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RESEARCH REPORT

No. 6

Integrated classification and assessment of lakes in Wales: Phase 1

A Preliminary Data Report to the Countryside Council for Wales under Contract No: FC 73-01-71

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

Executive Summary

1. This report presents preliminary data from the first phase of the study on integrated classification and assessment of lakes in Wales. The lakes assessed are Llyn Coron, Llyn Penrhyn and Llyn Dinam on Anglesey and Llyn Idwal and Llyn Cwellyn in Snowdonia.

2. The methodology of field survey is detailed and the data collected for the range of physical, chemical and biological variables from the five lakes is presented and briefly discussed.

3. The sites in Anglesey and Snowdonia are so different in character that a broad distinction between the two lake types (lowland, shallow, nutrient rich v. upland, deep, nutrient poor) is apparent from virtually all the criteria employed before any attempt at integrating the data has been made.

4. A second report in June 1994 will review the literature on classification and conservation, present the full data-set from these five sites, assess the lakes in comparative terms, and outline analytical methodologies for integrated classification.

5. An assessment of the suitability and cost-effectiveness of the sampling and analytical methodologies is ongoing throughout the first phase of this programme and will be addressed fully in the June 1994 report. The need to change the protocols for sampling macroinvertebrates in nutrient-rich sites, and doubts about the reliability of field pH data are already apparent.

6. Many more than five sites will be required for the development of a robust, widely applicable, integrated classification scheme of Welsh lakes

7. Data collected during field survey provide a contemporary 'baseline' against which future ecosystem changes at these sites can be assessed. Palaeolimnological techniques, not included in this programme, could allow the definition of historical 'baseline' or 'background' conditions to be established in a quantitative form.

List of Contributors

Allott, T.E.H.	Environmental Change Research Centre, University College London.
Duigan, C.A.	Countryside Council for Wales, Bangor.
Harriman, R.	Freshwater Fisheries Laboratory, Pitlochry.
Kirika, A.	Institute of Freshwater Ecology, Penicuick.
Lancaster, J.	School of Biological Sciences, Queen Mary and Westfield College.
Monteith, D.T.	Environmental Change Research Centre, University College London.
Patrick, S.T.	Environmental Change Research Centre, University College London.
Seda, M.	Department of Biology, Royal Holloway and Bedford New College.

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Scope of Preliminary Report

This preliminary data report outlines the sampling methodology used in the current programme to develop an 'integrated classification and assessment of Welsh lakes', and it presents data collected from the first five sites to be studied, prior to 28 February 1994. Some of the data for the study remain outstanding; the final set of water chemical samples will be taken in March 1994, the second (spring) macroinvertebrate samples will be taken in April 1994, and analysis of littoral Cladocera samples is ongoing. Full data analyses and site assessments are therefore beyond the scope of the report, although a brief discussion considers the broad similarities and differences of the sites. The report also outlines the strategy that will be adopted for data analyses and integrated site classification once a sufficiently large database of sites is available.

A second report for this first phase will be submitted in June 1994. This will include a more extensive literature review and discussion of lake classification for conservation, full site description tables, final tabulations of data collected, data analyses, and assessment of the lake ecosystems based on existing classification methods. Once the sampling programme has been completed and analyses undertaken it will be appropriate to critically review the methodology with a view to improving it for later phases of this programme.

The second report will also include, for the purpose of exemplifying the techniques and their output, a preliminary integrated classification based on multi-variate analyses of the data collected from the first five study lakes. However, full utilisation of the ecological statistics which would allow the various chemical, biological and physical characteristics of the sites to be interrelated, classified and potentially modelled will require many more than five sites (*c.* 30+).

1 Background

Site selection and evaluation are key aspects of UK conservation practice. Criteria for evaluating sites of nature conservation interest include factors such as the diversity of species and habitats, the area of the site, rarity of species or habitats, naturalness and representativity of the site (Usher 1986). It is increasingly recognised that the series of sites selected for conservation should contain adequate representation of the total range of variation in ecosystem types (NCC 1989). Effective site evaluation is therefore dependent on two key factors:

i) The availability of classifications to allow each site to be placed in the context of regional site variation.

ii) The collection of field survey data which adequately represent the environment, flora and fauna of each site of interest.

In the UK classifications have always provided an important framework for the selection of key conservation sites, including standing waters. The Nature Conservation Review (NCR) selected key standing water sites using a classification of six site types; dystrophic, oligotrophic, mesotrophic, eutrophic, marl and brackish (Ratcliffe 1977). More recently Palmer (1992) has classified standing waters throughout Great Britain using aquatic macrophytes. Ten site types are defined based on the occurrence of individual macrophyte species. The site types broadly correspond to a gradient from low > high alkalinity, conductivity and pH values. These approaches are based on the assumption that broad environmental gradients or individual vegetation communities can be used as surrogates for ecosystem variation.

However, it is increasingly being suggested that classification should be based on all the relevant biological and environmental attributes of an ecosystem. The conservation ethic is moving away from the consideration of single species and towards approaches based on the full range of site resources (Usher 1986). There is therefore a clear requirement for the development of integrated site classifications that take into account a fuller range of environmental and biological variation exhibited by standing water sites.

Effective integrated classification requires the collection or collation of field survey data for relevant environmental and biological attributes. It also requires effective analysis of the survey data to provide a robust, objective and widely-applicable classification.

This study has two primary aims:

i) To develop and critically assess a methodology of field survey for the key physical, chemical and biologically variables necessary for integrated classification of lakes.

ii) To develop and evaluate an integrated classification for lakes in Wales suitable for nature conservation practice.

For the first phase of this programme five lakes were chosen by the Countryside Council for Wales for survey and assessment. Data have been collected from these lakes on key variables of biological importance including the physio-chemical environment, algal, aquatic macrophyte, zooplankton and macroinvertebrate communities.

2 Site Descriptions

Llyn Idwal

Llyn Idwal lies in the Snowdonia National Park at 370 m altitude, above Llyn Ogwen at the head of the Nant Ffrancon Valley (Figure 2.1). The lake and its immediate catchment are a designated National Nature Reserve.

The lake covers an area of approximately 0.14 km^2 and is relatively shallow for an upland corrie lake of this size (mean depth 3.4 m, maximum depth 13 m). The deeper, broad northern basin of the lake is quite different in character from the shallow, macrophyte-filled southern arm which in limnological terms may almost be considered a separate system.

A precipitous catchment of 3.05 km^2 drains to the lake via a series of steep streams and falls. Three small upland 'tarns' lie high above Llyn Idwal. One of these, Llyn Clyd, has been the subject of palaeolimnological and chemical study in the past (Walker 1977, Patrick 1989).

Catchment geology is a complex combination of granite and Ordovician sedimentary rock of the Caradoc Series. The lower catchment supports a Gramineae-dominated moorland vegetation which is grazed by sheep. The upper catchment is primarily bare rock. Soils are thin, and particularly above the steep back wall, they are peaty.

There is a significant recreational pressure on the catchment of Llyn Idwal, hill walkers, climbers and visitors to the lake pass through in great numbers and paths, stream and lake margins suffer from erosion.

Llyn Cwellyn

Llyn Cwellyn (Figure 2.2) is the largest lake in this study, covering some 0.85 km^2. It lies at an altitude of 150 m in the Nant y Betws valley within the Snowdonia National Park. The lake comprises a simple deep basin (mean depth 22.6 m) which attains a maximum depth of 36 m. A large upland catchment drains to the lake via a series of upland streams and two larger influents, the Afon Treweundydd and Afon Gwyrfai. The outflow from the lake has been regulated but there is little evidence of significant fluctuations in water level.

The Llyn Cwellyn catchment is extensive. It covers some 19.88 km^2 and reaches a maximum altitude of 1085 m at Snowdon (Figure 2.2). One other significant lake, Llyn y Gadair, a dammed reservoir and other smaller upland tarns lie in the upper catchment. The uppermost of these tarns, Llyn Glas, has been the subject of past palaeolimnological and chemical study (Walker 1977, Patrick 1989) as has Llyn y Gadair (Flower *et al.* 1989).

The slopes immediately to the west of the lake and parts of the southern, upper catchment have been afforested with conifers. Some of this area has been thinned and felled and secondary planting instigated. There are a few scattered houses, a youth hostel, a hotel and one hamlet (Rhyd-Ddu) in the catchment. A minor road - the A4085 transverses the eastern shore of the lake. In the vicinity of Llyn y Gadair and more sporadically on the slopes adjacent to Llyn Cwellyn, there is evidence of past quarrying activity.

The geology of the catchment is complicated and includes Ordovician and Cambrian sedimentary rocks together with outcrops of granite, tuffs and basalt. Away from the forested area the catchment supports moorland vegetation, which has been marginally improved on the lower slopes, and which throughout, is utilised for rough grazing for sheep and cattle. The uppermost slopes are characterised by thin soils and bare rock.

Llyn Coron

Llyn Coron lies at 10 m above sea level just 2 km from the coast in south-west Anglesey. The lake covers an area of approximately 0.26 km^2 and drains a catchment of 17.17 km^2 (Figure 2.3).

The lake is shallow and comprises a simple broad basin (mean depth 1.8 m) which reaches a maximum depth of 2.8 m. A significant wildfowl population, whose numbers vary seasonally, is supported by the lake and its immediate surrounds and a recreational fishery is maintained.

The catchment is of low relief with a maximum altitude of only 65 m. Drainage is by one principal stream, the Afon Gwna and is supplemented in places by minor artificial drainage ditches. The extremely ancient Pre-Cambrian sedimentary geology which dominates the catchment outcrops in places and gives rise to poor agricultural land which is utilised for rough grazing for sheep and cattle. Isolated farms and a diffuse rural population are present and domestic drainage to septic tanks and production and storage of silage may represent relevant land-uses in terms of their impact on lake water quality. A small battery hen farm is also present within the catchment.

Llyn Penrhyn and Llyn Dinam

These two lakes lie only 0.5 km apart some 1.5 km from the coast of western Anglesey. The two lakes are low lying (< 10 m altitude) and the catchment of Llyn Penrhyn is rather difficult to distinguish topographically. The two sites are portrayed together in Figure 2.4.

Llyn Penrhyn has an area of approximately 0.19 km^2 and is shallow (mean depth 2.2 m) with a maximum depth of 3.0 m occurring in a minor basin at the northern end of the lake. The lake is part of a RSPB reserve and is an important wildfowl sanctuary. The catchment area is approximately 0.43 km^2.

Llyn Dinam is also shallow (mean depth 1.4 m, maximum depth 1.8 m) and supports a significant wildfowl population. The lake is smaller than Llyn Penrhyn, covering approximately 0.09 km^2. Llyn Dinam drains a catchment of approximately 6.48 km^2 through which flows one minor stream and a series of small artificial drainage channels. The A5 trunk road passes through the middle of the catchment and the small village of Caergeiliog lies only 0.5 km to the north of the lake. The catchment is of very low relief with a maximum altitude of about 25 m. The Ordovician sedimentary rocks which underlie most of the catchment, abut sedimentary rocks of the Pre-Cambrian at the extreme western edge. This geology gives rise to agricultural land, managed in places for arable and better quality rough grazing which is utilised for sheep and cattle. Apart from the village of Caergeiliog, drainage from individual farms and rural dwellings together with that from silage stores, may constitute relevant land-use impacts in the catchment.

Llyn Penrhyn is separated from Llyn Dinam by a low lying marshy area and receives no discrete drainage from its poorly distinguished, small catchment. However, immediately adjacent to the north and east of the lake are residential and operational facilities for the Valley air base (Dowyn), and a further 0.5 km to the north, the village of Llanfihangel yn Nhowyn. These settlements house a significant population and a sewage treatment plant serving this community lies within the catchment. Non built-up land in the catchment is dominated by scrub vegetation and some rough grazing.

A further potential impact on these lakes may come from the extreme low altitude with which incoming and outgoing aircraft fly over the lake and its catchment and the exhaust plumes from aircraft readying for take-off on the main runway just at the southern proximity of the catchment.

