluitans	**R**
Juncus articulatus/acutiflorus	**F**
Equisetum fluviatile	**O**
Schoenoplectus lacustris	**R**
Menyanthes trifoliata	**R**
Phragmites australis	**R**
Carex rostrata	**O**
Sparganium angustifolium	**F**
Littorella uniflora	**F**
Hydrocotyle vulgaris	**F**
Carex demissa	**F**
Scutellaria minor	**O**
Drosera intermedia	**R**
Drosera rotundifolia	**R**
Juncus bulbosus	**F**
Potentilla erecta	**F**
Sphagnum sp.	**A**
Eleocharis palustris	**R**
Salix sp.	**F**
Viola palustris	**F**
Galium saxitle	**F**

Table 3.6.13 Macrophyte abundance for Llyn Cwm Bychan – wading and boat survey

Taxon	DAFOR Abundance
Carex rostrata	**O**
Eleocharis palustris	**R**
Eleogiton fluitans	**R**
Equisetum fluviatile	**F**
Isoetes lacustris/echinospora	**A**
Juncus bulbosus	**A**
Juncus effusus	**R**
Littorella uniflora	**A**
Lobelia dortmanna	**A**
Luronium natans	**R**
Menyanthes trifoliata	**R**
Myriophyllum alterniflorum	**R**
Phragmites australis	**R**
Potamogeton berchtoldii	**R**
Schoenoplectus lacustris	**R**
Sparganium angustifolium	**O**
Sphagnum auriculatum	**A**
Utricularia minor	**R**
Utricularia vulgaris agg. *(cf australis)*	**O**

Potamogeton polygonifolius was noted around site but was not present in the survey. Both *Isoetes lacustris* and *I. echinospora* were found in the survey. Distinction was not possible on site and therefore all *Isoetes* records are given as '*Isoetes lacustris/echinospora'*.

3.6.2.5 Short core analysis

A 26 cm Glew core, CWBY1, was taken in a water depth of 13 m from Llyn Cwm Bychan on 10-Sep-04. A summary diagram of the common taxa (>2%) is shown in Figure 3.6.8 and summary data are given in Table 3.6.14. The core top and bottom samples contained a total of 79 diatom taxa. The assemblage of the bottom sample was comprised mostly of non-planktonic taxa typical of mildly acid waters with *Achnanthes minutissima* being the most abundant taxon, and *Brachysira vitrea and Eunotia incisa* present in relatively high amounts. The planktonic taxon, *Cyclotella* [*kuetzingiana* agg.] also occurred, albeit in small relative abundance. The top sample was markedly different being comprised of taxa commonly found in moderately acid waters. *Eunotia incisa* was the most abundant species but other *Eunotia* taxa (e.g. *rhomboidea, curvata, exigua*) were present along with *Navicula leptostriata*, *Navicula tenuicephala, Tabellaria flocculosa* and *Peronia fibula*. The planktonic *Cyclotella* spp. were absent from the top sample. The squared chord distance dissimilarity score between the two samples was 0.827.

Reconstructions of diatom-inferred pH (DI-pH) were produced using the SWAP training set. A high percentage of the taxa in the fossil samples were present in the SWAP training set and there were no major analogue problems (Table 3.6.14). The DI-pH values decline from 6.24 at the bottom sample to 4.96 at the top sample, indicating significant acidification. The annual mean current pH based on quarterly water samples collected during 2004-2005 is 5.91 and therefore the diatom model appears to under-estimate current pH by ~1 pH unit.

In summary, there has been a large amount of floristic change in the Llyn Cwm Bychan core indicating significant acidification of the lake.

Figure 3.6.8 Summary diagram of diatom assemblages in top and bottom samples from core CWBY1

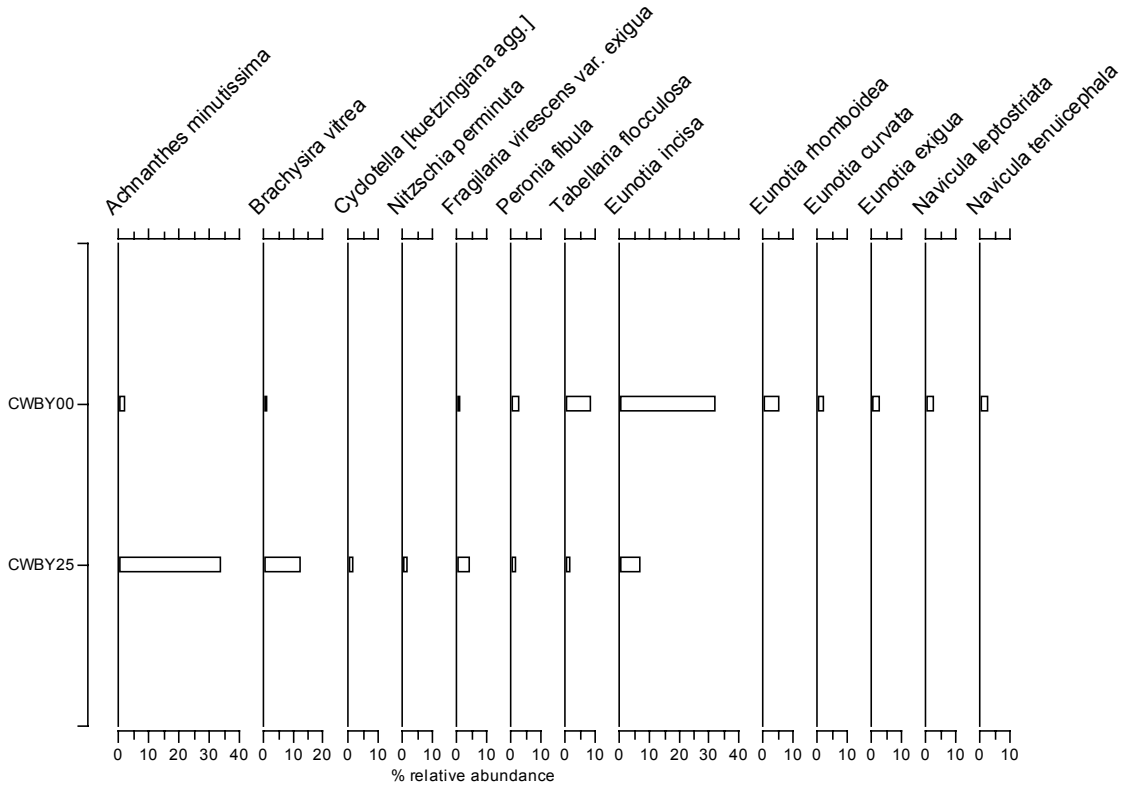


Table 3.6.14 Results of Llyn Cwm Bychan short core analysis

Sample code	Depth (cm)	Annual mean current pH	DI-pH	No. taxa in fossil sample	% of taxa in fossil sample present in SWAP training set	Squared chord distance dissimilarity score between core top and bottom
CWBY00	0	5.91	4.96	51	91	0.827
CWBY25	25		6.24	59	91	

3.6.3 Llyn Eiddew-mawr

3.6.3.1 Site Description

Llyn Eiddew-mawr lies at an altitude of 355 m. The catchment is composed primarily of dry acid heath, likewise much of the vegetation adjacent to the lake is dominated by *Calluna* heath with areas of bare rock. Information on the solid geology of the Llyn Eiddew-mawr catchment and land cover data are given in Tables 3.6.15 and 3.6.16 respectively. A catchment map is given in Figure 3.6.9.

Table 3.6.15 Solid geology of the Llyn Eiddew-mawr catchment
(Data from British Geological Survey solid geology data at 1:62,500)

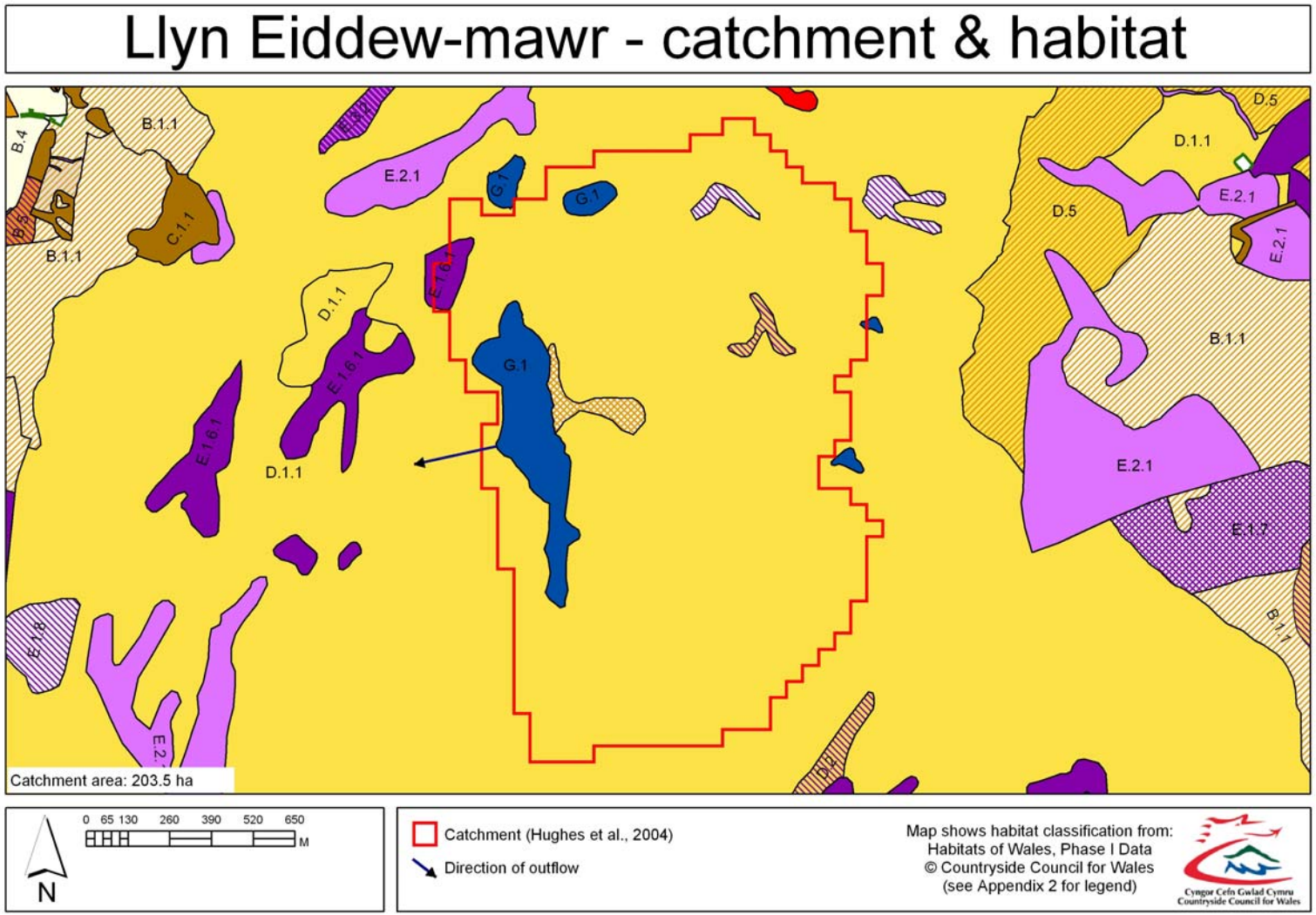
Name	Type	Percentage cover
Lower Cambrian	Sedimentary	99.3
Middle Cambrian	Sedimentary	0.7

Table 3.6.16 Land cover data for the Llyn Eiddew-mawr catchment
(Data from CCW Phase 1 Habitat Survey)

Classification	Code	Percentage cover
Grassland and marsh		
Unimproved calcareous grassland	B.3.1	1.2
Heathland		
Dry acid heath	D.1.1	90.7
Open water		
Standing water	G.1	6.3
Other*		1.8

* Percentage cover >1% and /or data not available

Figure 3.6.9 Llyn Eiddew-mawr catchment map



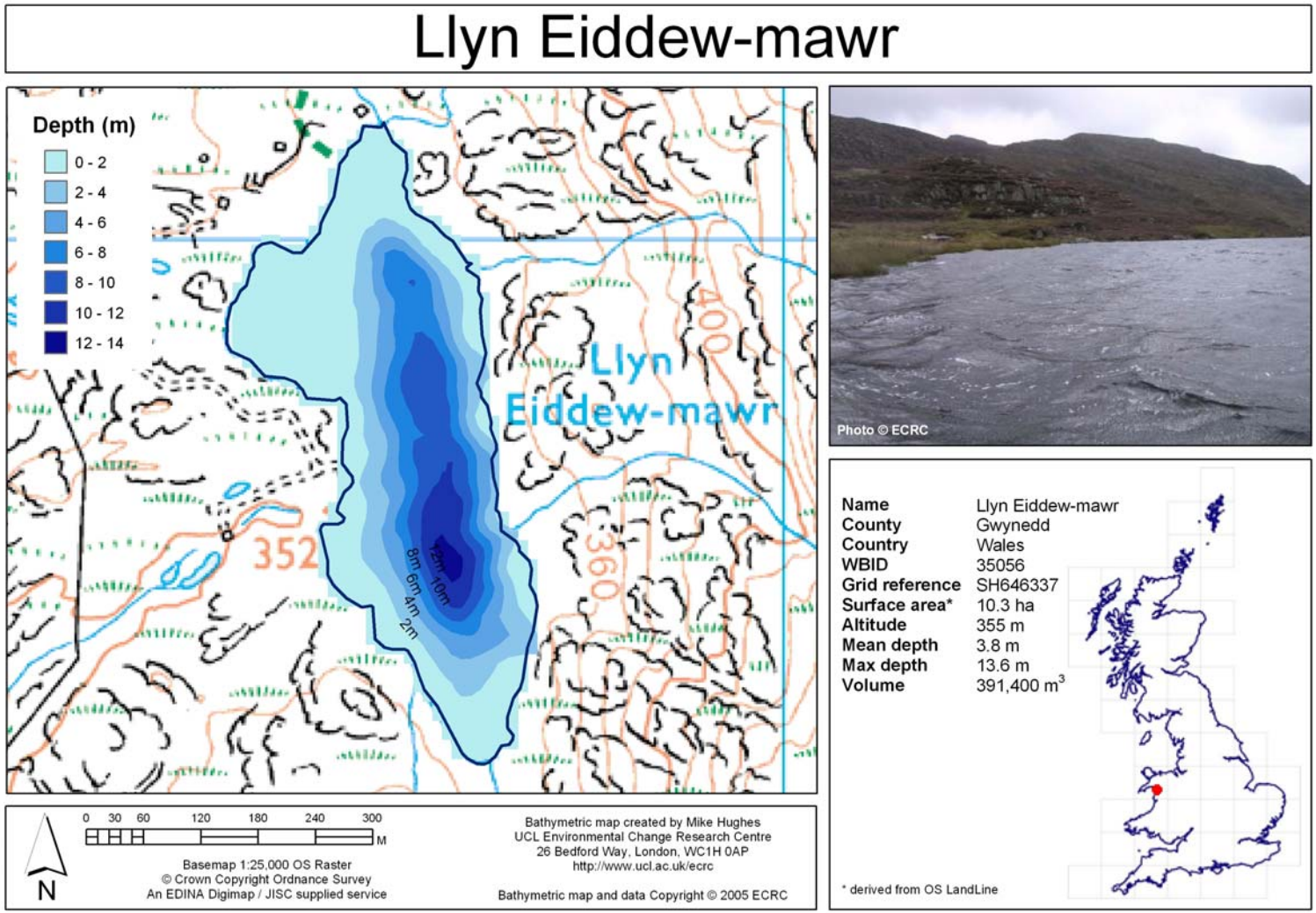
3.6.3.2 Bathymetry

The bathymetry of Llyn Eiddew-mawr is shown in Figure 3.6.10, physical and morphometric parameters are given in Table 3.6.17.

Table 3.6.17 Llyn Eiddew-mawr - physical and morphometric parameters

Lake altitude (m)	355
Maximum depth (m)	13.6
Mean depth (m)	3.8
Lake volume ($x10^3m^3$)	391.4
Area of lake surface (ha)	10.3
Perimeter of lake (km)	1.6
Shoreline development index	1.43
Estimated hydraulic residence time (days)	40.7
Secchi disc depth (m)	2.2
Catchment area (ha)	203.5
Catchment to lake area ratio	19.8

Figure 3.6.10 Llyn Eiddew-mawr bathymetry map



3.6.3.3 Physico-chemical data

Temperature and oxygen profiles for Llyn Eiddew-mawr are given in Figure 3.6.11 and water chemistry data shown in Table 3.6.18.

Figure 3.6.11 Temperature and oxygen profiles for Llyn Eiddew-mawr

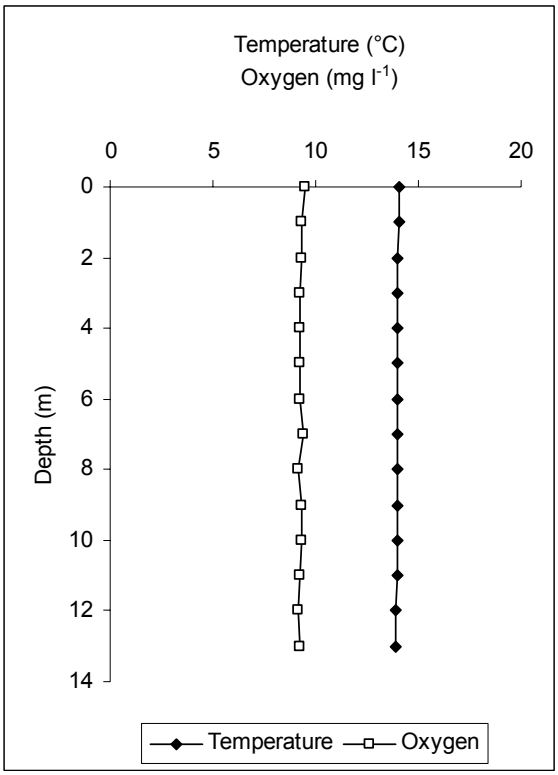


Table 3.6.18 Water chemistry data for Llyn Eiddew-mawr

	Sept 04	Dec 04	Mar 05	Jun 05	Annual mean
pH	5.6	5.5	5.6	6.0	5.7
Cond	25	31	52	41	37
Alk	<114	<114	<114	31.3	n.c.
DOC	5.15	3.00	1.90	3.19	3.31
SRP	7	4	3	7	5
TP	78.5	83	<50	3.7	n.c.
Chl *a*	15.1	1.3	1.8	5.0	5.8
TN	0.26	0.23	0.37	0.27	0.28
NO_3^--N	0.28	0.67	1.07	0.54	0.64
Labile Al	<23	17.0	51.6	26.3	n.c.
SO_4^{2-}	48	53	54	59	53
Total Fe	88	54	16	25	46
Na^+	168.0	181.9	282.8	230.2	215.7
K^+	1.8	5.7	11.4	3.5	5.6
Mg^{2+}	41.0	45.7	70.1	52.0	52.2
Ca^{2+}	41.7	42.0	Error	49.8	n.c.
Cl^-	175.3	211.1	335.9	257.5	244.9
Total Mn	58.4	19.3	39.1	33.8	37.7
ANC					-26.38

(n.c. – not calculated, one or more values below analytical detection)

3.6.3.4 Macrophyte survey

Results of the macrophyte survey are given in Tables 3.6.19 and 3.6.20. A strandline survey recorded the presence of *Eleogition fluitans*. High winds on the day of sampling made boat work dangerous and only 2 boat transects were completed. The water level was approximately 10 cm above normal after heavy rain.

Table 3.6.19 Macrophyte abundance for Llyn Eiddew-mawr – emergent and marginal survey

Taxon	DAFOR Abundance
Juncus effusus	**A**
Juncus articulatus/acutiflorus	**A**
Juncus bulbosus	**F**
Carex echinita	**F**
Carex demissa	**F**
Potamogeton polygonifolius	**O**
Viola palustris	**F**
Potentilla erecta	**F**
Sphagnum sp.	**A**
Drosera rotundifolia	**F**
Galium saxitle	**F**
Eriophorum angustifolium	**F**
Juncus conglomeratus	**O**
Carex panicea	**F**
Salix sp.	**O**
Sparganium angustifolium	**F**
Glyceria fluitans	**O**
Equisetum fluviatile	**O**
Carex lasiocarpa	**R**
Carex flacca	**R**
Carex rostrata	**R**
Ranunculus flammula	**R**

Table 3.6.20 Macrophyte abundance for Llyn Eiddew-mawr – wading and boat survey

Taxon	DAFOR Abundance
Callitriche hamulata	**O**
Carex rostrata	**R**
Equisetum fluviatile	**R**
Isoetes lacustris	**A**
Juncus bulbosus	**F**
Juncus effusus	**R**
Littorella uniflora	**A**
Lobelia dortmanna	**D**
Myriophyllum alterniflorum	**R**
Sparganium angustifolium	**O**
Sphagnum auriculatum	**A**
Subularia aquatica	**R**

3.6.3.5 Short core analysis

A 21 cm Glew core, EIF1, was taken in a water depth of 13 m from Llyn Eiddew-mawr on 12-Sep-04. A summary diagram of the common taxa (>2%) is shown in Figure 3.6.12 and summary data are given in Table 3.6.21. The core top and bottom samples contained a total of 79 diatom taxa. The assemblage of the bottom sample was diverse with a non-planktonic flora typical of moderately acid waters, the most abundant taxa being *Fragilaria virescens* var. *exigua*, *Eunotia incisa, Achnanthes minutissima, Navicula leptostriata* and *Tabellaria flocculosa*. The top sample was also diverse and had many taxa in common with the lower sample. However, notable differences included higher amounts of *Tabellaria quadriseptata, Tabellaria binalis* and *Navicula tenuicephala*, taxa associated with strongly acid conditions. The squared chord distance dissimilarity score between the two samples was 0.478.

Reconstructions of diatom-inferred pH (DI-pH) were produced using the SWAP training set. A high percentage of the taxa in the fossil samples were present in the SWAP training set and there were no major analogue problems (Table 3.6.21). The DI-pH values decline slightly from 5.30 for the bottom sample to 5.02 for the top sample, indicating mild acidification. However, the inferred change in pH is less than the RMSEP of the model of 0.32 pH units. The annual mean current pH based on quarterly water samples collected during 2004-2005 is 5.71 and therefore the diatom model appears to under-estimate current pH by ~0.7 pH units.

In summary, there has been a moderate degree of floristic change in the Llyn Eiddew-mawr core which indicates acidification of the lake. Nevertheless the data suggest that the lake has been acid for the whole of the period represented by the core.

Figure 3.6.12 Summary diagram of diatom assemblages in top and bottom samples from core EIF1

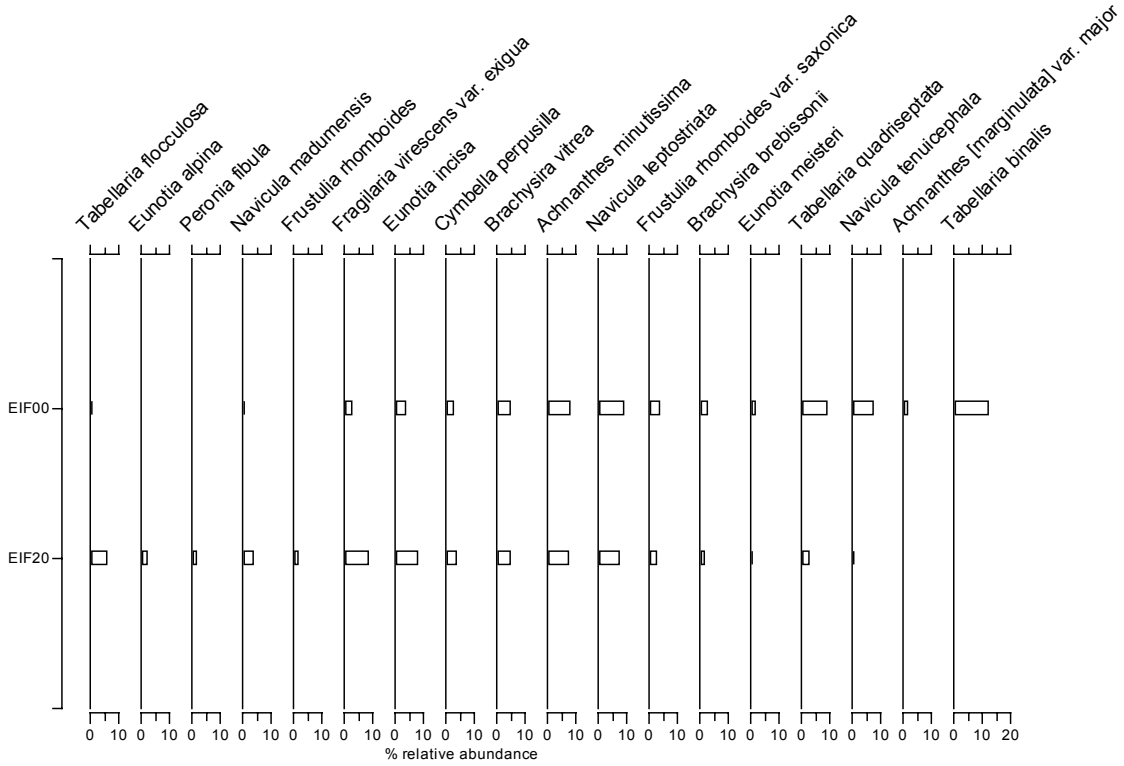


Table 3.6.21 Results of Llyn Eiddew-mawr short core analysis

Sample code	Depth (cm)	Annual mean current pH	DI-pH	No. taxa in fossil sample	% of taxa in fossil sample present in SWAP training set	Squared chord distance dissimilarity score between core top and bottom
EIF00	0	5.71	5.02	56	93	0.478
EIF20	20		5.30	62	91	

3.6.4 Llyn Perfeddau

3.6.4.1 Site Description

Llyn Perfeddau is a small upland lake (surface area 0.9 ha, altitude 469 m). The catchment is covered by unimproved grassland and dry acid heath. Vegetation adjacent to the lake is dominated by *Calluna* and *Vaccinium* upland heath and bare rock. Information on the solid geology of the Llyn Perfeddau catchment is not available from the GBLakes database as the lake area is less that 1 ha. Land cover data is given in Table 3.6.22. A catchment map is given in Figure 3.6.13.

Table 3.6.22 Land cover data for the Llyn Perfeddau catchment
(Data from CCW Phase 1 Habitat Survey)

Classification	Code	Percentage cover
Grassland and marsh		
Unimproved acid grassland	B.1.1	49.5
Heathland		
Dry acid heath	D.1.1	50.5

3.6.4.2 Bathymetry

The bathymetry of Llyn Perfeddau is shown in Figure 3.6.14, physical and morphometric parameters are given in Table 3.6.23.

Table 3.6.23 Llyn Perfeddau - physical and morphometric parameters

Lake altitude (m)	469
Maximum depth (m)	2.2
Mean depth (m)	1
Lake volume ($x10^3m^3$)	9.0
Area of lake surface (ha)	0.9
Perimeter of lake (km)	0.3
Shoreline development index	1.09
Estimated hydraulic residence time (days)	7.6
Secchi disc depth (m)	>2.2
Catchment area (ha)	27.9
Catchment to lake area ratio	31

Figure 3.6.13 Llyn Perfeddau catchment map

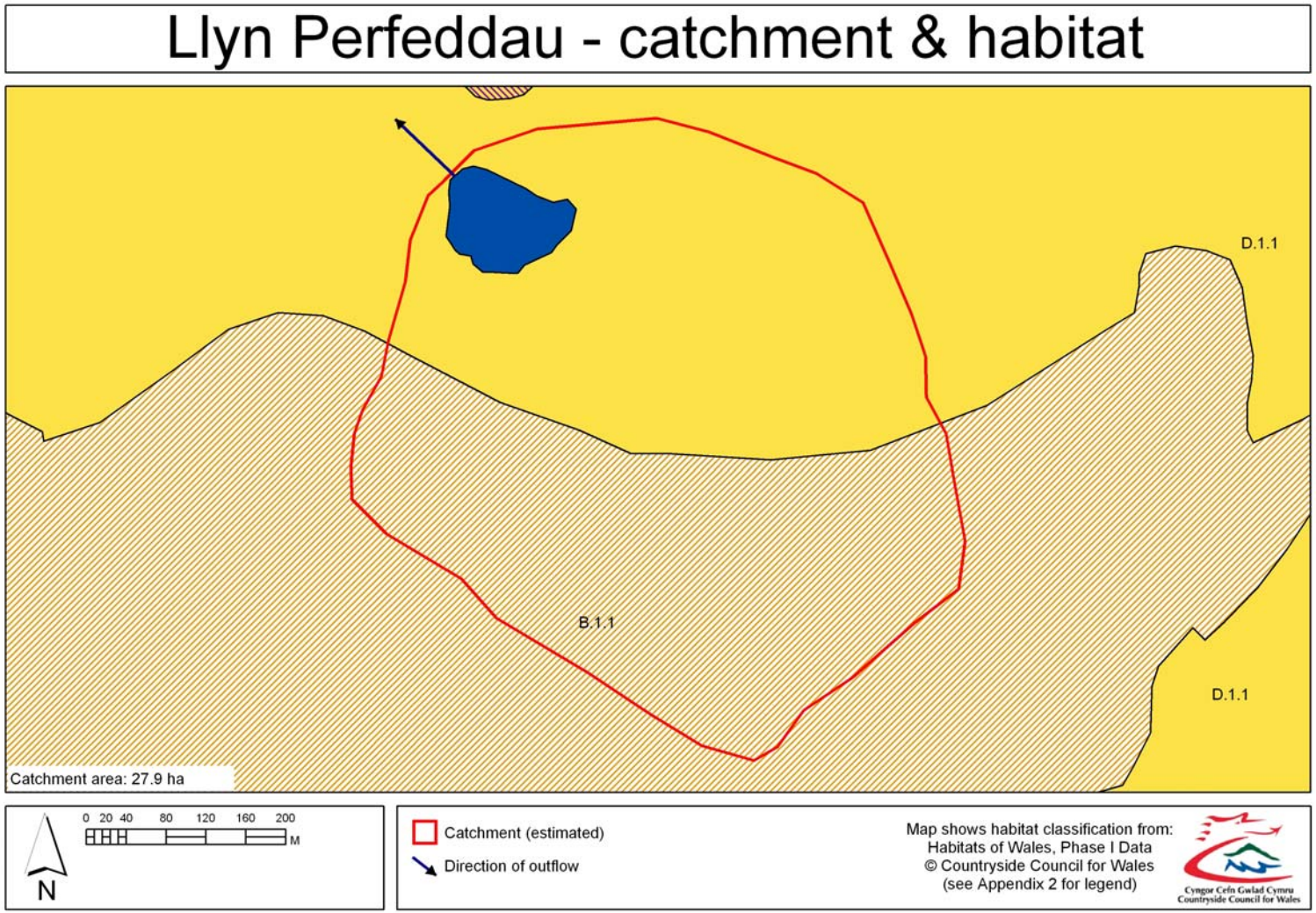
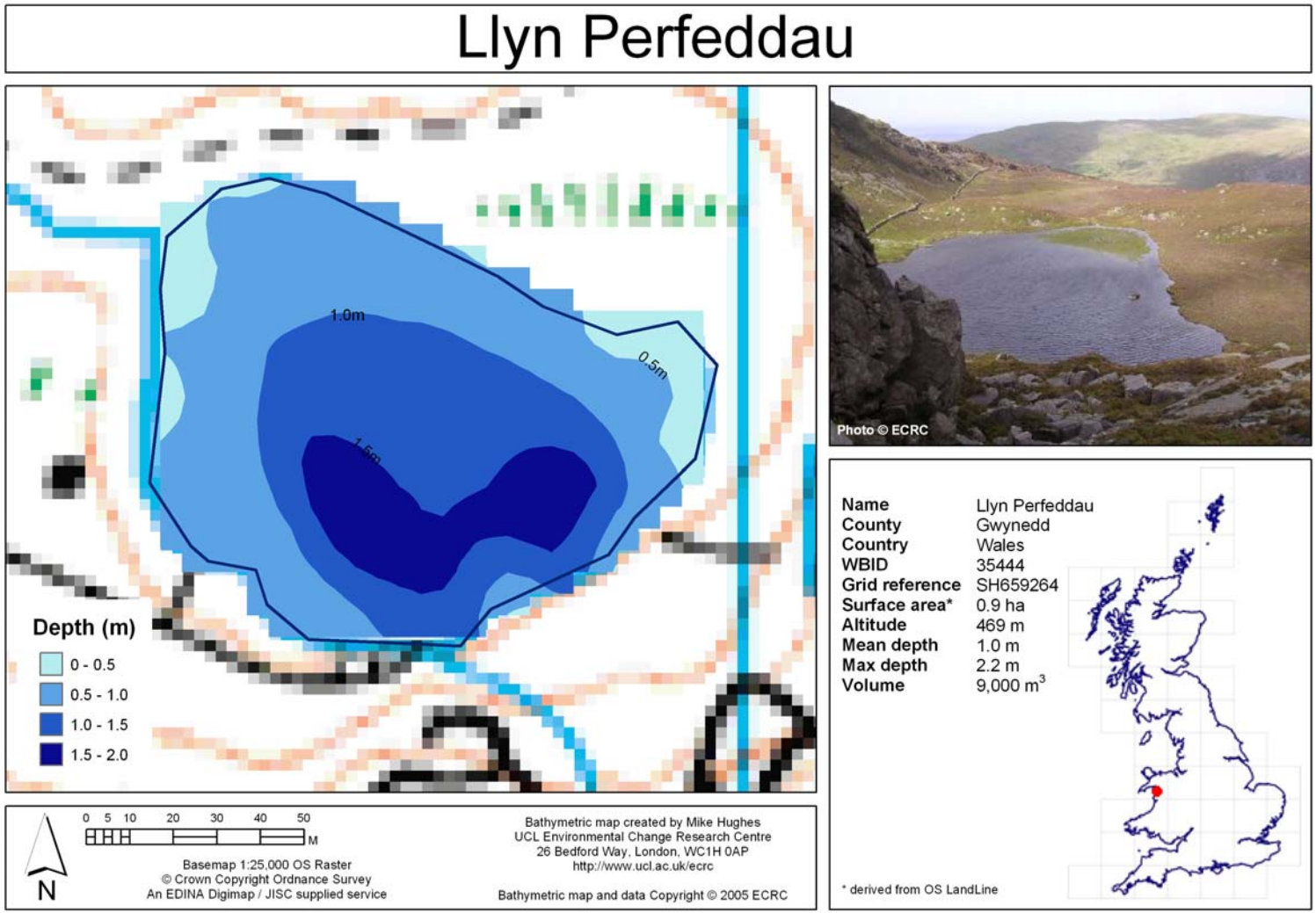


Figure 3.6.14 Llyn Perfeddau bathymetry map



3.6.4.3 Physico-chemical data

Temperature and oxygen profiles for Llyn Perfeddau are given in Figure 3.6.15 and water chemistry data shown in Table 3.6.24.

Figure 3.6.15 Temperature and oxygen profiles for Llyn Perfeddau

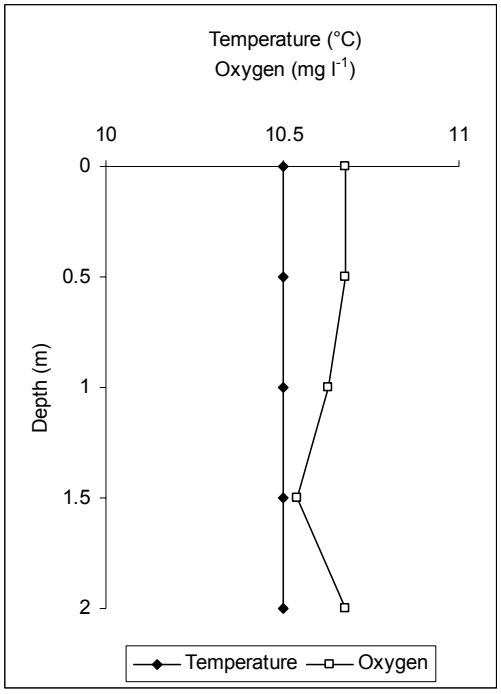


Table 3.6.24 Water chemistry data for Llyn Perfeddau

	Sept 04	Dec 04	Mar 05	Jun 05	Annual mean
pH	5.9	6.2	6.2	6.3	6.1
Cond	26	36	48	38	37
Alk	<114	<114	<114	46.9	n.c.
DOC	2.80	1.34	0.90	3.56	2.15
SRP	7	6	2	7	5
TP	<50	<50	<50	4.6	n.c.
Chl *a*	1.9	17.8	0.5	1.8	5.5
TN	0.27	0.43	0.55	0.30	0.39
NO_3^--N	0.53	1.48	1.84	0.66	1.13
Labile Al	<23	<23	<23	<23	n.c.
SO_4^{2-}	57	76	65	70	67
Total Fe	10	19	<6	22	17
Na^+	171.2	178.2	253.3	194.2	199.2
K^+	3.3	4.3	4.9	4.5	4.3
Mg^{2+}	53.3	68.2	84.8	60.2	66.6
Ca^{2+}	55.3	76.7	Error	69.4	n.c.
Cl^-	184.9	192.4	289.6	203.9	217.7
Total Mn	20.2	42.0	11.8	18.0	23.0
ANC					-28.30

(n.c. – not calculated, one or more values below analytical detection)

3.6.4.4 Macrophyte survey

Results from the macrophyte survey are given in Tables 3.6.25 and 3.6.26

Table 3.6.25 Macrophyte abundance for Llyn Perfeddau – emergent and marginal survey

Taxon	DAFOR Abundance
Carex demissa	**F**
Carex echinita	**F**
Carex rostrata	**F**
Juncus articulatus/acutiflorus	**F**
Viola palustris	**F**
Carex panicea	**F**
Sphagnum sp.	**A**
Potentilla erecta	**F**
Galium saxitile	**F**
Agrostis stolonifera	**F**
Potamogeton polygonifolius	**F**
Juncus effusus	**A**
Juncus squarrosus	**F**
Equisetum fluviatile	**A**
Trichophorum cespitosum	**F**

Table 3.6.26 Macrophyte abundance for Llyn Perfeddau – wading and boat survey

Taxon	DAFOR Abundance
Callitriche hamulata	**R**
Equisetum fluviatile	**A**
Isoetes lacustris	**F**
Juncus articulatus/acutiflorus	**R**
Littorella uniflora	**D**
Lobelia dortmanna	**D**
Myriophyllum alterniflorum	**F**
Potamogeton polygonifolius	**R**
Subularia aquatica	**A**

A strandline survey recorded no additional species. At the time of sampling the water level was approximately 15 cm higher than normal after heavy rain.

3.6.4.5 Short core analysis

A 26 cm Glew core, PERF1, was taken in a water depth of 2 m from Llyn Perfeddau on 13-Sep-04. A summary diagram of the common taxa (>2%) is shown in Figure 3.6.16

and summary data are given in Table 3.6.27. The core top and bottom samples contained a total of 68 diatom taxa. The assemblage of the bottom sample was dominated by *Achnanthes minutissima,* a diatom which prefers circumneutral waters, along with a range of other non-planktonic species typical of circumneutral to slightly acid conditions. The top sample was markedly different being dominated by *Fragilaria virescens* var. *exigua*., with small amounts of taxa commonly found in acid waters (e.g. *Navicula leptostriata, Cymbella gaeumannii*). The squared chord distance dissimilarity score between the two samples was 0.820.

Reconstructions of diatom-inferred pH (DI-pH) were produced using the SWAP training set. A high percentage of the taxa in the fossil samples were present in the SWAP training set and there were no major analogue problems (Table 3.6.27). The DI-pH values decline from 6.56 for the bottom sample to 5.77 for the top sample, indicating significant acidification. The annual mean current pH based on quarterly water samples collected during 2004-2005 is 6.15 and therefore the diatom model appears to under-estimate current pH by ~0.5 pH units.

In summary, there has been a significant degree of floristic change in the Llyn Perfeddau which indicates acidification of the lake.

