Cyfoeth Naturiol Cymru
Natural Resources Wales

# Biodiversity Action Plan Lakes Survey 2012-14

Goldsmith B, Salgado J, Shilland J, Bennion H, Yang H & Turner SD.

ENSIS Ltd, London

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# 1. Crynodeb Gweithredol

**Cefndir, safleoedd a dulliau**
Mae ecosystemau llynnoedd dan fygythiad yn genedlaethol ac yn rhyngwladol. Mae ymrwymiadau dan ddeddfwriaeth Ewrop a chytundebau rhyngwladol yn ei gwneud yn ofynnol i'r DU warchod a chyfoethogi'r cynefinoedd hyn, sydd o bwys cadwraethol a diwylliannol. Er bod ansawdd a chyflwr llynnoedd yn y gyfres o safleoedd gwarchodedig (Safleoedd o Ddiddordeb Gwyddonol Arbennig (SoDdGA) ac Ardaloedd Cadwraeth Arbennig (ACA)) yn cael eu deall yn weddol dda, nid yw hyn yn wir yng nghefn gwlad ehangach. Nod yr adroddiad hwn yw llenwi rhai o'r bylchau hyn trwy gasglu data arolwg manwl o lynnoedd dethol a all fod o bwys o ran bioamrywiaeth yng Nghymru, ac mae'n rhan o raglen arolygon strategol barhaus a luniwyd gan Cyfoeth Naturiol Cymru i wella dealltwriaeth o ddosbarthiad ac ansawdd gwahanol fathau o lynnoedd yng Nghymru.

Dewiswyd wyth llyn a all fod o bwys o ran bioamrywiaeth, ar sail ffotograffau o'r awyr a gwybodaeth leol, lle'r oedd honno ar gael. Y safleoedd yw Llynnau Cregennen (2 safle), Llyn Dinas, Llyn Mair, Llyn Cerrig-y-myllt, Llyn Gwernan, Llyn Gwyddior a Llyn Coch-hwyad.

Mae'r asesiadau wedi eu seilio ar arolygon macroffyt dyfrol a mapio, arolwg bathymetrig, mesuriadau ffisigocemegol ac, ym mhedwar safle, dadansoddiadau paleolimnolegol. Caiff pob un o'r technegau hyn eu defnyddio'n eang i asesu ansawdd amgylcheddol systemau llynnoedd, a chawsant eu cynnal yn unol â'r dulliau safonol.

**Adroddiadau safleoedd**
Llynnau Cregennen – pâr o lynnoedd sydd ychydig i'r gogledd o fasiff Cadair Idris. Mae'r ddau ohonynt yn eithriadol yn gymaint â bod ganddynt ansawdd ac eglurder dŵr rhagorol ac mae gan y ddau ohonynt gymunedau helaeth ac amrywiol o blanhigion dyfrol sy'n ymestyn i oddeutu 8m o ddyfnder. Mae'r ddau lyn mewn cyflwr ffafriol ac yn cynnal y planhigion dan fygythiad, dyfrllys hirgoes (*Potamogeton praelongus*) a rhawn yr ebol llyfn (*Nitella flexillis* ss.)

Llyn Dinas - llyn cymharol fawr, bas yn Nyffryn Nantgwynant yn Eryri. Mae gan y llyn ddŵr clir iawn ac mae'n cynnal cymuned o blanhigion dyfrol, sy'n nodweddiadol o lynnoedd â maetholion isel. Mae gan y llyn boblogaeth fawr o lyriad nofiadwy (Luronium natans). Mae'r rhywogaeth hon yn un o rywogaethau â blaenoriaeth y Cynllun Gweithredu Bioamrywiaeth ac fe'i gwarchodir gan Atodiad II Cyfarwyddeb Cynefinoedd Ewrop. Mae'r safle'n ffafriol, ond mae angen rheoli'r dalgylch mawr yn ofalus er mwyn atal unrhyw lygredd rhag cyrraedd y llyn o anheddau gwledig a ffermydd, a all niweidio ansawdd y dŵr.

Llyn Gwernan - llyn bach sydd mewn dyffryn i'r dde-orllewin o Ddolgellau ar ochr ogleddol Cadair Idris. Mae gan y llyn fflora dyfrol cyfoethog sy'n cynnwys 8 rhywogaeth nodweddiadol, y mae un ohonynt (dyfrllys coch (*Potamogeton alpinus*)) yn brin yng Nghymru. Mae ansawdd y dŵr yn rhagorol. Fodd bynnag, mae gan y llyn amledd uchel o'r rhywogaethau anfrodorol goresgynnol, alaw Canada (*Elodea canadensis*) ac alaw Nuttal (*E. nuttallii*). Mae cynnal ansawdd da y dŵr ac atal y

planhigion goresgynnol anfrodorol rhag lledaenu yn negeseuon allweddol o Lyn Gwernan.

Llyn Mair - llyn bas iawn â dŵr clir sydd i'r de-orllewin o Flaenau Ffestiniog. Adeiladwyd y llyn fel rhan o Ystad Plas Tan y Bwlch, i ddarparu colofn o ddŵr i bweru melin flawd a melin lifio'r ystâd. Er ei fod wedi ei amgylchynu gan hen goetir derw, mae'r dalgylch ehangach wedi ei goedwigo'n helaeth â chonifferau, ac mae effeithiau siltio cyflymedig i'w gweld yn y gwaddodion. Mae lefelau'r maetholion ychydig yn uchel, ynghyd â'r fflora dyfrol. Mae'r llyn yn cynnal fflora macroffyt prin eu rhywogaethau ar orchudd isel, ac yn cael ei oruchafu gan rywogaethau cyffredinol. Er bod gan y llyn boblogaeth fechan o wair merllyn bychan (*Isoetes echinospora*), mae o ddiddordeb bioamrywiaeth isel fel arall.

Llyn Cerrig-y-Myllt - llyn ucheldirol bach iawn a bas i'r dwyrain o Feddgelert. Yn rhyfeddol, am safle mor anghysbell, nid oes ganddo unrhyw blanhigion bron iawn, ac mae ganddo grynodiadau P uwch na'r disgwyl, er bod ganddo ddalgylch bach iawn heb unrhyw ffynonellau amlwg o faetholion. Caiff y safle ei ddosbarthu'n anffafriol ac nid oes iddo lawer o ddiddordeb o ran bioamrywiaeth.

Llyn Coch-hwyad a Llyn Gwyddior - dau lyn ucheldirol bas ar Gorsydd Llanbrynmair. Cafodd y gorgorsydd cwmpasol eu draenio ym 1985 ac mae llawer o'r dalgylch wedi ei goedwigo â chonifferau. Yn Llyn Coch-hwyad, mae creiddiau gwaddod wedi eu dyddio yn dangos cydberthyniad agos rhwng plannu a chynnydd cyflym yng nghynnwys organig y gwaddodion. Mae'r dŵr yn frown iawn o ganlyniad i ddraenio o'r mawn, ac mae'r planhigion wedi eu cyfyngu o ran y dyfnder y gallant dyfu iddo. Os cânt eu hasesu'n gamfaethol, mae'r fflora dyfrol yn ffafriol ac, er bod TP ddwywaith yn fwy na'r uchafswm targed, gall hyn fod yn un o swyddogaethau'r asidau organig. Mae'r safle o ddiddordeb oherwydd ei fod yn cynnal poblogaeth fawr o lyriad nofiadwy (*Luronium natans*).

Yn wahanol i Lyn Coch-hwyad, mae dalgylch Llyn Gwyddior wedi ei goedwigo'n rhannol yn unig. Mae ansawdd y dŵr yn well a'r safle'n llai hwmig. Mae'r fflora dyfrol yn ffafriol ac yn cynnwys llyriad nofiadwy (*Luronium natans*). Er bod rhai arwyddion o gyfoethogiad (e.e. algâu ffilamentaidd) caiff y safle ei ystyried i fod o werth da o ran bioamrywiaeth, a chaiff ei ddosbarthu'n ffafriol.

**Casgliadau a phwyntiau trafod terfynol**

Mae chwech o'r wyth safle yn dangos potensial da o ran bioamrywiaeth, ag ansawdd dŵr uchel a chasgliad cyfoethog o blanhigion, er nad yw'r canlyniad hwn yn cynrychioli llynnoedd yng Nghymru yn eu cyfanrwydd. Oherwydd eu hansawdd eithriadol, byddai Llynnau Cregennen a Llyn Gwernan yn gymwys i gael eu dynodi'n SoDdGA ac ACA ar sail cynefin, a dylid ystyried eu dynodi. Gellid ystyried dynodi Llyn Dinas, Llyn Coch-hwyad a Llyn Gwyddior hefyd, oherwydd presenoldeb poblogaethau sylweddol o lyriad nofiadwy. I'r gwrthwyneb, nid oes lawer o ddiddordeb i Lyn Mair a Llyn Cerrig-y-Myllt o ran bioamrywiaeth.

Mae angen i ymyrraeth reoli, fel yr argymhellir yn yr adroddiad hwn, gyd-fynd ag ymdrech o'r newydd i adfer cyflwr gwaelodlin y safleoedd a monitor parhaus o hyn ymlaen i olrhain newidiadau i'w cyflwr ac asesu effeithiolrwydd ymyriadau.

Caiff allbynnau o'r gwaith hwn eu defnyddio i helpu i gyflawni Cynlluniau Gweithredu Bioamrywiaeth lleol a chenedlaethol ar gyfer llynnoedd, cyfrannu at wyliadwriaeth ac adrodd ar statws cadwraeth llynnoedd dan Erthygl 11 y Gyfarwyddeb Cynefinoedd (92/43/EEC) a helpu i gyflawni Rhaglen Cymru Fyw Llywodraeth Cymru.

# 2. Executive Summary

**Background, sites and methods**
Lake ecosystems are threatened both nationally and globally. Commitments under European legislation and international treaties require the UK to protect and enhance these conservationally and culturally important habitats. Although the quality and condition of lakes in the protected site series (SSSIs and SACs) is reasonably well understood, this is not the case in the wider countryside. This report aims to fill some of these gaps by collecting detailed survey data from selected lakes of potential biodiversity importance in Wales and is part of an ongoing strategic survey programme designed by NRW to improve the understanding of the distribution and quality of different lake types in Wales.

Eight lakes of potential biodiversity importance were selected based on aerial photography and where available, local knowledge. The sites are Llynnau Cregennen (2 sites), Llyn Dinas, Llyn Mair, Llyn Cerig-y-Myllt, Llyn Gwernan, Llyn Gwyddior and Llyn Coch-hwyad.

Assessments are based on aquatic macrophyte surveys and mapping, bathymetric survey, physico-chemical measurements, and at 4 sites, palaeolimnological analyses. All of these techniques are widely used for assessing environmental quality of lake systems and were carried out according to standard methods.

**Site reports**
Llynnau Cregennen are a pair of lakes lying just to the north of the Cadair Idris massif. There are both exceptional in that they have excellent water quality and clarity and both have extensive and diverse aquatic plant communities extending to approximately 8 m in depth. Both lakes are in favourable condition and support the threatened plants long-stalked pondweed (*Potamogeton praelongus*) and smooth stonewort (*Nitella flexillis* ss.)

Llyn Dinas is a relatively large, shallow lake in the Nantgwynant Valley in Snowdonia. The lake has very clear water and supports an aquatic plant community, typical of low nutrient lakes. The lake has a large population of floating water plantain, (*Luronium natans*). This species is a BAP priority species and protected under Annex II of the European Habitats Directive. The site is favourable, but the large catchment requires careful management to prevent any pollution reaching the lake from rural dwellings and farms compromising water quality.

Llyn Gwernan is a small lake lying in a valley southwest of Dolgellau on the north side of Cadair Idris. The lake has a rich aquatic flora which includes 8 characteristic species one of which (red pondweed (*Potamogeton alpinus*)) is rare in Wales. Water quality is excellent. However, the lake has high frequency of the invasive non-native species, Canadian waterweed (*Elodea canadensis*) and Nuttall's waterweed (*E. nuttallii*). Maintaining good water quality and preventing the spread of non-native invasive plants are key messages from Llyn Gwernan.

Llyn Mair is a very shallow, clear-water lake lying to the southwest of Blaenau Ffestiniog. The lake was built as part of the Plas Tan y Bwlch Estate, to provide a head of water to power the estate flour and saw mills. Although surrounded by old

oak woodland, the wider catchment is extensively afforested with conifers and impacts of accelerated siltation are clear from the sediments. Nutrient levels are slightly high and the aquatic flora The lake supports only a species-poor macrophyte flora at low cover, and is dominated by generalist species. Although the lake has a small population of spring quillwort (*Isoetes echinospora*) it is otherwise of low biodiversity interest.

Llyn Cerrig-y-Myllt is a very small, shallow upland lake to the east of Beddgelert. Remarkably, for such a remote site, it has almost no plants and higher than expected P concentrations, despite having a tiny catchment with no obvious sources of nutrients. The site as classed as being unfavourable and is of little biodiversity interest.

Llyn Coch-hwyad and Llyn Gwyddior are two shallow upland lakes on the Llabrynmair Moors. The surrounding blanket bogs were drained in 1985 and much of the catchment afforested with conifers. At Llyn Coch-hwyad, dated sediment cores show a close correlation between planting and a rapid increase in the organic content of the sediments. The water is very brown due to draining from the peat, and plants limited in the depth they can grow. If assessed as dystrophic, the aquatic flora is favourable and although TP double the target maximum, this may be a function of the organic acids. The site is of interest because it supports a large population of floating water plantain (*Luronium natans*).

Unlike Llyn Coch-hywad, the catchment of Llyn Gwyddior is only partially afforested. Water quality is better and the site less humic. The aquatic flora is favourable and includes floating water plantain (*Luronium natans*). Although there are some signs of enrichment (e.g. filamentous algae) the site is considered to be of good biodiversity value and is classifies as favourable,

**Conclusions and final discussion points**

Six of the eight sites show good biodiversity potential with high water quality and rich plant assemblages, although this result is not representative of Welsh lakes as a whole. Due to their exceptional quality, Llynnau Cregennen and Llyn Gwernan would qualify for designation as SSSIs and SAC on habitat grounds, and should be considered for designation. Llyn Dinas, Coch-hwyad and Llyn Gwyddior could also be considered for designation due to the presence of significant populations of floating water-plantain. By contrast, Llyn Mair and Llyn Cerrig-y-Myllt are of little biodiversity interest.

Management intervention as recommended in this report needs to be accompanied by a renewed effort to establish the past baseline condition of the sites and continuous monitoring from now on, both to track changes in condition and assess the effectiveness of interventions.

Outputs from this work will be used to assist with the delivery of local and national Biodiversity Action Plans for lakes, contribute to the surveillance and reporting of the conservation status of lakes under Article 11 of the Habitats Directive (92/43/EEC) and assist with the delivery of Welsh Government's Living Wales Programme.

# 3. Introduction

## 3.1. Background

Lakes are a globally threatened habitat. They are subject to a wide range of pressures including nutrient enrichment, acidification, invasive species and recreation. In the UK, lakes are protected as Special Area of Conservation (SAC) features under the Habitats Directive, as Site of Special Scientific Interest (SSSI) features, and as Biodiversity Action Plan (BAP) Priority Habitat as part of the UK's international obligations under the Rio Biodiversity Convention.

In Wales, the UK BAP process has carried out an initial screening exercise of lakes within the BAP to assign them to different broad types and collect basic map-based data such as grid references, altitude, and local authority area (Hughes et al. 2004). This identified 559 water bodies >1ha in area within Wales.

The status of lakes in the protected site series (SSSIs and SACs) is reasonably well understood through regular monitoring (e.g. Burgess *et al*. 2006; 2009; 2013). A few large lakes are also monitored for other purposes such as the Water Framework Directive. However, in general detailed information on the biodiversity importance and status of most lakes in Wales is limited. This survey aims to fill some of these gaps by collecting detailed survey data and is part of an ongoing strategic survey programme designed by NRW to improve the understanding of the distribution and quality of different lake types in Wales.

Outputs from this work will be used to assist with the delivery of local and national Biodiversity Action Plans for lakes, contribute to the surveillance and reporting of the conservation status of lakes under Article 11 of the Habitats Directive (92/43/EEC) and assist with the delivery of Welsh Government's Living Wales Programme.

## 3.2. Aim of the Report

The primary objective of this project is to improve the understanding of the distribution and status of lakes as a BAP priority habitat so they can be better conserved both at a strategic and a local level.

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# 4. Methods

## 4.1. Study sites

Study sites were selected on the basis that they had the potential to be of high biodiversity importance. A combination of aerial photography, local information, and expert knowledge was used to identify suitable lakes. Priority was also given to surveying lakes that were within land holdings of organisations with a strong environmental focus and that would therefore be likely to use the information collected to inform sympathetic management. Since this procedure is likely to be biased towards the best unprotected sites, the sites surveyed here should not be seen as a representative sample of lakes in Wales.

The data presented in Table 1 provides details of the 8 lakes included in this report, detailing habitat feature types, WFD typologies and aquatic macrophyte survey dates.

| Lake Name | WBID | NGR | WFD Type* | Habitat Feature(s) | Survey date 2013 |
|---|---|---|---|---|---|
| Llyn Cregennen Isaf | 36134 | SH660143 | MA, S | Oligotrophic | 4 July |
| Llyn Cregennen Uchaf | 36154 | SH664141 | MA, S | Oligotrophic | 5 July |
| Llynnau Cerrig-y-Myllt | 34366 | SH631472 | LA, V | Oligotrophic | 30 June |
| Llyn Mair | 34668 | SH652412 | LA, V | Oligotrophic | 28 June |
| Llyn Dinas | 34244 | SH617496 | LA, S | Oligotrophic | 29 June |
| Llyn Coch-hwyad | None | SH921109 | LA, V | Oligotrophic | 1 July |
| Llyn Gwyddior | 36615 | SH934073 | LA, V | Oligotrophic | 2 July |
| Llyn Gwernan | 36021 | SH704160 | LA, S | Oligotrophic | 3 July |

LA = low alkalinity; MA = moderate alkalinity. S = shallow (Zmean = 3-15m); V = very shallow (Zmean <3m).

Table 1 . Details of the lakes included in this report - for notation, see key at foot of table.

## 4.2. Aquatic Macrophyte Surveys

The full description of the survey methods used to collect macrophyte data are detailed in the Joint Nature Conservation Committee publication for the Common Standards Monitoring (CSM) guidance for standing waters (see JNCC, 2005). In brief, the plant surveys consisted of four components; a strandline survey, emergent and marginal survey, shoreline wader survey and boat survey. These were carried out at each site on four discrete 100m sections of shoreline which were considered representative of the lake and gave good geographical coverage. In order to reduce disturbance, a maximum of 25% of the shoreline was surveyed, resulting in less than four sections being selected at smaller lakes. Where possible, surveying was performed using a bathyscope, but a double-headed rake was used in deeper water or where poor water clarity restricted visibility. The locations of all survey sections and boat transects were recorded using a Global Positioning System (GPS), backed up with digital photographs where necessary.

These methods were devised to provide quantitative species-abundance data that can be obtained in a pragmatic and repeatable manner. The technique optimises the chance of recording those species most typical of a lake site and detecting marked changes in their frequency. However, they do not aim to produce a complete species list for a lake. Additional efforts such as sampling drift line flora were made to record other species which did not occur in any of the survey sections, but the absence of species expected or known to occur from a particular lake does not necessarily denote absence from the site.

The specified survey methods use a point-abundance approach, with abundance recorded on a scale of 1-3. However, for the purposes of data analysis for condition assessment, the presence/absence data only are utilized (except in the case of emergent and marginal species). Plant data are therefore presented as frequency of occurrence rather than abundance, and it should be noted that this is frequency within the survey sections.

The survey sections are assumed to be collectively representative of the site. However, to enable comparison with historic survey data, estimates of species abundance for each set of survey points at a site have been made from the total number of occurrences, and these data have been converted to a DAFOR scale. For submerged and floating-leaved species the category was estimated from the total number of occurrences of each species in the wader and boat surveys as a proportion of the total number of vegetated survey points at the site, where an occurrence at >50% of points = D, 25-50% = A, 10-24% = F, 5 - 9% = O and <5% = R.

The CSM aquatic macrophyte surveys, upon which the condition assessments in this report are based, were carried out during June and July 2013 (Table 2.1). All field data were recorded onto standard forms printed onto waterproof paper and transferred onto a Microsoft Access database specifically designed to hold CSM records.

Field macrophyte identifications were made by Ben Goldsmith (JNCC accredited). Voucher specimens were collected for all taxonomically ambiguous species, unless very rare, and identifications confirmed either from fresh materials (usually in the evening of the survey) or at a later date from pressed specimens. Specimens of charophytes and *Utricularia* were preserved in alcohol and sent to Nick Stewart for confirmation. Quality control was performed in-house with reference to previously collected herbaria specimens. Botanical nomenclature followed Stace (1997) for higher plants and Moore (1986) for Stoneworts (updated by N. Stewart, pers. comm.).

### 4.3. Mapping Aquatic Macrophytes

In addition to using Common Standard Monitoring methods, whole site data were also collected for aquatic macrophytes at each lake. Data were collected using similar survey techniques (double-headed rake and bathyscope) as described above, but sample locations were chosen to ensure representative data were collected from the entire site. In shallow sites, this involved evenly spaced sample points throughout

the lake, whereas in deeper lakes, with depth-zoned vegetation, sample points were spaced to best capture the shifts in zonation.

All sample points were recorded using hand-held GPS and macrophyte species recorded onto a geo-reference, gridded lake outline. Species abundance was recorded on a 1-5 scale where: 1 = <2.5% cover (or one or two small individual), 2 = 2.5-10% cover (a few isolated individuals or small patch), 3 = 10-25% cover (several larger individuals, or a few patches), 4 = 25-50% cover (very obvious with many small individuals or substantial larger plans, but not dominant) and 5 = >50% cover (dominant). Consistency of scoring was maximised by Ben Goldsmith undertaking all the mapping surveys. The scores were in most parts decided by a combination of visual assessment (bathyscope) and rake sampling.

The patchy nature of aquatic plant distributions within a site means that no assumption should be made that any one species is growing between two or more other points where it is recorded. The use of single-species layers is not therefore appropriate and data are instead presented as geo-referenced abundance points for each species within a lake outline map. All data are listed with the data appendix.

### 4.4. Physico-Chemical Survey

Dissolved oxygen concentration and temperature profiles were taken at the deepest recorded point of each site on the same dates as the macrophyte surveys, using a YSI 550 meter. These data were used to assess oxygen availability within the water. Secchi disc depths were recorded at the time of the macrophyte surveys from the deepest point of all lakes and further measurements were taken at each survey section at sites where variability in water clarity was observed. A standard 20 cm diameter Secchi plate was used and the Secchi depth ($Z_s$) expressed in metres.

CSM requires at least four quarterly samples for an assessment of water quality. The water quality data used in this report have been collated from two sources. Quarterly water samples were collected by ENSIS Ltd. from 6 lakes between December 201 and October 2013. Chemistry from Llyn Coch-hwyad and Llyn Gwiddior were collected by NRW staff from May 2012 to May 2013. All samples were analysed by the National Laboratory Service (NLS).

A list of determinands, their units of measurement, limits of detection (LOD) and the conversion equations used to convert ionic and alkalinity measurements from mg $l^{-1}$ to µeq $l^{-1}$ for ANC calculations are given in Table 2.

| Chemical Variable / Test | Code | Units | LOD | Conversion from $mgl^{-1}$ to $\mu eql^{-1}$ |
|---|---|---|---|---|
| pH | pH | pH units | 0.05 | |
| Conductivity at 20ºC | Cond | $\mu S\ cm^{-1}$ | 10.0 | |
| Alkalinity (to pH 4.5: Grans Plot) | Alk (Gran) | $mg\ l^{-1}$ | -5 | Alk in $mg\ l^{-1}$*20 |
| Alkalinity (to pH 4.5 as CaCO3) | Alk (CaCO3) | $mg\ l^{-1}$ | 5 | |
| Carbon, Organic, Dissolved as C (DOC) | DOC | $mg\ l^{-1}$ | 0.2 | |
| Chlorophyll a, Acetone extraction | Chl a | $\mu g\ l^{-1}$ | 0.5 | |
| Phosphorus: Total as P | TP | $\mu g\ l^{-1}$ | 3 | |
| Orthophosphate, reactive as P | SRP | $\mu g\ l^{-1}$ | 1 | |
| Nitrogen: Total Oxidized as N | TON | $mg\ l^{-1}$ | 0.005 | TON in $mg\ l^{-1}$/14 *1000 |
| Sodium, determined by ICPMS | $Na^+$ | $mg\ l^{-1}$ | 0.02 | Na in $mg\ l^{-1}$/23 *1000 |
| Potassium, determined by ICPMS | $K^+$ | $mg\ l^{-1}$ | 0.02 | K in $mg\ l^{-1}$/39 *1000 |
| Magnesium, determined by ICPMS | $Mg^{2+}$ | $mg\ l^{-1}$ | 0.02 | Mg in $mg\ l^{-1}$/12 *1000 |
| Calcium, determined by ICPMS | $Ca^{2+}$ | $mg\ l^{-1}$ | 0.02 | Ca in $mg\ l^{-1}$/20 *1000 |
| Chloride | $Cl^-$ | $mg\ l^{-1}$ | 1 | Cl in $mg\ l^{-1}$/35.5 *1000 |
| Sulphate, determined by OES | $SO_4^{2-}$ | $mg\ l^{-1}$ | 0.5 | $SO_4$ in $mg\ l^{-1}$/48 *1000 |
| Total Aluminium | Total Al | µg l-1 | 10 | |
| Active (labile) Aluminium | Active Al | µg l-1 | 10 | |
| Iron, dissolved | Fe | µg l-1 | 3 | |
| Silicate, reactive as SiO2 | $SiO_2$ | mg l-1 | 0.01 | |
| Manganese, dissolved, determined by OES | Mn | µg l-1 | 10 | |
| Copper | Cu | µg l-1 | 0.5 | |
| Suspended solids | S. Solids | mgl-1 | 0.5 | |

Table 2. List of chemical variables analysed by the EA NLS and ENSIS Ltd. & conversion equations

## 4.5. Shoreline Development Indices (SDIs) and other lake data

Lake surface area and perimeter data are derived from the UKLakes database (Hughes *et al.* 2004) and are quoted in hectares and kilometres respectively. Lake to catchment area ratios are also derived from this database.

A Shoreline development index (SDI) has been calculated for each lake. The SDI is the ratio of the total length of the shoreline to the length of the circumference of a circle, the area of which is equal to the lake (Wetzel & Likens 1990) and has been derived from the UKLakes database. This measurement is of interest within the context of this report because it reflects the potential availability of the littoral zone of

a water body and thus the area within which plants can colonise. Lakes with a SDI near to 1.0 are generally close to being circular, whereas lakes with an SDI greater than 2 have more complex and convoluted shorelines and hence a greater potential to support a more diverse littoral community.

The collection of full Lake Habitat Survey (LHS) data for each lake was not undertaken as part of this study, but summary data were collected on a range of physical and habitat features in and around the lakes and are discussed in the condition assessment text and presented in the accompanying Microsoft Access database.

## 4.6. Palaeolimnological data

For many lakes, palaeolimnological evidence is used to assist with the assessment of current condition. Sedimentary diatom remains are used to reconstruct past and present environmental conditions, providing evidence for change or stability of individual lake ecosystems over time. Diatoms are used to estimate changes in total phosphorus (DI-TP) and acidity (DI-pH), and hence to compare the current status of the lakes with conditions in the past (Battarbee *et al*. 2012; Bennion, H. *et al*. 2004; Bennion *et al*. 1996).

### 4.6.1. Sediment core dating

Radiometric dating was applied to four of the cores in order to place the observed biological changes in a time context. Lead-210 (half-life is 22.3 year) is a naturally-produced radionuclide, derived from atmospheric fallout (termed unsupported $^{210}$Pb). Caesium-137 ($^{137}$Cs, half-life is 30 years) and americium-241 ($^{241}$Am, half life 432 years) are artificially produced radionuclides, introduced to the study area by atmospheric fallout from nuclear weapons testing and nuclear reactor accidents. They have been extensively used in the dating of recent sediments. Dried sediment samples from the four cores were analysed for $^{210}$Pb, $^{226}$Ra, $^{137}$Cs and $^{241}$Am by direct gamma assay in the Environmental Radiometric Facility at University College London, using ORTEC HPGe GWL series well-type coaxial low background intrinsic germanium detector. Lead-210 was determined via its gamma emissions at 46.5 keV, and $^{226}$Ra by the 295 keV and 352 keV gamma rays emitted by its daughter isotope $^{214}$Pb following 3 weeks storage in sealed containers to allow radioactive equilibration. Caesium-137 and $^{241}$Am were measured by their emissions at 662 keV and 59.5 keV (Appleby *et al.* 1986). The absolute efficiencies of the detector were determined using calibrated sources and sediment samples of known activity. Corrections were made for the effect of self absorption of low energy gamma rays within the sample (Appleby *et al*. 1992).

## 4.7. Bathymetric Survey

Visiting the sites in December 2012 when plant growth is at its minimum provides the best opportunity to collect accurate bathymetric data from lakes. Bathymetric maps and calculation of lake volume are determined using a boat-mounted, combined GPS receiver and echo sounder (Lowrance LMS240). Many thousands of geo-referenced depths can be recorded from a lake by rowing or motoring along evenly spaced transects across the entire lake surface. These data are stored electronically and can be used in various GIS packages to calculate lake volume and to produce high resolution contour maps (bathymetric maps) of the lakes. Protocols for the

standardisation of bathymetric data collection, interpretation and output were developed by Turner *et al*. (2011) in line with NRW requirements.

### 4.8. Interpretation of the attribute data and overall assessment of site condition

The attribute data presented in this report has been used to assess each water body for its site condition based upon the Common Standards Monitoring (CSM) methods (JNCC, 2005). This method is designed as a monitoring method for assessing the quality of lake protected sites, but it is considered applicable as a standardized general health check. The advantage of using this approach is also that results can be easily compared with existing work.

A summary table of the significance of the various attributes listed in the report is provided in Table 3. For the full method describing site condition assessment see JNCC (2005).

A healthy lake ecosystem consists of many components. It should preferably have a natural morphology and sediment load; water chemistry unmodified by human impacts; and a fauna and flora appropriate to the lake environment. In practice it is too expensive to monitor all of these variables in detail, so a compromise is needed that is both cost-effective and yet maximizes its ability to detect damage to the ecosystem. The common standards protocol focuses on two main components: the aquatic plant community and water chemistry.

Where previous information exists for a site, this has been used to suggest possible temporal changes or stability at a site. The addition of diatom palaeolimnological data provides a powerful additional tool that can be used to set results in context. Diatom palaeolimnological data provides a temporal perspective and can reveal trends indicating stability or change in lake ecosystems. Therefore, in addition to stating whether a lake is in favourable or unfavourable condition, examination of diatom palaeolimnological data enables an assessment of whether its conservation interest is being maintained, is recovering, is declining or has been destroyed.

Bathymetric (depth) data similarly provides important contextual information that can be used to interpret the data in a more site-specific way. For example, shallow lakes tend to be less sensitive to nutrient enrichment, because they have a larger area where macrophytes can grow, and the macrophytes are able to absorb excess nutrients to a certain extent. However, they are more sensitive to increased numbers of fish and waterfowl, which tend to thrive in shallow warm water and uproot the macrophytes. An understanding of the depth profile of a lake is also helpful if the need arises to manage water levels, and to predict areas of suitable habitat for fish spawning or for certain rare plants such as *Luronium natans* or *Potamogeton praelongus*.

None of the sites in this report have been assessed before using the CSM method. The method aims to identify general categories of impact (e.g. acidification, eutrophication, management) and, in the case of a site being in unfavourable condition, recommendations are made for further investigation and / or management action. Llyn Gwernan, Llyn Coch-hwyad and Llyn Gwyddior have all been subject to recent surveys and comparisons, where possible, have been made in the individual site reports.

| Attribute | Significance and Interpretation |
|---|---|
| Extent | This attribute is to assess changes caused by active management, such as infilling or channel diversion resulting in loss of habitat. Loss of part of a lake (by reduction of the water level) may also have significant effects on the rest of the water body, since other areas will be shallower and warmer. Changes due to drying out or successional changes are covered under other attributes. |
| Macrophyte community composition | Macrophytes are useful biological indicators in their own right, especially for nutrient enrichment. They are also an important structural component for other species. However, macrophytes are relatively poor indicators of acidification. At least a significant proportion of the vegetated area of the water body should have an expected frequency of characteristic aquatic species for a given lake type. Two aspects of composition are measured: whether overall taxonomic composition is representative of the lake type, and whether the most frequent macrophyte(s) are typical. There may be valid reasons why a characteristic species is not present at a site (such as biogeographic range or isolation from source populations) which are considered when applying targets to an individual site. |
| Negative indicator species | Highlights invasive non-native species and atypical species for the water body.<br>A number of non-natives have such invasive potential that they should be assessed separately. Species of particular concern are: *Crassula helmsii*, *Hydrocotyle ranunculoides*, *Myriophyllum aquaticum* and *Azolla filiculoides*. If any of these species are present, a water body should be considered as being in unfavourable condition. This list is not exhaustive and should be updated as new threats become apparent.<br>Colonisation since the previous field visit by *Elodea nuttallii* or *Elodea canadensis* is indicative of unfavourable condition, as is dominance of naturalised non-native species, such as *E. canadensis*. Occurrence of such species at >40% frequency in unproductive waters, and >50% frequency in more productive waters, is indicative of unfavourable condition.<br>Excessive growths of filamentous algae on lake substrate or macrophytes are indicative of nutrient enrichment. Cover of benthic and epiphytic filamentous algae should be less than 10% |

| Attribute | Significance and Interpretation |
|---|---|
| Macrophyte community structure | Most lakes have a characteristic zonation, with deep water submerged plants, shallow water submerged plants, floating leaved vegetation, swamp vegetation and marginal plants - with no plants at all in the deepest areas. The maintenance of this hydrosere is an important part of the functioning of a lake. The maximum depth at which submerged vegetation is able to grow is a direct indicator of water clarity and can be a useful indicator of nutrient enrichment or sedimentation, since increased water turbidity will kill plants growing in deepest water first. Maxiumum depth distribution is also a general indicator of the status of the macrophyte community and should be maintained during future visits. |
| Water quality | Mean annual TP concentrations (based on at least quarterly measurements), should meet the targets appropriate for the lake type documented in the guidance, unless site-specific targets are available from hindcast or palaeoecological studies. There should be no evidence of excessive blue-green or green algal blooms. In low nutrient waters, blooms would not be expected to occur. Lakes should exhibit stable and characteristic pH values for their type and poorly buffered upland lakes should be assessed for signs of acidification. Sites should demonstrate adequate dissolved oxygen to support aquatic fauna. Brackish sites should be assessed for stable salinity ranges. |
| Hydrology | There should be a natural hydrological regime. There should be no evidence of impact from lowered or artificially raised water levels due to abstraction or increased / reduced flows to in- / out-flows. Bank modifications should be limited to less than 5% of the shore length and the impact of grazing or erosion from boat wash assessed. |
| Lake substrate and sediment load | Natural substrates and shorelines should be maintained. Increased sediment loads may result in smothering of coarse substrates with fine sediments. Changes in plant community may result from enriched sediments without an accompanying change in water chemistry. Increases in siltation could result from increased lake productivity, changes in catchment land-use (particularly over-grazing), lake level fluctuations, climatic fluctuations, or changes in sewage treatment. |
| Indicators of local distinctiveness | Maintain rare species and habitat features at current extent/levels and/or in current locations. For “notable” species (e.g. nationally scarce plants), it is not intended that a target is set for detailed species monitoring. It is intended that a rapid indication of presence/absence and /or approximate extent should be provided. Allowing for natural fluctuations in population size. The same approach applies to “notable” habitats. |

| Attribute | Significance and Interpretation |
|---|---|
| Diatom Palaeo-limnology | Diatoms are a group of ubiquitous microscopic algae with siliceous valves (shells) that persist in lake sediments. Unlike macrophytes, they are excellent dispersers and this means that changes in the diatom flora can be reliably linked to changes in environmental conditions rather than colonization effects. These algae are therefore good indicators of the health of a lake, both in the past and in the future, and therefore provide the best means of assessing trends in condition. |

Table 3. Significance and interpretation of the CSM attributes used for site condition assessment

## 4.9. Total Phosphorus limits

Total phosphorus (TP) is a key parameter used in the assessment of a water body (JNCC 2005). It is well understood that there is often a direct relationship between TP concentrations and increased phytoplankton biomass (OECD, 1982) and that this algal growth can have significant impacts upon the lake ecosystem. Increased algal biomass suppresses plant growth through increased turbidity and nutrient competition and can alter a water body in other ways by influencing pH, oxygen concentrations as well as affecting other biotic and abiotic factors.

Table 4 shows the generic upper limits for TP for different lake types recommended in JNCC (2005). In general these have been used for assessing TP concentrations. However, to provide a site-specific picture we have also used the UK morphoedaphic index (MEI) model to calculate reference phosphorus values for each lake (Carvalho *et al*. 2005).

| Lake Type | Corresponding Feature Type | Depth Category | Upper TP limit ($\mu g\ l^{-1}$ as P) |
|---|---|---|---|
| Peat | Dystrophic | Deep | 10 |
| | | Shallow | 10 |
| Low Alkalinity | Oligotrophic | Deep | 10 |
| | | Shallow | 10 |
| Medium Alkalinity | Mesotrophic | Deep | 15 |
| | | Shallow | 20 |
| High Alkalinity | Eutrophic | Deep | 35 |
| | | Shallow | 50 |
| Marl | Hard water | Deep | 20 |
| | | Shallow | 35 |
| Brackish | Brackish | Deep | 35 |
| | | Shallow | 35 |

Table 4. Total phosphorus targets for designated lakes (CSM, JNCC, 2005). There is some uncertainty around the targets for dystrophic lakes.

MEI uses alkalinity, altitude and mean depth as predictor variables to estimate the reference total phosphorus and class boundaries corresponding to different WFD reporting classes from High to Poor status.

## 4.10. Acidification environmental standards (ANC boundaries)

Acidification is the total outcome of a complex set of chemical processes. pH reflects acidity rather than acidification, although it is a good proxy for the toxic effects of labile aluminium (L-Al). Acid Neutralising Capacity (ANC) is typically taken as a measure of available buffering capacity in aquatic systems and is a direct measure of anthropogenic acidification. Two forms of ANC are currently used: Cantrell (ANC-C) and Ion balance / ionic (ANC-I). ANC-C requires less data (alkalinity and dissolved organic carbon) than ionic (all acid anions and base cations).

The current ANC-I standard consistent with the protection of natural waters is >20 µeq $l^{-1}$ (JNCC, 2005), except in cases where it is estimated that ANC has always been lower than this value, in which case the recommended standard is 0 µeq $l^{-1}$ (DEFRA, 2004). However, revised CSM guidance (JNCC, in draft) will use the WFD standard of 40 µeq $l^{-1}$

In the current report, both ANC-I or ANC-C (or both) have been calculated and reference is made to ANC-I and/or ANC-C standards as appropriate. Equations used to calculate ANC-I and ANC-C are provided below:

$$\text{ANC-I} = (\text{base cations} - \text{acid anions}) \text{ in } \mu\text{eq } l^{-1}$$
$$= (Ca^{2} + Mg^{2+} + Na^{+} + K^{+}) - (Cl^{-} + SO_4^{2-} + \text{TON} + \text{SRP})$$

$$\text{ANC-C} = (\text{Alk in } \mu\text{eq } l^{-1} + (4.5 \times \text{DOC in mg } l^{-1}))$$

## 4.11. Trophic scores (TRS and PLEX)

Trophic scores are a method designed to infer the ecological condition of standing waters using the composition of the submerged plant community. Scoring systems such as this use the known nutrient preferences of the plant community to infer the trophic status of the lake. These systems have been used in rivers with some success (e.g. Holmes *et al*. 1999, Schneider & Melzer, 2003), and in the UK, a modified form of this system (LEAFPACs) has recently been developed as a WFD tool for both rivers and lakes (Willby *et al*., 2009).

Trophic scores are not a formal part of the CSM methods, but have been presented here to provide additional contextual information. Two different trophic scores have been calculated: Trophic Ranking Score (Palmer, 1992) and the Plant Lake Ecosystem Index (PLEX) (Duigan *et al*., 2006).

Trophic Ranking Scores (TRS: Palmer, 1992) were calculated from presence / absence data. In additions to TRS scores, Plant Lake Ecosystem Index (PLEX) scores (Duigan *et al*., 2006) have been calculated for each lake. PLEX is essentially a development of the older TRS system, but has been developed using a larger dataset and incorporates a greater range of species. It can be used for comparing different sites and for detecting change over time at individual sites.

Although trophic scores may provide useful, easily accessible information, they need to be interpreted with caution. Macrophyte communities respond to various factors, of which nutrients are not always the most important (Demars & Harper, 1999). The ability of any macrophyte community to reflect changes in nutrient loading will depend on the species pool present and many macrophyte species have a broad nutrient tolerance, making them relatively poor indicators of trophic status (Holmes *et al*., 1999). Macrophyte populations in stressed communities may also fluctuate widely and unpredictably (Jeppesen *et al*., 2005).

Consequently, the trophic indices have not been used directly as part of the condition assessments, though where a change in a fertility score tracks a corresponding change in one of the key variables, this is discussed. The trophic scores also provide a means of general comparison between sites and between the current surveys and historic macrophyte survey data. Once further work has been carried out in this field, it may be possible to compare these results with future CSM data and place them in their proper context.

## 4.12. Changes to the CSM methods

Following the publication of the CSM guidance for standing waters (JNCC, 2005) and subsequent trials and implementations of these methods by the UK conservation agencies, subsequent review has recommended various changes to the assessment method. These have been incorporated into the assessments in discussion with NRW.

The methodology has been under further review in 2013 /14. While we have been unable to include all the recommendations of the as yet unpublished guidance, the removal of *Potamogeton pusillus* as a characteristic species for naturally eutrophic sites was included within this report. The fine leaved *Potamogeton* spp. are considered as being representative of more degraded eutrophic lakes and therefore the target species are focussed more towards broadleaved *Potamogeton* species.

## 4.13. List of Abbreviations Used.

### Depths

- $Z_{max}$ = Maximum recorded water depth
- $Z_s$ = Secchi depth (recorded summer 2013)
- $Z_v$ = Maximum macrophyte colonisation depth (recorded)

### Limnological data

- TP = total phosphorus
- TN = total nitrogen
- Chl *a* = chlorophyll *a*
- Alk = total alkalinity
- DOC = dissolved organic carbon
- ANC-I = acid neutralising capacity – ion balance (base cations – acid anions)
- ANC-C = acid neutralising capacity – Cantrell (Alk $\mu eql^{-1}$ + (4.5 × DOC in $mgl^{-1}$))

### Water Framework Directive (WFD) lake typologies

Alkalinity

- D = dystrophic
- LA = low alkalinity <10 mg $l^{-1}$ $CaCO_3^{2-}$
- MA = medium alkalinity 10-50 mg $l^{-1}$ $CaCO_3^{2-}$
- HA = high alkalinity >50 mg $l^{-1}$ $CaCO_3^{2-}$

Depth

- D = deep ($Z_{mean}$ > 15 m)
- S = shallow ($Z_{mean}$ 3-15 m)
- V = very shallow ($Z_{mean}$ <3 m)

# 5. Site Assessments

## Llynnau Cregennen

Llynnau Cregennen[1] are two relatively small lakes lying towards the north-western edge of the Cadir Idris massif. According to visitwales.com, Cregennen is said to be a corruption of 'Crog gangen' (hanging branch). In the 12th century the lakes were within the territory of Ednowain ap Bradwen, the head of one of the fifteen tribes of Wales, and Cregennen was the site where criminals were hung. The lakes and the surrounding land are owned by the National Trust

The lakes are separated by a ridge, with the outflow from Llyn Cregennen Uchaf being a small stream that cuts through the ridge to Llyn Cregennen Isaf. Llyn Cregennen Uchaf has a low intensity trout fishery of both wild brown trout and some stocked rainbow trout; the lower lake is unstocked and has only wild brown trout (www.cregennen.co.uk). Llyn Cregennen Isaf receives water from the upper lake to the south-east, and also from Pared y Cefn Hir to the north. Rather unusually, the lower lake has two outlows, one to the east and another to the west, the latter with a crude sluice, now disused.

Both lakes are in the region of 15 m deep, but also have quite extensive areas of shallower water (<5 m), which along with very clear water, affords ample areas for aquatic plant growth.

[1] There is some uncertainty as to the correct spelling: both 'Cregennen' and 'Cregennan' seem to be in use. We have used the name as shown on the current edition of the Ordnance Survey 1: 50 000 map.

## 5.1. Llyn Cregennen Uchaf

Annex 1 type: H3130: Oligo-mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the Isoëto-*Nanojuncetea*.

### 5.1.1. Site description

| | |
|---|---|
| Name: | Llyn Cregennen Uchaf |
| County: | Gwynedd |
| WBID: | 36154 |
| Grid reference: | SH664141 |
| OS Grid reference (X,Y): | 266427,314130 |
| Latitude / Longitude | N52°42.5',W003°58.71' |
| Altitude (m): | 239 |
| Maximum recorded depth (m): | 14.7 |
| Mean depth (m): | 4.7 |
| Lake volume ($m^3$): | 235624 |
| Surface area – UKLakes (ha): | 5.5 |
| Surface area – measured (ha) | 5.01 |
| Perimeter of lake (km): | 0.9 |
| Shoreline Development Index (SDI): | 1.101 |
| WFD alkalinity based typology: | Low Alkalinity, Shallow (LA, S) |
| Phase 1 habitat type: | Standing water: Oligotrophic: G1.3 |
| Survey Date: | 4 July 2013 |

Table 5. Summary characteristics for Llyn Cregennen Uchaf.

### 5.1.2. Condition Assessment and Discussion

Table 6. Assessment Summary Table for Llyn Cregennen Uchaf.

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | None |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise) | ✓ | 3 characteristic *Littorelletea* spp in 2013: *Isoetes lacustris, Littorella uniflora & Lobelia dortmanna.* 4 other characteristic mesotrophic spp: *P. gramineus, P. praelongus, P. perfoliatus* & *U. minor*. *Also Nitella spp.* and *Chara virgata* |
| | No loss of characteristic species (see Box 2) | **NA** | No previous data |
| | ≥ 6/10 vegetated sample spots (boat / wader survey) have ≥ 1 characteristic spp. | ✓ | 76% of vegetated sample spots comply (78% wader, 74% boat) |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | None recorded |
| | Benthic and epiphytic filamentous algae <10%. | ✓ | Filamentous algae were present, but well below 10 % cover. |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (site specific) | ✓ | Good zonation present. *L . uniflora* & *L. dortmanna* to 2.5 m, *I. lacustris* from 0.5 - 5.3 m – *Potamogeton* spp forming beds 1.5 - c. 4.0m. *C. virgata* > 7.0 m |
| | Maximum depth distribution should be maintained | ✓ | $Z_{max}$ (recorded) = 14.7m, $Z_s$ = 7.00m, $Z_v$ = 7.6m. |
| | At least present structure should be maintained | **NA** | No evidence of change |
| **Water quality** | Stable nutrients levels: TP target / limit: Oligotrophic = 10 $\mu g l^{-1}$ | ✓ | TP (mean 2012/13) = 6.5 $\mu g\ l^{-1}$ $N0_3$-N = 0.11 mg $l^{-1}$ |
| | Stable pH values: pH ~ 5.5 – circumneutral | ✓? | Mean pH 2006-11 = 7.35 (Range 6.98 – 7.93). Slightly higher than expected. |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 $mg l^{-1}$) | ✓ | > 10 mg $l^{-1}$ from 0 – 14 m. Water column mixed |
| | No excessive growth of cyanobacteria / green algae | ✓ | Low Chl a values (mean 1.45 $\mu g\ l^{-1}$, range 0.9 – 2.1 $\mu g\ l^{-1}$) |
| **Hydrology** | Natural hydrological regime | ✓ | Appears natural. |
| **Lake substrate** | Natural shoreline maintained | ✓ | Extensive upland grazing to shore. Small boathouse, but otherwise unmodified |
| | Natural and characteristic substrate maintained | ✓ | Sediment core analysis shows no significant changes to sediments |
| **Sediment load** | Natural sediment load maintained | ✓ | Appears natural |

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Indicators of local distinctive-ness** | Distinctive elements maintained at current extent / levels / locations | ✓? | *P. praelongus* and deep *Chara* beds are distinctive features that should be maintained |
| **Disturbance** | No introduced species | ✓ | None recorded |
| | Minimal negative impacts from recreation and navigation. No fish farming | ✓? | Current fish stocking unknown, but possible introduction of rainbow trout. |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | ✓ | Very slight increase in organic content. Diatom flora suggests little change. |

Status: ✓ = favourable; X = unfavourable; NA = Not assessed

## Extent

The surface area of the lake is 5.01 ha. There is no evidence of any recent loss of extent of open water.