Figure 2.1 Catchment of Llyn Idwal

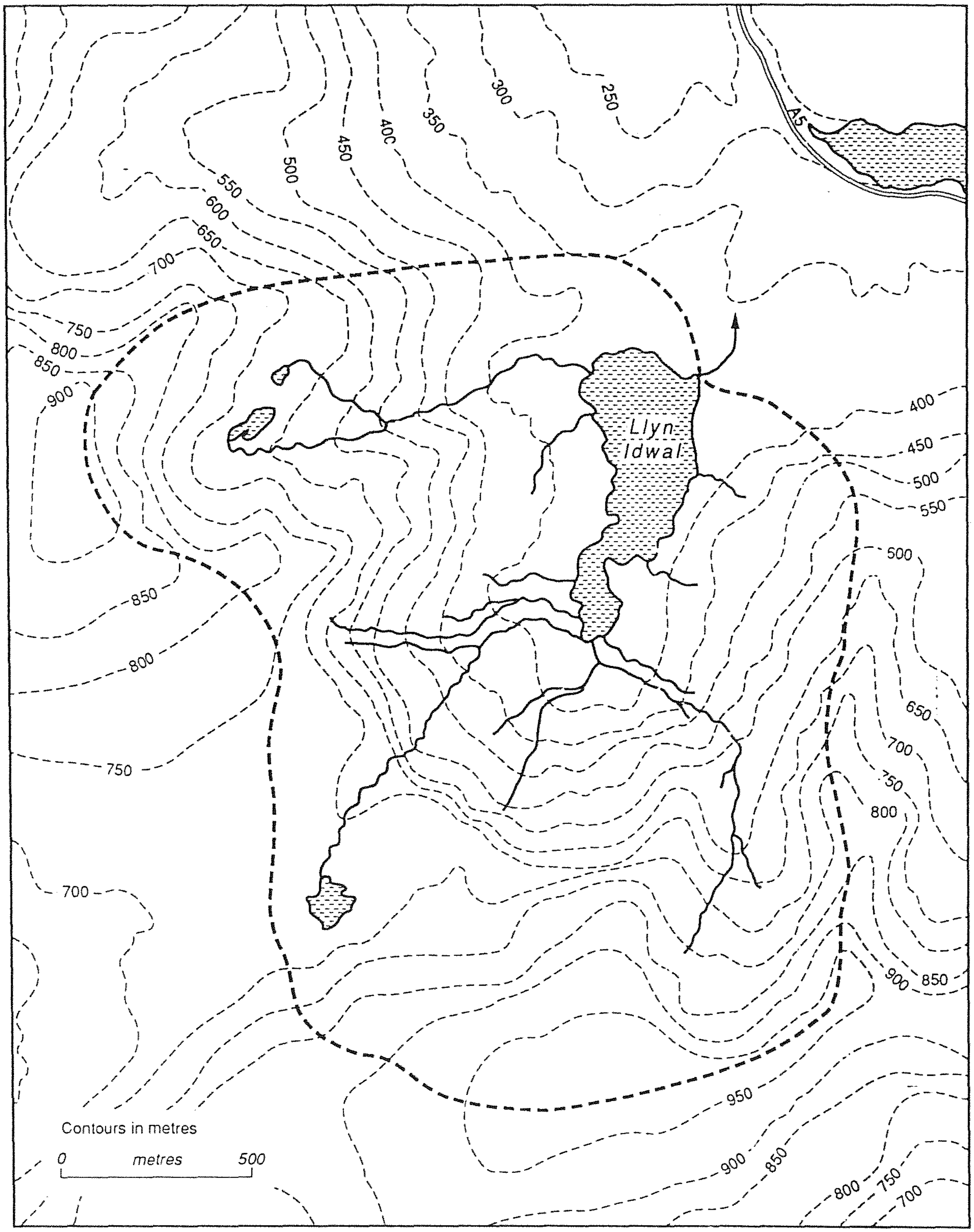


Figure 2.2 Catchment of Llyn Cwellyn

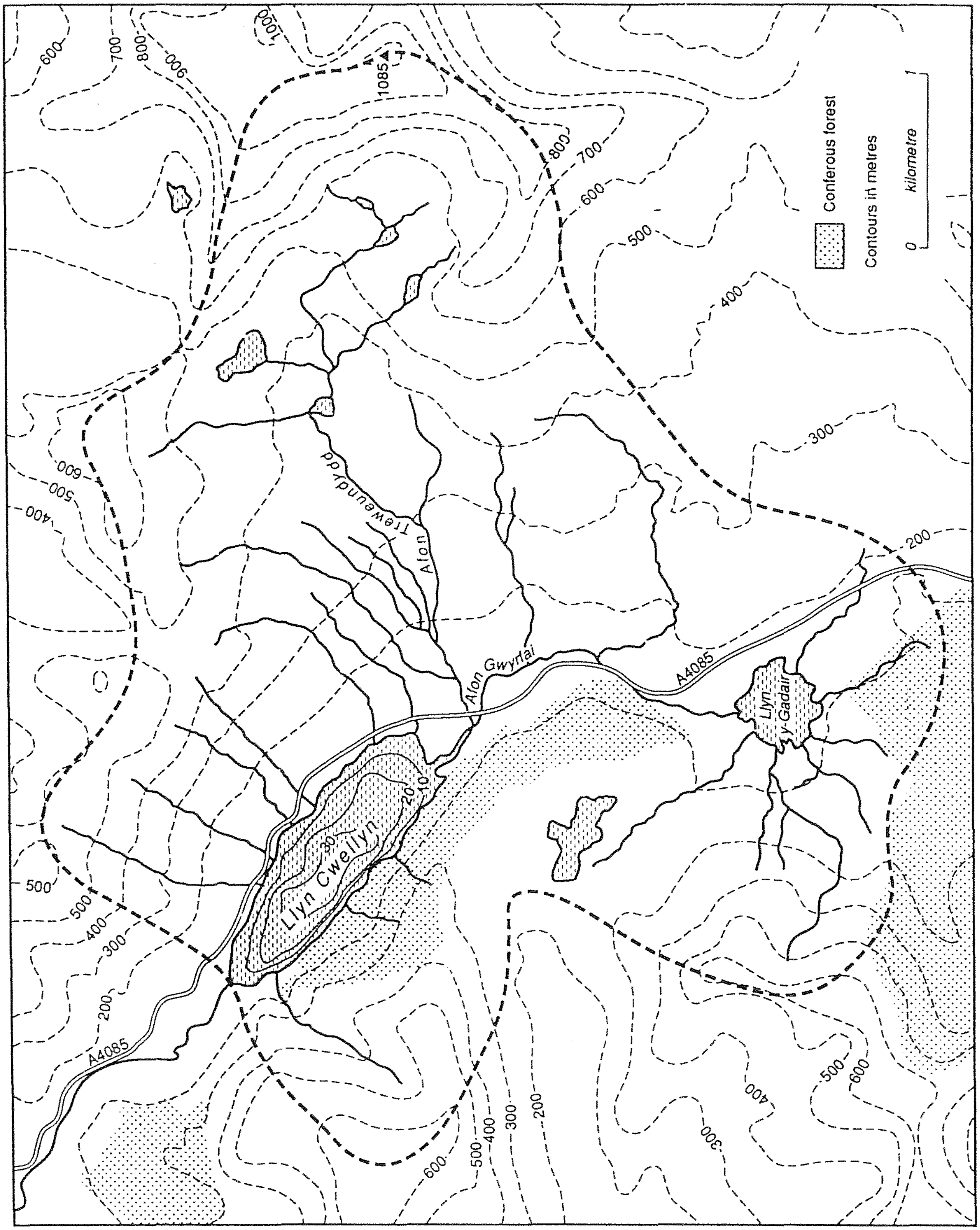


Figure 2.3 Catchment of Llyn Coron

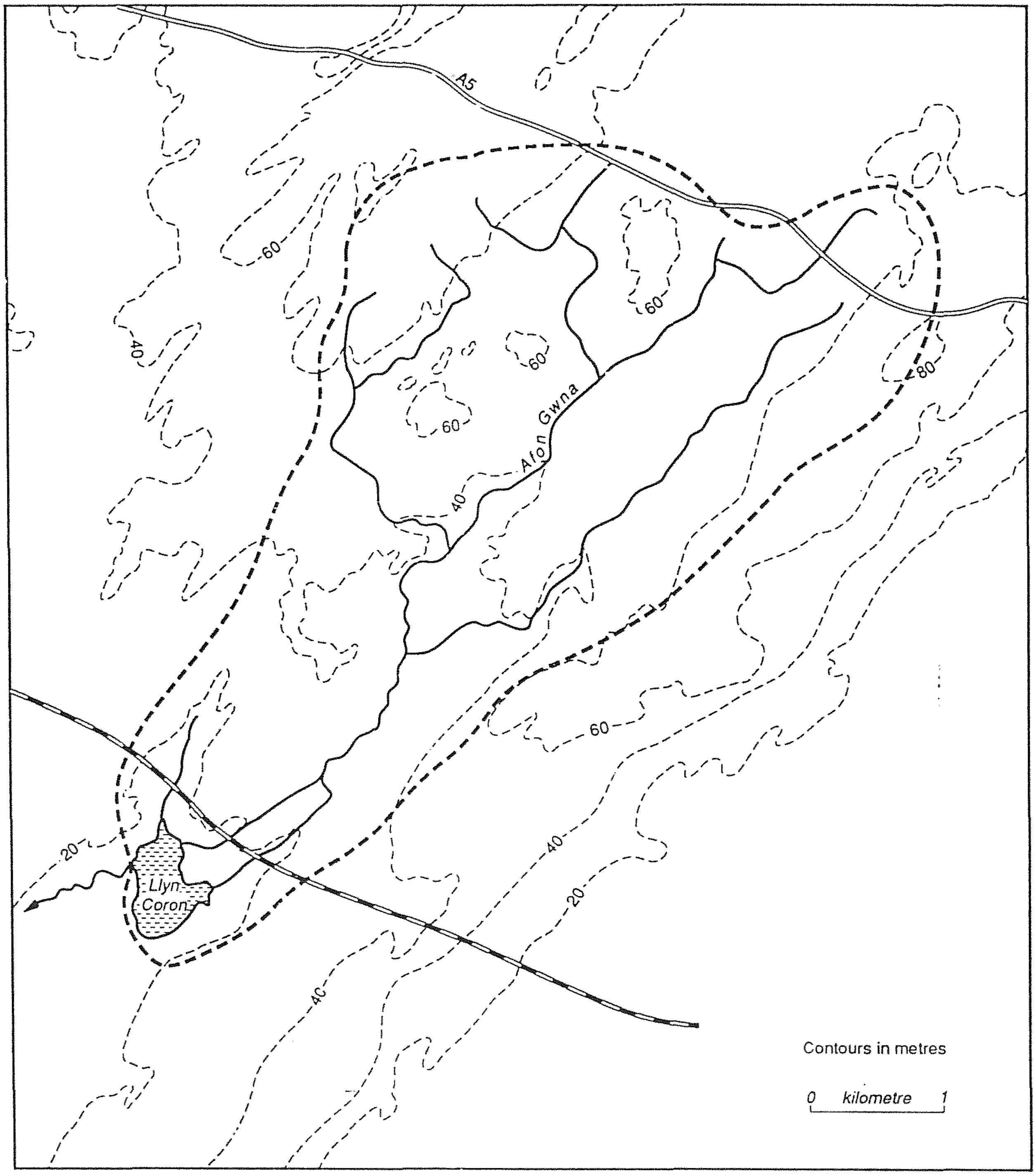
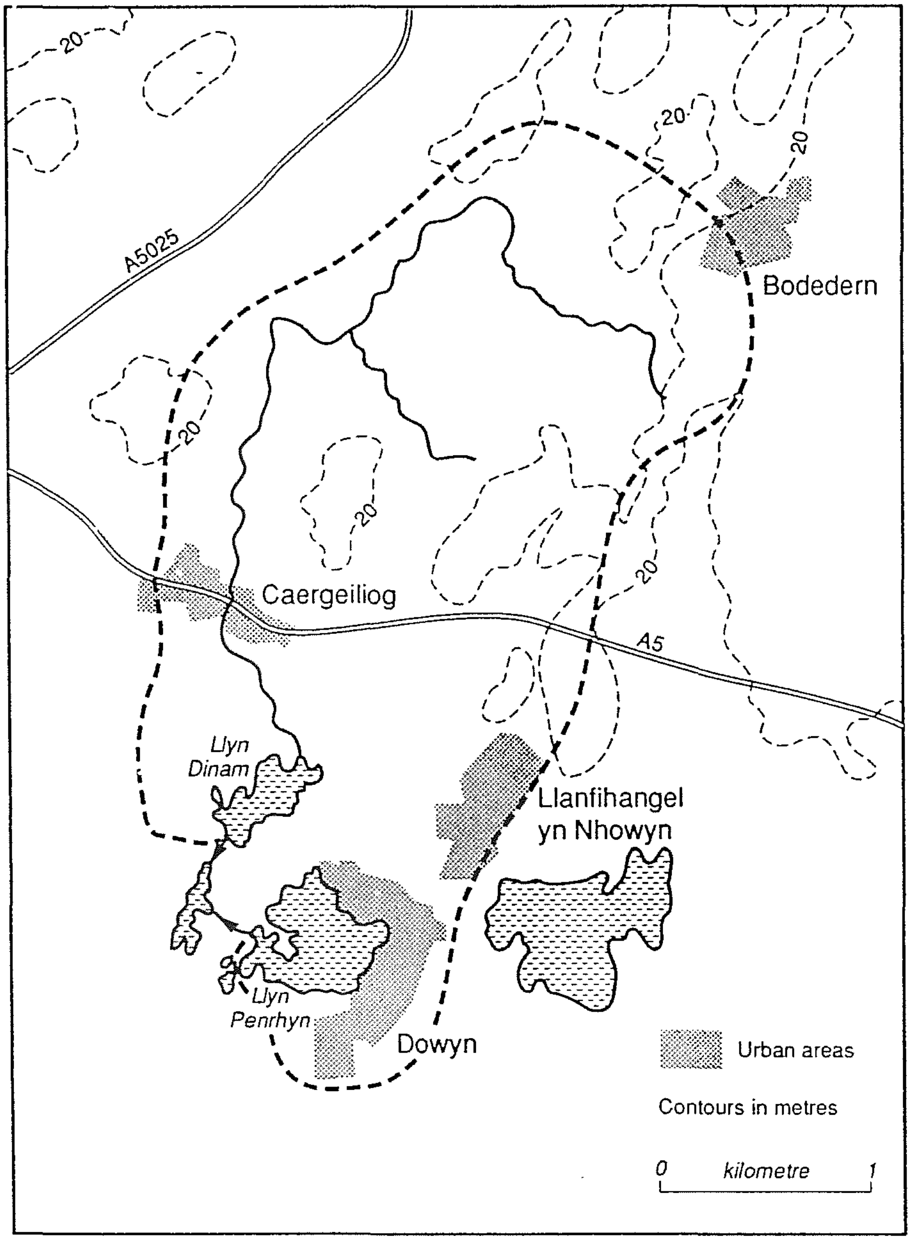


Figure 2.4 Catchments of Llyn Dinam and Llyn Penrhyn



3 Methods

The variables recorded and measured and the sampling methods employed were determined by the Countryside Council for Wales in their original tender document for this programme. The methods are kept under review and their applicability will be re-assessed at the end of the first survey period in May - June 1994.

3.1 Site and catchment data

Catchment and lake areas were determined using Ordinance Survey 1:25,000 scale maps, and catchment geology taken from British Geological survey maps. Catchment land-use was determined by field survey. The cost-effectiveness of utilising 1 km^2 resolution data of land cover from the GIS database at the Institute of Terrestrial Ecology is being investigated.

An approximate bathymetry for lake each was obtained using existing data sources and point echo soundings.

3.2 Physio-chemical analyses

Oxygen and temperature profiles were determined for each of the lakes during summer 1993. Profiles were taken during the period 10-11 July 1993 and again during the period 1-5 September 1993. Measurements were made from the deepest point using an EIL oxygen and temperature meter. Secci disc transparency was also recorded at the deepest point.

Water chemistry has been sampled at quarterly intervals using a standard sampling and analytical methodology based on that adopted by the UK Acid Waters Monitoring Network (Patrick *et al.* 1991). To date samples have been taken in July 1993, September 1993 and December 1993. The sample for March 1994 is outstanding.

Water samples were taken from the middle of the lake from elbow depth and measured on site immediately for pH (using a Beckmann Φ10 pH meter with Beckmann electrodes) and conductivity (using a PHOX 52E conductivity meter).

The following determinands were measured at the Freshwater Fisheries Laboratory, Pitlochry using standard methods (Harriman *et al.* 1987); pH, H^+, alkalinity, conductivity, Ca, Mg, Na, K, SO_4, Cl, soluble monomeric Al, non-labile monomeric Al, soluble labile Al, total organic carbon and absorbtion at 250nm. Samples have been stored pending analyses for Cu, Zn, Fe and Mn.

The following determinands were measured at the Institute of Freshwater Ecology, Penicuick according to the methodology of Wolfe-Murphy *et al.* (1991-1992); total silica, soluble reactive silica, chlorophyll a, total phosphorus, total soluble phosphorus, soluble reactive phosphorus, and nitrate.

Both the laboratories used for chemical determinations meet the necessary criteria required for BS quality assurance, and participate in ongoing inter- and intra-laboratory AQC programmes.

3.3 Epilithic diatoms

Epilithic diatoms were sampled during 1-5 September 1993. Ten cobble size stones are selected from the permanently submerged littoral at three or four locations around the shore, with areas close to inflow or outflow streams being avoided (Figures A.1 - E.1). The diatoms are removed by brushing into a tray, decanting into plastic vials and preserved with Lugols Iodine.

Samples are prepared using standard techniques (e.g. Battarbee 1986) and examined by light microscopy at x1000. A minimum of 500 valves are counted from each site and the abundance of each taxon is expressed as a percentage of the total count. Identification and nomenclature follows that developed by the Royal Society SWAP programme (Munro *et al.* 1990) and the ENSIS eutrophic lake survey (Anderson and Bennion, pers. comm.). Slides and diatom solutions are archived for quality control.

All diatom counts are stored on the central database. For the purposes of this report a list of taxa comprising >1% of the total count is presented.

3.4 Surface sediment diatoms

Surface sediments were sampled during the period 1-5 September 1993. A short core was extracted from the deepest point in each of the sites (Figures A.1 - E.1) using a Glew gravity corer (Glew 1989). The surface sediment samples (0-0.5 cm or 0-1 cm) from each core were sub-sampled in the field and subsequently analysed in the laboratory.

Samples are prepared using standard techniques (e.g. Battarbee 1986) and examined, archived, computed and reported in the same way as the epilithon (Section 3.3).

3.5 Aquatic macrophytes

Aquatic macrophyte surveys were conducted during the period 1-5 September 1993. A methodology was adopted, broadly following that of the Northern Ireland Lake Survey (Wolfe-Murphy *et al.* 1991-1992) and the NCC survey of Sutherland lochs (Bell 1991). The aim was to maximise species detection and best summarise the abundance and location of individual species and communities, within the time constraint of one lake per day. The survey concentrated on those species which are regarded as strictly aquatic. Owing to the difficulty of defining the extent of adjacent wetland habitats, the time required to record the species therein and the limited usefulness of non open water vegetation in deriving classifications of lakes (Palmer 1992), it was decided to only record wet marginal vegetation that was easily visible from the open water.

Two techniques were applied to establish the presence and estimate the abundance of all submerged, floating and emergent aquatic macrophyte taxa.

Firstly the perimeter of the lake was inspected in a shoreline walk. Where shoreline morphology or the presence of deep growing emergent vegetation (eg. *Phragmites* or *Scirpus* beds) made access to the perimeter difficult, a small rubber dingy was employed. The littoral zone was searched thoroughly by wading out to a depth of approximately one metre. At frequent intervals during the shoreline walk, a double headed rake grapnel was cast perpendicularly from the lake shore to retrieve vegetation floating in the water column or attached to substrate beyond wadeable depth.

In addition the inflatable dingy was employed in a "spot rake" survey. This again followed the methodology of the Northern Ireland Lake Survey. Two roughly perpendicular transects (Figures A.1 - E.1) were chosen, the first of which usually traversed the longest axis of the lake. Along each transect the grapnel was used, at 10 roughly equi-distant points to trawl approximately two metres of the lake bed. Care was taken to avoid areas which might have been suitable for sediment coring.

For each site, a list was compiled of all aquatic taxa, under the categories of emergent, floating or submergent. Using information gathered from the two survey techniques the abundance of each taxon was given a score according to the DAFOR scale as used in NCC lake surveys; dominant (D), abundant (A), frequent (F), occasional (O), rare (R). The classification of "dominant" was applied to taxa with a cover of 80% or more of the shoreline or open water. The occurrence of macrophyte stands, associations and isolated "rare" specimens was recorded on a map outline, photocopied on to an A4 sheet of waterproof paper. Notes were also made of the type of substrate, the location of inflows and outflows, potential pollutant inputs and other catchment details. In addition, photographs were taken of the most notable features of each site.

Voucher specimens of the more difficult plant groups were collected and subsequently dried, pressed and archived. *Potamogeton* specimens were sent to Chris Preston, of the Biological Records Office, for verification. Charophytes were preserved in alcohol and samples of filamentous green and blue-green algae in Lugol's iodine.

Species lists were used to type each site according to Palmer (1992) and in addition Palmer's DOME index was applied to provide the Trophic Ranking Score.

3.6 Littoral Cladocera

The littoral Cladoceran populations of the five study sites were sampled during the period 1-5 September 1993. Six or seven sampling sites were chosen around the lake shores (Figures A.1 - E.1) in a range of vegetation communities and substrate types (Appendix F). The samples were taken using a hand-held net (0.2 mm mesh; 17 cm diameter) which was moved for one minute over the substrate and through any submerged vegetation present at each sampling site, from the edge of the lake down to a depth of one metre where possible. Replicates were taken at a number of sites to investigate the degree of variation between samples. All the material collected was preserved in the field in (approximately) 4% formalin. In the laboratory successive aliquots of each sample were examined in a scored petri dish using a binocular microscope.

A species list for each sample was compiled following the examination of all the material. Taxonomic monographs by Scourfield and Harding (1966), Flössner (1972) and Smirnov (1971) were used for the identifications.

Five aliquots were removed from each sample in suspension. The frequency of occurrence of the component species in each sample was estimated by counting the individuals of each species in each aliquot. Each sub-sample was returned to the sample before the next aliquot was withdrawn. These data will be converted to percentages when all the samples have been analysed.

3.7 Open water zooplankton

Open water zooplankton were sampled during the period 1-5 September 1993 using an Apstein plankton net (diameter 20 cm, mesh size 200 μm) using vertical hauls from bottom to surface. At least two hauls were combined in each sample. The sample was divided into three size fractions using sieves with mesh 0.71 mm and 0.42 mm respectively (e.g. Kořínek 1971). The larger size fraction retained on the 0.71 mm sieve was formed entirely by cladoceran species. The two smaller fractions were separated into cladocera, copepoda and algae using the narcotic-floatation technique of Straškraba (1964). The biomass of all fractions were measured as dry weight after 14 days storage in bottles with 4% formaldehyde. The correction factor for conversion of formaldehyde fixed dry weight into unfixed dry weight was established for the charge of formaldehyde used. Its value corresponds to a general 30% weight loss after fixation by formaldehyde that has been recognised by Giguere and St-Pierre (1989). All dry weights referred to include this correction for weight loss. The sample from the deepest point of the lake was used for analyses of zooplankton structure.

To estimate the heterogeneity of lake zooplankton three vertical hauls at three different stations (A, B, C) were taken (Figures A-E.1). The material from each haul was individually preserved and the total dry weights per single haul was estimated. Samples for determining the species composition of zooplankton were taken from two stations, at the deepest point (station A) and central part of the lake (station B) respectively. A species list was generated, and in this report species abundance is divided into three classes; common (>5% abundance), rare (species found in both samples analysed) and very rare (species found in one of samples analysed).

3.8 Littoral macroinvertebrates

The sampling protocol followed for littoral macroinvertebrates is adapted from the annual survey of lakes of the UK Acid Waters Monitoring Network (Patrick *et al.* 1991). However, in this programme the lakes will be sampled during two periods, autumn and spring, to obtain the fullest range of species. Macroinvertebrates in the five study lakes were sampled during the period 9-10 October 1993 to represent autumn populations. The lakes will be sampled for spring populations in April 1994. Five one minute kick/sweep samples are collected using a standard pond net (300 μm mesh) from the littoral zone of each lake. Sampling is carried out in the dominant habitat types for which it is feasible to collect replicate kick/sweep samples. All material is preserved in 4% formalin. In the laboratory, all macroinvertebrates in each sample are separated from organic and inorganic material using a magnifying lamp, identified to the lowest possible taxonomic grouping, and counted.

3.9 Sediment cores

Quantitative reconstructions of lake water quality derived from palaeolimnological analyses comprise a powerful technique for determining 'pre-pollution', 'background' levels. Such information might well be considered central to any classification and assessment of the conservation status of lakes. However, these techniques have not been funded as part of the current programme, but sediment cores were retrieved and archived as a contingency measure.

Short sediment cores (*c.* 25-30 cm) were extracted from the deepest point in each lake using a gravity corer (Glew 1989) and extruded at 0.5 cm intervals down to 5 cm, and then 1 cm intervals to the base of the core. The sub-samples were returned to the laboratory and archived.

3.10 Data storage and analyses

All physical, chemical and biological data collected from the five lakes are stored within a central PARADOX database at the ECRC. Some data collection and analysis remains outstanding, notably the final chemical samples and the spring invertebrate samples. The second project report will contain comprehensive analyses of the data and will permit determination of site classifications.

4 Results

Results of the study to date are presented as data tables in appendices A-E. In the following section the main chemical and biological attributes of the sites are briefly discussed.

4.1 Physio-chemical Data

The pH data reported in Tables A-E.3 are the laboratory determinations. Field pH is not yet reported. The pH characteristics of Llyn Idwal and Llyn Cwellyn (circumneutral - mildly acidic) and Llyns Coron, Dinam and Penrhyn (alkaline) are sufficiently dissimilar to require the use of different electrodes and buffer solutions with the Beckmann field pH meter. An assessment of the most appropriate equipment to use and indeed, the necessity of taking pH measurements in the field, is currently being made.

Llyn Idwal

The water chemistry of Llyn Idwal is indicative of an oligotrophic, upland water body (Table A.3), although the lake shows relatively high alkalinity and pH compared to similar sites in north Wales (cf. Flower *et al.* 1989). Levels of phosphorus and nitrate are low, as are levels of aluminium. Secci disc transparency is relatively high (6-7 m) and low total organic carbon (TOC) concentrations are low, indicating the clear water nature of the site. The oxygen and temperature data (Tables A.1 and A.2) indicate that during the summer sampling periods the lake was isothermal and oxygen saturation was high.

Llyn Cwellyn

The water chemistry of this site is also indicative of oligotrophic conditions (Table B.3), with low nutrient concentrations. The high secci disc transparency (7-9 m) and low TOC concentrations emphasise the clear water nature of the site. Alkalinity is low, typically below 40 $\mu eq\ l^{-1}$. The oxygen and temperature data indicate that the lake stratifies during the summer period with a thermocline developing at a depth of 10-15 m (Tables B.1 and B.2). However, oxygen levels remain high in the hypolimnion, and it is unlikely that the water column ever becomes deoxygenated.

Llyn Coron

The water chemistry of Llyn Coron is indicative of a highly alkaline, eutrophic lake (Table C.3). Alkalinity values typically exceed 2000 μeq l^{-1}, total phosphorus >100 μg l^{-1} and nitrate levels reach 1000 μg l^{-1} in the winter period. Chlorophyll a values are high, particularly in the autumn 1993 sample (56 μg l^{-1}). Chloride levels are around 900 μeq l^{-1}, suggesting some marine influence on the chemistry. Nutrient and pH levels fluctuate considerably indicating the importance of biological processes in determining annual variation in water chemistry. The oxygen and temperature data indicate relatively isothermal conditions with little evidence for water column stratification (Tables C.1 and C.2). There is no evidence of significant water column deoxygenation from the data collected. The shallow, exposed nature of the lake almost certainly leads to regular mixing of the water column.