Figure 3.6.16 Summary diagram of diatom assemblages in top and bottom samples from core PERF1

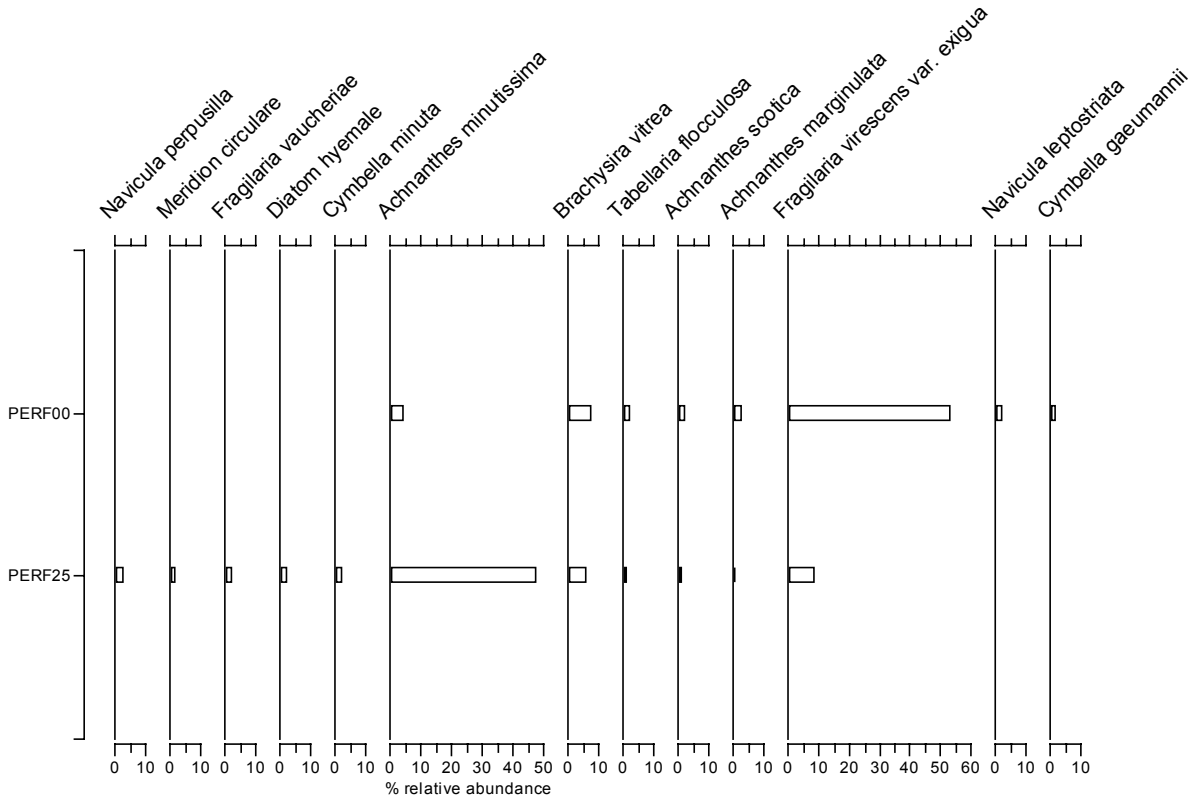


Table 3.6.27 Results of Llyn Perfeddau short core analysis

Sample code	Depth (cm)	Annual mean current pH	DI-pH	No. taxa in fossil sample	% of taxa in fossil sample present in SWAP training set	Squared chord distance dissimilarity score between core top and bottom
PERF00	0	6.15	5.77	41	93	0.820
PERF25	25		6.56	47	87	

3.7 Migneint–Arenig–Dduallt
Llyn Conglog-Mawr, Llyn Hesgyn, Llyn Hiraethlyn, Llyn Tryweryn & Llyn y Dywarchen, Llyn y Garn

Location of SAC

SAC Details	
Grid Ref. (approx. centre)	SH816440
SAC EU Code	UK0030205
Total Area	19968 ha
Total area of Freshwater	160 ha

General site character:
Inland water bodies (standing water, running water) (0.8%)
Bogs. Marshes. Water fringed vegetation. Fens (51.9%)
Heath. Scrub. Maquis and garrigue. Phygrana (16.3%)
Dry grassland. Steppes (14.8%)
Humid grassland. Mesophile grassland (12.9%)
Improved grassland (0.1%)
Broad-leaved deciduous woodland (0.4%)
Coniferous woodland (2.2%)
Inland rocks. Screes. Sands. Permanent snow and ice (0.4%)
Other land (including towns, villages, roads, waste places, mines, industrial sites) (0.2%)

Annex I habitats that are a primary reason for selection of this site
4030 European dry heaths
Upland European dry heath at Migneint–Arenig–Dduallt is predominantly referable to NVC type H12 *Calluna vulgaris – Vaccinium myrtillus* heath. Locally at higher altitudes this shows the effects of wind-pruning, and is lichen-rich in places. Other forms of heath present include H18 *Vaccinium myrtillus – Deschampsia flexuosa* heath, H21 *Calluna vulgaris – Vaccinium myrtillus – Sphagnum capillifolium* heath on damp north- to north-east facing cliffs, and H8 *Calluna vulgaris – Ulex gallii* heath at lower altitudes. The *Calluna – Vaccinium – Sphagnum* heath supports the Red Data Book liverwort *Gymnocolea acutiloba*.
7130 Blanket bogs
Migneint and Dduallt mark the limits of a large upland block located along the eastern fringe of Snowdonia National Park. The site supports the largest area of blanket bog in north Wales after Berwyn and is particularly significant for the extent and quality of comparatively Sphagnum-rich M19 *Calluna vulgaris – Eriophorum vaginatum* blanket

mire. M18 *Erica tetralix – Sphagnum papillosum* blanket mire is also widespread, with localised representation of the bog-moss *Sphagnum magellanicum* and, rarely, *S. imbricatum* ssp. affine. Other notable species found at the site include lesser twayblade *Listera cordata*, tall bog-sedge *Carex magellanica* and few-flowered sedge *C. pauciflora*, here approaching the southern limit of its British distribution. The significant representation of more degraded vegetation types, including M20 *Eriophorum vaginatum* blanket mire, attests to a long history of anthropogenic modification including burning, grazing and moor-gripping – significant parts of the site were formerly managed as grouse moor. Large areas of dry and wet heath are also present, while soligenous mire communities feature as widespread and extensive components of the blanket mire.

Annex I habitats present but not a primary reason for selection of this site include: 3130 Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea,* 3160 Natural dystrophic lakes and ponds, 4010 Northern Atlantic wet heaths with *Erica tetralix* and 91A0 Old sessile oak woods with *Ilex* and *Blechnum* in the British Isles.

(JNCC 2005b)

3.7.1 Llyn Conglog-Mawr

3.7.1.1 Site Description

Llyn Conlog-mawr lies at an altitude of 425 m and has a surface area of 3.5 ha. Approximately half of the catchment is covered with dry acid heath and there are also significant areas of swamp, mire and wet grassland. Vegetation adjacent to the lake is comprised of rough upland grazing, *Calluna*-dominated heath (partly burnt) and marsh.

Information on the solid geology of the Llyn Conlog-mawr catchment and land cover data are given in Tables 3.7.1 and 3.7.2 respectively. A catchment map is given in Figure 3.7.1.

Table 3.7.1 Solid geology of the Llyn Conlog-mawr catchment
(Data from British Geological Survey solid geology data at 1:62,500)

Name	Type	Percentage cover
Diorite and allied intermediate types	Igneous	13.7
Upper Cambrian, including Tremadoc	Sedimentary	86.3

Table 3.7.2 Land cover data for the Llyn Conlog-mawr catchment
(Data from CCW Phase 1 Habitat Survey)

Classification	Code	Percentage cover
Grassland and marsh		
Unimproved acid grassland	B.1.1	8.8
Marshy grassland	B.5	5.7
Heathland		
Dry acid heath	D.1.1	50.3
Dry heath/acid grassland mosaic	D.5	2.7
Mire		
Blanket bog	E.1.6.1	7.7
Wet modified bog	E.1.7	1.9
Acid/neutral flush	E.2.1	1.4
Valley mire	E.3.1	16.8
Swamp, marginal and inundation		
Swamp	F.1	1.6
Open water		
Standing water	G.1	2.9
Other*		0.2

* Percentage cover >1% and /or data not available

3.7.1.2 Bathymetry

The bathymetry of Llyn Conlog-mawr is shown in Figure 3.7.2, physical and morphometric parameters are given in Table 3.7.3.

Table 3.7.3 Llyn Conlog-mawr - physical and morphometric parameters

Lake altitude (m)	425
Maximum depth (m)	5.9
Mean depth (m)	1.1
Lake volume ($x10^3m^3$)	38.5
Area of lake surface (ha)	3.5
Perimeter of lake (km)	0.8
Shoreline development index	1.22
Estimated hydraulic residence time (days)	7.7
Secchi disc depth (m)	0.8
Catchment area (ha)	111.5
Catchment to lake area ratio	31.9

Figure 3.7.1 Llyn Conlog-mawr catchment map

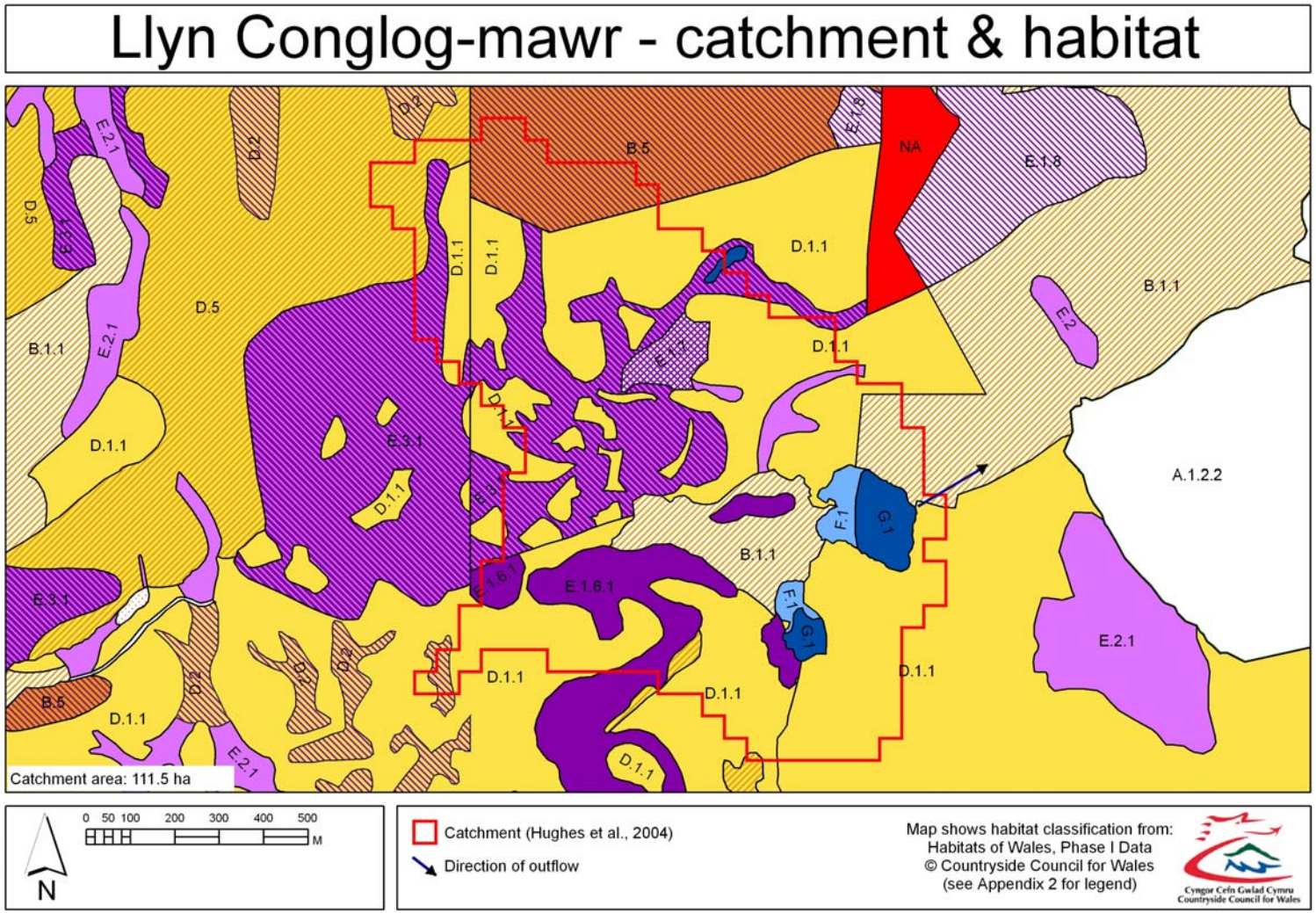
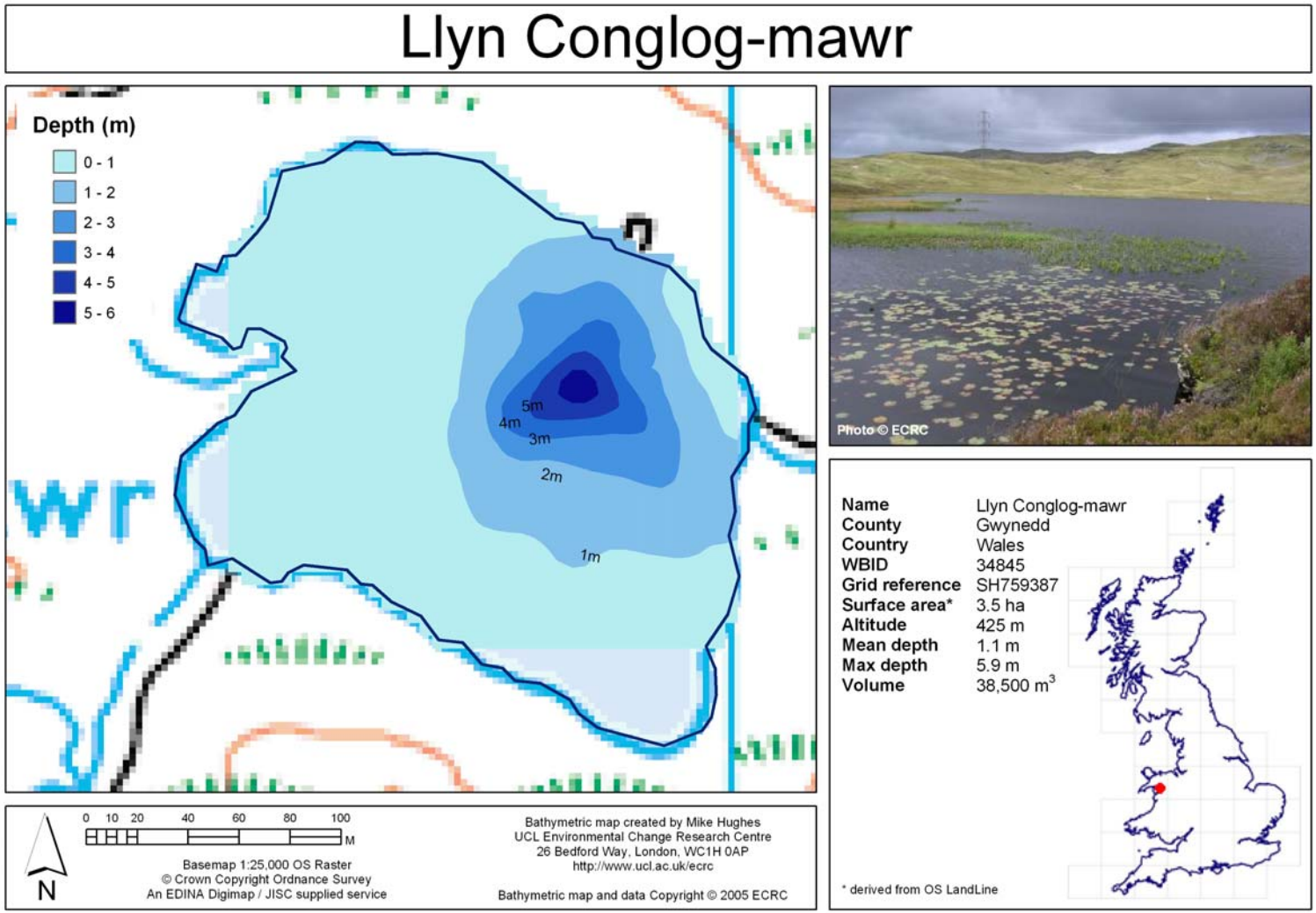


Figure 3.7.2 Llyn Conlog-mawr bathymetry map



3.7.1.3 Physico-chemical data

Temperature and oxygen profiles for Llyn Conlog-mawr are given in Figure 3.7.3 and water chemistry data shown in Table 3.7.4.

Figure 3.7.3 Temperature and oxygen profiles for Llyn Conlog-mawr

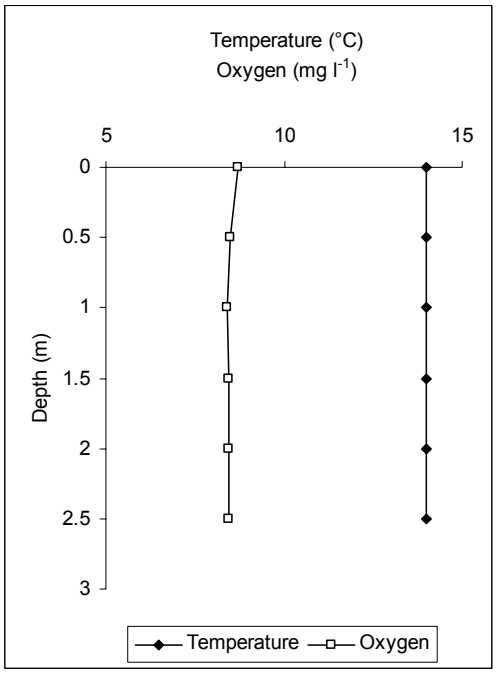


Table 3.7.4 Water chemistry data for Llyn Conlog-mawr

	Sept 04	Dec 04	Mar 05	Jun 05	Annual mean
pH	5.8	6.4	6.0	6.4	6.1
Cond	14	27	35	27	26
Alk	<114	<114	<114	52.5	n.c.
DOC	9.23	3.81	2.06	5.52	5.16
SRP	7	7	7	6	6
TP	188.9	<50	<50	16.4	n.c.
Chl *a*	4.0	2.8	4.0	6.1	4.2
TN	0.34	0.17	0.26	0.21	0.24
NO_3^--N	0.22	0.22	0.34	0.20	0.24
Labile Al	16.8	<23	<23	21.2	n.c.
SO_4^{2-}	59	39	55	33	46
Total Fe	376	409	179	1092	514
Na^+	90.5	146.1	198.2	140.9	143.9
K^+	2.1	2.6	3.3	1.9	2.5
Mg^{2+}	31.2	51.7	48.8	35.7	41.8
Ca^{2+}	51.0	54.7	61.5	61.6	57.2
Cl^-	194.9	147.0	226.6	152.7	180.3
Total Mn	83.4	42.1	55.5	48.2	57.3
ANC					0.84

(n.c. – not calculated, one or more values below analytical detection)

3.7.1.4 Macrophyte survey

Results of the macrophyte survey are given in Tables 3.7.5 and 3.7.6.

Table 3.7.5 Macrophyte abundance for Llyn Conlog-mawr – emergent and marginal survey

Taxon	DAFOR Abundance
Galium palustre	**A**
Hydrocotyle vulgaris	**O**
Carex demissa	**A**
Carex panicea	**A**
Juncus effusus	**A**
Carex echinita	**F**
Galium saxatile	**F**
Ranunculus flammula	**O**
Fontinalis antipyretica	**A**
Potamogeton polygonifolius	**A**
Potamogeton natans	**O**
Juncus conglomeratus	**O**
Juncus articulatus/acutiflorus	**A**
Juncus bulbosus	**F**
Sagina sp.	**O**
Anagallis tenella	**O**
Equisetum fluviatile	**F**
Myosotis sp.*	**O**
Utricularia minor	**O**
Viola palustris	**F**
Carex rostrata	**A**
Menyanthes trifoliata	**A**
Nymphaea alba	**O**
Sphagnum sp.	**A**

*no flower

Table 3.7.6 Macrophyte abundance for Llyn Conlog-mawr – wading and boat survey

Taxon	DAFOR Abundance
Carex rostrata	**F**
Equisetum fluviatile	**D**
Juncus bulbosus	**R**
Juncus articulatus/acutiflorus	**R**
Juncus effusus	**R**
Littorella uniflora	**R**
Menyanthes trifoliata	**F**
Myriophyllum alterniflorum	**F**
Nitella gracillis	**R**
Nitella flexilis agg	**R**
Nymphaea alba	**F**
Potamogeton natans	**R**
Potamogeton polygonifolius	**R**
Ranunculus flammula	**R**
Sphagnum sp	**R**

A strandline survey recorded the presence of *Nuphar lutea*.

3.7.1.5 Short core analysis

A 30 cm Glew core, CONM1, was taken in a water depth of 3 m from Llyn Conglog-Mawr on 26-Aug-04. Unfortunately, poor diatom preservation prevented analysis of the core bottom sample and therefore data are available only for the top sample. A summary diagram of the common taxa (>2%) is shown in Figure 3.7.4 and summary data are given in Table 3.7.7. The core top sample contained 57 diatom taxa. The assemblage was comprised of non-planktonic species typical of moderately acid waters, the most abundant being *Fragilaria virescens* var. *exigua, Eunotia incisa*, *Brachysira vitrea* and *Tabellaria flocculosa.*

Diatom-inferred pH (DI-pH) using the SWAP training set gave a value of 5.42 for the top sample (Table 3.7.7). The annual mean current pH based on quarterly water samples collected during 2004-2005 is 6.14 and therefore the diatom model appears to under-estimate current pH by ~0.7 pH units.

In summary, the degree of floristic change in the Llyn Conglog-Mawr core could not be assessed owing to poor preservation down-core. The diatom flora of the top sample is typical of moderately acid waters.

Figure 3.7.4 Summary diagram of the diatom assemblage in the top sample from core CONM1

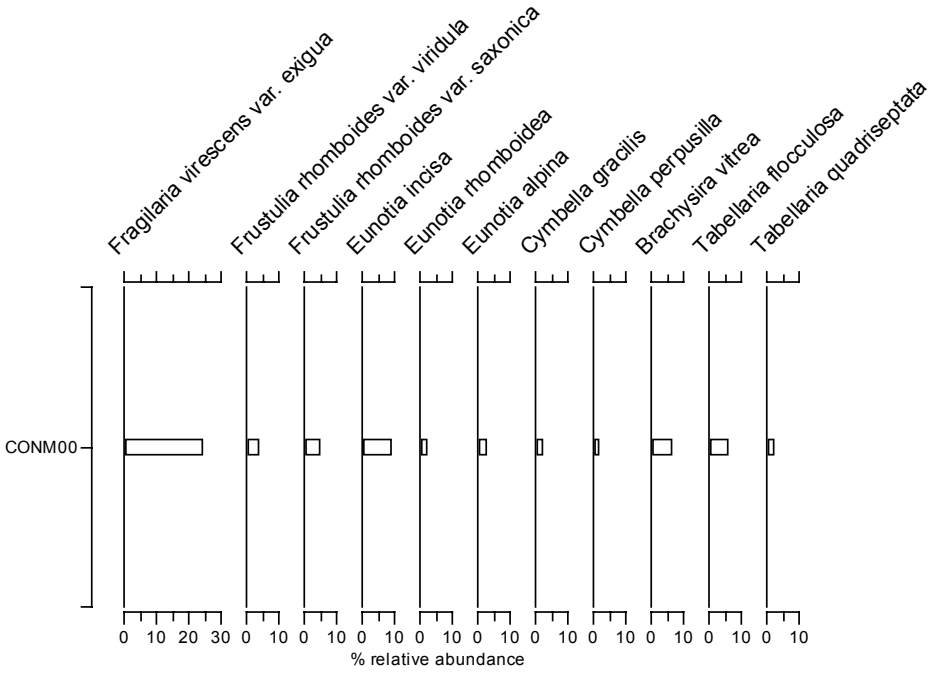


Table 3.7.7 Results of Llyn Conglog-Mawr short core analysis

Sample code	Depth (cm)	Annual mean current pH	DI-pH	No. taxa in fossil sample	% of taxa in fossil sample present in SWAP training set
CONM00	0	6.14	5.42	57	92

3.7.2 Llyn Hesgyn

3.7.2.1 Site Description

Llyn Hesgyn is a small, shallow lake which lies at an altitude of 425 m. Vegetation around the lake is composed of *Calluna*-dominated upland heath which is grazed. A site description is given in Carvalho *et al.* (2003).

Information on the solid geology of the Llyn Cadarn catchment and land cover data are given in Tables 3.7.8 and 3.7.9 respectively. A catchment map is given in Figure 3.7.5.

Table 3.7.8 Solid geology of the Llyn Hesgyn catchment
(Data from British Geological Survey solid geology data at 1:62,500)

Name	Type	Percentage cover
Rhyolitic and trachytic lava and tuff undifferentiated	Igneous	36.2
Caradoc	Sedimentary	63.8

Table 3.7.9 Land cover data for the Llyn Hesgyn catchment
(Data from CCW Phase 1 Habitat Survey)

Classification	Code	Percentage cover
Grassland and marsh		
Unimproved acid grassland	B.1.1	1.8
Heathland		
Dry acid heath	D.1.1	24.9
Mire		
Blanket bog	E.1.6.1	54.2
Acid/neutral flush	E.2.1	17.2
Open water		
Standing water	G.1	1.9
Other*		

* Percentage cover >1% and /or data not available

3.7.2.2 Bathymetry

The bathymetry of Llyn Hesgyn is shown in Figure 3.7.6, physical and morphometric parameters are given in Table 3.7.10.

Table 3.7.10 Llyn Hesgyn - physical and morphometric parameters

Lake altitude (m)	425
Maximum depth (m)	5.2
Mean depth (m)	1.8
Lake volume ($x10^3m^3$)	55.8
Area of lake surface (ha)	3.1
Perimeter of lake (km)	0.5
Shoreline development index	1.01
Estimated hydraulic residence time (days)	7.5
Secchi disc depth (m)	1.0
Catchment area (ha)	170.8
Catchment to lake area ratio	55.1

Figure 3.7.5 Llyn Hesgyn catchment map

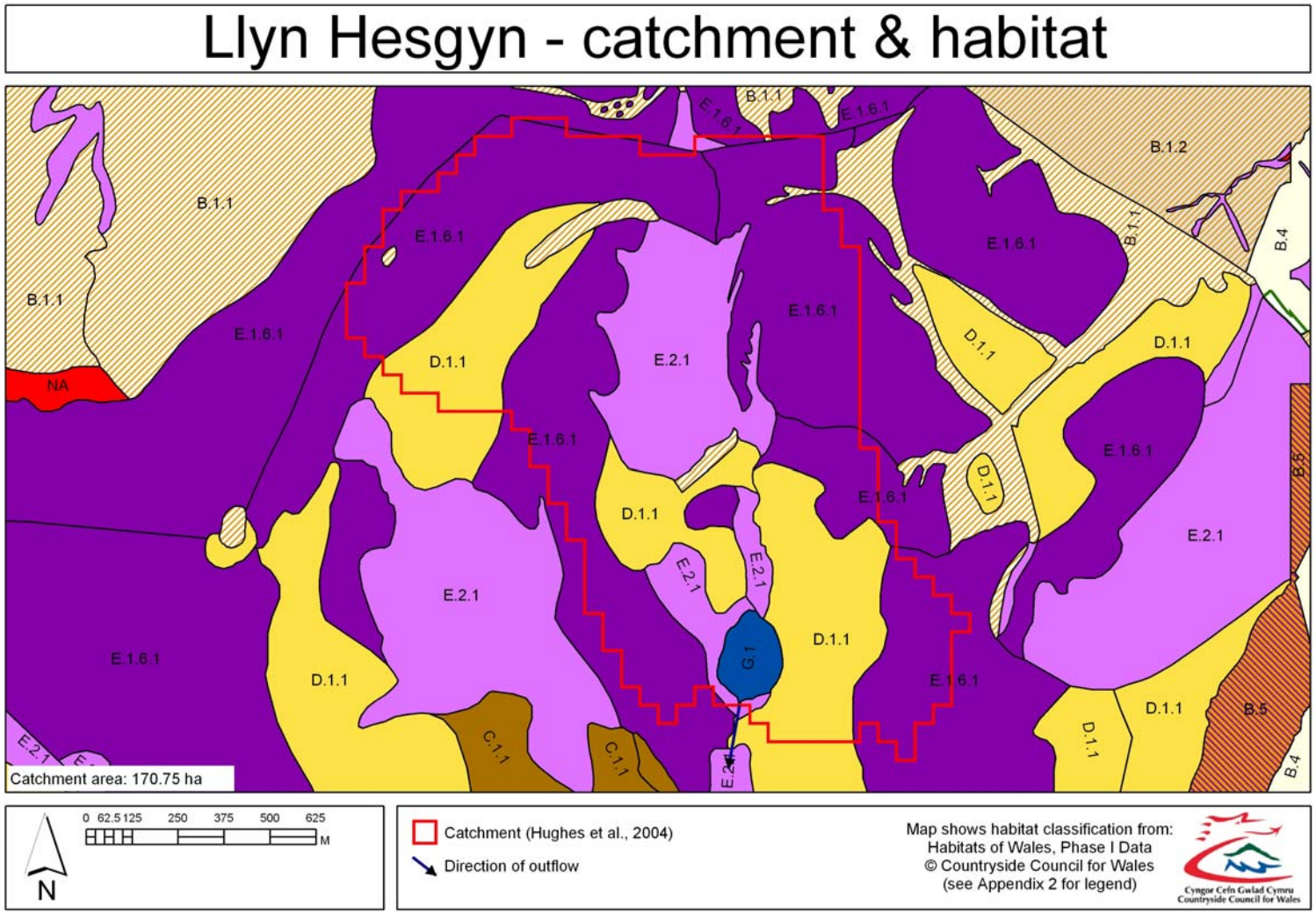
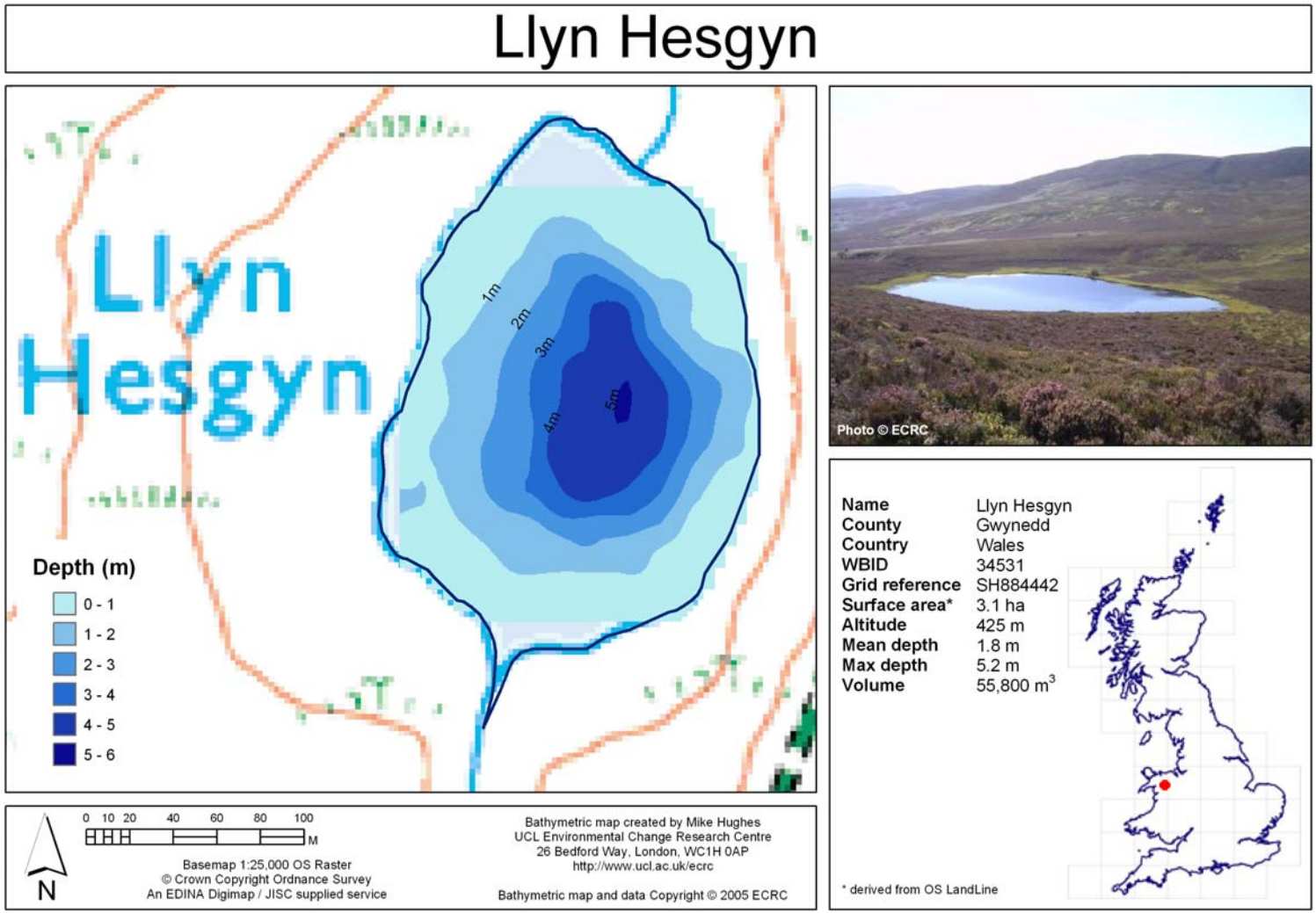


Figure 3.7.6 Llyn Hesgyn bathymetry map



3.7.2.3 Physico-chemical data

Temperature and oxygen profiles for Llyn Hesgyn are given in Figure 3.7.7 and water chemistry data shown in Table 3.7.11.

Figure 3.7.7 Temperature and oxygen profiles for Llyn Hesgyn

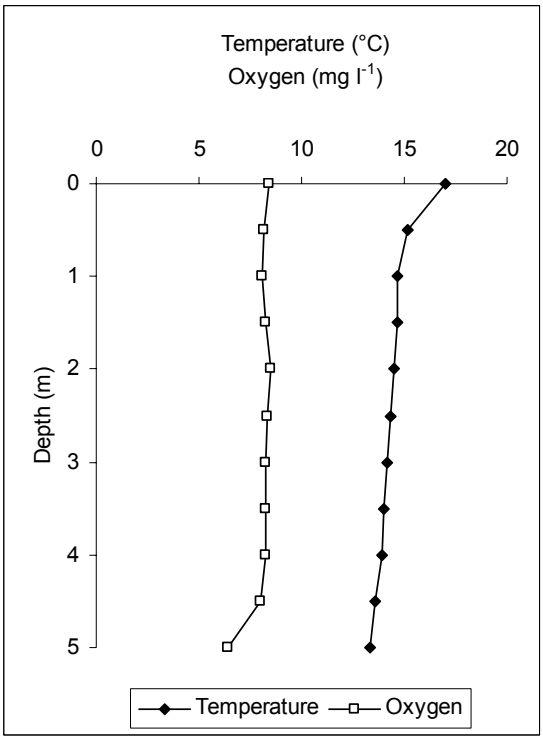


Table 3.7.11 Water chemistry data for Llyn Hesgyn

	Sept 04	Dec 04	Mar 05	Jun 05	Annual mean
pH	6.0	6.0	6.6	6.6	6.2
Cond	27	33	39	36	34
Alk	<114	<114	<114	99.3	n.c.
DOC	14.24	6.31	3.49	7.58	7.90
SRP	8	10	7	8	8
TP	71.5	<50	<50	15.5	n.c.
Chl *a*	4.7	1.8	3.9	6.5	4.2
TN	0.42	0.32	0.34	0.23	0.33
NO_3^--N	0.23	0.48	0.30	0.11	0.28
Labile Al	15.1	15.7	<23	36.0	n.c.
SO_4^{2-}	46	67	57	41	53
Total Fe	1047	521	232	778	644
Na^+	175.7	168.8	200.0	167.4	178.0
K^+	7.6	7.8	8.9	2.7	6.7
Mg^{2+}	73.6	68.5	82.3	80.0	76.1
Ca^{2+}	94.1	73.3	84.0	95.9	86.8
Cl^-	158.5	225.4	227.9	174.2	196.5
Total Mn	266.7	96.5	95.2	141.5	150.0
ANC					77.45

(n.c. – not calculated, one or more values below analytical detection)

3.7.2.4 Macrophyte survey

Results of the macrophyte survey are given in Tables 3.7.12 and 3.7.13.

Table 3.7.12 Macrophyte abundance for Llyn Hesgyn – emergent and marginal survey

Taxon	DAFOR Abundance
Potamogeton polygonifolius	**F**
Juncus effusus	**A**
Littorella uniflora	**O**
Galium palustre	**F**
Liverwort "A"	**O**
Fontinalis antipyretica	**O**
Ranunculus omiophyllus	**O**
Viola palustris	**A**
Sphagnum sp.	**D**
Ranunculus flammula	**F**
Carex rostrata	**D**
Menyanthes trifoliata	**O**
Potentilla erecta	**O**
Hydrocotyle vulgaris	**O**

Table 3.7.13 Macrophyte abundance for Llyn Hesgyn – wading and boat survey

Taxon	DAFOR Abundance
Callitriche hamulata	**D**
Carex rostrata	**A**
Fontinalis antipyretica	**R**
Isoetes lacustris	**R**
Juncus effusus	**R**
Littorella uniflora	**F**
Myriophyllum alterniflorum	**A**
Nuphar lutea	**A**
Potamogeton polygonifolius	**O**
Sparganium angustifolium	**A**
Sphagnum auriculatum	**A**

A strandline survey recorded the presence of *Nymphaea alba*.

3.7.2.5 Short core analysis

A 26 cm Glew core, HESG1, was taken in a water depth of 5 m from Llyn Hesgyn on 05-Sep-04. A summary diagram of the common taxa (>2%) is shown in Figure 3.7.8 and

summary data are given in Table 3.7.14. The core top and bottom samples contained a total of 89 diatom taxa. The assemblage of the bottom sample was diverse with numerous non-planktonic species typical of mild to moderately acid waters, the most abundant being *Fragilaria virescens* var. *exigua*, *Achnanthes minutissima,* and *Tabellaria flocculosa*. The top sample also contained relatively high abundances of *Fragilaria virescens* var. *exigua* and *Tabellaria flocculosa* but *Achnanthes minutissima* was not present. The most marked difference between the bottom and top samples was the increase in two taxa, *Eunotia incisa* and *Aulacoseira distans* [cf. *septentrionalis*], in the latter. The squared chord distance dissimilarity score between the two samples was 0.620.

Reconstructions of diatom-inferred pH (DI-pH) were produced using the SWAP training set. A high percentage of the taxa in the bottom sample were present in the SWAP training set but there were relatively poor analogues for the top sample, largely owing to the absence of *Aulacoseira distans* [cf. *septentrionalis*] from the SWAP dataset (Table 3.7.14). The DI-pH values decline slightly from 5.85 for the bottom sample to 5.52 for the top sample, indicating mild acidification. The annual mean current pH based on quarterly water samples collected during 2004-2005 is 6.31 and therefore the diatom model appears to under-estimate current pH by ~0.8 pH units.

In summary, there has been a significant degree of floristic change in the Llyn Hesgyn core which appears to signify slight acidification of the lake. However the DI-pH value for the top sample must be interpreted with caution owing to the absence of *Aulacoseira distans* [cf. *septentrionalis*] from the SWAP training set.

Figure 3.7.8 Summary diagram of diatom assemblages in top and bottom samples from core HESG1

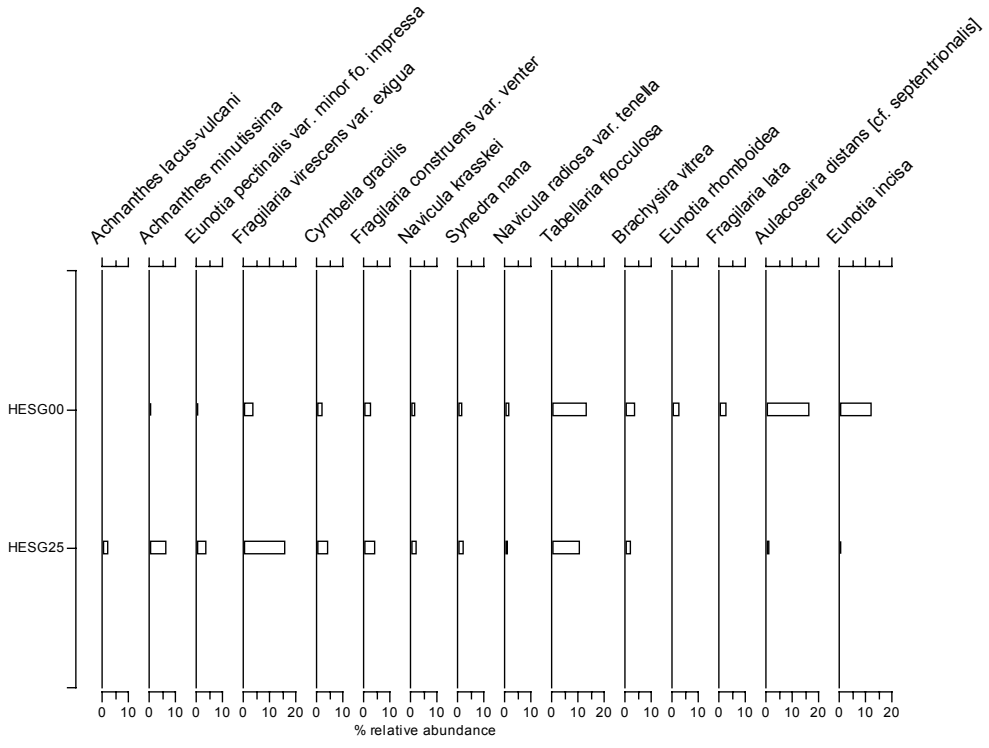


Table 3.7.14 Results of Llyn Hesgyn short core analysis

Sample code	Depth (cm)	Annual mean current pH	DI-pH	No. taxa in fossil sample	% of taxa in fossil sample present in SWAP training set	Squared chord distance dissimilarity score between core top and bottom
HESG00	0	6.31	5.52	59	74	0.620
HESG25	25		5.85	68	87	

3.7.3 Llyn Hiraethlyn

3.7.3.1 Site Description

Llyn Hiraethlyn is a relatively small lake which lies at an altitude of 309 m. A site description can be found in Carvalho *et al.* (2003). The rough grassland around the lake is heavily grazed right to the shore of the lake. Large numbers of geese were observed at the lake perimeter during the sampling trip. Information on the solid geology of the Llyn Hiraethlyn catchment and land cover data are given in Tables 3.7.15 and 3.7.16 respectively. A catchment map is given in Figure 3.7.9.

Table 3.7.15 Solid geology of the Llyn Hiraethlyn catchment
(Data from British Geological Survey solid geology data at 1:62,500)

Name	Type	Percentage cover
Upper Cambrian, including Tremadoc	Sedimentary	100

Table 3.7.16 Land cover data for the Llyn Hiraethlyn catchment
(Data from CCW Phase 1 Habitat Survey)

Classification	Code	Percentage cover
Grassland and marsh		
Unimproved acid grassland	B.1.1	12.6
Semi-improved acidic grassland	B.1.2	21.4
Improved grassland	B.4	6.9
Marshy grassland	B.5	1.7
Heathland		
Dry acid heath	D.1.1	42.5
Dry heath/acid grassland mosaic	D.5	4.5
Open water		
Standing water	G.1	9.9
Other*		0.5

* Percentage cover >1% and /or data not available

3.7.3.2 Bathymetry

The bathymetry of Llyn Hiraethlyn is shown in Figure 3.7.10, physical and morphometric parameters are given in Table 3.7.17.