## Macrophyte community composition and structure

Llyn Cregennen Uchaf is an oligotrophic lake with very high water clarity and supports a relatively rich flora with excellent depth distribution. Fourteen aquatic plant species were recorded in 2013, seven of which were characteristic oligotrophic species. Furthermore, over 75 per cent of the vegetated sample points had one or more characteristic oligotrophic species present. The shallow littoral areas are dominated by rocky substrates with only sparse vegetation.

*Littorella uniflora* and *Lobelia dortmanna* were recorded most commonly where finer gravels occurred in very shallow water (0 - 50 cm) and in deeper water (1.2 - 2.5 m) where sediment deposition was more prevalent. *Isoetes lacustris* was most common at depths of more than 1.0 m, and was often dominant at around 2.5 m, extending to 5.3 m in places (Figure 2). Where co-occurring with *Chara virgata* the exact depth distribution of *I. lacustris* was difficult to determine and it may have been under recorded in deeper water due to the high density of the *Chara* beds.

*Chara virgata* dominated the aquatic flora, forming low-growing “lawns” in shallower water (0.75-1.5 m) and dense beds with taller plants in deeper water, extending to a maximum depth of 7.6 m (8.1 m was recorded during plant mapping). Much of the lake bed between 5.0 to 8.0 m was dominated by very dense growths of *C. virgata.*

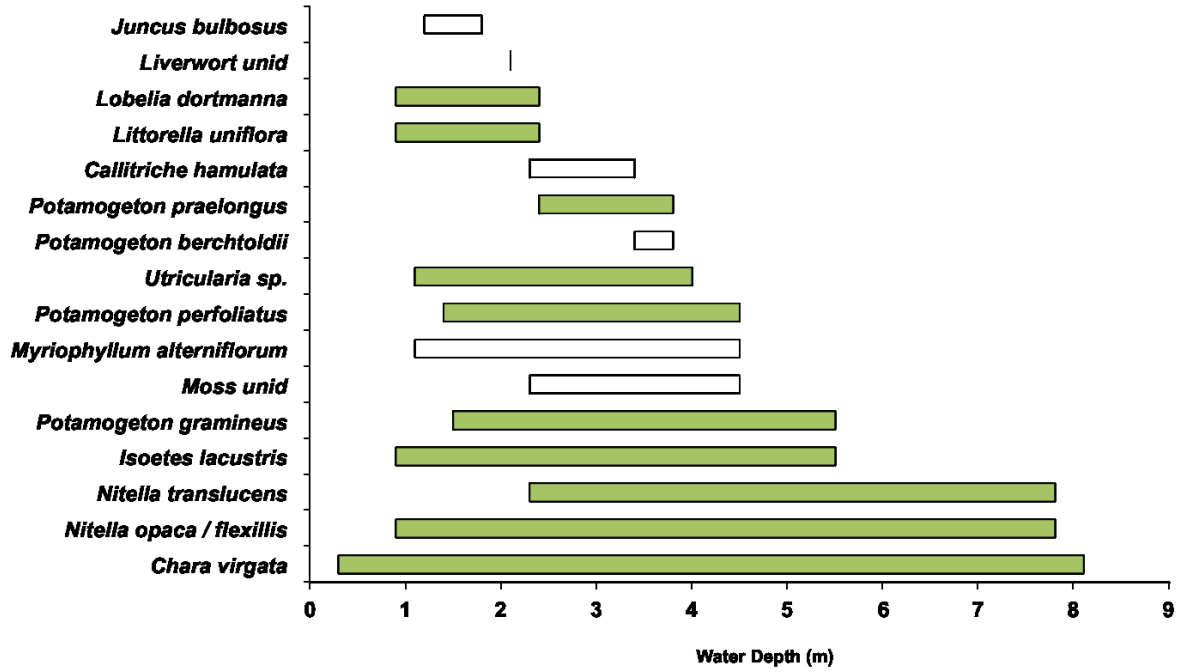
| Submerged and floating vegetation | TRS | PLEX | % occur-ence (n=77) | DAFOR abundance [2] | Min depth (cm) | Max depth (cm) |
|---|---|---|---|---|---|---|
| *Callitriche hamulata* | 6.3 | 6.15 | 2.0 | R | 230 | 270 |
| ***Chara virgata*** | **7.3** | **7.69** | **68.0** | **D** | **25** | **760** |
| *Glyceria fluitans* | 7.0 | 6.54 | 1.0 | R | 25 | |
| ***Isoetes lacustris*** | **5.0** | **4.23** | **49.0** | **A** | **50** | **550** |
| *Juncus bulbosus* | 5.3 | 3.08 | 6.0 | R | 90 | 180 |
| ***Littorella uniflora*** | **6.7** | **4.23** | **47.0** | **A** | **0** | **270** |
| ***Lobelia dortmanna*** | **5.0** | **3.08** | **38.0** | **A** | **25** | **250** |
| *Myriophyllum alterniflorum* | 6.7 | 4.23 | 37.0 | A | 75 | 450 |
| ***Nitella flexilis*** | **6.7** | **5.38** | **28.0** | **A** | **50** | **530** |
| ***Nitella opaca*** | **6.7** | **5.38** | **18.0** | **F** | **50** | **760** |
| ***Nitella translucens*** | **6.7** | **5.38** | **-** | **-** | **-** | **-** |
| ***Potamogeton gramineus*** | **7.0** | **7.31** | **5.0** | **O** | **100** | **550** |
| ***Potamogeton perfoliatus*** | **7.3** | **7.69** | **11.0** | **F** | **100** | **450** |
| ***Potamogeton praelongus*** | **8.5** | **5.38** | **1.0** | **R** | **120** | |
| ***Utricularia minor*** | **4.0** | **3.08** | **14.0** | **F** | **50** | **270** |
| **Average score** | **6.4** | **5.25** | | | | |
| **Species richness** | | | | 15 | | |

Table 7. Aquatic macrophyte community composition for Llyn Cregennen Uchaf in June 2012. Characteristic species are highlighted in **bold**.

The broad-leaved pondweeds *Potamogeton perfoliatus* and to a lesser extent, *P. gramineus* and *P. praelongus,* formed distinct beds at a number of locations within the lake, most commonly at depths of 1.5- 4.5 m, the latter species rare in the site. *Myriophyllum alterniflorum* and *Nitella* spp. were common up to 5.0 m, often co-occurring with *Chara virgata.* Both *N. flexilis* sensu stricto and *N. opaca* were recorded from the site and *N. translucens* also recorded, but only during the plant mapping survey. Other species were less common, but distributed throughout the site (Figure 2).

[2] Based on presence / absence data from all vegetated plots in the wader and boat based surveys. DAFORs are calculated from the total number of occurrences across the wader and boat surveys as a proportion of the total number of vegetated points.

Figure 1. Depth range of the aquatic macrophytes recorded from Llyn Cregennen Uchaf, characteristic oligo- mesotrophic species are shaded green.




The assemblage places the lake into either Group C2 or Group E as defined by Duigan *et al*. (2006); the presence of *Glyceria fluitans* just tipping it into E, a lake type not previously recorded in Wales. A high percentage of Group E lakes have *Chara* sp. and broadleaved pondweeds, as well as the more typical *Littorelletea uniflorae* assemblage, potentially qualifying them for three Natura 2000 habitat types[3] on vegetation grounds. The TRS and PLEX scores are consistent with oligotrophic lakes. Llyn Cregennen Uchaf is favourable with respect to its aquatic macrophyte composition and structure.

The data from Llyn Cregennen Uchaf were run against the LEAFPACS2 Lake Macrophyte Classification Tool (UKTAG, 2014). The results of this are shown in Table 8.

[3] These are H3130 Oligotrophic to mesotrophic waters with vegetation of the *Littorelletea uniflorae*; H3140 Hard oligotrophic waters with *Chara*; and H3150 Natural eutrophic water bodies with *Magnopotamion*.

Figure 2 Distribution maps of the aquatic plant species recorded in Llyn Cregennen Uchaf.

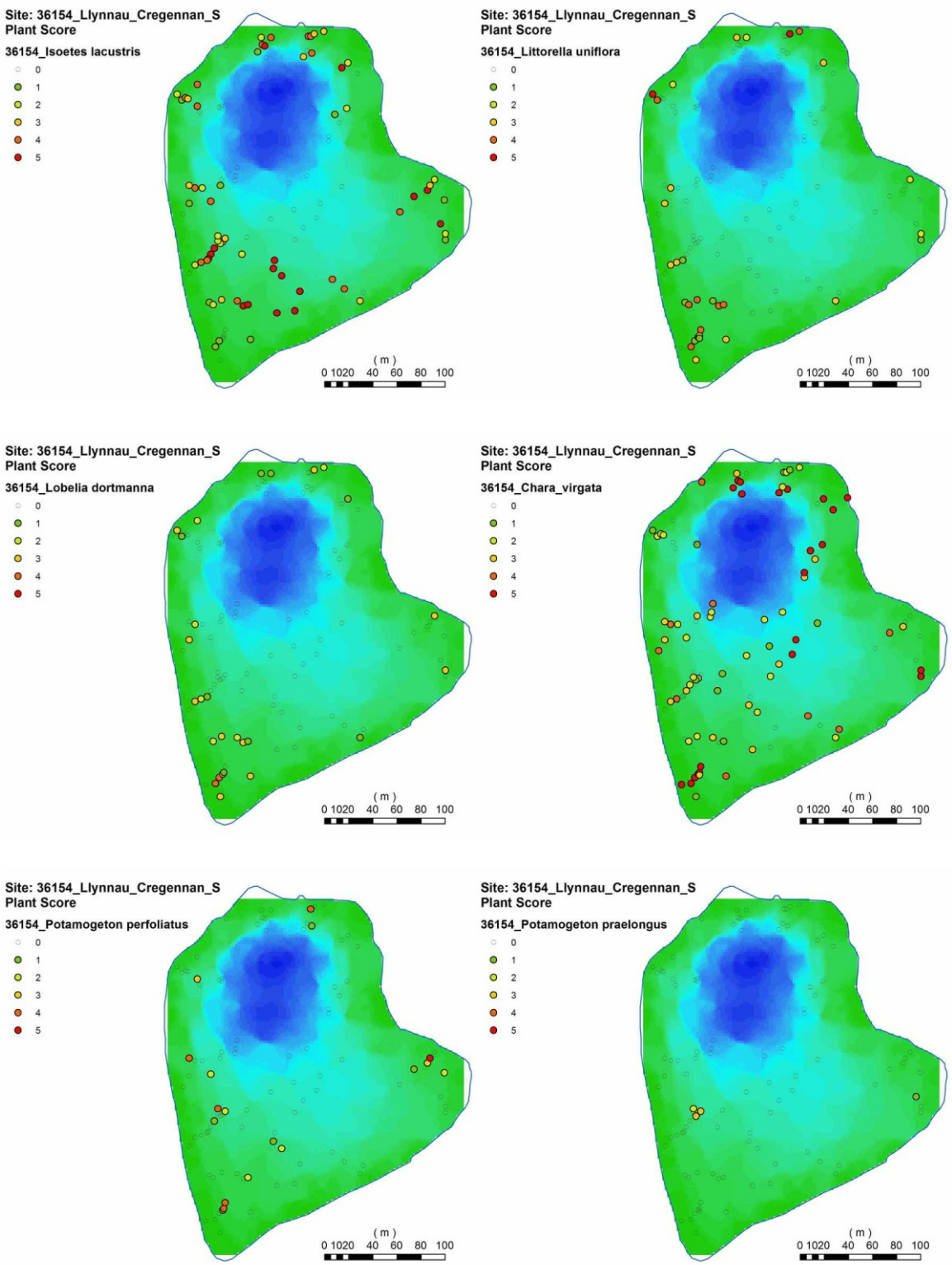


Figure 2 (contd.).

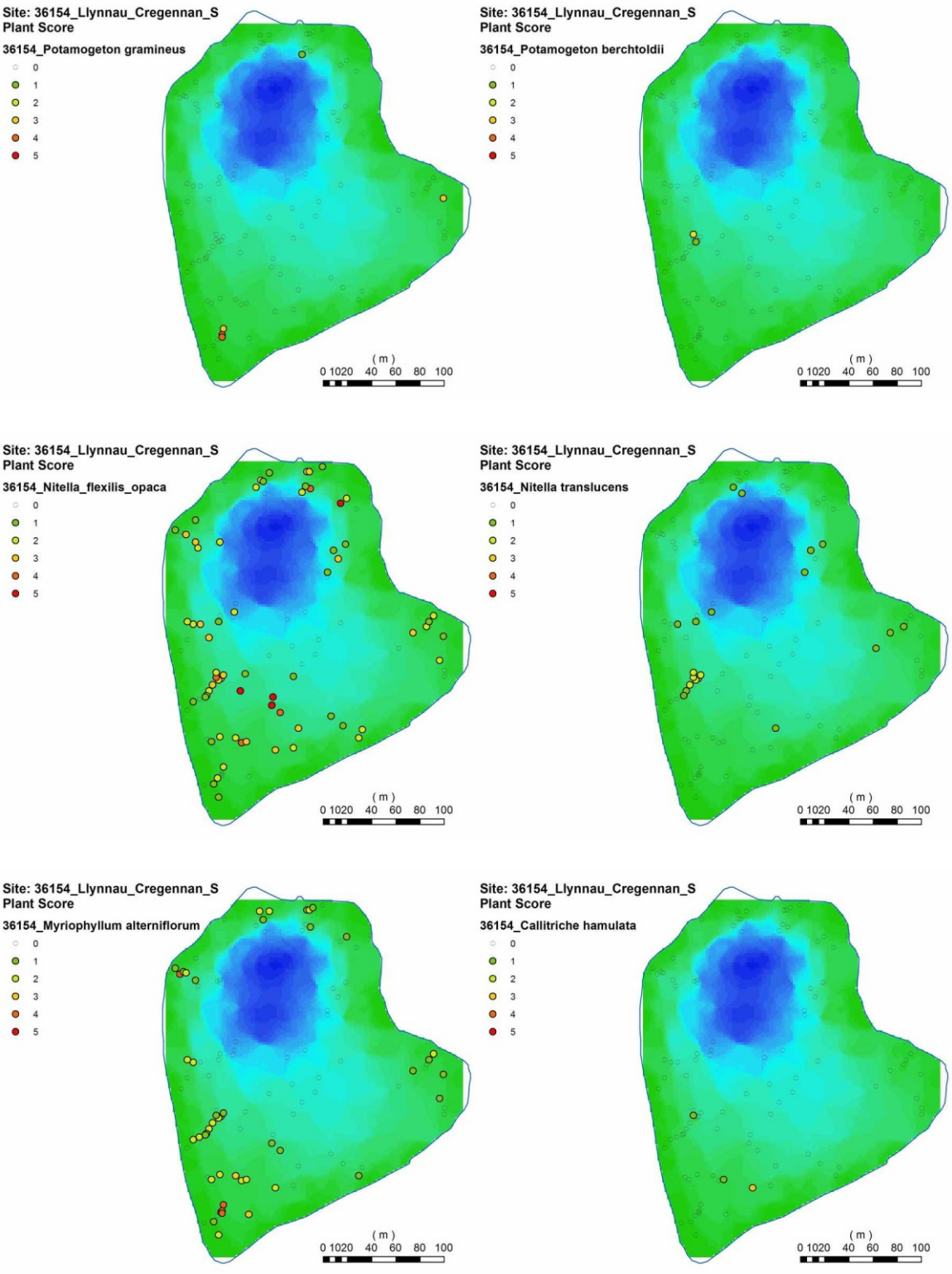
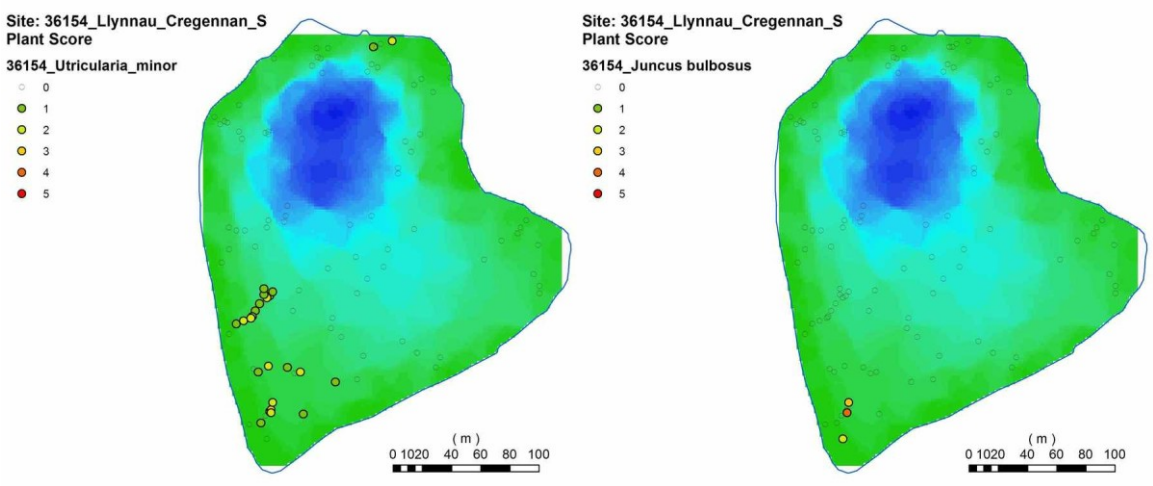


Figure 2 (contd.).




(a)

| | LMNI | NTaxa | NFG | COV | ALG |
|---|---|---|---|---|---|
| Observed | 3.31 | 14.00 | 8.00 | 4.43 | 0.14 |
| Expected | 3.14 | 9.99 | 6.51 | 8.20 | 0.05 |
| EQR | 0.967 | 1.402 | 1.229 | 0.735 | 0.910 |

(b)

| | Bad | Poor | Moderate | Good | High |
|---|---|---|---|---|---|
| Probabilities | 0.0 | 0.0 | 0.0 | 0.1 | 99.9 |

Table 8 (a) LEAFPACS2 classification tool observed and expected metrics for Llyn Cregennen Uchaf in June 2012. (b) Confidence in class.

Llyn Cregennen Uchaf was classified at High Status with respect to macrophytes with 99.9% confidence. This is if anything likely to be slightly pessimistic, as the classification result is being driven by the relatively low EQR for cover (COV), which is a consequence of the loose cobbles and gravels that dominate the lake shore, offering naturally poor conditions for plant growth.

## Negative indicator species

No aquatic negative indicator species were recorded and the site was without any significant growths of filamentous algae.

## Water quality

The water chemistry of Llyn Cregennen Uchaf is consistent with that of an oligotrophic, low to moderate alkalinity water body at reference condition (Table 9). The mean annual TP concentration is low (6.6 µg $l^{-1}$) and soluble reactive phosphorus was below the detection limit on all four sampling occasions. Total oxidised nitrogen was also very low (0.11 mg $l^{-1}$). There is no evidence of nutrient enrichment and therefore the site is considered to be in favourable condition with respect to trophic status.

Alkalinity and pH are slightly higher than expected for oligotrophic lakes, and reflect the complex nature of the local geology which includes basic tuffs as well as more acid volcanic rocks (Woodall 2000). The alkalinity of just over 200 µeq $l^{-1}$ and slightly above neutral pH places the site just within the 'moderate alkalinity' category which is usually associated with meotrophic lakes. ANC-C data suggest the lake to be well buffered with values well above the High/Good ecological boundary (WFD-UKTAG 2007) and therefore not at risk of acidification.

At the time of survey in July 2013, the lake was not stratified and was well oxygenated throughout with DO from 0-14 m >10 mg $l^{-1}$ (Figure 3).

| Determinand | Dec 5th | Feb 25th | Jul 4th | Oct 5th | Mean |
|---|---|---|---|---|---|
| pH | 7.93 | 6.98 | 7.44 | 7.56 | **7.35** |
| Cond | 68.6 | 57.5 | 56 | 57 | **59.8** |
| Alk (Gran) | 13.9 | 13.4 | 13.5 | 14.1 | **13.7** |
| SRP | <1.0 | <1.0` | <1.0 | <1.0 | **<1.0** |
| TP | 5.5 | 7.3 | 8 | 5.7 | **6.6** |
| Chl a | 1.5 | 2.1 | 0.88 | 1.3 | **1.4** |
| TON | 0.151 | 0.212 | 0.0388 | 0.0286 | **0.11** |
| $Na^+$ | 4.59 | 4.44 | 4.63 | 4.72 | **4.60** |
| $K^+$ | 0.612 | 0.572 | 0.427 | 0.427 | **0.51** |
| $Mg^{2+}$ | 0.85 | 0.762 | 0.975 | 1.03 | **0.90** |
| $Ca^{2+}$ | 4.98 | 4.88 | 5.11 | 5.34 | **5.08** |
| $Cl^-$ | 7.15 | 6.8 | 7.3 | 7.4 | **7.16** |
| $SO4^{2-}$ | <10 | <10 | <10 | <10 | **5** |
| $SiO_2$ | 1.24 | 1.66 | 0.145 | 0.417 | **0.87** |
| Sus. Solids | <3.0 | <3.0 | <3.0 | <3.0 | **<3.0** |
| Labile Al | 4.82 | 4.6 | 4.1 | <4 | **4.5** |
| DOC | 2.48 | 1.94 | 2.01 | 1.95 | **2.10** |
| ANC-I (ionic) | | | | | **228.5** |
| ANC-C (Cantrell) | | | | | **283.9** |

Table 9. Water chemistry data for Llyn Cregennen Uchaf (for units see methodology).

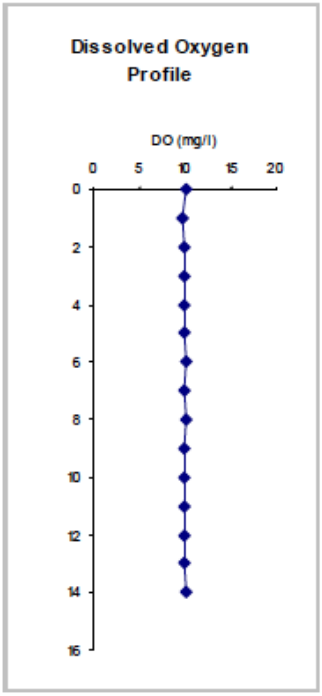
Figure 3. Dissolved oxygen (DO) profile for Llyn Cregennen Uchaf (09/09/2009).

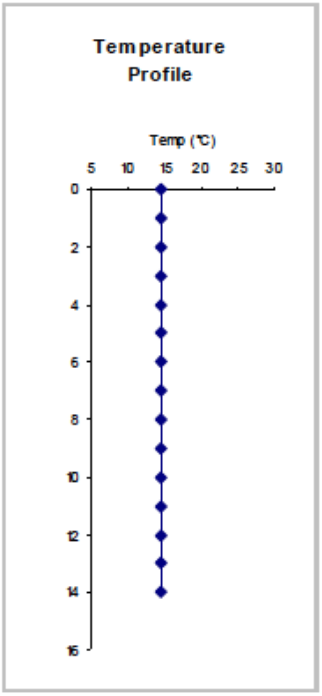
**Dissolved Oxygen Profile**

| | |
|---|---|
| GPS Location | SH6640114220 |
| Maximum Depth (m) | 14.1 m |
| Secchi Depth (cm) | 700 cm |

Notes:

| Depth (m) | DO (mg/l) | Temp (°C) |
|---|---|---|
| 0 | 10.14 | 14.4 |
| 1 | 9.81 | 14.4 |
| 2 | 10.06 | 14.4 |
| 3 | 9.99 | 14.4 |
| 4 | 10.06 | 14.4 |
| 5 | 10.07 | 14.4 |
| 6 | 10.12 | 14.4 |
| 7 | 10.09 | 14.4 |
| 8 | 10.12 | 14.4 |
| 9 | 10.01 | 14.4 |
| 10 | 10.02 | 14.4 |
| 11 | 10.05 | 14.4 |
| 12 | 10.01 | 14.4 |
| 13 | 10.01 | 14.4 |
| 14 | 10.12 | 14.4 |




## Hydrology

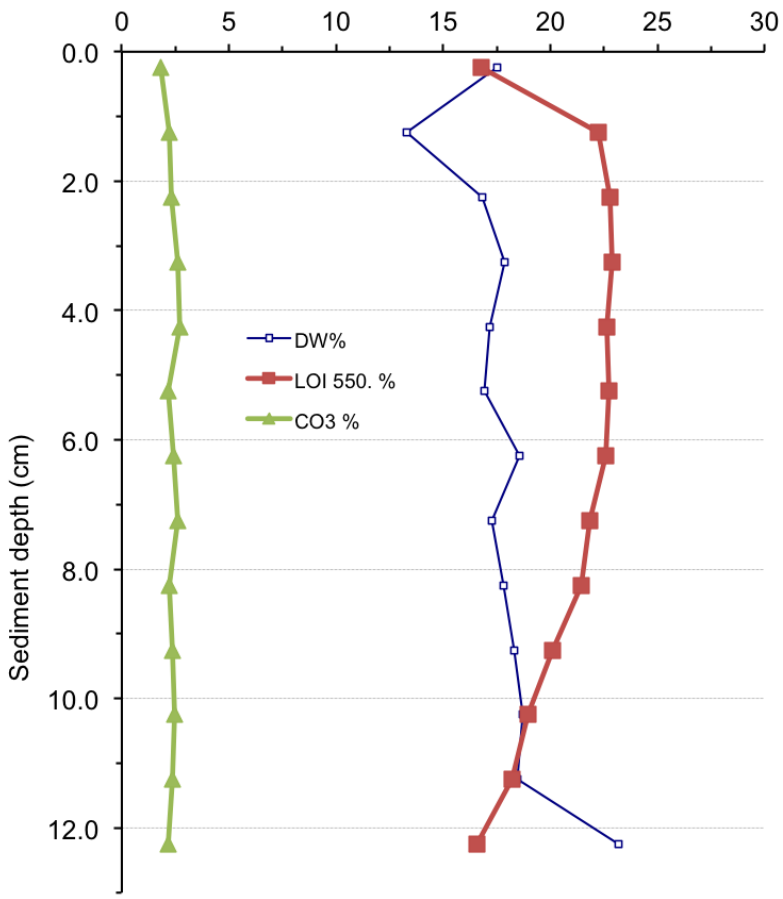
The upper lake has a very small catchment extending little more than a few hundred meters from any shore. The majority of water draining from the Cadair Idris massif is intercepted by streams flowing to the coast around the western and eastern sides of Llynnau Cregennen. A small surface inflow entering the upper lake at the south-west shore was the only inflow observed and no others are marked on the OS map. A single outflow exits the site at on the north shore and flows approximately 90 m to the lower lake. The hydrology appears natural.

## Lake substrate and sediment loads

The littoral substrates were comprised mainly of cobbles and boulders with smaller areas of loose gravels and pebbles. More consolidated gravels and pebbles occur at 1-2 m water depth, giving way to silts at 1.5- 2.0m. The lack of fine substrates in the littoral zone results in relatively sparse vegetation in shallow water (i.e. <1.0 m deep). There is no evidence of any significant sediment in-wash to the lake.

Sediment coring showed the site to have very little sediment accumulation in the deepest point, and although the short core showed distinctive colour changes, there was only a gradual change in the organic content, increasing towards the top before dropping sharply at the surface sediment (Figure 4). The apparent decline in organic content may simply reflect a loss of flocculent material from the core top during sampling. Initial dating results suggest very slow sediment accumulation rates, consistent with the small catchment and low productivity.

Figure 4 Physical characteristics from core CREGU1. DW = dry weight; LOI = loss on ignition, CO3 = (carbonate content)



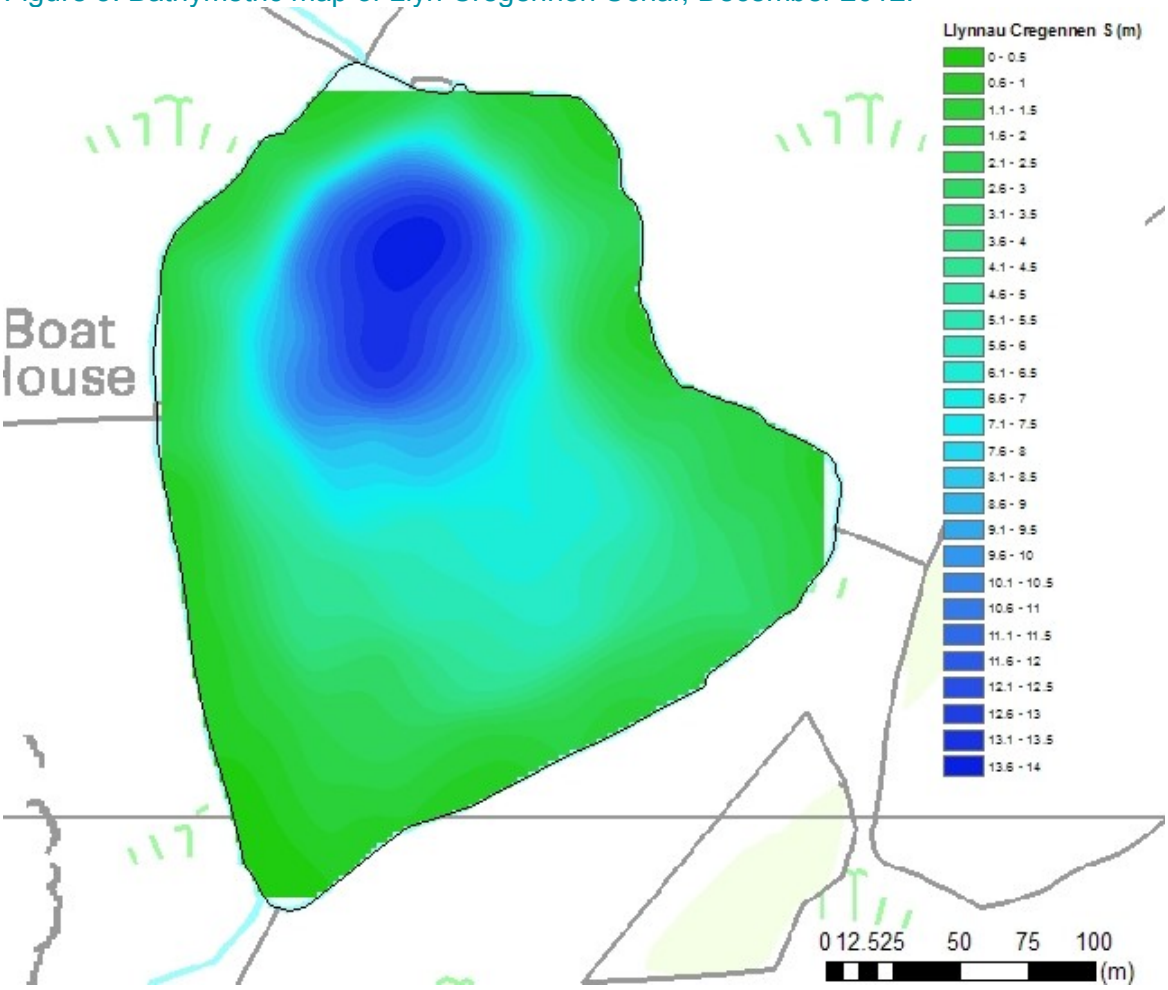

## Indicators of local distinctiveness

The presence of large beds of any aquatic plant (in this case *Chara virgata*) growing to depths of approximately 8.0 m is very rare in the UK and reflects the excellent water quality and clarity in the site. The record of *Potamogeton praelongus* is a new location; this species is considered Near Threatened in Britain and Critically Endangered in Wales (Dines 2008). *P. gramineus* is also a new record and is also uncommon in Wales. *Nitella flexilis sensu stricto* is a BAP priority stonewort species.

## Bathymetry

The lake shelves gently around the southern shore with a large area being less than 8 m deep. The north shore shelves more steeply and there is a relatively small deep area with a maximum recorded depth of 14.7 m. The clear water and gently sloping lake bed provides extensive areas of habitat for plant growth (Figure 5).

Figure 5. Bathymetric map of Llyn Cregennen Uchaf, December 2012.




## Palaeolimnological evidence

A 13 cm sediment core (CREGU1) was taken from the deep point at SH6641214210 using a Renberg gravity corer. The core was sliced at 1 cm intervals in the field and analysed for dry weight, organic content and carbonate content. The physical analysis of the core is discussed above and presented in Figure 4. Dating results from Llyn Cregennen Isaf showed very slow sediment accumulation rates which, given the catchment similarities, are likely also to apply to the CREG1 core.

| Sample Code | Depth (cm) | 2012/13 mean pH | DI-pH | 2012/13 mean TP | DI-TP | SCD |
|---|---|---|---|---|---|---|
| CREGU1-00 | 0 | 7.35 | 7.25 | 6.6 | 36.6 | 0.47 |
| CREGU1-12 | 12 | | 7.31 | | 33.7 | 0.00 |

Table 10 Results of Llyn Cregennen Uchaf sediment core analysis

The diatom flora shows very little change between the core top and base and is dominated by a diverse assemblage of benthic taxa, typical of clear water lakes of low nutrient status. Species turnover between the core base and core top samples

was low, with squared chord distance (SCD) between the samples of only 0.47 and therefore not significant (Table 10).

Reconstructions of diatom-inferred pH (DI-pH) were produced using the SWAP training set (RMSEP = 0.32 pH units). Fossil assemblages from both samples were dominated by benthic species that are typical of plant dominated lakes and generally reflect habitat quality better than water quality. For example, *Fragilaria pinnata,* which dominated both fossil assemblages, is found across a very broad ecological range, and often in plant dominated eutrophic waters. As a result, DI-pH inferred circum-neutral conditions with little change over the time period covered by the core. The surface sediment assemblage estimates current pH to be similar to measured values.

Reconstructions of diatom-inferred TP (DI-TP) are less successful. The generalist nature of the common species in both fossil assemblages result in a gross overestimate of TP. This is a commonly encountered problem with TP reconstructions from lakes dominated by *Fragilaria* species (Bennion, *pers. comm.*).

In summary, there has been only very minor floristic change in the sediment core diatoms from Llyn Cregennen Uchaf. The fossil diatom assemblages overestimate TP, but nonetheless show the lake to have remained very stable between the core top and bottom and therefore close to reference condition. High resolution diatom analysis and sediment dating of the upper sediments would be beneficial to understanding the impact of atmospheric deposition and any changes in land management over the past 150 years.

## Site condition summary and overview

Llyn Cregennen Uchaf is in **favourable condition** with **high confidence**. The lake supports a species rich aquatic macrophtye flora, including seven characteristic oligotrophic species. Species are well distributed throughout the site with typical vegetation zones in evidence with water depth and the majority of vegetated sample points had at least one characteristic species present. A maximum depth of colonization of approximately 8.0 m is possibly unprecedented in Welsh lakes and the extensive beds of *Chara virgata,* as well as *Nitella* spp. also very rare in lakes of this type. In addition to the Stoneworts, the site supports an extensive *Littorelletea uniflorae* plant community as well as broad-leaf *Potamogeton* species, including *P. praelongus*.

The mean annual TP in 2012/3 lies well within the recommended upper limit for oligotrophic lakes and there was no evidence of eutrophication within the site. Comparison with the UK Morpho-edaphic Index model (Environment Agency, unpublished) provides a reference TP of 9 µg $l^{-1}$, indicating that this lake is at reference condition with respect to phosphorus. pH was slightly above the normal range for this site type, but while the geology is primarily acidic, there are significant areas of basic tuff and sedimentary mudstones within the catchment and it is therefore likely that the increased pH is natural.

The surrounding land is mostly unimproved upland grazing and there are no dwellings within the catchment. Any change in land use could potentially place the site at risk and therefore the site, including the catchment, would benefit from greater protection (e.g. SSSI). From the perspective of the Water Framework Directive, these

lakes are also two extremely rare potential examples of lakes in Britain at reference condition, as the plant community is at high status, the diatom community shows no evidence of long-term change and the water chemistry shows no evidence of either acidification or eutrophication.

Llyn Cregennen Uchaf, along with the lower lake, are two of very few oligotrophic lakes in the UK that support aquatic macrophytes to beyond 7.0 m depth and probably represent the best examples of this habitat type in Wales. They contain a range of rare and declining plant species. They should be considered for special protection measures such as formal site designation under domestic and / or European conservation legislation. Additionally, River Basin Management Planning should take account of the likely High Status of these water bodies and the need to prevent deterioration.

| Water Body | Status | Reason(s) for Failure | Comments |
|---|---|---|---|
| Llyn Cregennen Uchaf | **Favourable (high confidence)** | N/A | Llyn Cregennen has excellent water quality and clarity and supports a species rich characteristic oligotrophic macrophyte flora. The flora shows characteristic zonation with depth and the maximum depth of colonization is approximately 8.0 m. The site shows no evidence of any significant degradation and current catchment management poses low threat to the site. |

Table 11 Llyn Cregennen Uchaf overview

## Recommendations for monitoring and management:

The current catchment management of low intensity grazing by sheep and cattle appears to have little impact on the water quality and overall condition of the site. This situation should be monitored and any changes to land management within the catchment reviewed with respect to the potential risk to Llynnau Cregennen. Angling within the site is currently at low intensity, and although stocking information was unavailable, there are reportedly rainbow and blue trout stocked at the site (www.cregennan.co.uk). It is recommended that if stocking continues, only native brown trout be used, and stocking rates carefully controlled.

Water quality (and particularly clarity) is considered to be the key to maintaining the current favorable status of the site. A minimum of quarterly (or monthly) water quality monitoring is recommended to ascertain any directional change in water quality and provide an early warning of any deterioration to the site. The site would also benefit from regular (every 3 years recommended) macrophyte surveys to ascertain shifts in rarer species (e.g. *P. praelongus*) and to monitor the maximum depth of colonization.

Any unexplained reduction in the depth distribution of macrophytes should trigger additional monitoring. The following recommendations are based on the evidence collected for this report:

- Monitor water quality – minimum of quarterly sampling.
- Liaise with Cregennen angling club to ensure best practice with regards stocking, ideally to limit or stop stocking of non-native fish species.
- Work with local land owners to ensure any changes to land management are communicated to NRW for approval.
- Monitor the aquatic flora every 3 years to ascertain any increase or decline of the characteristic flora and monitor depth distribution.

## CSM Database output

### Site Condition Assessment: Llyn Cregennen Uchaf (04/07/2013)

| Lake Details | | Survey Details | | |
|---|---|---|---|---|
| Lake Name | Llyn Cregennen (Upper) | Survey Date | 04/07/2013 | |
| SSSI Name | | Surveyors | BG, JoS & JS | |
| SAC Name | | Shore Surveys | 4 | out of |
| Grid Ref | SH660143 | Wader Surveys | 4 | 4 |
| WBID / NI No. | 36134 / | Boat Surveys | 4 | sections |

Site Notes:
Wow!

Survey Notes:
Sparse littoral on cobbles, but amazing in deeper water. Chara virgata to c. 8m. Site used for fly fishing - low intensity. Extensive sheep grazing around lake. pH = 7.15, Cond 48.2

#### Section Summaries

| | | |
|---|---|---|
| **Section 1** | Maximum depth of colonisation (cm) | 720 cm |
| | Compass bearing of boat transect (°) | 290 ° |
| | Lateral distance from waters edge to 75cm depth (m) | 3 m |
| | Notes: | |
| **Section 2** | Maximum depth of colonisation (cm) | 710 cm |
| | Compass bearing of boat transect (°) | 60 ° |
| | Lateral distance from waters edge to 75cm depth (m) | 10 m |
| | Notes: | |
| **Section 3** | Maximum depth of colonisation (cm) | 740 cm |
| | Compass bearing of boat transect (°) | 120 ° |
| | Lateral distance from waters edge to 75cm depth (m) | 5 m |
| | Notes: | |
| **Section 4** | Maximum depth of colonisation (cm) | 760 cm |
| | Compass bearing of boat transect (°) | 50 ° |
| | Lateral distance from waters edge to 75cm depth (m) | 8 m |
| | Notes: | |

#### Section Locations

| | Shore Survey GPS Co-ords | | Boat Survey GPS Co-ords | |
|---|---|---|---|---|
| | start | end | start (shore) | end (lake) |
| **Section 1** | SH6657714134 | SH6652314056 | SH6654214079 | SH6644314142 |
| **Section 2** | SH6639713988 | SH6634114051 | SH6636314005 | SH6646614133 |
| **Section 3** | SH6632414163 | SH6636914239 | SH6633414206 | SH6636514198 |
| **Section 4** | SH6640814283 | SH6649214221 | SH6645114261 | SH6643714246 |

#### Section Photos

| | Start of Section | Whole Section | End of Section |
|---|---|---|---|
| **Section 1** | 82 | 84 | 83 |
| **Section 2** | 85 | 86 | 87 |
| **Section 3** | 88 | 89 | 90 |
| **Section 4** | 94 | 91 | 92 |

## Species Abundance - Boat Survey

Total number of sample plots 80
Total number of vegetated sample plots 50

| Plant Species | Occurrence *n* | Occurrence % |
|---|---|---|
| *Callitriche hamulata* | 2 | 4 |
| *Chara virgata* | 38 | 76 |
| *Isoetes lacustris* | 32 | 64 |
| *Juncus bulbosus* | 2 | 4 |
| *Littorella uniflora* | 16 | 32 |
| *Lobelia dortmanna* | 15 | 30 |
| *Mosses aquatic* | 5 | 10 |
| *Myriophyllum alterniflorum* | 25 | 50 |
| *Nitella flexilis* | 12 | 24 |
| *Nitella opaca* | 15 | 30 |
| *Potamogeton gramineus* | 4 | 8 |
| *Potamogeton perfoliatus* | 9 | 18 |
| *Utricularia minor* | 9 | 18 |

## Species Abundance - Wader Survey

Total number of sample plots 80
Total number of vegetated sample plots 50

| Plant Species | Occurrence *n* | Occurrence % |
|---|---|---|
| *Chara virgata* | 30 | 60 |
| *Glyceria fluitans* | 1 | 2 |
| *Isoetes lacustris* | 17 | 34 |
| *Juncus bulbosus* | 4 | 8 |
| *Littorella uniflora* | 31 | 62 |
| *Lobelia dortmanna* | 23 | 46 |
| *Menyanthes trifoliata* | 3 | 6 |
| *Myriophyllum alterniflorum* | 12 | 24 |
| *Nitella flexilis* | 16 | 32 |
| *Nitella opaca* | 3 | 6 |
| *Potamogeton gramineus* | 1 | 2 |
| *Potamogeton perfoliatus* | 2 | 4 |
| *Potamogeton praelongus* | 1 | 2 |
| *Utricularia minor* | 5 | 10 |

Note: Species abundance % = ((number of plots / total number of vegetated sample plots) * 100)

## Plant Scores

**Total plant species** 26 **Filamentous algae (%)** 18.2 % WADER 7.9 % BOAT
**Total plant cover (%)** 153.67

### S U R V E Y S C O R E S

| PLANT SPECIES | PERIMETER | WADER | BOAT | COVER % | DAFOR | ABUNDANCE |
|---|---|---|---|---|---|---|
| *Chara virgata* | 0 | 0.0746 | 0.2609 | 29.82 | A | 4 |
| *Isoetes lacustris* | 0 | 0.0411 | 0.1555 | 17.6 | F | 3 |
| *Juncus acutiflorus* | 0.5 | 0 | 0 | 12.5 | F | 3 |
| *Myriophyllum alterniflorum* | 0 | 0.0278 | 0.1078 | 12.17 | F | 3 |
| *Littorella uniflora* | 0 | 0.1136 | 0.0549 | 11.17 | F | 3 |
| *Nitella opaca* | 0 | 0.0051 | 0.0993 | 10.18 | F | 3 |
| *Lobelia dortmanna* | 0 | 0.0725 | 0.0555 | 9.18 | O | 2 |
| *Nitella flexilis* | 0 | 0.0368 | 0.0411 | 5.95 | O | 2 |
| *Juncus effusus* | 0.2125 | 0 | 0 | 5.31 | O | 2 |
| *Potentilla erecta* | 0.2125 | 0 | 0 | 5.31 | O | 2 |
| *Ranunculus flammula* | 0.1875 | 0 | 0 | 4.69 | R | 1 |
| *Carex nigra* | 0.175 | 0 | 0 | 4.38 | R | 1 |
| *Utricularia minor* | 0 | 0.0099 | 0.027 | 3.2 | R | 1 |
| *Potamogeton perfoliatus* | 0 | 0.0049 | 0.0291 | 3.16 | R | 1 |
| *Mosses unid* | 0.125 | 0 | 0 | 3.12 | R | 1 |
| *Carex echinata* | 0.125 | 0 | 0 | 3.12 | R | 1 |
| *Sphagnum sp.* | 0.125 | 0 | 0 | 3.12 | R | 1 |
| *Menyanthes trifoliata* | 0.0625 | 0.0209 | 0 | 2.61 | R | 1 |
| *Mosses aquatic* | 0 | 0 | 0.0181 | 1.81 | R | 1 |
| *Eriophorum vaginatum* | 0.0625 | 0 | 0 | 1.56 | R | 1 |
| *Potamogeton gramineus* | 0 | 0.0031 | 0.0141 | 1.56 | R | 1 |
| *Juncus bulbosus* | 0 | 0.0089 | 0.0043 | 0.88 | R | 1 |
| *Rhododendron ponticum* | 0.025 | 0 | 0 | 0.62 | R | 1 |
| *Callitriche hamulata* | 0 | 0 | 0.0046 | 0.46 | R | 1 |
| *Glyceria fluitans* | 0 | 0.0021 | 0 | 0.1 | R | 1 |
| *Potamogeton praelongus* | 0 | 0.0018 | 0 | 0.09 | R | 1 |

## 5.2. Llyn Cregennen Isaf

Annex 1 type: H3130: Oligo-mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the Isoëto-*Nanojuncetea*.