Llyn Dinam

The water chemistry of Llyn Dinam is indicative of an alkaline, eutrophic lake (Table D.3). Total phosphorus concentrations are consistently above 110 μg l^{-1} and alkalinity above 1500 μeq l^{-1}. Levels of TOC are also high (>10 mg l^{-1}). Chloride values are very high (>1400 μeq l^{-1}) suggesting a significant marine influence on water chemistry. There is no evidence of water column stratification in the oxygen and temperature data collected (Table D.1). The water column was isothermal during both sample periods and it is likely that the exposed, shallow nature of the site leads to regular mixing of the water column.

Llyn Penrhyn

The water chemistry of Llyn Penrhyn is indicative of a highly alkaline, highly eutrophic lake (Table E.3). Alkalinity is consistently above 2000 μeq l^{-1}. Phosphorus concentrations are particularly high, with total phosphorus never falling below 1000 μg l^{-1}. Nitrate levels are also very high, reaching 413 μg l^{-1} in winter 1993. Chloride levels are high, indicating a significant marine influence on water chemistry. There is no evidence of water column stratification in the oxygen and temperature data collected (Table E.1), and the water column was isothermal during both sample periods. It is likely that the exposed, shallow nature of the site leads to regular mixing of the water column.

4.2 Epilithic Diatoms

Llyn Idwal

The epilithic diatom flora of Llyn Idwal is typical of oligotrophic, circumneutral to slightly acid upland water bodies (Table A.4). The dominant taxon is *Achnanthes minutissima*, a cosmopolitan species very common in circumneutral waters. Other common species include *Brachysira vitrea* and *Nitzschia* [cf. *perminuta*]. Species diversity is relatively low with the three most common species accounting for nearly 70% of the total count.

Llyn Cwellyn

The epilithic diatom flora is indicative of low alkalinity waters (Table B.4). The flora is dominated by *Achnanthes minutissima*, a species widely tolerant of circumneutral to slightly acid conditions. Other common species include *Tabellaria flocculosa*, characteristic of slightly acid water bodies with pH between 5 and 5.5, and *Fragilaria vaucheriae* which is indicative of more circumneutral waters. Species diversity is low with the three most common taxa accounting for over 80% of the total count.

Llyn Coron

The epilithic flora is dominated by *Fragilaria vaucheriae*, here split into two major types; fine (i.e. >12 striae in 10 µm) and coarse (i.e. <12 striae in 10 µm). Other common species include *Nitzschia fonticola* and *Navicula tripunctata* (Table C.4). The flora is alkaliphilous and indicative of eutrophic waters. Species diversity is relatively high.

Llyn Dinam

The epilithic diatom assemblages are dominated by *Nitzschia* species, particularly *Nitzschia inconspicua* and *Nitzschia palea* var. *debilis* (Table D.4). Other abundant species are *Rhoicosphenia curvata* and *Amphora pediculus*. These taxa are all associated with the littoral zones of alkaliphilous, meso-eutrophic waters.

Llyn Penrhyn

The epilithic diatom flora is dominated by *Rhoicosphenia curvata* with *Navicula radiosa* var. *tenella*, *Nitzschia amphibia* and *Navicula tripunctata* also common (Table E.4). The flora is indicative of high alkalinity, eutrophic waters.

4.3 Surface Sediment Diatoms

Llyn Idwal

The surface sediment diatom assemblage is indicative of an oligotrophic, circumneutral, upland lake with relatively high alkalinity (Table A.5). The dominant species is *Achnanthes minutissima*, which has a pH optima of 6.3 (Stevenson *et al.* 1991). Other common species include *Brachysira vitrea*, *Nitzschia* [cf. *perminuta*] and *Fragilaria virescens* var. *exigua*. The similarity of the surface sediment assemblages to the epilithic assemblages suggests that the epilithic habitat is the dominant source of diatoms to the sediments and the extent of other habitat types is restricted. Planktonic diatoms are poorly represented in the sediment, although *Cyclotella* [*kuetzingiana* var. *minor*] and *Synedra acus* are present in abundances >2%.

Llyn Cwellyn

The surface sediment diatom assemblages are dominated by *Achnanthes minutissima*, with *Tabellaria flocculosa*, *Brachysira vitrea*, *Eunotia incisa* and *Fragilaria vaucheriae* also common (Table B.5). These species are typical of low alkalinity, oligotrophic, soft-water lakes, and have pH optima around 6.0 (Stevenson *et al.* 1991). *Eunotia incisa*, however, is typical of more acid waters and has a pH optima of 5.1 (Stevenson *et al.* 1991). The assemblages are compositionally similar to the epilithic diatom flora, suggesting that the other habitat types are relatively unimportant sources of diatoms for the sediments. Planktonic diatoms are particularly poorly represented, with only *Cyclotella rossii* achieving an abundance >1%.

Llyn Coron

The surface sediment diatom assemblage is dominated the planktonic taxa *Stephanodiscus parvus*, *Aulacoseira granulata* var. *angustissima* and *Cyclostephanos* [cf. *tholiformis*] (Table C.5). The flora is typical of strongly eutrophic, alkaline waters.

Llyn Dinam

The surface sediment diatom assemblage is dominated by the planktonic diatom *Stephanodiscus parvus* and the periphytic *Fragilaria construens* var. *venter* (Table D.5). High abundances of *Cyclostephanos* [cf. *tholiformis*] and *Fragilaria pinnata* are also recorded. There is a balance between the abundance of planktonic and periphytic forms. The assemblage is typical of alkaline, eutrophic, shallow waters. The high abundance of *Fragilaria* species could be due to these taxa growing *in situ* on the surface sediment. This is consistent with data on Secci disc transparency (Tables D.1 and D.2), which indicate that the lake bottom is periodically within the photic zone.

Llyn Penrhyn

The surface sediment diatom assemblages are dominated by the planktonic *Stephanodiscus parvus* with the periphytic *Navicula menisculus* and non-planktonic *Fragilaria* species and *Cocconeis* species also common (Table E.5). The high proportions of *Cocconeis* types indicates the importance of epiphytic habitats at this site. The assemblages are indicative of alkaline, eutrophic, shallow waters.

4.4 Aquatic Macrophytes

Llyn Idwal

The main bay of Llyn Idwal is largely dominated by the isoetids *Isoetes lacustris*, *Lobelia dortmanna* and *Littorella uniflora* and *Juncus bulbosus* var. *fluitans* (Figure A.2 and Table A.6). The maximum depth of *Isoetes lacustris* is restricted to approximately 2.5 m although bryophytes occur below this. The charophyte *Nitella* sp. (to be verified) is locally abundant and is particularly evident in shallow water in the north-west. *Potamogeton berchtoldii* is locally frequent in deeper water in the north. *Subularia aquatica*, *Myriophyllum alterniflorum* and *Callitriche hamulata* occur frequently throughout. Emergent and floating vegetation is mainly confined to the relatively sheltered, shallow sub-basin at the south end, where *Sparganium angustifolium* forms extensive mats alongside stands of *Phragmites australis*, *Equisetum fluviatile* and *Carex rostrata*.

The site is typed as 3 according to Palmer (1992) and has a Trophic Ranking Score of 5.57.

Llyn Cwellyn

The macrophyte flora of Llyn Cwellyn is typical for an oligotrophic lake, characterised by the abundance of the isoetids *Isoetes lacustris*, *Lobelia dortmanna* and *Littorella uniflora* and *Juncus bulbosus* var. *fluitans* (Figure B.2 and Table B.6). *Isoetes lacustris* grows to a depth of 5.5 m which is considerable, even for a clear water lake. *Myriophyllum alterniflorum* occurs frequently, and the rare oligotrophic species *Subularia aquatica* is also abundant in places. The acidophilous moss *Sphagnum auriculatum* occurs occasionally and the moss *Fontinalis antipyretica* is locally abundant in the south where *Juncus bulbosus* grows most prolifically. Surprisingly, a small number of individuals of *Elatine hexandra* were detected in shallow water off the north shore. There is little growth on the north-west shore littoral zone above approximately 40 cm depth presumably as a result of wave action and the general instability of the shoreline environment. The shoreline is generally boulder strewn with a predominance of slates in the north-west.

The site is typed as 3 according to Palmer (1992) and has a Trophic Ranking Score of 5.32.

Llyn Coron

The macrophyte distribution within Llyn Coron is shown in Figure C.2 and a species list is presented in Table C.6. The littoral zone of the lake is dominated by sand and gravel. During the survey the lake was covered by a bloom of the alga *Microcystis aeruginosa* which severely limited the transparency of the water and made the detection of some littoral species difficult. The alga *Enteromorpha* was present throughout and appeared to be growing profusely in places often in association with *Callitriche stagnalis*. The western shoreline is dominated by several stands of *Scirpus lacustris* ssp. *tabernaemontani* fringed occasionally on the open water side by *Polyganum amphibium*. *Elatine hydropiper* is locally abundant in shallow water on both the northern and southern shoreline. The eastern margin of the lake is largely open and free of emergent vegetation, *Callitriche stagnalis* forming only sparse cover over the stony littoral. A single large stand of *Phragmites australis* exists in a silty bay in the south-east. Despite the largely eutrophic characteristics of the site *Littorella uniflora* is present on the northern shoreline and a single specimen of *Myriophyllum alterniflorum* was found close to a nearby inflow. Occasional specimens of *Potamogeton perfoliatus* were found close to the southern and northern shorelines. A single specimen only of *Potamogeton trichoides* was recovered from a rake trawl.

Due to the occurrence of *Littorella uniflora* and a single specimen of *Myriophyllum alterniflorum* this site is typed as 5a according to Palmer (1992). Without the presence of *Myriophyllum* the site would have been typed as 8. Applying the DOME index provides a Trophic Ranking Score of 8.59.

Llyn Dinam

Llyn Dinam is extremely shallow with a shoreline dominated by *Phragmites australis* and to a lesser extent *Scirpus lacustris* ssp. *lacustris* (Figure D.2 and Table D.6). In the north there is a limited stretch of open shoreline, maintained by cattle grazing, and the open water here contains abundant *Elatine hydropiper*, *Callitriche hermaphroditica* and *Littorella uniflora. Ceratophyllum demersum* occurs in abundance in much of the open water habitat often in association with *Callitriche hermaphroditica* and *Lemna trisulca*. The charophyte *Nitella* sp. (to be verified) and the moss *Fontinalis antipyretica* thrive at the far eastern end. A second charophyte species *Chara* sp. (to be verified) was found close to the shore at the western end. *Nymphaea alba* and *Nuphar lutea* dominate a sheltered arm of the lake in the west. Three species of *Potamogeton*, *P. pectinatus*, *P. perfoliatus* and *P. pusillus* were found, the latter being the most frequent and occurring mainly close to the shore in the eastern half of the lake.

This site is typed as 10B according to Palmer (1992) and the DOME index provides a Trophic Ranking Score of 8.59.

Llyn Penrhyn

Slightly deeper than Llyn Dinam with a maximum depth of 3 m, Llyn Penrhyn includes a significant deeper water zone where submerged vegetation is either sparse or absent. However, like the neighbouring site, the margin is dominated by *Phragmites australis* often fringed on the open water side by *Scirpus lacustris* ssp. *lacustris* (Figure E.2 and Table E.6). A few large stands of *Nymphaea alba*, with associated *Nuphar lutea*, occur in sheltered bays in the west.

Ceratophyllum demersum dominates some submerged areas and often occurs with *Callitriche hermaphroditica* and *Elodea canadensis*. Of the three *Potamogeton* species found *P. crispus* and *P. pectinatus* are most frequent, occurring mainly on the western margins. The alga *Enteromorpha* sp. is locally abundant, particularly in the east. No charophyte or bryophyte species were found.

According to Palmer (1992), Llyn Penrhyn is typed as 10A and differs from the 10B typing of Llyn Dinam due to the presence of *Elodea canadensis* and *Potamogeton crispus* and the absence of *Chara* species. The Trophic Ranking score using the DOME index is 8.68.

4.5 Littoral Cladocera

To date, 24 cladocera species have been recorded from the 10 samples examined from the five study sites (Figures A-E.1, Appendix F). A number of samples remain to be analysed. Results are given in Tables A-E.7. The number of species was in the range 3-9 for each sample and 5-11 for each lake.

Llyn Cwellyn and Llyn Penrhyn had the highest species diversity with a total of 11 species being recorded in each lake (Tables B.7 and E.7). Llyn Coron (Table C.7) had the lowest species diversity with only five species being recorded. Although Llyn Idwal had high species diversity (9 species) there was a relatively small concentration of specimens (Table A.7). Only five intact specimens were found in Idwal 3 and less than 10 specimens of any species were found in Idwal 6.

Eurycercus lamellatus and *Pleuroxus aduncus* are found in all lakes. However, the latter species was noticeable less abundant in the Snowdonia lakes (Tables A.7 and B.7). It is evident that there is little species overlap between the Anglesey and Snowdonia sites. *Alona affinis*, *Bosmina coregoni* and *Chydorus sphaericus* are the only additional species which occurred in both an Anglesey and Snowdonia lakes.

The differences in cladoceran species composition between the Anglesey and Snowdonia lakes is amplified when the ecology of the rarer component species is examined. For example, *Alona rustica*, *Alonopsis elongata*, *Alonella excisa*, *Chydorus piger*, *Diaphanosoma brachyurum*, *Drepanothrix dentata* and *Polyphemus pediculus* are confined to the Snowdonia sites and all are known to favour waters with low productivity (Duigan 1992). Scourfield (1895) remarked that *Alonopsis elongata* was one of the most abundant and widely distributed Cladocera of North Wales. He also frequently found *Polyphemus pediculus* in the Snowdon district.

In contrast, *Daphnia longispina*, *Daphnia pulex*, *Pseudochydorus globosus* and *Simocephalus vetulus* are confined to the Anglesey lakes. Other studies have shown that they are most frequently found in lowland, relatively alkaline sites with abundant macrophyte growth (Fryer 1993). The ubiquitous nature of species such as *Eurycercus lamellatus*, *Alona affinis* and *Chydorus sphaericus* is supported by investigations in other regions (Duigan 1992, Fryer 1993).

As a result of the general paucity of knowledge on the distribution of Cladocera in Wales, a complete assessment of the importance of communities reported here is dependent on further investigations.

4.6 Open Water Zooplankton

There were considerable differences in the zooplankton species composition of the study lakes. Of the 31 planktonic taxons identified in the five lakes no single taxon was common to all five lakes. This is probably because of the wide gradient of trophic conditions covered in the study.

Species common in Llyn Idwal included *Cyclops abyssorum*, *Eubosmina longispina*, *Daphnia longispina* and *Arctodiaptomus laticeps*. However, diversity at this site was low with only five species identified (Table A.8). Llyn Cwellyn had a comparatively diverse zooplankton fauna, with nine species identified from the samples (Table B.8). Common species included *Cyclops abyssorum*, *Sida crystalina*, *Diaphanosoma brachyurum* and *Eudiaptomus gracilis*.

Llyn Coron also had a relatively diverse fauna with a total of 10 species identified from the samples. Common species included *Cyclops strenuus*, *Cyclops vicinus* and *Daphnia galeata* (Table C.8). The most similar sites in terms of zooplankton species composition were Llyn Dinam and Llyn Penrhyn; out of 13 planktonic crustacean species identified in the study seven were common to both these lakes (Tables D.8 and E.8). Llyn Dinam was characterised by *Eudiaptomus gracilis*, *Eucyclops serrulatus*, *Ceriodaphnia dubia*, *Macrocyclops albidus* and *Bosmina longirostris*. Llyn Penrhyn was characterised by high abundances of *Daphnia pulicaria*, *Daphnia galeata*, *Cyclops strenuus* and *Eudiaptomus gracilis*.

McQueen (1990) has described the expected characteristics of zooplankton structure along a gradient of lake trophy. The calanoids are expected to be the dominant herbivores in oligotrophic systems while cladocerans and micro-zooplankton dominate eutrophic systems. The data on zooplankton structure from the five lakes in this study (Tables A-E.8-9) seems to support this concept for the oligotrophic Llyn Idwal where the fraction of copepods was significantly high.

The level of cladoceran dominance in eutrophic lakes is often dependent on the presence or absence of planktivorous fish, which may significantly modify the size and structure of cladoceran populations. We have little information on the fish populations of the study lakes, but the highest proportion of large-bodied cladocerans in total zooplankton biomass which was observed in Llyn Coron may be connected with a low planktivorous fish population, perhaps resulting from artificial stocking of piscivorous species. The presence of large bodied daphnids (*Daphnia pulicaria*) in Llyn Penrhyn may indicate that this lake also has a low population of planktivorous fish.

4.7 Macroinvertebrates

Macroinvertebrates were abundant in the littoral zones of all the lakes studied (see Tables A-E.10), however, the following should be noted in reading these data tables:

i. It is not possible to identify triclads to species level from preserved specimens.
ii. Individuals of Baetidae, *Leptophlebia* sp., Corixidae - immatures and *Limnephilus* sp. are all very small and can not be identified to species level.
iii. There are no identification keys to the groups Haliplidae sp. - larvea; Dytiscidae - larvea; *Hydroptila* sp.; and *Oxyethira* sp.
iv. More detailed identification of the *Haliplus ruficollis* group rely on male genitalia and are beyond the scope of this project.
v. More detailed descriptions of Diptera are extremely difficult and beyond the scope of this project.
vi. To avoid duplication, the measure of species richness does not include unidentified immatures where more mature specimens in the same group were present. (e.g. for Llyn Coron, immature Corixidae were not included in the count as adults of the same group were present.

The most marked division among the lakes based on the macroinvertebrate fauna was between the upland, oligotrophic lakes (Llyn Idwal and Llyn Cwellyn) and the lowland, eutrophic lakes of Anglesey. The upland lakes have fewer species, but by no means a particularly impoverished fauna, whereas the lowland lakes are more species rich and have higher invertebrate densities.

The macroinvertebrate fauna of both oligotrophic lakes is dominated by insect taxa typical of stony lake shores. The littoral food webs are probably based in attached algae and fine detritus on the lake bottom. Species of leptophlebiid and caenid mayflies that typically occur in the silt/mud between stones, feeding on periphyton and detritus, were common. Similar habitats are characteristic of both larvae and adults of the abundant elmid beetle *Oulimnius troglodytes*. Other abundant taxa such as the net-spinning polycentropodid caddis flies and Corixidae are primarily predatory in their feeding habits. The Plecoptera found in Llyn Cwellyn are perhaps more usually associated with running waters, but are characteristic of wave lashed lake shores - a dominant feature of this lake. The samples from Llyn Idwal indicate a species list that is shorter and invertebrate densities lower than might be anticipated, possible as a result of sub-optimal sampling conditions. Further samples (i.e. the spring samples) may well indicate even greater similarity between these two lakes.

The three lowland lakes (Llyn Coron, Llyn Dinam and Llyn Penrhyn) are all characterised by abundant and diverse assemblages of molluscs, leaches, amphipods, isopods and various insects, all typical of highly productive, eutrophic conditions. The macroinvertebrate food web is dominated by the well developed macrophyte beds found in all these lakes. The molluscs graze periphyton growing on plant stems and leaves, whereas the super-abundant *Asellus* and *Gammarus* shred decomposing plant parts and other detritus. The leaches are all predatory on invertebrates, and primarily those living on macrophyte surfaces, with the exception of *Theromyzon tessusatum* which is parasitic on water birds. The Corixidae and Odonata are also important predators within macrophyte beds where they escape the predation pressures of fish restricted to the more open water. Llyn Penrhyn and Llyn Dinam have very similar species assemblages. Differences between them probably reflect small-scale variations among local micro-habitats rather than whole-basin differences. The most distinguishing feature of Llyn Coron is the dominance of *Asellus meridianus*, whereas the other two Anglesey lakes are dominated by the more common *A. aquaticus*. *A. aquaticus* is widely distributed throughout the British Isles; *A. meridianus* tends to be restricted to western and island areas, although the ecological differences between these two species are unclear.