Table 3.7.17 Llyn Hiraethlyn - physical and morphometric parameters

Lake altitude (m)	309
Maximum depth (m)	9
Mean depth (m)	2.8
Lake volume ($x10^3m^3$)	128.8
Area of lake surface (ha)	4.6
Perimeter of lake (km)	1.0
Shoreline development index	1.27
Estimated hydraulic residence time (days)	63.2
Secchi disc depth (m)	4.15
Catchment area including lake (ha)	47
Catchment to lake area ratio	10.2

Figure 3.7.9 Llyn Hiraethlyn catchment map

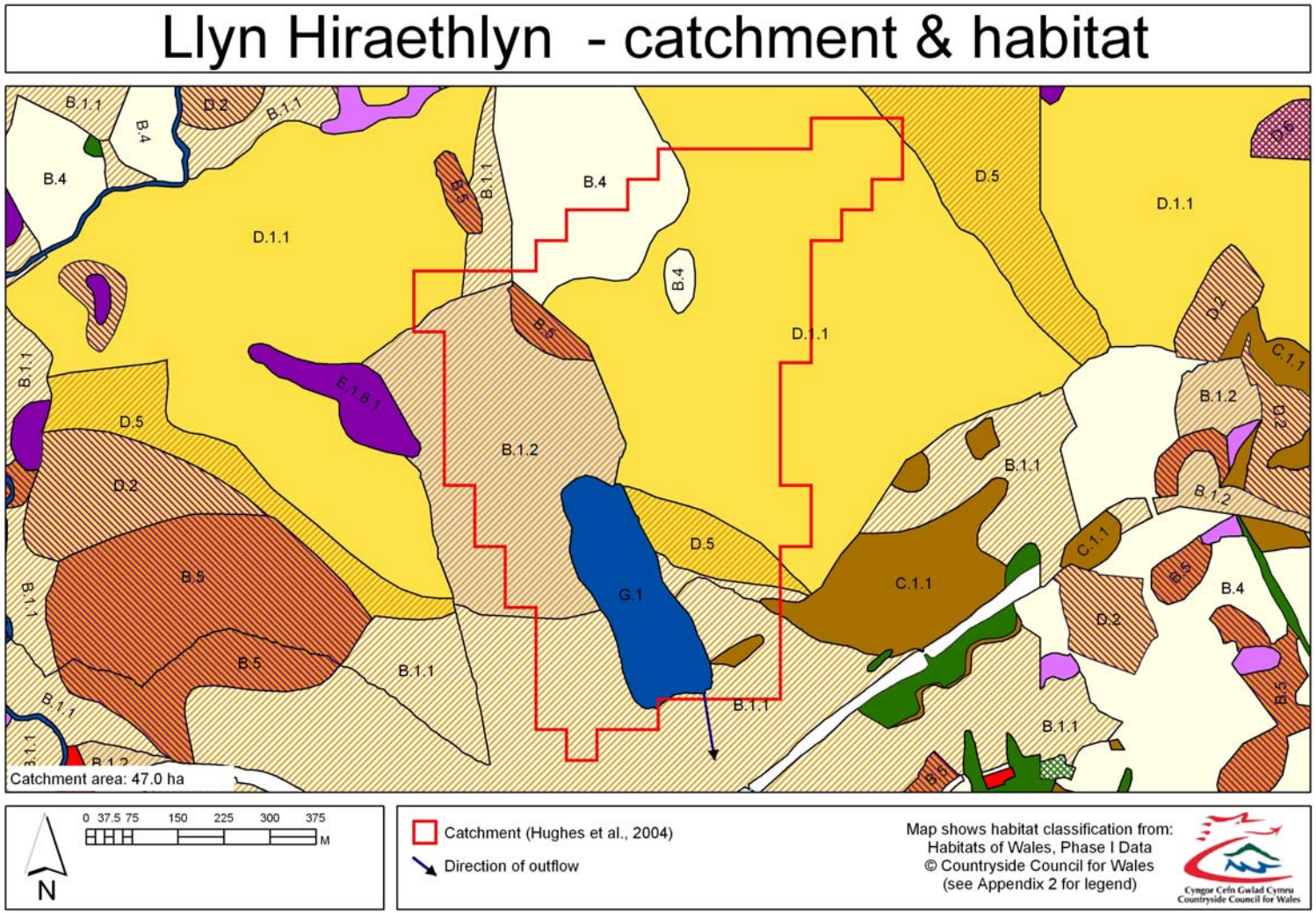
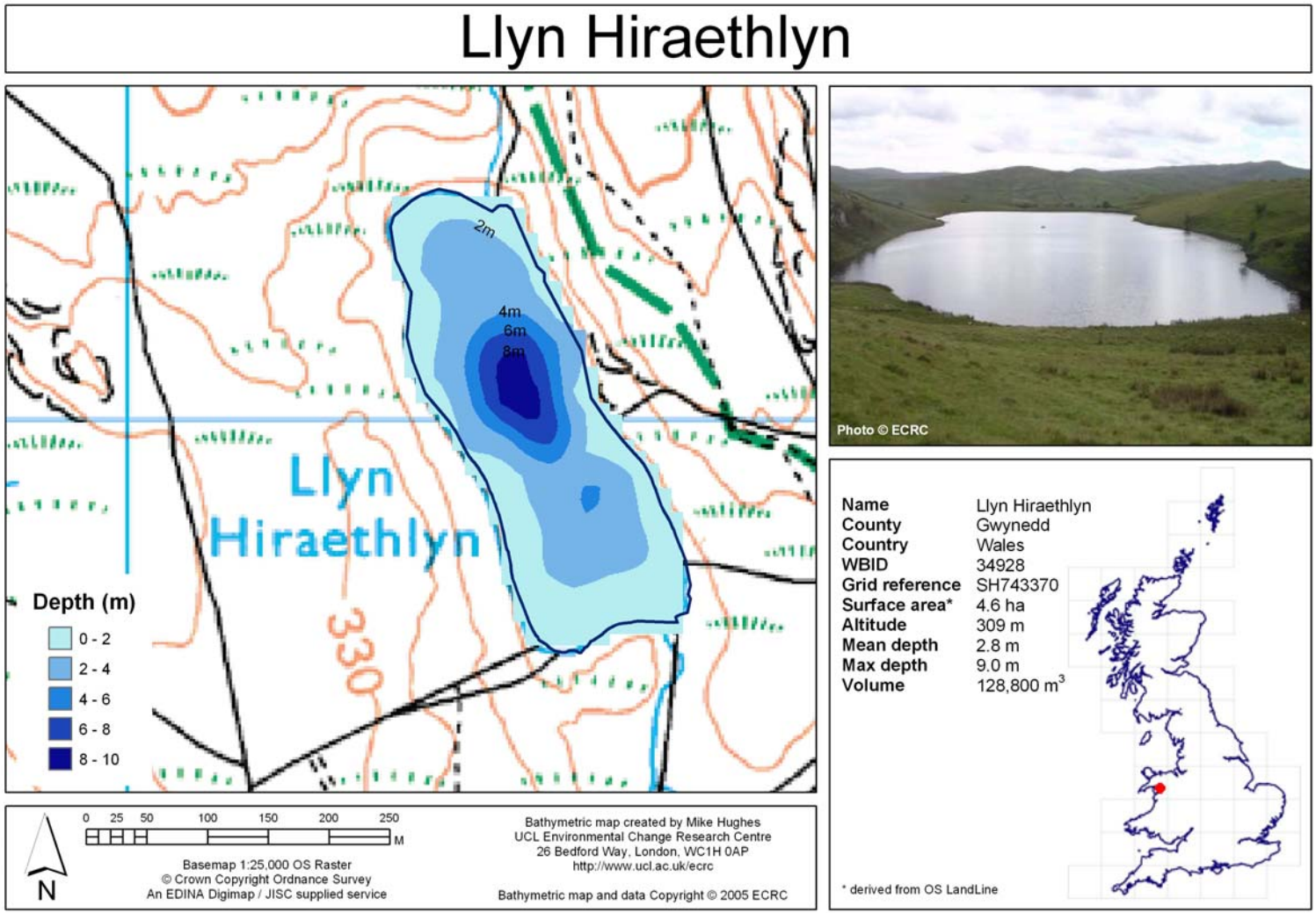


Figure 3.7.10 Llyn Hiraethlyn bathymetry map



3.7.3.3 Physico-chemical data

Temperature and oxygen profiles for Llyn Hiraethlyn are given in Figure 3.7.11 and water chemistry data shown in Table 3.7.18.

Figure 3.7.11 Temperature and oxygen profiles for Llyn Hiraethlyn

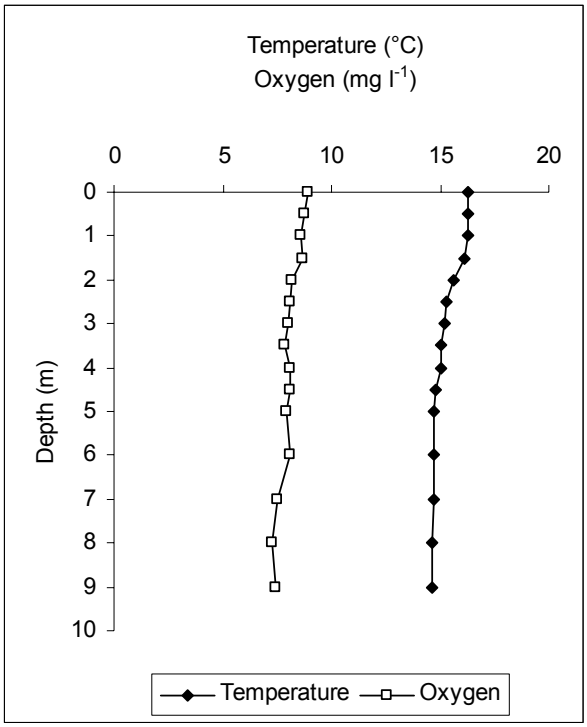


Table 3.7.18 Water chemistry data for Llyn Hiraethlyn

	Sept 04	Dec 04	Mar 05	Jun 05	Annual mean
pH	6.2	6.1	6.4	6.6	6.3
Cond	29	33	42	37	35
Alk	<114	<114	<114	52.5	n.c.
DOC	5.21	3.09	2.72	3.35	3.59
SRP	7	6	7	6	7
TP	136.4 (?)	<50	<50	8.2	n.c.
Chl *a*	5.3	4.2	3.2	10.3	5.8
TN	0.32	0.30	0.39	0.30	0.33
NO_3^--N	0.53	0.64	0.75	0.11	0.51
Labile Al	<23	<23	<23	<23	n.c.
SO_4^{2-}	57	74	78	77	72
Total Fe	164	79	41	37	80
Na^+	165.9	153.1	210.3	175.3	176.2
K^+	7.4	7.0	10.5	4.3	7.3
Mg^{2+}	64.2	59.3	68.0	61.4	63.2
Ca^{2+}	96.4	78.3	84.2	88.3	86.8
Cl^-	184.9	176.5	238.0	200.0	199.8
Total Mn	65.2	20.8	8.1	24.8	29.7
ANC					25.10

(n.c. – not calculated, one or more values below analytical detection)

3.7.3.4 Macrophyte survey

Results of the macrophyte survey are given in Tables 3.7.19 and 3.7.20.

Table 3.7.19 Macrophyte abundance for Llyn Hiraethlyn – emergent and marginal survey

Taxon	DAFOR Abundance
Juncus effusus	**A**
Utricularia minor	**F**
Juncus articulatus/acutiflorus	**A**
Juncus bulbosus	**F**
Hydrocotyle vulgaris	**A**
Viola palustris	**A**
Galium palustre	**F**
Galium saxatile	**F**
Ranunculus flammula	**F**
Potentilla erecta	**F**
Carex demissa	**F**
Carex panicea	**F**
Polygala vulgaris	**F**
Mentha aquatica	**O**
Anagallis tenella	**O**
Potamogeton polygonifolius	**A**
Achillea ptarmica	**O**
Littorella uniflora	**F**
Lotus pedunculatus	**F**

Table 3.7.20 Macrophyte abundance for Llyn Hiraethlyn – wading and boat survey

Taxon	DAFOR Abundance
Isoetes lacustris	**A**
Juncus bulbosus	**A**
Juncus articulatus/acutiflorus	**O**
Littorella uniflora	**A**
Lobelia dortmanna	**D**
Myriophyllum alterniflorum	**F**
Potamogeton polygonifolius	**R**
Sphagnum auriculatum	**F**
Utricularia minor	**F**

A strandline survey recorded no additional species.

3.7.3.5 Short core analysis

A 26 cm Glew core, HIRA2, was taken in a water depth of 9.5 m from Llyn Hiraethlyn on 03-Sep-04. A summary diagram of the common taxa (>2%) is shown in Figure 3.7.12 and summary data are given in Table 3.7.21. The core top and bottom samples contained a total of 82 diatom taxa. The bottom sample was diverse with the presence of both planktonic and non-planktonic species typical of circumneutral to mildly acid waters. The planktonic component was comprised of *Cyclotella comensis* and *Cyclotella* [*kueztingiana* agg.] and the most abundant non-planktonic taxa were *Achnanthes minutissima, Brachysira vitrea* and *Fragilaria virescens* var. *exigua*. The top sample contained many of the same taxa as the bottom sample but the planktonic *Cyclotella* spp. declined markedly and small amounts of taxa commonly found in more moderately acid conditions appeared, including *Brachysira brebissonii, Navicula mediocris* and *Achnanthes marginulata*. The squared chord distance dissimilarity score between the two samples was 0.471.

Reconstructions of diatom-inferred pH (DI-pH) were produced using the SWAP training set. A high percentage of the taxa in the fossil samples were present in the SWAP training set and there were no major analogue problems (Table 3.7.21). The DI-pH values decline from 6.30 for the bottom sample to 5.67 for the top sample, indicating acidification. The annual mean current pH based on quarterly water samples collected during 2004-2005 is 6.30 and therefore the diatom model appears to under-estimate current pH by ~0.6 pH units.

In summary, there has been a modest degree of floristic change in the Llyn Hiraethlyn core with a notable decline in the planktonic *Cyclotella* taxa. The species shifts indicate acidification of the lake.

Figure 3.7.12 Summary diagram of diatom assemblages in top and bottom samples from core HIRA2

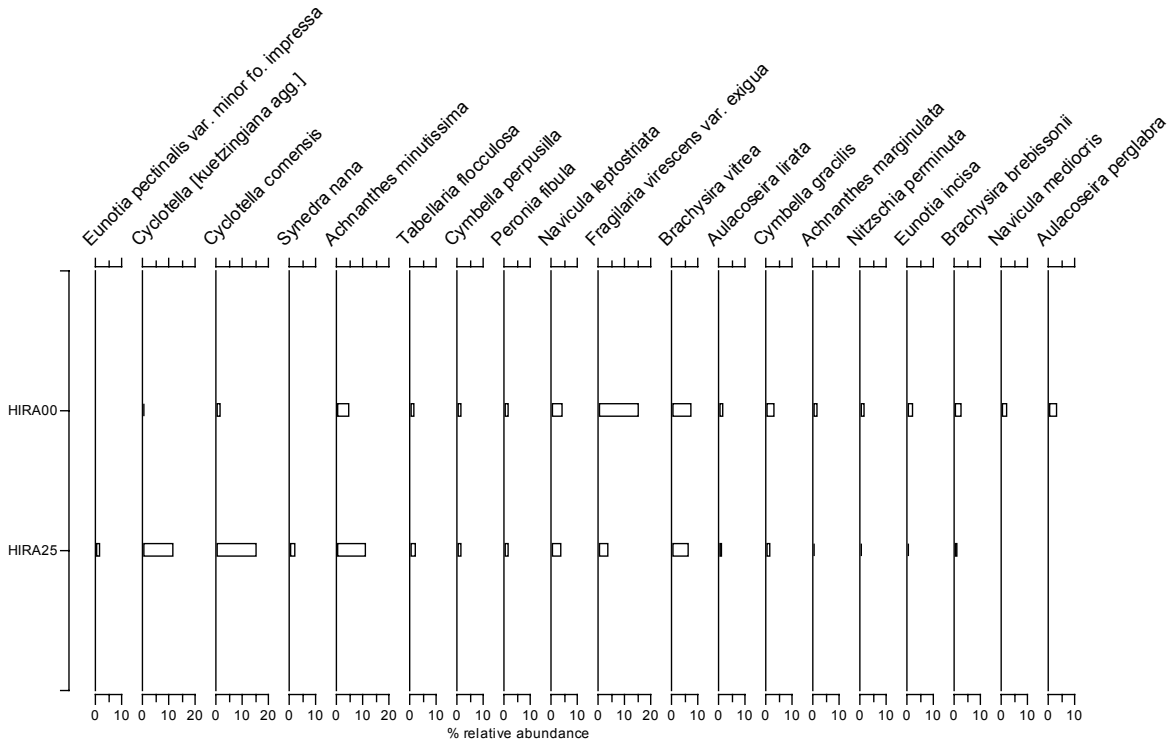


Table 3.7.21 Results of Llyn Hiraethlyn short core analysis

Sample code	Depth (cm)	Annual mean current pH	DI-pH	No. taxa in fossil sample	% of taxa in fossil sample present in SWAP training set	Squared chord distance dissimilarity score between core top and bottom
HIRA00	0	6.30	5.67	69	86	0.471
HIRA25	25		6.30	54	90	

3.7.4 Llyn y Garn

3.7.4.1 Site Description

Llyn y Garn lies at an altitude of 448 m in a catchment dominated by dry acid heath. The land adjacent to the lake slopes steeply to the shore, with vegetation types dominated by *Calluna* and *Vaccinium* upland heath. Information on the solid geology of the Llyn y Garn catchment and land cover data are given in Tables 3.7.22 and 3.7.23 respectively. A catchment map is given in Figure 3.7.13.

Table 3.7.22 Solid geology of the Llyn y Garn catchment
(Data from British Geological Survey solid geology data at 1:62,500)

Name	Type	Percentage cover
Diorite and allied intermediate types	Igneous	61.9
Upper Cambrian, including Tremadoc	Sedimentary	38.1

Table 3.7.23 Land cover data for the Llyn y Garn catchment
(Data from CCW Phase 1 Habitat Survey)

Classification	Code	Percentage cover
Heathland		
Dry acid heath	D.1.1	61.7
Open water		
Standing water	G.1	38.3

3.7.4.2 Bathymetry

The bathymetry of Llyn y Garn is shown in Figure 3.7.14, physical and morphometric parameters are given in Table 3.7.24.

Table 3.7.24 Llyn y Garn - physical and morphometric parameters

Lake altitude (m)	448
Maximum depth (m)	19.8
Mean depth (m)	8.3
Lake volume ($x10^3m^3$)	713.8
Area of lake surface (ha)	8.6
Perimeter of lake (km)	1.8
Shoreline development index	1.73
Estimated hydraulic residence time (days)	711.1
Secchi disc depth (m)	4.64
Catchment area including lake (ha)	23
Catchment to lake area ratio	2.7

Figure 3.7.13 Llyn y Garn catchment map

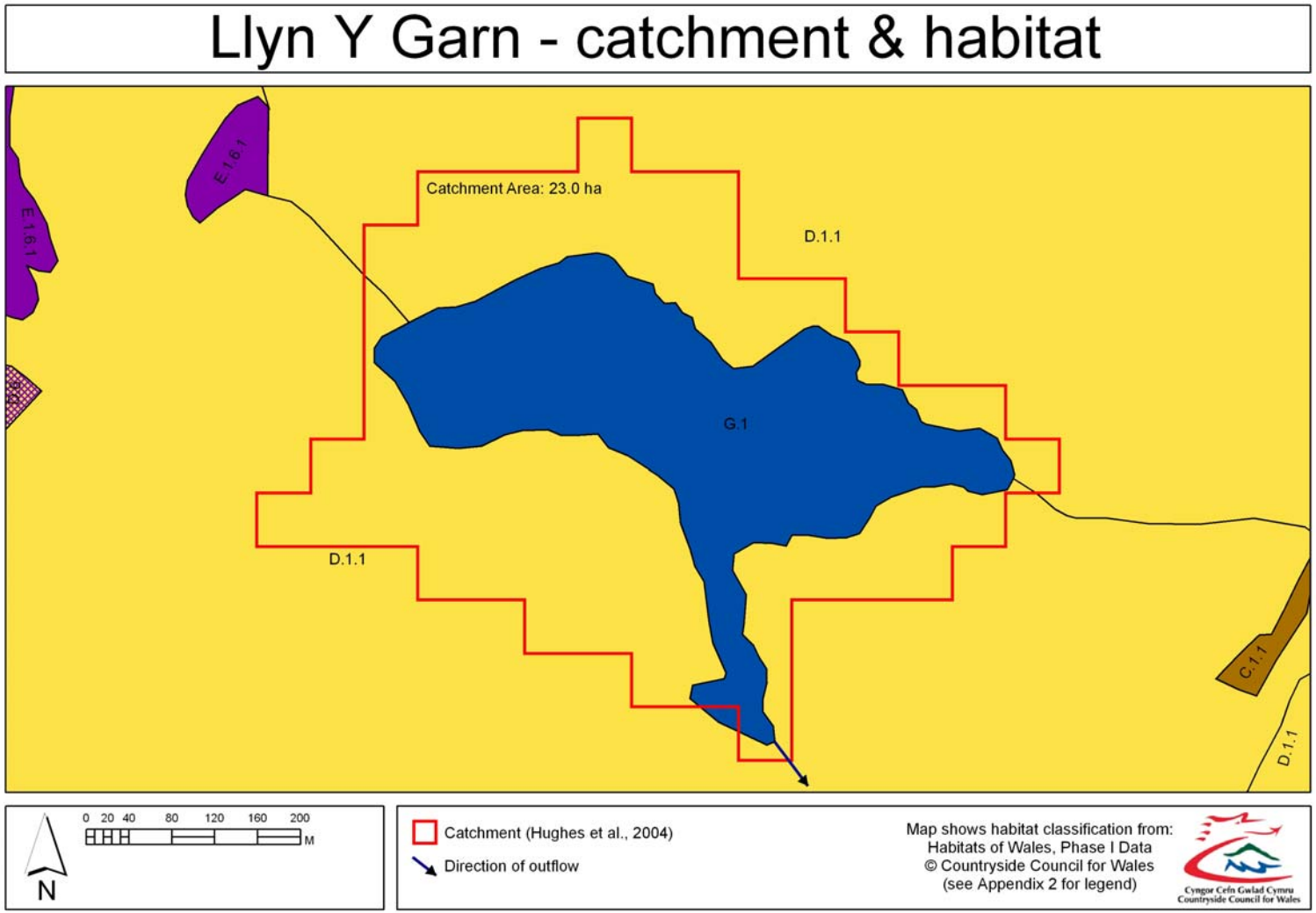
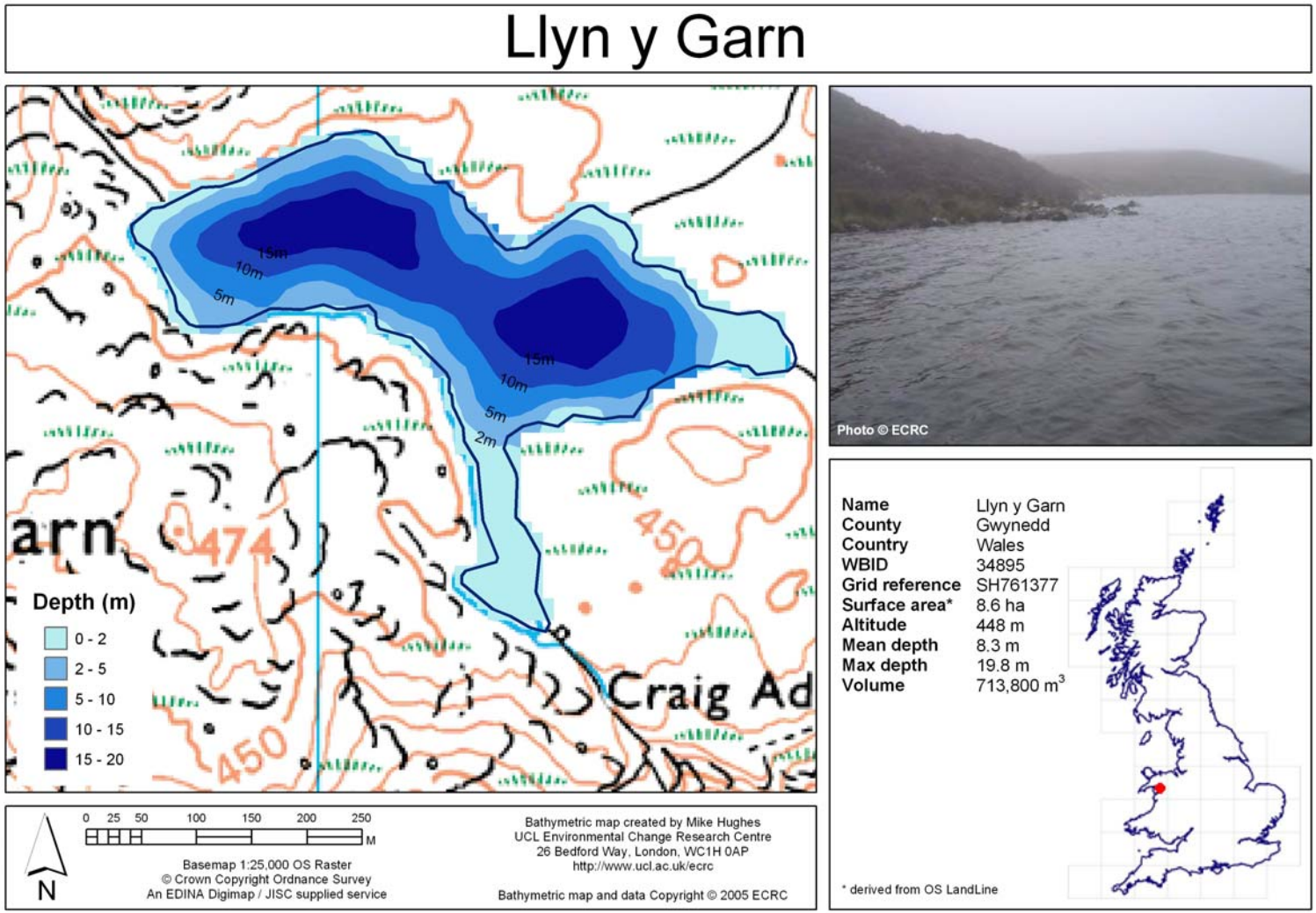


Figure 3.7.14 Llyn y Garn bathymetry map



3.7.4.3 Physico-chemical data

Temperature and oxygen profiles for Llyn y Garn are given in Figure 3.7.15 and water chemistry data shown in Table 3.7.25.

Figure 3.7.15 Temperature and oxygen profiles for Llyn y Garn

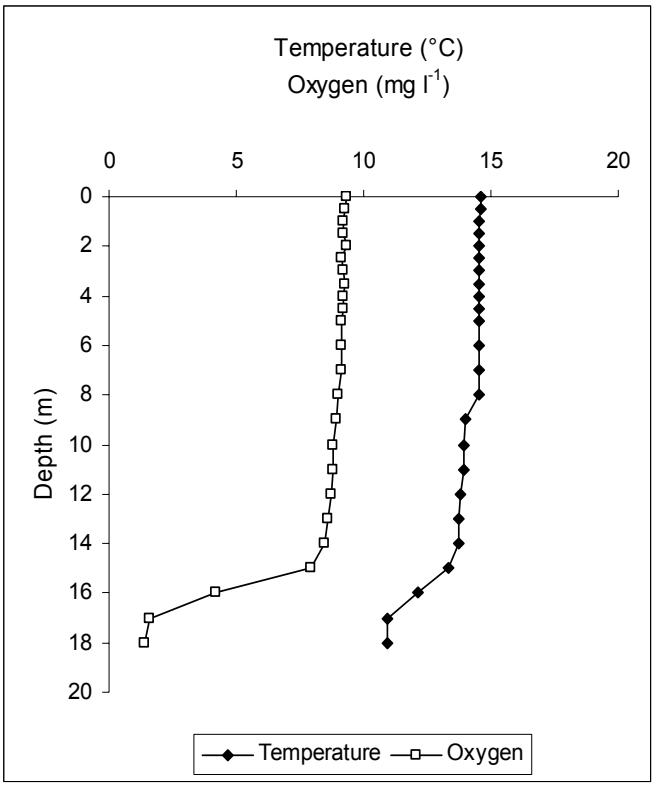


Table 3.7.25 Water chemistry data for Llyn y Garn

	Sept 04	Dec 04	Mar 05	Jun 05	Annual mean
pH	6.3	6.4	6.5	6.7	6.4
Cond	29	34	34	36	33
Alk	<114	<114	<114	64.7	n.c.
DOC	3.19	2.61	2.47	3.76	3.01
SRP	7	3	7	6	6
TP	414.4	<50	<50	6	n.c.
Chl *a*	5.2	2.2	2.4	1.4	2.8
TN	0.30	0.22	0.29	0.28	0.27
NO_3^--N	0.54	0.67	0.69	1.15	0.76
Labile Al	<23	<23	50.2	<23	n.c.
SO_4^{2-}	64	62	61	57	61
Total Fe	6	15	13	16	13
Na^+	166.3	159.9	173.4	165.8	166.3
K^+	6.3	3.6	<1.8	8.4	n.c.
Mg^{2+}	45.0	49.8	54.2	48.7	49.4
Ca^{2+}	114.1	107.6	97.4	108.5	106.9
Cl^-	185.1	178.2	190.2	194.2	186.9
Total Mn	6.3	1.6	<2.0	8.9	n.c.
ANC					26.00

(n.c. – not calculated, one or more values below analytical detection)

3.7.4.4 Macrophyte survey

Results of the macrophyte survey are given in Tables 3.7.26 and 3.7.27.

Table 3.7.26 Macrophyte abundance for Llyn y Garn – emergent and marginal survey

Taxon	DAFOR Abundance
Juncus effusus	**F**
Galium saxitile	**F**
Luzula sylvatica	**O**
Sphagnum sp.	**F**
Juncus articulatus/acutiflorus	**A**
Viola palustris	**F**
Potentilla erecta	**F**
Polygala vulgaris	**O**
Littorella uniflora	**F**
Salix sp.	**O**
Juncus squarrosus	**R**
Carex panicea	**R**
Juncus conglomeratus	**R**
Carex demissa	**O**
Juncus bulbosus	**R**
Ranunculus flammula	**O**
Fontinalis antipyretica	**R**
Anagallis tenella	**R**
Carex echinita	**R**
Narthecium ossifragum	**R**
Potamogeton polygonifolius	**R**
Succisa pratensis	**O**

Table 3.7.27 Macrophyte abundance for Llyn y Garn – wading and boat survey

Taxon	DAFOR Abundance
Isoetes lacustris	**O**
Juncus bulbosus	**O**
Littorella uniflora	**F**
Lobelia dortmanna	**F**
Luronium natans	**R**
Myriophyllum alterniflorum	**R**
Potamogeton natans	**F**
Nymphaea alba	**R**
Nitella sp	**R**

A strandline survey recorded no additional species, although *Luronium natans* was found at location SH 7617537502. Most of the lake had no plants at depths greater than 75cm.

3.7.4.5 Short core analysis

A 26 cm Glew core, GARN1, was taken in a water depth of 18 m from Llyn y Garn on 04-Sep-04. A summary diagram of the common taxa (>2%) is shown in Figure 3.7.16 and summary data are given in Table 3.7.28. The core top and bottom samples contained a total of 42 diatom taxa. The assemblages of both samples were dominated by *Cyclotella* taxa typically found in the plankton of oligotrophic, circumneutral to mildly acid waters. The only notable difference was the lower abundance of *Cyclotella* [*kuetzingiana* agg.] relative to *Cyclotella comensis* in the top sample. The squared chord distance dissimilarity score between the two samples was therefore low (0.388).

Reconstructions of diatom-inferred pH (DI-pH) were produced using the SWAP training set. A high percentage of the taxa in the fossil samples were present in the SWAP training set and there were no major analogue problems (Table 3.7.28). The DI-pH values increase slightly from 7.19 for the bottom sample to 7.25 for the top sample. However, the inferred change in pH is less than the RMSEP of the model of 0.32 pH units and cannot, therefore, be considered as significant. The annual mean current pH based on quarterly water samples collected during 2004-2005 is 6.43 and therefore the diatom model appears to over-estimate current pH by ~0.8 pH units.

In summary, there has been only a small degree of floristic change in the Llyn y Garn core with the assemblages of both the bottom and top samples being dominated by *Cyclotella* spp. associated with nutrient-poor, circumneutral to slightly acid waters. There is no evidence of acidification of the lake.

Figure 3.7.16 Summary diagram of diatom assemblages in top and bottom samples from core GARN1

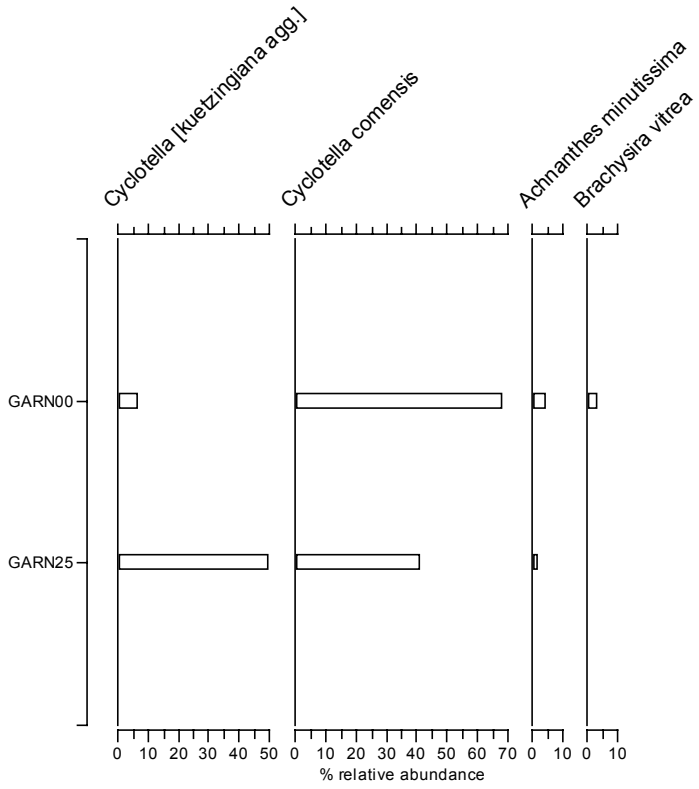


Table 3.7.28 Results of Llyn y Garn short core analysis

Sample code	Depth (cm)	Annual mean current pH	DI-pH	No. taxa in fossil sample	% of taxa in fossil sample present in SWAP training set	Squared chord distance dissimilarity score between core top and bottom
GARN00	0	6.43	7.25	36	98	0.388
GARN25	25		7.19	19	99	

3.7.5 Llyn Tryweryn

3.7.5.1 Site Description

Llyn Tryweryn is lake of 7.9 ha which lies at an altitude of 388 m. A site description is given in Carvalho *et al.* (2003). At the time of the present survey there had been a recent felling of the conifer plantation to the south east of the catchment. Much of the vegetation adjacent to the sampling sites is given to *Juncus*-dominant rough grazing. Information on the solid geology of the Llyn Tryweryn catchment and land cover data are given in Tables 3.7.29 and 3.7.30 respectively. A catchment map is given in Figure 3.7.17.

Table 3.7.29 Solid geology of the Llyn Tryweryn catchment
(Data from British Geological Survey solid geology data at 1:62,500)

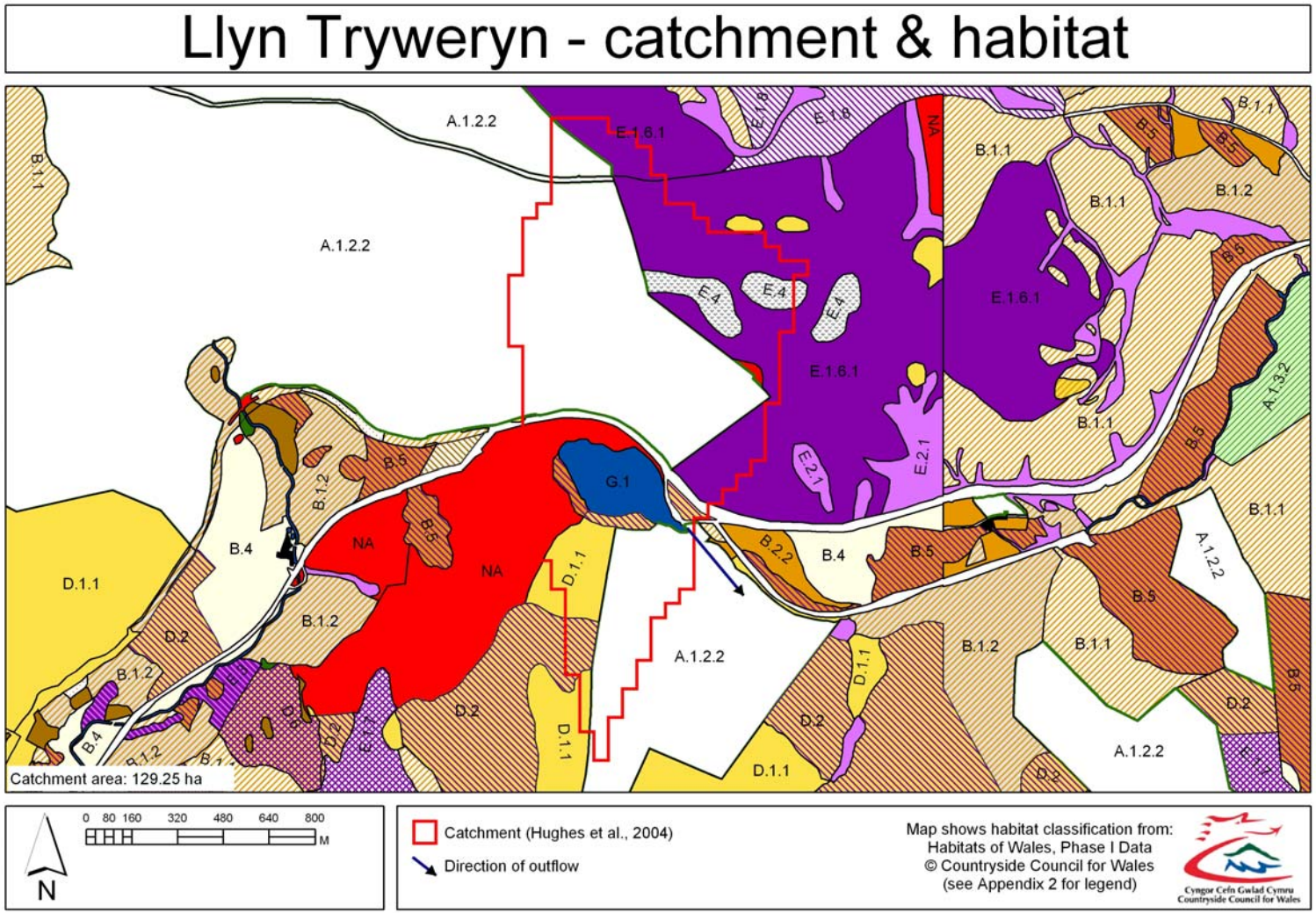
Name	Type	Percentage cover
Upper Cambrian, including Tremadoc	Sedimentary	89.1
Llanvirn and Arenig	Sedimentary	10.9

Table 3.7.30 Land cover data for the Llyn Tryweryn catchment
(Data from CCW Phase 1 Habitat Survey)

Classification	Code	Percentage cover
Woodland and scrub		
Planted coniferous woodland	A.1.2.2	51.6
Heathland		
Dry acid heath	D.1.1	5.3
Wet heath	D.2	2.9
Mire		
Blanket bog	E.1.6.1	21.5
Bare peat	E.4	4.1
Open water		
Standing water	G.1	6.0
Other*		8.6

* Percentage cover >1% and /or data not available

Figure 3.7.17 Llyn Tryweryn catchment map.



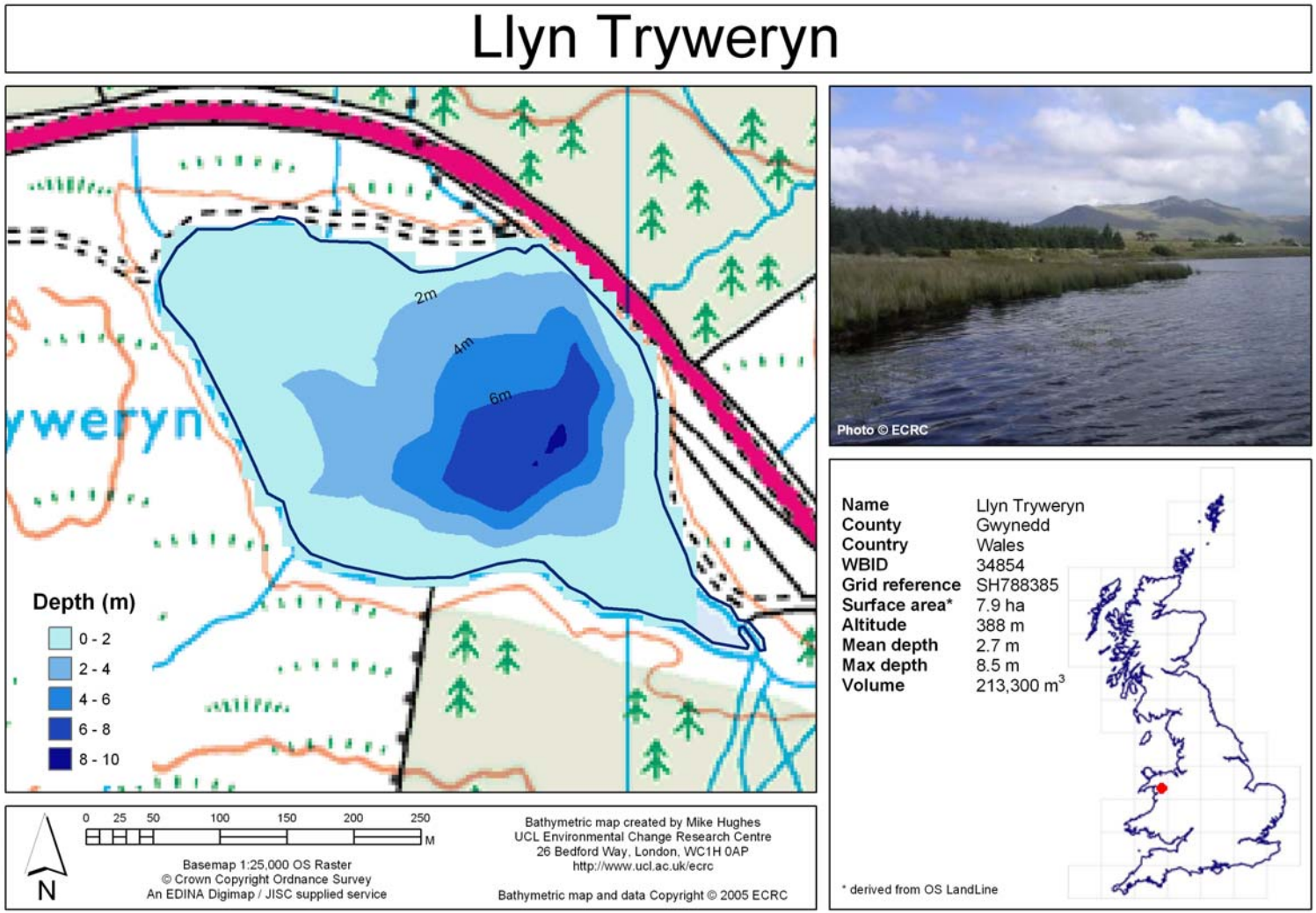
3.7.5.2 Bathymetry

The bathymetry of Llyn Tryweryn is shown in Figure 3.7.18, physical and morphometric parameters are given in Table 3.7.31.