### 5.2.1. Site description

| | |
|---|---|
| Name: | Llyn Cregennen Isaf |
| County: | Gwynedd |
| WBID: | 36134 |
| Grid reference: | SH664141 |
| OS Grid reference (X,Y): | 266427,314130 |
| Latitude / Longitude | N52°42.62',W003°59.03' |
| Altitude (m): | 237 |
| Maximum recorded depth (m): | 15.9 |
| Mean depth (m): | 4.41 |
| Lake volume ($m^3$): | 456984 |
| Surface area – UKLakes (ha): | 11.10 |
| Surface area – measured (ha) | 10.37 |
| Perimeter of lake (km): | 1.6 |
| Shoreline Development Index (SDI): | 1.321 |
| WFD alkalinity based typology: | Low Alkalinity, Shallow (LA, S) |
| Phase 1 habitat type: | Standing water: Oligotrophic: G1.3 |
| Survey Date: | 4/5 July 2013 |

Table 12. Summary characteristics for Llyn Cregennen Isaf.

### 5.2.2. Condition Assessment and Discussion

Table 13 Condition Assessment Summary Table for Llyn Cregennen Isaf

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | None |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise)<br>Mesotrophic: ≥ 8 species listed in Box 2 inclusive of 3 *Potamogeton* spp | ✓ | 3 characteristic *Littorelletea* spp in 2013: *I. lacustris, L. uniflora & L. dortmanna.* 8 other characteristic mesotrophic spp: *C. virgata, E. hexandra, P. gramineus, P. praelongus, P. perfoliatus, S. angustifolium, Nitella* spp. & *Utricularia minor*. |
| | No loss of characteristic species (see Box 2) | - | No previous data |
| | ≥ 6/10 vegetated sample | ✓ | 85% of vegetated sample |

| Attribute | Target | Status | Comment |
|---|---|---|---|
| | spots (boat / wader survey) have ≥ 1 characteristic spp. | | spots comply (78% wader, 74% boat) |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | None recorded |
| | Benthic and epiphytic filamentous algae <10%. | ✓ | Filamentous algal was present, but well below 10% cover. |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (site specific) | ✓ | Good zonation present. *L. uniflora* & *L. dortmanna* to c. 2.5 m; *I. lacustris* to 5.6 m; *Potamogeton* spp. in beds 1.3-c.5.0 m. *C. virgata* and *Nitella* spp.to 7.9 m |
| | Maximum depth distribution should be maintained | ✓ | $Z_{max}$ (recorded) = 15.9 m, $Z_s$ = 6.95m, $Z_v$ = 7.9 m. |
| | At least present structure should be maintained | - | No evidence of change |
| **Water quality** | Stable nutrients levels: TP target / limit: Oligotrophic = 10 µgl$^{-1}$ | ✓ | TP (mean 2012/13) = 6.9 µg l$^{-1}$ $NO_3$-N = 0.07 mg l$^{-1}$. |
| | Stable pH values: pH ~ 5.5 – circumneutral | ✓? | Mean pH 2006-11 = 7.33 (Range 7.0-7.85). Slightly higher than expected. |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 mgl$^{-1}$) | ✓ | > 10 mg l$^{-1}$ from 0-15 m. Water column mixed |
| | No excessive growth of cyanobacteria / green algae | ✓ | None noted, and very low Chl-a values (mean 1.8 µg l$^{-1}$, range <0.5-2.6 µg l$^{-1}$) |
| **Hydrology** | Natural hydrological regime | ✓ | Appears natural. |
| **Lake substrate** | Natural shoreline maintained | ✓ | Extensive upland grazing to shore. Small boathouse and old sluice at west outflow, but otherwise unmodified |
| | Natural and characteristic substrate maintained | ✓ | Sediment core analysis shows no significant changes to sediments |
| **Sediment load** | Natural sediment load maintained | ✓ | Appears natural |
| **Indicators of local distinctive-** | Distinctive elements maintained at current extent / levels / locations | ✓ | *P. praelongus* and deep *Chara* beds are distinctive features that should be |

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **ness** | | | maintained. |
| **Disturbance** | No introduced species | ✓ | None recorded |
| | Minimal negative impacts from recreation and navigation. No fish farming | ✓ | No reported fish stocking and low intensity angling. |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | ✓ | Diatom flora suggests little change. |

**Status: ✓ = favourable; X = unfavourable; - = unable to assess**

## Extent

The surface area of the lake is 10.37 ha. There is no evidence of any recent loss of extent of open water.

## Macrophyte community composition and structure

Llyn Cregennen Isaf is very similar in species composition and structure to the Upper lake. The site is an oligotrophic lake with very high water clarity and supports a relatively rich flora with excellent depth distribution. Furthermore, 85% of the vegetated sample points had one or more characteristic species present. The shallow littoral areas are dominated by rocky substrates with only sparse vegetation.

*Littorella uniflora* and *Lobelia dortmanna* were recorded most commonly where finer gravels occurred in shallow water (0 - 50 cm) and where there was sedimentation between hard substrates in deeper water (1.0 - 2.7 m). *Isoetes lacustris* was most common at depths of more than 1.0 m, and was often dominant at 2.0 - 4.0 m, but recorded at a maximum of 5.6 m. Where co-occurring with *Chara virgata* the exact depth distribution of *I. lacustris* was difficult to determine and it may have been under recorded in deeper water due to the high density of the *Chara* beds.

*Chara virgata* was slightly less common than in Llyn Cregennen Uchaf, the large and relatively flat area of the western half of the site being dominated by *Isoetes lacustris,* with *C. virgata* forming discrete beds or growing more sparsely among the *I. lacustris.*

Three species of broad-leaved pondweed were growing in the lake. *Potamogeton perfoliatus* was common and in places grew in relatively large beds (up to approximately 500 $m^2$), but more often formed smaller discrete patches in 2.0 - 4.0 m of water. *Potamogeton praelongus* was less common, but recorded in a number of discrete beds throughout the lake at depths of 2 - 5.6 m. *Potamogeton gramineus* was only recorded in one location towards the south-west shore where it formed a relatively large bed (20 x 10 m) in approximately 1.5 m of water ( See Figure 7).

Due to their rather patchy distribution within the lake, all the *Potamogeton* species have been slightly under-recorded in the CSM survey transects when compared to the mapping data (Figure 7).

| Submerged and floating vegetation | TRS | PLEX | % occurrence (n=95) | DAFOR abundance[4] | Min depth (cm) | Max depth (cm) |
|---|---|---|---|---|---|---|
| ***Chara virgata*** | **7.3** | **7.69** | **53.7** | **D** | **20** | **790** |
| ***Elatine hexandra*** | **7.0** | **5.38** | **1.1** | **R** | **75** | **100** |
| *Eleogiton fluitans* | 4.0 | 3.08 | 1.1 | R | 80 | 80 |
| ***Isoetes lacustris*** | **5.0** | **4.23** | **46.3** | **A** | **50** | **560** |
| *Juncus bulbosus* | 5.3 | 3.08 | 9.5 | O | 50 | 320 |
| ***Littorella uniflora*** | **6.7** | **4.23** | **62.1** | **D** | **0** | **270** |
| ***Lobelia dortmanna*** | **5.0** | **3.08** | **46.3** | **A** | **25** | **330** |
| *Myriophyllum alterniflorum* | 6.7 | 4.23 | 21.1 | F | 50 | 570 |
| ***Nitella flexilis* agg.** | **6.7** | **5.38** | **21.1** | **F** | **20** | **800** |
| ***Nitella opaca*** | **6.7** | **5.38** | **6.3** | **O** | **270** | **780** |
| ***Nitella translucens*** | **6.7** | **5.38** | **+** | **R** | **480** | **830** |
| *Potamogeton berchtoldii* | 7.3 | 7.69 | + | R | 50 | 600 |
| ***Potamogeton gramineus*** | **7.0** | **7.31** | **+** | **R** | **140** | **160** |
| *Potamogeton natans* | 7.0 | 4.23 | 4.2 | R | 50 | 130 |
| ***Potamogeton perfoliatus*** | 7.3 | 7.69 | 6.3 | **O** | **70** | **500** |
| *Potamogeton polygonifolius* | 3.7 | 3.08 | + | R | 30 | 30 |
| ***Potamogeton praelongus*** | **8.5** | **5.38** | **4.2** | **R** | **200** | **560** |
| ***Sparganium angustifolium*** | **4.0** | **4.23** | **+** | **R** | **460** | **460** |
| ***Utricularia minor*** | **4.0** | **3.08** | **10.5** | **F** | **40** | **270** |
| **Average score** | **6.4** | **5.25** | | | | |
| **Species richness** | | | | 19 | | |

Table 14. Aquatic macrophyte community composition for Llyn Cregennen Isaf in June 2014. Characteristic oligo- mesotrophic species are highlighted in **bold**.

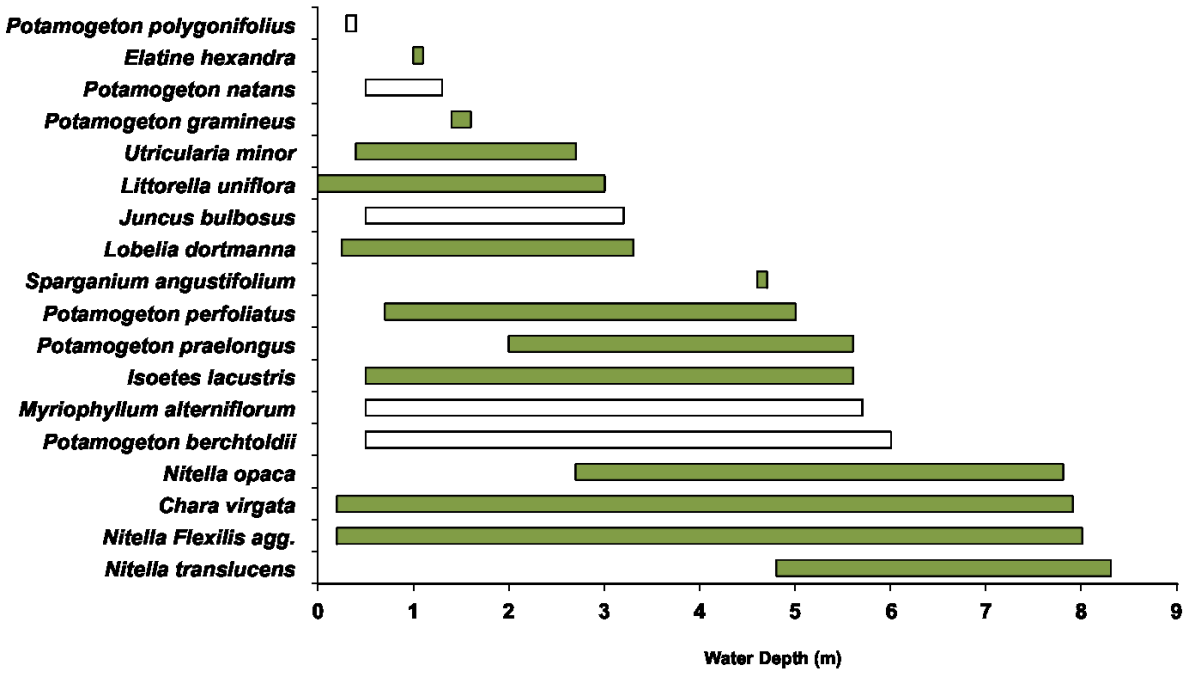
*Myriophyllum alterniflorum* and *Nitella flexilis* agg. were common up to 5.0 m, often co-occurring with *I. lacustris. N. translucens* was restricted to deeper water, whereas *N. flexilis* agg. grew throughout the lake. Material with oogonia was all identified as the more common *N. opaca*, but many plants lacked oogonia and hence recorded as *N. flexilis* agg. The presence of the rare *N. flexilis* sensu stricto cannot however be ruled out, as this species was recorded in the upper lake.

*Juncus bulbosus* and *P. natans* were only common in the bay to the south-west of the site. *Elatine hexandra* was recorded only in the north-east of the site. Other

[4] Based on presence / absence data from all vegetated plots in the wader and boat based surveys. DAFORs are calculated from the total number of occurrences across the wader and boat surveys as a proportion of the total number of vegetated wader and boat survey points.

species were less common, but distributed throughout the site (Figure 7). See Figure 6 for a summary of the depth distribution of aquatic plants.

Figure 6. Depth range of the aquatic macrophytes recorded from Llyn Cregennen Isaf, characteristic species are shaded green.




The assemblage places the lake into Group C2 as defined by Duigan *et al*. (2006). However, the species richness is the highest for this lake type in Wales and among the highest in the UK. In common with Llyn Cregennen Uchaf, the flora is linked to both Types C2 and E. The TRS (6.4) and PLEX (5.25) scores are consistent with oligotrophic lakes. Llyn Cregennen Isaf is favourable with respect to its aquatic macrophyte composition and structure.

Nineteen aquatic plant species were recorded in 2013, 13 of which were characteristic oligotrophic / mesotrophic species. This is a very high species richness for an upland lake (the mean richness for type C2 is 9.14 ± 3.45 - Duigan *et al*. 2006). and reflects the very high water quality and elevated alkalinity.

Using the LEAFPACS2 Water Framework Directive lakes classification tool (Table 15). The results are very similar to Llyn Cregennen uchaf, with higher than expected species richness and number of functional groups, LMNI and algal cover close to reference condition and the cover metric being slightly lower than expected. This gave an overall status of High, with 99.5% confidence (Table 15 (b)).

## Negative indicator species

The site had no invasive or negative indicator species present. There was a higher frequency of *Juncus bulbosus* and *Potamogeton natans* in the bay to the south-west of the site which may represent a minor influence of nutrients from the nearby farm buildings. The site was without any significant growths of filamentous algae.

(a)

| | LMNI | NTaxa | NFG | COV | ALG |
|---|---|---|---|---|---|
| Observed | 3.64 | 16.00 | 9.00 | 3.98 | 0.08 |
| Expected | 3.21 | 10.69 | 6.89 | 8.20 | 0.05 |
| EQR | 0.957 | 1.403 | 1.305 | 0.691 | 0.972 |

(b)

| | Bad | Poor | Moderate | Good | High |
|---|---|---|---|---|---|
| Probabilities | 0.0 | 0.0 | 0.0 | 0.5 | 99.5 |

Table 15 a) LEAFPACS2 classification tool observed and expected metrics for Llyn Cregennen Isaf in June 2012. (b) Confidence in class.

Figure 7. Distribution maps of the aquatic plant species recorded in Llyn Cregennen Isaf.

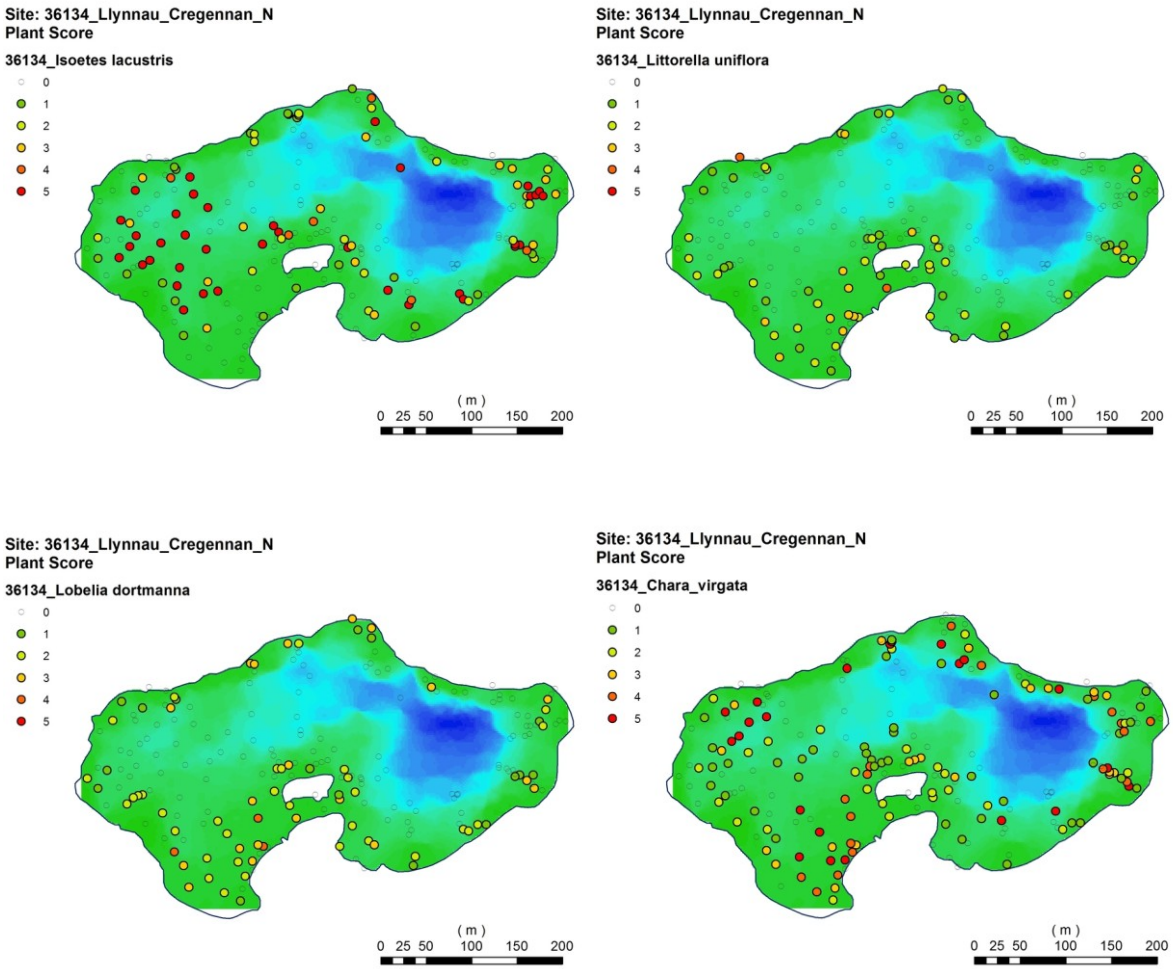
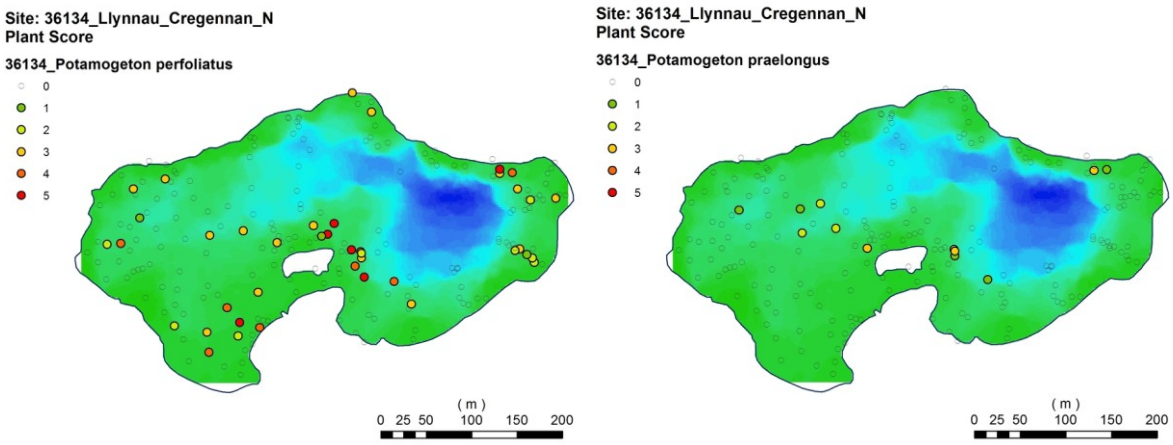
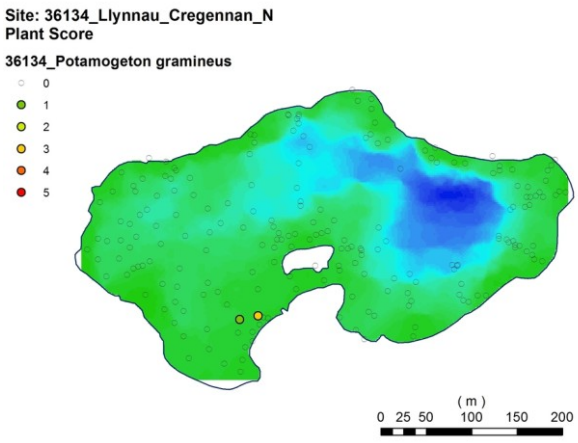


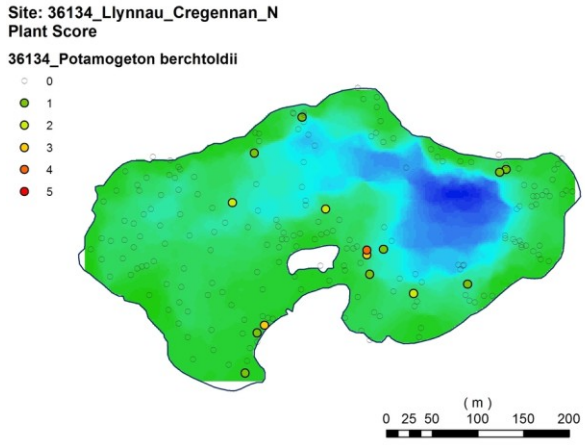
Figure 7 (contd.).

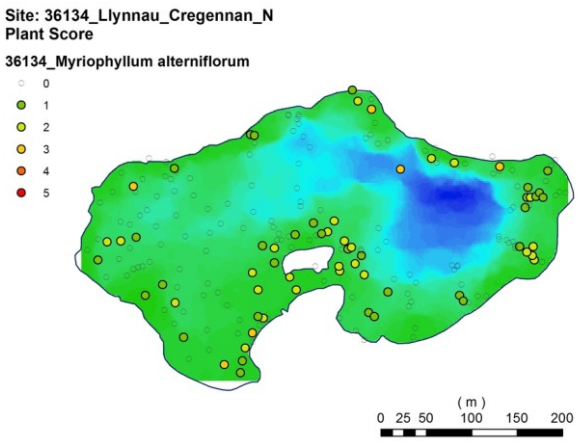








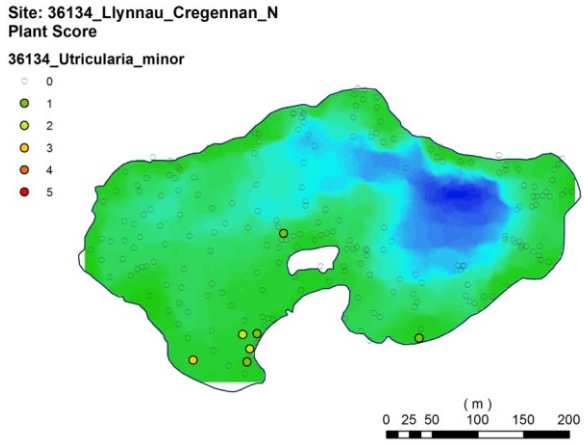
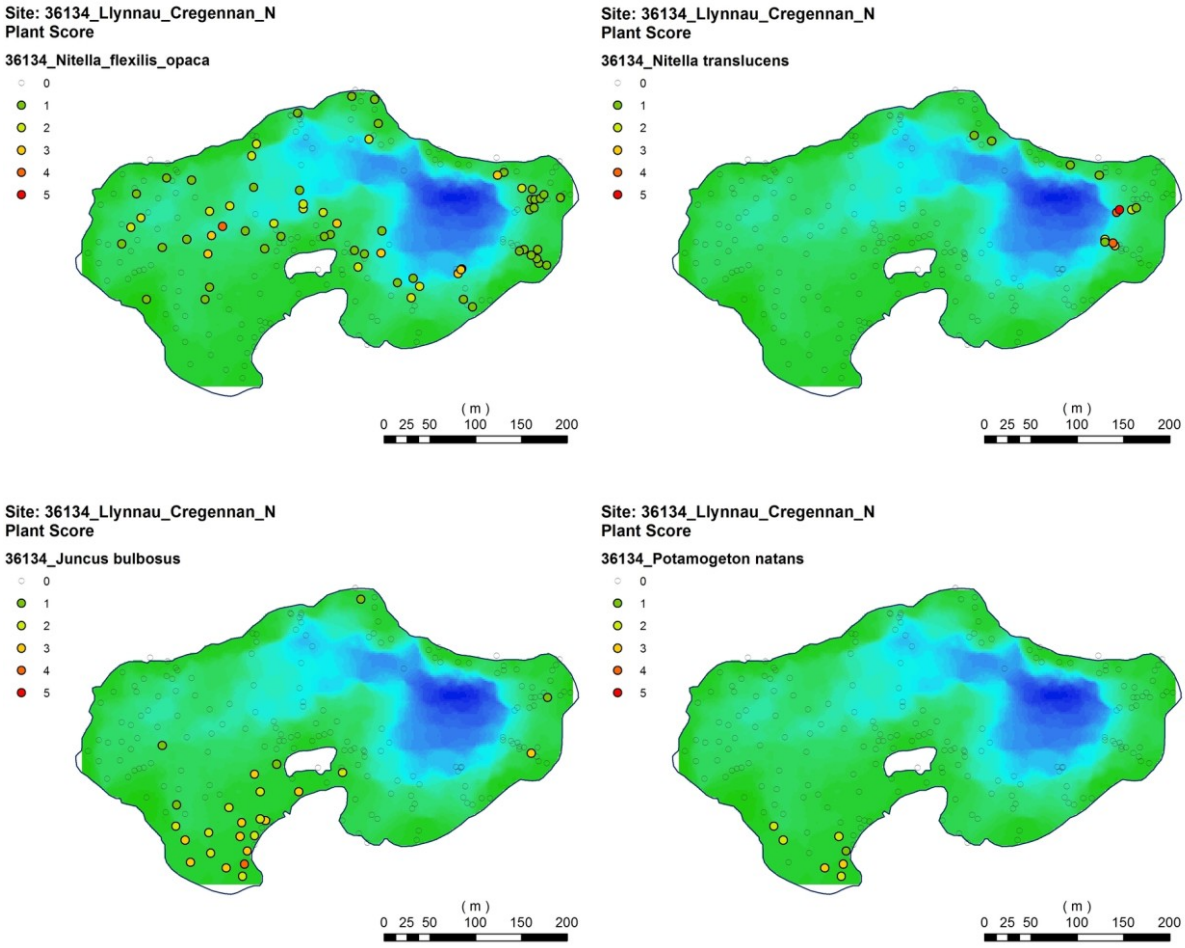



Figure 7 (contd.).




## Water quality

The water chemistry of Llyn Cregennen Isaf is consistent with that of an oligotrophic water body at reference condition and very similar to the upper lake. The mean annual TP concentration is low (6.9 µg $l^{-1}$) and soluble reactive phosphorus was below the detection limit on all four sampling occasions. The Morphoedaphic Index (MEI) model for the Water Framework Directive predicts a site-specific reference geometric mean TP of 7 µg $l^{-1}$ for the lake, indicating that the lake is pristine with regard to phosphorus. Total oxidised nitrogen was also very low (0.07 mg $l^{-1}$). Like Llyn Cregennen Uchaf, the alkalinity and pH are slightly higher than expected for oligotrophic lakes, and reflect the complex nature of the local geology which includes basic tuffs as well as more acid volcanic rocks (Woodall 2000). There is no evidence of nutrient enrichment and therefore the site is considered to be in favourable condition with respect to trophic status. At the time of survey in July 2013, the lake was well oxygenated throughout with DO from 0 - 14m was >10 mg $l^{-1}$ (Figure 8). This is consistent with favourable condition and equivalent to high status under WFD.

ANC values indicate the lake to be well buffered with values well above the high/good ecological of 40 µeq $l^{-1}$ and therefore not at risk of acidification.

| Determinand | Dec 5th | Feb 25th | Jul 4th | Oct 5th | Mean |
|---|---|---|---|---|---|
| pH | 7.85 | 7 | 7.44 | 7.42 | **7.33** |
| Cond | 61.2 | 55 | 56 | 63 | **58.8** |
| Alk (Gran) | 11.6 | 10.7 | 11.9 | 12.8 | **11.8** |
| SRP | <1.0 | <1.0 | <1.0 | <1.0 | **<1.0** |
| TP | 2.8 | 3.7 | 4.51 | 16.7 | **6.9** |
| Chl a | 1.2 | 1.6 | <0.5 | 2.6 | **1.5** |
| TON | 0.105 | 0.153 | 0.0162 | 0.0245 | **0.07** |
| $Na^+$ | 4.84 | 4.67 | 4.94 | 4.93 | **4.85** |
| $K^+$ | 0.514 | 0.459 | 0.345 | 0.305 | **0.41** |
| $Mg^{2+}$ | 0.7 | 0.595 | 0.837 | 0.915 | **0.76** |
| $Ca^{2+}$ | 4.32 | 4.06 | 4.93 | 5.29 | **4.65** |
| $Cl^-$ | 7.58 | 7.08 | 7.7 | 7.7 | **7.52** |
| $SO4^{2-}$ | <10 | <10 | <10 | <10 | **<10** |
| $SiO_2$ | 1.17 | 1.49 | 0.124 | 0.465 | **0.81** |
| Sus. Solids | <3 | <3 | <3 | 6 | **<3.8** |
| Labile Al | 4.79 | 6.3 | <4 | <4 | **<4.8** |
| DOC | 2.67 | 2.01 | 2.05 | 2.44 | **2.29** |
| ANC-I (ionic) | | | | | **195.8** |
| ANC-C (Cantrell) | | | | | **245.3** |

Table 16 Water chemistry data for Llyn Cregennen Isaf (for units see methodology)

## Hydrology

The Lower lake not only receives water from the Upper lake, but also from the high ground to the north of the site (Pared y Cefn Hîr) with a small inflow stream entering near the boathouse on the north-west shore. Rather unusually, the lake has two outflows, one to the east, which appears natural, and another to the north-west, which has a crude metal sluice which is no longer functional. It is unclear if the latter outflow is natural. The hydrology appears natural.

## Lake substrate and sediment loads

The littoral substrates are comprised mainly of cobbles and boulders with smaller areas of loose gravels and pebbles. More consolidated gravels and pebbles occur at 1 - 2 m water depth, giving way to silts at 1.5 - 2.0 m. The exception to this was the bay to the south-west of the site which although mainly cobbles in the shallow water (<80 cm) was primarily silt after approximately 80 cm water depth.

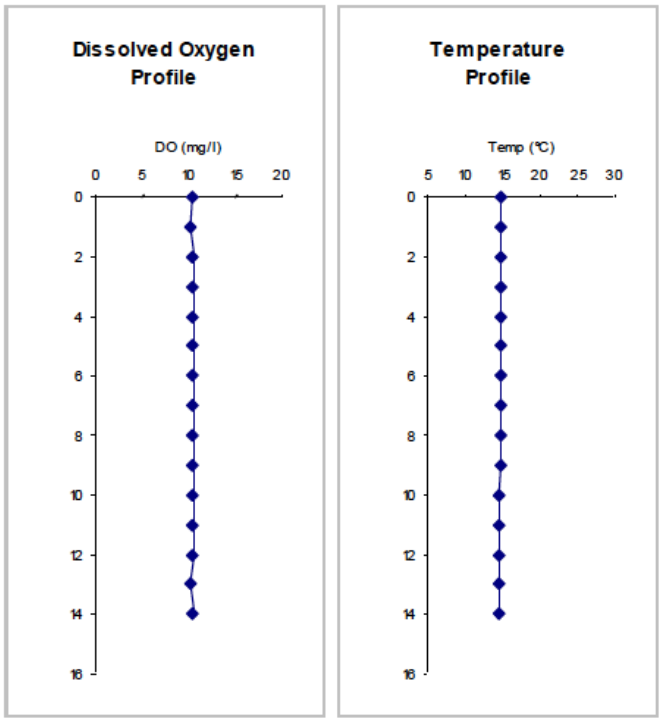
A 29 cm sediment core was collected from the deep point. Organic content (% LOI) was relatively stable below 11 cm in the sediment core, but declined relatively quickly between 11-7 cm followed by a slight increase at the top (Figure 10). This would appear to suggest an increase in mineral in-wash during this period, but there is no obvious reason for this. Preliminary results from the sediment dating suggest relatively slow accumulation rates, with 8 cm corresponding to approximately 1850 AD, and therefore these changes relate to the pre-industrial period.

Figure 8. Dissolved oxygen (DO) profile for Llyn Cregennen Isaf (04/07/13).

**Dissolved Oxygen Profile**

| | |
|---|---|
| GPS Location | SH6626014423 |
| Maximum Depth (m) | 14.9 m |
| Secchi Depth (cm) | 695 cm |
| Notes: | |

| Depth (m) | DO (mg/l) | Temp (°C) |
|---|---|---|
| 0 | 10.32 | 14.8 |
| 1 | 10.29 | 14.7 |
| 2 | 10.38 | 14.7 |
| 3 | 10.47 | 14.7 |
| 4 | 10.46 | 14.7 |
| 5 | 10.34 | 14.7 |
| 6 | 10.42 | 14.7 |
| 7 | 10.43 | 14.7 |
| 8 | 10.45 | 14.7 |
| 9 | 10.43 | 14.7 |
| 10 | 10.42 | 14.6 |
| 11 | 10.32 | 14.6 |
| 12 | 10.38 | 14.6 |
| 13 | 10.27 | 14.6 |
| 14 | 10.34 | 14.6 |



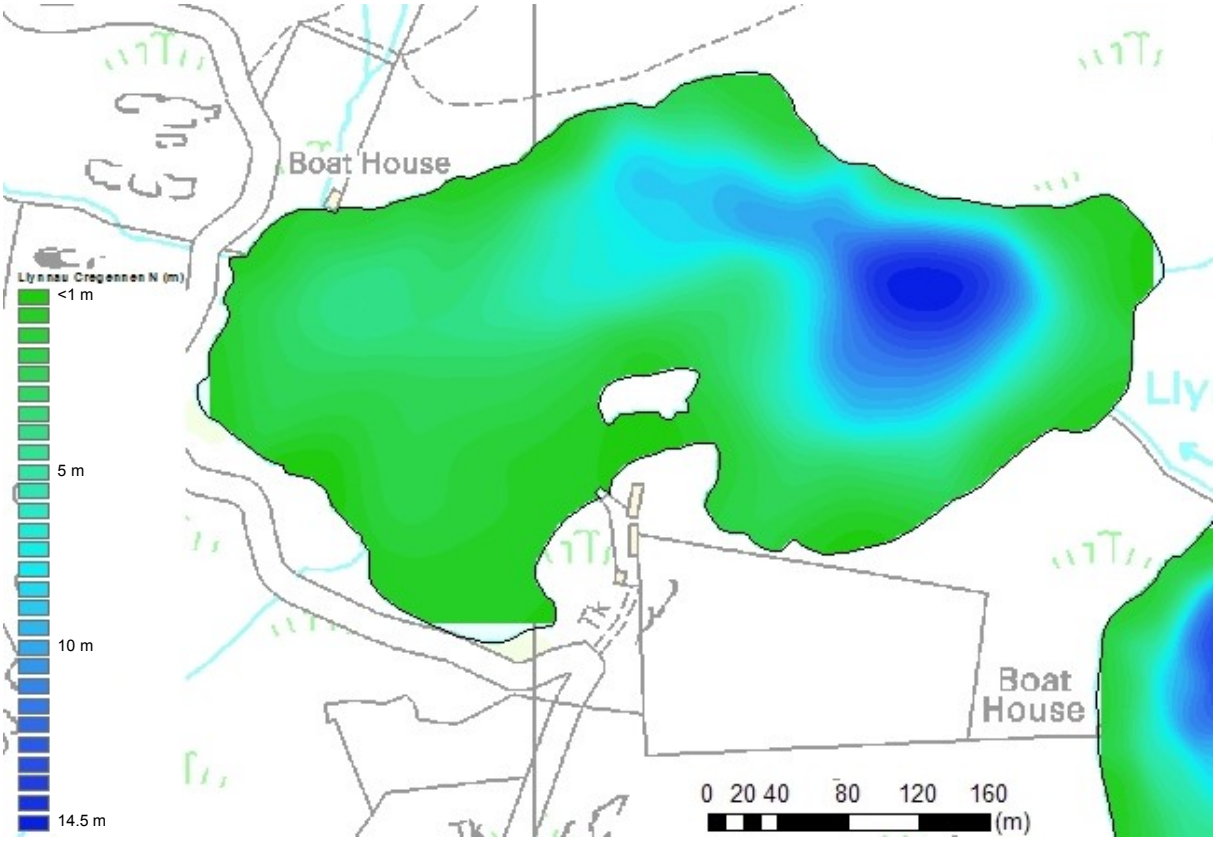

## Indicators of local distinctiveness

The presence of aquatic plants (e.g. *Nitella* spp. and *Chara virgata*) growing to depths of approximately 8.0 m is very rare in the UK and reflects the excellent water quality and clarity in the site. The record of *Potamogeton praelongus* is a new location; this species is considered Near Threatened in Britain and Critically Endangered in Wales (Dines 2008). *P. gramineus* is also a new record and is uncommon in Wales.

## Bathymetry

There is a relatively small area of deep water near the eaters end of the lake with a maximum recorded depth of 15.9 m, the lake shelves steeply in this area. By contrast, the western half of the lake is a relatively flat basin of 3.5 - 5 m depth. This area is dominated by *Isoetes lacustris* and *Chara virgata*. The clear water results in a large area of lake bed being within the photic zone and thus provides extensive habitat for plant growth (Figure 9).

Figure 9 Bathymetric map of Llyn Cregennen Isaf, December 2012




## Palaeolimnological evidence

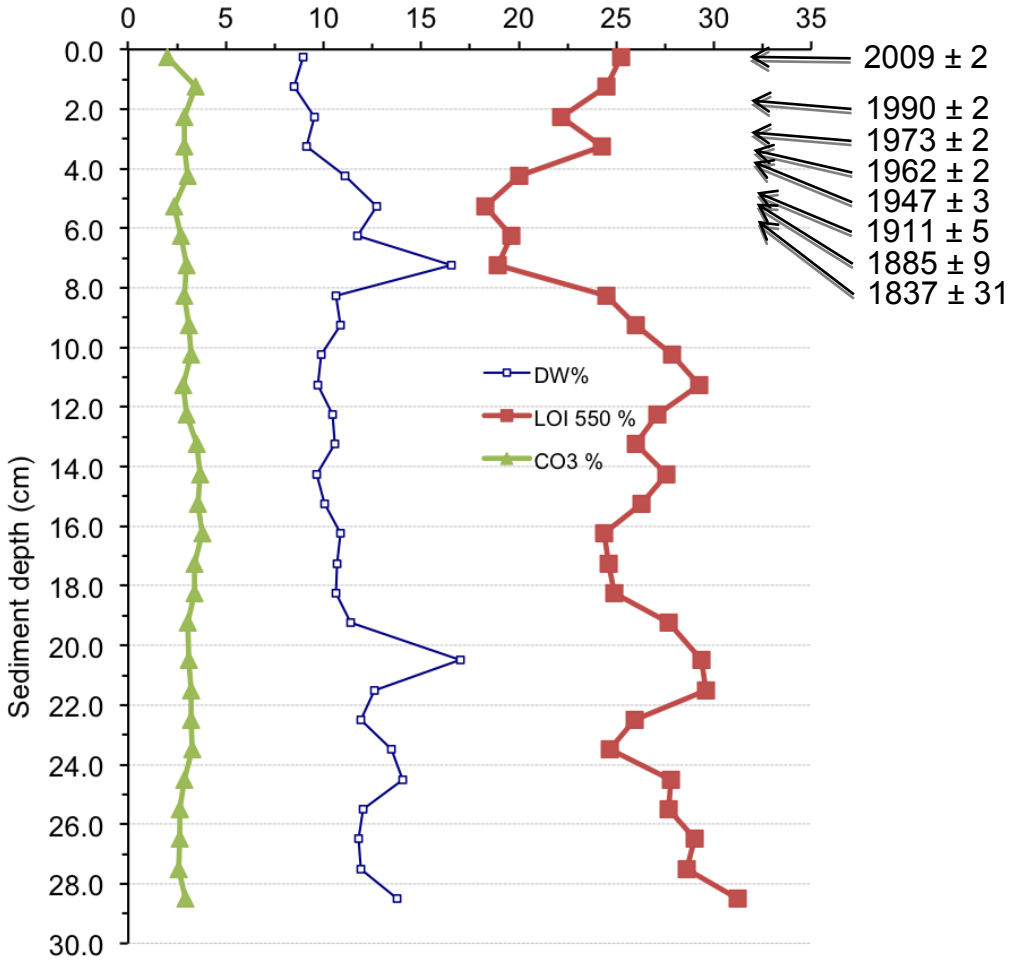
A 29 cm sediment core (CREG2) was taken from the deep point at SH6626014423 using a Renberg gravity corer. The core was sliced at 1 cm intervals in the field and analysed for dry weight, organic content and carbonate content. A subset of samples were dried and subjected to radiometric dating. The physical analysis of the core is discussed above and presented in Figure 10. Radiometric dating of the sediments show the core to have very slow accumulation rates with the upper 5 cm corresponding with approximately the last 160 years (Figure 10). The diatom flora shows very little change between the core top and base and is dominated by a oligotrophic *Cyclotella* species alongside a diverse assemblage of benthic taxa.

Species turnover was relatively low with squared chord distance (SCD) between the samples of only 0.55 and therefore not significant (Table 17).

| Sample Code | Depth (cm) | 2012/13 mean pH | DI-pH | 2012/13 mean TP | DI-TP | SCD |
|---|---|---|---|---|---|---|
| CREG2-00 | 0 | 7.33 | 6.94 | 6.9 | 10.4 | 0.55 |
| CREG2-28 | 28 | | 6.79 | | 8.1 | 0.00 |

Table 17 Results of Llyn Cregennen Isaf sediment core analysis

Figure 10. Physical characteristics from core CREG2 DW = dry weight; LOI = loss on ignition, CO3 = (carbonate content)




Reconstructions of diatom-inferred pH (DI-pH) were produced using the SWAP training set (RMSEP = 0.32 pH units). There were no major analogue problems between the training set and the CREG2 samples and the DI-pH results suggest the site to have remained just below circum-neutral over the time period covered by the core. The surface sediment assemblage estimates current pH to be slightly lower than measured.

Reconstructions of diatom-inferred TP (DI-TP) show a slight increase in modelled TP from the core bottom and top (8.1 to 10.4 $\mu gl^{-1}$). There were no analogue problems with the basal diatom assemblage, but some of the surface sediment species were less well represented in the NW European training set. The current annual mean TP based on quarterly water samples was 6.9 $\mu gl^{-1}$ and therefore the diatom model only slightly overestimates current conditions and there is no evidence of significant enrichment at Llyn Cregennen Isaf.

In summary, there has been only very minor floristic change in the sediment core diatoms from Llyn Cregennen Isaf and the fossil diatom assemblages indicate very little change in the water quality between the core top and bottom. High resolution diatom analysis of the upper sediments would be beneficial to understanding the

impact of atmospheric deposition and any changes in land management over the past 150 years.

## Site condition summary and overview

Llyn Cregennen Isaf is in **favourable condition** with **high confidence**. The lake supports a species rich aquatic macrophtye flora, including nine characteristic oligotrophic species. Furthermore, the characteristic taxa are well distributed throughout the site, and typical vegetation zones are evident with water depth. The the majority of vegetated sample points also had at least one characteristic species present. A maximum depth of colonization of approximately 8.0 m is possibly unprecedented in Welsh lakes and very rare in the UK. The extensive beds of *Chara virgata,* as well as *Nitella* spp. are also very rare in lakes of this type. In addition to the stoneworts, the site supports a extensive *Littorelletea uniflorae* plant community as well as broad-leaf *Potamogeton* species, including *P. praelongus*.

The mean annual TP in 2012/3 lies well within the recommended upper limit for oligotrophic lakes and there was no evidence of acidification or eutrophication within the site. pH was slightly above the target value for this site type, but while the geology is primarily acidic, there are significant areas of basic tuff and sedimentary mudstones within the catchment and it is therefore likely that the increased pH is natural.

Table 18 Llyn Cregennen Isaf overview

| Water Body | Status | Reason(s) for Failure | Comments |
|---|---|---|---|
| Llyn Cregennen Isaf | **Favourable (high confidence)** | N/A | Llyn Cregennen has excellent water quality and clarity and supports a species-rich, characteristic oligotrophic macrophyte flora. The flora shows characteristic zonation with depth and the maximum depth of colonization is approximately 8.0 m). The site shows no evidence of significant degradation and current catchment management poses low threat to the site. Possible runoff from the farm should be investigated. |

The surrounding land is mostly unimproved upland grazing and there is only one dwelling (Ffridd Boedel Farm) within the catchment along with associated farm buildings. The bay to the south west of the site (SH 65952 14216) supports a higher density of *Juncus bulbosus* than the rest of the lake and this is potentially indicative of nutrient enrichment from the nearby farm buildings (see below). Any change in land use could potentially place the site at risk and therefore the site, including the catchment, would benefit from formal protection (e.g. SSSI). From the perspective of

the Water Framework Directive, these lakes are also two extremely rare potential examples of lakes in Britain at reference condition, as the plant community is at high status, the diatom community shows no evidence of long-term change and the water chemistry shows no evidence of either acidification or eutrophication.

Llynnau Cregennen are two of very few oligotrophic lakes in the UK that support aquatic macrophytes to beyond 7.0 m depth and certainly represent the best lakes of conservation importance in Wales, including those lakes currently protected under UK and European legislation. They contain a range of rare and declining plant species. They should be considered for special protection measures such as formal site designation under domestic and / or European conservation legislation. Additionally, River Basin Management Planning should take account of the likely High Status of these water bodies and the need to prevent deterioration.

## Recommendations for monitoring and management:

The current catchment management of low intensity grazing by sheep and cattle appears to have little impact on the water quality and overall condition of the site. This situation should be monitored and any changes to land management within the catchment reviewed with respect to the potential risk to Llynnau Cregennen. The increased frequency of *Juncus bulbosus* in the SW bay close to the farm buildings may indicate slight enrichment and is the only potential area of immediate concern and it is recommended that a detailed site walk-over be undertaken to establish any potential risk. The farm house also lies within the catchment and although there is no evidence of any problem, the sewerage and wastewater arrangements should nonetheless be assessed to ensure they pose no risk to the site.

Angling at the lower lake is currently at low intensity, and according to the Cregennen Lakes website (www.cregennan.co.uk) the site has only wild brown trout and is not stocked.

Water quality (and particularly clarity) is considered to be the key to maintaining the current favorable status of the site. A minimum of quarterly (or monthly) water quality monitoring is recommended to ascertain any directional change in water quality and provide an early warning of any deterioration to the site. The site would also benefit from regular (every 3 years recommended) macrophyte surveys to ascertain shifts in rarer species (e.g. *P. praelongus*) and to monitor the maximum depth of colonization. Any unexplained reduction in the depth distribution of macrophytes should trigger additional monitoring. The following recommendations are based on the evidence collected for this report:

- Monitor water quality – minimum of quarterly sampling.
- Liaise with Cregennen angling club to ensure best practice with fisheries management – in this case only wild brown trout.
- Work with local land owners to ensure any changes to land management are communicated to NRW for approval.
- Monitor the aquatic flora every 3 years to ascertain any increase or decline of the characteristic flora and monitor depth distribution.