Methodological observations

The sampling protocol adapted from the UK Acid Waters Monitoring Network was appropriate for the nutrient-poor, soft-water lakes (Llyn Idwal and Llyn Cwellyn). However, it is probably not the best strategy for the more productive sites. The mechanics of collecting samples was not particularly difficult, although extensive macrophyte beds can make access difficult. Processing littoral macroinvertebrate samples is time consuming and labour intensive, and the huge numbers of organisms associated with vegetative material that were recovered from the productive lakes resulted in an exorbitant laboratory effort. The very nature of the vegetative material precluded sub-sampling.

In future surveys of productive sites it should be possible to make the sampling process much more efficient and effective by reducing sample kick/sweeps to 30 or even 20 seconds, yet still maintain the same degree of replication. An additional measure that would improve the labour/cost-effectiveness of the invertebrate programme would be to reduce the sampling programme to one survey per year. Which season is most suitable will be ascertained once the results of the April 1994 survey are available.

5 Discussion

5.1 Site Comparison

Although full data analyses and discussion will be presented in the second report, some preliminary observations can be made on the characteristics exhibited by the five study lakes.

There is a very clear distinction between the physical, chemical and biological characteristics of the Anglesey lakes (Llyn Coron, Llyn Dinam and Llyn Penrhyn) and the Snowdonia lakes (Llyn Idwal and Llyn Cwellyn). The former are shallow and eutrophic, the latter oligotrophic and relatively deep. Classification using almost any of the chemical or biological data collected would emphasise the dichotomy between these lake types. There are few similarities in the biological communities present in the two lake types, and few species are common to both the eutrophic and oligotrophic sites.

The data also indicate some differences within the oligotrophic and eutrophic lake types. Several important distinctions can be made between Llyn Idwal and Llyn Cwellyn, even though both lakes are oligotrophic. There are obvious differences in topographic and bathymetric factors such as altitude, lake and catchment size, mean depth, and extent of shallow water. Llyn Idwal is a high altitude, relatively shallow, oligotrophic corrie lake whereas Llyn Cwellyn is much deeper, larger and at lower altitude. In addition, the alkalinity of Llyn Idwal is considerably higher than Llyn Cwellyn. There are also differences in the biological communities of the two lakes. For instance, Llyn Idwal includes taxa indicative of relatively high alkalinity conditions such as the diatom *Nitzschia* [cf. *perminuta*], and the macrophytes *Phragmites* and *Nitella*. However, when the Palmer (1992) aquatic macrophyte classification is applied to the two sites they are both typed as 3. This suggests that there is scope for refining classification systems for oligotrophic lake ecosystems.

Although the physical characteristics of the three eutrophic lakes are broadly similar, there are clear differences in water chemistry and biological communities. Llyn Dinam has a somewhat lower alkalinity than the other two sites. All three sites have high concentrations of phosphorus and nitrate, but Llyn Penrhyn is outstanding in experiencing phosphorus concentrations an order of magnitude higher than the other two sites. There are also considerable differences in biological communities. For instance, the diatom assemblages of Llyn Penrhyn and Llyn Coron are dominated by the planktonic *Stephanodiscus parvus*. This taxon is less abundant in Llyn Dinam. There are also contrasts between the aquatic macrophyte communities of the lakes. When the macrophyte data is applied to the Palmer (1992) classification the three lakes fall into different site types; Llyn Coron as type 8, Llyn Dinam as type 10B and Llyn Penrhyn as type 10A.

5.2 Strategy for Data Analyses and Integrated Classification

A range of ordination and classification techniques may be applied to the different individual data types or data formats that are presented in this report. For example, Palmer (1992) used the ordination programme DECORANA (Hill 1979a) and the classification programme TWINSPAN (Hill 1979b) to produce the classification based on aquatic macrophyte communities. Classifications based on individual biological groups and physical and chemical data will comprise an ongoing component of this programme. However, the field survey data provide an excellent basis for the assessment and <u>integrated</u> classification of lake ecosystems and a wide variety of powerful techniques are available for analysing the types of multi-variate chemical and ecological data presented in this report (e.g. Jongman *et al.* 1987, ter Braak 1987).

Data analyses in the second and later reports will focus on four areas;

i) Application of existing classification systems to the study lakes. These systems include chemical classifications (e.g. Vollenweider 1968) and biological classifications (e.g. Palmer 1992). The data on water chemistry and selected biological groups will also be assessed with respect to existing data-sets of lake chemistry and biology (e.g. Flower *et al.* 1989, Stevenson *et al.* 1991, Anderson & Bennion unpublished).

ii) Development of lake classifications based on individual biological groups, physical and chemical data. These classifications will be generated using ordination and classification techniques appropriate to the individual data types.

iii) Development of data analytical methodology for an integrated classification system. An important aspect is the mixed nature of the data collected. The dataset includes nominal, ordinal, proportional and continuous data types. Gower's similarity index for mixed data will therefore be used to construct a similarity matrix which can be applied to site ordination and classification.

iv) Comparison of integrated classification with results of existing lake classifications and classifications generated from individual biological groups, physical and chemical data.

i) can be addressed as each new lake is added to the database but a major weakness of the current study is the need to utilise many more than five sites in an integrated classification scheme. The five sites studied to date clearly do not adequately represent the full range of standing water types in the region of interest and therefore ii) and iii) will develop only when the database of sites reaches a size appropriate for the relevant statistical techniques (*c.* 30+). Until such a time the classifications generated will be preliminary, and will need to be progressively refined by the addition of data from a wider range of sites.

The ultimate objective of this work must be to survey a sufficient number of sites of diverse nature to permit a full comparative evaluation of both the individual and integrated classification schemes generated (i.e. iv) above).

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APPENDIX A DATA TABLES AND FIGURES: LLYN IDWAL

Table A.1 Llyn Idwal: physical data: 10 July 1993

Air temperature = 10°C
Secci disc transparency = 6.3 m

Depth (m)	Temperature (°C)	Oxygen (mg l^{-1})
0	13.3	9.4
1	13.3	9.4
2	13.3	9.2
3	13.3	9.2
4	13.2	9.4
5	13.0	9.3
6	12.8	9.3
7	12.6	9.3
8	12.5	9.3
9	12.4	9.3
10	12.3	9.2
11	12.3	9.2
12	12.3	9.2
13	12.3	9.2

Table A.2 Llyn Idwal: physical data: 5 September 1993

Air temperature = 14°C
Secci disc transparency = 7.3 m

Depth (m)	Temperature (°C)	Oxygen (mg l^{-1})
0	14.0	10.2
1	14.0	9.7
2	14.0	9.8
3	14.0	10.6
4	14.0	11.2
5	14.0	11.2
6	14.0	10.6
7	13.8	10.4
8	13.6	10.2
9	13.2	10.0
10	13.0	9.5
11	12.6	9.0
12	12.4	8.7
13	12.2	8.4

Table A.3 Llyn Idwal: water chemistry

Determinand		Sample date			
		11-7-93	5-9-93	6-12-93	-3-93
pH		6.81	6.77	6.67	-
Alkalinity 1	μeq l^{-1}	82	91	58	-
Alkalinity 2	μeq l^{-1}	72	83	49	-
Conductivity	μS cm^{-1}	28	27	28	-
Sodium	μeq l^{-1}	105	108	101	-
Potassium	μeq l^{-1}	3	4	5	-
Magnesium	μeq l^{-1}	31	31	32	-
Calcium	μeq l^{-1}	100	113	90	-
Chloride	μeq l^{-1}	99	98	100	-
Aluminium $_{\text{total monomeric}}$	μg l^{-1}	3	1	2	-
Aluminium $_{\text{non-labile}}$	μg l^{-1}	3	0	2	-
Aluminium $_{\text{labile}}$	μg l^{-1}	0	1	0	-
Absorbtion	(250nm)	.027	.044	.029	-
Carbon $_{\text{total organic}}$	mg l^{-1}	1.1	1.4	1.4	-
Phosphorus $_{\text{total}}$	μgP l^{-1}	4.6	6.9	5.8	-
Phosphorus $_{\text{total soluble}}$	μgP l^{-1}	3.8	6.2	3.4	-
Phosphorus $_{\text{soluble reactive}}$	μgP l^{-1}	2.8	4.2	1.1	-
Nitrate	μgN l^{-1}	42	49	231	-
Silica $_{\text{total}}$	μg l^{-1}	-	0.84	1.32	-
Silica $_{\text{soluble reactive}}$	μg l^{-1}	0.36	0.60	1.28	-
Chlorophyll a	μg l^{-1}	0.4	1.9	0.9	-

Table A.4 Llyn Idwal: epilithic diatom taxon list (including taxa >1.0%)

Taxon	Relative Frequency (%)
Achnanthes minutissima	39.3
Brachysira vitrea	17.3
Nitzschia [cf. *perminuta*]	10.9
Denticula tenuis	3.6
Tabellaria flocculosa	3.1
Nitzschia frustulum	2.7
Cymbella microcephela	2.7
Synedra acus	2.7
Cymbella cesatii	2.2
Achnanthes flexella	1.5
Brachysira brebissonii	1.3
Cymbella lunata	1.3
Navicula radiosa var. *tenella*	1.1

Total count = 550
Total number of taxa = 29

Table A.5 Llyn Idwal: surface sediment diatom taxon list (including taxa >1.0%)

Taxon	Relative Frequency (%)
Achnanthes minutissima	30.7
Brachysira vitrea	6.2
Nitzschia [cf. *perminuta*]	5.7
Fragilaria virescens var. *exigua*	5.7
Cymbella lunata	3.3
Cymbella microcephela	2.9
Cyclotella [*kuetzingiana* var. *minor*]	2.7
Navicula radiosa var. *tenella*	2.7
Synedra acus	2.2
Tabellaria floculosa	2.0
Frustulia rhomboides var. *saxonica*	1.8
Fragilaria vaucheriae	1.6
Neidium alpinum	1.6
Achnanthes marginulata	1.5
Cymbella gaeumannii	1.5
Navicula cocconeiformis	1.3
Achnanthes sp.	1.1
Cymbella descripta	1.1

Total count = 548
Total number of taxa = 74

Table A.6 Llyn Idwal: aquatic macrophyte abundance summary: 5 September 1993

Taxon	code	Abun.	comments
Emergent taxa			
Caltha palustris	361201	R	
Juncus articulatus	383003	F	widespread on shoreline
Equisetum fluviatile	350202	O	locally abundant
Menyanthes trifoliata	364701	R	south end only
Ranunculus flammula	366904	O	
Carex rostrata	381129	R	locally abundant in south
Juncus effusus	383010	F	widespread on shoreline
Phragmites australis	383801	R	one stand in south end
Floating taxa			
Glyceria fluitans	382502	R	
Potamogeton natans	384012	R	one stand in south end
Potamogeton polygonifolius	384017	O	in stream inlets, mainly in south
Sparganium angustifolium	384601	O	locally abundant in south
Submergent taxa			
Filamentous green algae	170000	F	
Nitella sp.	220000	O	abundant in shallows in north-east
Fontinalis antipyretica	323401	O	
Hygrohypnum sp. (to be verified)	323900	R	in deeper water in north
Polytrichum sp.	326200	O	
Sphagnum auriculatum	327401	O	
Isoetes lacustris	350302	A	present in shallows,dominant 2-2.5m
Callitriche hamulata	361103	F	
Littorella uniflora	363901	F	patchy but widespread
Lobelia dortmanna	364001	A	
Myriophyllum alterniflorum	365401	F	
Subularia aquatica	368701	F	
Juncus bulbosus var. fluitans	383006	F	
Potamogeton berchtoldii	384003	O	recovered from deeper water in north

Table A.7 Llyn Idwal: littoral Cladocera taxon list

Taxon	Count in Sample 3	Count in Sample 6
Alonopsis elongata	3	+
Alonella excisa		+
Chydorus piger	+	+
Drepanothrix dentata		+
Eubosmina longispina		+
Eurycerus lamellatus	2	+
Pleuroxus abuncus		+
Pleuroxux trogonellus		+
Pleuroxus truncatus		+

+ = Species present

Table A.8 Llyn Idwal: open water zooplankton taxon list

Taxon	Abundance
Cyclops abyssorum	2
Eubosmina longispina	2
Daphnia longispina	2
Acroperus elongatus	+
Arctodiaptomus laticeps	2

2 = Species common (abundance >5%)
1 = Species rare (found in both samples analysed)
+ = Species very rare (found in one of samples analysed)

Table A.9 Llyn Idwal: open water zooplankton characteristics: 5 September 1993

Station sampled: A

Depth of Station (m)	10.5
Total zooplankton biomass (gDM m^{-2})	0.81
Net algal biomass (gDM m^{-2})	0
% Cladoceran biomass in total zooplankton biomass	32
% large Cladocera (>710 μm) in total zooplankton biomass	0.1
% large Copepoda (>420 μm) in total zooplankton biomass	50

Table A.10 Llyn Idwal: littoral invertebrate data

code	species	mean no. per sample
	BIVALVIA	
14 03 02 00	*pisidium* spp.	56.0
	HIRUDINIA	
17 04 01 02	*Erpobdella octoculata* (L.)	0.3
	MALACOSTRACA	
28 07 03 03	*Gammarus lacustris* Sars	1.0
	EPHEMEROPTERA	
30 04 01 00	*Leptophlebia* sp.	15.3
30 08 02 04	*Caenis horaria* (L.)	36.0
	PLECOPTERA	
31 05 03 01	*Diura bicaudata* (L.)	1.0
	HEMIPTERA	
33 11 00 00	Corixidae - immatures	28.3
	COLEOPTERA	
35 01 00 00	Haliplidae sp. - larvae	0.3
35 03 00 00	Dytiscidae - larvae	0.3
35 11 06 02	*Oulimnius troglodytes* (Gyllenhal)	47.3
	TRICHOPTERA	
38 03 03 01	*Polycentropus flavomaculatus* (Pictet)	1.3
38 03 05 01	*Cyrnus trimaculatus* (Curtis)	0.7
38 06 03 00	*Hydroptila* sp.	6.0
38 06 06 00	*Oxyethira* sp.	2.0
38 12 01 07	*Athripsodes cinereus* (Curtis)	0.3
38 12 02 03	*Mystacides longicornis* (L.)	1.0
	DIPTERA	
40 01 00 00	Tipulidae	2.7
40 09 00 00	Chironomidae	70.0
	Total invertebrates	270.0
	Species richness (minimum)	18