Table 3.7.31 Llyn Tryweryn - physical and morphometric parameters

Lake altitude (m)	388
Maximum depth (m)	8.5
Mean depth (m)	2.7
Lake volume ($x10^3m^3$)	213.3
Area of lake surface (ha)	7.9
Perimeter of lake (km)	1.2
Shoreline development index	1.26
Estimated hydraulic residence time (days)	37.7
Secchi disc depth (m)	1.0
Catchment area including lake (ha)	129.3
Catchment to lake area ratio	16.4

Figure 3.7.18 Llyn Tryweryn bathymetry map



3.7.5.3 Physico-chemical data

Temperature and oxygen profiles for Llyn Tryweryn are given in Figure 3.7.19 and water chemistry data shown in Table 3.7.32.

Figure 3.7.19 Temperature and oxygen profiles for Llyn Tryweryn

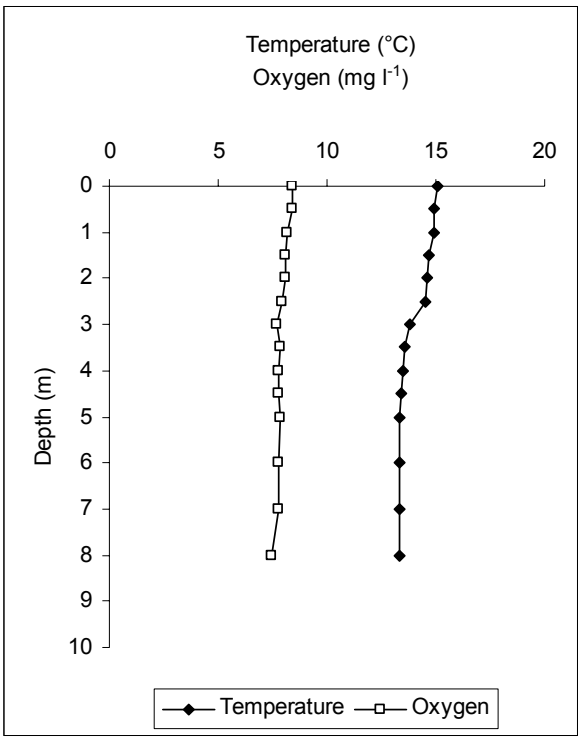


Table 3.7.32 Water chemistry data for Llyn Tryweryn

	Sept 04	Dec 04	Mar 05	Jun 05	Annual mean
pH	5.1	4.7	4.6	5.1	4.8
Cond	35	37	71	49	48
Alk	<114	<114	<114	15.6	n.c.
DOC	20.81	10.82	5.94	9.90	11.87
SRP	24	10	9	10	13
TP	774.2	<50	<50	32.8	n.c.
Chl *a*	1.6	2.0	1.3	5.2	2.5
TN	0.69	0.34	0.32	0.40	0.44
NO_3^--N	0.28	0.20	0.26	0.14	0.22
Labile Al	85.6	38.3	19.3	31.5	43.7
SO_4^{2-}	48	38	47	38	43
Total Fe	1773	855	482	1023	1033
Na^+	267.8	216.0	479.8	311.6	318.8
K^+	7.1	2.6	4.3	3.4	4.4
Mg^{2+}	44.4	39.2	51.2	40.4	43.8
Ca^{2+}	51.0	36.0	50.0	41.5	44.6
Cl^-	175.3	231.0	527.9	327.4	315.4
Total Mn	69.6	44.2	43.0	52.8	52.4
ANC					36.52

(n.c. – not calculated, one or more values below analytical detection)

3.7.5.4 Macrophyte survey

Results of the macrophyte survey are given in Tables 3.7.33 and 3.7.34.

Table 3.7.33 Macrophyte abundance for Llyn Tryweryn – emergent and marginal survey

Taxon	DAFOR Abundance
Liverwort "A"	**A**
Juncus effusus	**D**
Glyceria fluitans	**A**
Sparganium angustifolium	**O**
Juncus articulatus/acutiflorus	**F**
Juncus bulbosus	**F**
Fontinalis antipyretica	**O**
Juncus squarrosus	**O**
Galium saxatile	**F**
Potamogeton polygonifolius	**O**
Carex rostrata	**F**
Ranunculus flammula	**F**
Carex echinita	**F**
Carex nigra	**O**
Potentilla erecta	**F**
Carex ovalis	**O**
Carex demissa	**O**
Viola palustris	**O**

Table 3.7.34 Macrophyte abundance for Llyn Tryweryn – wading and boat survey

Taxon	DAFOR Abundance
Carex rostrata	**O**
Fontinalis antipyretica	**R**
Glyceria fluitans	**O**
Isoetes lacustris	**A**
Liverwort A	**A**
Liverwort B	**A**
Nuphar lutea	**F**
Nymphaea alba	**F**
Sparganium angustifolium	**F**

A strandline survey recorded no additional species.

3.7.5.5 Short core analysis

A 21 cm Glew core, TREW1, was taken in a water depth of 8 m from Llyn Tryweryn on 02-Sep-04. A summary diagram of the common taxa (>2%) is shown in Figure 3.7.20 and summary data are given in Table 3.7.35. The core top and bottom samples contained a total of 36 diatom taxa. The assemblage of the bottom sample was comprised of non-planktonic species typical of moderate to strongly acid waters, the most abundant being *Eunotia incisa*, *Cymbella perpusilla* and *Navicula soehrensis*. The top sample was similar to the bottom sample in that the same three taxa were present in the highest relative abundances. The only notable differences between the two samples were the absence of *Frustulia rhomboides* and its variety *saxonica* from the top sample and instead the presence of the variety *viridula,* and slightly higher amounts of *Eunotia* taxa and *Fragilaria construens* in the top sample. The squared chord distance dissimilarity score between the two samples was relatively low (0.432).

Reconstructions of diatom-inferred pH (DI-pH) were produced using the SWAP training set. A high percentage of the taxa in the bottom sample were present in the SWAP training set but there were relatively poor analogues for the top sample, largely owing to the absence of *Eunotia* sp. and *Fragilaria construens var. binodis* from the SWAP dataset (Table 3.7.35). The DI-pH values were the same for the bottom and the top samples at ~4.7 pH units. The annual mean current pH based on quarterly water samples collected during 2004-2005 is 4.87 and therefore the diatom model is in good agreement with the current measured value.

In summary, there has been a relatively small degree of floristic change in the Llyn Tryweryn core. The assemblages of both the bottom and top samples are associated with moderate to strongly acid waters and the data indicate that the lake has been acid for the whole of the period represented by the sediment core.

Figure 3.7.20 Summary diagram of diatom assemblages in top and bottom samples from core TREW1

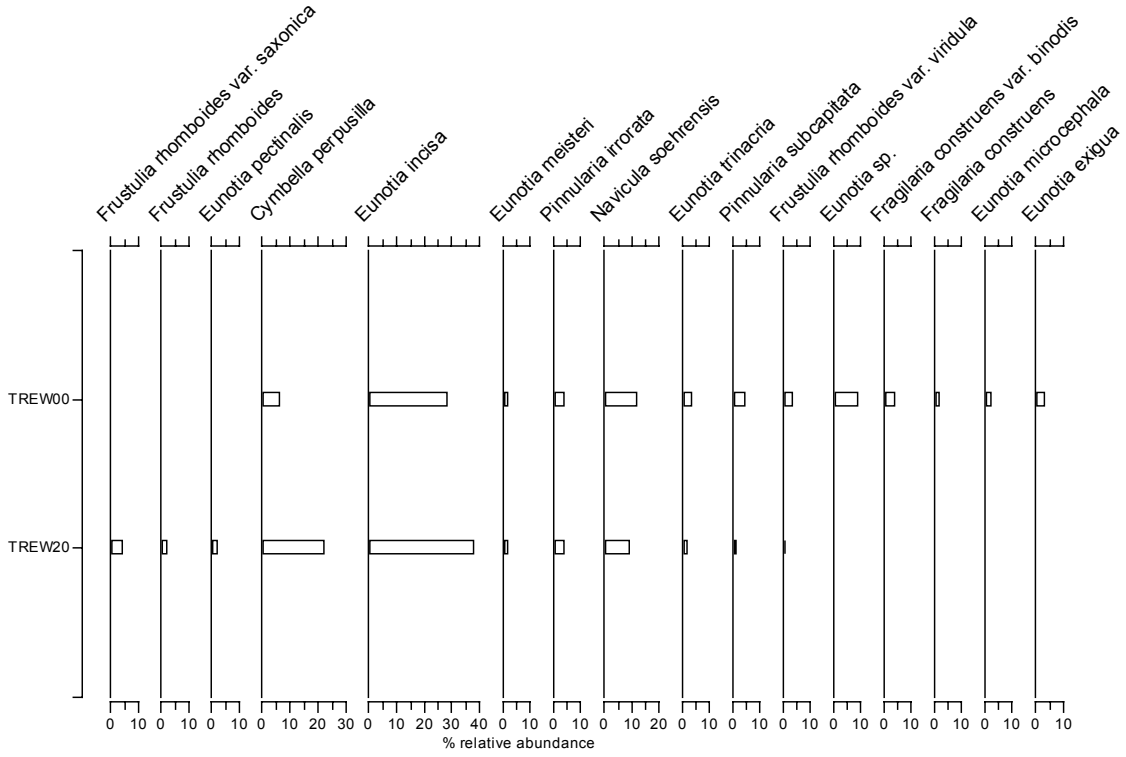


Table 3.7.35 Results of Llyn Tryweryn short core analysis

Sample code	Depth (cm)	Annual mean current pH	DI-pH	No. taxa in fossil sample	% of taxa in fossil sample present in SWAP training set	Squared chord distance dissimilarity score between core top and bottom
TREW00	0	4.87	4.78	31	78	0.432
TREW20	20		4.73	22	95	

3.7.6 Llyn y Dywarchen

3.7.6.1 Site Description

Llyn y Dywarchen is a high altitude lake (503 m) with a small catchment (7.25 ha including the lake). The catchment is dominated by blanket bog. This is a brown water site with no submerged higher plants. Information on the solid geology of the Llyn y Dywarchen catchment and land cover data are given in Tables 3.7.36 and 3.7.37 respectively. A catchment map is given in Figure 3.7.21.

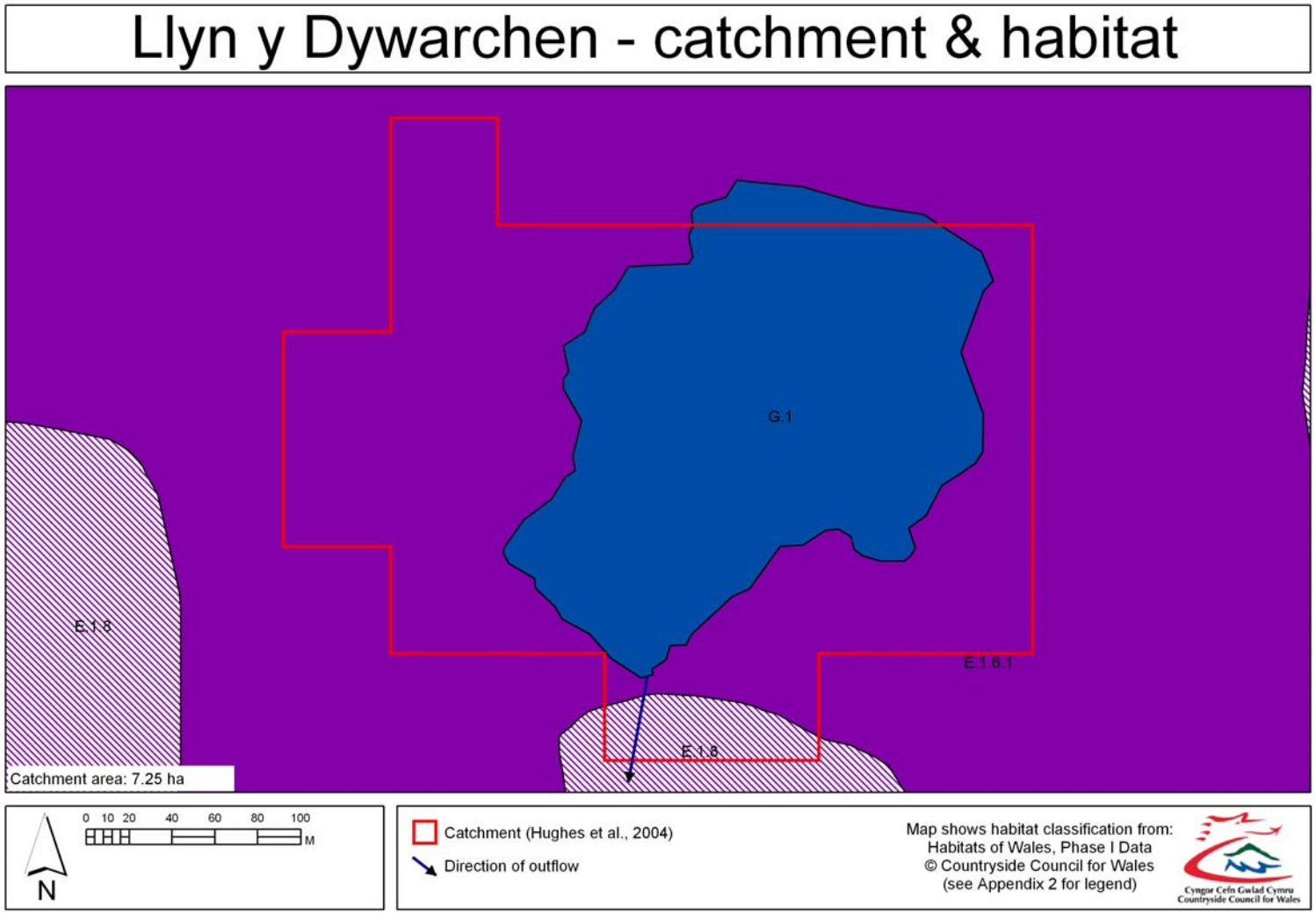
Table 3.7.36 Solid geology of the Llyn y Dywarchen catchment
(Data from British Geological Survey solid geology data at 1:62,500)

Name	Type	Percentage cover
Upper Cambrian, including Tremadoc	Sedimentary	100

Table 3.7.37 Land cover data for the Llyn y Dywarchen catchment
(Data from CCW Phase 1 Habitat Survey)

Classification	Code	Percentage cover
Mire		
Blanket bog	E.1.6.1	53.7
Dry modified bog	E.1.8	3.6
Open water		
Standing water	G.1	42.7

Figure 3.7.21 Llyn y Dywarchen catchment map



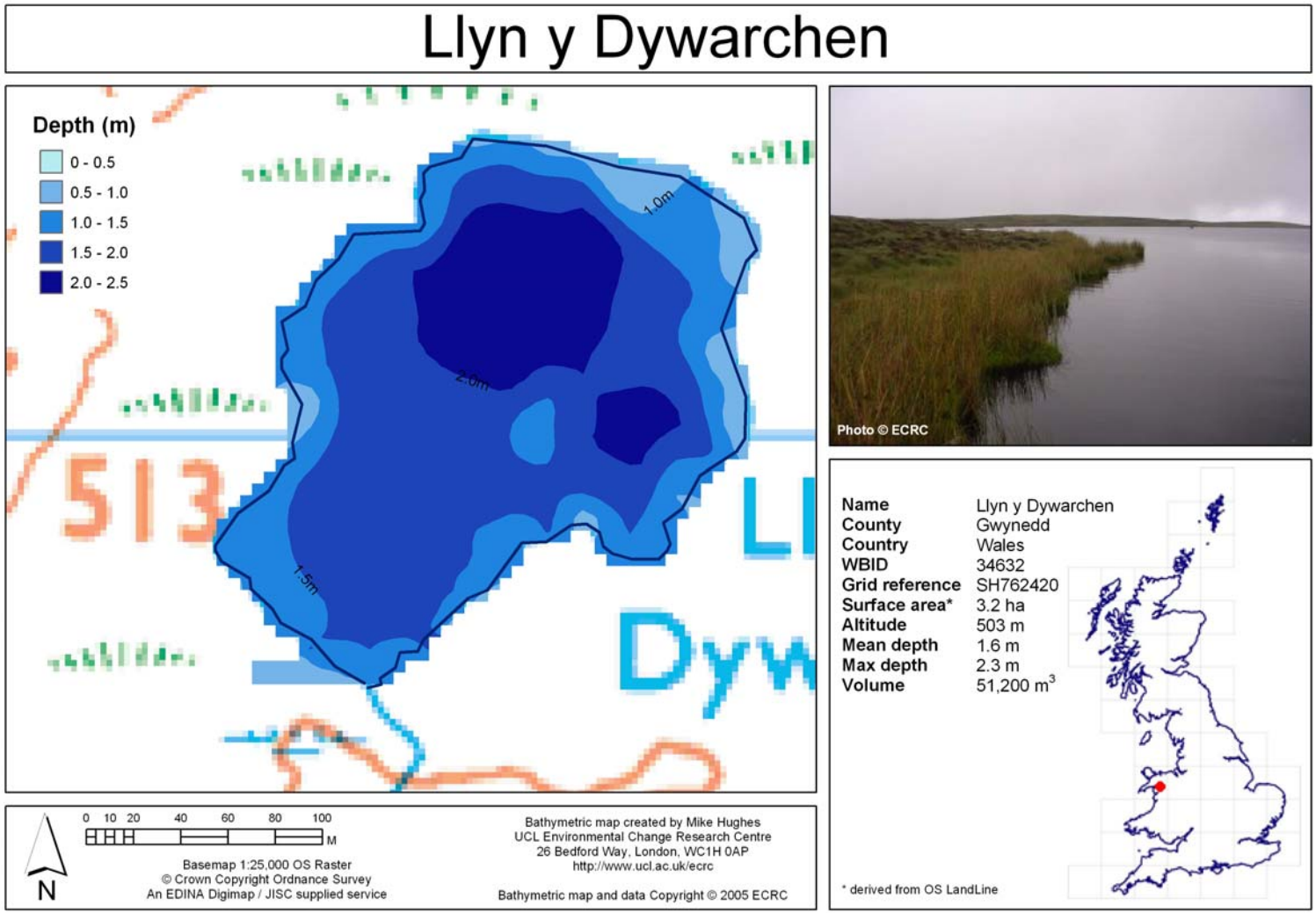
3.7.6.2 Bathymetry

The bathymetry of Llyn y Dywarchen is shown in Figure 3.7.22, physical and morphometric parameters are given in Table 3.7.38.

Table 3.7.38 Llyn y Dywarchen - physical and morphometric parameters

Lake altitude (m)	503
Maximum depth (m)	2.3
Mean depth (m)	1.6
Lake volume ($x10^3m^3$)	51.2
Area of lake surface (ha)	3.2
Perimeter of lake (km)	0.7
Shoreline development index	1.17
Estimated hydraulic residence time (days)	130.0
Secchi disc depth (m)	0.8
Catchment area including lake (ha)	7.25
Catchment to lake area ratio	2.3

Figure 3.7.22 Llyn y Dywarchen bathymetry map



3.7.6.3 Physico-chemical data

Temperature and oxygen profiles for Llyn y Dywarchen are given in Figure 3.7.23 and water chemistry data shown in Table 3.7.39.

Figure 3.7.23 Temperature and oxygen profiles for Llyn y Dywarchen

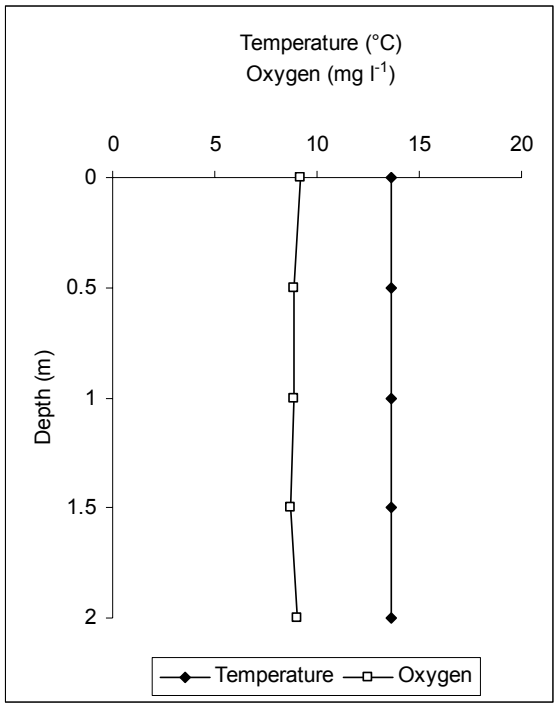


Table 3.7.39 Water chemistry data for Llyn y Dywarchen

	Sept 04	Dec 04	Mar 05	Jun 05	Annual mean
pH	5.9	5.5	5.6	5.2	5.5
Cond	11	24	28	25	22
Alk	<114	<114	<114	19.0	n.c.
DOC	3.80	5.03	3.86	4.65	4.33
SRP	7	5	8	7	7
TP	60.8	45.7	<50	22.3	n.c.
Chl *a*	26.0	8.5	22.1	12.9	17.4
TN	0.22	0.29	0.34	0.23	0.27
NO_3^--N	0.07	0.27	0.24	0.17	0.19
Labile Al	<23	<23	<23	29.6	n.c.
SO_4^{2-}	51	31	32	32	37
Total Fe	171	340	220	226	239
Na^+	68.6	120.8	168.0	126.4	121.0
K^+	1.9	2.4	8.0	4.4	4.2
Mg^{2+}	17.1	39.2	39.7	33.0	32.3
Ca^{2+}	18.5	25.4	25.5	25.3	23.7
Cl^-	171.1	139.6	191.7	161.0	165.9
Total Mn	22.7	35.6	31.6	38.5	32.1
ANC					-35.35

(n.c. – not calculated, one or more values below analytical detection)

3.7.6.4 Macrophyte survey

Results of the macrophyte survey are given in Tables 3.7.40 and 3.7.41.

Table 3.7.40 Macrophyte abundance for Llyn y Dywarchen – emergent and marginal survey

Taxon	DAFOR Abundance
Carex echinita	**A**
Carex rostrata	**A**
Juncus effusus	**D**
Juncus squarrosus	**A**
Sphagnum sp.	**D**
Polytrichum commune	**A**
Viola palustris	**O**
Narthecium ossifragum	**O**
Galium saxitile	**F**
Agrostis stolonifera	**O**
Carex nigra	**O**

Table 3.7.41 Macrophyte abundance for Llyn y Dywarchen – wading and boat survey

Taxon	DAFOR Abundance
Carex rostrata	**O**
Juncus effusus	**O**
Liverwort A	**O**
Sphagnum sp	**R**

No species were recorded during a strandline survey.

3.7.6.5 Short core analysis

A 20 cm Glew core, DWYA1, was taken in a water depth of 2.3 m from Llyn y Dywarchen on 25-Aug-04. A summary diagram of the common taxa (>2%) is shown in Figure 3.7.24 and summary data are given in Table 3.7.42. The core top and bottom samples contained a total of 48 diatom taxa although preservation was poor, particularly in the bottom sample. The assemblage of the bottom sample was comprised of taxa typical of acid waters, the most abundant being *Eunotia incisa*, with relatively high amounts of *Aulacoseira perglabra* and *Pinnularia* spp. The top sample was markedly different being dominated by *Asterionella ralfsii*, a diatom commonly associated with strongly acid conditions. Hence, the squared chord distance dissimilarity score between the two samples was very high (1.373).

Reconstructions of diatom-inferred pH (DI-pH) were produced using the SWAP training set. A high percentage of the taxa in the fossil samples were present in the SWAP training set and there were no major analogue problems (Table 3.7.42). The DI-pH values decline slightly from 5.01 for the bottom sample to 4.68 for the top sample, indicating mild acidification. The annual mean current pH based on quarterly water samples collected during 2004-2005 is 5.53 and therefore the diatom model appears to under-estimate current pH by ~0.8 pH units.

In summary, there has been a significant degree of floristic change in the Llyn y Dywarchen core which indicates acidification of the lake. Nevertheless the data suggest that the lake has been acid for the whole of the period represented by the core.

Figure 7.24 Summary diagram of diatom assemblages in top and bottom samples from core DWYA1

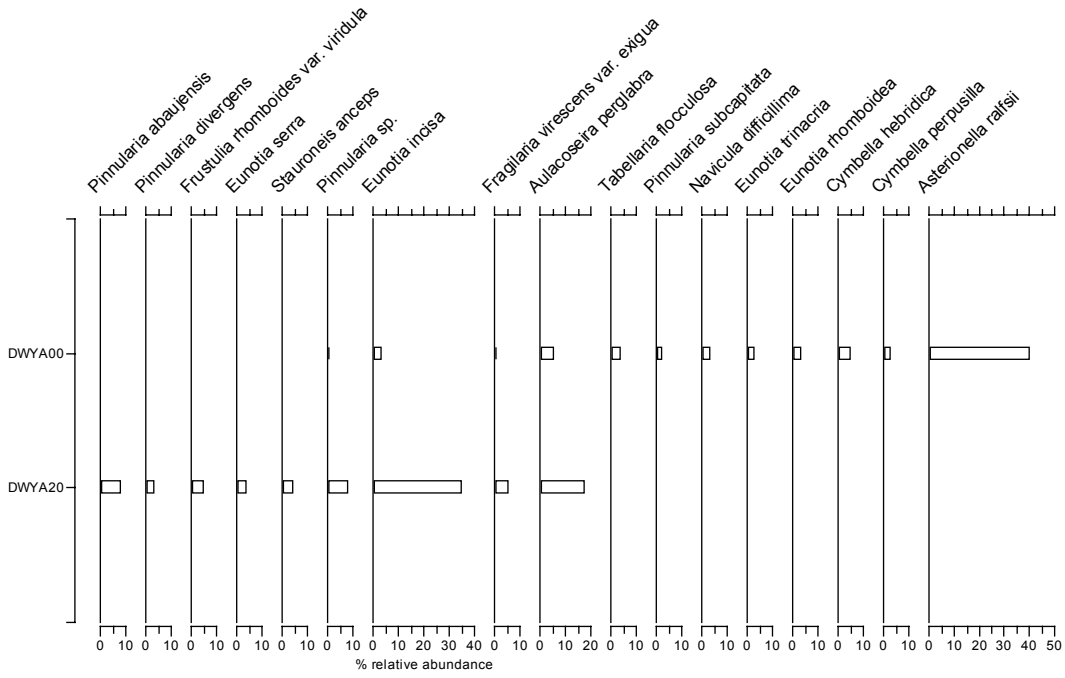


Table 3.7.42 Results of Llyn y Dywarchen short core analysis

Sample code	Depth (cm)	Annual mean current pH	DI-pH	No. taxa in fossil sample	% of taxa in fossil sample present in SWAP training set	Squared chord distance dissimilarity score between core top and bottom
DWYA00	0	5.53	4.68	36	90	1.373
DWYA20	20		5.01	20	80	

3.8 Cadair Idris SAC
Llyn Cau, Llyn Gafr & Llyn Arran

Location of SAC

SAC Details	
Grid Ref. (approx. centre)	SH704132
SAC EU Code	UK0030104
Total Area	3785 ha
Total area of Freshwater	32 ha

General site character:
Inland water bodies (standing water, running water) (0.8%)
Bogs. Marshes. Water fringed vegetation. Fens (11%)
Heath. Scrub. Maquis and garrigue. Phygrana (23%)
Dry grassland. Steppes (46%)
Humid grassland. Mesophile grassland (0.1%)
Improved grassland (1.3%)
Broad-leaved deciduous woodland (3%)
Coniferous woodland (0.3%)
Mixed woodland (1.4%)
Inland rocks. Screes. Sands. Permanent snow and ice (13%)
Other land (including towns, villages, roads, waste places, mines, industrial sites) (0.6%)

Annex I habitats that are a primary reason for selection of this site
3130 Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*
Within the Cadair Idris range, Llyn Cau is a mountain lake representative of this type, located in an upland cirque. The lake's conical basin, which reaches a water depth of almost 50 m, results from glacial scour of Ordovician volcanic and sedimentary rocks. Quillwort *Isoetes lacustris* is abundant and shoreweed *Littorella uniflora* occurs frequently. The boulder-dominated shore has abundant growths of liverworts and mosses, including *Sphagnum denticulatum* and *Rhytidiadelphus squarrosus*. There are distinct associations of I. *lacustris*, starwort *Callitriche hamulata* and bulbous rush *Juncus bulbosus* var. *fluitans*, the latter being most abundant adjacent to inflow streams. The water is moderately acid with low conductivity but relatively high nitrate concentrations for an upland lake. A lake sediment study did not reveal any evidence of acidification. It has been classified as a type 1 (dystrophic lake) on the basis of its vegetation but its water transparency is very high with a distinctive blue colour. It stratifies with a thermocline at 10-15 m depth. Brown trout *Salmo trutta fario* are present.
8110 Siliceous scree of the montane to snow levels (*Androsacetalia alpinae* and

***Galeopsietalia ladani*)**
Cadair Idris is the most southerly site in the UK selected for high-altitude siliceous scree and as such is not as species-rich as more northerly examples. Much of the rock is dry and unstable, but on the extensive screes on steep slopes U21 *Cryptogramma crispa – Deschampsia flexuosa* vegetation is well-distributed, and on the boulder screes, lemon-scented fern *Oreopteris limbosperma* can be found together with a range of characteristic bryophytes and lichens.

8210 Calcareous rocky slopes with chasmophytic vegetation
Cadair Idris is one of three Welsh sites representing Calcareous rocky slopes with chasmophytic vegetation. It is the highest mountain in the south of the Snowdonia National Park and has a number of cliffs and rock outcrops with base-rich exposures, with the moist, north-facing cliffs supporting a number of notable bryophytes. Many of the higher plants are clustered below the tall-herb ledge vegetation where water streams down from above and include species such as green spleenwort *Asplenium viride* and purple saxifrage *Saxifraga oppositifolia*.

8220 Siliceous rocky slopes with chasmophytic vegetation
Cadair Idris is one of three Welsh sites representing Siliceous rocky slopes with chasmophytic vegetation. Cliffs and rock outcrops are abundant on the site, with many supporting characteristic assemblages of lichen and bryophyte communities, particularly on the steep, moist, north-facing cliffs. Vascular plants include Wilson's filmy-fern *Hymenophyllum wilsonii*, starry saxifrage *Saxifraga stellaris* and fir clubmoss *Huperzia selago*.

Other Annex I habitats include in the SAC, but not primary reasons for designation are: 4010 Northern Atlantic wet heaths with *Erica tetralix*, 4030 European dry heaths, 6410 *Molinia* meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*), 6430 Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels, 7130 Blanket bogs, 7230 Alkaline fens, 91A0 Old sessile oak woods with Ilex and Blechnum in the British Isles

(JNCC, 2005b)

3.8.1 Llyn Cau

3.8.1.1 Site Description

Llyn Cau, one of the deepest natural lakes in Wales (maximum depth 49 m), is situated in an upland cirque in the Cadir Idris National Nature Reserve and SSSI within the Snowdonia National Park in North Wales. A site description is given in Monteith (1997).

Information on the solid geology of the Llyn Cau catchment and land cover data are given in Tables 3.8.1 and 3.8.2 respectively. A catchment map is given in Figure 3.8.1.

Table 3.8.1 Solid geology of the Llyn Cau catchment
(Data from British Geological Survey solid geology data at 1:62,500)

Name	Type	Percentage cover
Granite, syenite, granophyre and allied types	Igneous	5.7
Basalt, spilite, hyaloclastic and related tuffs	Igneous	30.6
Rhyolitic lava	Igneous	22.4
Llanvern and Arenig	Sedimentary	41.3

Table 3.8.2 Land cover data for the Llyn Cau catchment
(Data from CCW Phase 1 Habitat Survey)

Classification	Code	Percentage cover
Grassland and marsh		
Unimproved acid grassland	B.1.1	32.0
Heathland		
Dry acid heath	D.1.1	27.1
Dry heath/acid grassland mosaic	D.5	27.0
Open water		
Standing water	G.1	13.6
Other*		0.3

* Percentage cover >1% and /or data not available

3.8.1.2 Bathymetry
The bathymetry of Llyn Cau is shown in Figure 3.8.2, physical and morphometric parameters are given in Table 3.8.3.

Table 3.8.3 Llyn Cau - physical and morphometric parameters

Lake altitude (m)	478
Maximum depth (m)	49
Mean depth (m)	20.1
Lake volume ($x10^3m^3$)	2693.4
Area of lake surface (ha)	13.5
Perimeter of lake (km)	1.6
Shoreline development index	1.20
Estimated hydraulic residence time (days)	503.3
Secchi disc depth (m)	12.5
Catchment area including lake (ha)	98
Catchment to lake area ratio	7.3

Figure 3.8.1 Llyn Cau catchment map

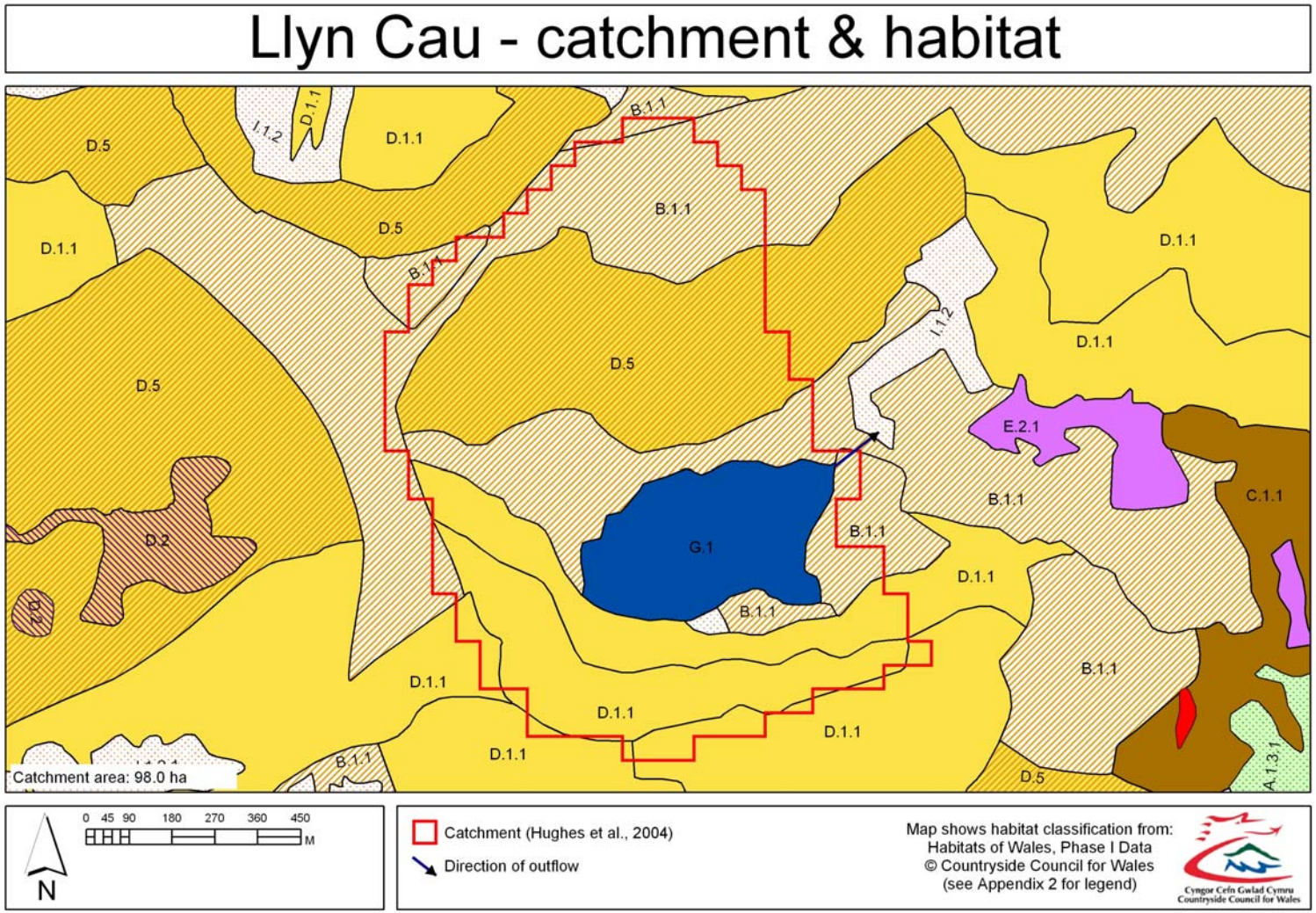
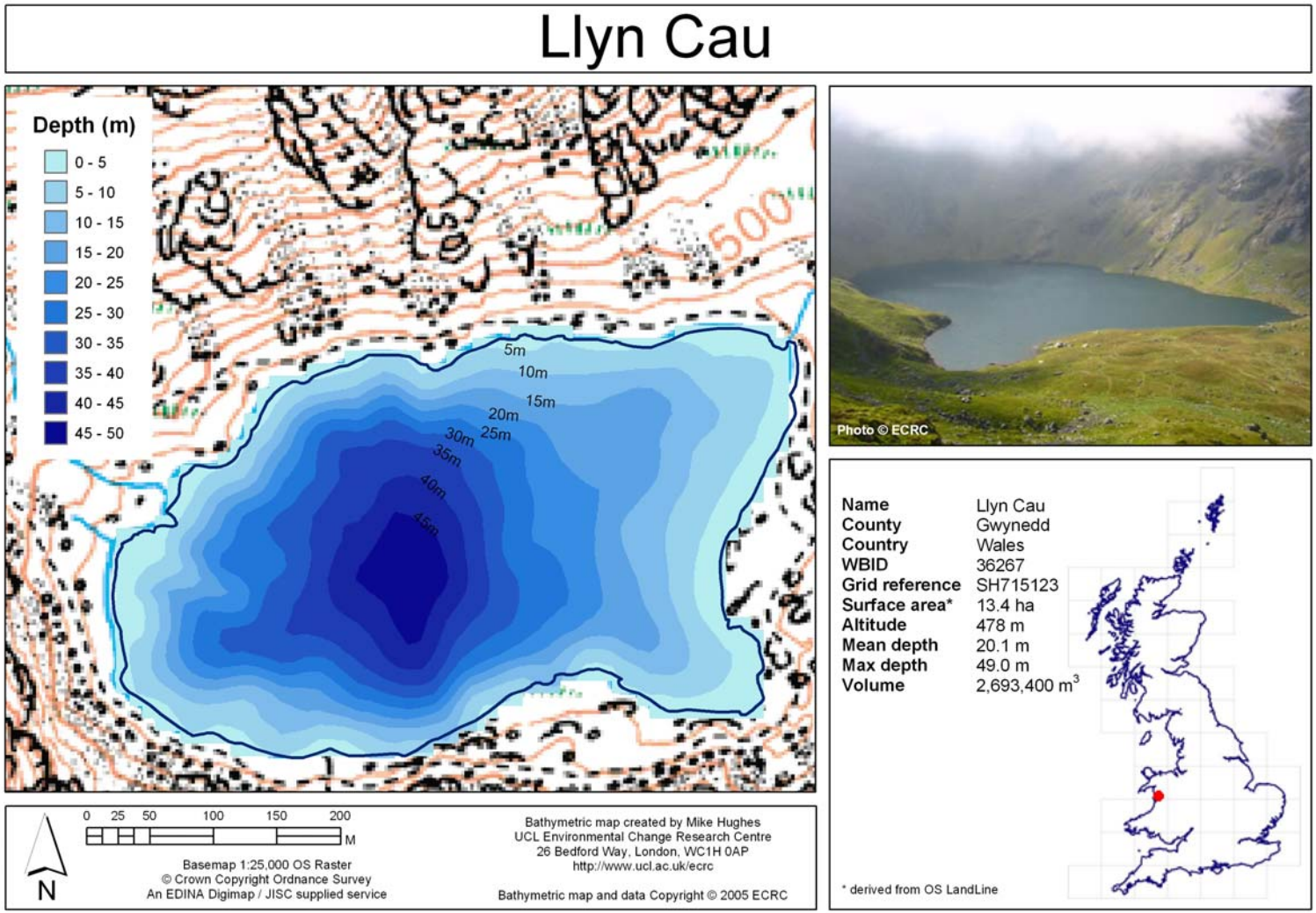


Figure 3.8.2 Llyn Cau bathymetry map



3.8.1.3 Physico-chemical data

Temperature and oxygen profiles for Llyn Cau are given in Figure 3.8.3 and water chemistry data shown in Table 3.8.4.