## CSM Database output

### Site Condition Assessment: Llyn Cregennen (Lower) (04/07/2013)

| Lake Details | | Survey Details | | |
|---|---|---|---|---|
| Lake Name | Llyn Cregennen (Lower) | Survey Date | 04/07/2013 | |
| SSSI Name | | Surveyors | BG, ST & JS | |
| SAC Name | | Shore Surveys | 4 | out of |
| Grid Ref | SH664141 | Wader Surveys | 4 | 4 |
| WBID | 36154 | Boat Surveys | 4 | sections |

Site Notes:
Lower lake

Survey Notes:
Nitella opaca confirmed (NS). Possibly N. flexillis ss, but uncertain and all recorded as agg.. Appears enriched at S4 - possibly from nearby farm buildings? pH = 7.18. Cond = 47.7

#### Section Summaries

| | | |
|---|---|---|
| **Section 1** | Maximum depth of colonisation (cm) | 780 cm |
| | Compass bearing of boat transect (°) | 320 ° |
| | Lateral distance from waters edge to 75cm depth (m) | 6 m |
| | Notes: | |
| **Section 2** | Maximum depth of colonisation (cm) | 790 cm |
| | Compass bearing of boat transect (°) | - |
| | Lateral distance from waters edge to 75cm depth (m) | 5 m |
| | Notes: | |
| **Section 3** | Maximum depth of colonisation (cm) | 530 cm |
| | Compass bearing of boat transect (°) | - |
| | Lateral distance from waters edge to 75cm depth (m) | 10 m |
| | Notes: Plants to max depth of transect | |
| **Section 4** | Maximum depth of colonisation (cm) | 410 cm |
| | Compass bearing of boat transect (°) | - |
| | Lateral distance from waters edge to 75cm depth (m) | 12 m |
| | Notes: Plants to max depth of transect | |

#### Section Locations

| | Shore Survey GPS Co-ords | | Boat Survey GPS Co-ords | |
|---|---|---|---|---|
| | start | end | start (shore) | end (lake) |
| **Section 1** | SH6627814314 | SH6619014257 | SH6624114299 | SH6624614334 |
| **Section 2** | SH6614614523 | SH6604814510 | SH6609614526 | SH6610814478 |
| **Section 3** | SH6590414455 | SH6582914389 | SH6585714446 | SH6595214354 |
| **Section 4** | SH6600314221 | SH6591014247 | SH6595214216 | SH6595614374 |

#### Section Photos

| | Start of Section | Whole Section | End of Section |
|---|---|---|---|
| **Section 1** | 97 | 95 | 96 |
| **Section 2** | 2067 | 2068 | 2069 |
| **Section 3** | 2077 | 2080 | 2079 |
| **Section 4** | 2081 | 2082 | 2083 |

## Species Abundance - Boat Survey

| | |
|---|---|
| Total number of sample plots | 80 |
| Total number of vegetated sample plots | 39 |

| Plant Species | Occurrence *n* | Occurrence % |
|---|---|---|
| *Chara virgata* | 25 | 64 |
| *Isoetes lacustris* | 23 | 59 |
| *Juncus bulbosus* | 3 | 8 |
| *Littorella uniflora* | 12 | 31 |
| *Lobelia dortmanna* | 11 | 28 |
| *Myriophyllum alterniflorum* | 6 | 15 |
| *Nitella flexilis agg.* | 10 | 26 |
| *Nitella opaca* | 6 | 15 |
| *Potamogeton perfoliatus* | 5 | 13 |
| *Potamogeton praelongus* | 4 | 10 |
| *Utricularia minor* | 1 | 3 |

## Species Abundance - Wader Survey

| | |
|---|---|
| Total number of sample plots | 80 |
| Total number of vegetated sample plots | 56 |

| Plant Species | Occurrence *n* | Occurrence % |
|---|---|---|
| *Chara virgata* | 26 | 46 |
| *Elatine hexandra* | 1 | 2 |
| *Eleogiton fluitans* | 1 | 2 |
| *Isoetes lacustris* | 21 | 38 |
| *Juncus bulbosus* | 6 | 11 |
| *Littorella uniflora* | 47 | 84 |
| *Lobelia dortmanna* | 33 | 59 |
| *Menyanthes trifoliata* | 1 | 2 |
| *Myriophyllum alterniflorum* | 14 | 25 |
| *Nitella flexilis agg.* | 10 | 18 |
| *Potamogeton natans* | 4 | 7 |
| *Potamogeton perfoliatus* | 1 | 2 |
| *Utricularia minor* | 9 | 16 |

Note: Species abundance % = ((number of plots / total number of vegetated sample plots) * 100)

## Plant Scores

**Total plant species** 45 **Filamentous algae (%)** 10.6 % WADER 3.2 % BOAT
**Total plant cover (%)** 188.85

### S U R V E Y S C O R E S

| PLANT SPECIES | PERIMETER | WADER | BOAT | COVER % | DAFOR | ABUNDANCE |
|---|---|---|---|---|---|---|
| *Isoetes lacustris* | 0 | 0.0408 | 0.244 | 26.44 | A | 4 |
| *Chara virgata* | 0 | 0.0478 | 0.2142 | 23.81 | F | 3 |
| *Littorella uniflora* | 0.1125 | 0.1412 | 0.0628 | 16.15 | F | 3 |
| *Juncus acutiflorus* | 0.4625 | 0 | 0 | 11.56 | F | 3 |
| *Molinia caerulea* | 0.375 | 0 | 0 | 9.38 | O | 2 |
| *Nitella flexilis agg.* | 0 | 0.0238 | 0.0808 | 9.27 | O | 2 |
| *Lobelia dortmanna* | 0 | 0.0684 | 0.0545 | 8.87 | O | 2 |
| *Alnus glutinosa* | 0.275 | 0 | 0 | 6.88 | O | 2 |
| *Sphagnum sp.* | 0.25 | 0 | 0 | 6.25 | O | 2 |
| *Ranunculus flammula* | 0.2125 | 0 | 0 | 5.31 | O | 2 |
| *Nitella opaca* | 0 | 0 | 0.052 | 5.2 | O | 2 |
| *Myriophyllum alterniflorum* | 0 | 0.0262 | 0.035 | 4.81 | R | 1 |
| *Potamogeton perfoliatus* | 0.05 | 0.0021 | 0.034 | 4.76 | R | 1 |
| *Mosses unid* | 0.1875 | 0 | 0 | 4.69 | R | 1 |
| *Nardus stricta* | 0.175 | 0 | 0 | 4.38 | R | 1 |
| *Juncus effusus* | 0.175 | 0 | 0 | 4.38 | R | 1 |
| *Potentilla erecta* | 0.175 | 0 | 0 | 4.38 | R | 1 |
| *Juncus bulbosus* | 0.05 | 0.0129 | 0.0162 | 3.52 | R | 1 |
| *Potamogeton praelongus* | 0 | 0 | 0.027 | 2.7 | R | 1 |
| *Carex echinata* | 0.0875 | 0 | 0 | 2.19 | R | 1 |
| *Myrica gale* | 0.0875 | 0 | 0 | 2.19 | R | 1 |
| *Hydrocotyle vulgaris* | 0.075 | 0 | 0 | 1.88 | R | 1 |
| *Angelica sylvestris* | 0.075 | 0 | 0 | 1.88 | R | 1 |
| *Carex rostrata* | 0.0625 | 0 | 0 | 1.56 | R | 1 |
| *Carex nigra* | 0.05 | 0 | 0 | 1.25 | R | 1 |
| *Carex demissa* | 0.05 | 0 | 0 | 1.25 | R | 1 |
| *Mentha aquatica* | 0.05 | 0 | 0 | 1.25 | R | 1 |
| *Succisa pratensis* | 0.05 | 0 | 0 | 1.25 | R | 1 |
| *Scutellaria minor* | 0.05 | 0 | 0 | 1.25 | R | 1 |
| *Salix sp.* | 0.05 | 0 | 0 | 1.25 | R | 1 |
| *Utricularia minor* | 0 | 0.0136 | 0.005 | 1.18 | R | 1 |
| *Menyanthes trifoliata* | 0.025 | 0.0062 | 0 | 0.94 | R | 1 |
| *Eleocharis palustris* | 0.025 | 0 | 0 | 0.62 | R | 1 |
| *Trichophorum cespitosum* | 0.025 | 0 | 0 | 0.62 | R | 1 |
| *Pinguicula vulgaris* | 0.025 | 0 | 0 | 0.62 | R | 1 |
| *Liverworts unid* | 0.025 | 0 | 0 | 0.62 | R | 1 |
| *Crocosmia pottsii x aurea = C. x* | 0.025 | 0 | 0 | 0.62 | R | 1 |
| *Juncus conglomeratus* | 0.025 | 0 | 0 | 0.62 | R | 1 |
| *Epilobium palustre* | 0.025 | 0 | 0 | 0.62 | R | 1 |
| *Fontinalis antipyretica* | 0.025 | 0 | 0 | 0.62 | R | 1 |
| *Viola palustris* | 0.025 | 0 | 0 | 0.62 | R | 1 |
| *Achillea ptarmica* | 0.025 | 0 | 0 | 0.62 | R | 1 |
| *Potamogeton natans* | 0 | 0.0079 | 0 | 0.4 | R | 1 |
| *Elatine hexandra* | 0 | 0.0021 | 0 | 0.1 | R | 1 |
| *Eleogiton fluitans* | 0 | 0.0018 | 0 | 0.09 | R | 1 |

## 5.3. Llyn Dinas

Annex 1 type: H3130: Oligo-mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the Isoëto-*Nanojuncetea*.

### 5.3.1. Site description

Summary characteristics for Llyn Dinas

| | |
|---|---|
| Name: | Llyn Dinas |
| County: | Gwynedd |
| WBID: | 34244 |
| Grid reference: | SH616495 |
| OS Grid reference (X,Y): | 261694,349549 |
| Latitude / Longitude | N53°1.52',W004°3.82' |
| Altitude (m): | 55 |
| Maximum recorded depth (m): | 8.8 |
| Mean depth (m): | 3.37 |
| Lake volume ($m^3$): | 1015017 |
| Surface area – UKLakes (ha): | 28.50 |
| Surface area – measured (ha) | 30.08 |
| Perimeter of lake (km): | 3.0 |
| Shoreline Development Index (SDI): | 1.56 |
| WFD alkalinity based typology: | Low Alkalinity, Shallow (LA, S) |
| Phase 1 habitat type: | Standing water: Oligotrophic: G1.3 |
| Survey Date: | 29 June 2013 |

Llyn Dinas is a clear-water, shallow (8.8 m) oligotrophic lake lying in the Glaslyn valley to the northeast of Beddgelert. The lake itself is low-lying (55 m above sea level), but it receives water from a relatively large mountainous area including much of the south and east side of Snowdon. The Afon Glaslyn, which forms the main inflow, originates on the east side of the Snowdon summit flowing down through Llyn Glaslyn, the Llyn Llydaw reservoir and then Llyn Gwynant before reaching Llyn Dinas and passing out and flowing southwest to the Glaslyn Estuary at Porthmadog.

There are no detailed studies of the ecology of Llyn Dinas as a whole, but the lake has a long history as a field site for studies of the distribution and ecology of British freshwater invertebrates, especially triclads, leeches and mayflies (e.g. Brown 1943, Brittain 1972; Reynoldson 1958; Reynoldson & Bellamy 1975; Reynoldson & Jacques 1976; Young 1981; Young & Ironmonger 1981; Young & Proctor 1985; Young & Spelling 1986; Young & Reynoldson 1999). Bathymetric surveys were carried out by Jehu (1902) and later by Ferrar (1961).

Llyn Dinas is valued as a beauty spot and has populations of brown and sea trout and salmon, and the description of Ward (1931) suggests that the lake has changed little since the 1920s. Llyn Dinas is intimately connected with Welsh legend, including the stories of Merlin and Vortigern (see Roberts 1995 for a brief account). The lake was the mythical site of the battle between a red dragon and a white dragon, with the victorious red dragon being adopted as the emblem of Wales. More recently, the lake was a location for the Ingrid Bergman film ‘The Inn of the Sixth Happiness’

(Snowdoniaguide.com). In 2013 the Llyndy Farm and surrounding land was purchased by the National Trust.

### 5.3.2. Condition Assessment and Discussion

Table 19 Condition Assessment Summary Table for Llyn Dinas

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | None |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise) | ✓ | 5 characteristic *Littorelletea* spp in 2013: *Isoetes lacustris, Littorella uniflora & Lobelia dortmanna, Luronium natans & Sparganium angustifolius.* 2 other characteristic oligotrophic spp: *Elatine hexandra* & *Utricularia australis.* |
| | No loss of characteristic species (see Box 2) | - | No previous data |
| | ≥ 6/10 vegetated sample spots (boat / wader survey) have ≥ 1 characteristic spp. | ✓ | 71% of vegetated sample spots comply (75% wader, 67% boat) |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | None recorded |
| | Benthic and epiphytic filamentous algae <10%. | ✓ | Filamentous algal was present, but well below 10 % cover. |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (site specific) | ✓ | Good zonation present. *L . uniflora* & *L. dortmanna* to c. 2.6 m, *I. lacustris* to 3.1 m; *Nitella spp* to c. 5.8 m. *L. natans* 0.5 -1.2 m. *E. hexandra* 0.5 - 1.0 m. |
| | Maximum depth distribution should be maintained | ✓ | $Z_{max}$ (recorded) = 8.8 m, $Z_s$ = 3.83 m, $Z_v$ = 5.8 m. |
| | At least present structure should be maintained | - | No evidence of change. |
| **Water quality** | Stable nutrients levels: TP target / limit: Oligotrophic = 10 µgl$^{-1}$ | ✓ | TP (mean 2012/13) = 5.6 µg l$^{-1}$ $NO_3$-N = 0.13 mg l$^{-1}$ |
| | Stable pH values: pH ~ 5.5 – circumneutral | ✓? | Mean pH 2006-11 = 6.87 (Range 6.64 - 7.45). |
| | Adequate dissolved $O_2$ for | ✓ | > 10 mg l$^{-1}$ from 0 - 8 m. |

| Attribute | Target | Status | Comment |
|---|---|---|---|
| | health of characteristic fauna (> 5 $mgl^{-1}$) | | Water column mixed |
| | No excessive growth of cyanobacteria / green algae | ✓ | None noted, and low Chl a values (mean 1.23 µg $l^{-1}$, range <0.5 - 2.0 µg $l^{-1}$) |
| **Hydrology** | Natural hydrological regime | **NA** | Hydro-electric plant upstream. Impact unlikely. Outflow has been modified. |
| **Lake substrate** | Natural shoreline maintained | ✓ | |
| | Natural and characteristic substrate maintained | ✓? | Sediment core analysis shows an increase in organic material in no significant changes to sediments |
| **Sediment load** | Natural sediment load maintained | ✓ | Appears natural |
| **Indicators of local distinctive-ness** | Distinctive elements maintained at current extent / levels / locations | ✓ | Significant population of *Luronium natans* present. |
| **Disturbance** | No introduced species | ✓ | None recorded |
| | Minimal negative impacts from recreation and navigation. No fish farming | ✓ | None. |
| Palaeo evidence | No evidence of significant environmental change e.g. acidification or eutrophication | ✓ | Diatom flora indicates some degree of species turnover, but no major evidence of water quality change. |

**Status: ✓ = favourable; X = unfavourable; NA = Not assessed**

## Extent

There is no evidence of any recent loss of extent of open water.

## Macrophyte community composition and structure

Llyn Dinas has a typical oligotrophic flora with a relatively species-rich total of 17 aquatic plant species recorded in 2013, 7 of which were characteristic oligotrophic species (Table 20). Furthermore, 71% of the vegetated sample points had one or more characteristic species present and the vegetation showed characteristic species zones. Littorella uniflora and Lobelia dortmanna were recorded most commonly in shallower water (mostly < 2 m) with Isoetes lacustris overlapping in shallow water but extending in excess of 3.0 m. Nitella opaca and N. flexilis agg. were common alongside Myriophyllum alterniflorum and Juncus bulbosus down to depths in excess of 5.0 m. The maximum recorded depth was for Nitella opaca at 5.8 m (

Table 20 and Figure 11).

*Luronium natans* was not recorded at any of the CSM survey points, but occurred at relatively high abundance during the plant mapping (which was conducted independently of the CSM survey), mostly along the southeast shore, but also with small beds close to the main inflow and outflow. Total numbers of plants were estimated to be in excess of 1000, which constitutes a relatively large and important population in this part of Wales. *L. natans* has been reported from Llyn Dinas once before, in 2009, but this is the first systematic survey. *Elatine hexandra* was rare within the site, but recorded from three separate locations. See Table 20 for a summary of the species and Figure 11for the depth distribution of aquatic plants. Species maps are presented in Figure 12 (contd.)Figure 12.

| Submerged and floating vegetation | TRS | PLEX | % occurrence (n=128) | DAFOR abundance[5] | Min depth (cm) | Max depth (cm) |
|---|---|---|---|---|---|---|
| *Callitriche hamulata* | 6.3 | 6.15 | 2.9 | R | 0.4 | 3 |
| ***Elatine hexandra*** | **7** | **5.38** | **2.9** | **R** | **0.5** | **1.1** |
| ***Isoetes lacustris*** | **5** | **4.23** | **42.8** | **A** | **0.4** | **3.5** |
| *Juncus bulbosus* | 5.3 | 3.08 | 56.5 | D | 0.4 | 5.2 |
| ***Littorella uniflora*** | **6.7** | **4.23** | **26.1** | **A** | **0.2** | **2.8** |
| ***Lobelia dortmanna*** | **5** | **3.08** | **31.2** | **A** | **0.2** | **1.8** |
| ***Luronium natans*** | | | **+** | **O** | **0.5** | **1.7** |
| *Mosses aquatic* | | | 12.3 | O | 0.25 | 1.3 |
| *Myriophyllum alterniflorum* | 6.7 | 4.23 | 42 | A | 0.25 | 5.2 |
| *Nitella flexilis* agg | 6.7 | 5.38 | + | R | 0.5 | 5.2 |
| *Nitella opaca* | 6.7 | 5.38 | 21.7 | F | 180 | 5.8 |
| *Nuphar lutea* | 8.5 | 6.92 | 10.1 | O | 0.25 | 2.2 |
| *Nymphaea alba* | 6.7 | 3.08 | 4.3 | R | 0.25 | 0.75 |
| *Potamogeton berchtoldii* | 7.3 | 7.69 | + | R | 1.6 | 3.6 |
| *Potamogeton polygonifolius* | 3.7 | 3.08 | + | R | 0.8 | 125 |
| ***Sparganium angustifolium*** | **4** | **4.23** | **+** | **R** | **1** | **1.5** |
| ***Utricularia australis*** | **4** | **3.08** | **15.2** | **F** | **0.5** | **3.5** |
| **Average score** | **6.0** | **4.6** | | | | |
| **Species richness** | | | | 17 | | |

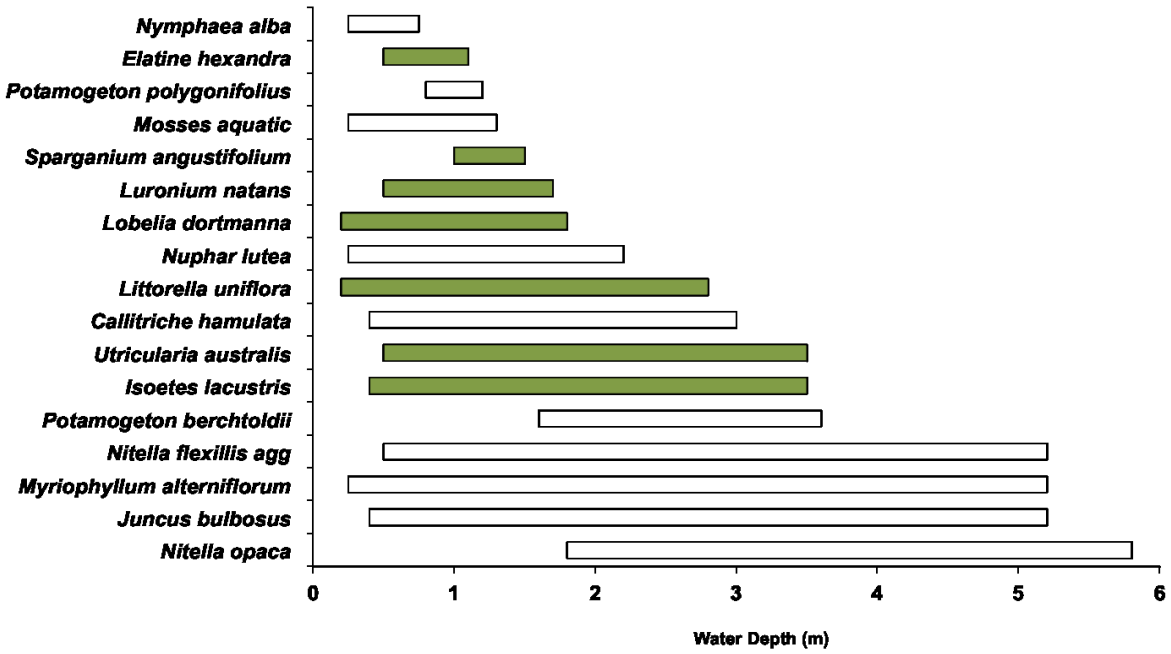
Table 20 Aquatic macrophyte community composition for Llyn Dinas in June 2013. Characteristic oligotrophic species are highlighted in **bold**.

The current assemblage places the lake into Group C2 as defined by Duigan *et al*. (2006) and the flora is a representative but species-rich example of the type. The TRS (6.0) and PLEX (4.6) scores are consistent with oligotrophic lakes. Llyn Dinas is

[5] Based on presence / absence data from all vegetated plots in the wader and boat based surveys. DAFORs are calculated from the total number of occurrences across the wader and boat surveys as a proportion of the total number of vegetated wader and boat survey points.

favourable with respect to its aquatic macrophyte composition, but the high frequency of *J. bulbosus* (and possibly *M. alterniflorum*) are a possible cause for concern (see below).

Figure 11. Depth range of the aquatic macrophytes recorded from Llyn Dinas; characteristic oligotrophic species are shaded green.




## Negative indicator species

*Juncus bulbosus* and *Myriophyllum alterniflorum* are both very common in the site and occur above the 40% frequency threshold recommended for favourable condition set out in the favourable condition tables (JNCC 2005). Both species occur widely in the site and across a wide depth range. Their presence can be a potential indicator of increased trophic status in oligotrophic lakes.

The site was without any significant growths of filamentous algae. There were no invasive species.

Figure 12. Distribution maps of the aquatic plant species recorded in Llyn Dinas.

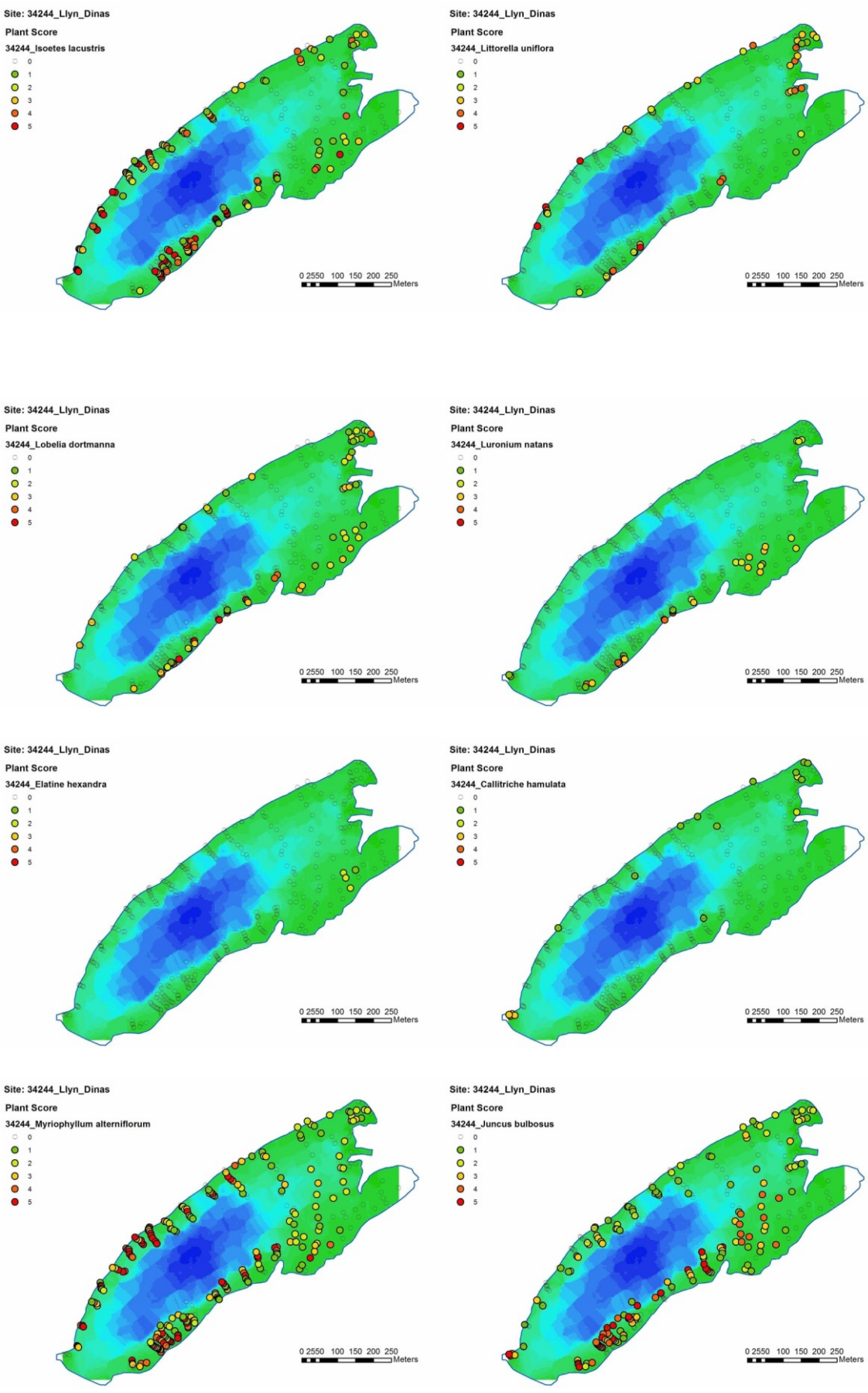
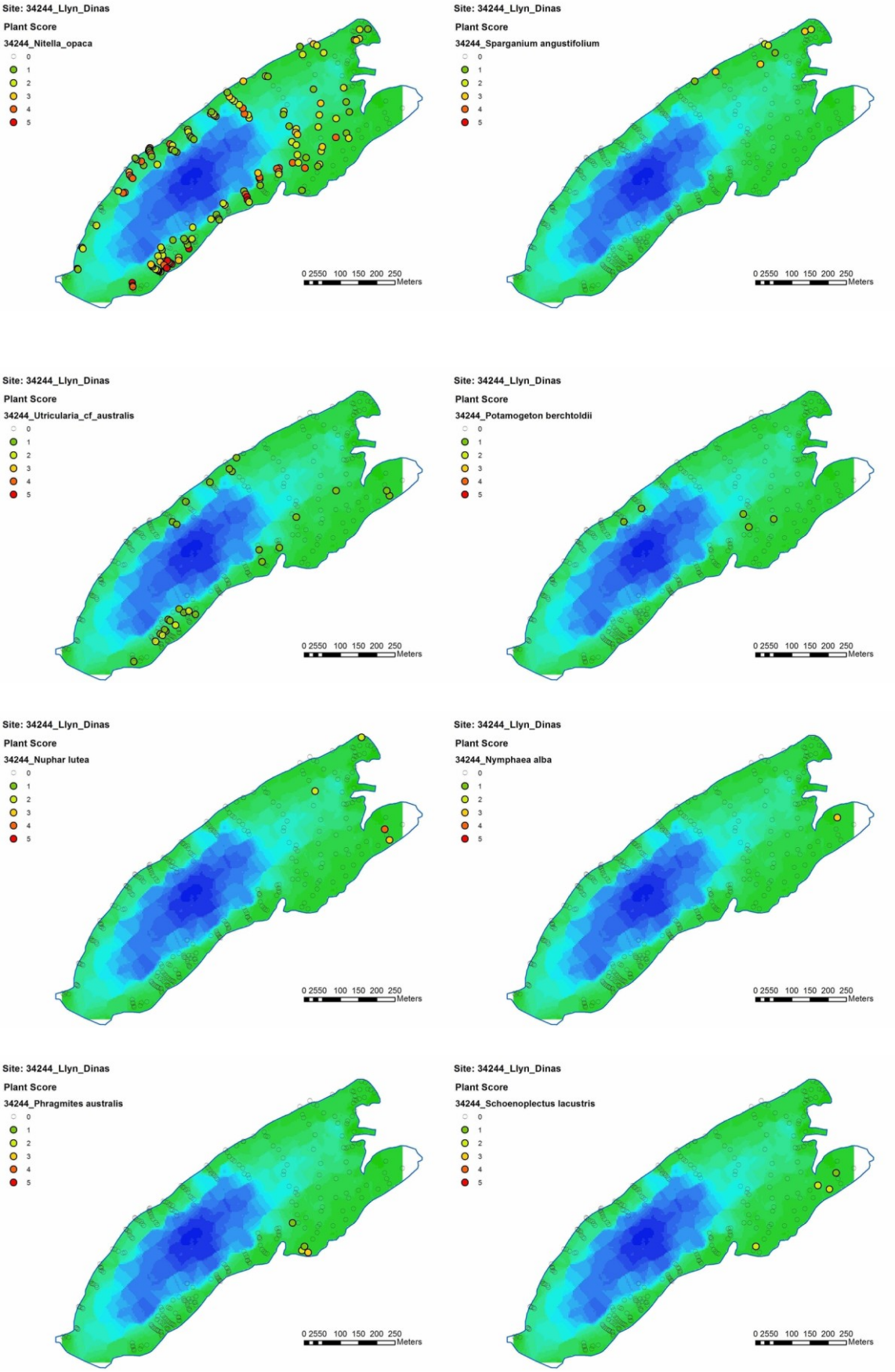


Figure 12 (contd.)



## Water quality

The water chemistry of Llyn Dinas is consistent with that of an oligotrophic water body with low mean annual TP concentration (5.6 µg $l^{-1}$) and soluble reactive phosphorus below the detection limit on all four sampling occasions. The geometric mean TP was 5.18 µg $l^{-1}$. Using the site-specific WFD Morphoedaphic Index (MEI) model for predicting the phosphorus concentration, this would place Llyn Dinas in reference condition. Soluble reactive phosphorus was below the detection limit on all sampling occasions. Total oxidised nitrogen was also very low (0.13 mg $l^{-1}$). pH and alkalinity are also typical for oligotrophic lakes.

The measured nutrient concentrations suggest no evidence of nutrient enrichment and fall well within the CSM limits for oligotrophic sites and therefore the site is considered to be in favourable condition with respect to trophic status.

At the time of survey in June 2013, the lake was well oxygenated throughout with DO from 0 -14 m exceeding 10 mg $l^{-1}$ (Figure 13).

ANC values fall very close to the high/good ecological boundary set in the revised CSM guidance (JNCC, in draft) which uses the WFD standard of 40 µeq $l^{-1}$. The site is therefore considered to be borderline in respect to ANC, and at potential risk of acidification and should therefore receive regular monitoring to asses any directional change. Overall the water quality of Llyn Dinas is considered to be excellent.

| Determinand | Dec 5th | Feb 25th | Jul 4th | Oct 5th | Mean |
|---|---|---|---|---|---|
| pH | 7.45 | 6.98 | 6.64 | 6.77 | **6.87** |
| Cond | 34.6 | 45.9 | 32 | 32 | **36.1** |
| Alk (Gran) | 3.24 | 5.8 | 2.68 | 3.45 | **3.8** |
| SRP | <1.0 | <1.0 | <1.0 | <1.0 | **<1.0** |
| TP | 3.2 | 3.9 | 8.9 | 6.5 | **5.6** |
| Chl a | 0.73 | <0.500 | 1.7 | 2 | **1.5** |
| TON | 0.144 | 0.202 | 0.0776 | 0.0998 | **0.13** |
| $Na^+$ | 3.1 | 4.68 | 3.53 | 3.33 | **3.66** |
| $K^+$ | 0.461 | 0.392 | 0.194 | 0.195 | **0.31** |
| $Mg^{2+}$ | 0.316 | 0.39 | 0.54 | 0.572 | **0.45** |
| $Ca^{2+}$ | <1 | 1.41 | 1.49 | 1.78 | **1.56** |
| $Cl^-$ | 4.9 | 7.98 | 5.9 | 5.7 | **6.12** |
| $SO4^{2-}$ | <10 | <10 | <10 | <10 | **<10.0** |
| $SiO_2$ | 1.56 | 1.55 | 0.842 | 1.19 | **1.29** |
| Sus. Solids | <3 | <3 | <3 | <3.00 | **<3.0** |
| Labile Al | 31 | 12.7 | 24.3 | 12.6 | **20.2** |
| DOC | 1.57 | 0.7 | 1.78 | 1.57 | **1.41** |
| ANC-I (ionic) | | | | | **38.7** |
| ANC-C (Cantrell) | | | | | **82.2** |

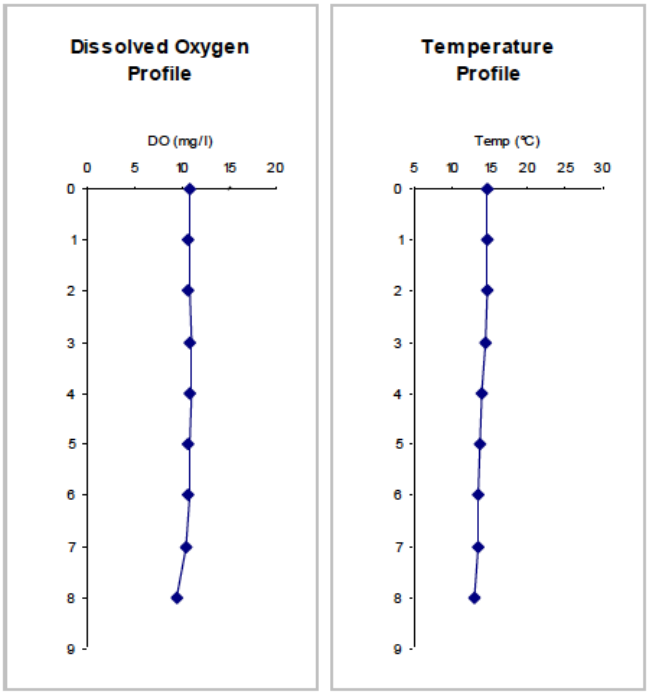
Table 21 Water chemistry data for Llyn Dinas (for units see methodology)

Figure 13. Dissolved oxygen (DO) profile for Llyn Dinas (29/06/2013).

**Dissolved Oxygen Profile**

| | |
|---|---|
| GPS Location | SH619549495 |
| Maximum Depth (m) | 8.4 m |
| Secchi Depth (cm) | 383 cm |
| Notes: | |

| Depth (m) | DO (mg/l) | Temp (°C) |
|---|---|---|
| 0 | 10.8 | 14.6 |
| 1 | 10.69 | 14.6 |
| 2 | 10.72 | 14.6 |
| 3 | 10.78 | 14.5 |
| 4 | 10.82 | 14 |
| 5 | 10.69 | 13.7 |
| 6 | 10.6 | 13.5 |
| 7 | 10.54 | 13.4 |
| 8 | 9.58 | 13 |




## Hydrology

The main inflow, Afon Glaslyn, enters the site from the northeast and drains an area reaching up to the summit of Snowdon via the south and east slopes of the mountain. Afon Glaslyn passes through three other lakes, L. Glaslyn, the Llyn Llydaw reservoir and then Llyn Gwynant before reaching Llyn Dinas and flowing southwest to the Glaslyn Estuary at Porthmadog. Llyn Llydaw acts as the supply for the Cwm Dyli hydro-electric plant with water being piped from the lake to the generating plant via a 2 km long pipeline before being released back to the Afon Glaslyn. The impact of the hydro-electric plant is thought unlikely to have a negative influence on Llyn Dinas. The lake has a number of smaller inflows from the high ground to the south, east and north, including Afon Llynedno and Afon Cwm Llan, tributaries of the Afon Glaslyn entering between Llyn Gwynant and Llyn Dinas.

The lake outflow is under natural control but appears to have been dredged in the past, which may have affected water level fluctuation and retention times. The impact of this is not considered serious.

## Lake substrate and sediment loads

The littoral substrates are comprised of a range of substrates including boulders, cobbles and gravels with peat and fine silts in the more sheltered areas. More consolidated sediments and silts occur at depths greater than 1m giving way to silts in deeper water. The bay to the north of the inflow had high levels of woody debris in shallow water and the region south of the inflow appeared to have more organic silts in the littoral zone.

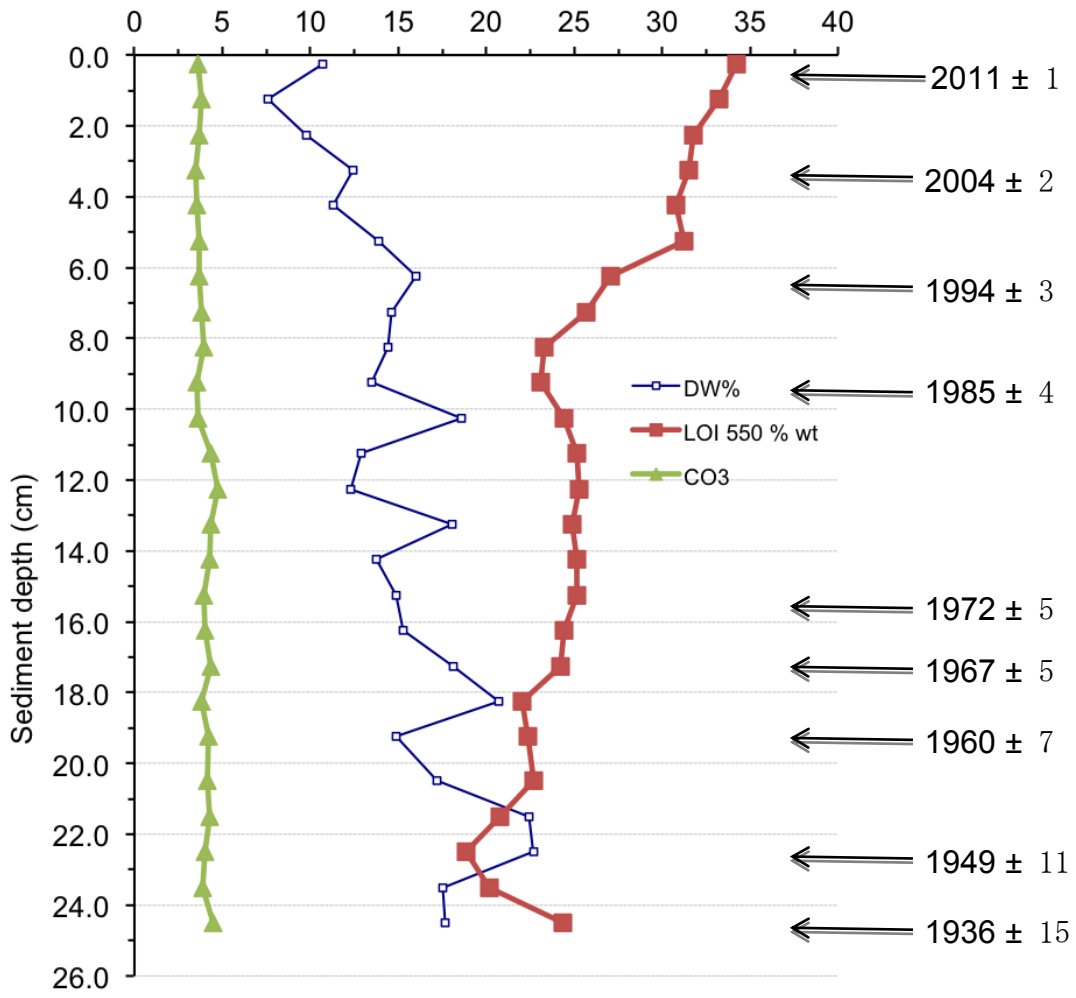
A 25 cm sediment core was collected from the deep point and subject to radiometric dating and organic content analysis (Figure 14). Two aspects of the sediment core are of particular interest. First it should be noted that the sediment accumulation rate

is relatively high for an oligotrophic lake, ranging from 4-7 mm per year in deep water. The 25 cm core therefore only covers a period of approximately 80 years. Secondly the organic content (% LOI) of the sediments is relatively stable below 8 cm, but increases rather rapidly between 8 - 6 cm and then gradually up to the sediment surface (Figure 14).

The high sediment accumulation rates are most likely explained by the inwash from a large catchment area into what is a relatively small and predominantly shallow lake coupled with sediment focusing towards the steeply shelving, small central basin. This is likely to result in greater deposition rates in the area from where the core was taken.

The increase in organic matter towards the top of the core suggests either increased productivity within the lake, or more likely increased inwash of organic material from the catchment. What facilitated this increase between approximately 1985 and 1995 is unclear, but it is suggested likely to be related to catchment management and possibly forestry work (felling / planting) in the Plas Gwynant forest area to the north east of the lake.

Figure 14 Physical characteristics from core DINS1 DW = dry weight; LOI = loss on ignition, CO3 = (carbonate content)



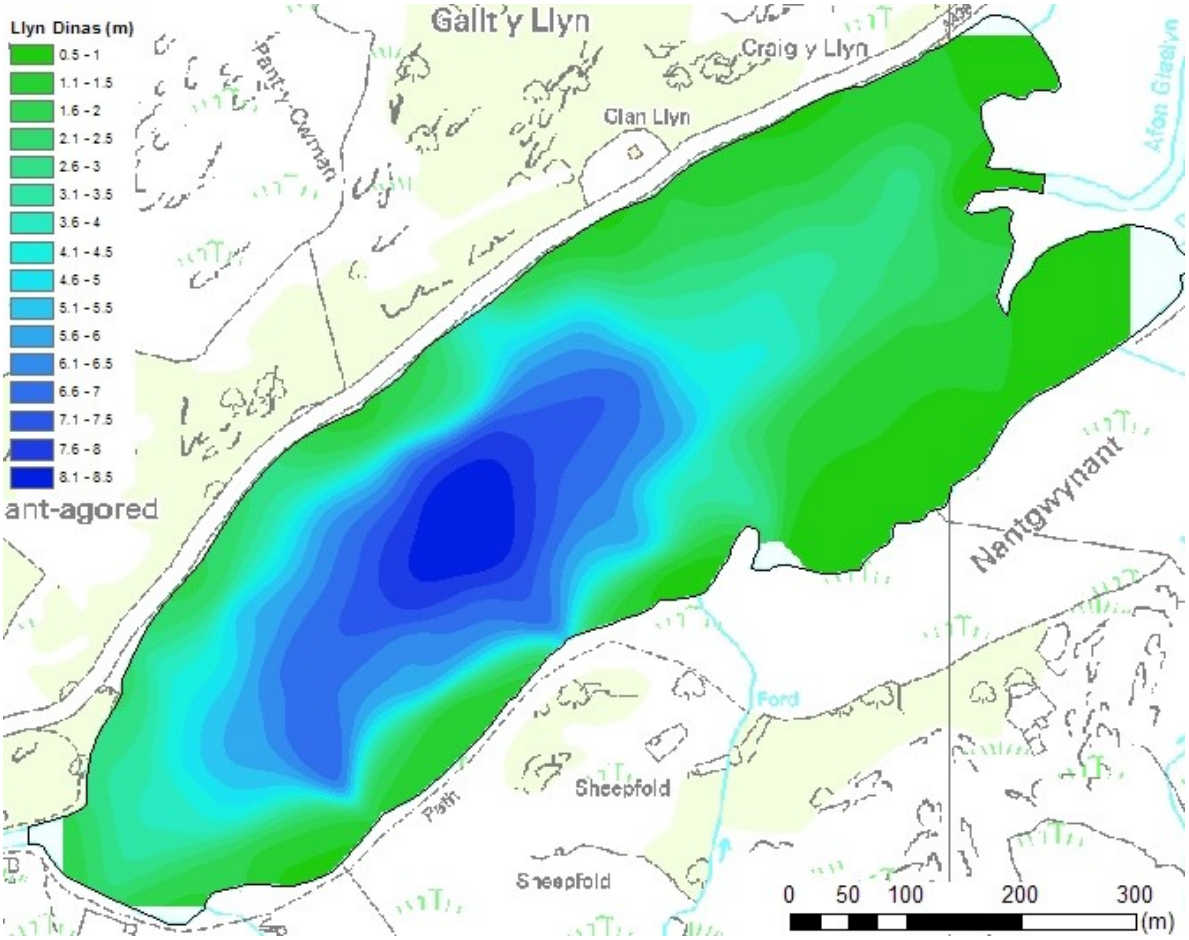
## Indicators of local distinctiveness

The presence of a significant population of *Luronium natans* is important. There was a large bed (approximately 200m x 100m) centred around SH 61916 49598 (Figure 12) in 1.0 - 1.7 m of water with many plants having floating leaves present. Total numbers of plants were estimated to be in excess of 1000. Other smaller beds of the plant were recorded from close to the inflow and outflow and along the south-east shore; again mostly at 1 - 1.5 m water depth. Llyn Dinas therefore has a relatively large population of this Habitats Directive Annexe II and BAP Priority species.

## Bathymetry

Llyn Dinas is a shallow lake (mean depth 3.37 m) with a relatively small area of deeper water slightly southwest of the centre (8.8 m) (Figure 15). The northern end of the lake slopes gently to less than 4.0 m and has macrophytes throughout. The lake bed slopes more steeply around the central and southern portions of the lake and has plants to a maximum depth of approximately 5.0 m.

Figure 15 Bathymetric map of Llyn Dinas, December 2012




## Palaeolimnological evidence

A 25 cm sediment core (DINS1) was taken from the deep point at SH 61620 49530 using a Renberg gravity corer. The core was sliced at 1 cm intervals in the field and analysed for dry weight, organic content and carbonate content. A subset of samples

were dried and subjected to radiometric dating. The physical analysis and dating of the core are discussed above and presented in Figure 14.

The diatom flora is dominated by benthic taxa, consistent with the lake being shallow and having clear water. Both the surface sediments and the basal sample were dominated by Achnanthes minutissima and Brachysira vitrea  Species turnover between the two samples was very low, with squared chord distance (SCD) between the samples of only 0.25 and therefore not significant (Table 22).

| Sample Code | Depth (cm) | 2012/13 mean pH | DI-pH | 2012/13 mean TP | DI-TP | SCD |
|---|---|---|---|---|---|---|
| DINS1-00 | 0 | 6.87 | 6.22 | 5.6 | 4.2 | 0.47 |
| DINS1-24 | 24 | | 6.40 | | 4.4 | 0.00 |

Table 22 Results of Llyn Dinas sediment core analysis

Reconstructions of diatom-inferred pH (DI-pH) were produced using the SWAP training set (RMSEP = 0.32 pH units). Fossil assemblages from both samples were dominated by benthic species typical of oligotrophic waters.  As a result, DI-pH inferred slightly acid conditions with little change over the time period covered by the core. The surface sediment assemblage estimates current pH to be only very slightly lower than to measured values.

Reconstructions of diatom-inferred TP (DI-TP) show no significant change in modelled TP from the core bottom and top (4.4 to 4.2 µg $l^{-1}$). There were no analogue problems with the core samples, with fossil assemblages being well represented in the NW European training set. The current annual mean TP based on quarterly water samples was 5.6 µg $l^{-1}$. Therefore, the diatom model gives a good estimate of current conditions and there is no evidence of any enrichment at Llyn Dinas.

In summary, there has been very little floristic change in the sediment core diatoms from Llyn Dinam and the fossil diatom assemblages indicate very little change in the water quality between the core top and bottom. High resolution diatom analysis of the upper sediments would be beneficial to understanding the impact of atmospheric deposition and any changes in land management over the past 80 years.