Figure A.1 Llyn Idwal: sample location & substrate map

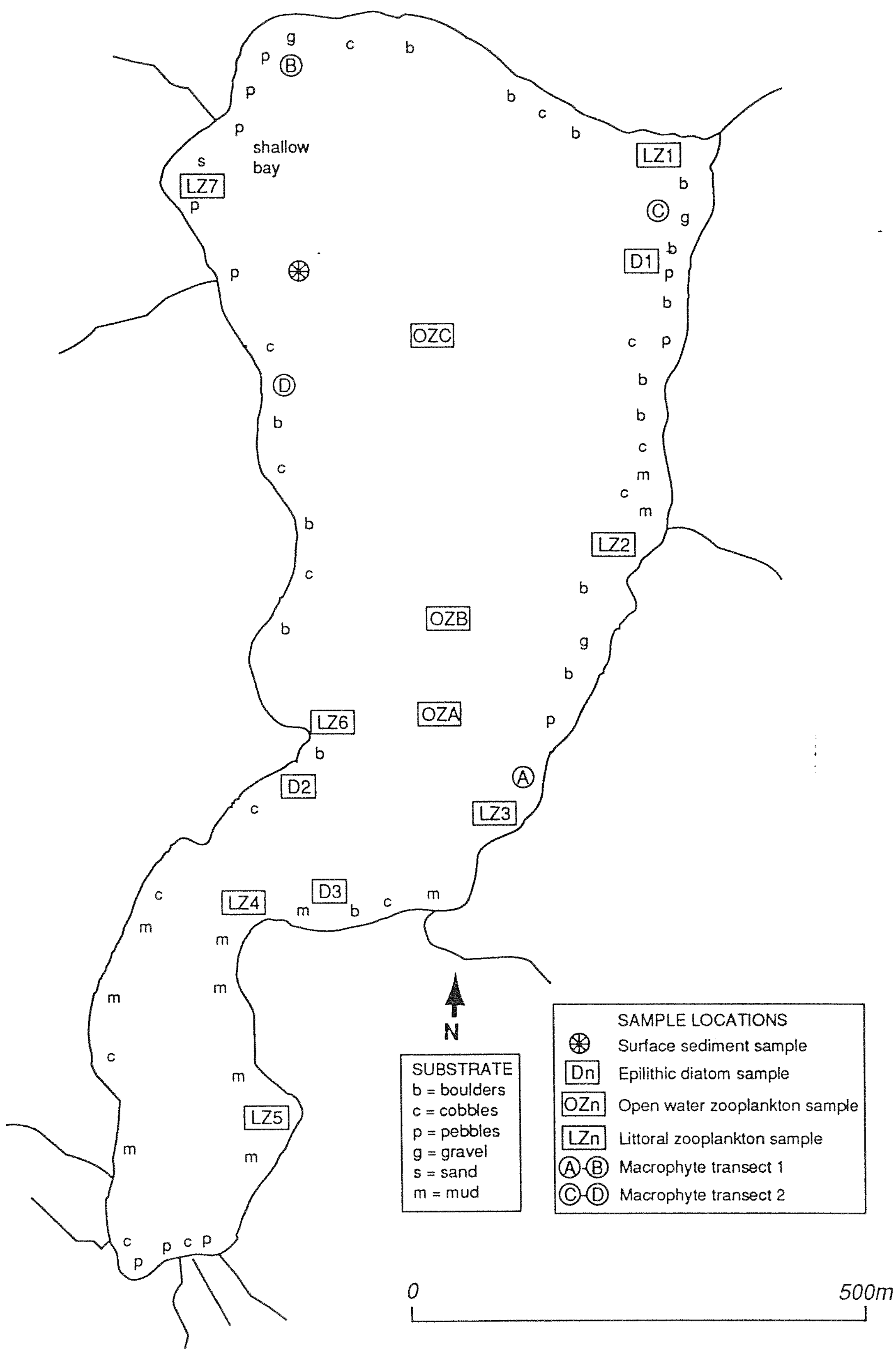


Figure A.2 Llyn Idwal: aquatic macrophyte distribution map

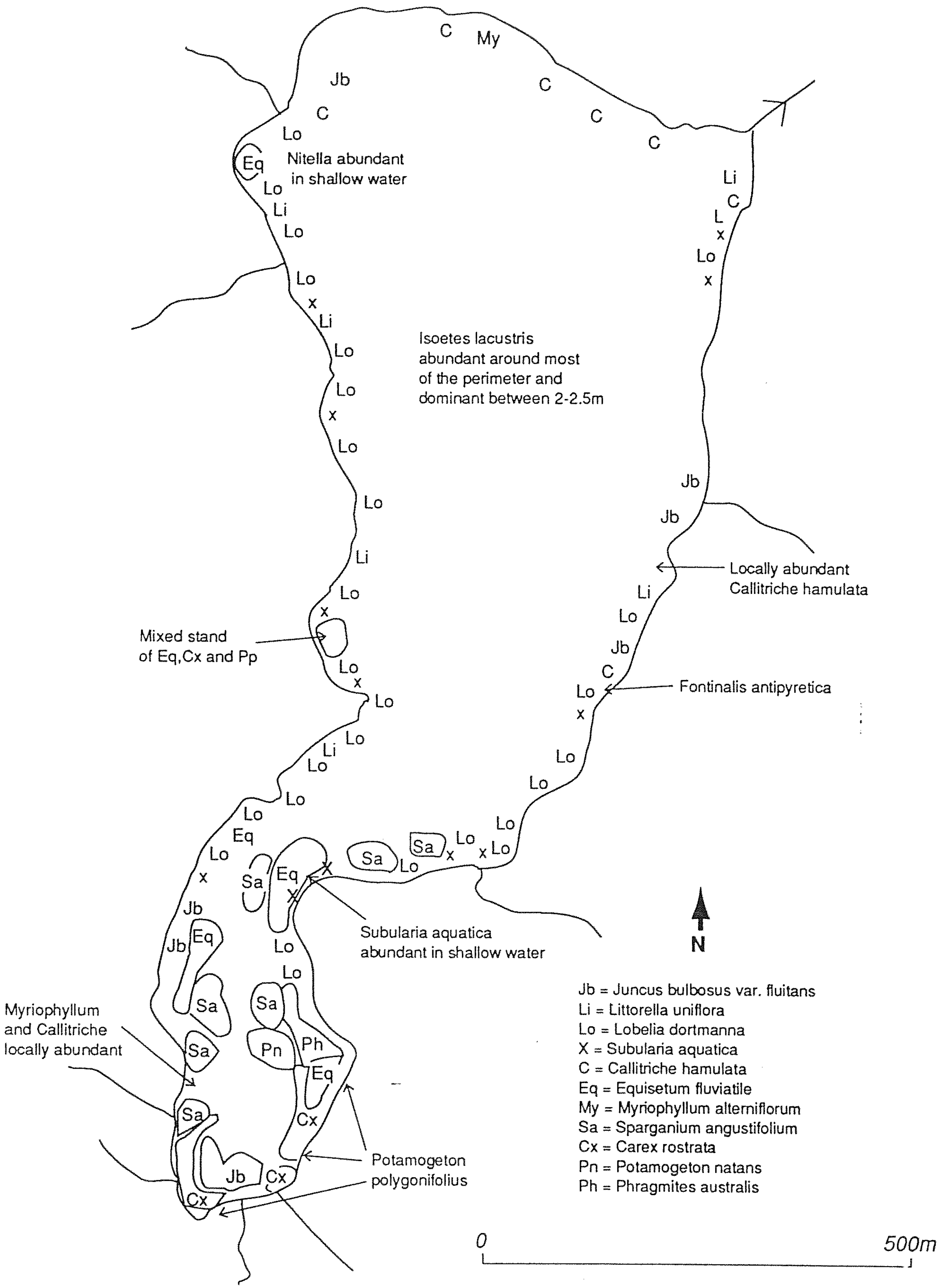


Table B.1 Llyn Cwellyn: physical data: 10 July 1993

Air temperature = 13°C
Secci disc transparency = 6.9 m

Depth (m)	Temperature (°C)	Oxygen (mg l^{-1})
0	15.0	10.8
1	15.0	10.8
2	15.0	10.6
3	15.0	10.4
4	15.0	10.4
5	15.0	10.4
6	15.0	10.3
7	15.0	10.3
8	15.0	10.3
9	14.8	10.3
10	13.0	10.3
11	12.0	10.5
12	11.2	10.5
13	11.0	10.5
14	10.8	10.5
15	10.8	10.5
16	10.5	10.5
17	10.3	10.5
18	10.2	10.5
19	10.2	10.4
20	10.2	10.4
21	10.1	10.4
22	10.1	10.2
23	10.1	10.3
24	10.1	10.2
25	10.1	10.2
26	10.1	10.0
27	10.0	10.0
28	10.0	10.0
29	10.0	9.4
30	10.0	9.3
31	10.0	9.0
32	10.0	8.9
33	10.0	8.6
34	10.0	8.4
35	10.0	8.4

Table B.2 Llyn Cwellyn: physical data: 4 September 1993

Air temperature = 14.8°C
Secci disc transparency = 9.0 m

Depth (m)	Temperature (°C)	Oxygen (mg l^{-1})
0	15.9	10.2
1	15.0	10.1
2	14.9	10.1
3	14.9	10.2
4	14.9	10.4
5	15.2	10.6
6	15.2	11.3
7	15.1	11.0
8	15.0	10.4
9	14.9	10.2
10	14.8	10.1
11	14.8	10.0
12	14.5	9.8
13	14.3	9.6
14	14.1	9.4
15	13.8	9.3
16	12.9	9.2
17	12.2	9.2
18	11.4	9.2
19	11.1	9.3
20	10.8	9.2
21	10.8	9.2
22	10.8	9.1
23	10.8	8.9
24	10.8	8.8
25	10.7	8.7
26	10.6	8.5
27	10.6	8.3
28	10.5	8.1
29	10.4	8.0
30	10.4	7.9
31	10.3	7.7
32	10.1	7.1
33	10.0	6.7
34	10.0	6.4
35	10.0	6.0

Table B.3 Llyn Cwellyn: water chemistry

Determinand		Sample date			
		10-7-93	4-9-93	6-12-93	-3-93
pH		6.44	6.41	6.39	-
Alkalinity 1	μeq l^{-1}	38	39	41	-
Alkalinity 2	μeq l^{-1}	30	31	32	-
Conductivity	μS cm^{-1}	36	34	36	-
Sodium	μeq l^{-1}	172	170	160	-
Potassium	μeq l^{-1}	5	6	7	-
Magnesium	μeq l^{-1}	40	40	41	-
Calcium	μeq l^{-1}	89	95	76	-
Chloride	μeq l^{-1}	194	189	168	-
Aluminium $_{total\ monomeric}$	μg l^{-1}	3	1	2	-
Aluminium $_{non-labile}$	μg l^{-1}	3	0	2	-
Aluminium $_{labile}$	μg l^{-1}	0	1	0	-
Absorbtion	(250nm)	.021	.054	.048	-
Carbon $_{total\ organic}$	mg l^{-1}	1.2	1.1	1.7	-
Phosphorus $_{total}$	μgP l^{-1}	5.1	9.0	7.0	-
Phosphorus $_{total\ soluble}$	μgP l^{-1}	4.7	6.7	4.2	-
Phosphorus $_{soluble\ reactive}$	μgP l^{-1}	4.2	5.0	1.5	-
Nitrate	μgN l^{-1}	161	112	175	-
Silica $_{total}$	μg l^{-1}	-	1.49	1.53	-
Silica $_{soluble\ reactive}$	μg l^{-1}	1.4	1.4	1.51	-
Chlorophyll a	μg l^{-1}	0.9	3.4	1.5	-

Table B.4 Llyn Cwellyn: epilithic diatom taxon list (including taxa >1.0%)

Taxon	Relative Frequency (%)
Achnanthes minutissima	47.9
Tabellaria flocculosa	21.3
Fragilaria vaucheriae	11.4
Brachysira vitrea	5.6
Peronia fibula	2.9
Cymbella lunata	1.4
Achnanthes altaica	1.1
Eunotia pectinalis var. *minor*	1.1

Total count = 553
Total number of taxa = 26

Table B.5 Llyn Cwellyn: surface sediment diatom taxon list (including taxa >1.0%)

Taxon	Relative Frequency (%)
Achnanthes minutissima	24.7
Tabellaria flocculosa	7.6
Brachysira vitrea	6.0
Eunotia incisa	4.5
Fragilaria vaucheriae	4.2
Eunotia exigua	4.0
Fragilaria virescens var. *exigua*	2.9
Achnanthes austriaca var. *helvetica*	2.5
Eunotia pectinalis var. *minor*	2.0
Cymbella lunata	1.8
Peronia fibula	1.8
Eunotia rhomboidea	1.6
Achnanthes marginulata	1.6
Cymbella perpusilla	1.6
Achnanthes subatomoides	1.3
Cyclotella rossii	1.1
Nitzschia perminuta	1.1

Total count = 552
Total number of taxa = 76

Table B.6 Llyn Cwellyn: aquatic macrophyte abundance summary: 4 September 1994

Taxon	code	Abun.	comments
Emergent taxa			
Caltha palustris	361201	O	on east shore-line
Equisetum fluviatile	350202	R	one small stand in south
Ranunculus flammula	366904	O	on southern shoreline
Juncus effusus	383010	F	
Floating taxa			
Potamogeton natans	384012	R	one bed near north-west shore
Potamogeton polygonifolius	384017	R	in stream inflows in south
Submergent taxa			
filamentous green algae	170000	F	
Batrachospermum sp.	20000	O	
Fontinalis antipyretica	323401	O	locally abundant in south end
Sphagnum auriculatum	327401	O	
Drepanocladus sp. (to be verified)	322900		
Scapania undulata	345410	R	on submerged boulders
Isoetes lacustris	350302	A	abundant from 1.5m dominant 3-5m
Callitriche hamulata	361103	F	widespread to depth of 3m
Elatine hexandra	362401	R	in shallow water on north shore
Littorella uniflora	363901	A	widespread to depth of 1.5m
Lobelia dortmanna	364001	F	widespread to depth of 1m
Myriophyllum alterniflorum	365401	F	
Subularia aquatica	368701	F	in shallow water on east shore only
Juncus bulbosus var.fluitans	383006	A	prolific growth at south end
other wetland taxa			
Oenanthe crocata	365802	O	
Deschampsia caespitosa	381801	F	
Juncus articulatus/acutiflorus	383001/3	F	
Molinia caerulea	383501	O	
Angelica sylvestris	360302	O	
Filipendula ulmaria	362701	O	
Viola palustris	369901	O	
Alnus glutinosa	360201	O	
Salix sp.	367500	O	

Table B.7 Llyn Cwellyn: littoral Cladocera taxon list

Taxon	Count in Sample 4	Count in Sample 6
Alona affinis		+
Alona rustica	+	
Alonopsis elongata	6	7
Alonella excisa	+	
Chydorus sphaericus	1	
Diaphanosoma brachyurum	1	8
Eurycerus lamellatus	4	3
Pleuroxus abuncus		1
Pleuroxus truncatus	6	1
Polyphemus pediculus	34	57
Sida crystallina	174	69

+ = Species present

Table B.8 Llyn Cwellyn: open water zooplankton taxon list

Taxon	Abundance
Eudiaptomus gracilis	2
Diaphanosoma brachyurum	2
Leptodora kindti	+
Sida crystalina	2
Biapertura affinis	+
Cyclops abyssorum	2
Bythotrephes longimanus	2
Conochilus sp.	2
Kellicottia longospina	+

2 = Species common (abundance >5%)
1 = Species rare (found in both samples analysed)
+ = Species very rare (found in one of samples analysed)

Table B.9 Llyn Cwellyn: open water zooplankton characteristics: 4th September 1993

Station sampled: A

Depth of Station (m)	34.5
Total zooplankton biomass (gDM m^{-2})	1.39
Net algal biomass (gDM m^{-2})	0
% Cladoceran biomass in total zooplankton biomass	43
% large Cladocera (>710 μm) in total zooplankton biomass	4
% large Copepoda (>420 μm) in total zooplankton biomass	28

Table B.10 Llyn Cwellyn: littoral invertebrate data

code	species	mean no. per sample
	TURBELLARIA	
03 12 00 00	Tricladida	0.3
	MOLLUSCA	
13 07 01 07	*L. peregra* (Muller)	6.7
13 10 01 01	*Acroloxus lacustris* (L.)	0.3
	BIVALVIA	
14 03 02 00	*pisidium* spp.	10.7
	HIRUDINIA	
17 04 01 02	*Erpobdella octoculata* (L.)	5.7
	EPHEMEROPTERA	
30 02 00 00	Baetidae	1.7
30 04 01 00	*Leptophlebia* sp.	45.0
30 08 02 04	*Caenis horaria* (L.)	25.0
30 08 02 06	*C. luctuosa* (Burmeister)	128.0
	PLECOPTERA	
31 02 04 04	*Nemoura cambrica* (Stephenes)	58.3
31 03 01 03	*Leuctra hippopus* (Kempny)	2.3
31 08 01 01	*Siphonoperla torrentium* (Pictet)	5.0
	HEMIPTERA	
33 11 00 00	Corixidae - immatures	33.7
	COLEOPTERA	
35 03 00 00	Dytiscidae - larvae	0.3
35 03 07 03	*P. depressus elegans* (Panzer)	0.7
35 11 03 01	*Limnius volckmari* (Panzer)	6.0
35 11 06 02	*Oulimnius troglodytes* (Gyllenhal)	31.0
	MEGALOPTERA	
36 01 01 01	*Sialis lutaria* (L.)	0.7
	TRICHOPTERA	
38 03 03 01	*Polycentropus flavomaculatus* (Pictet)	30.0
38 03 04 01	*Holocentropus dubius* (Rambur)	2.7
38 03 05 01	*Cyrnus trimaculatus* (Curtis)	11.0
38 04 02 01	*Tinodes waeneri* (L.)	9.3
38 06 03 00	*Hydroptila* sp.	8.3

Table B.10 Continued

code	species	mean no. per sample
38 07 04 03	*Agrypnia varia* (Fabricius)	0.3
38 12 01 07	*Athripsodes cinereus* (Curtis)	23.0
38 14 02 01	*Lepidostoma hirtum* (Fabricius)	3.3
38 15 01 01	*Sericostoma personatum* (Spence)	1.0
	DIPTERA	
40 01 00 00	Tipulidae	0.7
40 09 00 00	Chironomidae	479.0
40 17 00 00	Empididae	0.7
	Total invertebrates	930.7
	Species richness (minimum)	29

Figure B.1 Llyn Cwellyn: sample location & substrate map

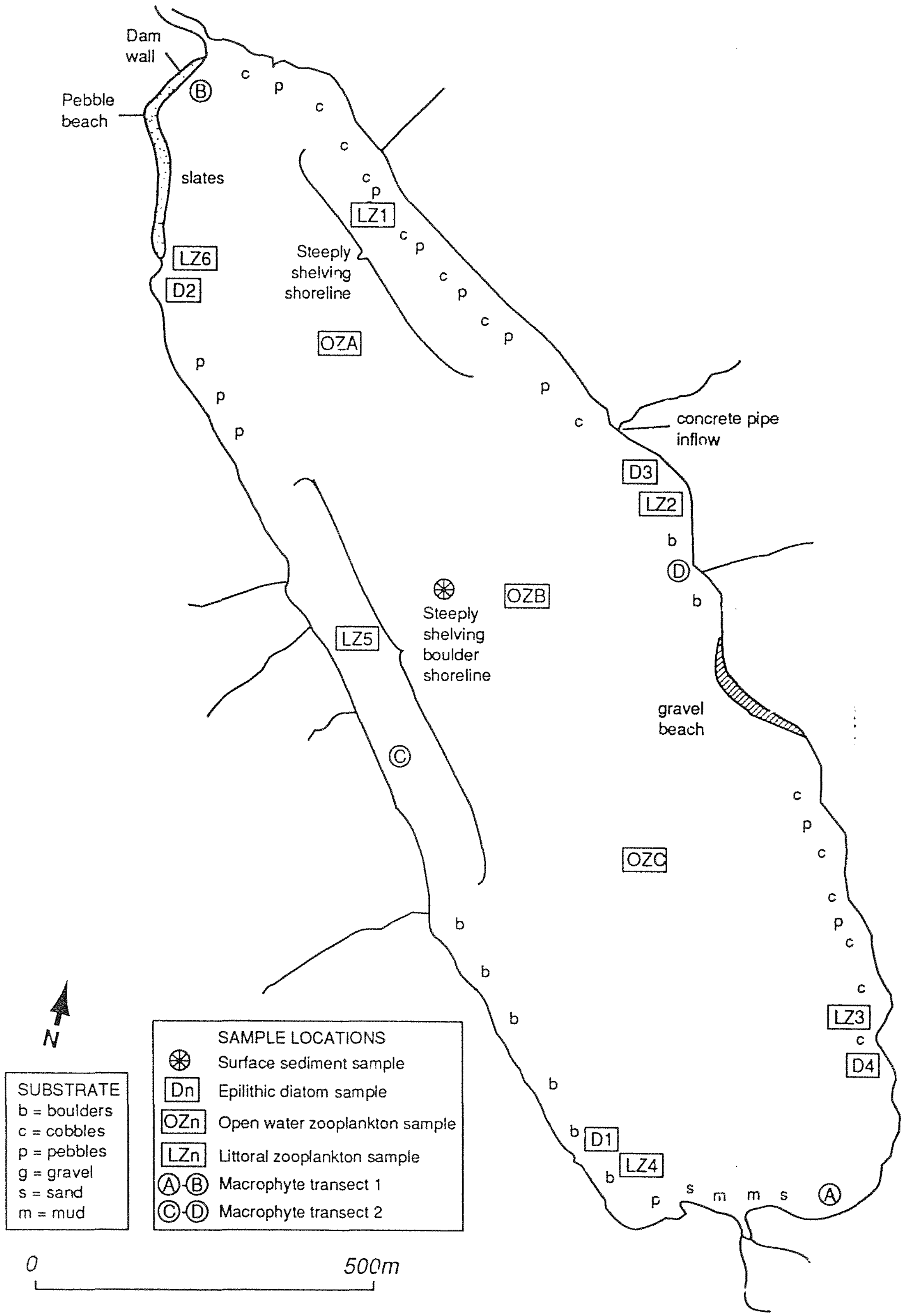
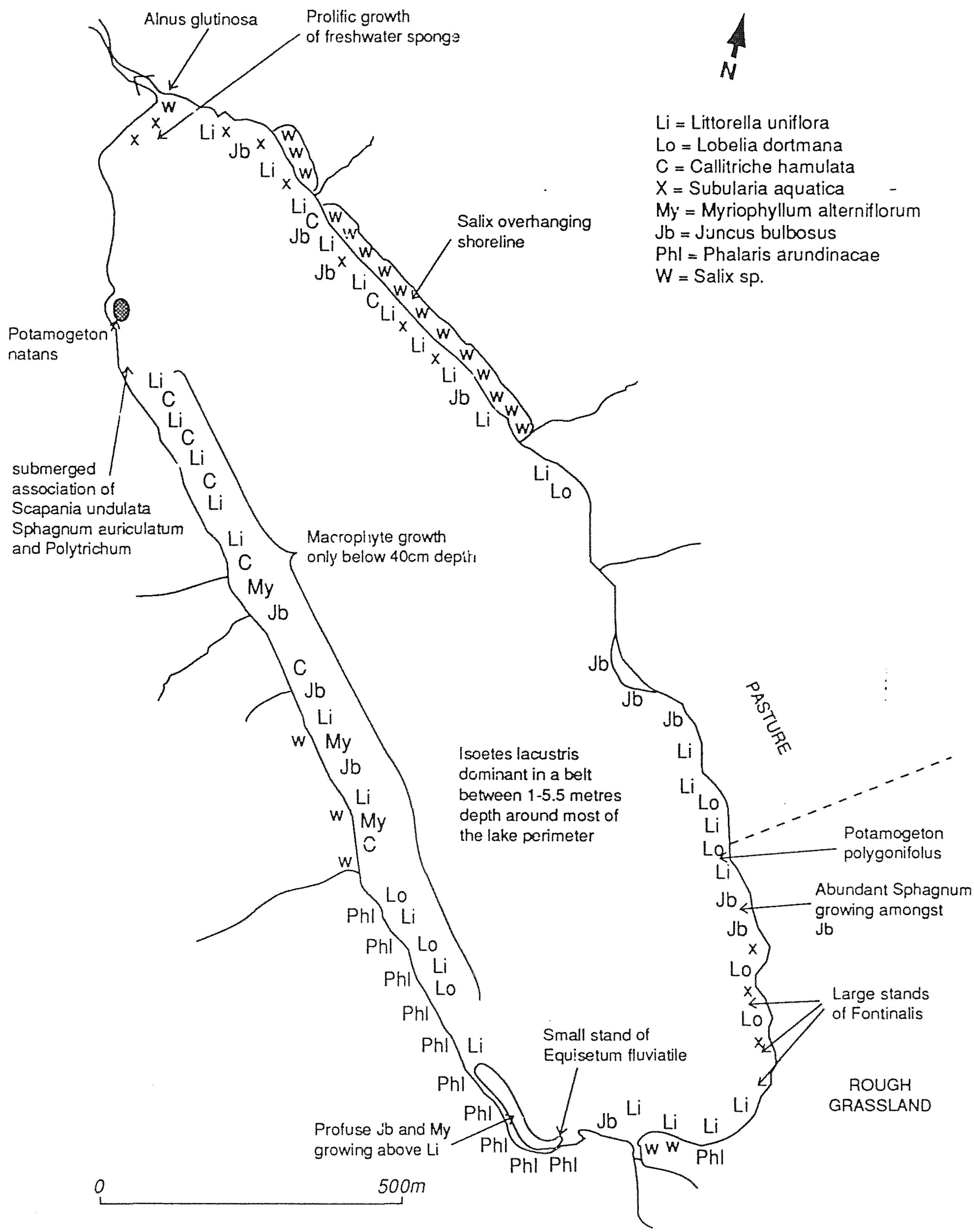