Figure 3.8.3 Temperature and oxygen profiles for Llyn Cau

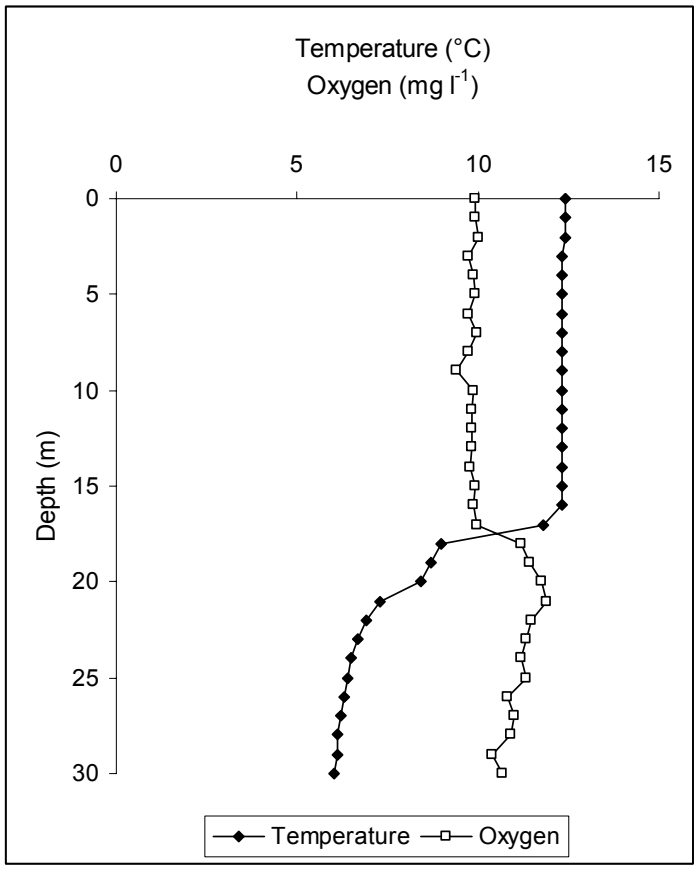


Table 3.8.4 Water chemistry data for Llyn Cau

	Sept 04	Dec 04	Mar 05	Jun 05	Annual mean
pH	5.8	6.1	6.2	6.4	6.1
Cond	22	27	30	30	27
Alk	<114	<114	<114	32.37	n.c.
DOC	1.05	0.36	1.00	0.99	0.85
SRP	2	5	3	6	4
TP	<50	<50	<50	2.8	n.c.
Chl *a*	2.0	2.1	2.6	1.4	2.0
TN	0.24	0.24	0.27	0.25	0.25
NO_3^--N	0.78	0.83	0.86	0.84	0.83
Labile Al	<23	<23	<23	<23	n.c.
SO_4^{2-}	52	54	47	50	51
Total Fe	<6	<6	<6	<6	n.c.
Na^+	141.8	140.7	168.4	143.4	148.6
K^+	3.9	6.4	4.9	7.5	5.7
Mg^{2+}	46.2	44.9	45.8	46.1	45.8
Ca^{2+}	44.9	46.4	Error	48.2	46.5
Cl^-	154.4	160.8	165.0	169.4	162.4
Total Mn	7.3	2.4	<2.0	<2.0	n.c.
ANC					-25.99

(n.c. – not calculated, one or more values below analytical detection)

3.8.1.4 Macrophyte survey

Results of the macrophyte survey are given in Tables 3.8.5 and 3.8.6.

Table 3.8.5 Macrophyte abundance for Llyn Cau – emergent and marginal survey

Taxon	DAFOR Abundance
Juncus effusus	**F**
Viola palustris	**R**
Juncus squarrosus	**F**
Carex echinita	**R**
Carex demissa	**F**
Sphagnum sp.	**F**
Potentilla erecta	**R**
Galium saxatile	**R**
Carex flacca	**R**

Table 3.8.6 Macrophyte abundance for Llyn Cau – wading and boat survey

Taxon	DAFOR Abundance
Callitriche hamulata	**A**
Isoetes lacustris	**A**
Juncus bulbosus	**F**
Littorella uniflora	**A**
Sphagnum sp	**R**

Only one boat-base survey was possible as the lake shelved steeply. No plants were present at depths greater than 100 cm. No additional species were noted during a strandline survey.

3.8.1.5 Short core analysis

A 33 cm Glew core, CAU4, was taken in a water depth of 47 m from Llyn Cau on 27-Jul-02. A summary diagram of the common taxa (>2%) is shown in Figure 3.8.4 and summary data are given in Table 3.8.7. The core top and bottom samples contained a total of 43 diatom taxa. Both the top and bottom samples were dominated by *Cyclotella comensis*, a planktonic diatom typical of circumneutral, nutrient-poor lakes. The only notable difference between the two samples was the slightly higher relative abundances of *Cyclotella* [*kuetzingiana* agg.], *Achnanthes marginulata, Frustulia rhomboides* var. *viridula* and *Surirella linearis*, albeit in low amounts, in the top sample. Hence, the squared chord distance dissimilarity score between the two samples was low (0.247).

Reconstructions of diatom-inferred pH (DI-pH) were produced using the SWAP training set. A high percentage of the taxa in the fossil samples were present in the SWAP training

set and there were no major analogue problems (Table 3.8.7). The DI-pH values decline slightly from 7.55 at the bottom sample to 7.02 at the top sample, indicating mild acidification although pH values remain circumneutral. The annual mean current pH based on quarterly water samples collected during 2004-2005 is 6.1 and therefore the diatom model appears to over-estimate current pH by ~1 pH unit.

In summary, there has been only a minor degree of floristic change in the Llyn Cau core, with the assemblages of both the bottom and top samples being dominated by *Cyclotella comensis*. Whilst the DI-pH values suggest a slight decline in pH, the lake still supports a planktonic diatom flora associated with circumneutral conditions. In light of the results, monitoring is recommended to ensure early detection of any acidification of the lake.

Figure 3.8.4 Summary diagram of diatom assemblages in top and bottom samples from core CAU4

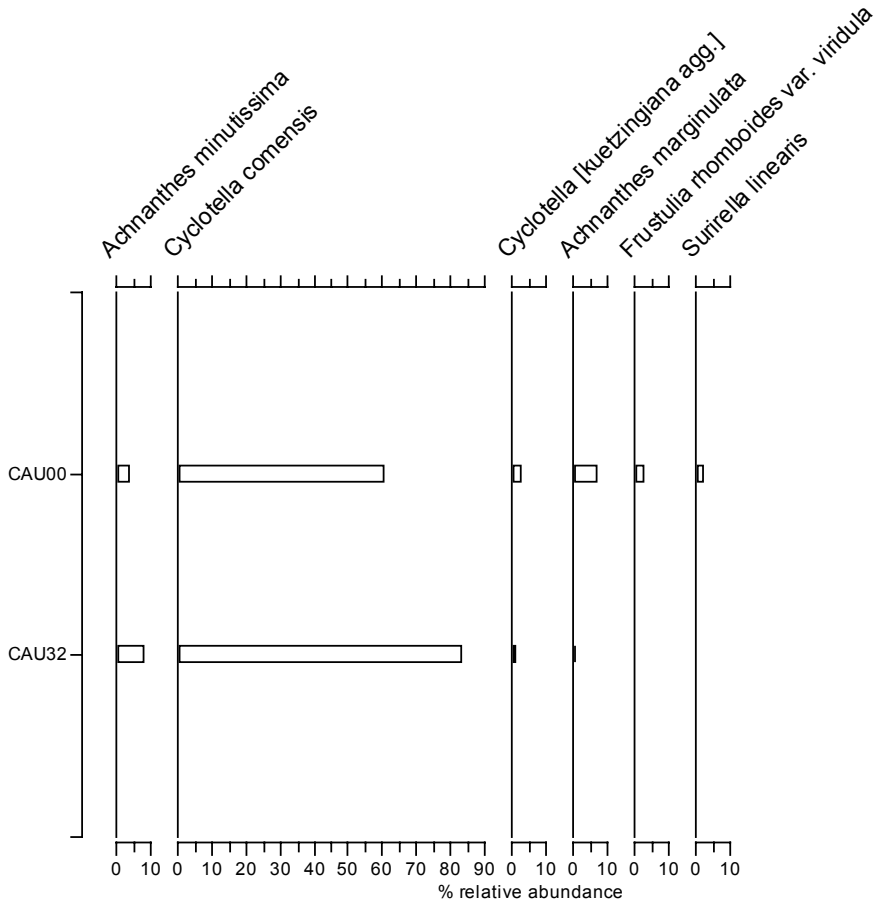


Table 3.8.7 Results of Llyn Cau short core analysis

Sample code	Depth (cm)	Annual mean current pH	DI-pH	No. taxa in fossil sample	% of taxa in fossil sample present in SWAP training set	Squared chord distance dissimilarity score between core top and bottom
CAU00	0	6.1	7.02	37	93	0.247
CAU32	32		7.55	19	87	

3.8.2 Llyn Gafr

3.8.2.1 Site Description

Llyn Gafr lies at an altitude of 416 m. The catchment is dominated by upland *Calluna* heath and bare rock. Areas of heath are grazed. Information on the solid geology of the Llyn Gafr catchment and land cover data are given in Tables 3.8.8 and 3.8.9 respectively. A catchment map is given in Figure 3.8.5.

Table 3.8.8 Solid geology of the Llyn Gafr catchment
(Data from British Geological Survey solid geology data at 1:62,500)

Name	Type	Percentage cover
Granite, syenite, granophyre and allied types	Igneous	34.6
Basalt, spilite, hyaloclastic and related tuffs	Igneous	23.4
Llanvern and Arenig	Sedimentary	42.0

Table 3.8.9 Land cover data for the Llyn Gafr catchment
(Data from CCW Phase 1 Habitat Survey)

Classification	Code	Percentage cover
Heathland		
Dry acid heath	D.1.1	88.6
Dry heath/acid grassland mosaic	D.5	4.1
Mire		
Blanket bog	E.1.6.1	1.2
Open water		
Standing water	G.1	2.6
Rock exposure and waste		
Other rock exposure	I.1.4	2.3
Other*		1.2

* Percentage cover >1% and /or data not available

3.8.2.2 Bathymetry

The bathymetry of Llyn Gafr is shown in Figure 3.8.6, physical and morphometric parameters are given in Table 3.8.10.

Table 3.8.10 Llyn Gafr - physical and morphometric parameters

Lake altitude (m)	416
Maximum depth (m)	1.5
Mean depth (m)	0.8
Lake volume ($x10^3m^3$)	21.6
Area of lake surface (ha)	2.7
Perimeter of lake (km)	0.7
Shoreline development index	1.18
Estimated hydraulic residence time (days)	3.8
Secchi disc depth (m)	>1.4
Catchment area (ha)	102.5
Catchment to lake area ratio	38

Figure 3.8.5 Llyn Gafr catchment map

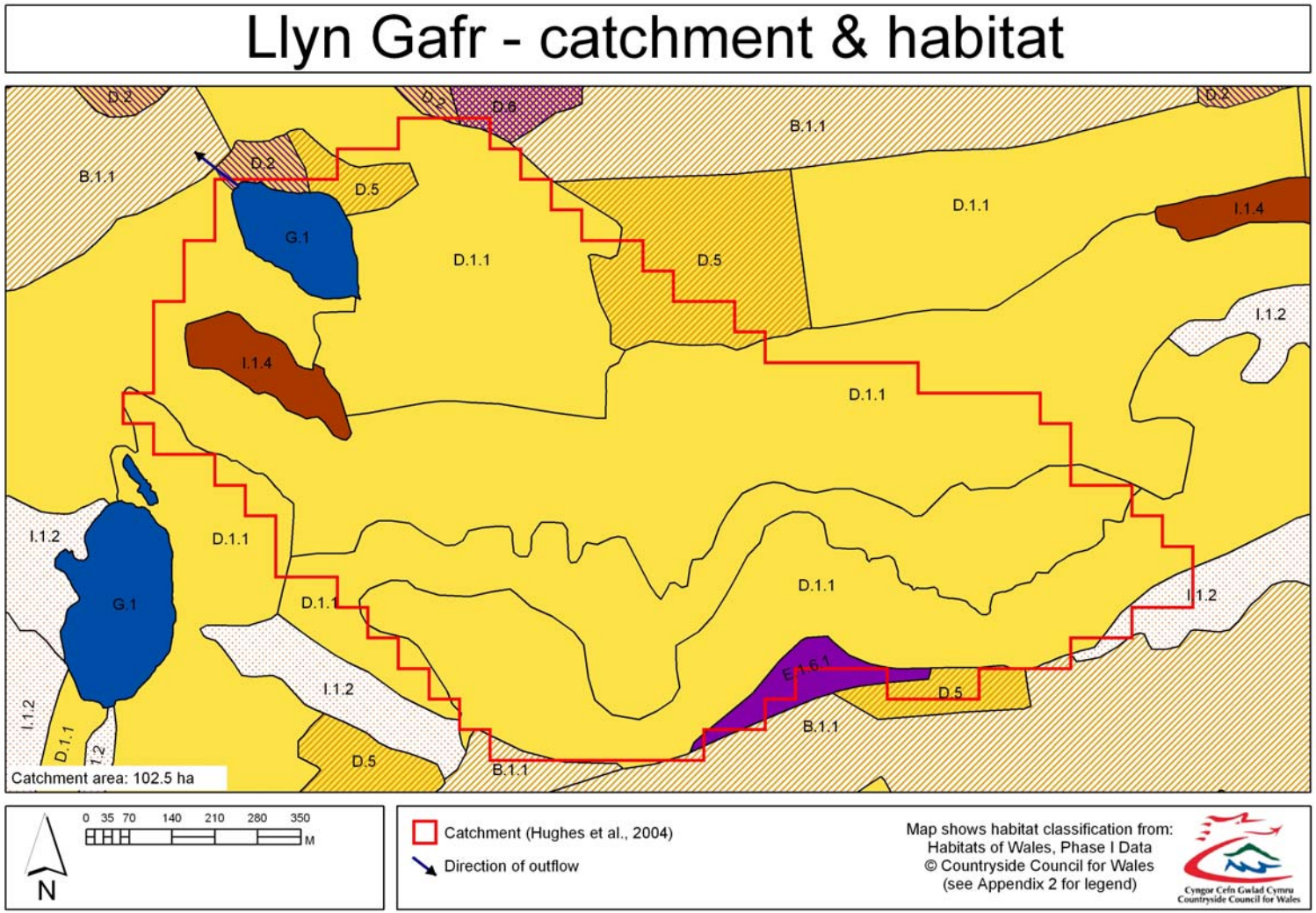
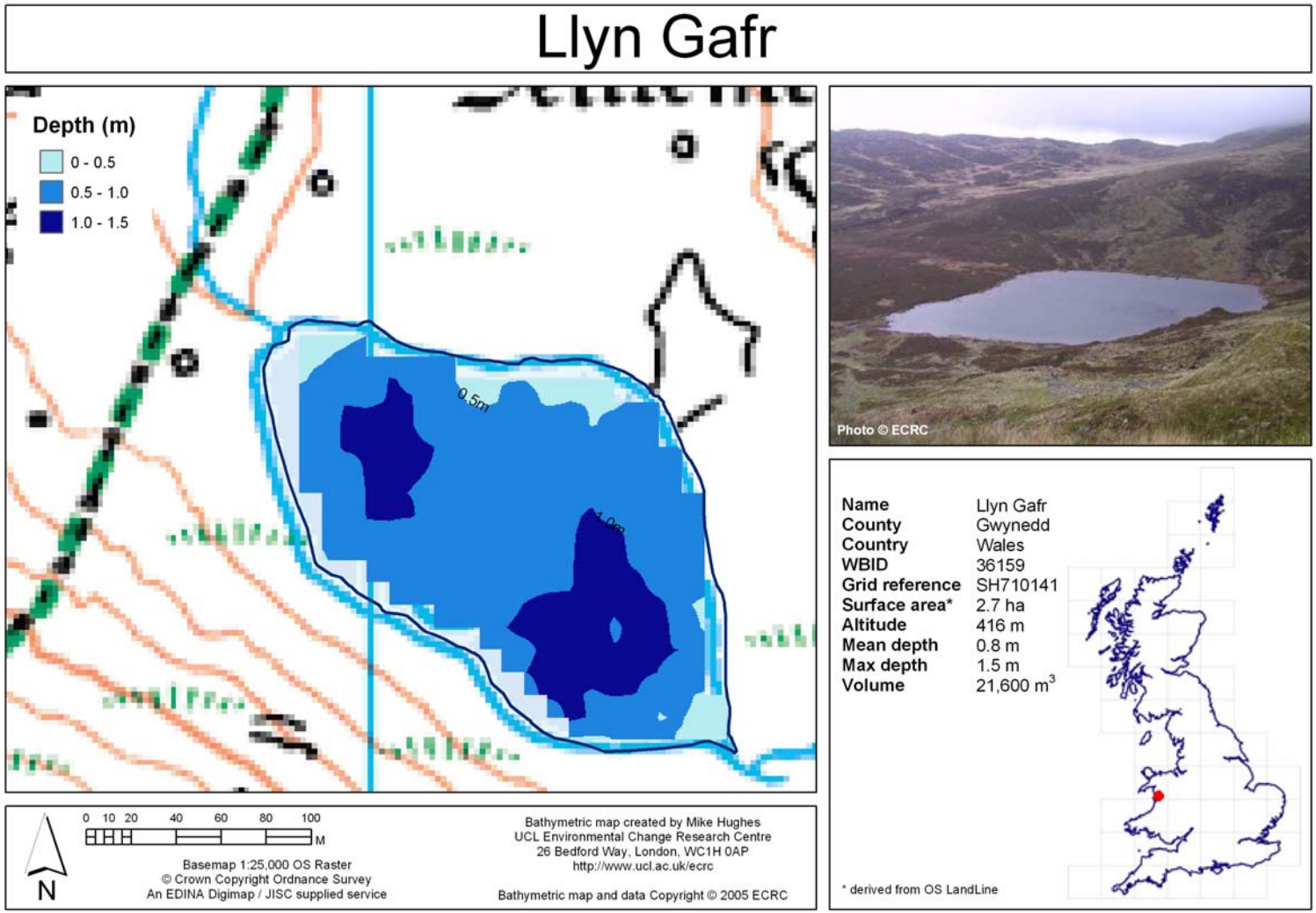


Figure 3.8.6 Llyn Gafr bathymetry map



3.8.2.3 Physico-chemical data

Temperature and oxygen profiles for Llyn Gafr are given in Figure 3.8.7 and water chemistry data shown in Table 3.8.11.

Figure 3.8.7 Temperature and oxygen profiles for Llyn Gafr

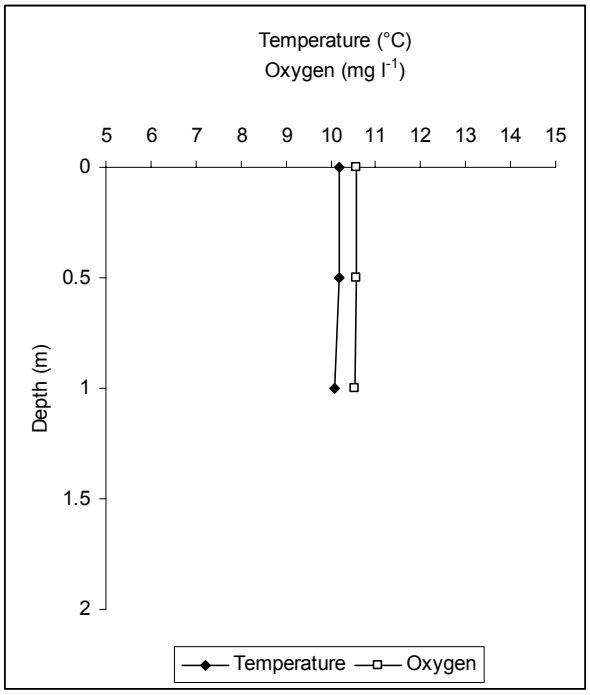


Table 3.8.11 Water chemistry data for Llyn Gafr

	Sept 04	Dec 04	Mar 05	Jun 05	Annual mean
pH	6.2	7.2	7.4	7.5	6.7
Cond	32	54	72	63	55
Alk	210.4	325.1	540.4	319.2	n.c.
DOC	1.05	0.31	0.80	1.19	0.84
SRP	2	11	4	7	6
TP	50.4	<50	<50	1	n.c.
Chl *a*	0.4	0.5	0.5	0.9	0.6
TN	0.24	0.32	0.30	0.20	0.26
NO_3^--N	0.88	1.07	0.94	0.60	0.87
Labile Al	<23	<23	<23	<23	<23
SO_4^{2-}	56	63	57	56	58
Total Fe	<6	<6	<6	<6	n.c.
Na^+	146.2	157.9	174.5	165.8	161.1
K^+	4.9	6.2	6.0	6.5	5.9
Mg^{2+}	48.4	67.6	75.8	69.0	65.2
Ca^{2+}	199.3	385.8	Error	400.2	n.c.
Cl^-	149.7	155.7	176.5	171.9	163.4
Total Mn	<2.0	<2.0	<2.0	<2.0	n.c.
ANC					276.28

(n.c. – not calculated, one or more values below analytical detection)

3.8.2.4 Macrophyte survey

Results of the macrophyte survey are given in Tables 3.8.12 and 3.8.13.

Table 3.8.12 Macrophyte abundance for Llyn Gafr – emergent and marginal survey

Taxon	DAFOR Abundance
Carex demissa	**F**
Carex panicea	**F**
Carex echinita	**F**
Carex nigra	**F**
Equisetum fluviatile	**A**
Juncus articulatus/acutiflorus	**A**
Potentilla erecta	**F**
Galium saxitile	**F**
Juncus effusus	**O**
Ranunculus flammula	**F**

Table 3.8.13 Macrophyte abundance for Llyn Gafr – wading and boat survey

Taxon	DAFOR Abundance
Equisetum fluviatile	**D**
Isoetes lacustris	**A**
Juncus bulbosus	**F**
Lobelia dortmanna	**O**
Myriophyllum alterniflorum	**A**
Nitella flexilis agg.	**O**
Potamogeton natans	**F**
Potamogeton polygonifolius	**O**
Sparganium angustifolium	**R**

No additional species were noted during a strandline survey.

3.8.2.5 Short core analysis

A 28 cm Glew core, GAFR1, was taken in a water depth of 1.4 m from Llyn Gafr on 16-Sep-04. A summary diagram of the common taxa (>2%) is shown in Figure 3.8.8 and summary data are given in Table 3.8.14. The core top and bottom samples contained a total of 55 diatom taxa. The assemblage of the bottom sample was dominated by *Aulacoseira lirata* var. *alpigena* (~50%), a diatom typical of moderately acid waters. The top sample was markedly different containing high relative abundances of *Achnanthes minutissima* and *Brachysira vitrea*, taxa more commonly found in mildly acid waters,

whilst the *Aulacoseira* taxon was not observed. The squared chord distance dissimilarity score between the two samples was therefore high (1.002).

Reconstructions of diatom-inferred pH (DI-pH) were produced using the SWAP training set. A high percentage of the taxa in the top sample were present in the SWAP training set but there were relatively poor analogues for the bottom sample, largely owing to the absence of *Denticula rainerensis* from the SWAP dataset (Table 3.8.14). The DI-pH values increase from 5.67 for the bottom sample to 6.76 for the top sample. The annual mean current pH based on quarterly water samples collected during 2004-2005 is 7.07 and therefore the diatom model appears to slightly under-estimate current pH by ~0.3 pH units.

In summary, there has been a significant degree of floristic change in the Llyn Gafr core. The species shifts indicate an increase in pH of approximately 1 pH unit over the time period represented by the core.

Figure 3.8.8 Summary diagram of diatom assemblages in top and bottom samples from core GAFR1

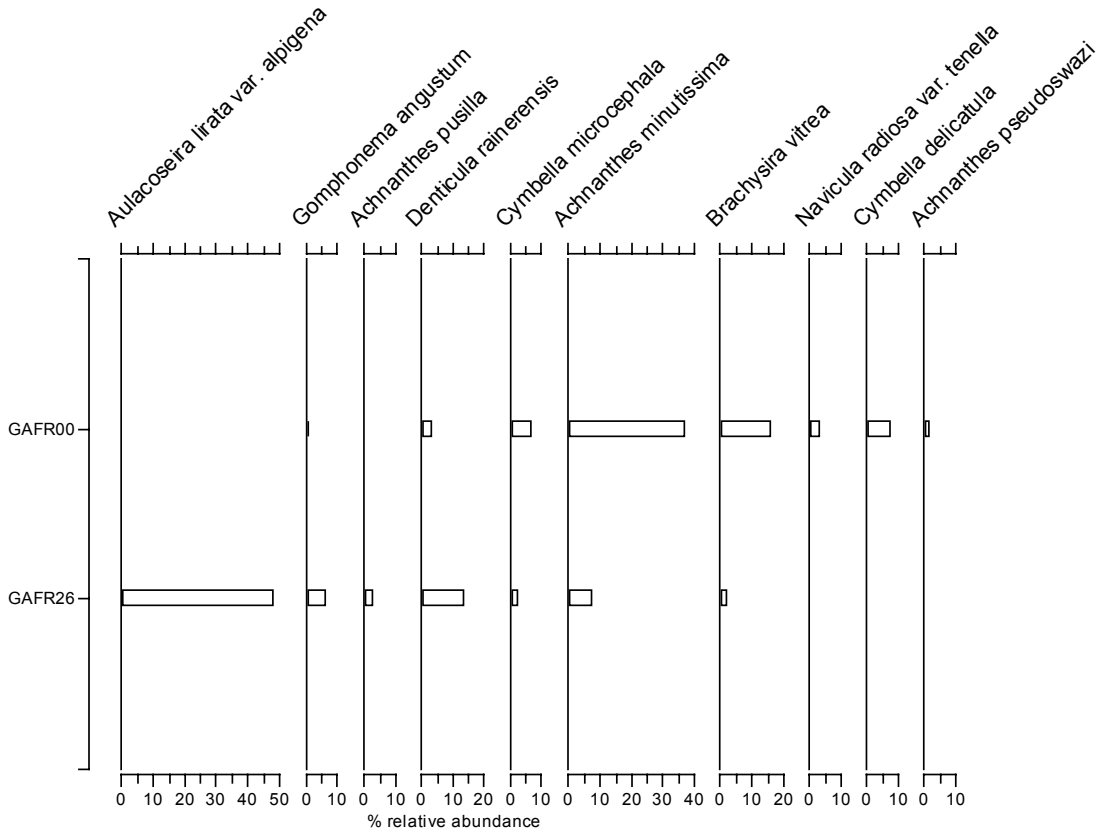


Table 3.8.14 Results of Llyn Gafr short core analysis

Sample code	Depth (cm)	Annual mean current pH	DI-pH	No. taxa in fossil sample	% of taxa in fossil sample present in SWAP training set	Squared chord distance dissimilarity score between core top and bottom
GAFR00	0	7.07	6.76	38	87	1.002
GAFR26	26		5.67	37	73	

3.8.3 Llyn Arran

3.8.3.1 Site Description

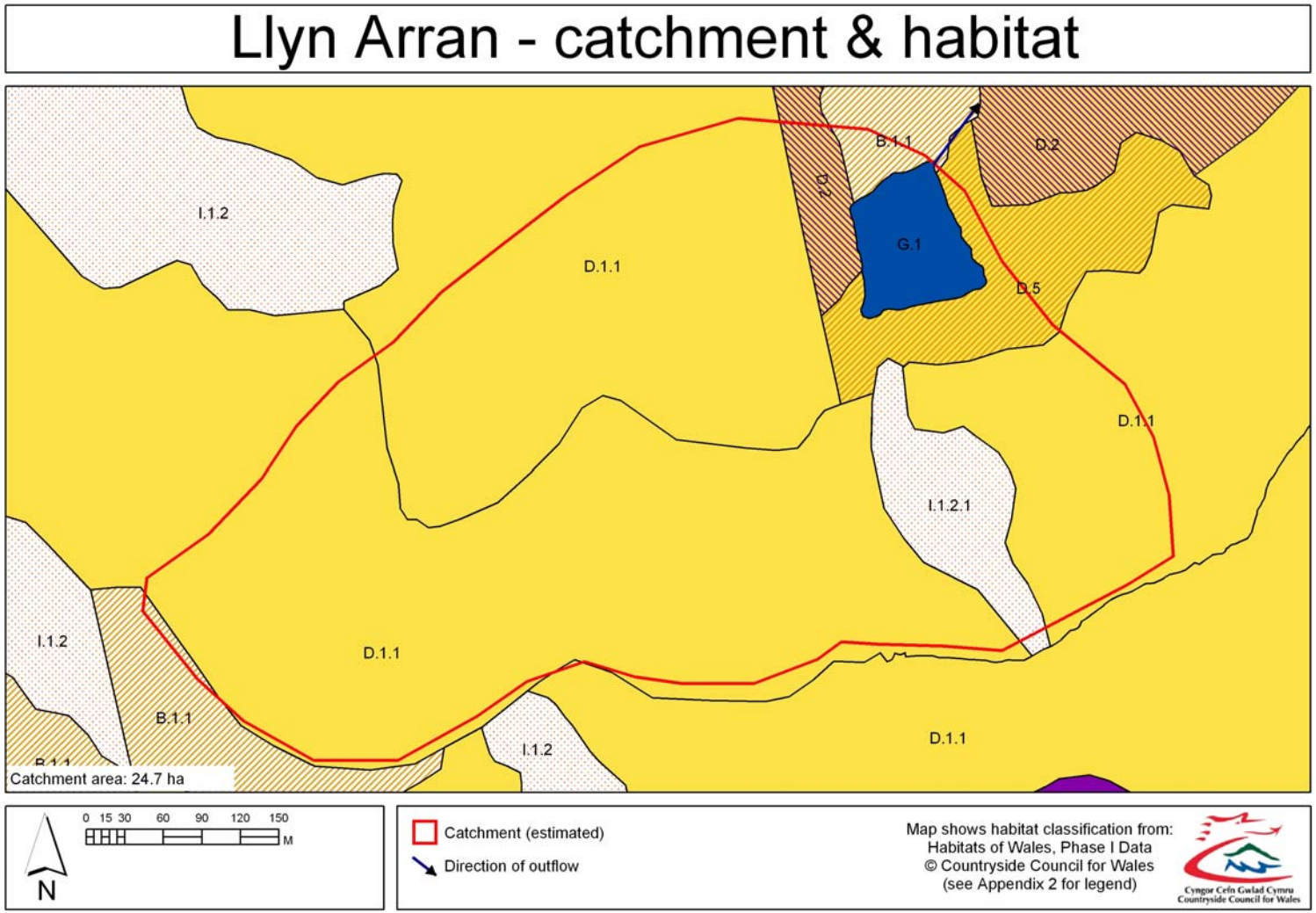
Llyn Arran is a small, high altitude lake (lake area less than 1 ha). The catchment supports rough upland grazing with areas of bare rock. Information on the solid geology of the Llyn Arran catchment is not available from the GBLakes database as the lake area is less that 1 ha. Information on land cover data is given in Table 3.8.15. A catchment map is given in Figure 3.8.9.

Table 3.8.15 Land cover data for the Llyn Arran catchment
(Data from CCW Phase 1 Habitat Survey)

Classification	Code	Percentage cover
Grassland and marsh		
Unimproved acid grassland	B.1.1	1.2
Heathland		
Dry acid heath	D.1.1	83.6
Wet heath	D.2	2.2
Dry heath/acid grassland mosaic	D.5	4.3
Open water		
Standing water	G.1	3.3
Rock exposure and waste		
Acid/neutral scree	I.1.2.1	5.3
Other*		0.1

* Percentage cover >1% and /or data not available

Figure 3.8.9 Llyn Arran catchment map



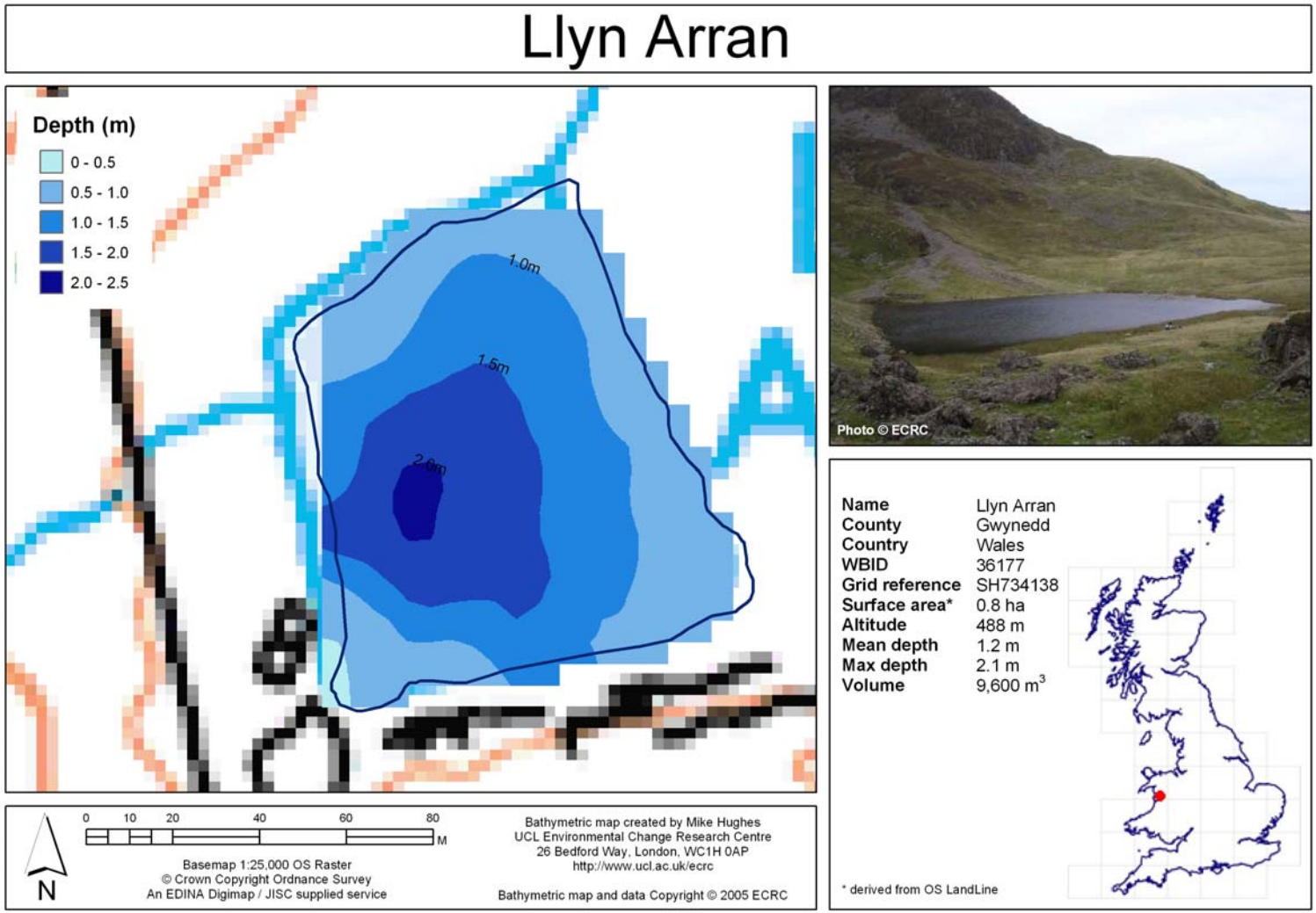
3.8.3.2 Bathymetry

The bathymetry of Llyn Arran is shown in Figure 3.8.10, physical and morphometric parameters are given in Table 3.8.16.

Table 3.8.16 Llyn Arran - physical and morphometric parameters

Lake altitude (m)	488
Maximum depth (m)	2.1
Mean depth (m)	1.2
Lake volume ($x10^3m^3$)	9.6
Area of lake surface (ha)	0.8
Perimeter of lake (km)	0.3
Shoreline development index	1.06
Estimated hydraulic residence time (days)	6.9
Secchi disc depth (m)	>2.1
Catchment area (ha)	24.7
Catchment to lake area ratio	30.9

Figure 3.8.10 Llyn Arran bathymetry map



3.8.3.3 Physico-chemical data

Temperature and oxygen profiles for Llyn Arran are given in Figure 3.8.11 and water chemistry data shown in Table 3.8.17.

Figure 3.8.11 Temperature and oxygen profiles for Llyn Arran

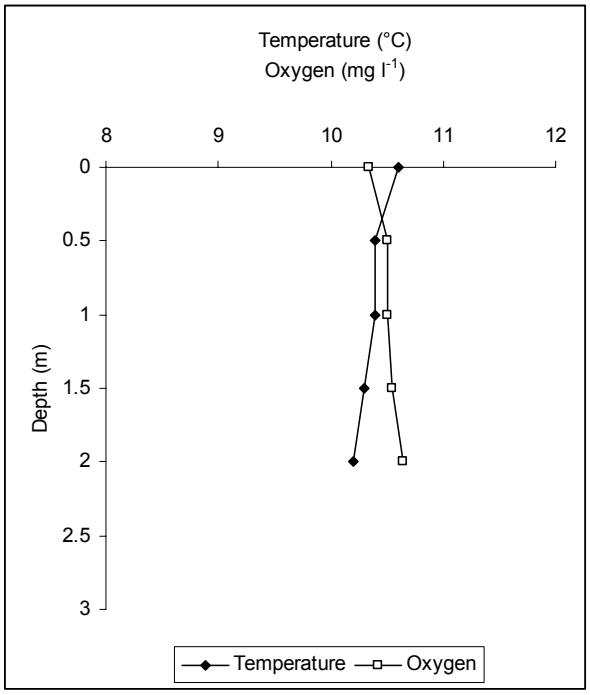


Table 3.8.17 Water chemistry data for Llyn Arran

	Sept 04	Dec 04	Mar 05	Jun 05	Annual mean
pH	6.1	6.5	6.5	6.7	6.4
Cond	21	28	34	32	29
Alk	<114	<114	<114	58.04	n.c.
DOC	0.92	0.36	0.80	1.66	0.94
SRP	2	9	12	6	7
TP	<50	<50	<50	4.6	n.c.
Chl *a*	0.6	7.8	1.4	1.6	2.8
TN	0.17	0.33	0.22	0.17	0.22
NO_3^--N	0.57	0.83	0.61	0.22	0.56
Labile Al	<23	<23	<23	<23	n.c.
SO_4^{2-}	51	61	50	59	55
Total Fe	<6	7	<6	8	n.c.
Na^+	130	151	166	158	151
K^+	3.45	2.8	4.0	5.4	3.9
Mg^{2+}	39.5	46.7	48.2	47.1	45.4
Ca^{2+}	49.1	68.5	Error	67.4	n.c.
Cl^-	146.4	150.7	180.2	173.9	162.8
Total Mn	3.30	<2.0	<2.0	3.10	n.c.
ANC					3.79

(n.c. – not calculated, one or more values below analytical detection)

3.8.3.4 Macrophyte survey

Results of the macrophyte survey are given in Tables 3.8.18 and 3.8.19.

Table 3.8.18 Macrophyte abundance for Llyn Arran – emergent and marginal survey

Taxon	DAFOR Abundance
Juncus effusus	**D**
Galium saxatile	**F**
Sphagnum sp.	**A**
Caerex curta	**F**
Carex demissa	**F**
Carex echinita	**F**
Viola palustris	**F**
Sparganium angustifolium	**F**

Table 3.8.19 Macrophyte abundance for Llyn Arran – wading and boat survey

Taxon	DAFOR Abundance
Callitriche hamulata	**D**
Isoetes lacustris	**D**
Juncus bulbosus	**D**
Juncus effusus	**F**
Littorella uniflora	**D**
Lobelia dortmanna	**D**
Myriophyllum alterniflorum	**F**
Fontinalis antipyretica	**O**
Potamogeton polygonifolius	**F**
Sparganium angustifolium	**F**
Sphagnum sp	**F**

No additional species were noted during a strandline survey. As this is a small site only one section surveyed as described in the methods in Appendix 1. At the time of sampling the water level was approximately 15 cm higher than normal after heavy rain.

3.8.3.5 Short core analysis

A 31 cm Glew core, ARRA1, was taken in a water depth of 2.1 m from Llyn Arran on 17-Sep-04. A summary diagram of the common taxa (>2%) is shown in Figure 3.8.12 and summary data are given in Table 3.8.20. The core top and bottom samples contained a total of 67 diatom taxa. The assemblage of the bottom sample was diverse with numerous non-planktonic species typical of moderately acid waters, the most abundant being *Eunotia exigua*, *Achnanthes minutissima, Brachysira brebissonii, Peronia fibula* and *Fragilaria virescens* var. *exigua*. The top sample was less diverse being co-

dominated by *Peronia fibula, Fragilaria virescens* var. *exigua* and *Navicula leptostriata*, with a relatively high abundance of *Brachysira vitrea*. The main species shifts between the bottom and top samples were the marked decline in *Eunotia exigua* and *Achnanthes minutissima*, increases in *Peronia fibula, Fragilaria virescens* var. *exigua* and *Brachysira vitrea*, and the appearance of *Navicula leptostriata.* The squared chord distance dissimilarity score between the two samples was 0.837 indicating significant floristic change.

Reconstructions of diatom-inferred pH (DI-pH) were produced using the SWAP training set. A high percentage of the taxa in the fossil samples were present in the SWAP training set and there were no major analogue problems (Table 3.8.20). The DI-pH values decline slightly from 5.48 at the bottom sample to 5.37 at the top sample, indicating mild acidification. However, the inferred change in pH is less than the RMSEP of the model of 0.32 pH units and cannot, therefore, be considered as significant. The annual mean current pH based on quarterly water samples collected during 2004-2005 is 6.43 and therefore the diatom model appears to under-estimate current pH by ~1 pH unit.

In summary, there has been a significant degree of floristic change in the Llyn Arran core but the assemblages of both the bottom and top samples are associated with moderately acid waters. The species shifts, therefore, appear to signify only minor acidification of the lake.