## Site condition summary and overview

Llyn Dinas is in **favourable condition** with **high confidence**. The lake supports a species rich aquatic macrophtye flora, including seven characteristic oligotrophic species. Furthermore, the characteristic taxa are well distributed throughout the site, and typical vegetation zones are evident with water depth with plants recorded to a maximum depth of 5.2 m. The majority of vegetated sample points also had at least one characteristic species present. In addition, the lake supports an extensive population of *Luronium natans* with well over 1000 plants estimated to be present in the main bed and a number of smaller beds also recorded.

Water quality was excellent. The mean annual TP in 2012/3 lies well within the recommended upper limit for oligotrophic lakes, the dissolved oxygen concentration was high and there was no evidence of acidification or eutrophication within the site.

The catchment is primarily low intensity upland grazing and includes a number of other lakes upstream. There were no obvious areas of concern noted within the catchment other than a relatively small number of rural dwellings and small areas of improved grassland associated with the valley farms. Although there is no evidence to suggest pollution is a problem within the site, diffuse pollution from rural dwellings and farms within the catchment poses a potential risk and should be investigated to ensure minimal release of nutrients.

JNCC guidelines (2005) suggest any oligotrophic site with greater than 40% frequency of *J. bulbosus* is indicative that the lake is not in favourable condition. In this case, there are no previous data with which to ascertain if *J. bulbosus* has increased at the site and nor is there any other evidence to suggest the site has become more eutrophic in recent years. Further monitoring of water quality and the plant population is therefore recommended.

Sediment accumulation rates show the site to have experienced a period of increased sedimentation starting in the mid-eighties and lasting approximately 10 years and associated with increased organic matter in the sediments. The reason for this is unclear, but possibly linked to dredging of the river upstream or nearby forestry activity. The extent of plantation forestry is very small within the Llyn Dinas catchment and therefore the risk of future impact on the lake is likely to remain low.

| Water Body | Status | Reason(s) for concern | Comments |
|---|---|---|---|
| Llyn Dinas | **Favourable (high confidence)** | Relatively poorly buffered and potential risk of acidification (low risk) | Llyn Dinas has excellent water quality and clarity and supports a species-rich, characteristic oligotrophic macrophyte flora. The flora shows characteristic zonation with depth and aquatic plants extend to a maximum depth of 5.2 m. The site shows no evidence of significant degradation and current catchment management poses low threat to the site. Diffuse pollution from rural dwellings and farms should be investigated and action taken to minimise nutrient inputs. |

Table 23 Llyn Dinas overview

## Recommendations for monitoring and management:

The current catchment management of mainly low intensity upland grazing by sheep appears to have little impact on the water quality and overall condition of the site. This situation should be monitored and any changes to land management within the catchment reviewed with respect to the potential risk to the lake. The only concern at the site to suggest a possible increase in trophic status is the high frequency of *Juncus bulbous,* but without additional evidence supporting this observation, the site is still considered to be in favourable condition. However, monthly chemical monitoring at the lake outflow is recommended to determine any changes in nutrient flux from the lake.

Other amenity uses at the lake are low despite its proximity to the road. Angling appears to be restricted to only naturally recruited fish and there are no formal launch points for boat use.

High water quality and clarity are the key factors in maintaining the favourable status of the site. A minimum of quarterly (or ideally monthly) water quality monitoring is recommended to ascertain any directional change in water quality and provide an early warning of any deterioration to the site. The site would also benefit from regular (every 3 years recommended) macrophyte surveys to ascertain any shifts in the population of *Luronium natans* and to monitor the extent and frequency of *Juncus bulbosus* within the site. Any future CSM surveys should target at least one survey section to coincide with the main population of *L. natans* within the lake. The fact *L. natans* was overlooked by the CSM methodology also highlights the advantage of building in whole site surveys in additional to routine CSM survey.

The large size of the *L. natans* population at Llyn Dinas is of conservation significance and we would recommend the site be afforded greater protection to recognize this (e.g. extension of the Eryri SAC to include Llyn Dinas).

The following recommendations are based on the evidence collected for this report:

- Monitor water quality – minimum of quarterly sampling.
- Work with local land owners to ensure any changes to land management are communicated to NRW for approval.
- Monitor the aquatic flora every 3 years to ascertain any increase or decline of the characteristic flora and monitor *Juncus bulbosus* populations.
- Ensure greater protection of the Annex II (Habitats Directive) species, *Luronium natans* by extending the Eryri SAC to include Llyn Dinas

## CSM Database output

### Site Condition Assessment: Llyn Dinas (29/06/2013)

| Lake Details | | Survey Details | | |
|---|---|---|---|---|
| Lake Name | Llyn Dinas | Survey Date | 29/06/2013 | |
| SSSI Name | | Surveyors | BG, JoS & JS | |
| SAC Name | | Shore Surveys | 4 | out of |
| Grid Ref | SH616495 | Wader Surveys | 4 | 4 |
| WBID | 34244 | Boat Surveys | 4 | sections |

Site Notes:
Luronium natans 2013

Survey Notes:
pH 6.25, Cond. = 26.9.

#### Section Summaries

| | | | |
|---|---|---|---|
| **Section** | **1** | Maximum depth of colonisation (cm) | 130 cm |
| | | Compass bearing of boat transect (°) | 170 ° |
| | | Lateral distance from waters edge to 75cm depth (m) | 5 m |
| | | Notes: Shallow bay - max 1.3 m | |
| **Section** | **2** | Maximum depth of colonisation (cm) | 550 cm |
| | | Compass bearing of boat transect (°) | 335 ° |
| | | Lateral distance from waters edge to 75cm depth (m) | 3 m |
| | | Notes: | |
| **Section** | **3** | Maximum depth of colonisation (cm) | 410 cm |
| | | Compass bearing of boat transect (°) | 355 ° |
| | | Lateral distance from waters edge to 75cm depth (m) | 5 m |
| | | Notes: PLANTS TO MAX DEPTH OF TRANSECT | |
| **Section** | **4** | Maximum depth of colonisation (cm) | 580 cm |
| | | Compass bearing of boat transect (°) | 170 ° |
| | | Lateral distance from waters edge to 75cm depth (m) | 3 m |
| | | Notes: | |

#### Section Locations

| | | Shore Survey GPS Co-ords | | Boat Survey GPS Co-ords | |
|---|---|---|---|---|---|
| | | start | end | start (shore) | end (lake) |
| **Section** | **1** | SH6213549765 | SH6205249747 | SH6207249714 | SH6209149683 |
| **Section** | **2** | SH6171649455 | SH6164849417 | SH6167349445 | SH6166249500 |
| **Section** | **3** | SH6124749230 | SH6136749219 | SH6130649208 | SH6129949303 |
| **Section** | **4** | SH6148449629 | SH6158249710 | SH6152449659 | SH6156749619 |

#### Section Photos

| | | Start of Section | Whole Section | End of Section |
|---|---|---|---|---|
| **Section** | **1** | 13 | 14 | 15 |
| **Section** | **2** | 16 | 17 | 18 |
| **Section** | **3** | 21 | 20 | 19 |
| **Section** | **4** | 22 | 23 | 24 |

## Species Abundance - Boat Survey

| | |
|---|---|
| Total number of sample plots | 80 |
| Total number of vegetated sample plots | 66 |

| Plant Species | Occurrence *n* | Occurrence % |
|---|---|---|
| *Elatine hexandra* | 2 | 3 |
| *Isoetes lacustris* | 36 | 55 |
| *Juncus bulbosus* | 48 | 73 |
| *Littorella uniflora* | 2 | 3 |
| *Lobelia dortmanna* | 7 | 11 |
| *Mosses aquatic* | 9 | 14 |
| *Myriophyllum alterniflorum* | 43 | 65 |
| *Nitella opaca* | 30 | 45 |
| *Nuphar lutea* | 4 | 6 |
| *Phragmites australis* | 1 | 2 |
| *Utricularia australis* | 19 | 29 |

## Species Abundance - Wader Survey

| | |
|---|---|
| Total number of sample plots | 80 |
| Total number of vegetated sample plots | 72 |

| Plant Species | Occurrence *n* | Occurrence % |
|---|---|---|
| *Callitriche hamulata* | 4 | 6 |
| *Carex rostrata* | 13 | 18 |
| *Elatine hexandra* | 2 | 3 |
| *Isoetes lacustris* | 23 | 32 |
| *Juncus bulbosus* | 30 | 42 |
| *Littorella uniflora* | 34 | 47 |
| *Lobelia dortmanna* | 36 | 50 |
| *Mosses aquatic* | 8 | 11 |
| *Myriophyllum alterniflorum* | 15 | 21 |
| *Nuphar lutea* | 10 | 14 |
| *Nymphaea alba* | 6 | 8 |
| *Phragmites australis* | 13 | 18 |
| *Schoenoplectus lacustris* | 2 | 3 |
| *Utricularia australis* | 3 | 4 |

Note: Species abundance % = ((number of plots / total number of vegetated sample plots) * 100)

## Plant Scores

**Total plant species** 24 **Filamentous algae (%)** 8.9% WADER 3.8% BOAT

**Total plant cover (%)** 176.68

**SURVEY SCORES**

| PLANT SPECIES | PERIMETER | WADER | BOAT | COVER % | DAFOR | ABUNDANCE |
|---|---|---|---|---|---|---|
| *Juncus bulbosus* | 0 | 0.104 | 0.1931 | 24.51 | F | 3 |
| *Isoetes lacustris* | 0 | 0.0676 | 0.1722 | 20.6 | F | 3 |
| *Myriophyllum alterniflorum* | 0 | 0.0484 | 0.1737 | 19.79 | F | 3 |
| *Juncus effusus* | 0.5 | 0 | 0 | 12.5 | F | 3 |
| *Nitella opaca* | 0 | 0 | 0.1136 | 11.36 | F | 3 |
| *Lobelia dortmanna* | 0 | 0.1384 | 0.027 | 9.62 | O | 2 |
| *Phragmites australis* | 0.2375 | 0.0422 | 0.0042 | 8.47 | O | 2 |
| *Mosses aquatic* | 0 | 0.0278 | 0.062 | 7.59 | O | 2 |
| *Carex rostrata* | 0.1875 | 0.0569 | 0 | 7.53 | O | 2 |
| *Littorella uniflora* | 0 | 0.134 | 0.0068 | 7.38 | O | 2 |
| *Utricularia australis* | 0 | 0.0052 | 0.0676 | 7.02 | O | 2 |
| *Juncus acutiflorus* | 0.275 | 0 | 0 | 6.88 | O | 2 |
| *Hydrocotyle vulgaris* | 0.25 | 0 | 0 | 6.25 | O | 2 |
| *Eriophorum angustifolium* | 0.2125 | 0 | 0 | 5.31 | O | 2 |
| *Ranunculus flammula* | 0.175 | 0 | 0 | 4.38 | R | 1 |
| *Nuphar lutea* | 0 | 0.0326 | 0.0217 | 3.8 | R | 1 |
| *Potentilla reptans* | 0.125 | 0 | 0 | 3.12 | R | 1 |
| *Oenanthe crocata* | 0.1125 | 0 | 0 | 2.81 | R | 1 |
| *Myrica gale* | 0.0875 | 0 | 0 | 2.19 | R | 1 |
| *Carex nigra* | 0.0625 | 0 | 0 | 1.56 | R | 1 |
| *Elatine hexandra* | 0 | 0.0056 | 0.0092 | 1.2 | R | 1 |
| *Nymphaea alba* | 0 | 0.0201 | 0 | 1 | R | 1 |
| *Callitriche hamulata* | 0 | 0.0186 | 0 | 0.93 | R | 1 |
| *Schoenoplectus lacustris* | 0.025 | 0.0052 | 0 | 0.88 | R | 1 |

## 5.4. Llyn Gwernan

Annex 1 type: H3130: Oligo-mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*.

### 5.4.1. Site description

Summary characteristics for Llyn Gwernan

| | |
|---|---|
| Name: | Llyn Gwernan |
| County: | Gwynedd |
| WBID: | 36021 |
| Grid reference: | SH704160 |
| OS Grid reference (X,Y): | 270463,316034 |
| Latitude / Longitude | N52°43.58',W003°55.18' |
| Altitude (m): | 165 |
| Maximum recorded depth (m): | 9.75 |
| Mean depth (m): | 2.00 |
| Lake volume ($m^3$): | 93940 |
| Surface area – UKLakes (ha): | 4.60 |
| Surface area – measured (ha) | 4.71 |
| Perimeter of lake (km): | 1.0 |
| Shoreline Development Index (SDI): | 1.56 |
| WFD alkalinity based typology: | Low Alkalinity, Shallow (LA, S) |
| Phase 1 habitat type: | Standing water: Oligotrophic: G1.3<br>Standing water: Mesotrophic: G1.2 |
| Survey Date: | 3 July 2013 |

Llyn Gwernan is a small lake lying in a valley southwest of Dolgellau on the north side of Cadair Idris. It has a relatively small catchment which includes some of the lower slopes of Cadair Idris, as well as an area of coniferous plantation to the north and semi-improved pasture to the east. The lake is shallow throughout most of the basin with large beds of water lilies around the western end and beds of bulrush extending out into open water around the north and east shore. There is a small area of deeper water shelving steeply to a maximum of 9.75 m in front of the hotel which takes its name from the lake. The lake flora is consistent with oligo/mesotrophic habitat type and the following assessment is based against both features.

The local geology is dominated by Upper Cambrian and Lower Ordovician mudstones, slates and rhyolites as well as localised igneous intrusions (Lowe *et al.* 1988). Radiocarbon dating studies reveal the lake to contain a continuous sediment record dating back to the last glacial ice sheet 14-13,000 years BP (Lowe 1981) with sediments of up to 14.25 m in depth. The geological interest in these sediments is the primary reason for the site being notified as a SSSI in 1990.

The lake is now managed by the owners of the Gwernan Hotel and has a low intensity angling interest. In 2010 the owners received funding under the EA Wales, Wild Fishing Wales initiative to improve access to the shore and encourage

sustainable and best-practice angling at the lake. The take is primarily wild brown trout, but some stocking of rainbow trout has also taken place (number unavailable).

### 5.4.2. Condition Assessment and Discussion

Table 24 Condition Assessment Summary Table for Llyn Gwernan

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | None |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise) | ✓ | 4 characteristic *Littorelletea* spp in 2013: *Isoetes lacustris, Littorella uniflora & Lobelia dortmanna & Sparganium angustifolium.* 2 other characteristic oligotrophic spp: *Potamogeton alpinus* & *Utricularia minor.* |
| | Mesotrophic: ≥ 8 characteristic species listed in Box 2 inclusive of 3 or more of the *Potamogeton* spp. listed in Box 2 (accept where valid reasons apply) | ✓ | 8 characteristic spp in 2013: *I. lacustris, L. uniflora, L. dortmanna, S. angustifolium, Utricularia minor, Nitella opaca, N. translucens, Potamogeton alpinus.* |
| | No loss of characteristic species (see Box 2) | **NA** | No previous CSM data, but current list is similar to that recorded by Seddon in 1960s – *P. perfoliatus* is the only characteristic species no longer present. |
| | ≥ 6/10 vegetated sample spots (boat / wader survey) have ≥ 1 characteristic spp. | ✓ | 89% of vegetated sample spots comply for Oligotrophic species and 90% for Mesotrophic species. |
| **Negative indicator species** | Non-native species absent or present at low frequency | **X** | *Elodea canadensis* (50%) & *E. nuttallii* (10%) |
| | Benthic and epiphytic filamentous algae <10%. | ✓ | Filamentous algal was rare and well below 10 % cover. |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (site specific) | ✓ | Good zonation present where depth exceeded 2.5 m: *L . uniflora* to 1.4 m, *L. dortmanna* & *I. lacustris* to 2.0 m, *S. angustifolium* to 3.4 m, *Nitella spp.* to c. 4.0 m. *P. alpinus* 0.2-2.1 m. |
| | Maximum depth distribution should be | ✓ | $Z_{max}$ (recorded) = 9.75 m, $Z_s$ = 3.10 m, $Z_v$ = 4.0 m. |

| Attribute | Target | Status | Comment |
|---|---|---|---|
| | maintained | | |
| | At least present structure should be maintained | - | No evidence of change |
| **Water quality** | Stable nutrients levels: TP target / limit: Oligotrophic = 10 $\mu g l^{-1}$ | ✓ | TP (mean 2012/13) = 7.4 $\mu g\ l^{-1}$ $NO_3$-N = 0.20 mg $l^{-1}$ |
| | Stable pH values: pH ~ 5.5 – circumneutral | ✓? | Mean pH 2006-11 = 7.16 (Range 6.77-7.96). |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 $mg l^{-1}$) | ✓ | > 9 mg $l^{-1}$ from 0-9 m. Water column mixed |
| | No excessive growth of cyanobacteria / green algae | ✓ | None noted, and low Chl-a values (mean 2.65 $\mu g\ l^{-1}$, range 1.1-4.7 $\mu g\ l^{-1}$) |
| **Hydrology** | Natural hydrological regime | ✓ | Natural |
| **Lake substrate** | Natural shoreline maintained | ✓ | Small area of concrete reinforcement at jetty. Minimal impact. |
| | Natural and characteristic substrate maintained | ✓? | Sediment core analysis shows relatively little change |
| **Sediment load** | Natural sediment load maintained | ✓ | Appears natural |
| **Indicators of local distinctive-ness** | Distinctive elements maintained at current extent / levels / locations | ✓ | *Potamogeton alpinus* recorded at 18% of survey points. Considered Critically Endangered in Wales. |
| **Disturbance** | No introduced species | X | *E. canadensis* (present since before 1966). *E. nuttallii* – recent introduction? |
| | Minimal negative impacts from recreation and navigation. No fish farming | ✓ | Low pressure. |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | ✓? | Diatom flora indicates some degree of species turnover, but no major evidence of water quality change. |

**Status: ✓ = favourable; X = unfavourable; NA = Not Assessed**

## Extent

The surface area of the lake is 4.7 ha. There is no evidence of any recent loss of extent of open water.

## Macrophyte community composition and structure

Llyn Gwernan has a relatively rich flora including 20 aquatic plant species recorded in 2013, 6 of which were characteristic oligotrophic species, and 8 of which are

characteristic mesotrophic species (Table 25). Furthermore, 89% of the vegetated sample points had one or more characteristic species present and the vegetation showed characteristic species zones. *Littorella uniflora* was recorded most commonly in shallower water (mostly < 1.4 m) with *Lobelia dortmanna* and *Isoetes lacustris* overlapping in shallow water but extending to 2.0 m. *Sparganium angustifolium* was frequent and grew at up to 3.4 m. *Nitella opaca* and *N. translucens* were found at mostly more than 1 m up to a maximum depth of 4.0 m.

| Submerged and floating vegetation | TRS | PLEX | % occurrence (n=125) | DAFOR abundance[6] | Min depth (cm) | Max depth (cm) |
|---|---|---|---|---|---|---|
| *Apium inundatum* | 6.3 | 7.5 | + | R | 1.1 | 1.1 |
| *Callitriche hamulata* | 7.0 | 5.38 | 0.8 | R | 9 | 2.9 |
| *Chara virgata* | 7.3 | 7.69 | 5.6 | O | 0.5 | 180 |
| *Eleogiton fluitans* | 4 | 3.08 | 1.6 | R | 0.9 | 1.5 |
| *Elodea canadensis* | 7.3 | 7.95 | 49.6 | A | 0.3 | 3.2 |
| *Elodea nuttallii* | | 7.95 | 10.4 | O | 0.25 | 2.1 |
| *Fontinalis antipyretica* | 6.3 | 5.38 | 1.6 | R | 0.25 | 0.9 |
| ***Isoetes lacustris*** | **5.0** | **4.23** | **31.2** | **A** | **0.4** | **2** |
| *Juncus bulbosus* | 5.3 | 3.08 | 11.2 | F | 0.25 | 1.6 |
| ***Littorella uniflora*** | **6.7** | **4.23** | **40** | **A** | **0** | **1.4** |
| ***Lobelia dortmanna*** | **5.0** | **3.08** | **24.8** | **F** | **0.25** | **2** |
| *Myriophyllum alterniflorum* | 6.7 | 4.23 | 8 | O | 4 | 2 |
| ***Nitella opaca*** | **6.7** | **5.38** | **21.6** | **F** | **0.2** | **3.1** |
| ***Nitella translucens*** | **6.7** | **5.38** | **13.6** | **F** | **1** | **4** |
| *Nuphar lutea* | 8.5 | 6.92 | 24.8 | F | 0.5 | 3.2 |
| *Nymphaea alba* | 6.7 | 3.08 | 16.8 | F | 0.4 | 2.5 |
| ***Potamogeton alpinus*** | **5.5** | **5.38** | **17.6** | **F** | **0.2** | **2.1** |
| *Potamogeton natans* | 7 | 4.23 | 16.8 | F | 5 | 2.5 |
| ***Sparganium angustifolium*** | **4.0** | **4.23** | **52.8** | **D** | **0.5** | **3.4** |
| ***Utricularia minor*** | **4** | **3.08** | **0.8** | **R** | **0.8** | **0.9** |
| **Average score** | **6.1** | **5.1** | | | | |
| **Species richness** | | | | **20** (18 native) | | |

Characteristic oligotrophic species are highlighted in bold and additional mesotrophic taxa in blue text.

Table 25 Aquatic macrophyte community composition for Llyn Gwernan in June 2013.

*Elodea canadensis* has been present in the lake for over 50 years (Seddon 1972) and remains very frequent throughout the lake, although rarely abundant. *Elodea nuttallii* was only recorded at 10 % of sample points.

[6] Based on presence / absence data from all vegetated plots in the wader and boat based surveys. DAFORs are calculated from the total number of occurrences across the wader and boat surveys as a proportion of the total number of vegetated wader and boat survey points.

*Potamogeton alpinus*, which is rare in Wales, was recorded at 18% of the survey points.

See Table 25 for a summary of the species and Figure 16 for the depth distribution of aquatic plants. Species maps are presented in (Figure 17).

The current assemblage places the lake into Group D as defined by Duigan *et al*. (2006). This group typically consists of sites that are circumneutral and species rich and includes many classically mesotrophic lakes. The TRS (6.1) and PLEX (5.1) scores are consistent with mesotrophic lakes. The site is favourable if assessed against oligotrophic features, but lacks the broadleaf *Potamogeton* spp. required for it to be favourable if assessed against the mesotrophic targets. No previous CSM survey data exists for the lake, but it was surveyed in the early 1960s and the data presented by Seddon (1972) and shows a very similar species list from Llyn Gwernan to that seen in 2013. He recorded 15 aquatic species, missing only the charophytes (which were not recorded in the study), *Elodea nuttallii* and *Sparganium angustifolium.* The only species that Seddon recorded that were not found in 2013 were *Potamogeton perfoliatus* and *P. berchtoldii.* This suggests that there has been no significant loss of species since the 1960s and therefore the plant community composition is considered favourable.

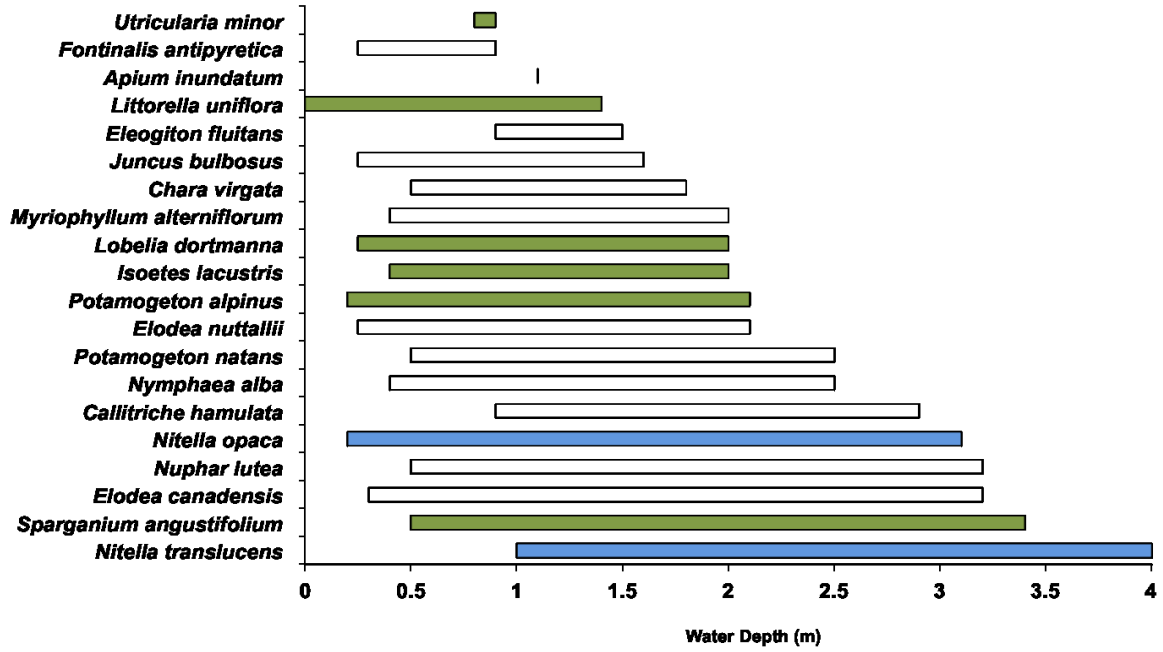



Figure 16 Depth range of the aquatic macrophytes recorded from Llyn Gwernan; characteristic oligotrophic species are shaded green, with additional mesotrophic coloured blue.

## Negative indicator species

*Elodea canadensis* has been present in Llyn Gwernan for at least 50 years (Seddon 1972) and is frequent throughout the lake; the current level of 50% frequency is unfavourable. The presence of *E. nuttallii*, a more recent introduction, is also unfavourable. The site was without any significant growths of filamentous algae.

Figure 17 Distribution maps of the aquatic plant species recorded in Llyn Gwernan

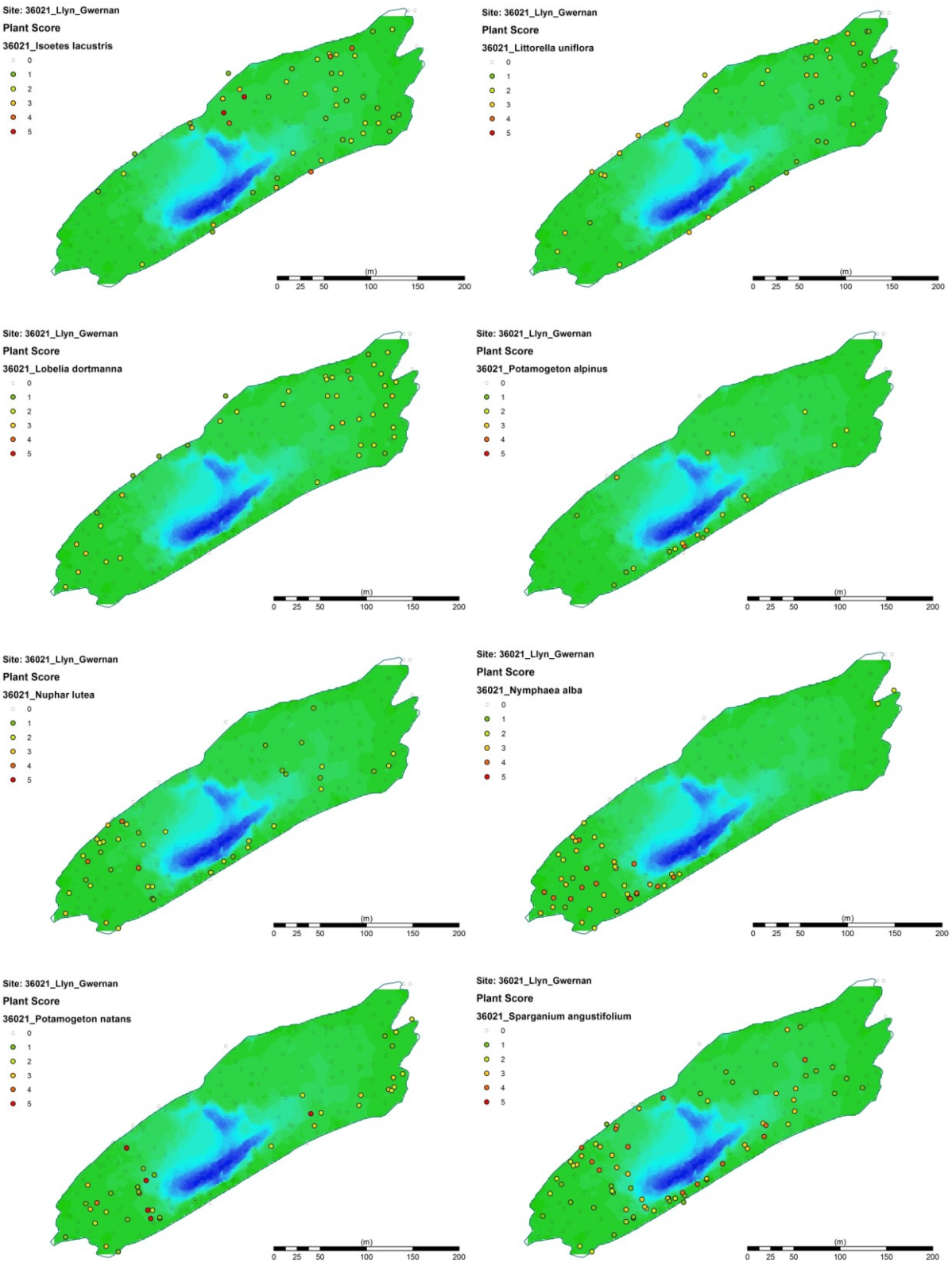
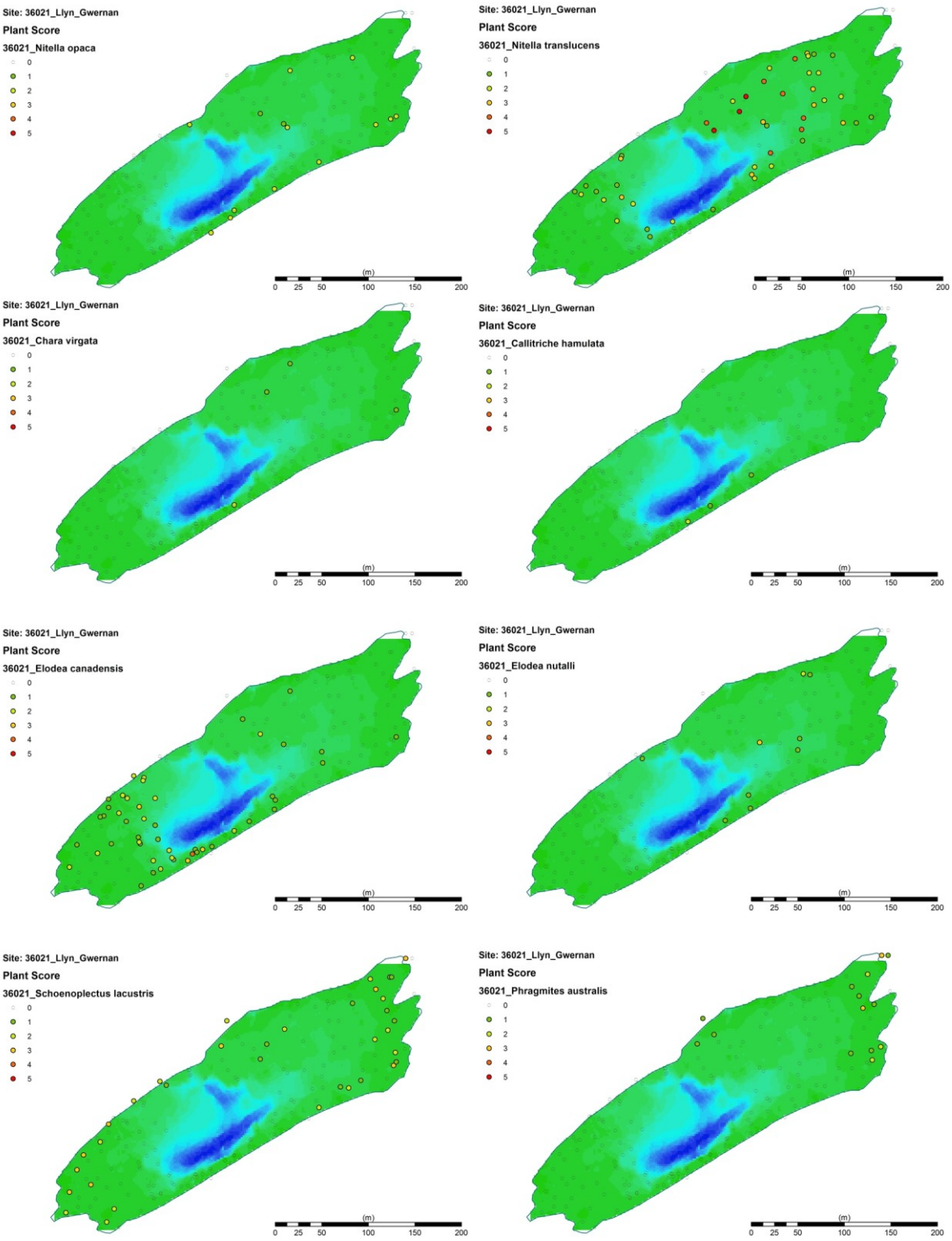


Figure 17 (Contd.)




## Water quality

The water chemistry of Llyn Gwernan (Table 26) is consistent with that of an oligo-mesotrophic water body with low mean annual TP concentration (7.4 µg $l^{-1}$) and soluble reactive phosphorus below the detection limit on three sampling occasions.

Geometric mean TP was 7.2 µg $l^{-1}$. Using the MEI model and site-specific data, the threshold for High / Reference TP was 9 µg $l^{-1}$, placing Llyn Gwernan in reference condition with respect to phosphorus. Total oxidised nitrogen was also very low (0.20 mg $l^{-1}$). The lake is circumneutral with pH and alkalinity reflecting the local geology which includes alkaline mudstones as well as more acid igneous rocks (Lowe *et al.* 1988). The measured nutrient concentrations suggest no evidence of nutrient enrichment and falls well within the CSM limits for oligo- mesotrophic sites and therefore the site is considered to be in favourable condition with respect to trophic status.

At the time of survey in July 2013, the lake was not stratified and was well oxygenated throughout with DO from 0 - 9.5 m >9.0 mg $l^{-1}$ (Figure 18).

Since the lake has an alkalinity of over 10mg/l, it is not considered acid sensitive. This is confirmed by the high ANC values of over 270 µeq $l^{-1}$.

In summary, water quality in Llyn Gwernan is excellent with no evidence of any problems.

| Determinand | Dec 5th | Feb 25th | Jul 4th | Oct 5th | Mean |
|---|---|---|---|---|---|
| pH | 7.96 | 6.77 | 7.3 | 7.37 | **7.16** |
| Cond | 77.1 | 61.4 | 65 | 65 | **67.1** |
| Alk (Gran) | 11.9 | 11 | 14.2 | 15.2 | **13.1** |
| SRP | 1.6 | <1.0 | <1.0 | <1.0 | **<1.1** |
| TP | 5.7 | 7 | 8.9 | 8.1 | **7.4** |
| Chl a | 1.1 | 1.1 | 3.7 | 4.7 | **2.7** |
| TON | 0.344 | 0.399 | 0.0198 | 0.0317 | **0.20** |
| $Na^+$ | 5.54 | 5.4 | 5.25 | 5.41 | **5.40** |
| $K^+$ | 0.608 | 0.456 | 0.307 | 0.231 | **0.40** |
| $Mg^{2+}$ | 1.02 | 0.904 | 1.2 | 1.32 | **1.11** |
| $Ca^{2+}$ | 4.92 | 4.67 | 5.54 | 5.98 | **5.28** |
| $Cl^-$ | 8.33 | 8.38 | 8.7 | 8.6 | **8.50** |
| $SO4^{2-}$ | <10 | <10 | <10 | <10 | **<10** |
| $SiO_2$ | 4.3 | 3.94 | 0.449 | 2.01 | **2.67** |
| Sus. Solids | <3.0 | <3.0 | <3.0 | <3.0 | **<3.0** |
| Labile Al | 14 | 8.4 | 4.3 | 4.08 | **7.7** |
| DOC | 2.82 | 1.69 | 2.92 | 3.47 | **2.73** |
| ANC-I (ionic) | | | | | **285.3** |
| ANC-C (Cantrell) | | | | | **273.8** |

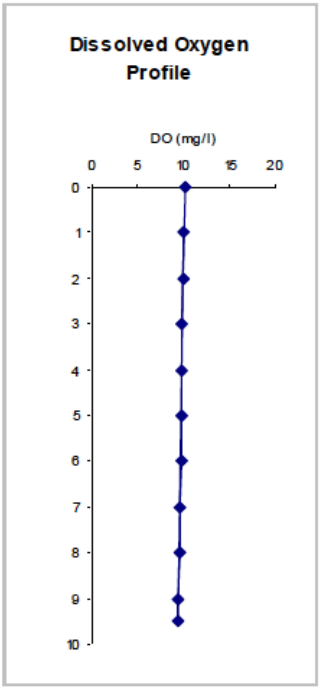
Table 26 Water chemistry data for Llyn Gwernan (for units see methodology)

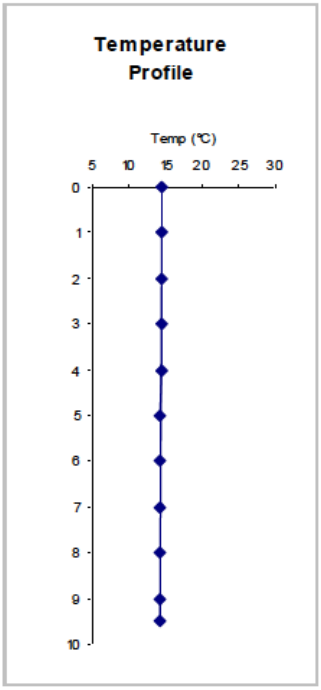
Figure 18 Dissolved oxygen (DO) profile for Llyn Gwernan (03/07/2013).

**Dissolved Oxygen Profile**

| | |
|---|---|
| GPS Location | SH7042115977 |
| Maximum Depth (m) | 9.5 m |
| Secchi Depth (cm) | 310 cm |
| Notes: | |

| Depth (m) | DO (mg/l) | Temp (°C) |
|---|---|---|
| 0 | 10.1 | 14.6 |
| 3 | 9.86 | 14.5 |
| 4 | 9.84 | 14.4 |
| 5 | 9.78 | 14.3 |
| 6 | 9.76 | 14.3 |
| 7 | 9.69 | 14.2 |
| 8 | 9.66 | 14.2 |
| 9 | 9.43 | 14.2 |
| 9.5 | 9.35 | 14.2 |
| 1 | 10.06 | 14.6 |
| 2 | 9.95 | 14.5 |




## Hydrology

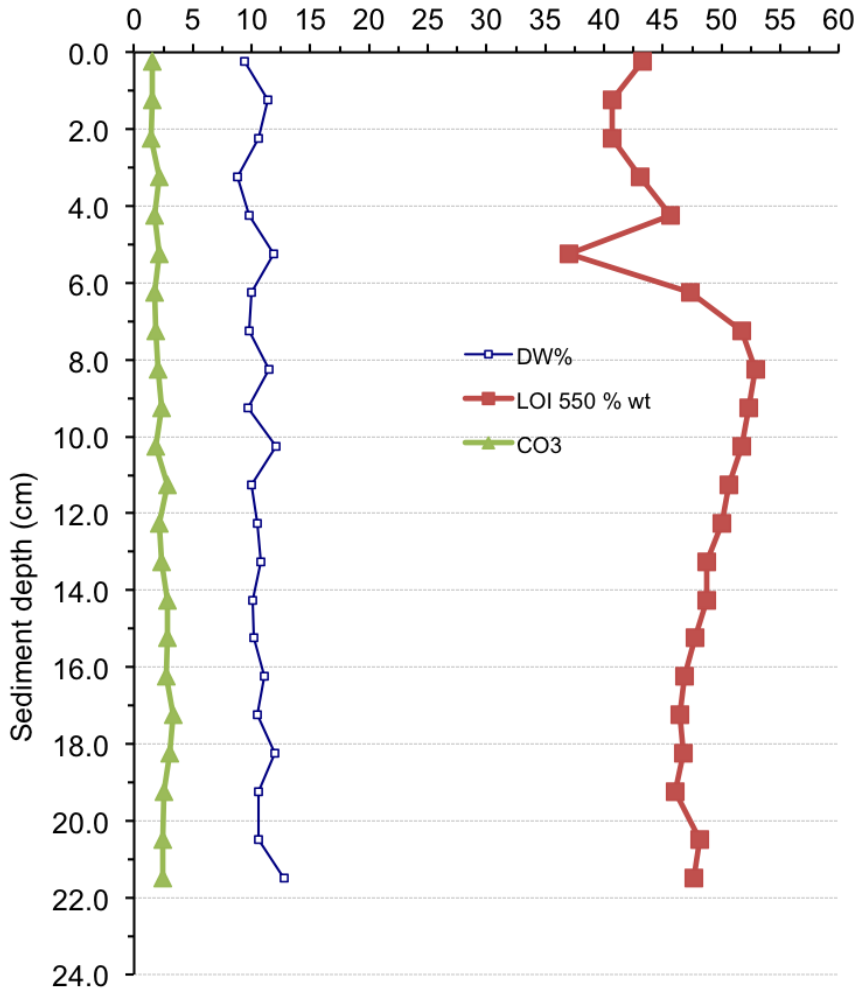
The lake has a small surface inflow stream entering on the edge of the coniferous woodland on the northeast side. This stream drains a relatively small area to the east and southeast of the lake, including the lower slopes of the Cadair Idris massif. The steep slopes to the north and south of the site are also likely to contribute significant surface flow inputs during heavy rain. The outflow at the southwest end passes through an area of wetland (the site of the deepest Holocene deposits (Lowe *et al.* 1988)) and forms a tributary of the Afon Gwynant which flows north to the Mawddach Estuary. The lake outflow is under natural control.

## Lake substrate and sediment loads

The littoral zone is comprised of a range of substrates including areas of boulders, cobbles and gravels  along the north and south shores, with more organic peat and fine silts aound the western and eastern ends. More consolidated sediments and silts occur at depths greater than 1.

A 22 cm sediment core (UKAT4) was collected from the deep point and analysed for organic content. The results show the sediments to be relatively organic (40-50% by weight) throughout the length of the core. There is a distinct trough in the LOI data at 5-5.5 cm (Figure 19), possibly as a result of inwash caused by the recent engineering work to re-grade the access path from the hotel. Without sediment dating this remains purely speculative.

Figure 19 Physical characteristics from core UKAT4 (Llyn Gwernan) DW = dry weight; LOI = loss on ignition, CO3 = (carbonate content)




## Indicators of local distinctiveness

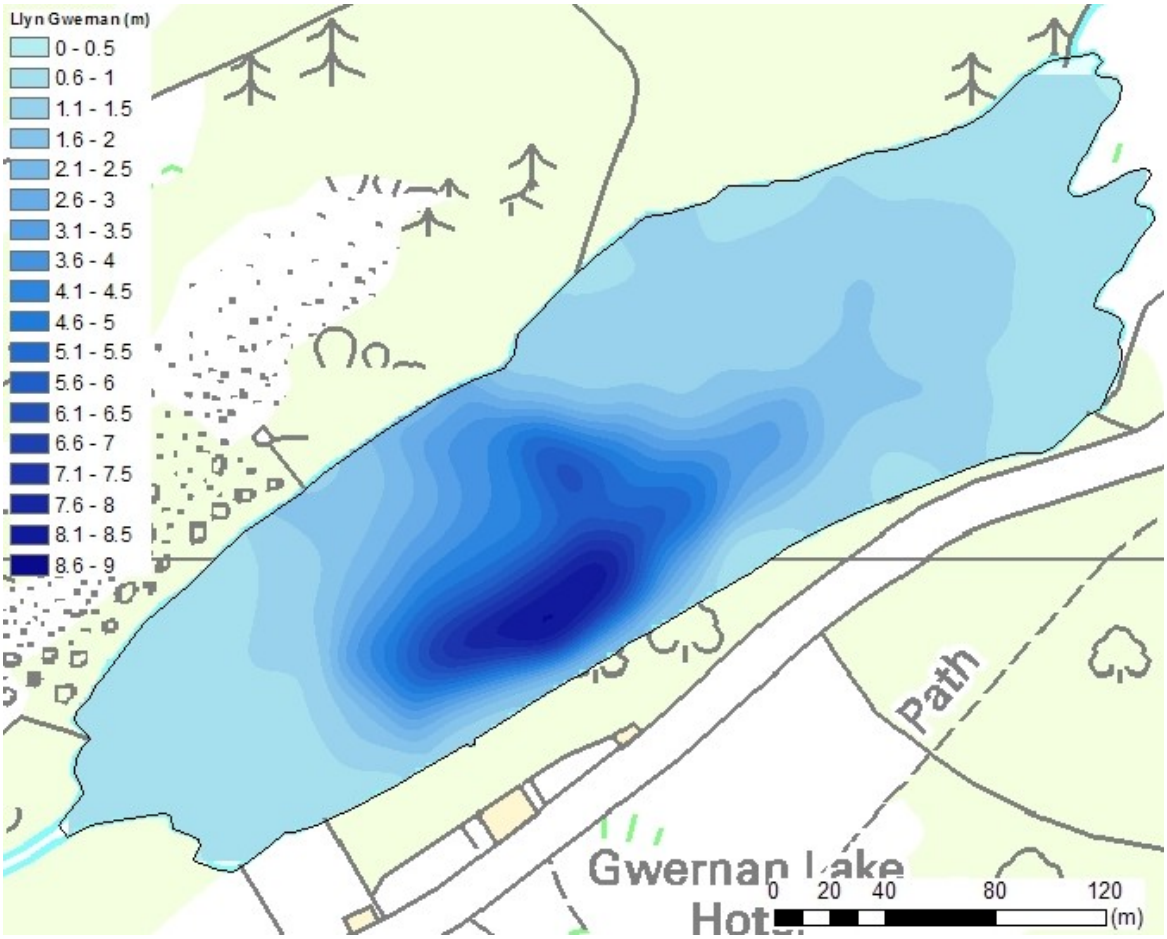
*Potmogeton alpinus* is Critically Endangered in Wales (Dines 2008) with only 4 recorded sites, inclusive of Llyn Gwernan. The population in Llyn Gwernan appears to be large and stable, consisting in 2013 of many hundreds of shoots recorded at different locations throughout much of the lake (Figure 17). Llyn Gwernan almost certainly represents the largest Welsh population.

## Bathymetry

Llyn Gwernan is a shallow lake (mean depth 2.00 m) with only a very small area of deeper water (9.75 m) lying off the south shore approximately 25 m to the northwest of the hotel jetty (Figure 20). The southwest end of the lake is mostly less than 1.0 m deep and dominated by extensive beds of *Nuphar lutea* and *Nymphaea alba* as well as *Potamogeton natans.* The shallow north-eastern part of the lake had a mixed flora including emergent stands of *Schoenopletus lacustris* in open water. The lake bed slopes very steeply around the central deep point.

The original shape of the lake basin is very different according to Lowe *et al.* (1988) with the deepest sediment deposits (14 m below the current bog surface) around the current outflow at the southeast end.

Figure 20 Bathymetric map of Llyn Gwernan, December 2012




## Palaeolimnological evidence

A 22 cm sediment core (ATUK4) was taken from the deep point at SH7044015992 using a Renberg gravity corer. The core was sliced at 1 cm intervals in the field and analysed for dry weight, organic content and carbonate content. The core has not been dated. The physical analysis of the core is discussed above and presented in Figure 19.