Figure B.2 Llyn Cwellyn: aquatic macrophyte distribution map



APPENDIX C DATA TABLES AND FIGURES: LLYN CORON

Table C.1 Llyn Coron: physical data: 10 July 1993

Air temperature = 15°C
Secci disc transparency = 1.3 m

Depth (m)	Temperature (°C)	Oxygen (mg l^{-1})
0	16.5	9.6
0.4	16.5	9.6
0.8	16.5	9.4
1.2	16.5	9.4
1.6	16.5	9.4
2.0	16.5	9.2
2.4	16.5	9.4
2.7	16.5	9.4

Table C.2 Llyn Coron: physical data: 1 September 1993

Air temperature = 22°C
Secci disc transparency = 0.5 m

Depth (m)	Temperature (°C)	Oxygen (mg l^{-1})
0	18.3	12.5
0.2	18.3	12.9
0.4	18.3	13.2
0.6	18.3	13.7
0.8	18.3	13.7
1.0	18.2	13.7
1.2	17.9	12.7
1.4	17.8	12.4
1.6	17.6	12.1
1.8	17.4	12.0
2.0	17.1	10.8
2.2	16.9	10.1
2.4	16.3	9.3

Table C.3 Llyn Coron: water chemistry

Determinand		Sample date			
		10-7-93	1-9-93	6-12-93	-3-94
pH		8.39	9.17	7.90	-
Alkalinity	µeq l^{-1}	2069	2150	1745	-
Alkalinity 2	µeq l^{-1}	2045	2171	1766	-
Conductivity	µS cm^{-1}	334	326	336	-
Sodium	µeq l^{-1}	821	884	828	-
Potassium	µeq l^{-1}	55	60	98	-
Magnesium	µeq l^{-1}	580	616	705	-
Calcium	µeq l^{-1}	1971	2124	2067	-
Chloride	µeq l^{-1}	967	1027	896	-
Aluminium $_{total\ monomeric}$	µg l^{-1}	5	15	4	-
Aluminium $_{non-labile}$	µg l^{-1}	4	0	3	-
Aluminium $_{labile}$	µg l^{-1}	1	15	1	-
Absorbtion	(250nm)	.279	.246	.309	-
Carbon $_{total\ organic}$	mg l^{-1}	7.2	6.5	6.8	-
Phosphorus $_{total}$	µgP l^{-1}	98.6	348.2	111.1	-
Phosphorus $_{total\ soluble}$	µgP l^{-1}	88.4	203.4	89.5	-
Phosphorus $_{soluble\ reactive}$	µgP l^{-1}	64.5	166.5	61.2	-
Nitrate	µg l^{-1}	322	14	1050	-
Silica $_{total}$	µg l^{-1}	-	15.80	11.03	-
Silica $_{soluble\ reactive}$	µg l^{-1}	2.22	14.90	10.95	-
Chlorophyll a	µg l^{-1}	5.0	56.2	2.3	

Table C.4 Llyn Coron: epilithic diatom taxon list (including taxa >1.0%)

Taxon	Relative Frequency (%)
Fragilaria vaucheriae (fine)	17.0
Fragilaria vaucheriae (coarse)	14.2
Nitzschia fonticola	13.4
Navicula tripunctata	7.7
Fragilaria capucina types (chains)	5.6
Aulacoseira granulata var. *angustissima*	5.2
Amphora pediculus	4.3
Nitzschia sp.	3.9
Nitzschia amphibia	3.6
Rhoicosphenia curvata	3.2
Nitzschia frustulum	2.6
Diatoma vulgaris	2.2
Nitzschia perminuta	1.5
Fragilaria sp.	1.2

Total count = 647
Total number of taxa = 48

Table C.5 Llyn Coron: surface sediment diatom taxon list (including taxa >1.0%)

Taxon	Relative Frequency (%)
Stephanodiscus parvus	24.4
Aulacoseira granulata var. *angustissima*	11.6
Cyclostephanos [cf. *tholiformis*]	7.5
Stephanodiscus hantzschii	5.9
Fragilaria capucina var. *mesolepta*	4.9
Nitzschia intermedia	3.1
Cyclostephanos invisitatus	2.4
Achnanthes minutissima	2.3
Cocconeis placentula	2.1
Amphora pediculus	1.9
Achnanthes lanceolata	1.9
Fragilaria vaucheriae (coarse)	1.9
Rhoicosphenia curvata	1.7
Fragilaria pinnata	1.7
Stephanodiscus hantschii fo. *tenuis*	1.6
Cocconeis placentula var. *lineata*	1.6
Asterionella formosa	1.4
Nitzschia amphibia	1.4
Fragilaria vaucheriae (fine)	1.2
Stephanodiscus sp.	1.0
Navicula lanceolata	1.0
Fragilaria construens var. *binodis*	1.0

Total count = 574
Total number of taxa = 64

Table C.6 Llyn Coron: aquatic macrophyte abundance summary: 1 September 1994

Taxon	code	Abun.	comments
Emergent taxa			
Caltha palustris	361201	O	
Mentha aquatica	364601	R	
Eleocharis acicularis	382001	O	
Eleocharis palustris	382004	O	
Iris pseudacorus	382901	O	locally abundant
Alisma plantago aquatica	380303	O	
Juncus effusus	383010	A	
Phalaris arundinacea	383701	O	
Phragmites australis	383801	R	one stand in in south-east
Scirpus lacustris ssp. *tabernaemontani*	384504	A	several stands in west
Sparganium erectum	384603	O	
Floating taxa			
Nymphaea alba	365601	R	on west shore only
Polyganum amphibium	366501	O	locally abundant in west
Submergent taxa			
Enteromorpha sp.	170000	A	widespread
Callitriche stagnalis	361108	A	widespread
Elatine hydropiper	362402	F	locally abundant on N+S shore
Littorella uniflora	363901	R	north shore only
Myriophyllum alterniflorum	365403	R	north shore only
Ranunculus circinatus	366970	O	
Elodea canadensis	382101	R	
Potamogeton perfoliatus	384016	O	
Potamogeton trichoides	384021	R	in deeper water in north
Zannichelia palustris	385201	O	
other wetland taxa			
Achillea ptarmica	360101	A	
Bidens triparta	360904	F	
Filipendula ulmaria	362701	O	
Juncus acutiflorus/articulatus	383001	O	
Juncus bufonius	383005	R	
Lythrum salicaria	364502	A	
Mentha arvensis	364600	R	
Salix sp.	367500	F	
Scutellaria galericulata	367901	R	
Solanum dulcamara	368301	F	
Stachys palustris	368501	O	

Table C.7 Llyn Coron: littoral Cladocera taxon list

Taxon	Count in Sample 4	Count in Sample 7
Alona affinis	+	
Alona rustica		+
Daphnia longispina	2	1
Eurycerus lamellatus		1
Pleuroxus abuncus	26	2
Scapholeberis mucronata	16	

+ = Species present

Table C.8 Llyn Coron: open water zooplankton taxon list

Taxon	Abundance
Eudiaptomus gracilis	2
Cyclops strenuus	2
Eucyclops serrulatus	+
Daphnia galeata	2
Megacyclops viridis	1
Leptodora kindti	1
Cyclops vicinus	2
Pleuroxus uncinatus	1
Keratella cochlearis	1
Keratella quadrata	+

2 = Species common (abundance >5%)
1 = Species rare (found in both samples analysed)
+ = Species very rare (found in one of samples analysed)

Table C.9 Llyn Coron: open water zooplankton characteristics: 1st September 1993

Station sampled: B

Depth of Station (m)	2.5
Total zooplankton biomass (gDM m^{-2})	2.11
Net algal biomass (gDM m^{-2})	2.87
% Cladoceran biomass in total zooplankton biomass	58
% large Cladocera (>710 μm) in total zooplankton biomass	33
% large Copepoda (>420 μm) in total zooplankton biomass	12

Table C.10 Llyn Coron: littoral invertebrate data

code	species	mean no. per sample
	TURBELLARIA	
03 12 00 00	Tricladida	19.0
	MOLLUSCA	
13 03 01 03	*Valvata piscinalis* (Muller)	27.5
13 07 01 01	*Lymnaea truncatula* (Muller)	2.5
13 07 01 07	*L. peregra* (Muller)	14.5
13 08 02 01	*Physa fontinalis* (L.)	126.5
13 09 03 07	*P. albus* (Muller)	5.0
13 09 03 10	*P. contortus* (L.)	19.0
13 09 04 01	*Segmentina complanata* (L.)	1.0
13 10 01 01	*Acroloxus lacustris* (L.)	1.5
	BIVALVIA	
14 03 02 00	*pisidium* spp.	1.0
	HIRUDINIA	
17 02 01 01	*Theromyzon tessulatum* (Muller)	6.0
17 02 03 01	*Glossiphonia heteroclita* (L.)	0.5
17 02 03 02	*G. complanata* (L.)	3.0
17 04 01 02	*Erpobdella octoculata* (L.)	1.0
	MALACOSTRACA	
28 03 01 04	*A. meridianus* Racovitza	630.5
28 07 03 05	*G. pulex* (L.)	2.0
	EPHEMEROPTERA	
30 02 03 01	*Cloen dipterum* (L.)	0.5
30 08 02 04	*Caenis horaria* (L.)	24.5
	ODONATA	
32 02 02 01	*Ischnura elegans* (Linden)	5.0
32 02 03 01	*Enallagma cyathigerum* (Charpentier)	2.0

Table C.10 Continued

code	species	mean no. per sample
	HEMIPTERA	
33 11 00 00	Corixidae - immatures	5.0
33 11 04 01	*Callicorixa praeusta* (Fieber)	1.5
33 11 05 02	*Corixa punctata* (Illinger)	0.5
33 11 08 01	*Sigara dorsalis* (Leach)	1.0
33 11 08 04	*S. falleni* (Fieber)	112.5
33 11 08 10	*S. concinna* (Fieber)	0.5
	COLEOPTERA	
35 01 00 00	Haliplidae sp. - larvae	38.5
35 01 03 01	*Haliplus confinis* Stephens	1.0
35 01 03 03	*H. lineatocollis* (Marsham)	0.5
35 01 03 04	*H. ruficollis* group	12.0
35 01 03 11	*H. fluvus* (Fabricius)	1.0
35 03 00 00	Dytiscidae - larvae	3.0
35 03 07 02	*Potamonectes assimilis* (Paykull)	0.5
35 03 07 03	*P. depressus elegans* (Panzer)	0.5
35 03 07 06	*Stictotarsus duodecimpustulatus* (Fabricius)	0.5
35 11 06 02	*Oulimnius troglodytes* (Gyllenhal)	131.5
	TRICHOPTERA	
38 04 03 02	*Lype reducta* (Hagen)	1.0
38 08 05 01	*Limnephilus* sp.	5.5
	DIPTERA	
40 01 00 00	Tipulidae	0.5
40 09 00 00	Chironomidae	122.0

Total invertebrates	1331.5
Species richness (minimum)	37

Figure C.1 Llyn Coron: sample location & substrate map

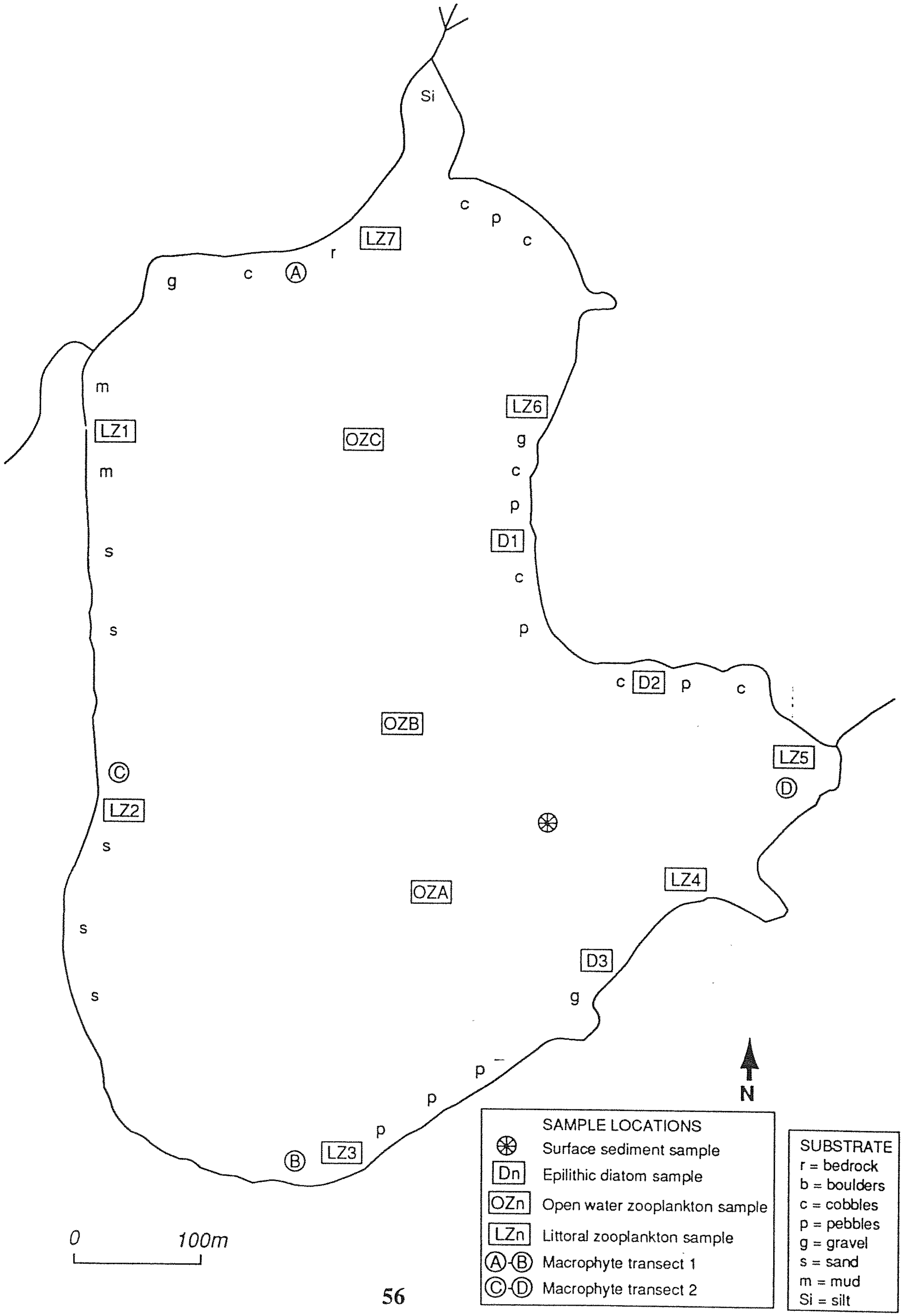


Figure C.2 Llyn Coron: aquatic macrophyte distribution map

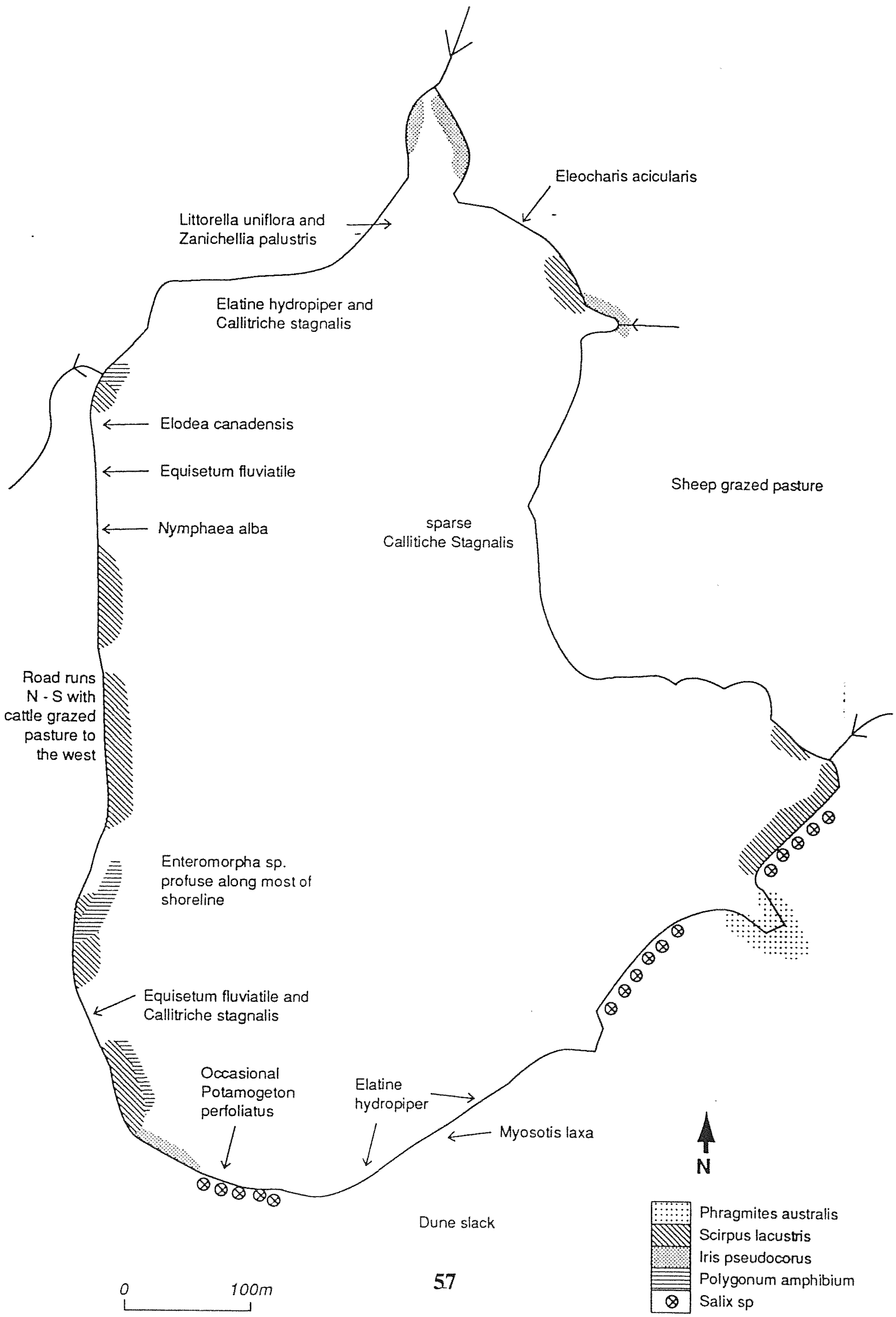


Table D.1 Llyn Dinam: physical data: 10 July 1993

Air temperature = 13°C
Secci disc transparency = 0.9 m

Depth (m)	Temperature (°C)	Oxygen (mg l^{-1})
0	16.0	10.0
0.2	16.0	10.0
0.4	16.0	10.0
0.6	16.0	10.0
0.8	16.0	10.0
1.0	16.0	10.0
1.2	16.0	10.0
1.4	16.0	10.0
1.6	15.8	10.0
1.8	15.8	9.6

Table D.2 Llyn Dinam: physical data: 2 September 1993

Air temperature = 17.1°C
Secci disc transparency = >1.6 m

Depth (m)	Temperature (°C)	Oxygen (mg l^{-1})
0	18.2	8.7
0.2	18.2	8.7
0.4	18.2	8.7
0.6	18.2	8.7
0.8	18.2	8.7
1.0	18.2	8.7
1.2	18.2	8.7
1.4	18.2	8.7
1.6	18.2	8.7