Figure 3.8.12 Summary diagram of diatom assemblages in top and bottom samples from core ARRA1

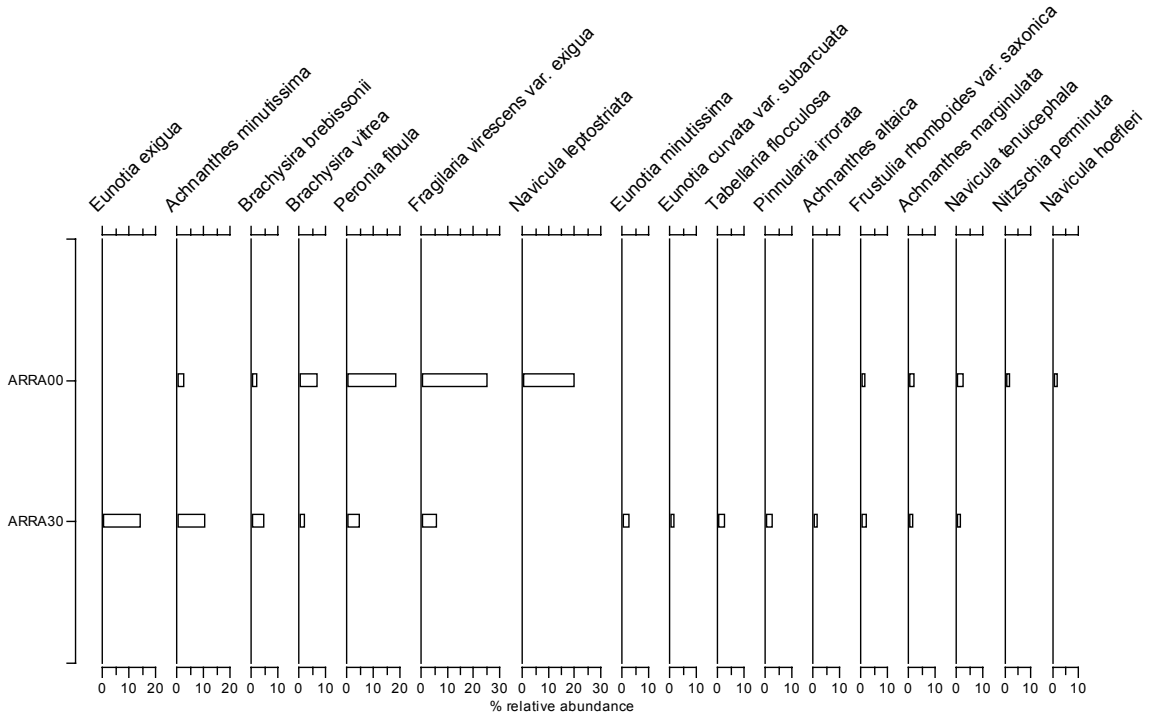


Table 3.8.20 Results of Llyn Arran short core analysis

Sample code	Depth (cm)	Annual mean current pH	DI-pH	No. taxa in fossil sample	% of taxa in fossil sample present in SWAP training set	Squared chord distance dissimilarity score between core top and bottom
ARRA00	0	6.43	5.37	34	94	0.837
ARRA30	30		5.48	60	81	

3.9 Elenydd SAC
Llyn Gynon, Llyn Cerrigllwydion Isaf, Llyn Fyrddon Fawr & Llyn Gwngu

Location of SAC

SAC Details	
Grid Ref. (approx. centre)	SN824704
SAC EU Code	UK0012928
Total Area	8609 ha
Total area of Freshwater	60 ha

General site character:
Inland water bodies (standing water, running water) (0.7%)
Bogs. Marshes. Water fringed vegetation. Fens (58%)
Heath. Scrub. Maquis and garrigue. Phygrana (6.2%)
Dry grassland. Steppes (16.1%)
Humid grassland. Mesophile grassland (18.2%)
Inland rocks. Screes. Sands. Permanent snow and ice (0.5%)
Other land (including towns, villages, roads, waste places, mines, industrial sites) (0.3%)

Annex I habitats that are a primary reason for selection of this site
6130 Calaminarian grasslands of the *Violetalia calaminariae*
Heavy metals have been extracted from the Ystwyth Valley for over 1000 years. At Cwm Ystwyth this activity has left extensive areas of rock outcrop, scree, spoil-heaps and abandoned shafts, adits and buildings variously affected by heavy metals available for colonisation by heavy metal-tolerant plant species. Lichens and bryophytes are a notable component of the developing flora and include a number of scarce species such as *Vezdaea cobria, Lecanora handelii, Gyalidea subscutellaris* and *Ditrichum plumbicola*.
7130 Blanket bogs
Elenydd comprises the largest tract of blanket mire within the central Wales uplands. Considerable areas of the habitat display signs of modification, with impoverished vegetation dominated by grasses and with reduced amounts of dwarf shrubs and widespread bog-mosses *Sphagnum* spp. Areas of good quality mire are typically fragmented by species-poor vegetation dominated by purple moor-grass *Molinia caerulea.* However, there are extensive stands of M18 *Erica tetralix – Sphagnum papillosum* mire that contain locally abundant bog-rosemary *Andromeda polifolia*, as well as areas of mire in which heather *Calluna vulgaris* and hare's-tail cottongrass *Eriophorum vaginatum* are dominant. Areas of hummock and hollow surface patterning are found locally.

The SAC also includes Annex I habitat: 3130 Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of *the Isoëto-Nanojuncetea* (including *Luronium natans* at Llyn Gynon) and 4030 European dry heaths.

(JNCC, 2005b)

3.9.1 Llyn Gynon

3.9.1.1 Site Description

Llyn Gynon lies within a shallow depression in the highland plateau east of Aberystwyth overlooking the Claerwen Reservoir. It is a remote site used occasionally by fly fishermen. The catchment comprises mainly of *Molinia* heath, rough grazing with areas of peat bog. A site description is given in Monteith (1995).

Information on the solid geology of the Llyn Gynon catchment and land cover data are given in Tables 3.9.1 and 3.9.2 respectively. A catchment map is given in Figure 3.9.1 .

Table 3.9.1 Solid geology of the Llyn Gynon catchment
(Data from British Geological Survey solid geology data at 1:62,500)

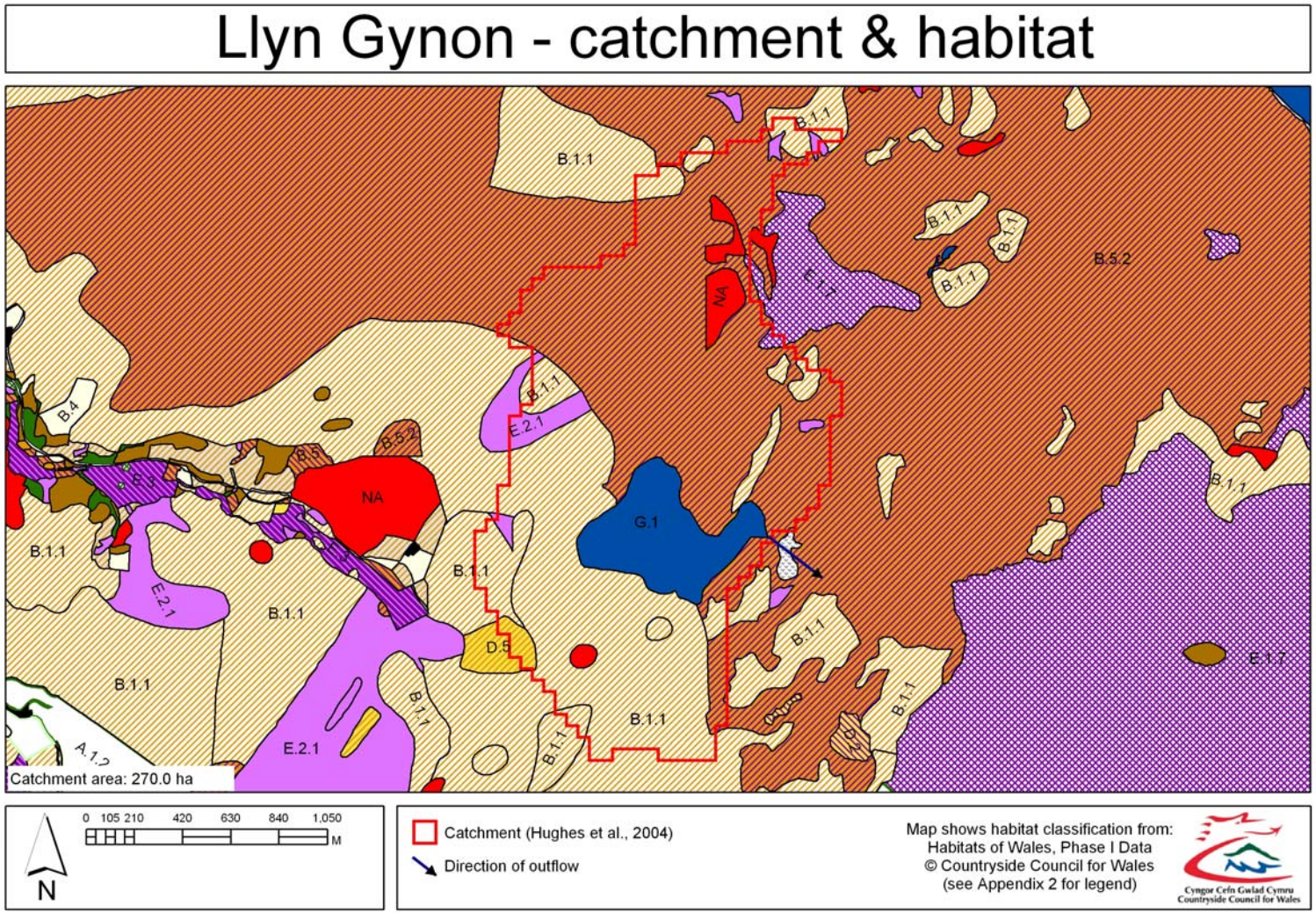
Name	Type	Percentage cover
Llandovery	Sedimentary	100

Table 3.9.2 Land cover data for the Llyn Gynon catchment
(Data from CCW Phase 1 Habitat Survey)

Classification	Code	Percentage cover
Grassland and marsh		
Unimproved acid grassland	B.1.1	37.2
Marshy grassland *Molinia* dominated	B.5.2	47.2
Mire		
Acid/neutral flush	E.2.1	2.3
Open water		
Standing water	G.1	9.5
Other*		3.8

* Percentage cover >1% and /or data not available

Figure 3.9.1 Llyn Gynon catchment map



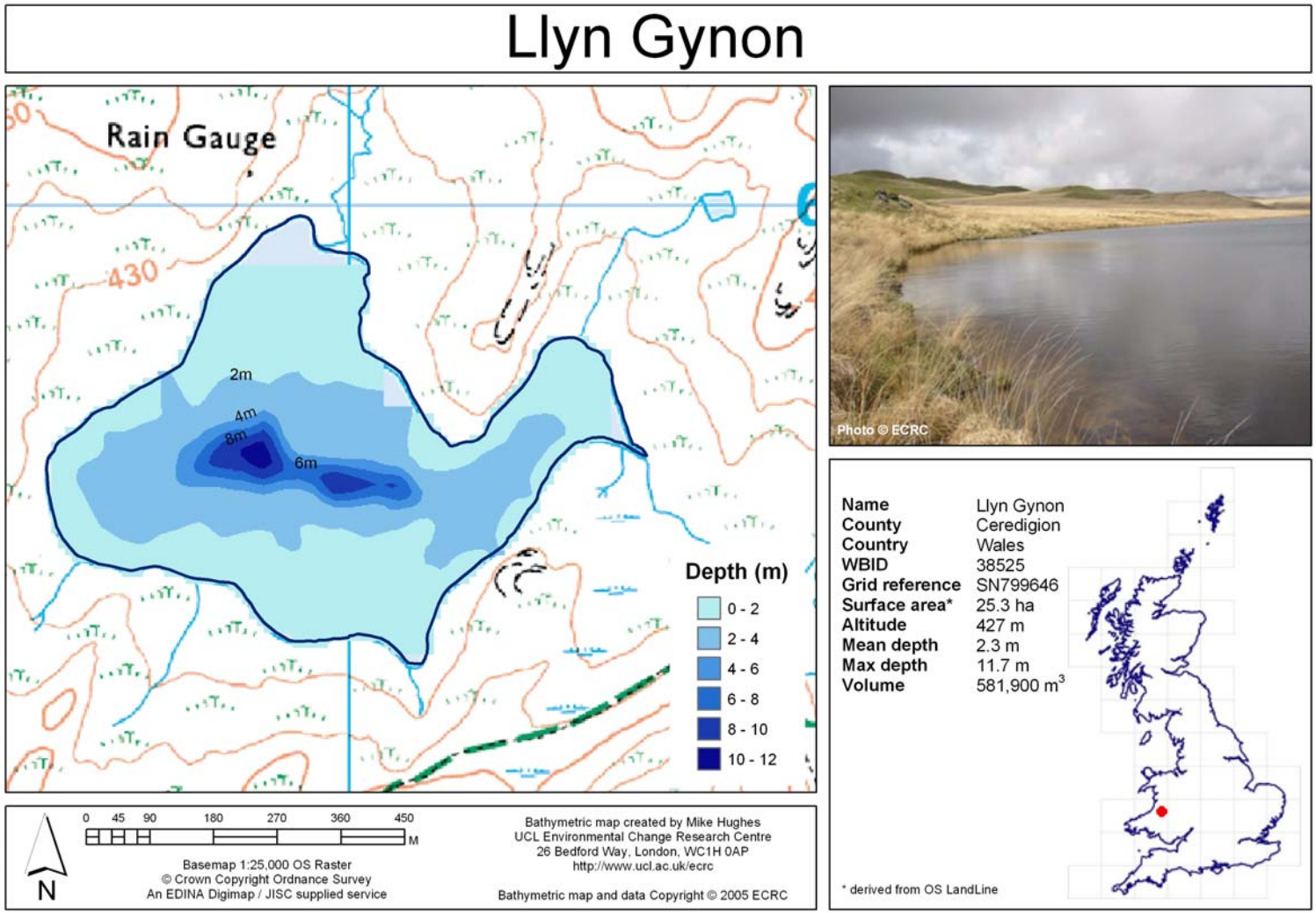
3.9.1.2 Bathymetry

The bathymetry of Llyn Gynon is shown in Figure 3.9.2, physical and morphometric parameters are given in Table 3.9.3.

Table 3.9.3 Llyn Gynon - physical and morphometric parameters

Lake altitude (m)	427
Maximum depth (m)	11.7
Mean depth (m)	2.3
Lake volume ($x10^3m^3$)	581.9
Area of lake surface (ha)	25.3
Perimeter of lake (km)	2.4
Shoreline development index	1.43
Estimated hydraulic residence time (days)	59.8
Secchi disc depth (m)	3.05
Catchment area including lake (ha)	270
Catchment to lake area ratio	10.7

Figure 3.9.2 Llyn Gynon bathymetry map



3.9.1.3 Physico-chemical data

Temperature and oxygen profiles for Llyn Gynon are given in Figure 3.9.3 and water chemistry data shown in Table 3.9.4.

Figure 3.9.3 Temperature and oxygen profiles for Llyn Gynon

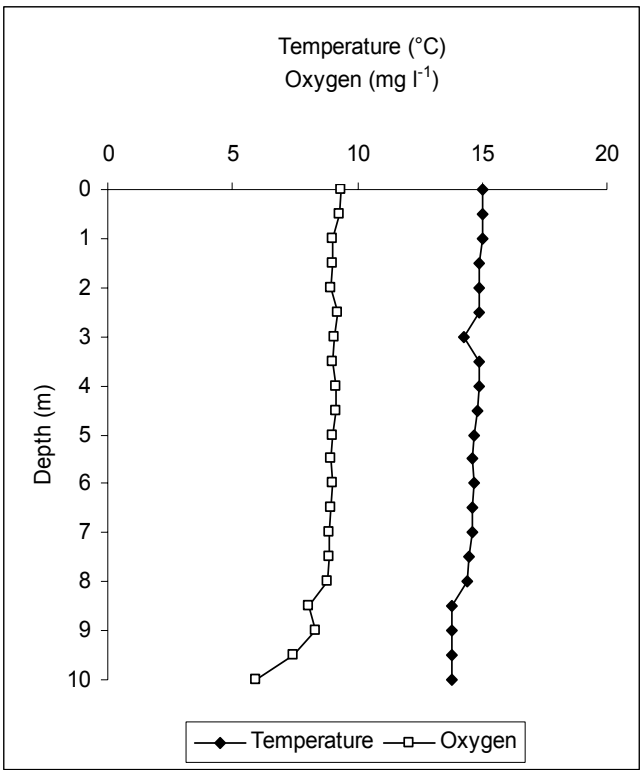


Table 3.9.4 Water chemistry data for Llyn Gynon

	Dec 03	Mar 04	Jul 04	Sept 04	Annual mean
pH	6.6	5.3	6.6	5.9	6.0
Cond	35	38	29	27	32
Alk	27.9	13.4	44.3	47.9	33.4
DOC	-	-	3.58	5.65	n.c.
SRP	-	2	7	4	n.c.
TP	11	11	15	13	13
Chl *a*	1.8	1.7	3.2	5.6	3.1
TN	0.24	0.72	0.20	0.36	0.38
NO_3^--N	0.06	0.47	0.01	0.01	0.14
Labile Al	-	-	-	-	-
SO_4^{2-}	-	-	66	55	n.c.
Total Fe	-	-	-	-	-
Na^+	-	0.0	0.0	0.0	n.c.
K^+	-	0.0	0.0	0.0	n.c.
Mg^{2+}	-	0.0	0.0	0.0	n.c.
Ca^{2+}	-	-	40.6	52.9	n.c.
Cl^-	-	-	191.8	155.1	n.c.
Total Mn	-	-	-	-	-
ANC	-	-	-	-	-

(n.c. – not calculated, one or more values below analytical detection)
(- denotes data not collected or analysed)

3.9.1.4 Macrophyte survey

Results of the macrophyte survey are given in Tables 3.9.5 and 3.9.6.

Table 3.9.5 Macrophyte abundance for Llyn Gynon – emergent and marginal survey

Taxon	DAFOR Abundance
Littorella uniflora	**D**
Lobelia dortmanna	**A**
Juncus bulbosus	**A**
Glyceria fluitans	**O**
Ranunculus flammula	**A**
Juncus effusus	**D**
Potamogeton polygonifolius	**A**
Fontinalis antipyretica	**R**
Filamentous algae	**F**
Liverwort "A"	**F**
Elatine hexandra	**R**
Subularia aquatica	**R**
Sparganium angustifolium	**R**
Callitriche hamulata	**R**
Equisetum fluviatile	**R**
Luronium natans	**R**
Utricularia sp	**R**
Sphagnum auriculatum	**R**
Carex rostrata	**R**

Table 3.9.6 Macrophyte abundance for Llyn Gynon – wading and boat survey

Taxon	DAFOR Abundance
Batrachospermum sp	**D**
Carex rostrata	**R**
Fontinalis antipyretica	**R**
Isoetes lacustris	**D**
Juncus bulbosus	**A**
Littorella uniflora	**D**
Lobelia dortmanna	**D**
Luronium natans	**O**
Myriophyllum alterniflorum	**F**
Nitella flexilis	**F**
Sphagnum auriculatum	**F**
Subularia aquatica	**R**
Utricularia minor	**O**

A strandline survey recorded the presence of no additional species, although *Nuphar lutea* was seen at a distance of about 25 m down the outflow stream.

3.9.1.5 Short core analysis

Short core analysis was not required as part of this study. Epilithon and surface sediment diatom taxon lists are given in Monteith (1995).

3.9.2 Llyn Cerrigllwydion Isaf

3.9.2.1 Site Description

Llyn Cerrigllwydion Isaf lies at an altitude of 498 m and covers an area of 5.5 ha. The catchment is largely comprised of bog vegetation, although around the lake itself there are areas of *Molinia*-dominated rough upland grazing. Information on the solid geology of the Llyn Cerrigllwydion Isaf catchment and land cover data are given in Tables 3.9.7 and 3.9.8 respectively. A catchment map is given in Figure 3.9.4.

Table 3.9.7 Solid geology of the Llyn Cerrigllwydion Isaf catchment
(Data from British Geological Survey solid geology data at 1:62,500)

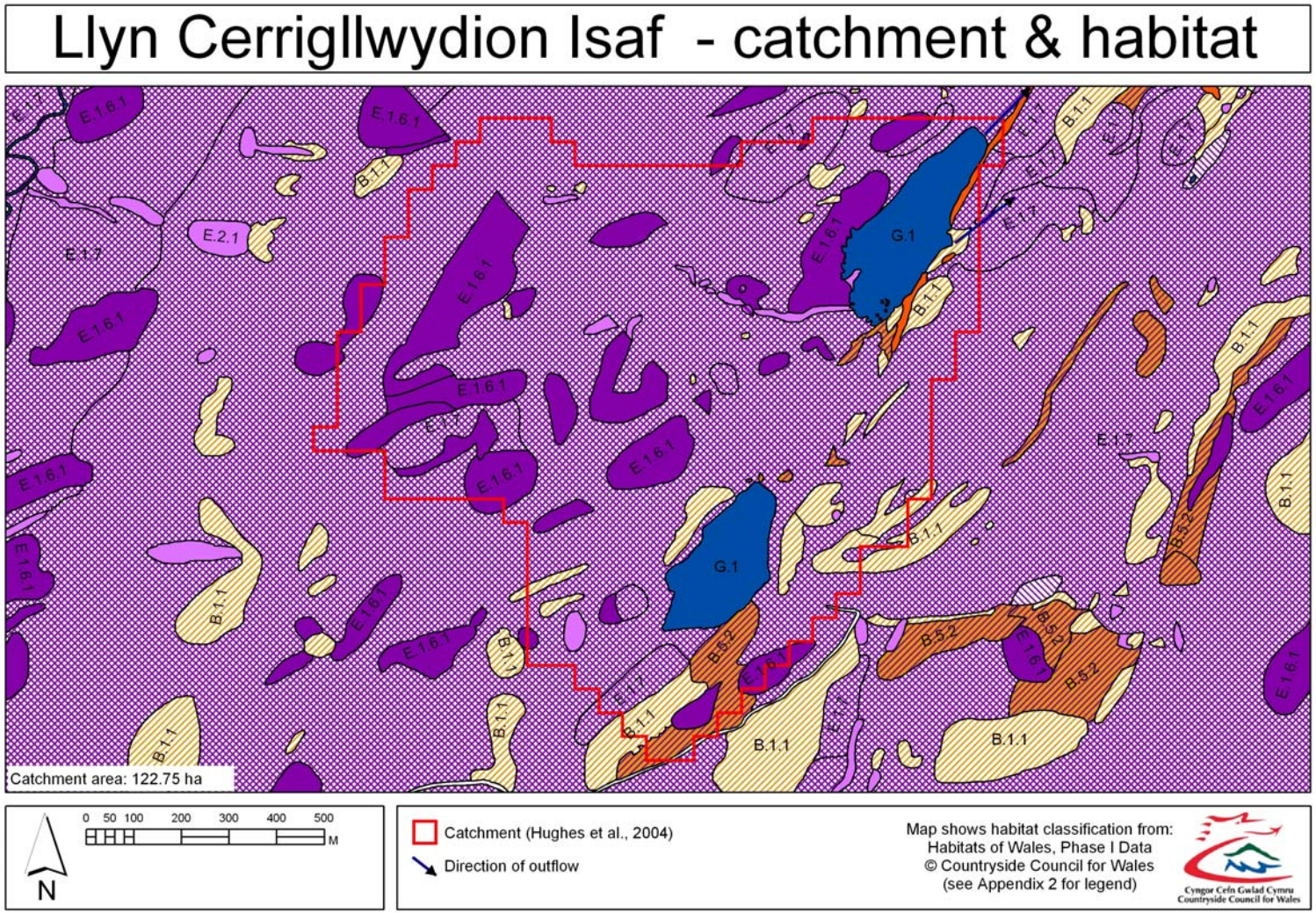
Name	Type	Percentage cover
Llandovery	Sedimentary	100

Table 3.9.8 Land cover data for the Llyn Cerrigllwydion Isaf catchment
(Data from CCW Phase 1 Habitat Survey)

Classification	Code	Percentage cover
Grassland and marsh		
Unimproved acid grassland	B.1.1	5.6
Marshy grassland *Molinia* dominated	B.5.2	2.4
Mire		
Blanket bog	E.1.6.1	16.5
Wet modified bog	E.1.7	65.9
Acid/neutral flush	E.2.1	1.0
Open water		
Standing water	G.1	8.1
Other*		0.5

* Percentage cover >1% and /or data not available

Figure 3.9.4 Llyn Cerrigllwydion Isaf catchment map



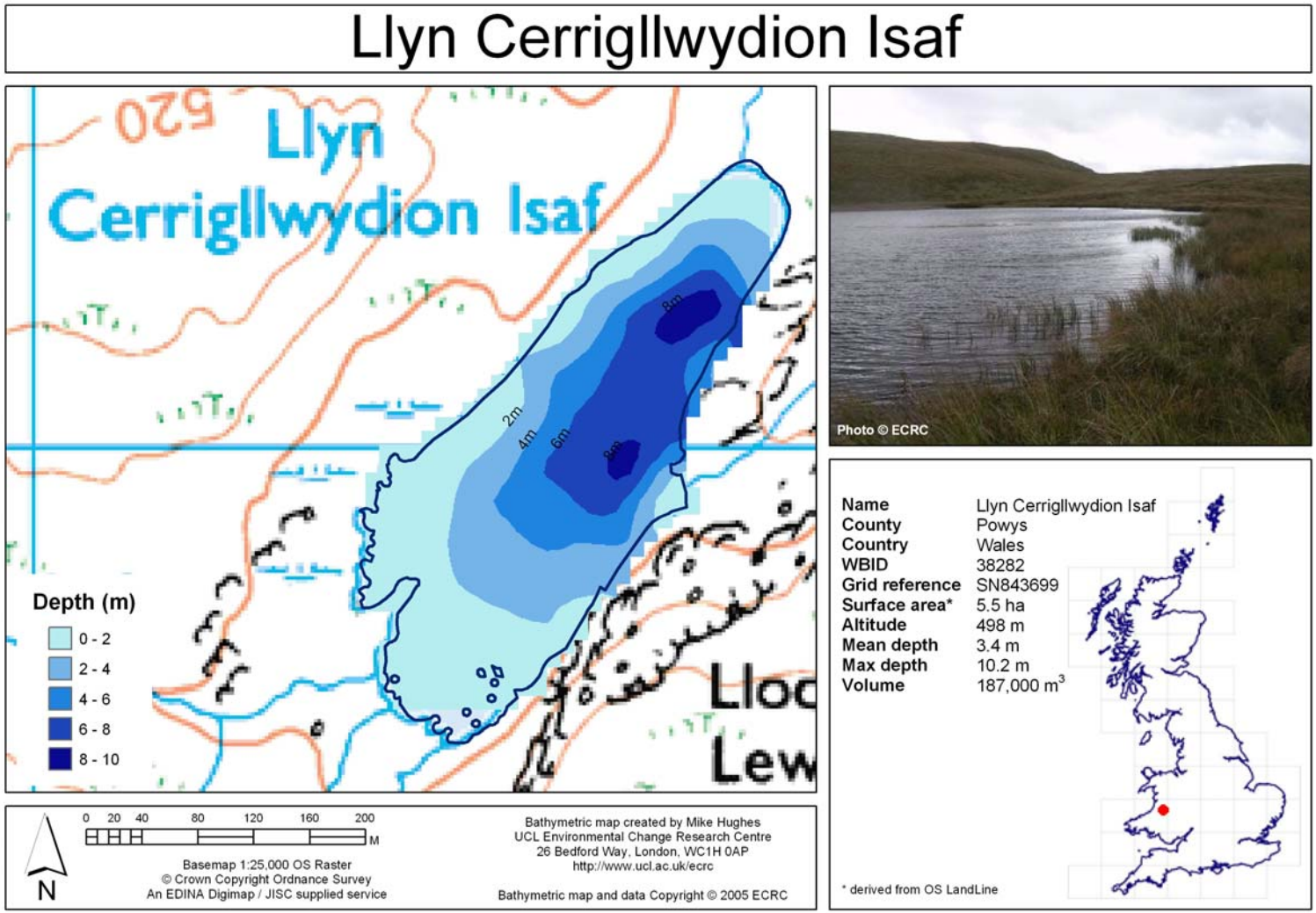
3.9.2.2 Bathymetry

The bathymetry of Llyn Cerrigllwydion Isaf is shown in Figure 3.9.5, physical and morphometric parameters are given in Table 3.9.9.

Table 3.9.9 Llyn Cerrigllwydion Isaf - physical and morphometric parameters

Lake altitude (m)	498
Maximum depth (m)	10.2
Mean depth (m)	3.4
Lake volume ($x10^3m^3$)	187.0
Area of lake surface (ha)	5.5
Perimeter of lake (km)	1.2
Shoreline development index	1.42
Estimated hydraulic residence time (days)	37.2
Secchi disc depth (m)	2.35
Catchment area including lake (ha)	122.8
Catchment to lake area ratio	22.3

Figure 3.9.5 Llyn Cerrigllwydion Isaf bathymetry map



3.9.2.3 Physico-chemical data

Temperature and oxygen profiles for Llyn Cerrigllwydion Isaf are given in Figure 3.9.6 and water chemistry data shown in Table 3.9.10.

Figure 3.9.6 Temperature and oxygen profiles for Llyn Cerrigllwydion Isaf

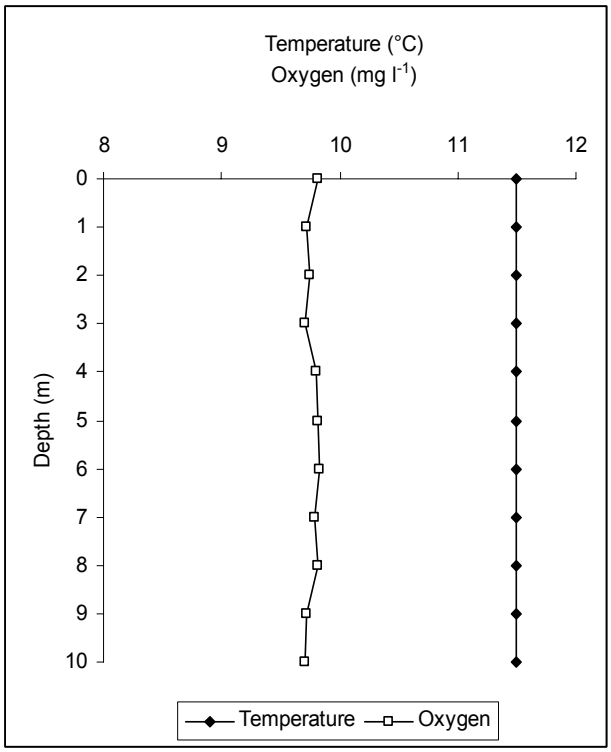


Table 3.9.10 Water chemistry data for Llyn Cerrigllwydion Isaf

	Sept 04	Dec 04	Mar 05	Jun 05	Annual mean
pH	5.5	5.3	5.5	5.9	5.5
Cond	24	25	29	30	27
Alk	<114	<114	<114	24.6	n.c.
DOC	5.88	4.69	3.40	4.02	4.49
SRP	2	5	21	6	9
TP	97.9	<50	<50	6.4	n.c.
Chl *a*	2.5	1.9	6.2	4.4	3.8
TN	0.39	0.38	0.51	0.27	0.39
NO_3^--N	0.51	0.81	1.29	1.05	0.91
Labile Al	<23	23.3	44.1	17.4	n.c.
SO_4^{2-}	44	44	42	45	44
Total Fe	169	105	58	78	103
Na^+	148.1	136.5	158.2	156.2	149.7
K^+	2.9	6.1	3.2	3.9	4.0
Mg^{2+}	49.2	40.9	41.3	48.8	45.0
Ca^{2+}	39.2	32.0	Error	39.6	n.c.
Cl^-	164.3	150.1	166.3	166.4	161.8
Total Mn	39.4	43.4	64.0	25.3	43.0
ANC					-35.99

(n.c. – not calculated, one or more values below analytical detection)

3.9.2.4 Macrophyte survey

Results of the macrophyte survey are given in Tables 3.9.11 and 3.9.12.

Table 3.9.11 Macrophyte abundance for Llyn Cerrigllwydion Isaf – emergent and marginal survey

Taxon	DAFOR Abundance
Carex rostrata	**O**
Sparganium angustifolium	**F**
Juncus effusus	**F**
Sphagnum sp.	**A**
Galium saxatile	**F**
Viola palustris	**O**
Agrostis stolonifera	**O**
Juncus bulbosus	**F**
Glyceria fluitans	**O**

Table 3.9.12 Macrophyte abundance for Llyn Cerrigllwydion Isaf – wading and boat survey

Taxon	DAFOR Abundance
Carex rostrata	**O**
Callitriche hamulata	**O**
Isoetes lacustris	**A**
Juncus bulbosus	**O**
Littorella uniflora	**A**
Lobelia dortmanna	**R**
Myriophyllum alterniflorum	**A**
Fontinalis antipyretica	**R**
Glyceria fluitans	**R**
Sparganium angustifolium	**F**
Sphagnum auriculatum	**R**
Luronium natans	**R**

A strandline survey found no additional species present. High winds made boat work too hazardous to complete 3 boat transects. The water level was raised by a low rock dam.

3.9.2.5 Short core analysis

A 21 cm Glew core, CERR1, was taken in a water depth of 10 m from Llyn Cerrigllwydion Isaf on 19-Sep-04. A summary diagram of the common taxa (>2%) is shown in Figure 3.9.7 and summary data are given in Table 3.9.13. The core top and bottom samples contained a total of 63 diatom taxa. The assemblages of the bottom and top samples had similar species composition with the main four taxa, *Eunotia incisa, Frustulia rhomboides* var. *viridula*, *Cymbella perpusilla* and *Tabellaria flocculosa,* occurring in approximately the same relative abundances in both samples. Nonetheless, slight differences were evident with *Eunotia rhomboidea* and *Navicula cumbriensis* being more abundant in the lower sample and conversely *Brachysira vitrea, Navicula leptostriata* and *Fragilaria virescens* var. *exigua* being present in higher relative amounts in the upper sample. The squared chord distance dissimilarity score between the two samples was 0.505.

Reconstructions of diatom-inferred pH (DI-pH) were produced using the SWAP training set. A high percentage of the taxa in the fossil samples were present in the SWAP training set and there were no major analogue problems (Table 3.9.13). The DI-pH values increase slightly from 4.87 for the bottom sample to 4.99 for the top sample but given that this is less than the RMSEP of the model (0.32 pH units), the change cannot be considered as significant. The annual mean current pH based on quarterly water samples collected during 2004-2005 is 5.54 and therefore the diatom model appears to under-estimate current pH by ~0.5 pH units.

In summary, there has been a moderate degree of floristic change in the Llyn Cerrigllwydion Isaf core but the assemblages of both the bottom and top samples are associated with moderately acid waters. The lake has been acid for the whole of the period represented by the sediment core.

Figure 3.9.7 Summary diagram of diatom assemblages in top and bottom samples from core CERR1

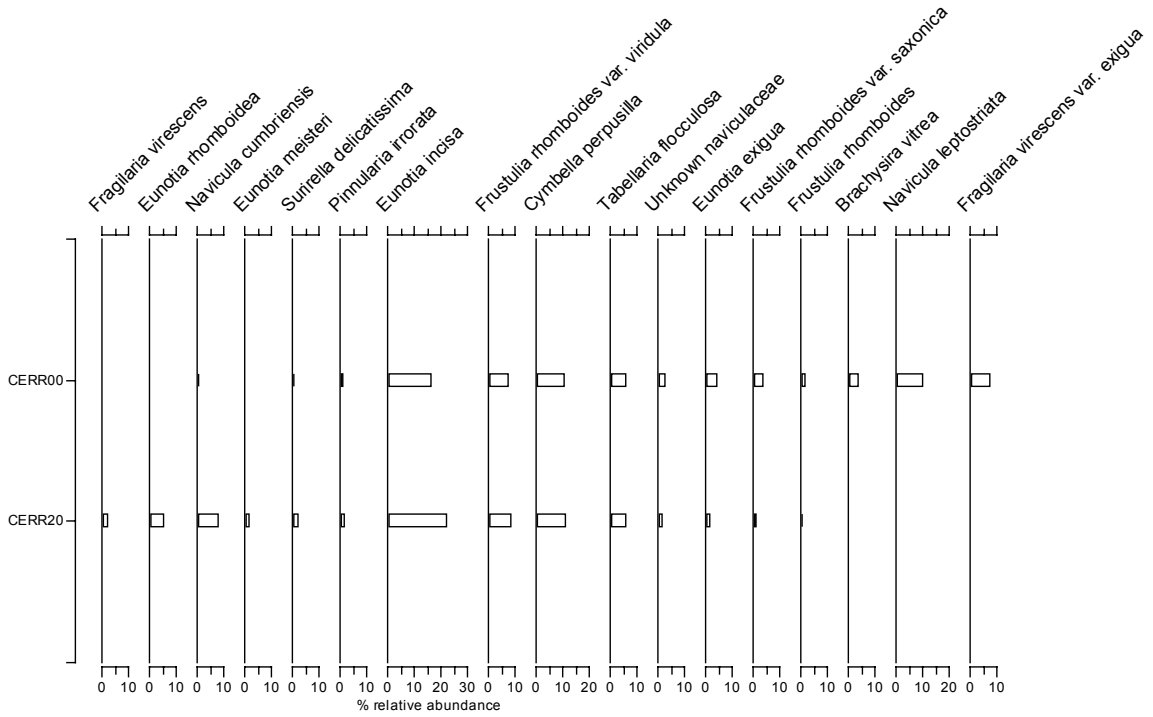


Table 3.9.13 Results of Llyn Cerrigllwydion Isaf short core analysis

Sample code	Depth (cm)	Annual mean current pH	DI-pH	No. taxa in fossil sample	% of taxa in fossil sample present in SWAP training set	Squared chord distance dissimilarity score between core top and bottom
CERR00	0	5.54	4.99	42	89	0.505
CERR20	20		4.87	51	90	

3.9.3 Llyn Fyrddon Fawr

3.9.3.1 Site Description

Llyn Fyrddon Fawr is an exposed upland lake (altitude 519 m). The catchment consists mainly of rough upland grazing dominated by *Molinia* and *Juncus squarross*. The southern shoreline has large expanses of exposed rock, with mainly eroded peat on the north-east and north-west shores. The water level of the lake has been raised by approximately 3.5 m by an old stone dam on the outflow.

Information on the solid geology of the Llyn Fyrddon Fawr catchment and land cover data are given in Tables 3.9.14 and 3.9.15 respectively. A catchment map is given in Figure 3.9.8.

Table 3.9.14 Solid geology of the Llyn Fyrddon Fawr catchment
(Data from British Geological Survey solid geology data at 1:62,500)

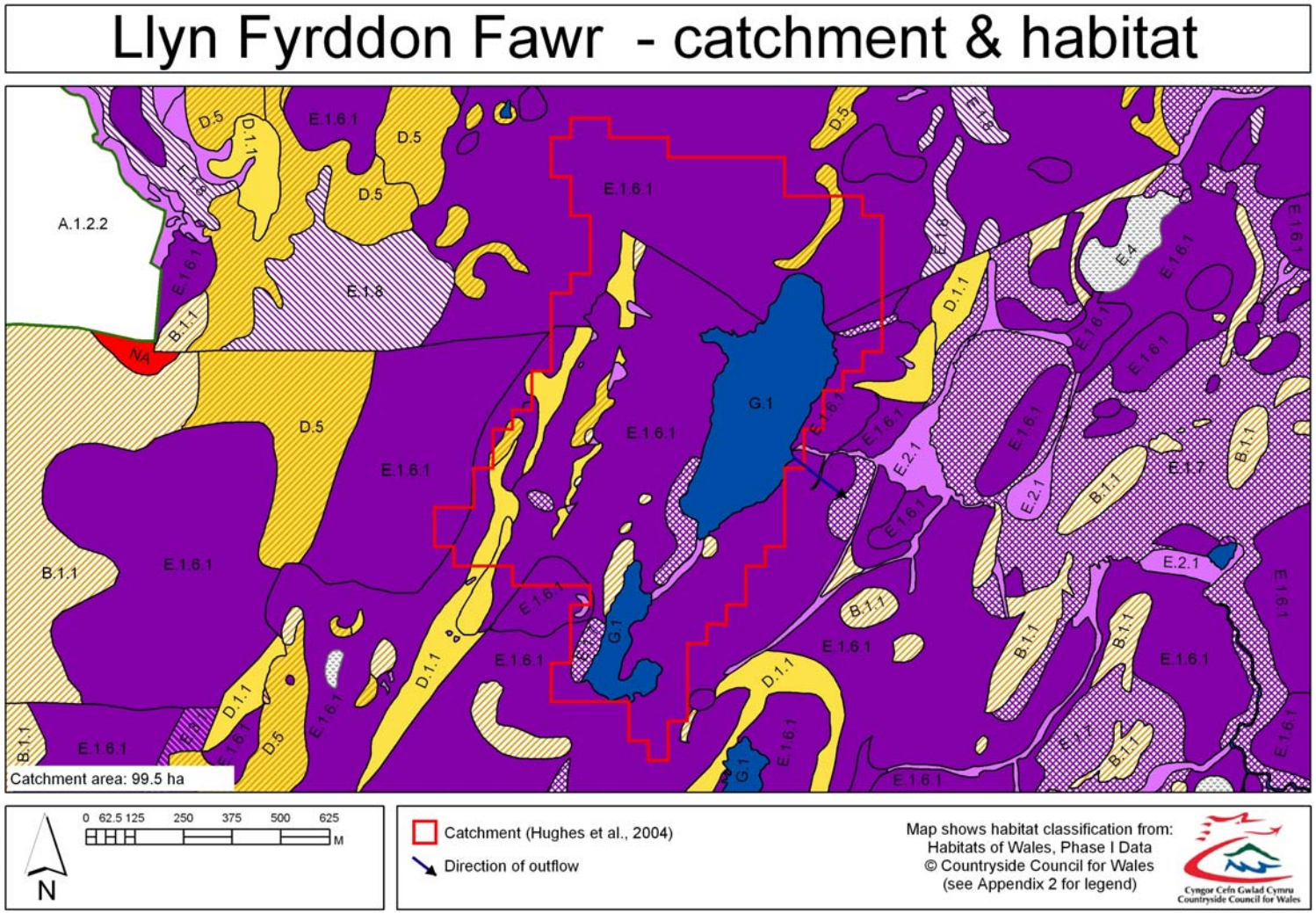
Name	Type	Percentage cover
Llandovery	Sedimentary	100

Table 3.9.15 Land cover data for the Llyn Fyrddon Fawr catchment
(Data from CCW Phase 1 Habitat Survey)

Classification	Code	Percentage cover
Grassland and marsh		
Unimproved acid grassland	B.1.1	1.4
Heathland		
Dry acid heath	D.1.1	4.8
Dry heath/acid grassland mosaic	D.5	1.8
Mire		
Blanket bog	E.1.6.1	71.0
Wet modified bog	E.1.7	2.8
Open water		
Standing water	G.1	17.3
Other*		0.9

* Percentage cover >1% and /or data not available

Figure 3.9.8 Llyn Fyrddon Fawr catchment map



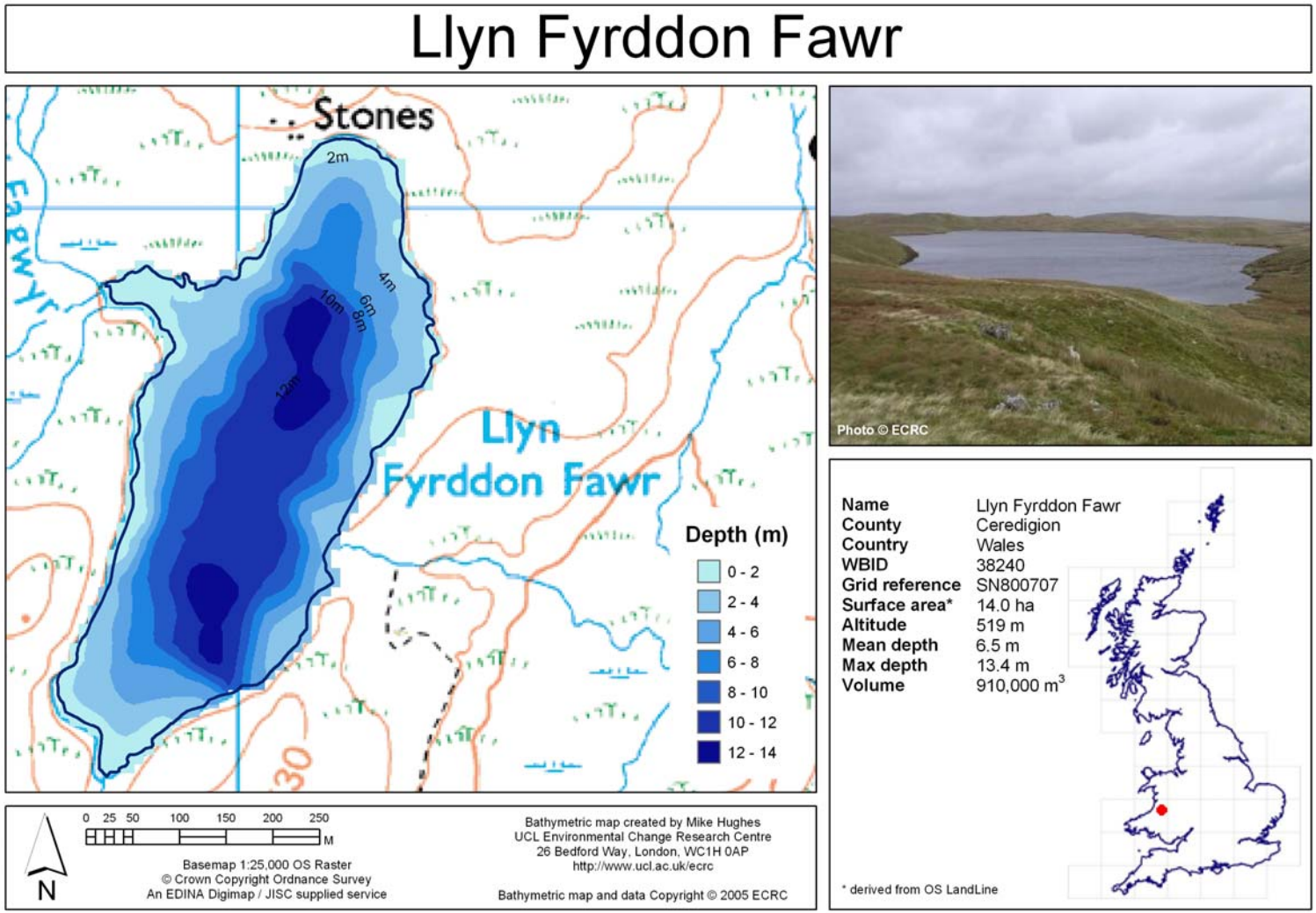
3.9.3.2 Bathymetry

The bathymetry of Llyn Fyrddon Fawr is shown in Figure 3.9.9, physical and morphometric parameters are given in Table 3.9.16.