The diatom flora is dominated by benthic taxa, consistent with the lake being shallow and having clear water. Both the surface sediments and the basal sample were dominated by *Achnanthes minutissima* and species turnover between the two samples was relatively low, with squared chord distance (SCD) between the samples of 0.45 and therefore not significant (Table 27).

| Sample Code | Depth (cm) | 2012/13 mean pH | DI-pH | 2012/13 mean TP | DI-TP | SCD |
|---|---|---|---|---|---|---|
| UKAT4-00 | 0 | 7.16 | 6.65 | 7.4 | 7.2 | 0.43 |
| UKAT4-22 | 22 | | 6.85 | | 8.1 | 0.00 |

Table 27 Results of Llyn Gwernan sediment core analysis

Reconstructions of diatom-inferred pH (DI-pH) were produced using the SWAP training set (RMSEP = 0.32 pH units). Fossil assemblages from both samples were dominated by benthic species typical of oligotrophic waters. As a result, DI-pH inferred slightly acid conditions with little change over the time period covered by the core. The surface sediment assemblage estimates current pH to be only very slightly lower than measured values.

Reconstructions of diatom-inferred TP (DI-TP) show no significant change in modelled TP from the core bottom and top (7.2 to 8.1 $\mu gl^{-1}$). There were no analogue problems with the core samples, with fossil assemblages being well represented in the NW European training set. The current annual mean TP based on quarterly water samples was 7.4 $\mu g\ l^{-1}$ and therefore the diatom model gives a good estimate of current conditions and there is no evidence of any enrichment at Llyn Gwernan.

In summary, there has been very little floristic change in the sediment core diatoms from Llyn Gwernan and the fossil diatom assemblages indicate very little change in the water quality between the core top and bottom. High resolution diatom analysis and radiometric dating of the upper sediments would be beneficial to understanding the impact of atmospheric deposition and any changes in land management over the past 80 years.

## Site condition summary and overview

Llyn Gwernan is in **unfavourable condition** with **high confidence** due to the presence of non-native invasive species. The habitat is most closely aligned to the mesotrophic lake type and the site supports a species rich aquatic macrophtye flora, including 8 characteristic mesotrophic species. It does not have the requisite three species of broadleaved *Potamogeton* species, but this target has been relaxed for the forthcoming revision of the CSM Guidance and therefore the site is considered favourable with respect to its native flora. The lake is classified as unfavourable due to the high frequency of *Elodea canadensis* (50%) as well as the more recently introduced *E. nuttallii* (10%) which place the site at high risk of deterioration due to the competitive nature of these introduced species.

Despite a high frequency of *Elodea* spp. the site has a diverse aquatic flora, which includes *Potamogeton alpinus,* a species listed as critically endangered in Wales (Dines 2008). In addition the aquatic flora is well distributed throughout the site, and typical vegetation zones are evident with water depth with plants recorded to a maximum depth of 4.0 m. The majority of vegetated sample points also had at least one characteristic species present

Water quality at the site is also excellent. The mean annual TP in 2012/3 lies well within the recommended upper limit for mesotrophic lakes and there was no evidence of acidification or eutrophication within the site.

The majority of the catchment to the south is low intensity upland grazing with a small area of improved grazing lying to the east. Management of these areas should remain at low intensity, with inputs of fertilizer and/or manure kept to a minimum to avoid nutrient run-off to the lake. The coniferous forest on the steep slopes of the northern shore pose a potential risk to the site if it is to be harvested and this should not be done without a full environmental impact assessment conducted to include specific mitigation of sediment and nutrients entering the lake. Other potential nutrient sources to the lake from the wastewater and sewerage facilities from the hotel and neighboring dwelling should undergo regular assessment to ensure no effluent is entering the lake.

There is evidence that the site once supported *Potamogeton perfoliatus* (Seddon 1972), but without additional evidence of other target species ever having been present at the site, we consider it justifiable to classify the site as favourable with less than 3 requisite *Potamogeton* species present. There is no geographical limit to these species reaching the site, *P. gramineus, P. perfoliatus* and *P. praelongus* are all present in Llynnau Cregennen less than 5 km away. The analysis of plant macrofossil remains and a more extensive search of historic records would be of benefit in defining site specific targets for the lake.

The current assessment of unfavourable condition is driven by one factor; the prevalence of *Elodea* spp. The presence of *Elodea canadensis* at 50% frequency automatically places a mesotrophic lake in unfavourable condition. Similarly, a new occurrence of *E. nuttallii* at greater than 5% frequency is deemed unfavourable (JNCC 2005). In this case further evidence is required to assess the stability of the populations of these species in order to ascertain if the site can be considered favourable.

Overall, Llyn Gwernan is a good example of a shallow mesotrophic lake with a species rich flora and very high water quality. Despite this, it fails to achieve the favourable condition targets for mesotrophic lakes due to the presence of non-native species and is therefore classified as unfavorable with high confidence. At least one additional survey within the next 5 years (before 2019) is required to provide evidence of the population stability of *Elodea* spp. Additional evidence of the past flora would also help to set informed site specific targets for the lake.

| Water Body | Status | Reason(s) for failure | Comments |
|---|---|---|---|
| Llyn Gwernan | **Unfavourable (high confidence)** | High frequency of *E. canadensis* (50%) Presence of *E. nuttallii* (10%) | Llyn Gwernan has excellent water quality and clarity and supports a species-rich, oligo-mesotrophic macrophyte flora. The flora shows characteristic zonation with depth and aquatic plants extend to a maximum depth of 4 m. The site shows no evidence of significant degradation and current catchment management poses low threat to the site (risk increased by forestry operations). *Elodea* spp. require further monitoring to assess population stability. The assessment would benefit from site specific targets being set with respect to the past flora. |

Table 28 Llyn Gwernan overview

## Recommendations for monitoring and management:

The high water quality suggests that current catchment management has relatively little negative impact on the lake. Any agricultural improvement within the catchment including drainage, fertilizer use and manure spreading could place the site at risk and should be avoided. The area of forestry on the steep slopes rising from the north shore pose a potential threat to the lake if felling and replanting work is carried out. It is advised than no forestry operations should be undertaken without a full impact assessment of the potential threats of sediment and nutrient inputs to the lake.

The only other potential threat of nutrient pollution comes from the Hotel and neighbouring house. It is recommended that the current sewerage and wastewater disposal is assessed on a regular basis to ensure correct function and environmental compliance, and that the biodiversity importance of the lake is communicated to the owners.

Angling at the site is limited by the availability of shore access and boats and therefore poses minimal impact to the site. We would recommend that the stocking of non-native fish species (e.g. rainbow trout) is minimised and the site promoted and managed as a natural fishery.

High water quality and clarity are the key factors in maintaining the favourable status of the site. A minimum of quarterly (or ideally monthly) water quality monitoring is recommended to ascertain any directional change in water quality and provide an

early warning of any deterioration to the site. The site would also benefit from regular (every 3 years recommended) macrophyte surveys to ascertain any shifts in the population of *Potamogeton alpinus* and to monitor the extent and frequency of *Elodea species* within the site.

Llyn Gwernan fails to meet the full species requirement for mesotropic lakes set out in the CSM guidance (JNCC 2005). This, and future assessments would benefit from a better knowledge of the past flora at the site in order that site specific species targets can be set. Analysis of dated lake sediments for plant macrofossils is one technique that can be used to establish a baseline species list for the site. The technique also enables any observed species shifts to be linked with other environmental factors, e.g. increased sedimentation rates, changes in inferred chemistry, afforestation etc.

The following recommendations are based on the evidence collected for this report:

- Monitor water quality – minimum of quarterly sampling.
- Work with local land owners to ensure any changes to land management, particularly deforestation / re-planting, are communicated to NRW for approval.
- Monitor the aquatic flora every 3 years and identify any trends in the populations of *P. alpinus* and *Elodea* spp.
- Ensure local wastewater and sewage effluent receives appropriate treatment and facilities are correctly maintained.
- Undertake plant macrofossil analysis to establish the pre-disturbance baseline flora in the lake.

## CSM Database output

### Site Condition Assessment: Llyn Gwernan (03/07/2013)

| Lake Details | | Survey Details | | |
|---|---|---|---|---|
| Lake Name | Llyn Gwernan | Survey Date | 03/07/2013 | |
| SSSI Name | | Surveyors | BG, JoS & ST | |
| SAC Name | | Shore Surveys | 4 | out of |
| Grid Ref | SH704160 | Wader Surveys | 4 | 4 |
| WBID | 36021 | Boat Surveys | 4 | sections |

Site Notes:

Survey Notes:
Site mostly shallow, but with deep area (9.5 m) close to hotel jetties. *P. alpinus* common.

#### Section Summaries

| | | | |
|---|---|---|---|
| **Section** | **1** | Maximum depth of colonisation (cm) | - |
| | | Compass bearing of boat transect (°) | 230 ° |
| | | Lateral distance from waters edge to 75cm depth (m) | 4 m |
| | | Notes: Plant to max depth of sectio | |
| **Section** | **2** | Maximum depth of colonisation (cm) | 320 cm |
| | | Compass bearing of boat transect (°) | 300 ° |
| | | Lateral distance from waters edge to 75cm depth (m) | 4 m |
| | | Notes: | |
| **Section** | **3** | Maximum depth of colonisation (cm) | - |
| | | Compass bearing of boat transect (°) | 130 ° |
| | | Lateral distance from waters edge to 75cm depth (m) | 3 m |
| | | Notes: Plants to max depth of transect | |
| **Section** | **4** | Maximum depth of colonisation (cm) | 340 cm |
| | | Compass bearing of boat transect (°) | 360 ° |
| | | Lateral distance from waters edge to 75cm depth (m) | 3 m |
| | | Notes: Steeply shelving after 1 m | |

#### Section Locations

| | | Shore Survey GPS Co-ords | | Boat Survey GPS Co-ords | |
|---|---|---|---|---|---|
| | | start | end | start (shore) | end (lake) |
| **Section** | **1** | SH7065316134 | SH7056116143 | SH7059816128 | SH7054916069 |
| **Section** | **2** | SH7055216004 | SH7044515957 | SH7049915999 | SH7049216008 |
| **Section** | **3** | SH7036216046 | SH7028215965 | SH7032516010 | SH7038016000 |
| **Section** | **4** | SH7033115899 | SH7043515950 | SH7037015927 | SH7037215953 |

#### Section Photos

| | | Start of Section | Whole Section | End of Section |
|---|---|---|---|---|
| **Section** | **1** | 65 | 67 | 66 |
| **Section** | **2** | 68 | 69 | 70 |
| **Section** | **3** | 76 | 77 | 78 |
| **Section** | **4** | 81 | 80 | 79 |

## Species Abundance - Boat Survey

| | |
|---|---|
| Total number of sample plots | 80 |
| Total number of vegetated sample plots | 49 |

| Plant Species | Occurrence *n* | Occurrence % |
|---|---|---|
| *Callitriche hamulata* | 1 | 2 |
| *Chara virgata* | 1 | 2 |
| *Chara virgata var. annulata* | 3 | 6 |
| *Eleogiton fluitans* | 2 | 4 |
| *Elodea canadensis* | 28 | 57 |
| *Elodea nuttallii* | 5 | 10 |
| *Isoetes lacustris* | 15 | 31 |
| *Juncus bulbosus* | 6 | 12 |
| *Littorella uniflora* | 11 | 22 |
| *Lobelia dortmanna* | 11 | 22 |
| *Myriophyllum alterniflorum* | 2 | 4 |
| *Nitella opaca* | 15 | 31 |
| *Nitella translucens* | 14 | 29 |
| *Nuphar lutea* | 21 | 43 |
| *Nymphaea alba* | 6 | 12 |
| *Phragmites australis* | 5 | 10 |
| *Potamogeton alpinus* | 11 | 22 |
| *Potamogeton natans* | 4 | 8 |
| *Schoenoplectus lacustris* | 2 | 4 |
| *Sparganium angustifolium* | 39 | 80 |

## Species Abundance - Wader Survey

| | |
|---|---|
| Total number of sample plots | 80 |
| Total number of vegetated sample plots | 76 |

| Plant Species | Occurrence *n* | Occurrence % |
|---|---|---|
| *Carex rostrata* | 11 | 14 |
| *Chara virgata* | 3 | 4 |
| *Elodea canadensis* | 34 | 45 |
| *Elodea nuttallii* | 8 | 11 |
| *Equisetum fluviatile* | 8 | 11 |
| *Fontinalis antipyretica* | 2 | 3 |
| *Isoetes lacustris* | 24 | 32 |
| *Juncus articulatus* | 5 | 7 |
| *Juncus bulbosus* | 8 | 11 |
| *Littorella uniflora* | 39 | 51 |
| *Lobelia dortmanna* | 20 | 26 |
| *Mentha aquatica* | 6 | 8 |
| *Myriophyllum alterniflorum* | 8 | 11 |
| *Nitella opaca* | 12 | 16 |
| *Nitella translucens* | 3 | 4 |
| *Nuphar lutea* | 10 | 13 |
| *Nymphaea alba* | 15 | 20 |
| *Phragmites australis* | 12 | 16 |
| *Potamogeton alpinus* | 11 | 14 |
| *Potamogeton natans* | 17 | 22 |
| *Schoenoplectus lacustris* | 24 | 32 |
| *Sparganium angustifolium* | 27 | 36 |
| *Utricularia minor* | 1 | 1 |

Note: Species abundance % = ((number of plots / total number of vegetated sample plots) * 100)

## Plant Scores

**Total plant species** 36 **Filamentous algae (%)** 1.2% WADER 3.5% BOAT
**Total plant cover (%)** 181.76

**S U R V E Y S C O R E S**

| PLANT SPECIES | PERIMETER | WADER | BOAT | COVER % | DAFOR | ABUNDANCE |
|---|---|---|---|---|---|---|
| *Sparganium angustifolium* | 0 | 0.0723 | 0.1889 | 22.5 | F | 3 |
| *Elodea canadensis* | 0 | 0.1003 | 0.1253 | 17.54 | F | 3 |
| *Schoenoplectus lacustris* | 0.5 | 0.0715 | 0.0083 | 16.9 | F | 3 |
| *Juncus articulatus* | 0.4375 | 0.0166 | 0 | 11.77 | F | 3 |
| *Nuphar lutea* | 0 | 0.0239 | 0.0893 | 10.12 | F | 3 |
| *Littorella uniflora* | 0 | 0.1164 | 0.0333 | 9.15 | O | 2 |
| *Isoetes lacustris* | 0 | 0.061 | 0.0511 | 8.16 | O | 2 |
| *Carex rostrata* | 0.25 | 0.028 | 0 | 7.65 | O | 2 |
| *Nitella translucens* | 0 | 0.0068 | 0.0697 | 7.31 | O | 2 |
| *Nitella opaca* | 0 | 0.0331 | 0.0467 | 6.32 | O | 2 |
| *Lobelia dortmanna* | 0 | 0.0546 | 0.0342 | 6.15 | O | 2 |
| *Mentha aquatica* | 0.1875 | 0.0174 | 0 | 5.56 | O | 2 |
| *Phragmites australis* | 0.0625 | 0.0405 | 0.0178 | 5.37 | O | 2 |
| *Juncus effusus* | 0.2125 | 0 | 0 | 5.31 | O | 2 |
| *Potamogeton alpinus* | 0 | 0.0278 | 0.0348 | 4.87 | R | 1 |
| *Nymphaea alba* | 0 | 0.0488 | 0.0242 | 4.86 | R | 1 |
| *Potamogeton natans* | 0 | 0.0429 | 0.0157 | 3.72 | R | 1 |
| *Juncus bulbosus* | 0.025 | 0.0179 | 0.0195 | 3.47 | R | 1 |
| *Ranunculus flammula* | 0.125 | 0 | 0 | 3.12 | R | 1 |
| *Elodea nuttallii* | 0 | 0.019 | 0.019 | 2.85 | R | 1 |
| *Equisetum fluviatile* | 0.0625 | 0.0173 | 0 | 2.43 | R | 1 |
| *Caltha palustris* | 0.0875 | 0 | 0 | 2.19 | R | 1 |
| *Potentilla anserina* | 0.0875 | 0 | 0 | 2.19 | R | 1 |
| *Galium palustre* | 0.0625 | 0 | 0 | 1.56 | R | 1 |
| *Potentilla palustris* | 0.0625 | 0 | 0 | 1.56 | R | 1 |
| *Valeriana dioica* | 0.0625 | 0 | 0 | 1.56 | R | 1 |
| *Myriophyllum alterniflorum* | 0 | 0.022 | 0.0043 | 1.53 | R | 1 |
| *Eleogiton fluitans* | 0.025 | 0 | 0.0078 | 1.4 | R | 1 |
| *Chara virgata* | 0 | 0.0104 | 0.0042 | 0.94 | R | 1 |
| *Chara virgata var. annulata* | 0 | 0 | 0.0072 | 0.72 | R | 1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Callitriche hamulata* | 0 | 0 | 0.0062 | 0.62 | R | 1 |
| *Epilobium hirsutum* | 0.025 | 0 | 0 | 0.62 | R | 1 |
| *Senecio aquaticus* | 0.025 | 0 | 0 | 0.62 | R | 1 |
| *Hydrocotyle vulgaris* | 0.025 | 0 | 0 | 0.62 | R | 1 |
| *Fontinalis antipyretica* | 0 | 0.0082 | 0 | 0.41 | R | 1 |
| *Utricularia minor* | 0 | 0.0018 | 0 | 0.09 | R | 1 |

## 5.5. Llyn Mair

Annex 1 type: H3130: Oligo-mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the Isoëto-*Nanojuncetea*.

### 5.5.1. Site description

Summary characteristics for Llyn Mair

| | |
|---|---|
| Name: | Llyn Mair |
| County: | Gwynedd |
| WBID: | 34668 |
| Grid reference: | SH652412 |
| OS Grid reference (X,Y): | 265226,341231 |
| Latitude / Longitude | N52°57.09',W004°0.45' |
| Altitude (m): | 79 |
| Maximum recorded depth (m): | 2.60 |
| Mean depth (m): | 1.00 |
| Lake volume ($m^3$): | 60986 |
| Surface area – UKLakes (ha): | 6.1 |
| Surface area – measured (ha) | 6.1 |
| Perimeter of lake (km): | 1.2 |
| Shoreline Development Index (SDI): | 1.339 |
| WFD alkalinity based typology: | Low Alkalinity, Shallow (LA, S) |
| Phase 1 habitat type: | Standing water: Oligotrophic: G1.3 |
| Survey Date: | 28 June 2013 |

Llyn Mair is a very shallow, clear-water oligotrophic lake lying to the southwest of Blaenau Ffestiniog. The lake as it stands today is artificial, being created by a low stone dam across the Afon Rhyd. The lake was reportedly built in the 1880's by the Oakeley family, the owners the Plas Tan y Bwlch Estate, to provide a head of water to power the estate flour and saw mills (Snowdonia National Park Authority website 2014). In addition, the water was piped to a power plant at the rear of the estate house where is was used to generate electricity, making Plas Tan y Bwlch one of the first houses in North Wales to be lit by its own hydroelectric power. The hydro-electric plant was used until 1928, after which the house linked into mains electricity. In 2013, a new turbine was installed, which will again supply the Plas with up to 70% of its electricity, the water again coming from Llyn Mair.

Although artificially raised, early maps (e.g. OS 1840, accessed through Vision of Britain 2014) suggest a small water body was present, the extent of which was approximately half the size of the current lake. The woodlands surrounding the lake are protected as part of the Meirionnydd Oakwoods and Bat Sites SAC which form a particularly good example of sessile oak woodlands, include many rare bryophytes and is a breeding area for lesser horseshoe bats. Higher up in the catchment to the north and west of the lake the steep slopes are planted with coniferous forest. There is a small reservoir, Llyn Hafod-y-llyn, upstream of Llyn Mair to the west, and to other lakes to the north; Llyn y Garnedd (reservoir) and Llyn y Garnedd Uchaf to the north.

### 5.5.2. Condition Assessment and Discussion

Table 29 Condition Assessment Summary Table for Llyn Mair

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | None |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise) | **X** | Only 2 characteristic *Littorelletea* spp in 2013: *Isoetes echinospora & Littorella uniflora* |
| | No loss of characteristic species (see Box 2) | **NA** | No previous data |
| | ≥ 6/10 vegetated sample spots (boat / wader survey) have ≥ 1 characteristic spp. | **X** | 12% of vegetated sample spots comply (18% wader, 5% boat) |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | None recorded |
| | Benthic and epiphytic filamentous algae <10%. | ✓ | Filamentous algae were present, but well below 10 % cover. |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (site specific) | **X** | Maximum depth only 2.6 m and characteristic *L . uniflora* & *I. echinospora* to localised to determine good zonation. Flora doinated by *J. bulbosus* and *I. fluitans* to maximum depth. |
| | Maximum depth distribution should be maintained | ✓ | $Z_{max}$ (recorded) = 2.6 m, $Z_s$ = 2.00 m, $Z_v$ = 2.6 m. |
| | At least present structure should be maintained | **NA** | No previous data |
| **Water quality** | Stable nutrients levels: TP target / limit: Oligotrophic = 10 µg $^{-1}$ | **✓(?)** | TP (mean 2012/13) = 8.8 µg $l^{-1}$ (range 5.1 – 13.3) $NO_3$-N = 0.32 mg $l^{-1}$ Values are high for oligotrophic waters |
| | Stable pH values: pH ~ 5.5 – circumneutral | ✓ | Mean pH 2012/13 = 6.23 (Range 5.74 – >7.00). |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 mg $l^{-1}$) | ✓ | 8-10 mg $l^{-1}$ from 0 – 2.5 m. Water column mixed |
| | No excessive growth of cyanobacteria / green algae | ✓ | None noted, and low chl-a values (mean 1.9 µg $l^{-1}$, range <0.5 – 2.8 µg $l^{-1}$) |
| **Hydrology** | Natural hydrological | **X** | Two impounded water bodies |

| Attribute | Target | Status | Comment |
|---|---|---|---|
| | regime | | upstream. Water levels maintained |
| **Lake substrate** | Natural shoreline maintained | ✓? | Mostly natural |
| | Natural and characteristic substrate maintained | ✓? | Sediment core analysis shows an increase in organic material in the upper sediments |
| **Sediment load** | Natural sediment load maintained | ✓ | Appears natural |
| **Indicators of local distinctive-ness** | Distinctive elements maintained at current extent / levels / locations | ✓ | *Isoetes echinospora* is uncommon in Wales. Present, but rare in L. Mair. |
| **Disturbance** | No introduced species | ✓ | None recorded |
| | Minimal negative impacts from recreation and navigation. No fish farming | ✓ | None |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | ✓? | Fossil diatom flora indicates relatively high species turnover between 22 cm and surface, but only a slight increase in modeled TP and pH. |

**Status: ✓ = favourable; X = unfavourable; - = unable to assess**

## Extent

The surface area of the lake is 6.1 ha. There is no evidence of any recent loss of extent of open water.

## Macrophyte community composition and structure

Llyn Mair has an impoverished oligotrophic flora with six aquatic plant species recorded in 2013 of which only two were characteristic species (Table 30). Instead of a typical *Littorelletea uniflorae* flora expected from an oligotrophic lake, the flora was instead dominated by *Juncus bulbosus* (53%) and *Isolepis* (*Eleogiton*) *fluitans* (78%). *Littorella uniflora* was only recorded at 8% of vegetated survey points and *Isoetes* spp. at 6%. While the CSM survey results probably underestimate both characteristic species slightly within the site, they are both nonetheless relatively uncommon in the site. A number of small beds of *Nymphaea alba* were present along the south shore and a larger bed around the northwest margin.

The mapping data recorded a relatively large bed of *L. uniflora* near the outflow at the east end (15% frequency) and although mostly in sparse beds, *Isoetes* was present in 13% of the mapping points (Figure 22). The scarcity and distribution of characteristic species within the site classifies the site as unfavourable with respect to its aquatic flora.

*Isoetes echinospora* was confirmed from fertile material, with those plants examined being mostly rather flaccid in form when removed from the water which is typical of

this species. There were however other *Isoetes* plants without megaspores that had a more rigid appearance and may have been *I. lacustris.* Due to the scarcity of *Isoetes* plants in the site, only a limited number were removed for identification, and only the flaccid plants were found to have mature megaspores; all were confirmed as *I. echinospora.*

| Submerged and floating vegetation | TRS | PLEX | % occurrence (n=118) | DAFOR abundance[7] | Min depth (cm) | Max depth (cm) |
|---|---|---|---|---|---|---|
| *Eleogiton fluitans* | 4 | 3.08 | 78 | D | 25 | 260 |
| ***Isoetes echinospora*** | | **5.38** | **6** | **O** | **50** | **120** |
| *Juncus bulbosus* | 5.3 | 3.08 | 53 | D | 25 | 260 |
| ***Littorella uniflora*** | **6.7** | **4.23** | **8** | **O** | ***25*** | **120** |
| Aquatic mosses | | | 4 | R | 75 | 85 |
| *Nymphaea alba* | 6.7 | 3.08 | 13 | F | 50 | 80 |
| **Average score** | **5.7** | **3.8** | | | | |
| **Species richness** | | | | 6 | | |

Table 30 Aquatic macrophyte community composition for Llyn Mair in June 2013. Characteristic oligotrophic species are highlighted in **bold**.

The current assemblage places the lake into Group C2 as defined by Duigan *et al*. (2006). The TRS (5.7) and PLEX (3.8) scores are consistent with oligotrophic lakes, but the characteristic flora has low cover and is species-poor, and the high frequency of *J. bulbosus* is considered as unfavourable (see below).

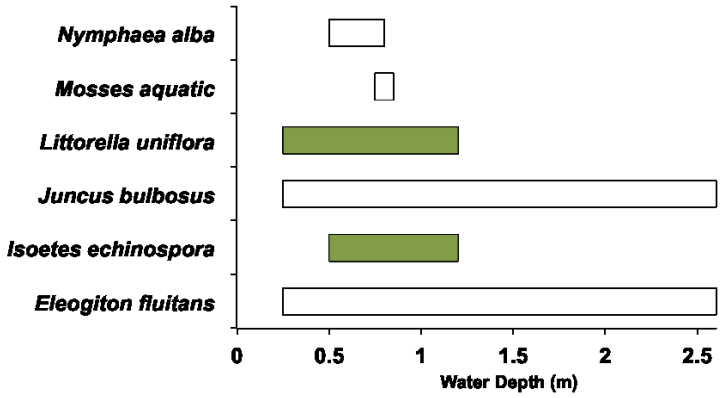



Figure 21. Depth range of the aquatic macrophytes recorded from Llyn Mair; characteristic oligotrophic species are shaded green.

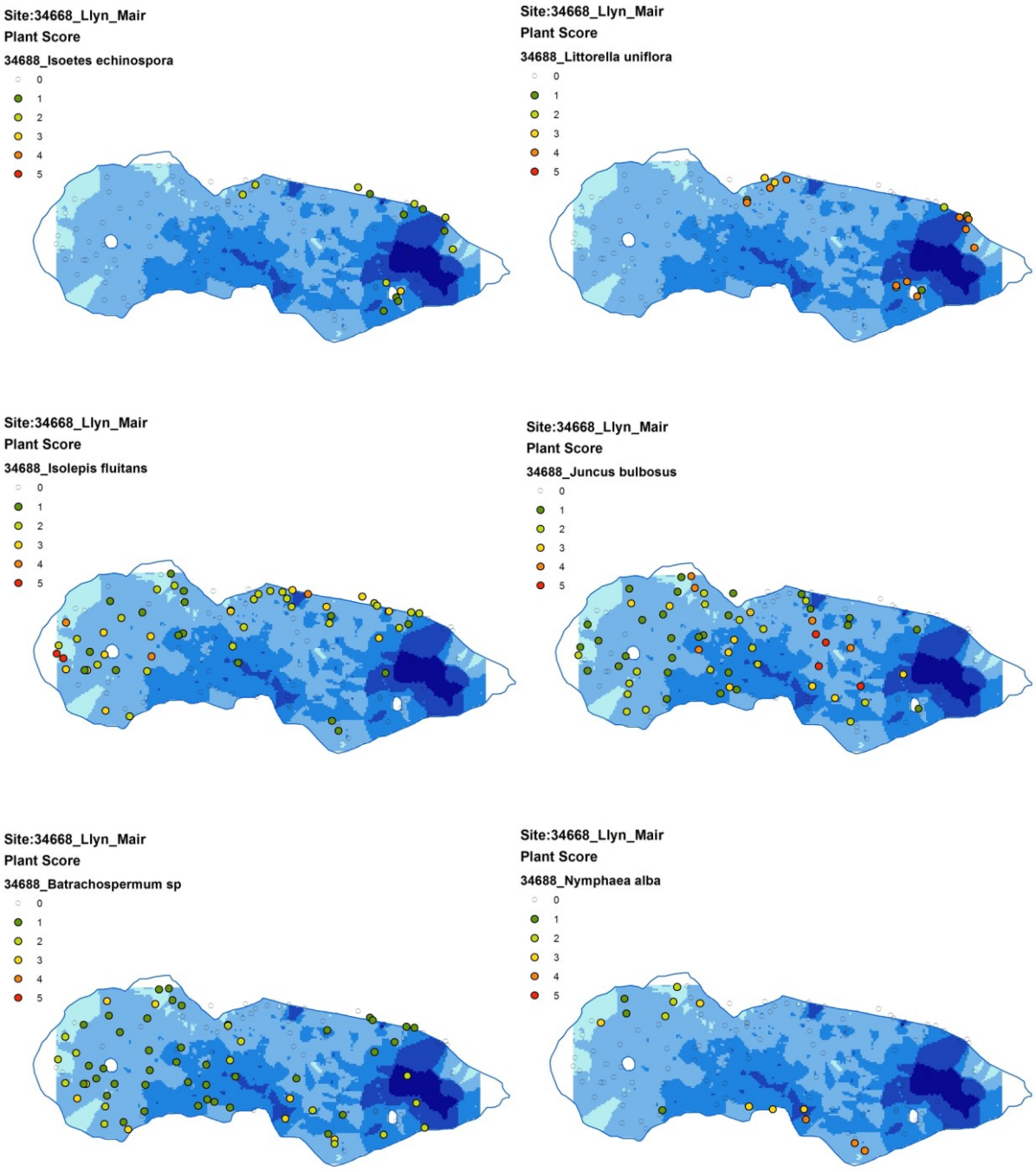
## Negative indicator species

*Juncus bulbosus* was frequent (53%) and where it occurred it was generally at high abundance. The CSM Guideance (JNCC 2005) places an upper frequency threshold of 40% for oligotrophic sites, above which is indicative of increased trophic status.

[7] Based on presence / absence data from all vegetated plots in the wader and boat based surveys. DAFORs are calculated from the total number of occurrences across the wader and boat surveys as a proportion of the total number of vegetated wader and boat survey points.

The site was without any significant growths of filamentous algae. No invasive non-native species were present.

Figure 22 Distribution maps of the aquatic plant species recorded in Llyn Mair




## Water quality

The water chemistry of Llyn Mair is consistent with that of an oligotrophic water body although the mean annual TP concentration (8.8 µg $l^{-1}$) was towards the upper limit for this lake type, and summer and autumn 2013 samples exceeded the 10 µg $l^{-1}$ threshold (Table 31). The geometric mean TP was 8.16 µg $l^{-1}$, which corresponds with High Status using the UK MEI model (Reference = 7 µg $l^{-1}$; High = <9 µg $l^{-1}$). Soluble reactive phosphorus remained very low on all four sampling occasions and

total oxidised nitrogen was low during the summer, but showed slightly elevated concentrations in winter. The measured nutrient concentrations, although within CSM guidelines and therefore favourable, do nonetheless appear to show slight enrichment at the site.

At the time of survey in June 2013, the lake was well oxygenated throughout with DO from 0 - 2.5 m was >8.0 mg $l^{-1}$ (Figure 23), with a mean of 8.92 mg $l^{-1}$. This is equivalent to Good status under WFD and would pass the CSM target.

pH and alkalinity are also typical for oligotrophic lakes; the high pH value recorded in December 2012 is possibly erroneous (see discussion below). ANC values are above those set within revised CSM guidelines (40 µeq $l^{-1}$),. The results suggest the site to be favourable within the CSM guidelines, but "at risk" given that they fall close to the high/good ecological boundary.

| Determinand | Dec 5th | Feb 25th | Jul 4th | Oct 5th | Mean |
|---|---|---|---|---|---|
| pH | 7.97 (?) | 5.74 | 6.42 | 6.92 | 6.23 |
| Cond | 72 | 63 | 65 | 82 | 70.4 |
| Alk (Gran) | 1.1 | 0.544 | 2.54 | 1.62 | 1.5 |
| SRP | <1.0 | <1.0 | 1.2 | 1.1 | <1.0 |
| TP | 5.07 | 5.9 | 13.3 | 11.1 | 8.8 |
| Chl a | <0.500 | 0.78 | 2.8 | 2.1 | 1.9 |
| TON | 0.495 | 0.519 | 0.048 | 0.225 | 0.32 |
| $Na^+$ | 6.81 | 7.63 | 8.72 | 7.12 | 7.57 |
| $K^+$ | 0.649 | 0.573 | 0.512 | 0.38 | 0.53 |
| $Mg^{2+}$ | 0.742 | 0.75 | 0.968 | 0.937 | 0.85 |
| $Ca^{2+}$ | 1.14 | 1.22 | 1.85 | 1.79 | 1.50 |
| $Cl^-$ | 11 | 12.8 | 14.4 | 11.7 | 12.48 |
| $SO4^{2-}$ | <10 | <10 | <10 | <10 | <10 |
| $SiO_2$ | 2.74 | 2.42 | 0.235 | 1.7 | 1.77 |
| Sus. Solids | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 |
| Labile Al | 100 | 78.4 | 24 | 50.7 | 63.3 |
| DOC | 3.23 | 1.95 | 4.04 | 3.43 | 3.16 |
| ANC-I (ionic) | | | | | 51.6 |
| ANC-C (Cantrell) | | | | | 43.3 |

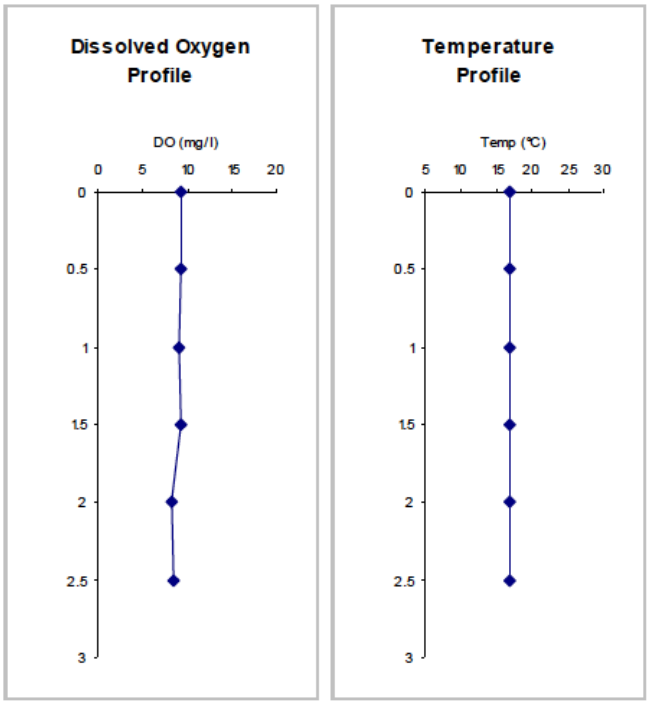
Table 31. Water chemistry data for Llyn Mair (for units see methodology).

Figure 23. Dissolved oxygen (DO) profile for Llyn Mair (28/06/2013).

**Dissolved Oxygen Profile**

| | |
|---|---|
| GPS Location | SH6534341199 |
| Maximum Depth (m) | 2.6 m |
| Secchi Depth (cm) | 200 cm |
| Notes: | |

| Depth (m) | DO (mg/l) | Temp (°C) |
|---|---|---|
| 0 | 9.18 | 16.8 |
| 0.5 | 9.28 | 16.8 |
| 1 | 9.16 | 16.8 |
| 1.5 | 9.18 | 16.8 |
| 2 | 8.33 | 16.8 |
| 2.5 | 8.38 | 16.8 |




## Hydrology

Being artificial, Llyn Mair does not have a natural hydrology. Favourable condition therefore necessitates that the hydrology ensures the site remains in as close to natural conditions as possible with water supply and water level being the key features. Llyn Mair receives water from two primary inflow streams, one from the west and another from the north. The western inflow drains an area of coniferous forest plantation, first into Llyn Hafod-y-llyn, a reservoir of similar age to Llyn Mair, and then the short distance through the Meirionnydd Oakwoods to where it meets the lake. The northern inflow also drains a significant area of coniferous plantation woodland. There is also a tributary which takes water from Llyn y Garnedd (reservoir) and Llyn y Garnedd-uchaf.

Neither of the old reservoirs appear to be used for abstraction and therefore pose very little threat to the natural supply of water to Llyn Mair. Forest operations within the catchment do however pose a potential risk of increased sedimentation to the site via the inflow streams. The outflow issues through two separate points in the stone dam. The current control on the dam appears passive, and the current outtake for the Plas hydro-electric plant was not located. While the current hydrological regime remains under natural control it can be considered as favourable. Any abstraction that impacts the water level of Llyn Mair, or impedes the supply to the lake from up-stream sources should be avoided.

## Lake substrate and sediment loads

The littoral substrates (including around the islands) are comprised of a range of substrates including clays, silts and peats as well as hard substrates from gravel through to areas of bed-rock. In open water, the site has organic-rich silts throughout the basin.

A 22 cm sediment core was collected from the deep point and analysed for dry-weight and organic content. The composition of the lake sediments have changed considerably from the core base to the surface, with a large decrease in dry weight and corresponding increase in organic content observed (Figure 24). The sediment core was not dated and therefore changes cannot be assessed against time.

The high sediment accumulation rates are most likely explained by the inwash from a large catchment area into what is a relatively small and predominantly shallow lake. Furthermore, sediment focusing towards the steeply shelving, small central basin is likely to result in greater deposition in the area from where the core was taken.

The increase in organic matter towards the top of the core suggests increased productivity within the lake and / or increased inwash of organic material from the catchment. The lack of dating on the core means we are unable to place the events within a temporal context, but given the high percentage of coniferous plantation within the catchment it is assumed that this will have resulted in significant inputs of organic matter to the lake, particularly during periods of planting and felling.

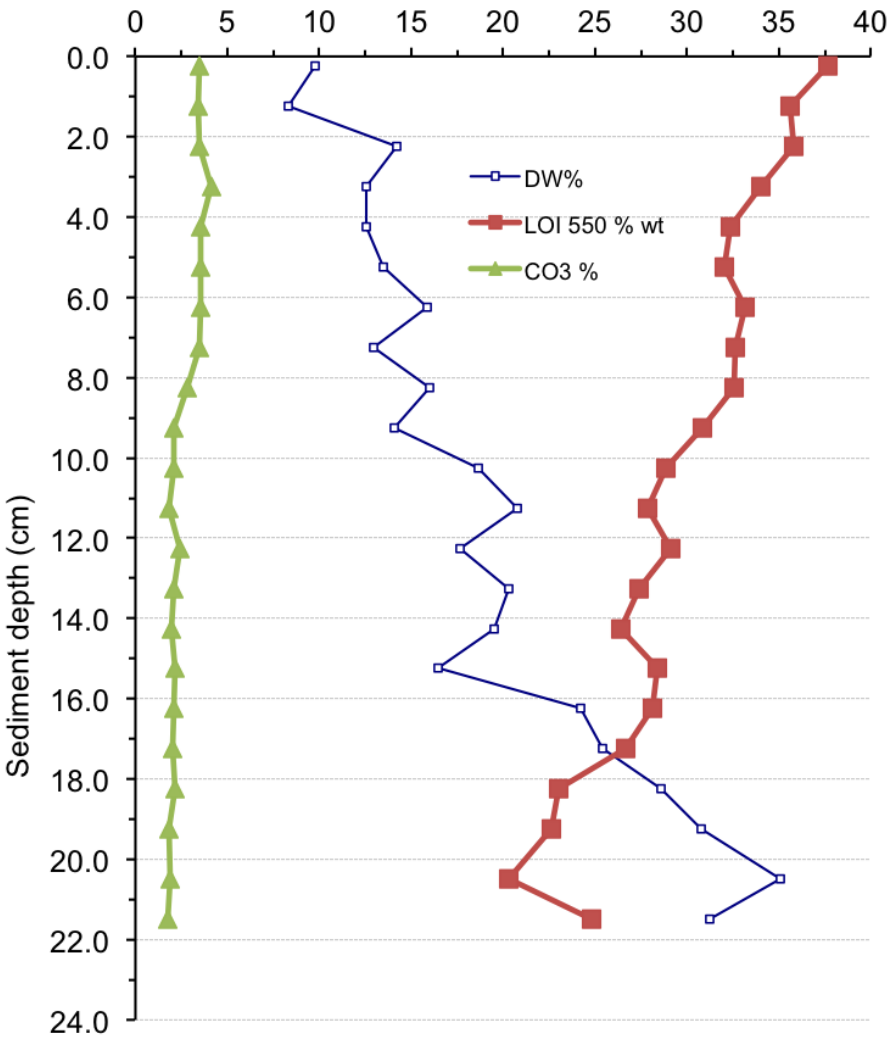



Figure 24 Physical characteristics from core MAIR1 DW = dry weight; LOI = loss on ignition, CO3 = (carbonate content)

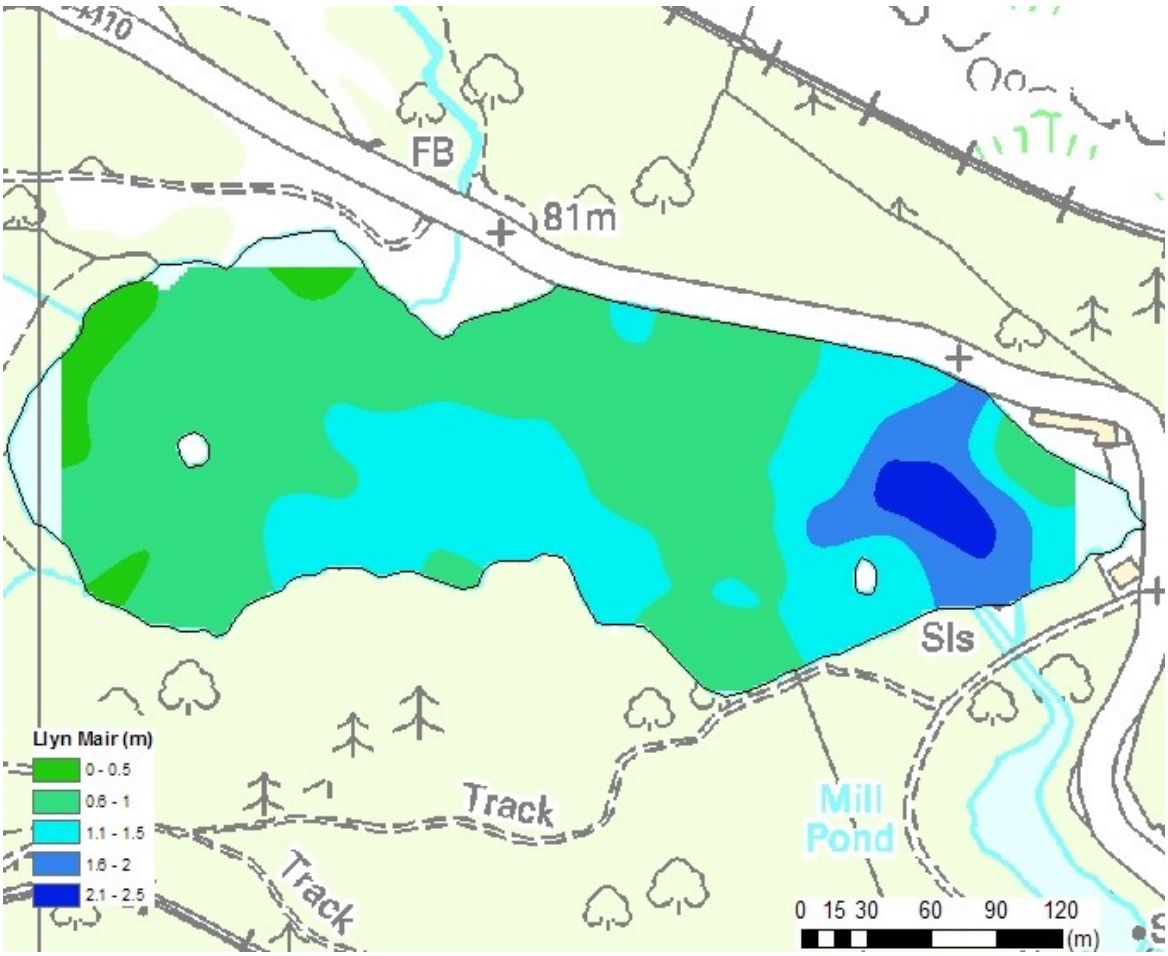
## Indicators of local distinctiveness

*Isoestes echinospora* is uncommon in Wales and its presence at Llyn Mair is therefore of significance. Management of the site should be sympathetic to the requirement of this species, particularly in terms of water quality, clarity and stable water levels.

## Bathymetry

Llyn Mair is a very shallow lake (mean depth 1.00 m) with the deepest area being towards the stone dam at the eastern end of the lake (Figure 25).

Figure 25 Bathymetric map of Llyn Mair, December 2012




## Palaeolimnological evidence

A 22 cm sediment core (MAIR1) was taken from 2.1 m water depth (SH6537541238) using a Renberg gravity corer. The core was sliced at 1 cm intervals in the field and analysed for dry weight, organic content and carbonate content. The physical analysis of the core are discussed above and presented in Figure 24.

Both levels from the sediment core were dominated by periphytic taxa, with a very low representation of planktonic species. The bottom sample was relatively diverse with *Achnanthes minutissima* (9.2%) co-dominant with *Frustulia rhomboides* (8%), *Fragilaria exigua* (8%), *Frustulia rhomboides* var. *saxonica* (7%) and 3 *Eunotia*

species (*E. bilunaris, E. paludosa* and *E. rhomboidea*) at similar abundance. These taxa are associated with slightly acidic, oligotrophic waters.

The top sample was less diverse and had only three species accounting for 76% of the diatoms present. *Fragilaria exigua* (44%) was dominant, with *Peronia fibula* and *Brachysira vitrea* at 20% and 12% respectively. All of these are acidophilous taxa. The SCD dissimilarity scores between the bottom and top samples was 1.26, which indicates significant floristic change.

Reconstructions of diatom-inferred pH (DI-pH) were produced using the SWAP training set. A high percentage of the taxa in the fossil samples were present in the SWAP training set and there were no major analogue problems. The DI-pH results show a slight increase in pH between the core bottom and top with the top sample. The current surface sediment assemblage slightly underestimates the measured pH (Table 32). This may in part be a result of the high pH reading recorded in December 2012. All six pH results returned by the laboratories (NLS Starcross) were high compared to subsequent readings suggesting a calibration error.

Reconstructions of diatom-inferred TP (DI-TP) show an increase in modelled TP from core bottom to top (3.9 to 5.7 µg $l^{-1}$). A high percentage of the taxa in the fossil samples were present in the NW European training set and there were no major analogue problems. The annual mean current TP based on quarterly water samples collected during 2012-13 was 8.8 µg $l^{-1}$ and therefore the diatom model slightly underestimates the current measured value.