Table D.3 Llyn Dinam: water chemistry

Determinand		Sample date			
		10-7-93	2-9-93	6-12-93	-3-94
pH		7.81	7.74	7.93	-
Alkalinity 1	µeq l^{-1}	1659	1706	1473	-
Alkalinity 2	µeq l^{-1}	1683	1727	1490	-
Conductivity	µS cm^{-1}	336	342	349	-
Sodium	µeq l^{-1}	1285	1400	1355	-
Potassium	µeq l^{-1}	42	48	97	-
Magnesium	µeq l^{-1}	500	537	629	-
Calcium	µeq l^{-1}	1542	1600	1490	-
Chloride	µeq l^{-1}	1465	1596	1488	-
Aluminium total monomeric	µg l^{-1}	2	1	2	-
Aluminium non-labile	µg l^{-1}	2	0	2	-
Aluminium labile	µg l^{-1}	0	1	0	-
Absorbtion	(250nm)	.424	.396	.387	-
Carbon total organic	mg l^{-1}	12	11.9	9.9	-
Phosphorus total	µgP l^{-1}	142.6	134.3	110.0	-
Phosphorus total soluble	µgP l^{-1}	116.3	130.8	78.9	-
Phosphorus soluble reactive	µgP l^{-1}	89.0	104.0	60.6	-
Nitrate	µg l^{-1}	0	0	210	-
Silica total	µg l^{-1}	-	1.05	6.38	-
Silica soluble reactive	µg l^{-1}	4.79	.99	6.09	-
Chlorophyll a	µg l^{-1}	3.6	3 1	16.6	-

Table D.4 Llyn Dinam: epilithic diatom taxon list (including taxa >1.0%)

Taxon	Relative Frequency (%)
Nitzschia inconspicua	15.9
Rhoicosphenia curvata	12.8
Nitzschia palaeo var. *debilis*	9.1
Amphora pediculus	7.8
Nitzschia palea	5.5
Nitzschia fonticola	5.3
Epithemia sorex	5.2
Nitzschia gracilis	4.8
Nitzschia sp.	3.9
Cocconeis placentula	3.2
Cocconeis placentula var. *euglypta*	2.7
Cocconeis placentula var. *lineata*	2.7
Achnanthes lanceolata	1.8
Achnanthes minutissima	1.8
Navicula scutelloides	1.8
Fragilaria construens var. *venter*	1.6
Navicula capitoradiata	1.2
Cymbella sinuata	1.2

Total count = 561
Total number of taxa = 47

Table D.5 Llyn Dinam: surface sediment diatom taxon list (including taxa >1.0%)

Taxon	Relative Frequency (%)
Fragilaria construens var. *venter*	15.4
Stephanodiscus parvus	14.2
Fragilaria pinnata	6.7
Cyclostephanos [cf. *tholiformis*]	6.2
Fragilaria construens	5.3
Rhoicosphenia curvata	4.8
Fragilaria exigua	3.1
Nitzschia dissipata	2.6
Cocconeis placentula var. *lineata*	2.6
Cyclostephanos invisitatus	2.1
Cyclotella meneghiniana	2.1
Achnanthes lanceolata	2.1
Achnanthes minutissima	2.1
Cocconeis placentula	1.7
Navicula trivialis	1.7
Navicula meniscus var. *upsaliensis*	1.7
Navicula gregaria	1.5
Nitzschia sunacicularis	1.2
Fragilaria brevistriata	1.2
Fragilaria sp.	1.2
Asterionella formosa	1.0
Nitzschia gracilis	1.0
Amphora pediculus	1.0
Navicula [cf. *rhyncocephela*]	1.0

Total count = 584
Total number of taxa = 71

Table D.6 Llyn Dinam: aquatic macrophyte abundance summary: 2 September 1993

Taxon	code	Abun	comments
Emergent taxa			
Caltha palustris	361201	R	
Eleocharis acicularis	382001	O	locally abundant in north
Hydrocotyle vulgaris	363401	R	in north
Mentha aquatica	364601	F	
Menyanthes trifoliata	364701	F	locally abundant
Polyganum hydropiper	366504	R	in north
Veronica beccabunga	369802	O	locally abundant in north-west arm
Iris pseudocorus	382901	F	
Juncus effusus	383010	F	
Phalaris arundinacea	383701	F	
Phragmites australis	383801	A	dominant around much of the lake margin
Scirpus lacustris	384504	F	locally dominant stands
Typha latifolia	384902	O	locally abundant
Floating taxa			
Nuphar lutea	365501	R	locally abundant in north-west arm
Nymphaea alba	365601	F	particularly in west
Polyganum amphibium	366501	O	locally abundant in north-east
Lemna minor	383302	R	
Lemna trisulca	383304	F	locally abundant
Submergent taxa			
Chara sp.	220000	R	in north
Nitella sp.	220000	O	in north
Campylium sp. (to be verified)	321400	R	in north-east bay
Fontinalis antipyretica	323401	F	locally abundant in north-west bay
Callitriche hermaphroditica	361104	A	mainly in north
Ceratophyllum demersum	361401	A	widespread
Elatine hydropiper	362402	F	in north
Littorella uniflora	363901	F	in north
Myriophyllum spicatum	365403	O	locally abundant on north-east shoreline
Ranunculus aquatilus	366969	O	in north
Potamogeton pectinatus	384015	R	
Potamogeton perfoliatus	384016	R	in north
Potamogeton pusillus	384019	O	

Table D.6 Continued

Taxon	code	Abun	comments
other wetland taxa			
Achillea ptarmica	360101	O	
Angelica sylvestris	360302	O	
Epilobium hirsutum	362504	O	
Lysmachia vulgaris	364404	O	
Lythrum salicaria	364502	O	
Myosotis laxa	365100	O	
Ranunculus ligua	366908	R	
Senecio aquaticus	368101	O	
Solanum dulcamara	368301	O	
Carex paniculata	381124	R	
Juncus bufonius	383005	O	

Table D.7 Llyn Dinam: littoral Cladocera taxon list

Taxon	Count in Sample 7
Alona affinis	+
Ceriodaphnia dubia	44
Chydorus sphaericus	+
Eubosmina longispina	7
Eurycerus lamellatus	29
Pleuroxus abuncus	+
Pseudochydorus globosus	+
Simocephalus vetulus	69

+ = Species present

Table D.8 Llyn Dinam: open water zooplankton taxon list

Taxon	Abundance
Eudiaptomus gracilis	2
Cyclops strenuus	+
Eucyclops serrulatus	2
Daphnia galeata	1
Diaphanosoma brachyurum	2
Ceriodaphnia dubia	2
Eurycercus lamellatus	2
Macrocyclops albidus	2
Megacyclops viridis	1
Bosmina longirostris	2
Pseudochydorus globosus	1

2 = Species common (abundance >5%)
1 = Species rare (found in both samples analysed)
+ = Species very rare (found in one of samples analysed)

Table D.9 Llyn Dinam: open water zooplankton characteristics: 2nd September 1993

Station sampled: A

Depth of Station (m)	1.4
Total zooplankton biomass (gDM m^{-2})	0.38
Net algal biomass (gDM m^{-2})	0
% Cladoceran biomass in total zooplankton biomass	55
% large Cladocera (>710 μm) in total zooplankton biomass	12
% large Copepoda (>420 μm) in total zooplankton biomass	24

Table D.10 Llyn Dinam: littoral invertebrate data

code	species	mean no. per sample
	TURBELLARIA	
03 12 00 00	Tricladida	41.5
	MOLLUSCA	
13 03 01 03	*Valvata piscinalis* (Muller)	7.5
13 07 01 06	*L. auricularia* (L.)	2.5
13 07 01 07	*L. peregra* (Muller)	2.0
13 08 02 01	*Physa fontinalis* (L.)	2.5
13 09 03 01	*Planorbis carinatus* (Muller)	0.5
13 09 03 07	*P. albus* (Muller)	59.5
13 09 03 09	*P. crista* (L.)	2.5
13 09 03 10	*P. contortus* (L.)	5.0
13 09 04 01	*Segmentina complanata* (L.)	3.0
13 10 01 01	*Acroloxus lacustris* (L.)	5.0
	BIVALVIA	
14 03 02 00	*pisidium* spp.	38.0
	HIRUDINIA	
17 02 01 01	*Theromyzon tessulatum* (Muller)	1.5
17 02 02 01	*Hemiclepsis marginata* (Muller)	0.5
17 02 03 01	*Glossiphonia heteroclita* (L.)	1.5
17 02 03 02	*G. complanata* (L.)	9.0
17 02 05 01	*Helobdella stagnalis* (L.)	6.5
17 04 01 02	*Erpobdella octoculata* (L.)	7.5
	MALACOSTRACA	
28 03 01 01	*Asellus aquaticus* (L.)	2788.0
28 07 03 05	*G. pulex* (L.)	399.5
	EPHEMEROPTERA	
30 02 00 00	Baetidae	0.5
30 02 03 01	*Cloen dipterum* (L.)	0.5
30 08 02 04	*Caenis horaria* (L.)	87.5
30 08 02 06	*C. luctuosa* (Burmeister)	15.0
	ODONATA	
32 02 02 01	*Ischnura elegans* (Linden)	130.5
32 02 03 01	*Enallagma cyathigerum* (Charpentier)	17.5

Table D.10 Continued

code	species	mean no. per sample
	HEMIPTERA	
33 11 00 00	Corixidae - immatures	5.5
33 11 04 01	*Callicorixa praeusta* (Fieber)	2.0
33 11 08 01	*Sigara dorsalis* (Leach)	6.0
33 11 08 04	*S. falleni* (Fieber)	5.5
	COLEOPTERA	
35 01 00 00	Haliplidae sp. - larvae	3.5
35 01 03 04	*H. ruficollis* group	4.0
35 03 07 02	*Potamonectes assimilis* (Paykull)	0.5
35 03 07 03	*P. depressus elegans* (Panzer)	3.0
35 03 07 06	*Stictotarsus duodecimpustulatus* (Fabricius)	0.5
35 11 06 02	*Oulimnius troglodytes* (Gyllenhal)	0.5
	MEGALOPTERA	
36 01 01 01	*Sialis lutaria* (L.)	2.0
	TRICHOPTERA	
38 03 03 01	*Polycentropus flavomaculatus* (Pictet)	12.5
38 03 04 01	*Holocentropus dubius* (Rambur)	8.0
38 04 01 01	*Ecnomus tenellus* (Rambur)	2.5
38 04 02 01	*Tinodes waeneri* (L.)	3.0
38 04 03 02	*Lype reducta* (Hagen)	1.0
38 06 01 01	*Agraylea multipunctata* (Curtis)	7.0
38 06 06 00	*Oxyethira* sp.	8.0
38 12 02 03	*Mystacides longicornis* (L.)	18.5
	DIPTERA	
40 09 00 00	Chironomidae	250.5
	Total invertebrates 3979.0	
	Species richness (minimum) 43	

Figure D.1 Llyn Dinam: sample location & substrate map

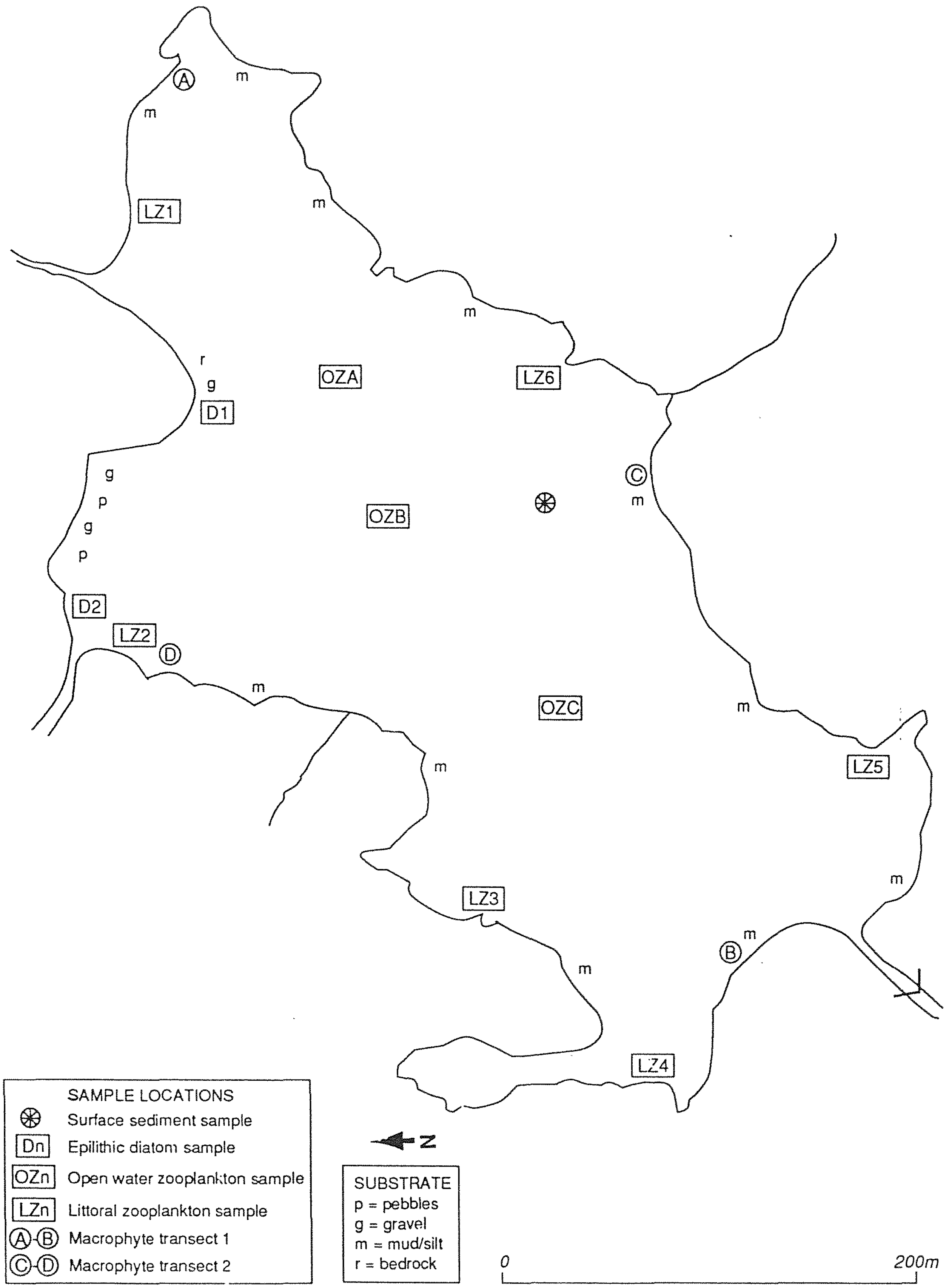


Figure D.2 Llyn Dinam: aquatic macrophyte distribution map

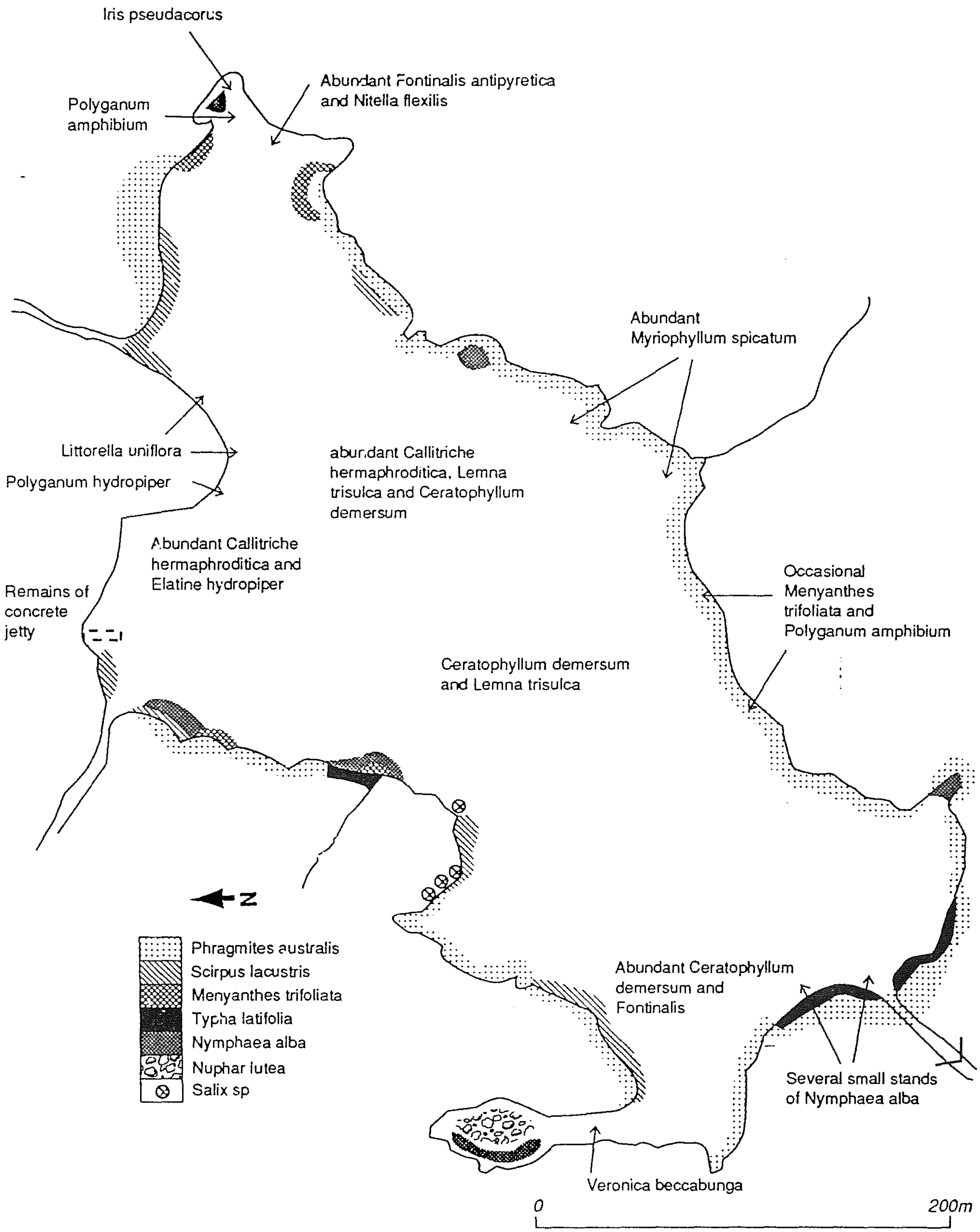


Table E.1 Llyn Penrhyn: physical data: 10 July 1993

Air temperature = 13°C
Secci disc transparency = 2.3 m

Depth (m)	Temperature (°C)	Oxygen (mg l^{-1})
0	16.8	9.4
0.4	16.8	9.4
0.8	16.8	9.4
1.2	16.8	9.4
1.6	16.8	9.4
2.0	16.8	9.4
2.4	16.8	9.4
2.8	16.8	9.4
3.0	16.8	9.4

Table E.2 Llyn Penrhyn: physical data: 3 September 1993

Air temperature = 15.3°C
Secci disc transparency = 2.5 m

Depth (m)	Temperature (°C)	Oxygen (mg l^{-1})
0	17.3	9.0
0.2	17.3	8.9
0.4	17.3	8.9
0.6	17.3	8.8
0.8	17.3	8.8
1.0	17.3	8.7
1.2	17.3	8.7
1.4	17.3	8.7
1.6	17.3	8.7
1.8	17.3	8.6
2.0	17.3	8.6
2.2	17.3	8.6
2.4	17.3	8.7
2.6	17.3	8.6

Table E.3 Llyn Penrhyn: water chemistry

Determinand		Sample date			
		10-7-93	3-9-93	6-12-93	-3-94
pH		8.04	7.88	7.66	-
Alkalinity 1	µeq l^{-1}	2180	2252	2187	-
Alkalinity 2	µeq l^{-1}	2197	2276	2219	-
Conductivity	µS cm^{-1}	446	455	453	-
Sodium	µeq l^{-1}	1869	1995	1750	-
Potassium	µeq l^{-1}	115	132	157	-
Magnesium	µeq l^{-1}	456	487	581	-
Calcium	µeq l^{-1}	2176	2283	2271	-
Chloride	µeq l^{-1}	1887	1973	1727	-
Aluminium $_{total\ monomeric}$	µg l^{-1}	3	0	2	-
Aluminium $_{non-labile}$	µg l^{-1}	3	0	1	-
Aluminium $_{labile}$	µg l^{-1}	0	0	1	-
Absorbtion	(250nm)	.247	.257	.256	-
Carbon $_{total\ organic}$	mg l^{-1}	9.6	10.4	8.8	-
Phosphorus $_{total}$	µgP l^{-1}	1064.5	1335.0	1247.5	-
Phosphorus $_{total\ soluble}$	µgP l^{-1}	1048.5	1324.5	1200.5	-
Phosphorus $_{soluble\ reactive}$	µgP l^{-1}	1037.0	1300.0	1181.0	-
Nitrate	µgN l^{-1}	42	63	413	-
Silica $_{total}$	µg l^{-1}	-	1.17	4.57	-
Silica $_{soluble\ reactive}$	µg l^{-1}	1181.0	1.14	4.5	-
Chlorophyll a	µg l^{-1}	3.9	5.1	3.9	-