Table 3.9.16 Llyn Fyrddon Fawr - physical and morphometric parameters

Lake altitude (m)	519
Maximum depth (m)	13.4
Mean depth (m)	6.5
Lake volume ($x10^3m^3$)	910.0
Area of lake surface (ha)	14
Perimeter of lake (km)	1.6
Shoreline development index	1.32
Estimated hydraulic residence time (days)	222.4
Secchi disc depth (m)	1.2
Catchment area (ha)	99.5
Catchment to lake area ratio	7.1

Figure 3.9.9 Llyn Fyrddon Fawr bathymetry map



3.9.3.3 Physico-chemical data

Temperature and oxygen profiles for Llyn Fyrddon Fawr are given in Figure 3.9.10 and water chemistry data shown in Table 3.9.17.

Figure 3.9.10 Temperature and oxygen profiles for Llyn Fyrddon Fawr

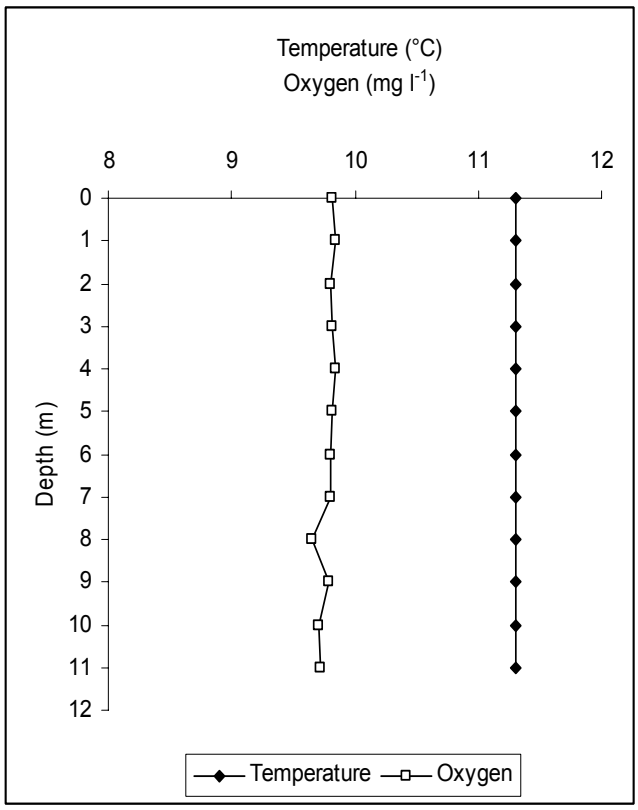


Table 3.9.17 Water chemistry data for Llyn Fyrddon Fawr

	Sept 04	Dec 04	Mar 05	Jun 05	Annual mean
pH	5.4	5.3	5.4	5.9	5.4
Cond	25	26	30	28	27
Alk	<114	<114	<114	29.0	n.c.
DOC	5.46	5.01	4.40	4.45	4.83
SRP	2	5	2	6	4
TP	297.6	<50	<50	7.3	n.c.
Chl *a*	0.9	2.0	1.8	2.0	1.7
TN	0.32	0.35	0.29	0.35	0.33
NO_3^--N	0.55	0.46	0.47	0.62	0.53
Labile Al	<23	26.5	28.2	<23	n.c.
SO_4^{2-}	45	40	36	39	40
Total Fe	369	311	213	210	276
Na^+	156.0	133.3	156.1	145.1	147.6
K^+	3.0	5.6	2.1	2.9	3.4
Mg^{2+}	51.0	41.9	42.0	46.1	45.3
Ca^{2+}	35.6	30.7	Error	33.6	n.c.
Cl^-	171.8	155.7	164.3	163.1	163.7
Total Mn	62.4	43.5	37.1	35.9	44.7
ANC					-12.09

(n.c. – not calculated, one or more values below analytical detection)

3.9.3.4 Macrophyte survey

Results of the macrophyte survey are given in Tables 3.9.18 and 3.9.19.

Table 3.9.18 Macrophyte abundance for Llyn Fyrddon Fawr – emergent and marginal survey

Taxon	DAFOR Abundance
Viola palustris	**O**
Galium saxatile	**F**
Juncus effusus	**A**
Juncus squarrosus	**F**
Sphagnum sp.	**F**
Polytrichum commune	**F**
Carex rostrata	**R**
Agrostis stolonifera	**O**
Glyceria fluitans	**R**
Carex demissa	**R**
Carex panicea	**R**
Carex echinita	**O**
Potentilla erecta	**R**

Table 3.9.19 Macrophyte abundance for Llyn Fyrddon Fawr – wading and boat survey

Taxon	DAFOR Abundance
Carex rostrata	**F**
Fontinalis antipyretica	**A**
Sphagnum sp	**F**

No macrophyte species were recorded during a strandline survey or during the boat survey.

3.9.3.5 Short core analysis

A 26 cm Glew core, FYRD1, was taken in a water depth of 13 m from Llyn Fyrddon Fawr on 21-Sep-04. A summary diagram of the common taxa (>2%) is shown in Figure 3.9.11 and summary data are given in Table 3.9.20. The core top and bottom samples contained a total of 56 diatom taxa. The assemblage of the bottom sample was dominated by *Asterionella ralfsii* (50%), a species typical of strongly acid waters. The top sample was markedly different and was comprised of approximately equal amounts of *Tabellaria flocculosa, Eunotia incisa, Cymbella perpusilla* and *Frustulia rhomboides* var. *viridula*, and contained no *Asterionella ralfsii*. Consequently the squared chord distance dissimilarity score between the two samples was very high (1.064).

Reconstructions of diatom-inferred pH (DI-pH) were produced using the SWAP training set. A high percentage of the taxa in the fossil samples were present in the SWAP training set and there were no major analogue problems (Table 3.9.20). The DI-pH values increase from 4.72 for the bottom sample to 5.09 for the top sample. The annual mean current pH based on quarterly water samples collected during 2004-2005 is 5.49 and therefore the diatom model appears to slightly under-estimate current pH by ~0.4 pH units.

In summary, there has been a significant degree of floristic change in the Llyn Fyrddon Fawr core which indicates an increase in pH. The assemblages of both the bottom and top samples are associated with strongly acid waters suggesting that the lake has been acid for the whole of the period represented by the sediment core.

Figure 3.9.11 Summary diagram of diatom assemblages in top and bottom samples from core FYRD1

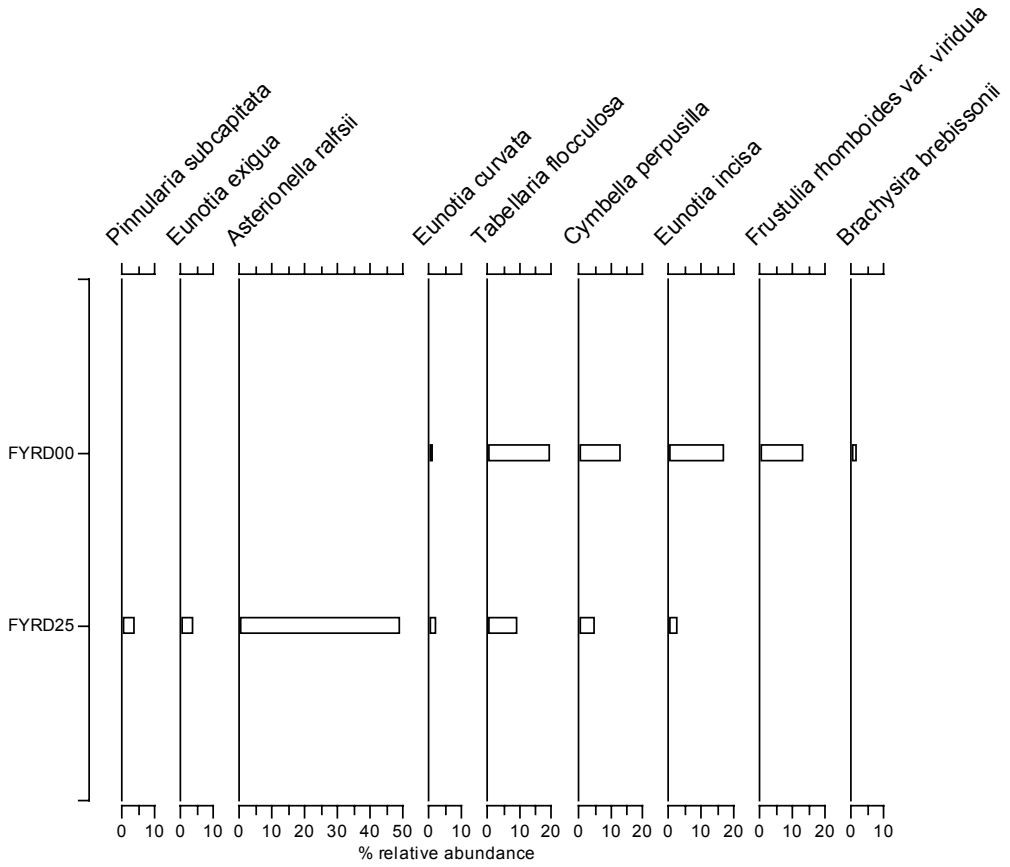


Table 3.9.20 Results of Llyn Fyrddon Fawr short core analysis

Sample code	Depth (cm)	Annual mean current pH	DI-pH	No. taxa in fossil sample	% of taxa in fossil sample present in SWAP training set	Squared chord distance dissimilarity score between core top and bottom
FYRD00	0	5.49	5.09	44	87	1.064
FYRD25	25		4.72	33	95	

3.9.4 Llyn Gwngu

3.9.4.1 Site Description

Llyn Gwngu lies at an altitude of 438 m. The catchment consists mainly of *Molinia* tussocks and wet upland grazing. Information on the solid geology of the Llyn Gwngu catchment and land cover data are given in Tables 3.9.21 and 3.9.22 respectively. A catchment map is given in Figure 3.9.12.

Table 3.9.21 Solid geology of the Llyn Gwngu catchment
(Data from British Geological Survey solid geology data at 1:62,500)

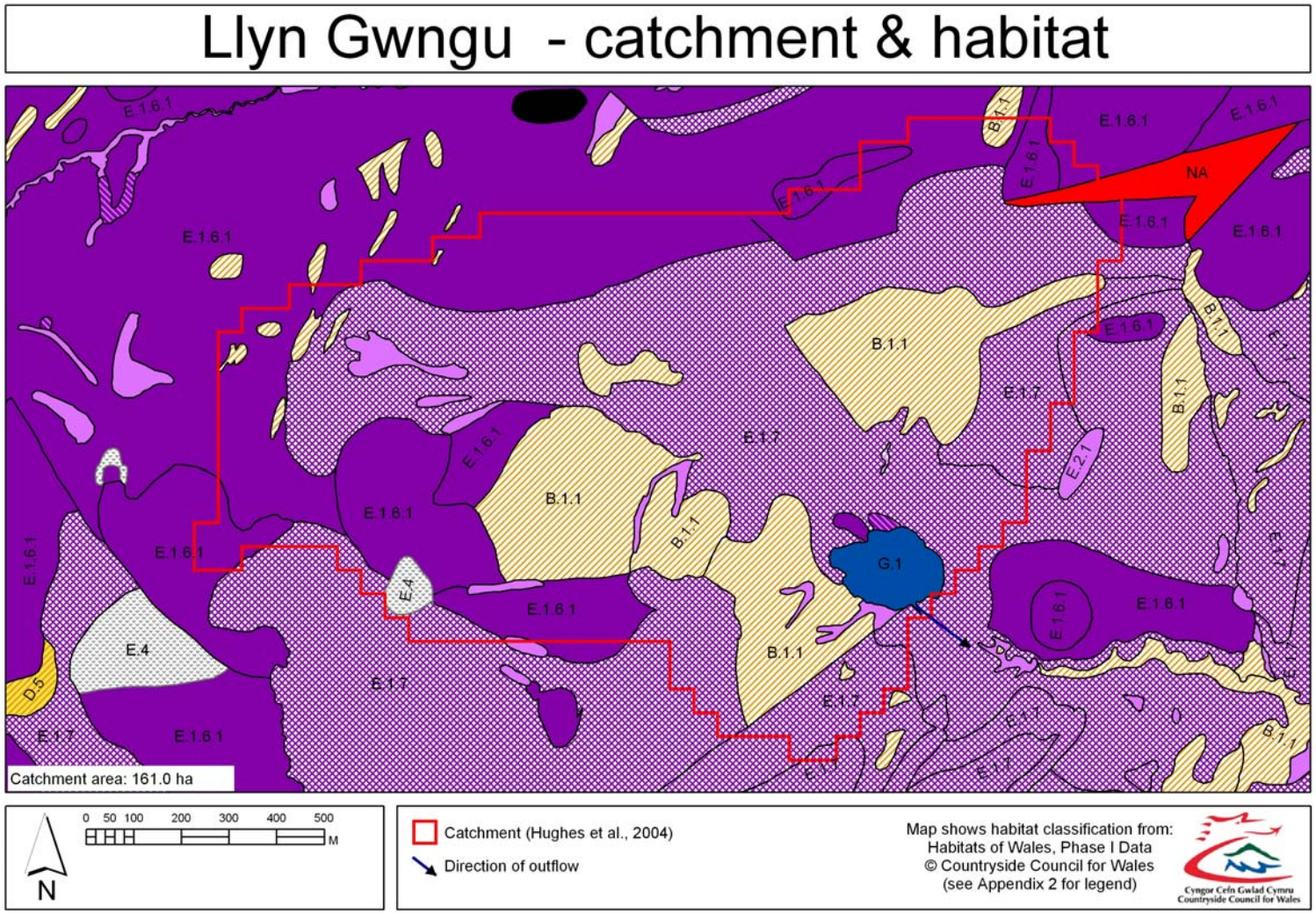
Name	Type	Percentage cover
Llandovery	Sedimentary	100

Table 3.9.22 Land cover data for the Llyn Gwngu catchment
(Data from CCW Phase 1 Habitat Survey)

Classification	Code	Percentage cover
Grassland and marsh		
Unimproved acid grassland	B.1.1	21.8
Mire		
Blanket bog	E.1.6.1	27.6
Wet modified bog	E.1.7	45.9
Acid/neutral flush	E.2.1	1.8
Open water		
Standing water	G.1	1.8
Other*		

* Percentage cover >1% and /or data not available

Figure 3.9.12 Llyn Gwngu catchment map



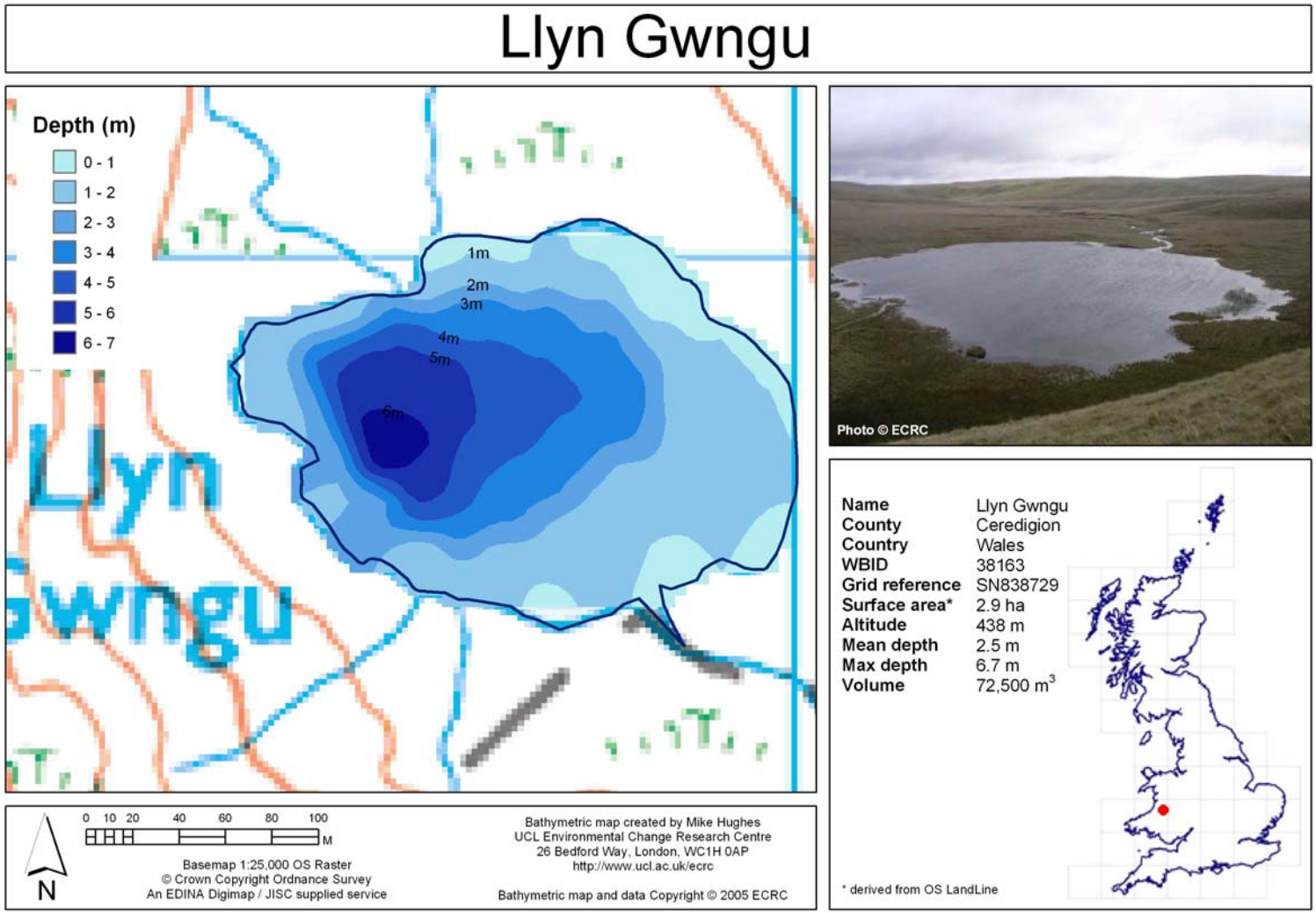
3.9.4.2 Bathymetry

The bathymetry of Llyn Gwngu is shown in Figure 3.9.13, physical and morphometric parameters are given in Table 3.9.23.

Table 3.9.23 Llyn Gwngu - physical and morphometric parameters

Lake altitude (m)	438
Maximum depth (m)	6.7
Mean depth (m)	2.5
Lake volume ($x10^3m^3$)	72.5
Area of lake surface (ha)	2.9
Perimeter of lake (km)	0.7
Shoreline development index	1.06
Estimated hydraulic residence time (days)	10.3
Secchi disc depth (m)	1.3
Catchment area (ha)	161
Catchment to lake area ratio	55.5

Figure 3.9.13 Llyn Gwngu bathymetry map



3.9.4.3 Physico-chemical data

Temperature and oxygen profiles for Llyn Gwngu are given in Figure 3.9.14 and water chemistry data shown in Table 3.9.24.

Figure 3.9.14 Temperature and oxygen profiles for Llyn Gwngu

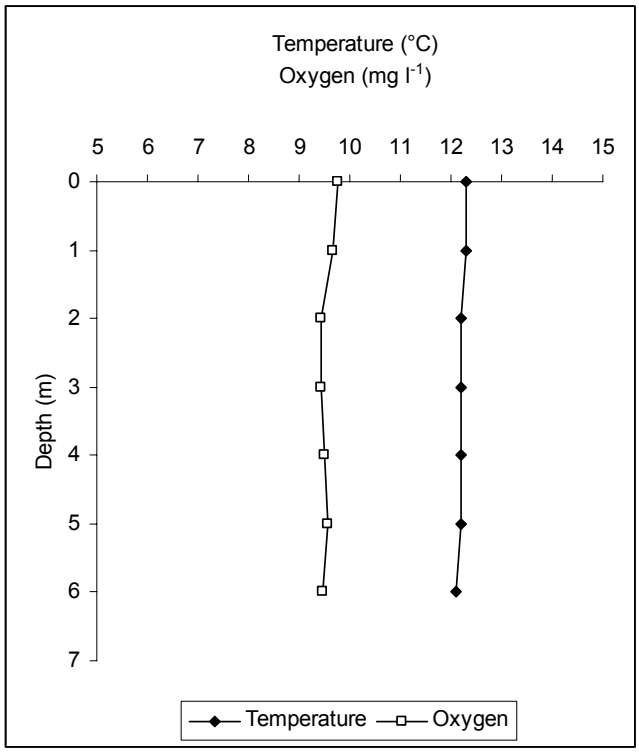


Table 3.9.24 Water chemistry data for Llyn Gwngu

	Sept 04	Dec 04	Mar 05	Jun 05	Annual mean
pH	5.2	5.9	6.1	6.7	5.6
Cond	22	22	30	30	26
Alk	<114	<114	<114	81.5	n.c.
DOC	8.40	5.26	3.10	5.24	5.50
SRP	2	5	2	6	4
TP	151.1	<50	<50	6.9	n.c.
Chl *a*	0.9	1.3	1.1	3.1	1.6
TN	0.30	0.33	0.31	0.41	0.34
NO_3^--N	0.07	0.40	0.68	0.03	0.30
Labile Al	30.4	20.5	<23	<23	n.c.
SO_4^{2-}	28	35	40	29	33
Total Fe	378	381	139	694	398
Na^+	120.7	127.7	168.4	153.5	142.6
K^+	3.5	4.8	3.2	1.5	3.3
Mg^{2+}	41.6	37.9	46.7	60.7	46.7
Ca^{2+}	32.1	37.1	Error	60.2	n.c.
Cl^-	147.2	124.9	173.3	148.8	148.5
Total Mn	129.6	79.6	80.3	45.9	83.9
ANC					32.70

(n.c. – not calculated, one or more values below analytical detection)

3.9.4.4 Macrophyte survey

Results of the macrophyte survey are given in Tables 3.9.25 and 3.9.26.

Table 3.9.25 Macrophyte abundance for Llyn Gwngu – emergent and marginal survey

Taxon	DAFOR Abundance
Carex rostrata	**D**
Carex echinita	**A**
Carex demissa	**O**
Phragmites australis	**O**
Equisetum fluviatile	**F**
Galium saxatile	**F**
Menyanthes trifoliata	**O**
Hydrocotyle vulgaris	**F**
Viola palustris	**F**
Potentilla erecta	**F**
Potamogeton polygonifolius	**F**
Nuphar lutea	**D**
Juncus effusus	**A**
Scutellaria minor	**F**
Juncus articulatus/acutiflorus	**O**

Table 3.9.26 Macrophyte abundance for Llyn Gwngu – wading and boat survey

Taxon	DAFOR Abundance
Carex rostrata	**D**
Equisetum fluviatile	**D**
Juncus bulbosus	**R**
Eleogiton fluitans	**D**
Juncus effusus	**R**
Callitriche hamulata	**R**
Menyanthes trifoliata	**R**
Myriophyllum alterniflorum	**A**
Nuphar lutea	**D**
Phragmites australis	**F**
Potamogeton polygonifolius	**F**
Sphagnum auriculatum	**A**
Utricularia minor	**A**

A strandline survey recorded the presence of *Potamogeton natans*. The water level was approximately 50 cm higher than usual after heavy rainfall prior to sampling, therefore

the wading survey was conducted by boat. High winds made boat work difficult and 10 point boat transects were not possible, although 5 points were achieved on both boat surveys.

3.9.4.5 Short core analysis

A 31 cm Glew core, GWYN2 (also known as CZSN87_2), was taken in a water depth of 6.8 m from Llyn Gwngu on 23-Sep-04. A summary diagram of the common taxa (>2%) is shown in Figure 3.9.15 and summary data are given in Table 3.9.27. The core top and bottom samples contained a total of 62 diatom taxa. The assemblage of the bottom sample was diverse with numerous non-planktonic species typical of moderately acid waters, including *Tabellaria flocculosa, Brachysira vitrea* and *Eunotia incisa*. The top sample was less diverse and contained higher amounts of *Eunotia incisa* along with a number of taxa indicative of strongly acid conditions, namely *Tabellaria quadriseptata*, *Peronia fibula*, and varieties of *Frustulia rhomboides*. The squared chord distance dissimilarity score between the two samples was 0.621.

Reconstructions of diatom-inferred pH (DI-pH) were produced using the SWAP training set. A high percentage of the taxa in the fossil samples were present in the SWAP training set and there were no major analogue problems (Table 3.9.27). The DI-pH values decline from 5.71 for the bottom sample to 5.26 for the top sample, indicating acidification. The annual mean current pH based on quarterly water samples collected during 2004-2005 is 5.95 and therefore the diatom model appears to under-estimate current pH by ~0.7 pH units.

In summary, there has been a significant degree of floristic change in the Llyn Gwngu core which indicates acidification of the lake. Nevertheless, the assemblage of the bottom sample contains many taxa associated with moderately acid waters, suggesting that the lake has been acid for the whole of the period represented by the core.

Figure 3.9.15 Summary diagram of diatom assemblages in top and bottom samples from core GWYN2 (CZSN87_2)

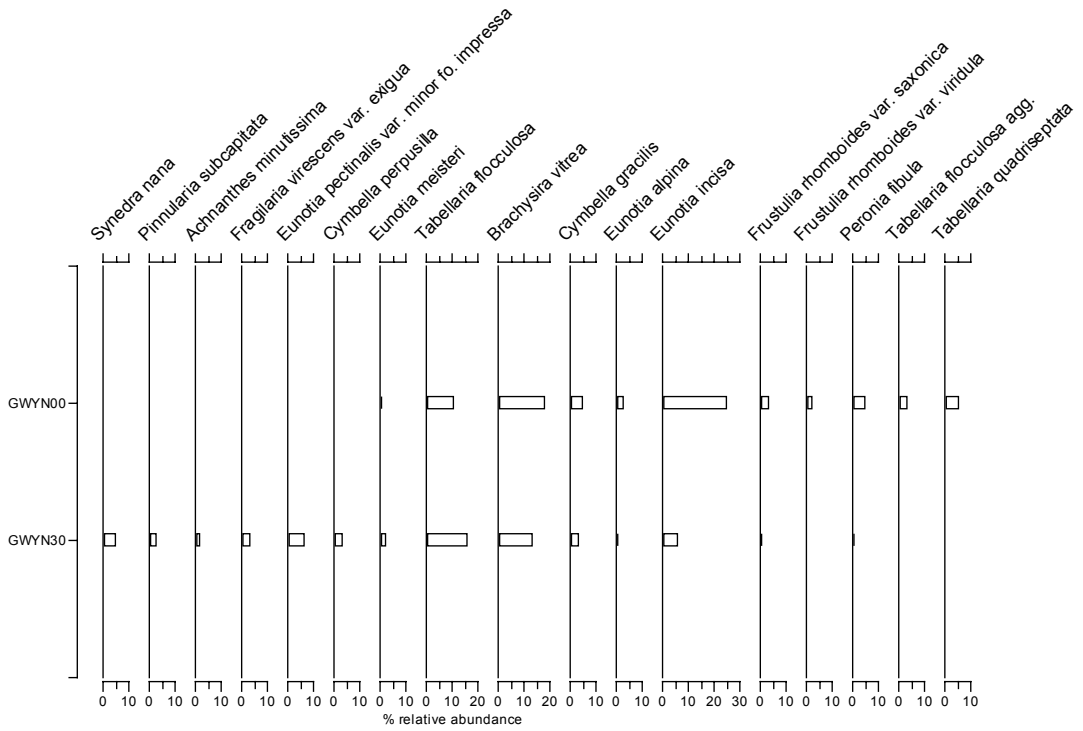


Table 3.9.27 Results of Llyn Gwngu short core analysis

Sample code	Depth (cm)	Annual mean current pH	DI-pH	No. taxa in fossil sample	% of taxa in fossil sample present in SWAP training set	Squared chord distance dissimilarity score between core top and bottom
GWYN00	0	5.95	5.26	30	96	0.621
GWYN30	30		5.71	51	92	

3.10 Kenfig / Cynffig SAC
Kenfig Pool

Location of SAC

SAC Details	
Grid Ref. (approx. centre)	SS790813
SAC EU Code	UK0012566
Total Area	1192 ha
Total area of Freshwater	30 ha

General site character:
Tidal rivers. Estuaries. Mud flats. Sand flats. Lagoons (including saltwork basins) (19%)
Salt marshes. Salt pastures. Salt steppes (1%)
Coastal sand dunes. Sand beaches. Machair (63%)
Shingle. Sea cliffs. Islets (4%)
Inland water bodies (standing water, running water) (2.5%)
Bogs. Marshes. Water fringed vegetation. Fens (0.5%)
Heath. Scrub. Maquis and garrigue. Phygrana (7.5%)
Broad-leaved deciduous woodland (2.5%)

Annex I habitats that are a primary reason for selection of this site
2130 Fixed dunes with herbaceous vegetation (`grey dunes`)
Kenfig is a largely intact dune system in south Wales with extensive areas of fixed dune vegetation with red fescue *Festuca rubra* and lady's bedstraw *Galium verum* and semi-fixed dune grassland with marram *Ammophila arenaria* and red fescue. There is also a relatively large area of more acidic vegetation dominated by sand sedge *Carex arenaria*, sheep's-fescue *Festuca ovina* and common bent *Agrostis capillaris*.
2170 Dunes with *Salix repens* ssp. *argentea* (*Salicion arenariae*)
Kenfig contains one of the largest series of dune slacks in Wales. The dune slacks are species-rich and there are extensive areas of dunes with *Salix repens* ssp. *argentea*, which represent a mature phase in dune slack development. This site is in the central part of the range of this community on the west coast and is a highly representative example of this habitat type.
2190 Humid dune slacks
Kenfig in south Wales contains the most important example of Humid dune slacks in the UK, owing to the extent of the habitat type and the conservation of its structure and function. These calcareous dune slacks are also amongst the most species-rich in the UK, supporting communities dominated by a variety of mosses and a number of rare plants, notably 1903 Fen orchid *Liparis loeselii*, for which the site is also selected. Some of the dune slacks on the site are still in the early successional stage of development.

3140 Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp.
Kenfig Pool is a shallow lake system within the extensive sand dune system of Kenfig, alongside Swansea Bay in south Wales. The water chemistry is indicative of a coastal, alkaline lake with a moderate nutrient status. High alkalinity, conductivity, sodium and chloride values reflect this marine influence. Elevated calcium values are probably derived from marine shell remains in the sandy substrate. Large stands of common reed *Phragmites australis* are found on the pool's seaward side. Grey club-rush *Schoenoplectus tabernaemontani*, sea club-rush *Scirpus maritimus*, branched bur-reed *Sparganium erectum* and yellow iris *Iris pseudacorus* are also present. A sheltered bay supports a plant association dominated by shining pondweed *Potamogeton lucens* and curled pondweed *P. crispus*. Hairlike pondweed *P. trichoides* is locally dominant in the north end and the south end has abundant rigid hornwort *Ceratophyllum demersum*, Canadian waterweed *Elodea canadensis*, fan-leaved water-crowfoot *Ranunculus circinatus,* spiked water-milfoil *Myriophyllum spicatum* and the charophytes *Chara aspera* var. *aspera* and *Nitella flexilis* var. *flexilis*. Shoreweed, *Littorella uniflora* can be found growing in association with *C. aspera* and the aquatic moss *Fontinalis antipyretica* along the sandy shore section. *C. aspera* also dominates the substrate off the grazed landward shoreline, to a depth of approximately 1.5 m.

The Annex I habitat 1330 Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*) is also presenting the SAC.

(JNCC, 2005b)

3.10.1 Kenfig Pool

3.10.1.1 Site Description

Kenfig Pool is situated on the south-east shoreline of Swansea Bay, 10 km to the south of the industrial conurbation of Port Talbot and 5 km to the north-west of the seaside resort of Porthcawl. A site description is given in Monteith (1996) and Davidson & Appleby (2003). There is public access to a beach area to the south side of the lake which is used for paddling and bathing.

Information on the solid geology of the Kenfig Pool catchment and land cover data are given in Tables 3.10.1 and 3.10.2 respectively. A catchment map is given in Figure 3.10.1.

Table 3.10.1 Solid geology of Kenfig Pool catchment
(Data from British Geological Survey solid geology data at 1:62,500)

Name	Type	Percentage cover
Triassic mudstones including Keuper Marl, Dolomitic Conglomerate and Rhaetic	Sedimentary	100

Table 3.10.2 Land cover data for the Kenfig Pool catchment
(Data from CCW Phase 1 Habitat Survey)

Classification	Code	Percentage cover
Grassland and marsh		
Semi-improved neutral grassland	B.2.2	2.6
Improved grassland	B.4	50.9
Open water		
Standing water	G.1	14.3
Coastland		
Dune slack	H.6.4	1.2
Dune grassland	H.6.5	11.6
Miscellaneous		
Arable	J.1.1	10.7
Caravan site	J.3.4	1.4
Buildings	J.3.6	2.2
Other*		5.1

* Percentage cover >1% and /or data not available

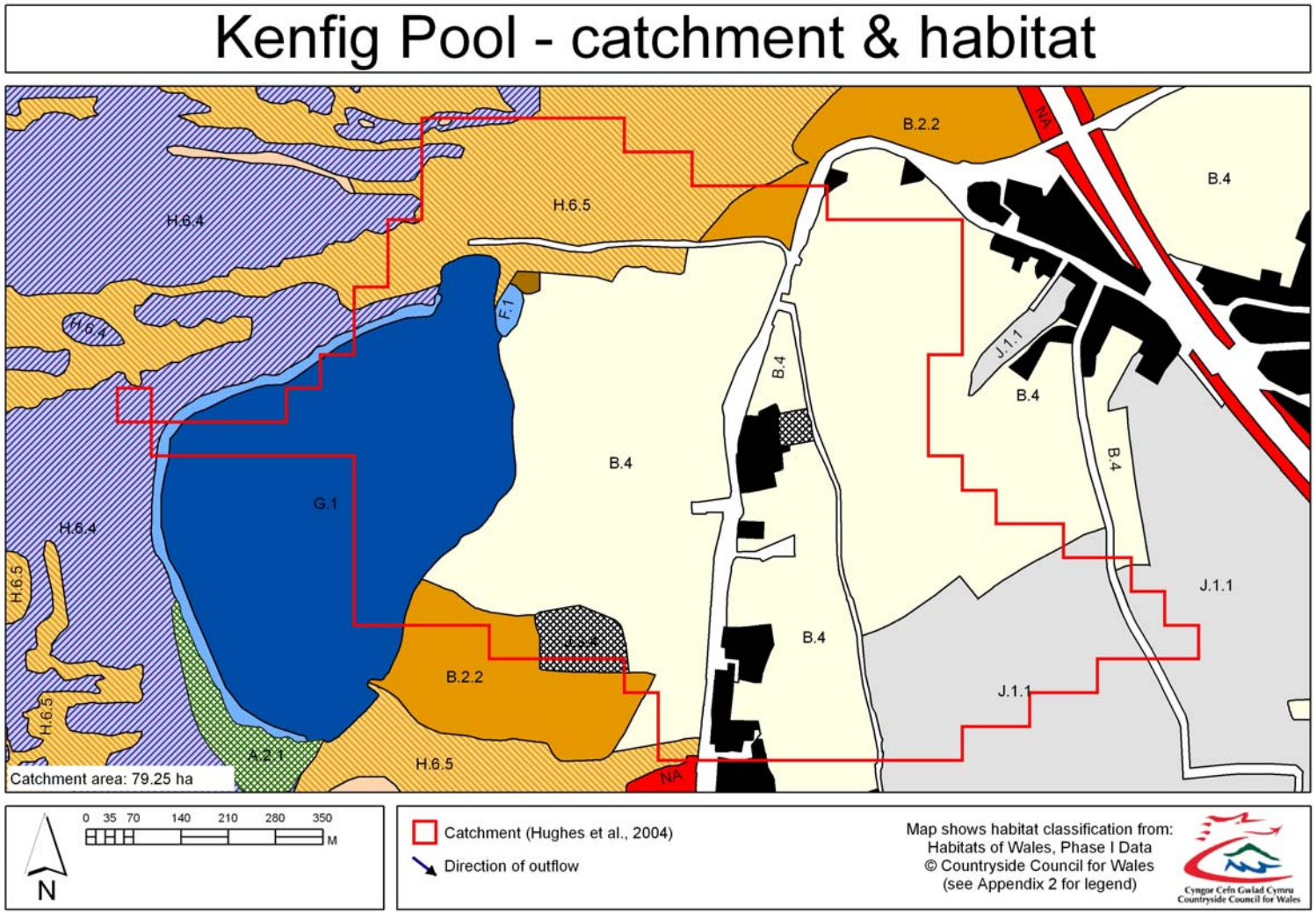
3.10.1.2 Bathymetry

A bathymetric map was not required as part of this study (bathymetric information is given in Monteith (1996)). Physical and morphometric parameters are given in Table 3.10.3.

Table 3.10.3 Kenfig Pool - physical and morphometric parameters

Lake altitude (m)	15
Maximum depth (m)	2.6
Mean depth (m)	1.8
Lake volume ($x10^3m^3$)	525.3
Area of lake surface (ha)	29.2
Perimeter of lake (km)	2.5
Shoreline development index	1.28
Estimated hydraulic residence time (days)	475.3
Secchi disc depth (m)	1.72
Catchment area (ha)	79.3
Catchment to lake area ratio	2.7

Figure 3.10.1 Kenfig Pool catchment map



3.10.1.3 Physico-chemical data

Temperature and oxygen profiles for Kenfig Pool are given in Figure 3.10.2 and water chemistry data shown in Table 3.10.4.

Figure 3.10.2 Temperature and oxygen profiles for Kenfig Pool

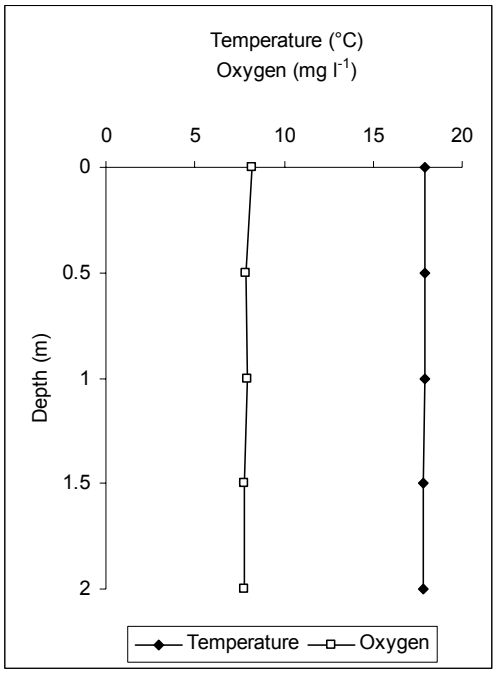


Table 3.10.4 Water chemistry data for Kenfig Pool

	Oct 03	Jan 04	Apr 05	Jul 05	Annual mean
pH	7.6	8.1	8.2	8.3	7.9
Cond	325	346	343	183	299
Alk	1804	1935	1984	508	1558
DOC	-	-	4	2	n.c.
SRP	-	7	7	13	n.c.
TP	16	28	8	28	20
Chl *a*	5.4	2.3	2.1	6.0	3.9
TN	1.01	0.89	0.20	0.25	0.59
NO_3^--N	0.18	0.30	0.06	0.12	0.16
Labile Al	-	-	-	-	-
SO_4^{2-}			580	528	n.c.
Total Fe	-	-	-	-	-
Na^+	-	-	-	-	-
K^+	-	-	-	-	-
Mg^{2+}	-	-	-	-	-
Ca^{2+}	-	-	2375.2	763.5	n.c.
Cl^-	-	-	978.5	693.7	n.c.
Total Mn	-	-	-	-	-
ANC	-	-	-	-	-

(n.c. – not calculated, one or more values below analytical detection)
(- denotes data not collected or analysed)

3.10.1.4 Macrophyte survey

Results of the macrophyte survey are given in Tables 3.10.5 and 3.10.6.