In summary, there has been a significant degree of floristic change in the sediment core from Llyn Mair. The diatom species shifts and DI-pH reconstruction results indicate a slight increase in trophic status and also increasing pH.

| Sample Code | Depth (cm) | 2012/13 mean pH | DI-pH | 2012/13 mean TP | DI-TP | SCD |
|---|---|---|---|---|---|---|
| MAIR1-00 | 0 | 6.23 | 5.7 | 8.8 | 5.7 | 1.26 |
| MAIR1-22 | 22 | | 5.3 | | 3.9 | 0.00 |

Table 32 Results of Llyn Mair overview sediment core analysis

## Site condition summary and overview

Llyn Mair is in **unfavourable condition** with **high confidence**. The lake supports only two characteristic aquatic macrophyte species and these are relatively rare in the site. The current flora is dominated by *Eleogiton fluitans* and *Juncus bulbosus*, the latter being indicative of enrichment at the site. It is possible that the relatively species-poor community is due to the artificial and modified nature of the lake.

The mean annual TP in 2012/3 lies just within the recommended upper limit for oligotrophic lakes and palaeolimnological evidence suggests the site to have become enriched over the timespan covered by the sediment core. This is supported by the

increased organic content of the sediments towards the top of the core. Although the site is marginal with respect to ANC boundaries, the current pH and diatom-inferred pH suggest the site to have become slightly less acid over time.

The high percentage of coniferous plantation within the Llyn Mair catchment is likely to be the major driver of change at the site. The impact of disturbance during forest planting is well known to rapidly increase sediment loads to lakes within the catchment (Battarbee *et al.* 1985) and heavily afforested catchment have also been demonstrated to cause increased TP, TN and DOC to lakes within peat catchments (Drinan *et al.* 2013). Drinan also found the greatest increases in nutrients occurred in catchments where clear felling had occurred, thus placing Llyn Mair at continued risk during timber harvesting.

The palaeolecological analysis shows major changes within the diatom flora between the base and top of the sediment core and infers aslight increase in trophic status at the site. The structure of the lake sediments has also changed significantly over time, from more mineral sediments at the base of the core, to organic rich sediments in the upper samples, most likely as a result of the catchment disturbance due to forestry and possibly increased productivity within the lake. With very few houses in the catchment, the impact of diffuse pollution is likely to be low, but it is recommended that wastewater arrangements are assessed to ensure minimal impact to the lake.

| Water Body | Status | Reason(s) for failure | Comments |
|---|---|---|---|
| Llyn Mair | **Unfavourable (high confidence)** | Only 2 characteristic spcies.<br><br>Poor distribution of characteristic species.<br><br>High frequency of *J. bulbosus* (>40%).<br><br>Palaeoecological evidence of water quality decline | Llyn Mair has reasonable water quality, but would benefit from a decrease in P and N. The lake supports only a sparse characteristic oligotrophic macrophyte flora and is dominated by more generalist species indicative of elevated trophic status. The site shows evidence of significant degradation likely to be driven by the extensive areas of conifer forestry in the upper catchment. |

Table 33 Llyn Mair overview

## Recommendations for monitoring and management:

Although in unfavourable condition, Llyn Mair retains elements of a characteristic oligotrophic flora and the mean annual water quality is just within the upper limit of the CSM guidelines. There are no previous data on the aquatic macrophytes and therefore it is not known to what extent the flora may have changed over the relatively short history of the lake. The site is of minor biodiversity importance due to supporting *Isoetes echinospora,* but the population is small and management for this species is perhaps better focused where the species if better established. Therefore,

the following recommendations for monitoring and management are relatively low priority.

The large area of coniferous plantation within the catchment poses a high risk to Llyn Mair, particularly during clear-fell harvesting and any subsequent re-planting. It is recommended that the potential impacts on the lake are included as part of environmental risk and impact assessments for all forest operations in the catchment; the major risks being identified as sediment in-wash and a decline in water quality due to nutrient release. Mitigation for these risks may be limited to following best practice to reduce surface run-off and limit erosion, but should include monitoring the impacts.

Amenity use at the lake is relatively low and restricted mainly to walkers and occasional shore angling.

Better water quality and clarity are the key factors for the future management of the lake if it is to be of future value to biodiversity. A minimum of quarterly (or ideally monthly) water quality monitoring is recommended to ascertain any directional change in water quality and provide an early warning of any deterioration to the site. The site would also benefit from regular (every 3-6 years recommended) macrophyte surveys to ascertain any shifts in the populations of *Littorella uniflora* and *Isoetes echinospora* and to monitor the extent and frequency of *Juncus bulbosus* within the site. It is also recommended that any additional sources of nutrients are investigated within the catchment to include assessments of the wastewater facilities for all dwellings in the catchment.

The following recommendations are based on the evidence collected for this report:

- Monitor water quality – minimum of quarterly sampling.
- Ensure impacts to the lake are included in environmental risk / impact assessments of all forestry operations.
- Investigate potential sources of diffuse pollution within the catchment.
- Monitor the aquatic flora every 3-6 years to ascertain any increase or decline of the characteristic flora and monitor *Juncus bulbosus* populations.

## CSM Database output

### Site Condition Assessment: Llyn Mair (28/06/2013)

| Lake Details | | Survey Details | | |
|---|---|---|---|---|
| Lake Name | Llyn Mair | Survey Date | 28/06/2013 | |
| SSSI Name | | Surveyors | BG, JoS & JS | |
| SAC Name | | Shore Surveys | 4 | out of |
| Grid Ref | SH652412 | Wader Surveys | 4 | 4 |
| WBID / NI No. | 34668 / | Boat Surveys | 4 | sections |

Site Notes:
Shallow (mainly less than 2 m - max 2.5). Retained by a stone dam approx 1.5 m high

Survey Notes:
All Isoetes with megaspores confirmed as I. echinospora. pH 6.17 & Cond 58.1

#### Section Summaries

| | | |
|---|---|---|
| **Section 1** | Maximum depth of colonisation (cm) | - |
| | Compass bearing of boat transect (°) | 50 ° |
| | Lateral distance from waters edge to 75cm depth (m) | 10 m |
| | Notes: Plants to max depth of transect (1.5 m) | |
| **Section 2** | Maximum depth of colonisation (cm) | - |
| | Compass bearing of boat transect (°) | 40 ° |
| | Lateral distance from waters edge to 75cm depth (m) | 4 m |
| | Notes: Plants to max depth of site (2.6 m) | |
| **Section 3** | Maximum depth of colonisation (cm) | - |
| | Compass bearing of boat transect (°) | 200 ° |
| | Lateral distance from waters edge to 75cm depth (m) | 3 m |
| | Notes: Plants to max depth of transect (2.5 m) | |
| **Section 4** | Maximum depth of colonisation (cm) | - |
| | Compass bearing of boat transect (°) | 200 ° |
| | Lateral distance from waters edge to 75cm depth (m) | 5 m |
| | Notes: Plants to max depth of transect (1.2 m) | |

#### Section Locations

| | Shore Survey GPS Co-ords | | Boat Survey GPS Co-ords | |
|---|---|---|---|---|
| | start | end | start (shore) | end (lake) |
| **Section 1** | SH6499841250 | SH6507141166 | SH6507141207 | SH6512541262 |
| **Section 2** | SH6524441196 | SH6534641144 | SH6528741169 | SH6533441210 |
| **Section 3** | SH6542841268 | SH6528711344 | SH6537241310 | SH6532941204 |
| **Section 4** | SH6520241306 | SH6510541335 | SH6514441304 | SH6513141250 |

#### Section Photos

| | Start of Section | Whole Section | End of Section |
|---|---|---|---|
| **Section 1** | 1 | 2 | 3 |
| **Section 2** | 4 | 5 | 6 |
| **Section 3** | 7 | 8 | 9 |
| **Section 4** | 10 | 11 | 12 |

## Species Abundance - Boat Survey

| | |
|---|---|
| Total number of sample plots | 80 |
| Total number of vegetated sample plots | 59 |

| Plant Species | Occurrence *n* | Occurrence % |
|---|---|---|
| *Batrachospermum sp.* | 26 | 44 |
| *Eleogiton fluitans* | 54 | 92 |
| *Isoetes echinospora* | 3 | 5 |
| *Juncus bulbosus* | 45 | 76 |
| *Mosses aquatic* | 2 | 3 |
| *Nymphaea alba* | 1 | 2 |
| *Schoenoplectus lacustris* | 1 | 2 |

## Species Abundance - Wader Survey

| | |
|---|---|
| Total number of sample plots | 80 |
| Total number of vegetated sample plots | 66 |

| Plant Species | Occurrence *n* | Occurrence % |
|---|---|---|
| *Batrachospermum sp.* | 28 | 42 |
| *Carex rostrata* | 5 | 8 |
| *Eleogiton fluitans* | 38 | 58 |
| *Iris pseudacorus* | 8 | 12 |
| *Isoetes echinospora* | 4 | 6 |
| *Juncus bulbosus* | 18 | 27 |
| *Littorella uniflora* | 10 | 15 |
| *Menyanthes trifoliata* | 10 | 15 |
| *Mosses aquatic* | 3 | 5 |
| *Nymphaea alba* | 14 | 21 |
| *Potentilla palustris* | 1 | 2 |
| *Schoenoplectus lacustris* | 3 | 5 |
| *Sparganium erectum* | 5 | 8 |
| *Typha latifolia* | 2 | 3 |

Note: Species abundance % = ((number of plots / total number of vegetated sample plots) * 100)

## Plant Scores

**Total plant species** 21 **Filamentous algae (%)** 3.2% WADER 7% BOAT

**Total plant cover (%)** 152.58

**SURVEY SCORES**

| PLANT SPECIES | PERIMETER | WADER | BOAT | COVER % | DAFOR | ABUNDANCE |
|---|---|---|---|---|---|---|
| *Eleogiton fluitans* | 0.1 | 0.1328 | 0.3719 | 46.33 | A | 4 |
| *Juncus bulbosus* | 0.075 | 0.0624 | 0.2708 | 32.08 | A | 4 |
| *Batrachospermum sp.* | 0 | 0.0686 | 0.1251 | 15.94 | F | 3 |
| *Iris pseudacorus* | 0.3375 | 0.037 | 0 | 10.29 | F | 3 |
| *Menyanthes trifoliata* | 0.25 | 0.0428 | 0 | 8.39 | O | 2 |
| *Juncus effusus* | 0.25 | 0 | 0 | 6.25 | O | 2 |
| *Littorella uniflora* | 0.075 | 0.0765 | 0 | 5.7 | O | 2 |
| *Hydrocotyle vulgaris* | 0.15 | 0 | 0 | 3.75 | R | 1 |
| *Nymphaea alba* | 0 | 0.0622 | 0.0039 | 3.5 | R | 1 |
| *Carex rostrata* | 0.0875 | 0.0239 | 0 | 3.38 | R | 1 |
| *Mosses unid* | 0.125 | 0 | 0 | 3.12 | R | 1 |
| *Sparganium erectum* | 0.075 | 0.018 | 0 | 2.78 | R | 1 |
| *Isoetes echinospora* | 0 | 0.0181 | 0.0165 | 2.56 | R | 1 |
| *Schoenoplectus lacustris* | 0.0625 | 0.0052 | 0.0039 | 2.21 | R | 1 |
| *Potentilla palustris* | 0.0625 | 0.0041 | 0 | 1.77 | R | 1 |
| *Mosses aquatic* | 0 | 0.0088 | 0.0075 | 1.19 | R | 1 |
| *Typha latifolia* | 0.025 | 0.0046 | 0 | 0.86 | R | 1 |
| *Myrica gale* | 0.025 | 0 | 0 | 0.62 | R | 1 |
| *Ranunculus flammula* | 0.025 | 0 | 0 | 0.62 | R | 1 |
| *Rhododendron ponticum* | 0.025 | 0 | 0 | 0.62 | R | 1 |
| *Juncus articulatus* | 0.025 | 0 | 0 | 0.62 | R | 1 |

## 5.6. Llyn Cerrig-y-Myllt (North)

Annex 1 type: H3130: Oligo-mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the Isoëto-*Nanojuncetea*.

### 5.6.1. Site description

Summary characteristics for Llyn Cerrig-y-Myllt

| | |
|---|---|
| Name: | Llyn Cerrig-y-Myllt |
| County: | Gwynedd |
| WBID: | 34366 |
| Grid reference: | SH631472 |
| OS Grid reference (X,Y): | 263162,347228 |
| Latitude / Longitude | N53°0.32',W004°2.45' |
| Altitude (m): | 405 |
| Maximum recorded depth (m): | 1.40 |
| Mean depth (m): | No data |
| Lake volume ($m^3$): | No data |
| Surface area – UKLakes (ha): | 1.1 |
| Surface area – measured (ha) | No data |
| Perimeter of lake (km): | 0.5 |
| Shoreline Development Index (SDI): | 1.311 |
| WFD alkalinity based typology: | Low Alkalinity, Shallow (LA, S) |
| Phase 1 habitat type: | Standing water: Oligotrophic: G1.3 |
| Survey Date: | 30 June 2013 |

Llynnau Cerrig-y-Myllt are a pair of small upland lakes to the east of Beddgelert and lying to the west of the summit of Cnicht (689 m). The lakes are approximately 100 m apart and separated by a low ridge with the southerly of the two lakes sitting 10 m above the other. The higher lake has no surface outflow and there is no surface-water link between the lakes. It is unclear there is any hydrological link between the two sites. The area mainly comprises of acid geology with the two lakes lying on thick volcanic tuffs (Yr Arddu tuffs) with rhyolitic intrusions making up much of the immediate higher ground around the lakes (Howells *et al.* 1987). The exposure of intrusive geology is excellent in this locality and is the primary reason for its designation as a SSSI in 2001; Llynnau Cerrig-y-Myllt lying towards the northeastern extent of the designated area. No mention of lakes or any biological interest is made within the SSSI designation. Other than the geological interest, the locality and lakes therein appear not to have been studied or surveyed in the past.

This report focuses only to the more northerly of the two lakes, which is referred to as Llyn Cerrig-y-Myllt or Llyn Cerrig-y-Myllt (North).

### 5.6.2. Condition Assessment and Discussion

Table 34 Condition Assessment Summary Table for Llyn Cerrig-y-Myllt

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | None |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise) | **X** | No characteristic *Littorelletea* spp in 2013: Only bryophytes and sparse *Juncus bulbosus* present |
| | No loss of characteristic species (see Box 2) | **NA** | No previous data |
| | ≥ 6/10 vegetated sample spots (boat / wader survey) have ≥ 1 characteristic spp. | **X** | No characteristic species |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | None recorded |
| | Benthic and epiphytic filamentous algae <10%. | ✓ | Filamentous algal was present, but well below 10% cover. |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (site specific) | **X** | Maximum depth only 1.4 m and vegetation very sparse. |
| | Maximum depth distribution should be maintained | **NA** | $Z_{max}$ (recorded) = 1.4 m, $Z_s$ = >1.4 m, $Z_v$ = 1.0 m. |
| | At least present structure should be maintained | **NA** | No previous data |
| **Water quality** | Stable nutrients levels: TP target / limit: Oligotrophic = 10 $\mu g l^{-1}$ | ✓ | TP (mean 2012/13) = 8.7 $\mu g\ l^{-1}$ (range 5.7 – 13.4) $NO_3$-N = 0.11 mg $l^{-1}$ TP Values are towards the upper limit for oligotrophic waters |
| | Stable pH values: pH ~ 5.5 – circumneutral | ✓ | Mean pH 2012/13 = 5.30 (Range 4.85 – >7.00). |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 $mg l^{-1}$) | ✓ | >10 mg $l^{-1}$ from 0 – 1.2 m. Water column mixed |
| | No excessive growth of cyanobacteria / green algae | ✓ | None noted, and low Chl a values (mean 3.1 $\mu g\ l^{-1}$, range 1.5 – 4.7 $\mu g\ l^{-1}$) |
| **Hydrology** | Natural hydrological regime | ✓ | Natural |
| **Lake substrate** | Natural shoreline maintained | ✓ | Natural |

| Attribute | Target | Status | Comment |
|---|---|---|---|
| | Natural and characteristic substrate maintained | ✓? | Sediment core analysis shows a rapid increase in organic material in the upper sediments |
| **Sediment load** | Natural sediment load maintained | ✓ | Appears natural |
| **Indicators of local distinctive-ness** | Distinctive elements maintained at current extent / levels / locations | | None noted |
| **Disturbance** | No introduced species | ✓ | None recorded |
| | Minimal negative impacts from recreation and navigation. No fish farming | ✓ | None |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | ✓ | Fossil diatom flora indicates relatively low species turnover between 20 cm and surface, and very little change in modeled TP and pH. |

**Status: ✓ = favourable; X = unfavourable; NA = Not assessed**

## Extent

The surface area of the lake is 1.1 ha. There is no evidence of any recent loss of extent of open water.

## Macrophyte community composition and structure

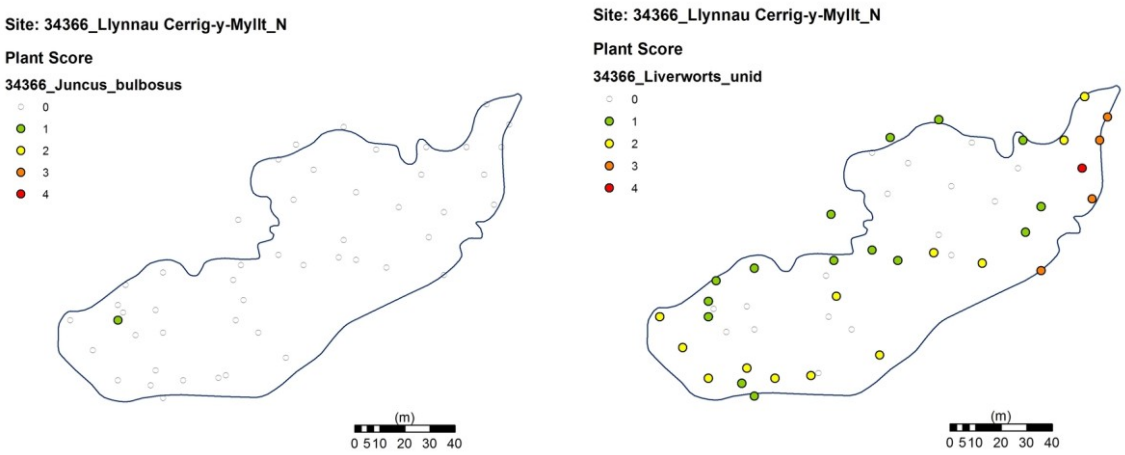
Llyn Cerrig-y-Myllt is a very shallow, wind-stressed lake which, with the exception of bryophytes growing on the littoral boulders and a few individual plants of *Juncus bulbosus*, there was otherwise no aquatic plants recorded from the site (Table 35 & Figure 26). The percentage occurrence data in Table 35 are based on the number of sample points with vegetation; it should be noted that the total vegetation cover across the site is estimated to have been less than 1%. Filamentous green algae were rare in the site, but the red alga *Batrachospermum* sp. was relatively common. The lack of any characteristic species classifies the site as unfavourable with respect to its aquatic flora.

Although not surveyed, the adjacent lake was noted as having *Littorella uniflora* growing within the littoral zone and had numerous individual plants of *L. uniflora* washed up along the strandline suggesting the species to be relatively common within the site. Given the proximity of the two lakes it would be expected that *Littorella* would be found in both sites, and its absence from the north site may therefore be due to poor substrate availability (see below).

| Submerged and floating vegetation | TRS | PLEX | % occurrence (n=16) | DAFOR abundance[8] | Min depth (cm) | Max depth (cm) |
|---|---|---|---|---|---|---|
| *Juncus bulbosus* | 5.3 | 3.08 | 38 | R | 25 | 100 |
| *Mosses* aquatic | | | 7 | R | 25 | 25 |
| *Liverworts* aquatic | | | 94 | O | 0 | 80 |
| **Average score** | **5.3** | **3.08** | | | | |
| **Species richness** | | | | 3 | | |

Table 35 Aquatic macrophyte community composition for Llyn Cerrig-y-Myllt in June 2013.

Figure 26 Distribution maps of the aquatic plant species recorded in Llyn Cerrig-y-Myllt




The lack of aquatic plants means the site falls outside the groups defined by Duigan *et al*. (2006). The TRS (5.3) and PLEX (3.08) scores are consistent with oligotrophic lakes, but are based only on the presence of very few *J, bulbosus* plants and not therefore considered meaningful.

## Negative indicator species

*Juncus bulbosus* was present in 38% of the vegetated sample points, but at extremely low abundance overall and not therefore considered as a negative indicator. The site was without any significant growths of filamentous algae.

## Water quality

The water chemistry of Llyn Cerrig-y-Myllt is consistent with that of an oligotrophic water body although the mean annual TP concentration (8.7 µg $l^{-1}$) was towards the upper limit for this lake type and summer and autumn 2013 samples exceeded the 10 µg $l^{-1}$ threshold (Table 36). Soluble reactive phosphorus remained below detection on all four sampling occasions and total oxidised nitrogen remained relatively low. The

[8] Based on presence / absence data from all vegetated plots in the wader and boat based surveys. DAFORs are calculated from the total number of occurrences across the wader and boat surveys as a proportion of the total number of vegetated wader and boat survey points.

current nutrient concentrations, although within CSM guidelines and therefore favourable, do nonetheless appear to show slight enrichment at the site.

The lake lies within a catchment of acid geology (Howells *et al.* 1987) with thin soils, peat and a significant area of exposed rock. The pH and alkalinity values reflect this and the lake falls slightly below the pH target of 5.5 set for oligotrophic lakes (JNCC 2005). The high pH value recorded in December 2012 is thought likely to be erroneous (see discussion below) and if removed from the dataset the mean pH based on 3 measurements is 5.19. ANC values fall well below the target value of 40 $\mu eql^{-1}$ for ANC-I set out in the revised CSM guidelines (JNCC, in prep.), and suggest the site is significantly acidified.

At the time of survey in June 2013, the lake was well oxygenated throughout with DO from 0–1.2 m was >10.0 mg $l^{-1}$.

| Determinand | Dec 5th | Feb 25th | Jul 4th | Oct 5th | Mean |
|---|---|---|---|---|---|
| pH | 7.8 (?) | 4.85 | 5.46 | 5.7 | 5.31 |
| Cond | 38.9 | 31.2 | 31 | 27 | 32.0 |
| Alk (Gran) | 0.458 | -0.072 | -0.26 | 0.013 | 0.0 |
| SRP | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| TP | 5.7 | 5.8 | 10.0 | 13.4 | 8.7 |
| Chl a | 4.7 | 1.5 | 2.2 | 3.8 | 3.1 |
| TON | 0.134 | 0.2 | 0.0539 | 0.0519 | 0.11 |
| $Na^+$ | 3.22 | 3.53 | 3.95 | 3.44 | 3.54 |
| $K^+$ | 0.602 | 0.585 | 0.504 | 0.449 | 0.54 |
| $Mg^{2+}$ | <0.3 | 0.322 | 0.496 | 0.45 | 0.42 |
| $Ca^{2+}$ | <1 | <1 | <1 | <1 | <1 |
| $Cl^-$ | 5.02 | 6.04 | 6.9 | 5.7 | 5.92 |
| $SO4^{2-}$ | <10 | <10 | <10 | <10 | <10 |
| $SiO_2$ | 1.59 | 1.62 | 0.497 | 0.544 | 1.06 |
| Sus. Solids | <3 | <3 | <3 | 3.4 | <3.0 |
| Labile Al | 95.4 | 104 | 65.7 | 64 | 82.3 |
| DOC | 2.57 | 1.33 | 1.67 | 2.2 | 1.94 |
| ANC-I (ionic) | | | | | -29.3 |
| ANC-C (Cantrell) | | | | | 9.4 |

Table 36 Water chemistry data for Llyn Cerrig-y-Myllt (for units see methodology)

## Hydrology

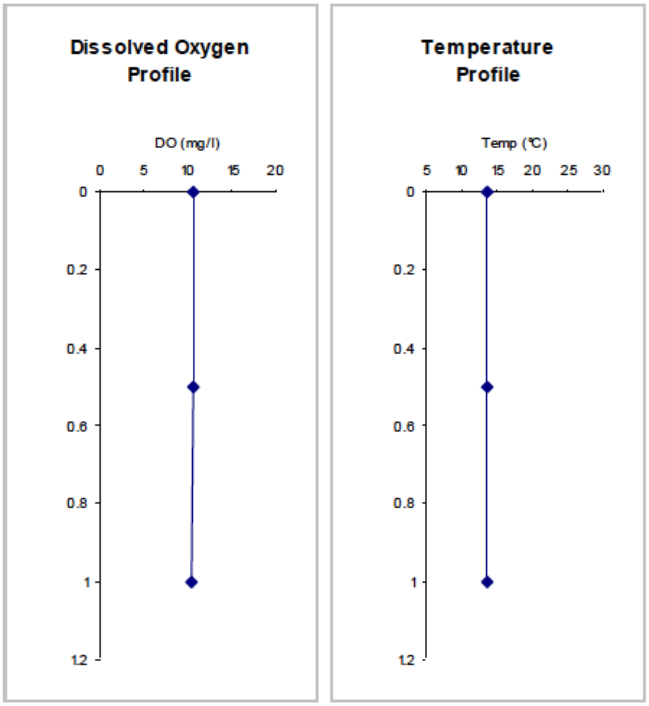
Llyn Cerrig-y-Myllt has only a very small catchment and is without any permanent surface inflows. The catchment is predominantly bare rock with thin soils on the slopes and peat development around the lake shore and in the valley bottoms. The south lake lies 10 m higher within the catchment, but a low ridge separates the sites and there is no surface water connection between the two sites. The lake outflow cuts through an area of *Sphagnum / Juncus effusus* wetland and flows northeast where it follows the valley north to the Namor which runs southwest to the Afon Glaslyn south of Beddgelert.

Figure 27 Dissolved oxygen (DO) profile for Llyn Cerrig-y-Myllt (30/06/2013).

**Dissolved Oxygen Profile**

| | |
|---|---|
| GPS Location | SH6320847325 |
| Maximum Depth (m) | 1.4 m |
| Secchi Depth (cm) | - |
| Notes: Water clear | |

| Depth (m) | DO (mg/l) | Temp (°C) |
|---|---|---|
| 0 | 10.58 | 13.6 |
| 0.5 | 10.54 | 13.6 |
| 1 | 10.5 | 13.6 |




## Lake substrate and sediment loads

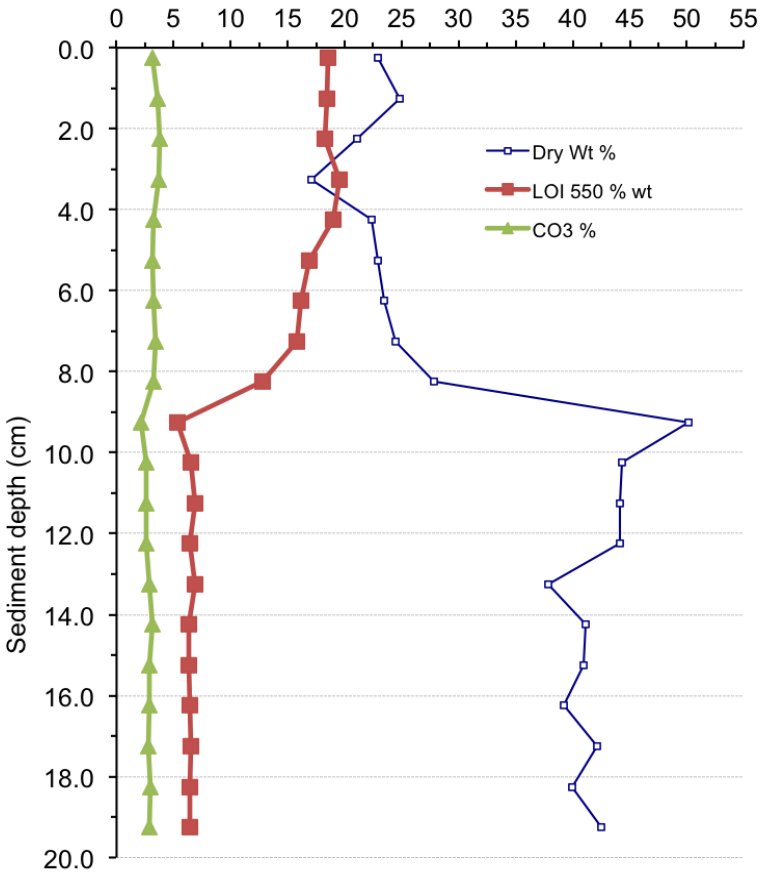
The littoral substrates are comprised mainly of boulders to a depth of 1.0 beyond which the lake bed is relatively flat and predominantly silt, with occasional boulders.

A 19 cm sediment core (MYLLTN1) was collected from 1.3 m water depth at SH6313447282 and analysed for dry-weight and organic content. There is an abrupt change at 9 cm from mineral-rich sediments in the lower core to more organic sediments in the upper core (Figure 28). Although the core is not date, the rate of change appears to be very sudden and cannot be related to any known disturbance events within what is a very small isolated catchment. One possibility is that the site used to be even shallower and as a result of the wind stress, fine organic material being re-worked and flushed through the lake without settling. If the outflow was in some way raised, either naturally, by wetland development or slumping, or artificially, the additional water depth may have allowed finer organic material to settle. This theory would explain the rapid change and may also explain why the site has very few plants (see below). There is no evidence of significant disturbance or increased sediment inwash from the catchment.

## Indicators of local distinctiveness

The lake has very few plants and no notable species were recorded.

Figure 28 Physical characteristics from core MYLLTN1 DW = dry weight; LOI = loss on ignition, CO3 = (carbonate content)




## Bathymetry

The collection of bathymetric data was not requested for Llyn Cerrig-y-Myllt. The site is surrounded by boulders and in most places drops vertically to approximately 1.0 m where it changes to silt which forms a very flat lake bed, the deepest point being only 1.4 m.

## Palaeolimnological evidence

The physical character of the 19 cm sediment core (MYLLTN1) are discussed above and presented in Figure 28. Diatom analysis from the core base and top showed both samples to be dominated by *Aulacoseira distans* var. *distans* (>25%), a planktonic or loosely associated periphytic taxon of base-poor conditions. The remaining flora was mainly periphytic with the bottom sample having *Eunotia incisa, Achnanthes helvetica* and *Tebellaria flocculosa* at greater than 5% abundance. These taxa are typical of more acidic, oligotrophic waters.

The top sample differed in the proportions of the species present rather than having a very different assemblage. *Navicula subtilissima, Frustlia rhomboides, Navicula jaagii* and *Brachysira vitrea* were all common and again are all acidophilous taxa. The SCD dissimilarity scores between the bottom and top samples was only 0.60 which indicates only moderate floristic changes between the samples.

Reconstructions of diatom-inferred pH (DI-pH) were produced using the SWAP training set. A high percentage of the taxa in the fossil samples were present in the SWAP training set and there were no major analogue problems. The DI-pH results show very little difference in pH between the core bottom and top with the top sample. The current surface sediment assemblage provides a good estimate of the measured pH (Table 37). It should be noted that the high pH reading recorded in December 2012 is likely to be erroneous and therefore the actual pH is nearer 5.2. All six pH results returned by the laboratories (NLS Starcross) in December 2012 were high compared to subsequent readings suggesting a calibration error.

Reconstructions of diatom-inferred TP (DI-TP) show very low modelled TP from the core bottom and top (2.0 to 1.8 µg $l^{-1}$). A high percentage of the taxa in the fossil samples were present in the NW European training set and there were no major analogue problems. The annual mean current TP based on quarterly water samples collected during 2012-13 was 8.7 µg $l^{-1}$ and therefore the diatom model underestimates the current measured value. Small, acid lakes are poorly represented within the NW European diatom training set and hence low confidence in the inferred TP values.

In summary, there has been only moderate of floristic change in the sediment core from Llyn Cerrig-y-Myllt and the fossil diatom assemblages indicate the site to have remained very stable with respect to TP and pH over the duration covered by the sediment core.

| Sample Code | Depth (cm) | 2012/13 mean pH | DI-pH | 2012/13 mean TP | DI-TP | SCD |
|---|---|---|---|---|---|---|
| MYLLT1-00 | 0 | 5.31 | 5.30 | 8.7 | 1.8 | 0.60 |
| MYLLT1-19 | 19 | | 5.20 | | 2.0 | 0.00 |

Table 37 Results of Llyn Cerrig-y-Myllt overview sediment core analysis

## Site condition summary and overview

Llyn Cerrig-y-Myllt is in **unfavourable condition** with **high confidence**. The lake supports almost no aquatic plants and has no characteristic aquatic macrophyte species.

Water quality data show the site to be very poorly buffered and below the CSM target value for pH (JNCC 2005). Similarly, although TP is just within the recommended upper limit for oligotrophic lakes, the values are considered unusually for such a remote upland location and warrant further investigation. The lake is unfavourable with respect to water quality.

Palaeolimnological evidence does not however show there to have been any significant change in pH or trophic status of the lake over the timespan covered by the sediment core.

The reason for the lack of plants within the lake is unclear. The adjacent lake has *Littorella uniflora* (and possibly other species) present, but these do not grow in Llyn Cerrig-y-Myllt (north). The rapid shift from mineral to more organic sediments suggests the lake level may have changed abruptly. If this was the case, an even shallower lake would have been extremely wind stressed and plants would have been unlikely to establish due to the physical stress as well as poor rooting substrate.

Based on the current data the lake is in unfavourable condition because it has no aquatic plants and cannot therefore be classed as favourable against this feature. There is no direct evidence of anthropogenic impact at the site however, and hence there may be valid reasons why plants have not established in the lake. The adjacent lake which is similar in size to the north lake, but appears to be deeper and is known to support at least one characteristic species. Given the proximity of the two sites and their almost identical catchment characteristics, it would be prudent to undertake a full assessment of both lakes in order to provide a more accurate assessment. If the south lake supports a more typical characteristic aquatic flora and is deeper, it may be assumed the north site is just too exposed and shallow to support plants. Alternatively it may have been too shallow in the past, and since becoming slightly deeper quite recently, a characteristic flora has yet to become established. Radiometric dating of the sediment core would help to identify the timing of the switch from mineral to more organic deposition.

| Water Body | Status | Reason(s) for failure | Comments |
|---|---|---|---|
| Llyn Cerrig-y-Myllt | **Unfavourable (high confidence)** | No characteristic species.<br>Poorly buffered and at risk of further acidification from atmospheric deposition. | Llyn Cerrig-y-Myllt has relatively good water quality, and there is no evidence of any decline in quality from the fossil diatom record. The site is naturally acidic, poorly buffered and therefore at risk of becoming more acid. The lake has almost no plants and although unfavourable, there may be valid reasons why plants are not present; primarily due to being very shallow and exposed. Survey of the adjacent lake would help to inform the assessment further. |

Table 38 Llyn Cerrig-y-Myllt overview

## Recommendations for monitoring and management:

The current catchment management is restricted to extensive upland grazing, mainly sheep, but cattle are also grazed locally and potentially have access to the upper

slopes. There was no evidence to suggest the current catchment management is having any negative influence on the site and is therefore deemed to be appropriate.

In order to ascertain if the current state of Llyn Cerrig-y-Myllt (North) is really unfavourable, or simply the result of natural processes, more information is required. The survey and assessment of the south lake would aid interpretation and this is recommended. If as suspected the south lake is deeper and supports at least some characteristic plant species, it would support the theory (in the lack of any other evidence) that the north lake is simply too shallow to support plants at such an exposed location. Analysis of the sediments for aquatic plant remains may also be useful in determining if the lake once supported characteristic plant species. The current condition of the lake means it is of low biodiversity importance and management recommendations are of low priority.

More information regarding the timing and reason for the change in sediment composition would also be beneficial. Dating of the sediment core is therefore recommended. It the lake level has been raised, it would be useful to determine if this was natural (though wetland development around the outflow) or done artificially. Local records and interviews with the land-owner (s) may help to shed light on this.

The site is in an area of poorly buffered acid geology and therefore at risk of acidification. Regular monitoring of pH, as well as nutrients and ionic composition are therefore recommended to ascertain any directional change in water quality and provide an early warning of deterioration at the site.

The following recommendations are based on the evidence collected for this report:

- Survey and condition assess the south lake.
- Monitor water quality – minimum of quarterly sampling (pH, TP, TON, TN, DOC anions and cations).
- Analyse the sediment core (already taken) for aquatic plant remains. Date the sediment core.
- Investigate past lake level change – natural or artificial.
- Monitor the aquatic flora of both lakes every 6 years to asses change at the sites.

## CSM Database output

### Site Condition Assessment: Llyn Cerrig-y-myllt (North) (30/06/2013)

| Lake Details | | Survey Details | | |
|---|---|---|---|---|
| Lake Name | Llyn Cerrig-y-myllt (North) | Survey Date | 30/06/2013 | |
| SSSI Name | YR ARDDU | Surveyors | BG, JS & JoS | |
| SAC Name | | Shore Surveys | 2 | out of |
| Grid Ref | SH631472 | Wader Surveys | 2 | 2 |
| WBID | 34366 | Boat Surveys | 2 | sections |

Site Notes:
Shallow, wind stressed lake. Clear water, but very few plants.

Survey Notes:
Cond = 26.8, pH 4.71. Very few plants, only mosses and liverworts. Shallow, wind stressed. Batrachospernum present. South lake not surveyed, but noted to have Littorella on the strandline.

#### Section Summaries

| | | | |
|---|---|---|---|
| **Section** | **1** | Maximum depth of colonisation (cm) | 50 cm |
| | | Compass bearing of boat transect (°) | - |
| | | Lateral distance from waters edge to 75cm depth (m) | 3 m |
| | | Notes: Batrachospermum common | |
| **Section** | **2** | Maximum depth of colonisation (cm) | 80 cm |
| | | Compass bearing of boat transect (°) | 250 ° |
| | | Lateral distance from waters edge to 75cm depth (m) | 5 m |
| | | Notes: Batrachospermum common | |

#### Section Locations

| | | Shore Survey GPS Co-ords | | Boat Survey GPS Co-ords | |
|---|---|---|---|---|---|
| | | start | end | start (shore) | end (lake) |
| **Section** | **1** | SH6309647291 | SH6314547254 | SH6310247263 | SH6314747283 |
| **Section** | **2** | SH6334447306 | SH6324947357 | SH6326647668 | SH6321647329 |

#### Section Photos

| | | Start of Section | Whole Section | End of Section |
|---|---|---|---|---|
| **Section** | **1** | 29 | 30 | 31 |
| **Section** | **2** | 32 | 34 | 33 |

## Species Abundance - Boat Survey

| | |
|---|---|
| Total number of sample plots | 20 |
| Total number of vegetated sample plots | 1 |

| Plant Species | Occurrence *n* | Occurrence % |
|---|---|---|
| *Juncus bulbosus* | 1 | 100 |

## Species Abundance - Wader Survey

| | |
|---|---|
| Total number of sample plots | 40 |
| Total number of vegetated sample plots | 15 |

| Plant Species | Occurrence *n* | Occurrence % |
|---|---|---|
| *Juncus bulbosus* | 5 | 33 |
| *Liverworts aquatic* | 14 | 93 |
| *Mosses aquatic* | 1 | 7 |

Note: Species abundance % = ((number of plots / total number of vegetated sample plots) * 100) *n*

## Plant Scores

**Total plant species** 7 **Filamentous algae (%)** 3.1% WADER 0% BOAT

**Total plant cover (%)** 25.34

**S U R V E Y S C O R E S**

| PLANT SPECIES | PERIMETER | WADER | BOAT | COVER % | DAFOR | ABUNDANCE |
|---|---|---|---|---|---|---|
| Liverworts aquatic | 0 | 0.1244 | 0 | 6.22 | O | 2 |
| *Potentilla reptans* | 0.175 | 0 | 0 | 4.38 | R | 1 |
| *Juncus effusus* | 0.175 | 0 | 0 | 4.38 | R | 1 |
| *Juncus bulbosus* | 0.05 | 0.0312 | 0.01 | 3.81 | R | 1 |
| *Juncus articulatus* | 0.125 | 0 | 0 | 3.12 | R | 1 |
| *Eriophorum angustifolium* | 0.125 | 0 | 0 | 3.12 | R | 1 |
| Mosses aquatic | 0 | 0.0062 | 0 | 0.31 | R | 1 |

## 5.7. Llyn Coch-hwyad

Annex 1 type: H3130: Oligo-mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the Isoëto-*Nanojuncetea*. OR
Annex 1 type: H1360: Natural dystrophic lakes and ponds

### 5.7.1. Site description

Summary characteristics for Llyn Coch-hwyad

| | |
|---|---|
| Name: | Llyn Coch-hwyad |
| County: | Powys |
| WBID: | Not listed on UK Lakes |
| Grid reference: | SH921110 |
| OS Grid reference (X,Y): | 292190,311000 |
| Latitude / Longitude | N52°41.9',W003°35.47' |
| Altitude (m): | 455 |
| Maximum recorded depth (m): | 1.69 |
| Mean depth (m): | 0.95 |
| Lake volume ($m^3$): | 90159 |
| Surface area – UKLakes (ha): | No data |
| Surface area – measured (ha) | 9.54 |
| Perimeter of lake (km): | 1.2 |
| Shoreline Development Index (SDI): | No data |
| WFD alkalinity based typology: | Low Alkalinity, Shallow (LA, S) |
| Phase 1 habitat type: | Standing water: Oligotrophic: G1.3 |
| Survey Date: | 1 July 2013 |

Llyn Coch-hwyad is a very shallow (1.7 m) lake lying at relatively high altitude (455 m) on the Llanbrynmair Moors, a large upland plateau that rises to 520 m, situated north-east of the village of Llanbrynmair in Montgomeryshire. The underlying geology comprises Silurian rocks dominated by Penstrowed Gritstones and occasional outcrops of mudstone. The lake receives surface water via a network of streams to the south and presumably from surface and sub-surface flow from the surrounding peats which result in the waters being stained brown. There is an outflow at the western end of the lake which flows west through the deeply incised Nant Llyn Coch-hwyad valley before ultimately draining to the Afon Dyfi.

The moors were once covered by large areas of blanket bog, but much of this was lost in the 1980s when the area was afforested with conifers. A few small areas of bog were not planted, and in 1994 were afforded SSSI status, these areas being Cors Bwlch Trosol, Cors Mynydd Tal-y-glannau and Cors Gordderwen. The lake itself is completely surrounded by the coniferous plantation with trees having been planted between 10 - 100 m from the shore. Although currently without any formal designation, the lake is a known site for floating water-plantain *Luronium natans* (listed as a BAP priority species and in Annex II of the Habitats Directive), first reported as present in 1993 (Kay *et al.* 1999) and confirmed as present in a 2006 survey conducted by ECUS (2007).

### 5.7.2. Condition Assessment and Discussion

Table 39 Condition Assessment Summary Table for Llyn Coch-hwyad

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | None |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise) | ✓ | 5 characteristic *Littorelletea* spp in 2013: *Isoetes lacustris, Littorella uniflora & Lobelia dortmanna, Luronium natans & Sparganium angustifolius.* |
| | No loss of characteristic species (see Box 2) | ✓ | Similar species list recorded by ECUS in 2006 – no losses |
| | ≥ 6/10 vegetated sample spots (boat / wader survey) have ≥ 1 characteristic spp. | **X**<br>✓ | Only 43% of vegetated sample spots comply (56% wader, 11% boat).<br>Favourable for dystrophic |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | None recorded |
| | Benthic and epiphytic filamentous algae <10%. | **X** | Filamentous algal was estimated to exceed 10 % cover. |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (site specific) | NA | Site very shallow and characteristic species limited to < 1.1 m |
| | Maximum depth distribution should be maintained | - | $Z_{max}$ (recorded) = 1.69 m, $Z_s$ = 1.00 m, $Z_v$ = 1.6 m. |
| | At least present structure should be maintained | - | No evidence of change |
| **Water quality** | Stable nutrients levels: TP target / limit: Oligotrophic = 10 µgl$^{-1}$ | **X** | TP (mean 2012/13) = 18 µg l$^{-1}$ (range 10.5 – 40 µg l$^{-1}$). TON = <0.009 mg l$^{-1}$ |
| | Stable pH values: pH ~ 5.5 – circumneutral | ✓ | Mean pH 2012/13 = 6.27 (Range 5.63 – 7.76). |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 mgl$^{-1}$) | ✓ | > 10 mgl$^{-1}$ from 0 – 1.5 m. Water column mixed July 2013 |
| | No excessive growth of cyanobacteria / green algae | ✓ | None noted, and low Chl a values (mean 3.52 µg l$^{-1}$, range <0.5 – 6.5 µg l$^{-1}$) |

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Hydrology** | Natural hydrological regime | ✓? | Under natural control, but possibly influenced by forestry drainage |
| **Lake substrate** | Natural shoreline maintained | ✓ | Appears natural |
| | Natural and characteristic substrate maintained | X? | Sediment core analysis shows an increase in organic material since afforestation |
| **Sediment load** | Natural sediment load maintained | X? | Sedimentation rates have increased since afforestation |
| **Indicators of local distinctive-ness** | Distinctive elements maintained at current extent / levels / locations | ✓ | *Luronium natans* remains present at multiple locations within the lake |
| **Disturbance** | No introduced species | ✓ | None recorded |
| | Minimal negative impacts from recreation and navigation. No fish farming | ✓ | Occasional shore angling. Minimal impact. |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | X? | Diatom flora indicates a high degree of species turnover and suggests slight acidification |

**Status: ✓ = favourable; X = unfavourable; - = unable to assess**

## Extent

The surface area of the lake is 9.54 ha. There is no evidence of any recent loss of extent of open water.

## Macrophyte community composition and structure

Llyn Coch-hwyad has a relatively rich flora with many elements being typical for nutrient-poor lakes. A total of 18 aquatic plant species were recorded in 2013, 5 of which were characteristic oligotrophic species (Table 40). The site was however dominated by non-characteristic taxa and only 43% of the vegetated sample points had one or more characteristic species which falls below the requited target of 60% in the CSM guidelines for oligotrophic lakes (JNCC 2005). *Littorella uniflora*, *Isoetes lacustris* and *Lobelia dortmanna* were all rare and restricted to water depths of less than 80 cm. Where deeper water was present it was either without vegetation or dominated by *Callitriche hamulata* and *Fontinalis antipyretica,* which formed very dense growth in places in the west and centre of the lake.

*Littorella uniflora* was under-recorded slightly when compared to the mapping data, but nonetheless restricted to very shallow water (<50 cm), presumably as a result of poor light penetration through the brown water. *Sparganium angustifolium* was more common in the site, but again rarely recorded at >75 cm water depth. See Table 40

for a summary of the species and Figure 29 for the depth distribution of aquatic plants. Species maps are presented in Figure 30.

The high humic content and brown waters appear to have a major influence on the plant distribution within the lake and while the flora is unfavourable with respect to oligotrophic targets is in favourable is assessed against dystrophic attributes.