Table E.4 Llyn Penrhyn: epilithic diatom taxon list (including taxa >1.0%)

Taxon	Relative Frequency (%)
Rhoicosphenia curvata	15.9
Navicula radiosa var. *tenella*	9.8
Nitzschia amphibia	7.0
Navicula tripunctata	6.2
Nitzschia palea	5.2
Achnanthes minutissima	4.9
Amphora pediculus	4.9
Nitzschia fonticola	3.6
Cocconeis placentula var. *lineata*	3.6
Navicula vitabunda	3.4
Nitzschia sp.	3.1
Cocconeis placentula	3.0
Cocconeis pediculus	3.0
Nitzschia frustulum	2.8
Cocconeis placentula var. *euglypta*	2.6
Nitzschia paleacea	2.1
Nitzschia silesiaca	2.1
Fragilaria construens var. *venter*	2.0
Fragilaria capucina types (chains)	2.0
Ellerbeckia arenaria	1.5
Cymbella minuta	1.3

Total count = 610
Total number of taxa = 44

Table E.5 Llyn Penrhyn: surface sediment diatom taxon list (including taxa >1.0%)

Taxon	Relative Frequency (%)
Stephanodiscus parvus	22.6
Navicula menisculus	14.0
Fragilaria brevistriata	11.6
Fragilaria construens var. *venter*	6.6
Fragilaria capucina var. *mesolepta*	3.6
Rhoicosphenia curvata	3.3
Cocconeis placentula	3.3
Amphora lybica	3.1
Navicula trivialis	2.8
Nitzschia amphibia	2.6
Cocconeis placentula var. *lineata*	2.6
Achnanthes clevei	2.3
Fragilaria pinnata	2.0
Cocconeis pediculus	2.0
Amphora pediculus	2.0
Ellerbeckii arenaria	1.7
Navicula [cf. *rhyncocephela*]	1.7
Cocconeis placentula var. *euglypta*	1.5
Navicula gregaria	1.3
Fragilaria vaucheriae (fine)	1.2

Total count = 605
Total number of taxa = 48

Table E.6 Llyn Penrhyn: aquatic macrophyte abundance summary: 3 September 1993

Taxon	code	Abun.	comments
Emergent taxa			
Menyanthes trifoliata	364701	R	in north-west bay
Veronica beccabunga	369802	R	
Alisma plantago aquatica	380303	O	
Eleocharis acicularis	382001	R	
Iris pseudocorus	382901	O	in west
Phalaris arundinacea	383701	O	in north bay
Phragmites australis	383801	D	around most of tne margin
Sparganium erectum	384603	O	
Scirpus lacustris ssp.lacustris	384504	F	
Typha latifolia	384902	O	locally abundant on southern shore
Floating taxa			
Nuphar lutea	365501	O	otten fringing stands of *Nymphaea*
Nymphaea alba	365601	F	locally abundant in western bays
Polyganum amphibium	366501	O	
Glyceria fluitans	382502	O	
Submergent taxa			
Enteromorpha sp.	170000	F	
Callitriche hermaphroditica	361104	A	widespread
Ceratophyllum demersum	361401	F	locally dominant particularly in south
Elodea canadensis	382101	F	widespread
Lemna minor	383302	R	in west
Lemna trisulca	383304	O	in west
Potamogeton crispus	384006	O	locally abundant in north bay
Potamogeton pectinatus	384015	O	in west
Potamogeton pusillus	384019	R	in west
Zannichelia palustris	385201	R	in north
other wetland taxa			
Berula erecta	360801	O	
Butomus umbellatus	380801	R	
Carex acutiformis	381102	O	
Epilobium hirsutum	362504	F	
Lysmachia vulgaris	364404	O	
Lythrum salicaria	364502	F	
Salix sp.	367500	R	
Senecio aquaticus	368101	O	
Solanum dulcamara	368301	F	
Stachys palustris	368501	O	

Table E.7 Llyn Penrhyn: littoral Cladocera taxon list

Taxon	Count in Sample 1	Count in Sample 6	Count in Sample 7
Acroperus harpae	1		
Ceriodaphnia dubia		220	
Chydorus sphaericus	7	+	
Daphnia hyalina var. *galeata*	4	+	
Daphnia longispina			30
Daphnia obtusa			3
Daphnia pulex		5	
Eurycerus lamellatus	1	+	
Pleuroxus abuncus	110	9	4
Pseudochydorus globosus	+		
Simocephalus vetulus	+	2	

+ = Species present

Table E.8 Llyn Penrhyn: open water zooplankton taxon list

Taxon	Abundance
Eudiaptomus gracilis	2
Cyclops strenuus	2
Eucyclops serrulatus	1
Daphnia galeata	2
Ceriodaphnia dubia	1
Eurycercus lamellatus	1
Macrocyclops albidus	1
Daphnia pulicaria	2
Asplanchna sp.	2
Daphnia magma/ephippium	+

2 = Species common (abundance >5%)
1 = Species rare (found in both samples analysed)
+ = Species very rare (found in one of samples analysed)

Table E.9 Llyn Penryn open water zooplankton characteristics: 3rd September 1993

Station sampled: C	
Depth of Station (m)	2.2
Total zooplankton biomass (gDM m^{-2})	0.72
Net algal biomass (gDM m^{-2})	0
% Cladoceran biomass in total zooplankton biomass	28
% large Cladocera (>710 μm) in total zooplankton biomass	6
% large Copepoda (>420 μm) in total zooplankton biomass	22

Table E.10 Llyn Penrhyn: littoral invertebrate data

code	species	mean no. per sample
	TURBELLARIA	
03 12 00 00	Tricladida	86.7
	MOLLUSCA	
13 03 01 03	*Valvata piscinalis* (Muller)	16.7
13 07 01 01	*Lymnaea truncatula* (Muller)	0.7
13 07 01 07	*L. peregra* (Muller)	1.3
13 08 02 01	*Physa fontinalis* (L.)	107.3
13 09 03 01	*Planorbis carinatus* (Muller)	13.3
13 09 03 04	*P. vortex* (L.)	58.7
13 09 03 07	*P. albus* (Muller)	10.0
13 09 03 09	*P. crista* (L.)	2.0
13 09 03 10	*P. contortus* (L.)	25.3
13 09 04 01	*Segmentina complanata* (L.)	177.3
13 10 01 01	*Acroloxus lacustris* (L.)	28.7
	BIVALVIA	
14 03 02 00	*pisidium* spp.	22.7
	HIRUDINIA	
17 02 01 01	*Theromyzon tessulatum* (Muller)	5.3
17 02 03 01	*Glossiphonia heteroclita* (L.)	56.0
17 02 03 02	*G. complanata* (L.)	8.0
17 02 05 01	*Helobdella stagnalis* (L.)	10.7
17 04 01 02	*Erpobdella octoculata* (L.)	2.0
	MALACOSTRACA	
28 03 01 01	*Asellus aquaticus* (L.)	146.0
28 07 03 05	*G. pulex* (L.)	130.7
	ODONATA	
32 02 02 01	*Ischnura elegans* (Linden)	15.3
	HEMIPTERA	
33 11 00 00	Corixidae - immatures	28.0
33 11 03 01	*Glaenocorisa propinqua* (Fieber)	0.7
33 11 04 01	*Callicorixa praeusta* (Fieber)	96.0
33 11 05 02	*Corixa punctata* (Illinger)	9.3
33 11 07 02	*Arctocorisa germari* (Fieber)	64.7
33 11 08 01	*Sigara dorsalis* (Leach)	15.3
33 11 08 04	*S. falleni* (Fieber)	73.3

Table E.10 Continued

code	species	mean no. per sample
	COLEOPTERA	
35 01 00 00	Haliplidae sp. - larvae	14.0
35 01 03 04	*H. ruficollis* group	13.3
35 03 00 00	Dytiscidae - larvae	0.7
35 03 10 01	*Noterus clavicornis* (DeGeer)	0.7
	TRICHOPTERA	
38 06 01 01	*Agraylea multipunctata* (Curtis)	30.0
	DIPTERA	
40 09 00 00	Chironomidae	120.0
	Total invertebrates	1390.7
	Species richness (minimum)	32

Figure E.1 Llyn Penrhyn: sample location & substrate map

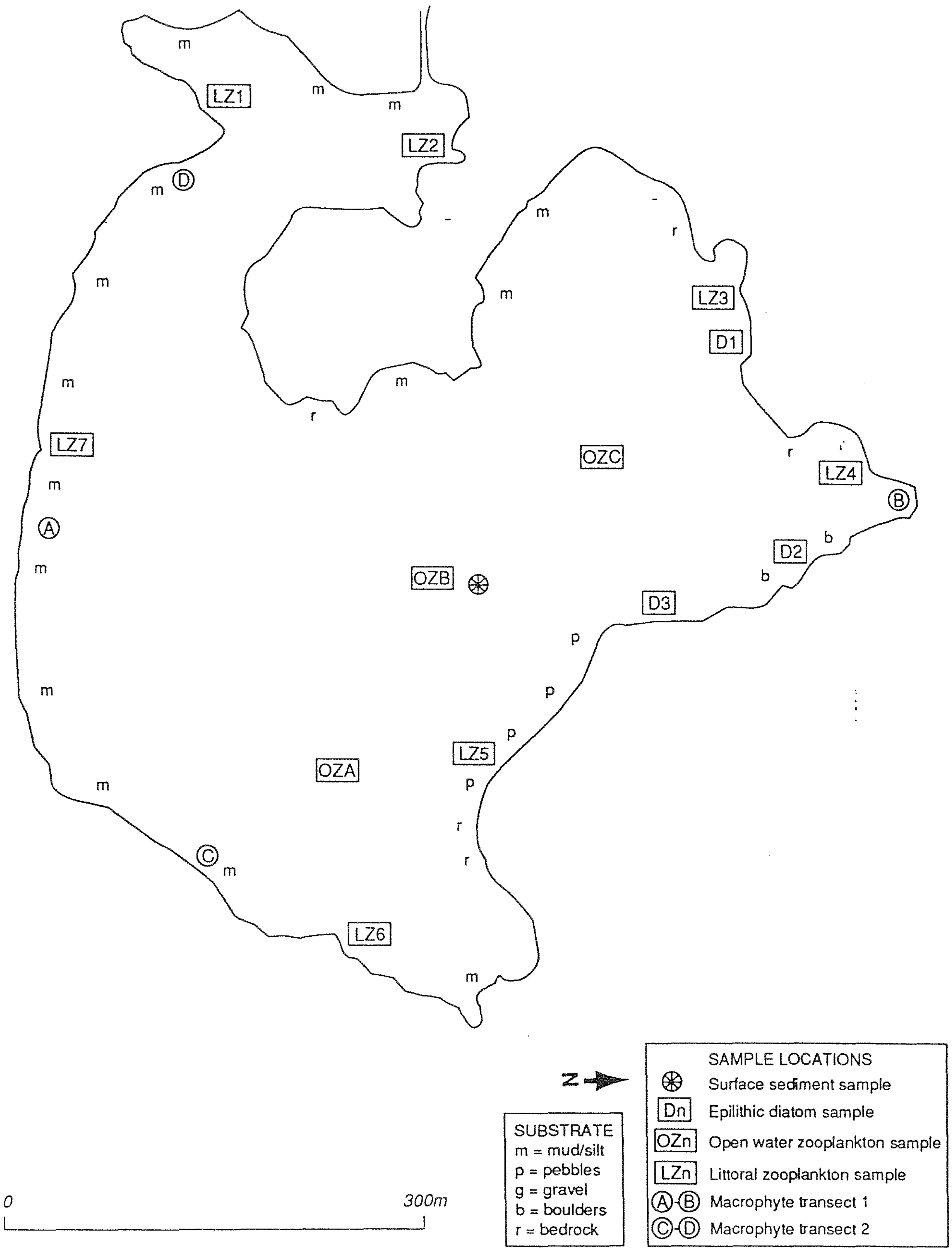
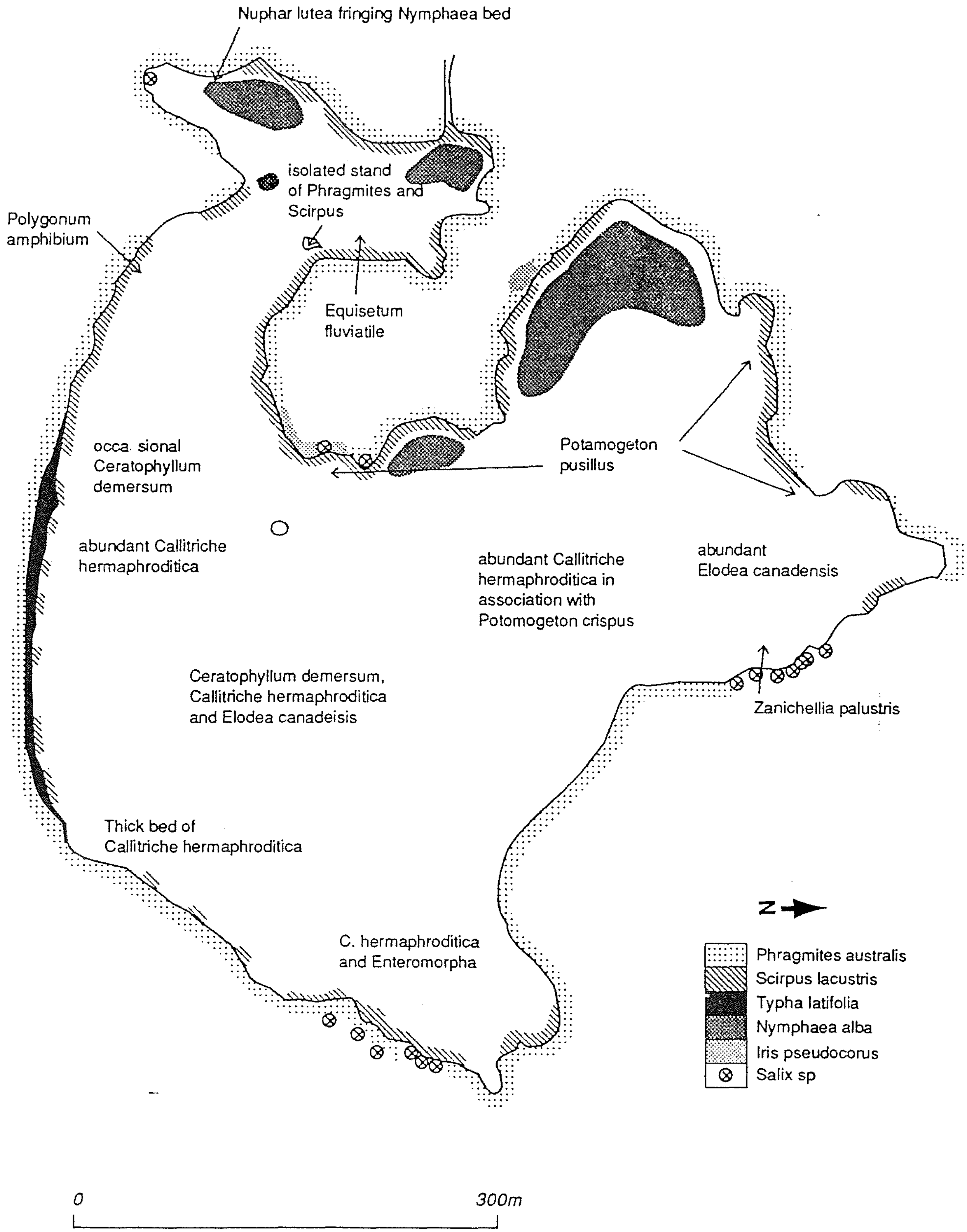


Figure E.2 Llyn Penrhyn: aquatic macrophyte distribution map



Appendix F Notes on substrate of Cladocera sampling sites

1 Llyn Idwal (sampled 05-09-93)

Samples taken while wading along shoreline.

SITE 1: At outflow; sand-rock substrate; abundant filamentous algae, *Juncus* sp., *Littorella* and *Callitriche* sp.
SITE 2: (replicate samples A & B): Inflowing stream; *Lobelia*, *Littorella* and *Myriophyllum*.
SITE 3: Rock-stone-boulder substrate; *Lobelia*, *Sparganium* and *Juncus bulbosus*
SITE 4: Rock substrate; *Equisetum* dominant; some *Littorella* and *Lobelia*.
SITE 5: Rock-mud substrate; peat seepage; *Phragmites* stand and *Juncus bulbosus*.
SITE 6: Rock-stone substrate; *Eriophorum ungustifolium*, floating *Potamogeton* sp. *Lobelia* and *Littorella*.
SITE 7: Sand-stone substrate; *Callitriche* dominant; *Littorella*, *Equisetum*, *Lobelia* and *Juncus bulbosus*.

2 Llyn Cwellyn (sampled 04-09-93)

Samples taken while wading along shoreline.

SITE 1: (replicate samples A & B): Sand-rock substrate; *Juncus bulbosus*, *Littorella*, *Lobelia*, *Sparganium*.
SITE 2: Sandy beach, rocky offshore; Submerged grass, *Fontinalis*, *Juncus bulbosus*, *Lobelia* and *Isoetes*.
SITE 3: Sand-rock substrate, *Fontinalis*, *Lobelia*, *Juncus bulbosus*, emergent *Juncus*.
SITE 4: Stones and boulders; *Fontinalis*, *Juncus bulbosus* and much filamentous algae.
SITE 5: Sand-rock-boulders; *Juncus bulbosus*, *Fontinalis*, *Littorella* and much filamentous algae.
SITE 6: Bare rock/boulder substrate devoid of plant growth.

3 Llyn Coron (sampled 01-09-93)

Samples taken while walking around the shore.

SITE 1: *Eleocharis*, *Nympheae*, *Polygonum amphibium* present.
SITE 2: Floating *Polygonium amphibium*, but mainly *Scirpus*.
SITE 3: Stony substrate devoid of plant growth.
SITE 4: Rocky substrate; sample taken through base of *Phragmites* stand.
SITE 5: Rocky substrate; *Scirpus* stand.
SITE 6: Rocky shore devoid of plant growth.
SITE 7: Rocky shore with little plant growth.

4 Llyn Dinam (sampled 02-09-93)

All samples taken from boat.

SITE 1: Scirpus with floating mass of *Callitriche* sp.
SITE 2: *Nymphaea* stand.
SITE 3: *Phragmites* stand with *Mentha aquatica* and some *Nymphaea* and *Scirpus*.
SITE 4: *Solanum*, *Iris*, *Scirpus*, *Nymphaea* and *Callitriche* sp.
SITE 5: *Veronica beccabunga* and *Callitriche* at base of *Phragmites* stand.
SITE 6: *Menyanthes*, *Callitriche* and *Ceratophyllum*.

5 Llyn Penrhyn (sampled 03-09-93)

All samples taken from boat.

SITE 1: *Iris*, *Ceratophyllum* and *Phragmites*.
SITE 2: *Nymphaea* and *Ceratophyllum* only.
SITE 3: *Scirpus*, *Phragmites*, *Callitriche* and *Ceratophyllum*.
SITE 4: Rocky substrate; *Phragmites*, *Ceratophyllum* and *Iris*.
SITE 5: Rocky substrate; *Phragmites* and *Ceratophyllum*.
SITE 6: Rocky substrate; *Scirpus* and *Ceratophyllum*.
SITE 7: *Scirpus* and *Ceratophyllum*.