Table 3.10.5 Macrophyte abundance for Kenfig Pool – emergent and marginal survey

Taxon	DAFOR Abundance
Equisetum palustre	**O**
Myosotis scorpioides	**O**
Mentha aquatica	**A**
Lycopus europaeus	**A**
Rumex hydrolapathum	**O**
Ranunculus flammula	**O**
Berula erecta	**R**
Hydrocotyle vulgaris	**F**
Phragmites australis	**D**
Schoenoplectus tabernaemontani	**O**
Bolboschoenus maritimus	**A**
Ranunculus lingua	**O**
Lysimachia vulgaris	**R**
Iris pseudacorus	**A**
Persicaria amphibia	**A**
Persicaria maculosa	**F**
Baldellia ranunculoides	**R**
Eleocharis palustris	**R**
Sparganium erectum	**O**
Littorella uniflora	**F**
Potentilla anserina	**O**
Epilobium hirsutum	**O**
Filipendula ulmaria	**R**
Eupatorium cannabinum	**R**
Menyanthes trifoliata	**R**
*Ranunculus cf circinatus**	**O**
Alisma plantago-aquatica	**R**
Juncus effusus	**R**
Solanum dulcamara	**R**
Juncus articulatus/acutiflorus	**R**

** capillary leaves only – rooted on shore*

Table 3.10.6 Macrophyte abundance for Kenfig Pool – wading and boat survey

Taxon	DAFOR Abundance
Alisma plantago-aquatica	**R**
Bolboschoenus maritimus	**O**
Ceratophyllum demersum	**R**
Chara aspera	**D**
Chara virgata	**D**
Equisetum palustre	**R**
Elodea canadensis	**R**
Fontinalis antipyretica	**F**
Lemna trisulca	**R**
Littorella uniflora	**O**
Myriophyllum alterniflorum	**O**
Myriophyllum spicatum	**F**
Nitella flexilis	**R**
Phragmites australis	**F**
Persicaria amphibia	**F**
Potamogeton pusillus	**F**
Potamogeton trichoides	**A**
Potamogeton gramineus	**R**
Potamogeton x nitens	**O**
Ranunculus circinatus	**F**
Schoenoplectus tabernaemontani	**O**
Zannichellia palustris	**R**

No additional species were recorded in a strandline survey. Many of the fine leaved *Potamogeton* species had died back making identification uncertain; no *P. pectinatus* was found. The majority of decayed material at greater depth was assumed to be *P. trichoides* based on a few better preserved specimens.

3.10.1.5 Short core analysis

Short core analysis was not required as part of this study. Epilithon and surface diatom taxon lists are given in Monteith (1996).

3.11 Pembrokeshire Bat Sites and Bosherston Lakes/ Safleoedd Ystlum Sir Benfro a Llynnoedd Bosherston SAC

Bosherston Lily Pond (Central Arm)

Location of SAC

SAC Details

Grid Ref. (approx. centre)	SR966954
SAC EU Code	UK0014793
Total Area	122 ha
Total area of Freshwater	40 ha

General site character:
Inland water bodies (standing water, running water) (33%)
Bogs. Marshes. Water fringed vegetation. Fens (5%)
Heath. Scrub. Maquis and garrigue. Phygrana (13%)
Dry grassland. Steppes (3%)
Improved grassland (1.8%)
Broad-leaved deciduous woodland (29%)
Mixed woodland (15%)
Other land (including towns, villages, roads, waste places, mines, industrial sites) (0.2%)

Annex I habitat that is a primary reason for selection of this site
3140 Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp.
Bosherston Lakes are an outstanding shallow marl lake system created at intervals in the late 18th and mid 19th centuries by damming a limestone river valley. They are fed in part by a series of calcium-rich springs and are isolated from the sea by a small sand dune ridge. Charophytes are represented by bristly stonewort *Chara hispida* which forms dense beds up to 1 m high, with individual plants up to 3.5 m long, and by variable quantities of *C. globularis, C. virgata* and *C. vulgaris*. Extensive white water lily *Nymphaea alba* beds also occur, mainly in the western and central arms. In contrast, the eastern arm is characterised by variably dense stands of curled pondweed *Potamogeton crispus*, fennel pondweed *Potamogeton pectinatus*, spiked water-milfoil *Myriophyllum spicatum* and Canadian waterweed *Elodea canadensis*. Emergent vegetation fringes parts of the system, mostly common reed *Phragmites australis*, greater reedmace *Typha latifolia*, common spike-rush *Eleocharis palustris* and branched bur-reed *Sparganium erectum*.

(JNCC, 2005b)

3.11.1 Bosherston Lily Ponds

3.11.1.1 Site Description

Information on Bosherston Lily Ponds is given in Davidson *et al* (2002) and the solid geology of the Bosherston Lily Ponds catchment and land cover data are given in Tables 3.11.1 and 3.11.2 respectively. A catchment map is given in Figure 3.11.1.

Table 3.11.1 Solid geology of the Bosherston Lily Ponds catchment
(Data from British Geological Survey solid geology data at 1:62,500)

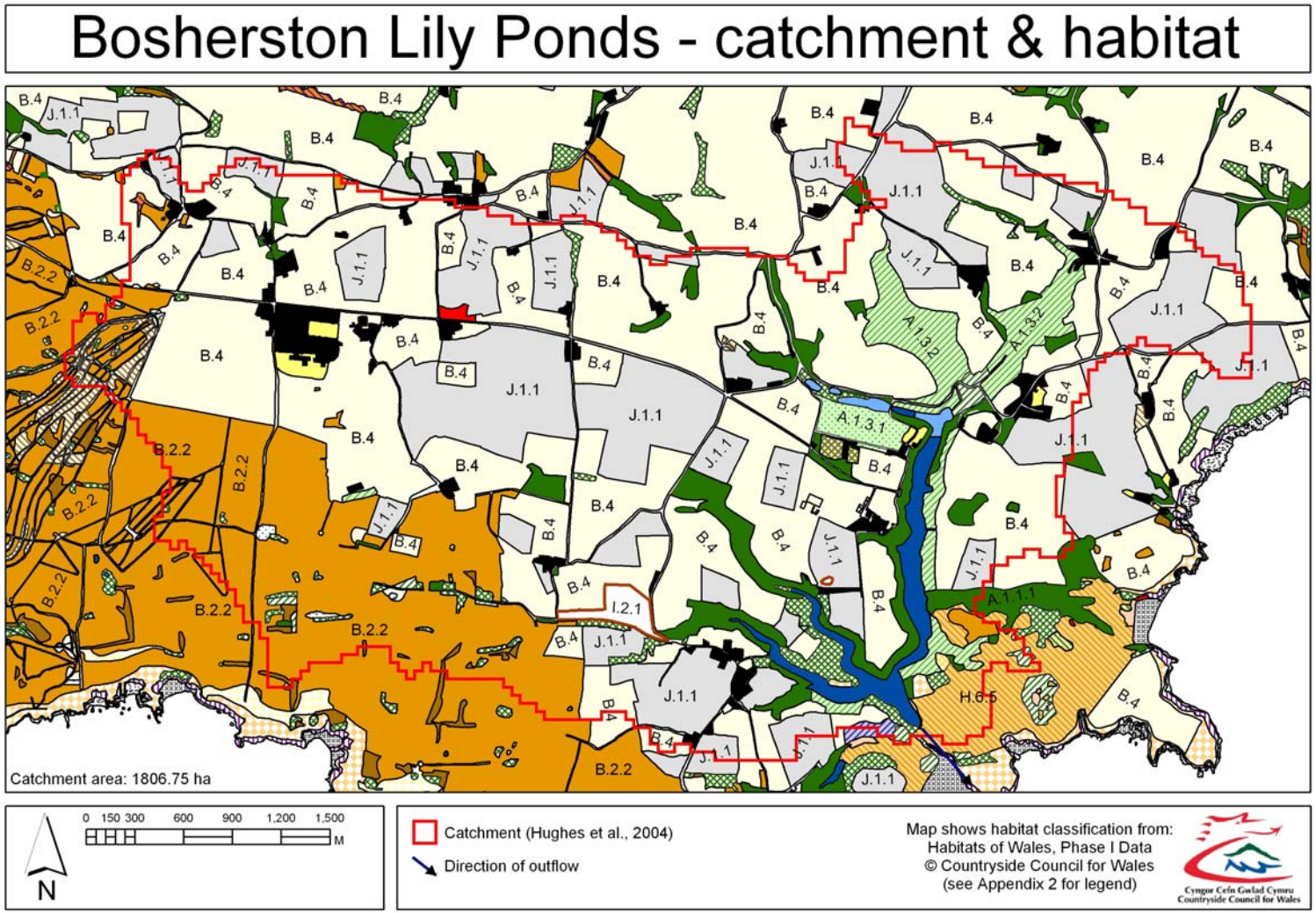
Name	Type	Percentage cover
Lower Devonian (England and Wales only)	Sedimentary	14.6
Upper Old Red Sandstone	Sedimentary	9.3
Tournaisian and Visean (Carboniferous Limestone Series)	Sedimentary	76.1

Table 3.11.2 Land cover data for the Bosherston Lily Ponds catchment
(Data from CCW Phase 1 Habitat Survey)

Classification	Code	Percentage cover
Woodland and scrub		
Semi-natural broadleaved woodland	A.1.1.1	4.6
Planted mixed woodland	A1.3.2	3.7
Dense scrub	A.2.1	1.6
Grassland and marsh		
Semi-improved neutral grassland	B.2.2	14.1
Improved grassland	B.4	43.6
Open water		
Standing water	G.1	1.7
Coastland		
Dune grassland	H.6.5	1.3
Miscellaneous		
Arable	J.1.1	20.6
Buildings	J.3.6	2.6
Other*		6.2

* Percentage cover >1% and /or data not available

Figure 3.11.1 Bosherston Lily Ponds catchment map



3.11.1.2 Bathymetry

A bathymetric map was not required as part of this study. Physical and morphometric parameters are given in Table 3.11.3.

Table 3.11.3 Bosherston Lily Ponds- physical and morphometric parameters

Lake altitude (m)	2
Maximum depth (m)	17.8
Mean depth (m)	7
Lake volume ($x10^3m^3$)	2,348.8
Area of lake surface (ha)	33.7
Perimeter of lake (km)	8.9
Shoreline development index	4.32
Estimated hydraulic residence time (days)	104.2
Secchi disc depth (m)	>1.0
Catchment area (ha)	1806.8
Catchment to lake area ratio	53.6

3.11.1.3 Physico-chemical data

Temperature and Dissolved Oxygen Measurements: The surface temperature was 16.5^oC and surface oxygen levels were 4.64 mg l^{-1}, but *Chara* growth was too dense to allow further measurements to be taken. Water chemistry data are given in Table 3.11.4.

Table 3.11.4 Water chemistry data for Bosherston Lily Ponds (Central Arm)

	Aug 03	Nov 03	Mar 04	Jun 04	Annual mean
pH	8.4	7.5	8.6	8.0	7.8
Cond	534	538	600	405	519
Alk	3477	3428	3821	2050	3194
DOC	-	-	-	2.44	n.c.
SRP	-	-	-	12	n.c.
TP	-	-	-	62	n.c.
Chl *a*	-	-	-	1.5	n.c.
TN	-	-	-	0.70	n.c.
NO_3^--N	-	-	-	0.31	n.c.
Labile Al	-	-	-	-	-
SO_4^{2-}	-	-	-	395	n.c.
Total Fe	-	-	-	-	-
Na^+	-	-	-	-	-
K^+	-	-	-	-	-
Mg^{2+}	-	-	-	-	-
Ca^{2+}	-	-	-	1941.1	n.c.
Cl^-	-	-	-	1708.9	n.c.
Total Mn	-	-	-	-	-
ANC	-	-	-	-	-

(n.c. – not calculated, one or more values below analytical detection)
(- denotes data not collected or analysed)

3.11.1.4 Macrophyte survey

Results of the macrophyte survey are given in Tables 3.11.5 and 3.11.6. Difficult access made a survey of the entire lake impossible and very steep rocky banks prevented shore access to all but the southern end. Boat access was restricted by very extensive growth of *Chara hispida* to the surface (calcified and decayed) and by a 10 m fringe of *Nymphaea alba.*

The dense degraded *Chara* also prevented depth measurements being accurately established.

Table 3.11.5 Macrophyte abundance for Bosherston Lily Ponds – emergent and marginal survey

Taxon	DAFOR Abundance
Phragmites australis	**D**
Sparganium erectum	**A**
Solanum dulcamara	**A**
Mentha aquatica	**A**
Hydrocotyle vulgaris	**A**
Bolboschoenus maritimus	**O**
Lythrum salicaria	**F**
Persicaria amphibia	**R**
Schoenoplectus lacustris	**R**
Alisma plantago-aquatica	**R**
Eupatorium cannabinum	**R**
Juncus effusus	**R**
Juncus articulatus/acutiflorus	**R**
Potentilla palustris	**R**
Nymphaea alba	**D**

Table 3.11.6 Macrophyte abundance for Bosherston Lily Ponds – wading and boat survey

Taxon	DAFOR Abundance
Chara hispida	**A**
Bolboschoenus maritimus	**O**
Berula erecta	**R**
Lemna trisulca	**D**
Fontinalis antipyretica	**R**
Nymphaea alba	**D**
Phragmites australis	**A**
Sparganium erectum	**F**
Schoenoplectus lacustris	**R**

A strandline survey recorded the presence of *Elodea canadensis*.

3.11.1.5 Short core analysis

Short core analysis was not required as part of this study. A number of sediment cores taken from Bosherston Lily Ponds were analysed for diatoms in a report by Davidson *et al* (2002).

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APPENDIX 1

Macrophyte surveys of standing waters

Rationale

The Water Framework Directive requires a measure of the composition and abundance of aquatic vegetation as part of the process of assessment of ecological quality of standing waters. This must be sufficiently sensitive to recognise deviations in the composition and abundance of vegetation from that which would be expected in lakes of a given type under reference conditions.
The methods proposed here have been devised with the following considerations in mind:

1. They yield quantitative data that is unambiguous and can be collected readily in a repeatable manner by different surveyors.
2. They optimise the chance of recording those species most typical of a site and detecting marked changes in their abundance
3. They require minimal specialist equipment or access to specially trained personnel.
4. They are adaptable to a range of different situations.
5. They yield data that is compatible with existing databases.
6. They are compatible with methods used previously in the collection of data that will form the basis for predictions of macrophyte composition under reference condition.
7. They are compatible with other methods currently in use in the UK or Europe including methods currently under development for use in Site Condition Monitoring of Standing Waters within SACs

All potential survey methods have strengths and weaknesses and will potentially give a different picture of the composition and abundance of the aquatic vegetation at a site. A detailed comparison of available methods is outside the scope of the present recommendations. Moreover, there is no single method or suite of methods that is universally applicable to standing waters found in the UK. The methods proposed below are essentially a formalised amalgamation of several previously well trialled approaches to surveying macrophytes in standing waters and are designed to provide quantitative data of low subjectivity that is obtainable in a pragmatic and repeatable manner. These proposals have been prepared by Nigel Willby, Iain Gunn and Laurence Carvalho. However, they draw significantly on the outputs of previous contracts and workshops and the survey experience of several individuals not specifically associated with the LEAFPACS project including Angela Darwell, Max Wade, Nick Stewart, Richard Lansdown, Mary Hennesy and Olivia Lassiere.

Survey methods

Selection of sample sites

Previous surveys have tended where possible to circumnavigate a water body by boat or on foot, recording at fixed or random points or simply where the vegetation looks interesting. This technique may be useful for generating comprehensive species lists for a site. However, it does not yield easily quantifiable data, it is relatively insensitive to changes in vegetation composition,

especially in large sites, it can be time consuming for very large sites (>500ha), and is highly susceptible to the skill, decisions and assessments of individual observers.

The approach adopted here is to subdivide a water body into discrete sampling units. Within each of these units surveys are undertaken of approx. 100m of shore, strandline and the shallowest part of the littoral zone (<0.75m). Deeper water habitats are surveyed based on a boat transect running perpendicular from the shore to the depth of maximum colonisation (see 2.2.4), leaving the shore at the mid point of the 100m shore transect. Where a water body is of a simple shape and there is no previous survey information the basic approach will be to subdivide it into quadrants based on major compass points. In larger or more complex sites, it may be necessary to define several basins or bays before applying this approach. Guidance on the location of sampling units can be obtained by reference to large scale maps, bathymetric maps, previous vegetation surveys, local landuse and geological surveys and by consultation with local agency staff, surveyors or other experts familiar with particular sites. As a general rule at least one unit should be located within a sheltered bay or near to the lake inflow where fine sediment is likely to accumulate, while another unit should encompass an area of shoreline with a large wave fetch, where uprooted material is likely to be deposited. Generally there should be very few sites that surveyors are visiting completely blind (i.e. without access to any previous survey data or expertise). Surveyors should be aware of the potential need to modify the locations of sampling units once in the field to take account of access and proximity to the road/parking and any restrictions imposed by local landowners.

It is difficult to be prescriptive about the number of sampling units used in a site because this depends partly on factors other than site area such as shoreline complexity, local topography, accessibility, numbers of inflows etc. Generally however, unless a site is very uniform or has highly regulated water levels, water bodies >500ha will require eight sampling units to be visited. By contrast, four sampling units will probably suffice in most sites <50ha in area. Note that to prevent excessive disturbance of very small lochans and pools, the total survey length should not be more than approximately 25 % of perimeter length.

Basic survey requirements

Equipment

Waterproof clothing
Life jacket
Mobile phone with waterproof housing
Walkie talkies (may also prove helpful to enable the survey teams to maintain contact).
Folding clipboard with hood and cheap propelling pencils
Field recording sheets (supplied) photocopied onto waterproof paper
Chest waders or dry suits
Double headed rake dressed with chicken wire on 5m rope (2) for shoreline survey and on 15m rope for boat based survey (2)
Bathyscope
Hand lens for field identification of specimens
Graduated 10m plumb line for measuring water depths from boat
Plastic bags and waterproof labels for sample
GPS
Large scale maps of site photocopied onto waterproof paper
Copies of any previous survey data

Brightly coloured sack to act as shoreline marker for aligning boat transect

Sample collection and storage

If a species is encountered which cannot be identified in situ, a specimen should be collected and bagged for later identification/verification. Surveyors are to note that specimens must not be taken where there are only one or two plants of this species present. Where specimens are taken, it is advisable to collect an entire plant including root/rhizome. Specimen bags are to be clearly labelled using waterproof paper filled out in pencil bearing the date, site name, name of surveyor, code name used for the species and the sampling unit in which it was collected.

Charophytes and *Utricularia* specimens should be placed in bottles with 75% alcohol (IMS). *Potamogeton* and *Callitriche* specimens can be preserved in 75% alcohol, but ideally should be floated onto plain paper positioned underneath the specimen in a sorting tray. Label the sheet as per the details on the field card, cover with a piece of greaseproof paper and then press amongst old newspapers.

Training

At least two of the three personnel involved in a survey should have extensive existing experience of macrophyte surveys of standing waters and aquatic plant identification. Specifically surveyors should have been previously employed on a major sampling campaign such as the SNH Loch Survey, have undertaken satisfactory contract surveys of over 50 sites or have attended a residential field course in macrophyte identification, such as those run by the Field Studies Council. To maximise knowledge transfer and quality control it is desirable for previous expertise to be distributed evenly across several teams rather than concentrated in a single team. It is appreciated that very few personnel will be able to confidently and correctly identify some taxa in the field; of greater importance in this respect is the ability to recognise that several different un named taxa are present and to collect appropriately labelled samples.

All personnel must have received training in basic First Aid and the principles of field based Risk Assessment. Staff involved in boat use should have been sent on a formal Power Boat Handling Course. It is a basic expectation that all staff are competent swimmers should this be required.

Safety considerations

The minimum number of personnel for a comprehensive survey as detailed below is three. This can be reduced to two if it is known in advance that a boat based survey is not possible or is inappropriate (see 3). The two surveyors on the boat must both wear compact life jackets at all times. It may prove safer and more comfortable for one of the shore based personnel to wear a membrane dry suit in preference to chest waders. Under no account should wader or boat based surveys be undertaken by lone personnel. Working in pairs is generally more efficient and less prone to error because tasks can be swapped which reduces tedium. The shore and boat based personnel must each have access to basic first aid supplies and a mobile phone kept in waterproof housing. The location of each survey team must be left with an independent person in advance of teams leaving for a site and any modifications to this program must be communicated to that person. Training in basic first aid, power boat handling and field risk assessment is required in advance for all personnel.

Survey protocols

The survey of macrophytes in a standing water body incorporates three components. It is important to appreciate that these are complementary not alternative methods. Field recording sheets are provided for the completion of each part of the survey using the techniques described below. A separate sheet must be completed for each sampling unit studied.

Perimeter survey and strandline search

For each 100 m section identified above, the surveyor records any easily viewed plants and drift material (plant fragments) encountered along the strandline [record presence/absence under submerged, floating, etc.].

The extent of the strandline in a given unit should be scored according to the following scale:
1: very sparse – one or two plants at wide intervals
2: common – more or less continuous unheaped line of material
3: extensive – continuous 'mound' of plant material

This offers an indication of the degree of exposure of different sampling units, the timing of the survey with respect to major storm events, and the abundance of aquatic vegetation within the waterbody itself.

It should be noted that no entry to the water itself is required as part of this component of the survey. In the event that a boat is unavailable particular attention must be given to searching strandline vegetation to ensure that as many of the aquatic species present in the water body are detected. On many occasions strandline surveys have also revealed species not recovered by intensive boat based sampling. If time is a major constraint, subsamples of strandline material may be collected and taken back to a base for sorting in trays.

Additionally record all emergent and marginal species plus any rooted submerged or floating leaved aquatic species "stranded" above the water line by receding water levels. In each unit species should be scored by cover (within the zone between waters edge and HWM and over the extent of the 100m strip) on a three point scale: viz; 1 = <1% cover; 2 = 1 25% cover; 3 = >25% cover. At end of whole site survey, estimate site DAFOR abundance of species recorded, according to the following guidelines:

	% of units in which present		
Median % cover within units	<25	25 50	>50
<1	R	O	F
1 25	O	F	A
>25	F	A	D

Finally list main edge vegetation type [wetland, moorland, pasture, trees] with as much taxonomic detail as possible. Ideally this should take the form of an NVC code.

Also note any signs of lakeshore/inflow/outflow modifications. Take a note of the approx lateral distance between current waters edge and high water mark (HWM) as an indicator of recent water level change, obvious water quality problems or other pressures/activities.

Shoreline wader survey

The sampling is undertaken by two surveyors, one remains on the shore and records the data, the second, wearing chest waders or dry suit, and equipped with a bathyscope and weed rake, wades out into the loch. The waders are calibrated to read water depth in 25cm intervals.

A sensible starting point representative of the sampling unit is determined on the ground and the point fixed using a GPS. At this point, four point samples are taken at 0.25 m, 0.5 m, 0.75 m and >0.75 m water depth.

At the three shallowest depths, the following occurs:

- A bathyscope survey (aided by rake sampling) of a 1 m^2 area at the target depth recording all species present, with an estimation of total vegetation cover within the 1 m^2 area (vegetation is graded 0 3, 0 being absent (bare substrate), 1 being less than 25% cover, 2 being between 25 to 75% cover, 3 being more than 75% cover).

- A 4 m long rake throw out along the target depth parallel to the shore, recording all species present

Following the 0.75 m depth sample, the surveyor wades out into the lake to establish a position where the lake depth ahead is greater than 0.75 m. The wading pole is to be used to estimate water depth ahead during sampling and to provide a safe footing. At this point, the surveyor is to throw the rake out into the lake, perpendicular to the shore, and obtain a 4 m long trawl of the lakebed [this requires 5 m of rope to be thrown out assuming the rake is pulled up from water about 1 m from surveyors feet]. Using this approach a 25cm rake will sample approx. 1m^2 of lake bed. All species retrieved on the rake are recorded as presence/absence plus an assessment of the overall abundance of vegetation on the following scale: 0 = macrophytes absent, 1 = two or less rake teeth covered (usually only two or three fragments of material present), 2 = several rake teeth covered, 3 = all teeth covered). It should be noted that the ability of a rake to sample and retain plant material is dependent to some extent on plant growth form. Thus, many small species, particularly those of an isoetid growth form, are likely to be poorly retained by the rake but also uproot very easily. Generally material of such species is very buoyant and surveyors should therefore check the water surface carefully after retrieving an apparently empty rake to look for floating plants. The spot samples from the three shallowest depths should provide an indication of whether lawns of isoetid species dominate the vegetation at a site.

The surveyor then returns to the shore and repeats the above process at a further four sampling points distributed at approx. 20 m intervals paced out along the shore section with sampling carried out at each of the four depths as stated above. Thus 20 (5 x 4) regular spot samples are taken in this part of the survey. The shoreline location of the last (tenth) sampling location is fixed with the GPS.

Note that if most of the shoreline within a sampling unit is inaccessible from the perspective of a wader based survey (e.g. due to extensive emergent reedswamp, alder/willow carr, or deep water) it is not desirable to undertake surveys in the single unrepresentative length in which the methods described can be applied. Modifications to deal with such circumstances are discussed in Table 1.

As a final consideration, if the entire bed of a waterbody is visible from the bank or by viewing with a bathyscope surveyors should refrain from the use of rakes in order to avoid unnecessary damage to beds of submerged plants. This applies especially to small pool complexes that may contain significant populations of uncommon or rare, slow growing species.

Boat based survey

A large, coloured marker (bag, buoy etc) is placed on the shoreline to mark the centre of the 100 m paced shore wader transect used above. A GPS fix is recorded for this position.

The boat travels out into the lake from this marker, perpendicular to the shore, and using a combination of bathyscope viewing and grapnel sampling, the maximum depth of macrophyte colonisation is determined and the water depth at this point is recorded. If it is apparent that the whole of the lake bed is vegetated then the transect should finish at the mid point of the lake or the interface between opposing sampling units. A GPS reading is then taken and the distance from shore estimated from the GPS output or co ordinates. A series of 10 approximately regularly spaced sample points are then surveyed back from the maximum depth of colonisation to the shoreline.

At each of the 10 points, the following should be carried out:

- The boat is anchored
- If the bed is visible using the bathyscope the species visible in one field of view are recorded. Failing this a 4 m length rake trawl (approx 1 m^2) should be collected adjacent to the boat
- Using a combination of bathyscope and rake sampling, all species occurring within a 1 m^2 area should be recorded, and the overall abundance of vegetation should be estimated on a 0 3 point scale (as in the shoreline wader method)
- The water depth for each quadrat/sampling point should be recorded

If any species are encountered which cannot be identified in situ, they are to be collected, bagged and stored for later identification.

In some large sites, especially those with limited road access, transport by boat may prove to be the only effective means of conveying surveyors around a site. If, when boating from one sampling unit to another, surveyors come across a population of a hitherto unrecorded species a note should be made of this on the main sample sheet for the site that provides room for general observations.

Overall survey approach

Assuming that three surveyors are available the most efficient deployment of manpower will be for all personnel to go to the sampling unit by boat and drop off the shore based surveyor. This person will undertake the perimeter and strandline survey while the other two surveyors carry out the boat based survey. These surveyors should then return to the shore, one of whom should record the data as it is collected during the shoreline survey while the other takes notes on environmental features or prepares equipment for the next sampling unit. Using the combination of approaches described here it may be possible to sample four units per day. Thus, adequate time should be allocated to surveys of large well vegetated sites where up to eight units may require sampling.

Applying different survey methodologies – extenuating circumstances

The ideal survey of macrophytes in a standing water body will use all three techniques described above in an integrated manner. It is recognised that this tier of survey methods will not be applicable or appropriate at all sites. Valid reasons for excluding one or more methods are given in the table below with options for modifying the other protocols.

Table 1. Reasons for not using certain methods and possible solutions

Method	Valid reason for not using	Solution
Perimeter and strandline survey	• Entire water body surrounded either by emergent reedswamp, quaking bog, steeply shelving or artificial shoreline. • Extensive, unvegetated drawdown zone (probably unique to reservoirs)	• Observe marginal vegetation by navigating parallel and as close as possible to the shore in a boat • Confirm using binoculars and note type of terrestrial vegetation at bank edge (Phase 1 standard)
Shoreline wader survey	• Entire water body surrounded either by emergent reedswamp to a depth >0.75m, very soft sediment, or >0.75m deep at waters edge (e.g. associated with floating mire, steeply shelving or artificial shoreline)	• Undertake equivalent survey by boat parallel to shore. Record composition of emergent swamp. If vegetation entirely aquatic, anchor boat at 0.5m depth, parallel to shore and use rake throws to cover points at 0.25 and 0.5m
Boat based transects	• Boat not available or transportable to site due to site remoteness. • Site too densely vegetated to allow use of boat • Too windy or exposed to maintain position in open water • Entire lake bed < 75cm • Wader survey indicates no vegetation beyond 0.75m	• If bank slope permits add a sampling station at 1m (waist) water depth to shoreline wader survey. Use all personnel for inspection of strandline aquatic material. Use binoculars to identify any beds of floating –leaved spp in deeper water, taking advantage of any nearby vantage points. • Take additional samples along transect parallel to shore at c1m depth using rake trawls perpendicular to the shore N/A N/A

Integrating data from different methods and sampling units into an overall measure of lake macrophyte composition

To combine the data from different methods and sampling units into a valid measure of the cover of different species at a site scale consideration of the type of data collected is required. Some estimate of the area covered by each method and of the different units must also be made to act as a weighting factor.

The shoreline method collects well replicated samples from a (potentially) narrow marginal strip of the littoral zone while the boat based survey collects spatially unreplicated data between the waters edge and the depth of maximum colonisation or the centre of the water body. In terms of assessing the macrophyte assemblage of the water body these two surveys yield different currencies of data. In the first place the simplest option will be to express the shoreline survey data for each depth sampled as percentage presence out of the 5 spot samples taken. This data can then be viewed as an intensively sampled shoreline end of the boat transect. However, even having done this these data points cannot be regarded as equivalent to the spot samples collected along the boat transect because the shoreline area (between the waters edge and 0.75m) may have been oversampled relative to the dispersion of the 10 points along the boat transect. For example, if the shoreline survey extends on average for 10m horizontally from the shore to the point at which the >0.75m sample is collected while the boat transect extends 100m out from the shore, the points on the boat transect are 'worth more' ((100/10)/(10/4) = 2 times as much) in terms of assessing the overall lake macrophyte community than the shoreline based points. If the density of sampling points in the two surveys is the same then the data points are worth the same. If on the other hand, the vegetated zone is highly compressed beyond the maximum depth considered by the shoreline survey, the shoreline data may be worth more than the boat transect data.

The same consideration applies to different sampling units. For example, the 20 spot samples collected from a shallow bay in which vegetation extends 100m from the shore are worth more than the 20 spot samples collected from an eroding, steeply shelving section of shoreline where the maximum depth of colonisation may occur within 5m of the shore. Weighting of the different sampling units to reflect this difference is thus required.

A final data sheet that takes the data from the various surveys and sampling units and aggregates it in an unbiased way will be prepared. The key additional requirement of this datasheet is information on the length of transect covered by different survey methods and in different sampling units. The average distance between the shore and the outermost of the four sampling points covered by the shore based survey should be estimated visually using the wading pole. For the boat based transect this information can be derived from the GPS readings. When returning the results of surveys it is critical that all paper copies of the data are provided and the information collected is transcribed to an electronic version of the recording sheets provided.

Overall measures of macrophyte abundance

The WFD requires an assessment of the abundance of macrophytes in a standing water body in addition to their composition. In theory the overall volume of a water body occupied by macrophytes could increase or decrease significantly independently of any change in the species composition of the vegetated zone. Two items of data collected as part of these surveys therefore provide key information on the overall abundance of macrophytes within a water body:

- The maximum depth of colonisation, Z_v

- The median rating of macrophyte volume within the vegetated zone

The data on frequency of occurrence of species within spot samples may complement the above information (e.g. if gaps in the plant cover result in zero scores) but this only relates to the occurrence of plants within the zone that is vegetated at the time of the survey.

The maximum depth of colonisation is effectively an indicator of the euphotic depth (i.e. the threshold depth at which net photosynthesis is possible). A general deterioration in the light climate will be reflected in a reduction in Z_v. Likewise plants will extend deeper if there is a clear directional improvement in water clarity that allows light penetration to greater depths. In general, given its ease of measurement, it will also be useful to collect data on Secchi disc depths (Z_s) in addition to estimating the lower limit of macrophyte growth to ensure that the two are broadly in equilibrium. If macrophytes are controlled by other factors such as the availability of a suitable rooting medium they may not extend to the theoretical maximum depth. A mismatch between Z_s and Z_v may also suggest that the measured Z_s is atypical of light conditions recently encountered.

Within the zone where net production is possible various factors, natural or human mediated, may constrain the volume of plant material relative to other comparable lakes, including wave action (or recreational disturbance), water level fluctuations, type of substrate and its stability, carbon availability, or grazing by water birds. Non directional inter annual variability in submerged light conditions due, for example, to variation in phytoplankton densities, could also contribute to changes in macrophyte volume without necessarily translating to a change in Z_v. Volume will be a particularly useful measure when Z_{eu} is equal to or greater than Z_{max} (i.e. the whole lake could potentially be vegetated).

Collection of environmental data

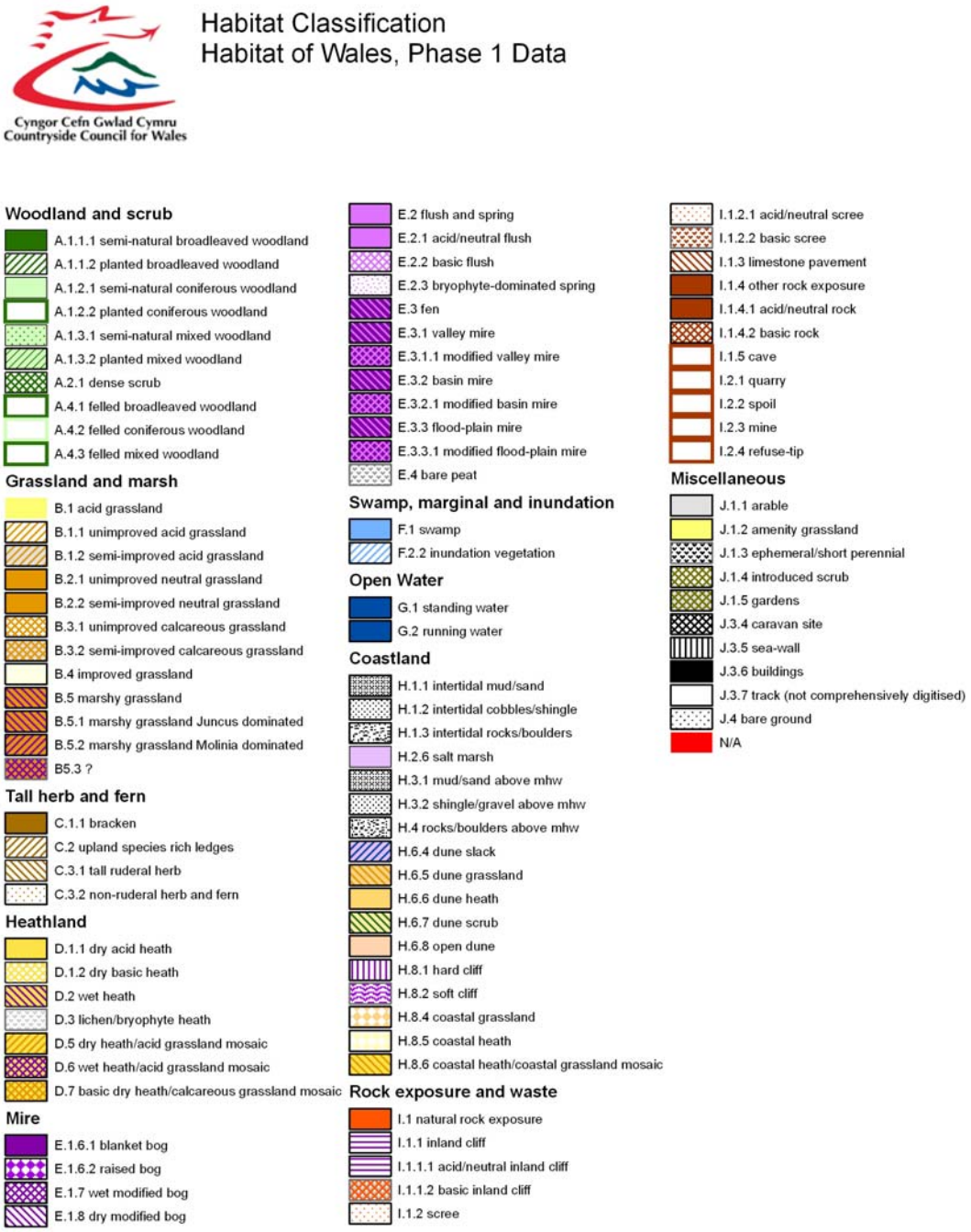
In the past macrophyte surveys of standing waters have often been undertaken without adequate attention to recording the environmental attributes of the site. For the purposes of this exercise the following information or samples MUST be collected irrespective of the existing available environmental data. Surveys which do not include the following samples and items of information would be regarded as incomplete.

1. A one litre water sample collected at the lake outflow and from each sampling unit. The latter sample should be collected at the mid point of the shoreline based survey at the 0.75m station, or, if more appropriate at a similar depth on the boat transect. Samples should be refrigerated and analysed within 48 hours of collection. The minimum set of determinands is pH, alkalinity, conductivity, TP, TON and NH_4^+
2. The average Secchi disc depth based on measurements along each boat transect. If a boat cannot be used transparency should be measured by the shoreline based surveyor. This should be done using the Secchi disc if transparency is <0.75m but where it is in excess of safe wading depth the surveyor should make a visual estimate of the maximum depth of water in which the bed is visible.
3. The extent of shoreline modification along each of the 100m perimeter surveys must be noted using a scoring system on the perimeter survey recording sheet. This variable should be regarded as analogous to the Habitat Modification Score component of River Habitat Survey.
4. The extent of emergent lake bed between the normal high water mark (or the face of the emergent reed fringe) and the current lake level must be estimated based on the average distance between these two points in each of the sampling units. This will be used as a measure of lake level stability and as baseline for comparison with subsequent surveys.

5. The substrate associated with each of the three shore most sampling stations (i.e. 25, 50 and 75cm) for the 10 points along each shoreline survey. This provides an indication of the suitability of the substrate as a rooting medium for vegetation and the likely degree of wave exposure.

The gradient of the littoral zone in each sampling unit. This is estimated by recording the average horizontal distance from the waters' edge at which the 0.75m depth station is sampled. It also acts as a weighting factor for integrating data from different sampling units.

APPENDIX 2


Cyngor Cefn Gwlad Cymru
Countryside Council for Wales
Habitat Classification
Habitat of Wales, Phase 1 Data
Woodland and scrub
A.1.1.1 semi-natural broadleaved woodland
A.1.1.2 planted broadleaved woodland
A.1.2.1 semi-natural coniferous woodland
A.1.2.2 planted coniferous woodland
A.1.3.1 semi-natural mixed woodland
A.1.3.2 planted mixed woodland
A.2.1 dense scrub
A.4.1 felled broadleaved woodland
A.4.2 felled coniferous woodland
A.4.3 felled mixed woodland
Grassland and marsh
B.1 acid grassland
B.1.1 unimproved acid grassland
B.1.2 semi-improved acid grassland
B.2.1 unimproved neutral grassland
B.2.2 semi-improved neutral grassland
B.3.1 unimproved calcareous grassland
B.3.2 semi-improved calcareous grassland
B.4 improved grassland
B.5 marshy grassland
B.5.1 marshy grassland Juncus dominated
B.5.2 marshy grassland Molinia dominated
B5.3 ?
Tall herb and fern
C.1.1 bracken
C.2 upland species rich ledges
C.3.1 tall ruderal herb
C.3.2 non-ruderal herb and fern
Heathland
D.1.1 dry acid heath
D.1.2 dry basic heath
D.2 wet heath
D.3 lichen/bryophyte heath
D.5 dry heath/acid grassland mosaic
D.6 wet heath/acid grassland mosaic
D.7 basic dry heath/calcareous grassland mosaic
Mire
E.1.6.1 blanket bog
E.1.6.2 raised bog
E.1.7 wet modified bog
E.1.8 dry modified bog
E.2 flush and spring
E.2.1 acid/neutral flush
E.2.2 basic flush
E.2.3 bryophyte-dominated spring
E.3 fen
E.3.1 valley mire
E.3.1.1 modified valley mire
E.3.2 basin mire
E.3.2.1 modified basin mire
E.3.3 flood-plain mire
E.3.3.1 modified flood-plain mire
E.4 bare peat
Swamp, marginal and inundation
F.1 swamp
F.2.2 inundation vegetation
Open Water
G.1 standing water
G.2 running water
Coastland
H.1.1 intertidal mud/sand
H.1.2 intertidal cobbles/shingle
H.1.3 intertidal rocks/boulders
H.2.6 salt marsh
H.3.1 mud/sand above mhw
H.3.2 shingle/gravel above mhw
H.4 rocks/boulders above mhw
H.6.4 dune slack
H.6.5 dune grassland
H.6.6 dune heath
H.6.7 dune scrub
H.6.8 open dune
H.8.1 hard cliff
H.8.2 soft cliff
H.8.4 coastal grassland
H.8.5 coastal heath
H.8.6 coastal heath/coastal grassland mosaic
Rock exposure and waste
I.1 natural rock exposure
I.1.1 inland cliff
I.1.1.1 acid/neutral inland cliff
I.1.1.2 basic inland cliff
I.1.2 scree
I.1.2.1 acid/neutral scree
I.1.2.2 basic scree
I.1.3 limestone pavement
I.1.4 other rock exposure
I.1.4.1 acid/neutral rock
I.1.4.2 basic rock
I.1.5 cave
I.2.1 quarry
I.2.2 spoil
I.2.3 mine
I.2.4 refuse-tip
Miscellaneous
J.1.1 arable
J.1.2 amenity grassland
J.1.3 ephemeral/short perennial
J.1.4 introduced scrub
J.1.5 gardens
J.3.4 caravan site
J.3.5 sea-wall
J.3.6 buildings
J.3.7 track (not comprehensively digitised)
J.4 bare ground
N/A