Populations of *Luronium natans* were recorded in three of the four survey sections and the mapping shows the plant to occur around much of the north and northwest of the site as well as towards the south shore (Figure 30). Total numbers of plants were estimated to be in excess of 1000 individuals and this therefore represents an important population.

| Submerged and floating vegetation | TRS | PLEX | % occurrence (n=100) | DAFOR abundance[9] | Min depth (cm) | Max depth (cm) |
|---|---|---|---|---|---|---|
| *Callitriche hamulata* | 6.3 | 6.15 | 52 | D | 25 | 160 |
| *Equisetum fluviatile* | | | 39 | A | 0 | 100 |
| *Fontinalis antipyretica* | 6.3 | 5.38 | 38 | A | 0 | 160 |
| *Glyceria fluitans* | 7.0 | 6.54 | 1 | R | 50 | 50 |
| ***Isoetes lacustris*** | **5.0** | **4.23** | **12** | **O** | **25** | **80** |
| *Juncus bulbosus* | 5.3 | 3.08 | + | R | 20 | 20 |
| ***Littorella uniflora*** | **6.7** | **4.23** | **4** | **R** | **0** | **50** |
| Liverworts aquatic | | | 5 | R | 0 | 80 |
| ***Lobelia dortmanna*** | **5.0** | **3.08** | **1** | **R** | **25** | **25** |
| ***Luronium natans*** | | | **16** | **F** | **50** | **110** |
| Mosses aquatic | | | 13 | F | 100 | 160 |
| *Myriophyllum alterniflorum* | 6.7 | 4.23 | 40 | A | 25 | 120 |
| *Nitella opaca* | 6.7 | 5.38 | + | R | 10 | 120 |
| *Nuphar lutea* | 8.5 | 6.92 | 5 | R | 25 | 80 |
| *Potamogeton natans* | 7.0 | 4.23 | + | R | 40 | 90 |
| *Potamogeton polygonifolius* | 3.7 | 3.08 | 11 | F | 25 | 80 |
| ***Sparganium angustifolium*** | **4.0** | **4.23** | **24** | **F** | **25** | **80** |
| *Sphagnum* sp. | 2.5 | 1.54 | 32 | A | 25 | 80 |
| **Average score** | **5.8** | **4.45** | | | | |
| **Species richness** | | | | 18 | | |

Table 40 Aquatic macrophyte community composition for Llyn Coch-hwyad in July 2013. Characteristic oligotrophic species are highlighted in **bold**.

The current assemblage places the lake into Group D as defined by Duigan *et al*. (2006) which is typified by oligo/mesotrophic lakes with high species richness. The TRS (5.8) and PLEX (4.45) scores are consistent with oligotrophic lakes and the

[9] Based on presence / absence data from all vegetated plots in the wader and boat based surveys. DAFORs are calculated from the total number of occurrences across the wader and boat surveys as a proportion of the total number of vegetated wader and boat survey points.

overall character of the flora, particularly the depth distribution is typical of lakes with peat-rich catchments and brown water lakes.

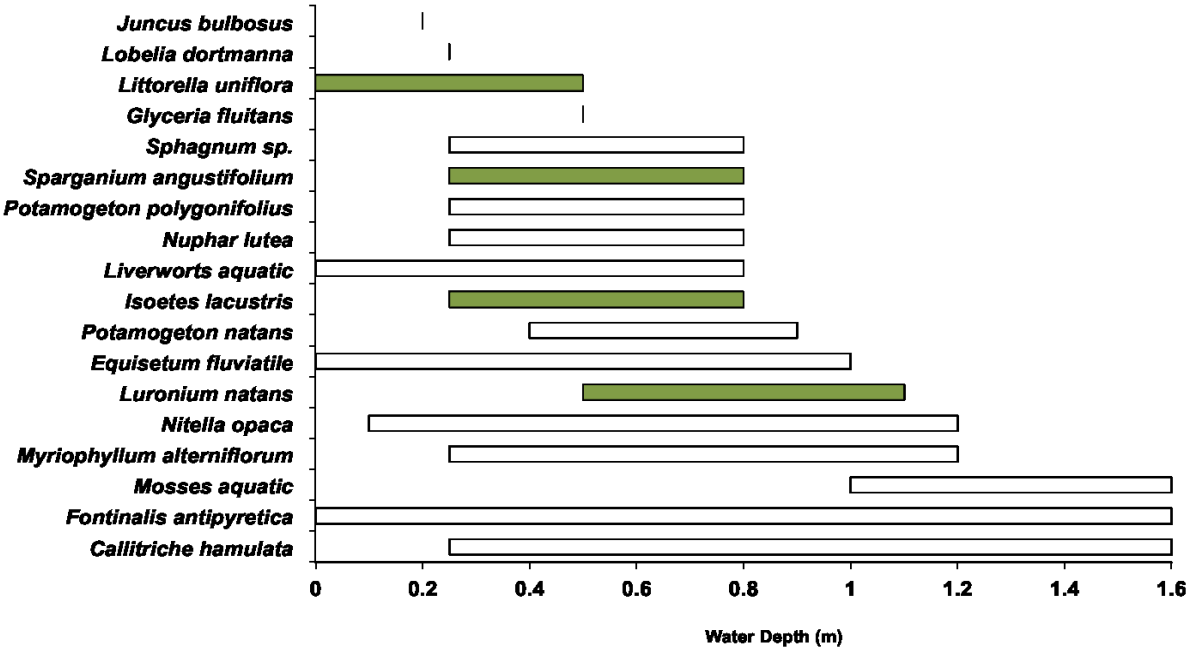



Figure 29 Depth range of the aquatic macrophytes recorded from Llyn Coch-hywad; characteristic oligotrophic species are shaded green.

Figure 30 Distribution maps of the aquatic plant species recorded in Llyn Coch-hwyad

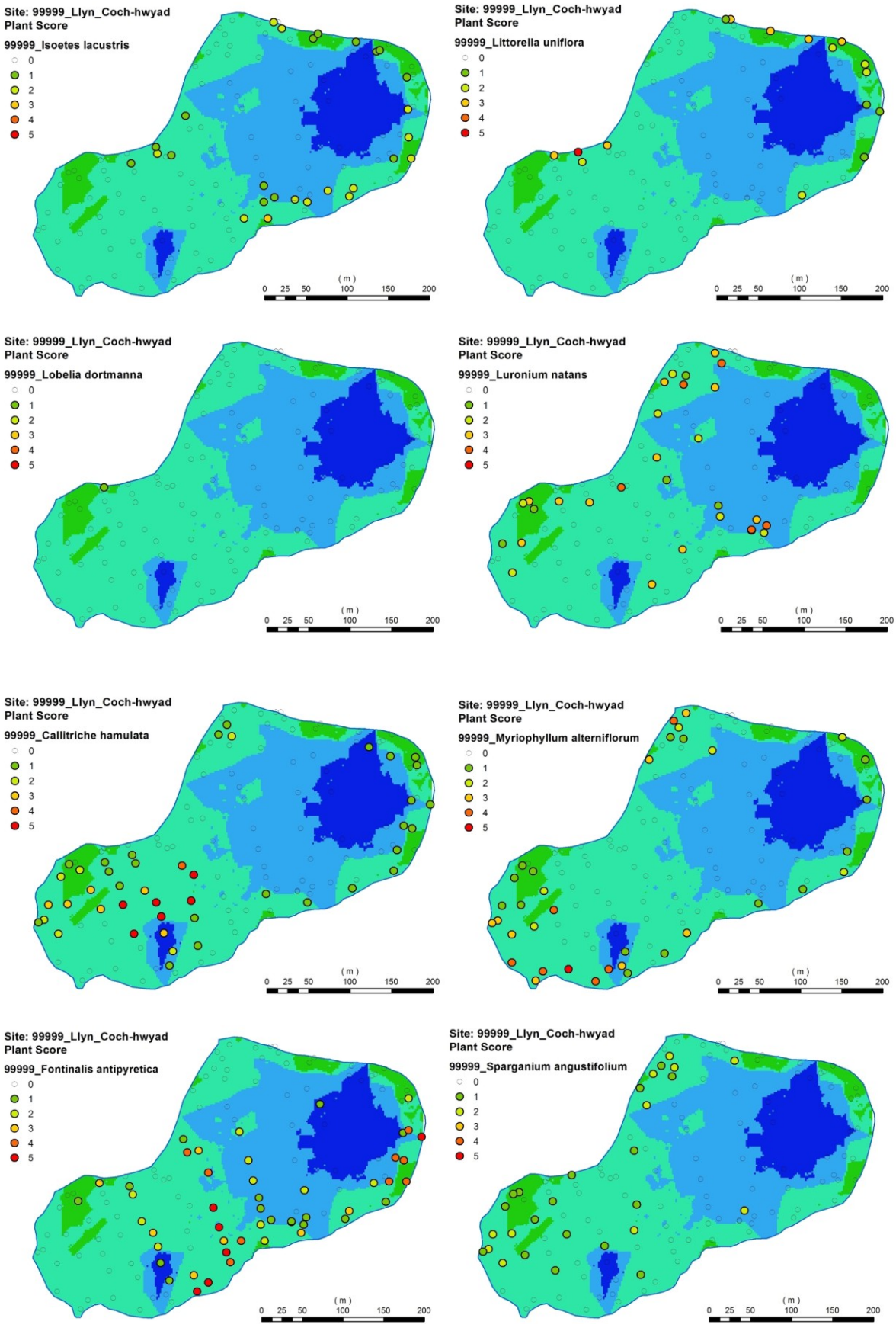
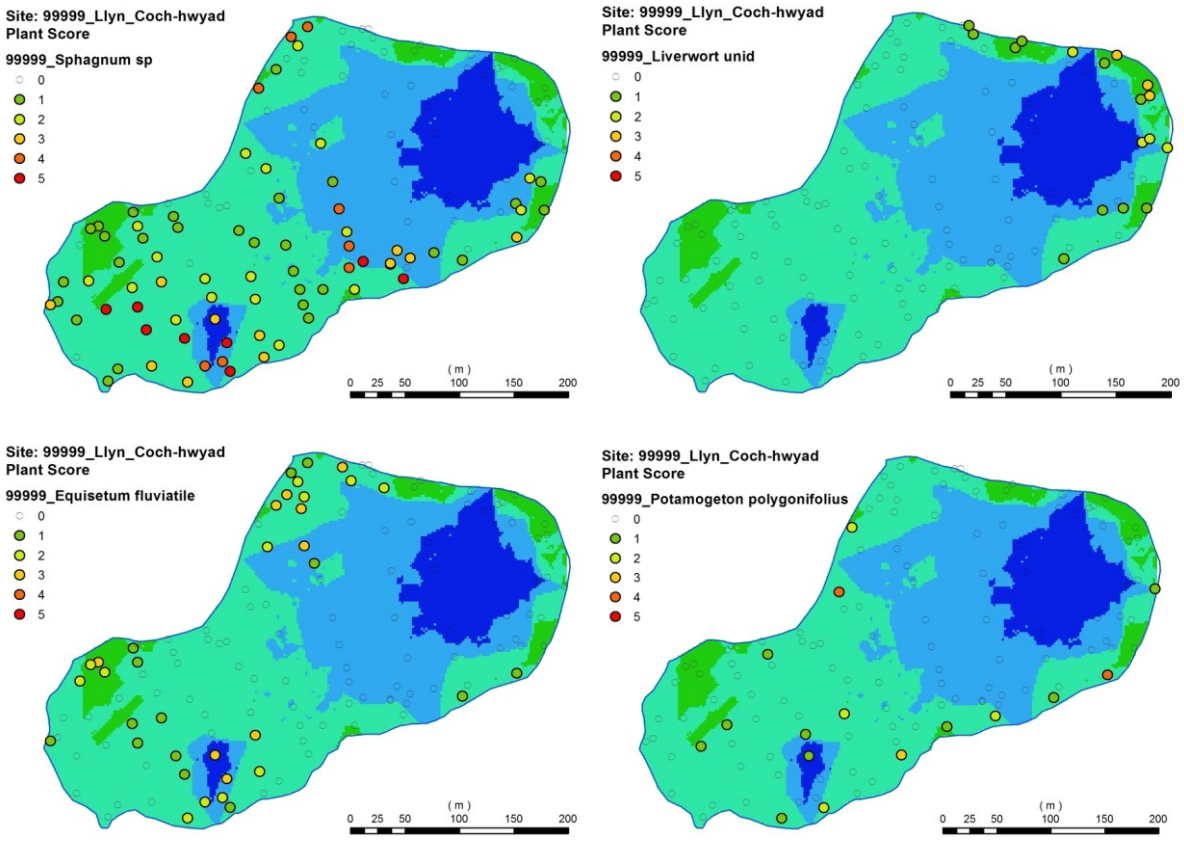


Figure 30




## Negative indicator species

*Myriophyllum alterniflorum* was frequent in the lake, albeit mainly restricted to very shallow water where in places it formed dense stands. Its occurrence at 40% frequency is considered a potential indicator of increased trophic status in oligotrophic lakes (JNCC 2005). Filamentous algae were recorded at scores of 2 (25-75% cover) or 3 (>75% cover) at 22% of sample points, while 53% of points had no filamentous algae. Although rather patchy, it is estimated that the site exceeded the 10% cover threshold

## Water quality

The collection of monthly water chemistry data for Llyn Coch-hwyad was organised by NRW staff, with samples being sent for analysis by NLS (May 2012-May 2013). The remote situation of the lake meant access was not possible during heavy snow cover and hence the February 2013 sample was missed.

The data show Llyn Coch-hwyad to be a slightly acid lake with relatively high dissolved organic carbon and brown water. Colour values of 86 mg $l^{-1}$ as Pt place the lake well within the WFD 'humic' category and close to the 'polyhumic' category used by Carvalho *et al*. (2008). Nitrogen is very low at the site, with total oxidized nitrogen being below or close to detection limits throughout the growing season, suggesting the site to be nitrogen limited. Conversely, mean annual total phosphorus concentrations are high for an oligotrophic lake (18 µg $l^{-1}$) and exceed the CSM target limit of 10 µg$l^{-1}$. The geometric mean TP was 16.8 µg $l^{-1}$ which corresponds with Good Status using the MEI model (Reference = 10 µg $l^{-1}$; H/G = 13 µg $l^{-1}$; G/M = 20

µg $l^{-1}$). This suggests that there has been some enrichment of the lake, probably as a result of the forestry activity. However, for a very shallow humic lake nutrient levels are not excessive.

Table 41 Water chemistry data for Llyn Coch-hwyad (for units see methodology). Based on 11 monthly values from May 2012 – May 2013

| Determinand | Min. | Max | Mean |
|---|---|---|---|
| pH | 5.63 | 7.76 | 6.27 |
| Cond | 29.1 (July 2013 only) | | |
| Colour ($mgl^{-1}$ Pt) | 31 | 148 | 86 |
| Alk (Gran) | -5 | 3.5 | 1.28 |
| SRP | <1.0 | 3 | 1.81 |
| TP | 10.5 | 39.9 | 17.98 |
| Chl a | 1.3 | 6.5 | 3.52 |
| TON | <0.005 | 0.027 | 0.01 |
| $Na^{+}$ | 2.36 | 4.15 | 3.07 |
| $K^{+}$ | 0.04 | 0.21 | 0.09 |
| $Mg^{2+}$ | 0.46 | 0.94 | 0.59 |
| $Ca^{2+}$ | 0.71 | 1.49 | 0.99 |
| $Cl^{-}$ | 3.3 | 7.5 | 5.30 |
| $SO4^{2-}$ | 1.58 | 2.84 | 2.04 |
| $SiO_2$ | No data | | |
| Sus. Solids | No data | | |
| Labile Al | No data | | |
| DOC | 3.94 | 13.8 | 8.91 |
| ANC-I (ionic) | | | 41.9 |
| ANC-C (Cantrell) | | | 65.6 |

At the time of survey in July 2013, the lake was well oxygenated throughout with DO from 0 - 14 m was >10 mg $l^{-1}$ (Figure 31). This corresponds with favourable condition and WFD High Status.

ANC values are within the updated CSM guidelines (40 µeq $l^{-1}$). Given the high levels of humic acids in the site, the site is unlikely to be at risk of further acidification is considered favourable in respect to ANC and this is refelected in the relatively high ANC-C.

## Hydrology

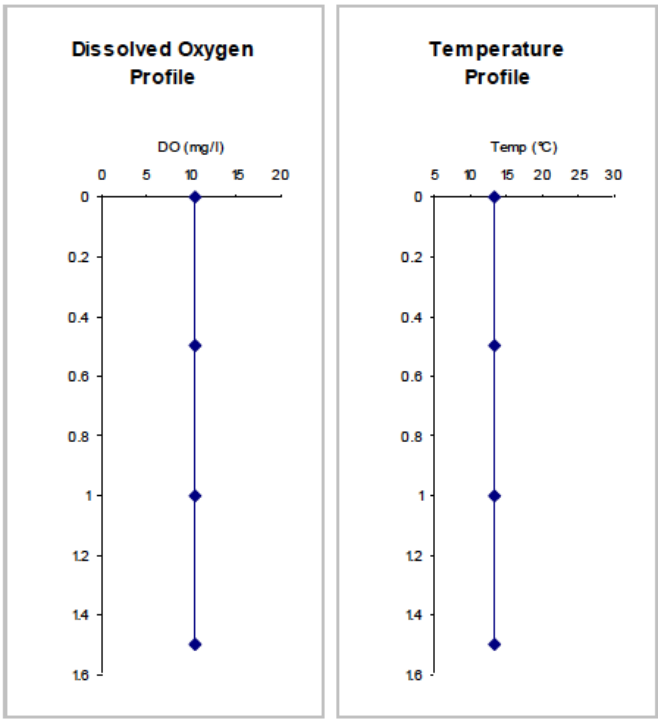
The lake has two surface inflow streams draining the slopes to the south. There are also a number of boggy areas around the shore where water can be seen issuing from the peats into the lake. The surface and sub-surface flow from the surrounding peats were noted as being very brown in colour. There is a single outflow at the western end of the lake which flows west through the deeply incised Nant Llyn Coch-hwyad valley before ultimately draining to the Afon Dyfi. The forest plantation has a network of drains cut into the peats and it is thought likely that these, along with the forest trees, will impact the natural hydrology of the lake, but to what extent is unknown.

Figure 31 Dissolved oxygen (DO) profile for Llyn Coch-hwyad (01/07/2013).

**Dissolved Oxygen Profile**

| | |
|---|---|
| GPS Location | SH9220211052 |
| Maximum Depth (m) | 1.6 m |
| Secchi Depth (cm) | 100 cm |
| Notes: | |

| Depth (m) | DO (mg/l) | Temp (°C) |
|---|---|---|
| 0 | 10.5 | 13.4 |
| 0.5 | 10.43 | 13.4 |
| 1 | 10.42 | 13.4 |
| 1.5 | 10.44 | 13.4 |

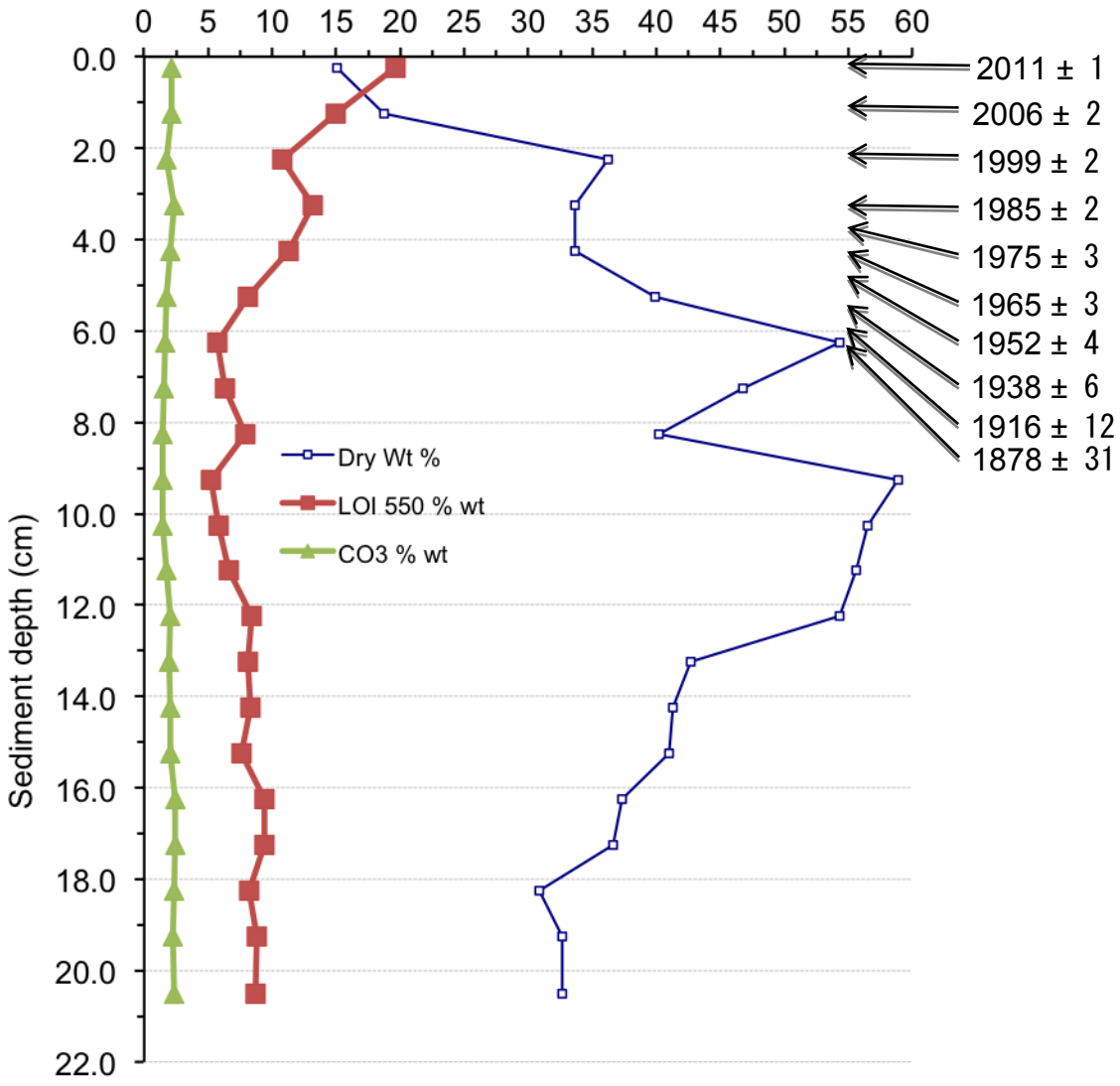



## Lake substrate and sediment loads

The littoral substrates are comprised of mainly sands, gravels and pebbles with areas of peat and soft sediments accumulating in sheltered areas. In open water the substrates were predominantly soft silts and fine organic sediments with more mineral, sandt deposits in shallower areas.

A 21 cm sediment core (COCH2) was collected from the deep point and subject to radiometric dating, dry weight and organic content analysis. It is interesting to note that sediment accumulation rates have in the past been very slow at the site, increasing only gradually until afforestation (mid 1980s), after which they increase faster, but still relatively slowly for a lake within an afforested catchment (Figure 32). Since afforestation the organic content has approximately doubled along with a significant decline in dry weight (mainly mineral content). The increase in organic matter most likely the reflects increased inwash of catchment peats, forest decay and potentially increased internal productivity due to nutrient release during catchment disturbance, especially the drainage work.

Figure 32 Physical characteristics from core COCH2 DW = dry weight; LOI = loss on ignition, CO3 = (carbonate content)



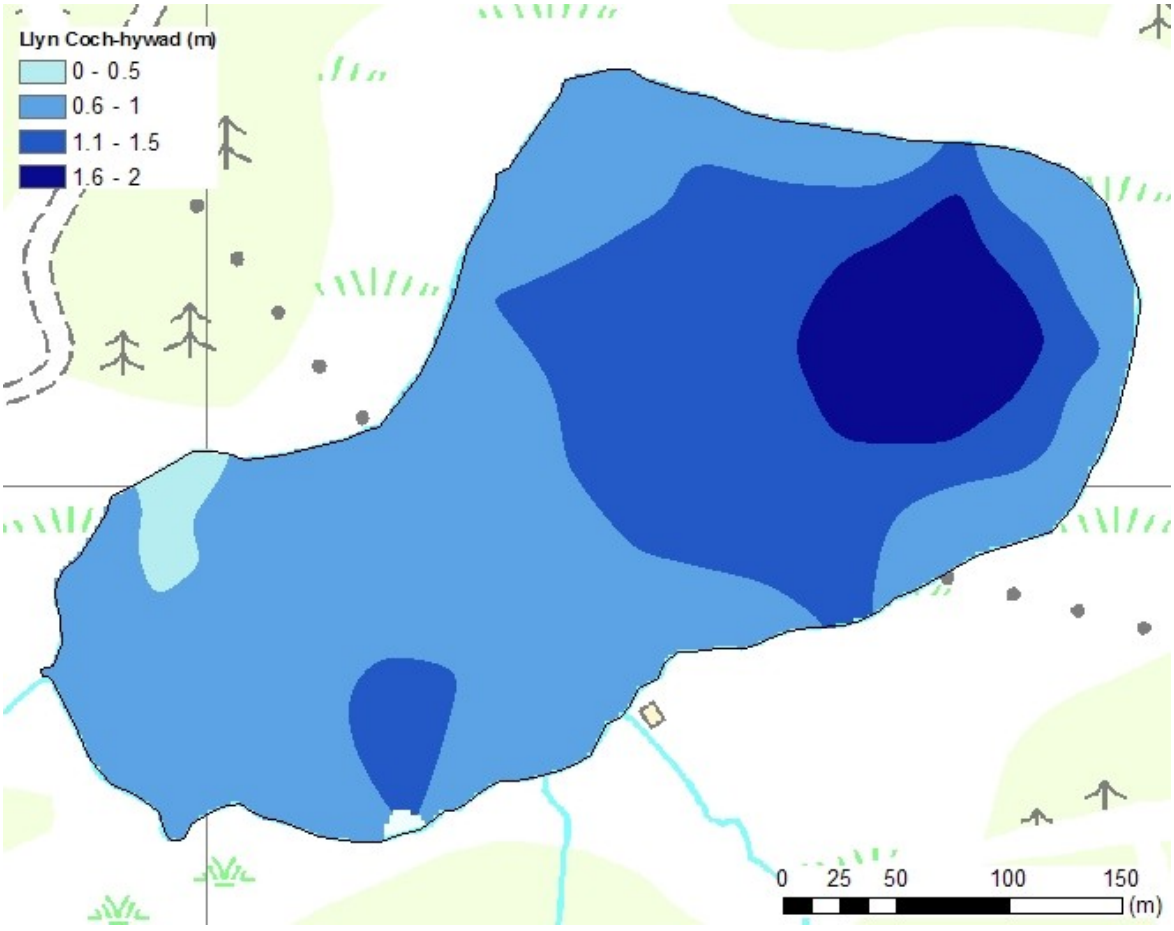

While there are obvious changes in the sediments that coincide with afforestation, the core also shows some quite major changes over its full length which is estimated to extend back over 500 years based on the pre-1900 accumulation rates. Since approximately AD 1878 (6.25 cm) there has been a trend towards increased organic content and reduced mineral deposition at the coring site. The lake is very shallow, and this may therefore reflect physical processes within the lake as well as increased productivity due to (for example) increased grazing or burning in the catchment over the past 150 years.

Although there have been considerable changes to the lake sedimentation, the data show sediment accumulation rates and organic content to be higher since afforestation, than at any other period during the time-span of the core. The environmental impact of any future forest operations in the catchment should therefore be fully assessed in relation to potential increases in sedimentation and release of nutrients to the lake.

## Indicators of local distinctiveness

The presence of a significant population of *Luronium natans* is of importance. There was a relatively large bed (75 x 30 m) growing towards the north shore centred on SH9216511134 and another smaller bed (25 x 25 m) on the south side centred on SH9224510962. Smaller patches of plants were then recorded regularly in quite shallow water (50-75 cm) along the north and north-west shore and sporadically on the south shore (Figure 30). Total numbers of plants were estimated to be in excess of 1000. No floating leaves were recorded and no flowering material was seen. Llyn Coch-hwyad appears to have a stable and relatively large population of this Schedule 4, Annexe II and UK BAP species.

Figure 33 Bathymetric map of Llyn Coch-hwyad, December 2013




## Bathymetry

Llyn Coch-hwyad is a very shallow (mean depth 0.95 m) lake with its deepest point of 1.69 m being towards the eastern end (Figure 33).

## Palaeolimnological evidence

A 21 cm sediment core (COCH2) was taken from the deep point at SH9226811014 using a Renberg gravity corer. The core was sliced at 1 cm intervals in the field and analysed for dry weight, organic content and carbonate content. A subset of samples were dried and subjected to radiometric dating. The physical analysis and dating of the core are discussed above and presented in Figure 32. The diatom flora of the

surface sediment was dominated by benthic taxa, consistent with the lake being very shallow. *Eunotia incisa* (36%) and *Fragilara exigua* (11.5%) dominated the flora. The diatom assemblage of the deepest sediments was significantly different with SCD between the samples of 1.08. The basal sediments were also dominated by periphytic taxa, but *Achnanthes minutissima* was dominant (30%), with *Eunotia incisa* (12%) and a planktonic species, *Cyclotella distinguenda* var. *unipunctata* also present at 10% abundance. The age of this sample is likely to be very old (>500 years BP).

| Sample Code | Depth (cm) | 2012/13 mean pH | DI-pH | 2012/13 mean TP | DI-TP | SCD |
|---|---|---|---|---|---|---|
| COCH2-00 | 0 | 6.27 | 5.60 | 17.9 | 4.5 | 1.08 |
| COCH2-20 | 20 | | 6.40 | | 5.2 | 0.00 |

Table 42 Results of Llyn Coch-hwyad sediment core analysis

Reconstructions of diatom-inferred pH (DI-pH) were produced using the SWAP training set (RMSEP = 0.32 pH units). A high percentage of the taxa in the fossil samples were present in the SWAP training set and there were no major analogue problems. The DI-pH results suggest the site has become more acid over the time period covered by the core, by about 0.8 pH unit. This is contrary to the measured ANC values however and may simply reflect a major species change brought about by the impact of afforestation on the lake rather than atmospheric deposition alone. It is likely that drainage of the surrounding blaket bog has increased DOC in the site and humic acids in the lake, both which will have impacted on the diatom flora. A higher resolution study of the fossil diatoms would be required to ascertain the extent to which the site has acidified and what may have caused the change.

The current surface sediment assemblage estimates current pH to be lower than measured pH which is possibly due to errors in pH measurement rather than the modelled results. A number of the monthly pH readings were higher than expected and several readings have been omitted due to a “faulty meter”, which gives low confidence in all the measured data. Similar problems were noted for samples sent to NLS by ENSIS in December 2012.

Reconstructions of diatom-inferred TP (DI-TP) show low modelled TP from the core bottom and top (5.2 to 4.5 µg $l^{-1}$). A high percentage of the taxa in the fossil samples were present in the NW European training set and there were no major analogue problems. The annual mean current TP based on quarterly water samples collected during 2012-13 was 17.9 µg $l^{-1}$ and therefore the diatom model significantly underestimates the current measured value. This possibly reflects the complex nature of phosphorus in humic lakes where much of the measured TP is bound within humic acids and not therefore biologically available and hence the modeled TP may therefore be a good estimate of ‘active’ P in the lake. Additionally, the lake appears to be N limited and thus the assumption that the diatom flora will be driven by P concentrations may not be valid. The problems associated with modeling diatom-based TP in sites with high DOC is well recognised (Bennion, pers. comm.) and confidence in the modeled results further compounded by poor coverage of this lake type within the training set.

In summary, there has been significant floristic change in the sediment core from Llyn Coch-hwyad and while the fossil diatom assemblages suggest the site to have acidified relative to baseline conditions, the reasons for this remain unlear. High resolution diatom analysis of the upper sediments would be beneficial to understanding the relative impact of atmospheric deposition over the past 150 years and of the forestry on the lake water quality in the last few decades. The modeling of TP at the site is not considered appropriate due to the high DOC concentration.

## Site condition summary and overview

Llyn Coch-hwyad was fond to have high concentrations of dissolved organic carbon and high colour values, making it a rare Welsh example of a dystrophic lake (see Hatton-Ellis 2014 for an overview). Dystrophic lakes are protected under the Habitats Directive as well as being a BAP type. Llyn Coch-hwyad increases the known area of this habitat in Wales by almost 25%; moreover with 14 aquatic plant species it is an unusually species-rich example.

The flora of the lake can therefore be considered favourable if assessed against dystrophic attributes, but overall the site remains in **unfavourable condition** due to the abundance of filamentous algae and concerns over the high frequency of *Myriophyllum alterniflorum,* both being indicative of enrichment.

The lake has a relatively large population of *Luronium natans* with the total number of plants estimated to be in excess of 1000 and these were present at a number of different locations within the site. This survey, inclusive of the plant mapping, supports the survey undertaken in 2006 (ECUS 2007) which showed a similar overall cover (estimated at 20%) and thus suggests the population to be stable. Llyn Coch-hwyad is therefore an important site for this Annex II (Habitat Directive) and UK BAP species and should be afforded greater protection accordingly. While the species appears to be stable at the site, increased sedimentation and nutrient enrichment increase the risk of a decline and should be avoided.

Mean annual TP concentration (2012/13) were relatively high for upland lake, but such sites with high DOC concentrations and nitrogen limitations are often observed to have TP concentrations in excess of 10 µg $l^{-1}$, even within un-impacted catchments (Carvalho *et al.* 2003, Burgess *et al.* 2006). However, the MEI model suggests that there is some nutrient enrichment above the expected level for this lake. A high percentage of coniferous plantation within the catchment can contribute to the increased availability of phosphorus (as well as nitrogen and DOC) in the surface waters (Drinan *et al.* 2013), although this is more likely during planting and clear-fell harvesting. In light of the high frequency of *Myriophyllum alterniflorum* and relatively high abundance of filamentous green algae observed at the site, the current TP concentrations are considered unfavourable and it is recommended the site receives regular chemical monitoring. It should be noted, however, that current data suggests the lake is nitrogen rather than phosphate limited and therefore control of nitrogen inputs will also be important.

In addition to the current status of the site, there is potentially an increased risk during any future forest operations. Drinan *et al.* (2013) found the greatest increases in surface water nutrients occurred in catchments where clear felling had occurred, thus placing Llyn Coch-hwyad at high risk during timber harvesting. The impact of

disturbance during forest planting is also well known to rapidly increase sediment loads to lakes within the catchment (Battarbee *et al.* 1985). Although on a smaller scale than the disturbance caused by forestry, similar implications apply to the potential disturbance from the planned wind turbines within the area.

We recommended that the site should not be replanted and efforts be made to return drainage patterns to a more natural state and promote conditions for the redevelopment of blanket bog in the region. The planned wind farm construction in the area offers a good opportunity for this, but care needs to be taken during construction and with the location of tracks. Felling and construction works should ensure minimal disturbance and make provision for the containment of sediments where there is a risk of material entering surface water runoff to the lake.

Table 43 Llyn Coch-hwyad overview

| Water Body | Status | Reason(s) for concern | Comments |
|---|---|---|---|
| Llyn Coch-hwyad | **Unfavourable (low confidence)** | Elevated TP concentrations and some evidence of acidification.<br>> 10% filamentous algae cover<br>High frequency of *M. alterniflorum* (40%)<br>High risk of increased sediment and nutrient load during timber harvest | Llyn Coch-hwyad has a species rich flora, and is a rare example of a dystrophic lake in Wales. *L. natans* populations appear healthy under current conditions and require better protection to prevent damage from increased siltation and nutrients from forest management. TP concentrations remain a concern and should be monitored along with pH and N. Current catchment management is considered to be a threat to the BAP interest within the site. |

## Recommendations for monitoring and management:

The high percentage of coniferous forest plantation within the catchment of Llyn Coch-hwyad is considered to be inconsistent with the conservation needs of the lake and likely to place the population of the Annex II (Habitats Directive) and UK BAP species *Luronium natans* at increased risk. NRW should be made fully aware of all future forestry operations and full ecological impact assessments made, including assessments of increased sediment loads and nutrient release.

The site is at some risk of further acidification and currently has TP well in excess of the CSM target value. A minimum of quarterly water quality monitoring (to include Colour in addition to the list of monitored variables in Table 2) is recommended to ascertain any directional change in water quality and provide an early warning of any further deterioration to the site. Additional monitoring should be undertaken during

any forestry operations within the catchment. Due to the likely importance of N at this lake, nitrogen species should also be monitored.

Amenity use at the lake is low and angling is restricted by limited access and controlled ticketing through the Llanbrymair Angling Association. This situation is considered appropriate.

Better water quality and low sedimentation rates are key factors in improving the habitat quality of Llyn Coch-hwyad and preserving the populations of *Luronium natans* and other characteristic oligotrophic plant species within the lake. The site would also benefit from regular (every 3 years recommended) macrophyte surveys to ascertain any shifts in the population of *Luronium natans* and to monitor the extent and frequency of filamentous algae and *Myriophyllum alterniflorum* within the site.

The following recommendations are based on the evidence collected for this report:

- Elevate the conservation status of the site to protect the significant population of *L. natans.*
- Ensure all catchment forestry operations are conducted within best practice guidelines and minimise sediment and nutrient inputs to the lake.
- Monitor water quality – minimum of quarterly sampling including nutrients, ANC and colour.
- Increase water quality monitoring during foresty operations.
- Monitor the aquatic flora, including *Luronium natans* populations, every 3 years to ascertain any directional trends.

## CSM Database output

### Site Condition Assessment: Llyn Coch-hwyad (01/07/2013)

| Lake Details | | Survey Details | | |
|---|---|---|---|---|
| Lake Name | Llyn Coch-hwyad | Survey Date | 01/07/2013 | |
| SSSI Name | | Surveyors | BG, JS & ST | |
| SAC Name | | Shore Surveys | 4 | out of |
| Grid Ref | SH921109 | Wader Surveys | 4 | 4 |
| WBID | 99999 | Boat Surveys | 3 | sections |

Site Notes:
Luronium natans

Survey Notes:
pH = 6.14, Cond. = 29.1. Site very shallow with very brown water. Surrounded by conifer plantation.

#### Section Summaries

| | | | |
|---|---|---|---|
| **Section** | **1** | Maximum depth of colonisation (cm) | 160 cm |
| | | Compass bearing of boat transect (°) | 270 ° |
| | | Lateral distance from waters edge to 75cm depth (m) | 15 m |
| | | Notes: Plants to max depth | |
| **Section** | **2** | Maximum depth of colonisation (cm) | 120 cm |
| | | Compass bearing of boat transect (°) | 180 ° |
| | | Lateral distance from waters edge to 75cm depth (m) | 30 m |
| | | Notes: Plants to max depth od transect | |
| **Section** | **3** | Maximum depth of colonisation (cm) | 80 cm |
| | | Compass bearing of boat transect (°) | - |
| | | Lateral distance from waters edge to 75cm depth (m) | 50 m |
| | | Notes: No boat survey - too shallow. | |
| **Section** | **4** | Maximum depth of colonisation (cm) | 80 cm |
| | | Compass bearing of boat transect (°) | 100 ° |
| | | Lateral distance from waters edge to 75cm depth (m) | 30 m |
| | | Notes: | |

#### Section Locations

| | | Shore Survey GPS Co-ords | | Boat Survey GPS Co-ords | |
|---|---|---|---|---|---|
| | | start | end | start (shore) | end (lake) |
| **Section** | **1** | SH9239811108 | SH9236110979 | SH9237611048 | SH9232311035 |
| **Section** | **2** | SH9220311196 | SH9211111088 | SH9217311097 | SH9217511074 |
| **Section** | **3** | SH9212110872 | SH9197210870 | - | - |
| **Section** | **4** | SH9193810915 | SH9203811016 | SH9200510969 | SH9208310953 |

#### Section Photos

| | | Start of Section | Whole Section | End of Section |
|---|---|---|---|---|
| **Section** | **1** | 36 | 37 | 38 |
| **Section** | **2** | 38 | 39 | 41 |
| **Section** | **3** | 42 | 44 | 43 |
| **Section** | **4** | 45 | 46 | 47 |

## Species Abundance - Boat Survey

Total number of sample plots 60
Total number of vegetated sample plots 28

| Plant Species | Occurrence *n* | Occurrence % |
|---|---|---|
| *Callitriche hamulata* | 20 | 71 |
| *Equisetum fluviatile* | 4 | 14 |
| *Fontinalis antipyretica* | 14 | 50 |
| *Luronium natans* | 3 | 11 |
| *Mosses aquatic* | 13 | 46 |
| *Myriophyllum alterniflorum* | 7 | 25 |
| *Sphagnum sp.* | 3 | 11 |

## Species Abundance - Wader Survey

Total number of sample plots 80
Total number of vegetated sample plots 72

| Plant Species | Occurrence *n* | Occurrence % |
|---|---|---|
| *Callitriche hamulata* | 32 | 44 |
| *Carex rostrata* | 12 | 17 |
| *Equisetum fluviatile* | 35 | 49 |
| *Fontinalis antipyretica* | 24 | 33 |
| *Glyceria fluitans* | 1 | 1 |
| *Isoetes lacustris* | 12 | 17 |
| *Littorella uniflora* | 4 | 6 |
| *Liverworts aquatic* | 5 | 7 |
| *Lobelia dortmanna* | 1 | 1 |
| *Luronium natans* | 13 | 18 |
| *Menyanthes trifoliata* | 1 | 1 |
| *Myriophyllum alterniflorum* | 33 | 46 |
| *Nuphar lutea* | 5 | 7 |
| *Potamogeton polygonifolius* | 11 | 15 |
| *Sparganium angustifolium* | 24 | 33 |
| *Sphagnum sp.* | 29 | 40 |

## Plant Scores

**Total plant species** 36 **Filamentous algae (%)** 23% WADER 3.3% BOAT
**Total plant cover (%)** 200.97

**S U R V E Y  S C O R E S**

| PLANT SPECIES | PERIMETER | WADER | BOAT | COVER % | DAFOR | ABUNDANCE |
|---|---|---|---|---|---|---|
| *Equisetum fluviatile* | 0.625 | 0.1432 | 0.05 | 27.78 | A | 4 |
| *Callitriche hamulata* | 0.1 | 0.1089 | 0.1545 | 23.4 | F | 3 |
| *Calluna vulgaris* | 0.625 | 0 | 0 | 15.62 | F | 3 |
| *Fontinalis antipyretica* | 0 | 0.0869 | 0.0975 | 14.1 | F | 3 |
| *Juncus effusus* | 0.5625 | 0 | 0 | 14.06 | F | 3 |
| *Carex rostrata* | 0.4375 | 0.0445 | 0 | 13.16 | F | 3 |
| *Myriophyllum alterniflorum* | 0.025 | 0.1241 | 0.0375 | 10.58 | F | 3 |
| *Mosses aquatic* | 0 | 0 | 0.1018 | 10.18 | F | 3 |
| *Juncus acutiflorus* | 0.3 | 0 | 0 | 7.5 | O | 2 |
| *Sphagnum sp.* | 0 | 0.1175 | 0.015 | 7.38 | O | 2 |
| *Luronium natans* | 0.025 | 0.0438 | 0.0228 | 5.1 | O | 2 |
| *Potentilla palustris* | 0.1875 | 0 | 0 | 4.69 | R | 1 |
| *Galium palustre* | 0.175 | 0 | 0 | 4.38 | R | 1 |
| *Ranunculus flammula* | 0.175 | 0 | 0 | 4.38 | R | 1 |
| *Sparganium angustifolium* | 0 | 0.0852 | 0 | 4.26 | R | 1 |
| *Rumex acetosa* | 0.15 | 0 | 0 | 3.75 | R | 1 |
| *Carex nigra* | 0.15 | 0 | 0 | 3.75 | R | 1 |
| *Galium saxatile* | 0.15 | 0 | 0 | 3.75 | R | 1 |
| *Eriophorum vaginatum* | 0.125 | 0 | 0 | 3.12 | R | 1 |
| *Viola palustris* | 0.1125 | 0 | 0 | 2.81 | R | 1 |
| *Cirsium palustre* | 0.0875 | 0 | 0 | 2.19 | R | 1 |
| *Potentilla erecta* | 0.0875 | 0 | 0 | 2.19 | R | 1 |
| *Isoetes lacustris* | 0 | 0.0388 | 0 | 1.94 | R | 1 |
| *Potamogeton polygonifolius* | 0 | 0.0333 | 0 | 1.66 | R | 1 |
| *Carex paniculata* | 0.0625 | 0 | 0 | 1.56 | R | 1 |
| *Caltha palustris* | 0.0625 | 0 | 0 | 1.56 | R | 1 |
| *Menyanthes trifoliata* | 0.025 | 0.0037 | 0 | 0.81 | R | 1 |
| *Nuphar lutea* | 0 | 0.016 | 0 | 0.8 | R | 1 |
| *Liverworts aquatic* | 0 | 0.0149 | 0 | 0.74 | R | 1 |
| *Littorella uniflora* | 0 | 0.0149 | 0 | 0.74 | R | 1 |
| *Eleocharis palustris* | 0.025 | 0 | 0 | 0.62 | R | 1 |
| *Carex ovalis* | 0.025 | 0 | 0 | 0.62 | R | 1 |
| *Cardamine pratensis* | 0.025 | 0 | 0 | 0.62 | R | 1 |
| *Phragmites australis* | 0.025 | 0 | 0 | 0.62 | R | 1 |
| *Lobelia dortmanna* | 0 | 0.0078 | 0 | 0.39 | R | 1 |
| *Glyceria fluitans* | 0 | 0.0031 | 0 | 0.16 | R | 1 |

## 5.8. Llyn Gwyddior

Annex 1 type: H3130: Oligo-mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the Isoëto-*Nanojuncetea*.

### 5.8.1. Site description

Summary characteristics for Llyn Gwyddior

| | |
|---|---|
| Name: | Llyn Gwyddior |
| County: | Powys |
| WBID: | 36615 |
| Grid reference: | SH935073 |
| OS Grid reference (X,Y): | 293514,307395 |
| Latitude / Longitude | N52°39.23',W003°34.54' |
| Altitude (m): | 415 |
| Maximum recorded depth (m): | 10.65 |
| Mean depth (m): | 3.73 |
| Lake volume ($m^3$): | 510309 |
| Surface area – UKLakes (ha): | 12.8 |
| Surface area – measured (ha) | 13.70 |
| Perimeter of lake (km): | 1.4 |
| Shoreline Development Index (SDI): | 1.121 |
| WFD alkalinity based typology: | Low Alkalinity, Shallow (LA, S) |
| Phase 1 habitat type: | Standing water: Oligotrophic: G1.3 |
| Survey Date: | 2 July 2013 |

Llyn Gwyddior is a relatively shallow lake lying at an altitude of 415 m on the Llabrynmair Moors, a large upland plateau situated north-east of the village of Llanbrynmair that rises to 520 m. The underlying geology comprises of Silurian rocks dominated by Penstrowed Gritstones with area of Devensian till covering the valley floor. The lake catchment is small with the watershed being within a few hundred metres of the lake margin. There are no permanent overland inflows, the lake instead being fed by surface and sub-surface flow through the surrounding peats. There is an outflow at the eastern end of the lake which flows east to join the Afon Cannon, a tributary of the Afon Gam which eventually joins the River Severn between Welshpool and Shrewsbury.

The moors were once covered by large areas of blanket bog, but much of this was lost in the 1980s when the areas was afforested with conifers. A few small areas of bog were not planted, and in 1994 were afforded SSSI status, these area being Cors Bwlch Trosol, Cors Mynydd Tal-y-glannau and Cors Gordderwen. The Llyn Gwyddior catchment is only partially afforested, with a small area coming close to shore on the south side and smaller areas in the upper catchment to the north and north-west. Although currently without any formal designation, the lake is a known site for *Luronium natans* (listed as a BAP priority species and in Annex II of the Habitats Directive), first reported as present in 1993 (Kay *et al.* 1999) and confirmed in a 2006 survey conducted by ECUS (2007). The lake is also reported to support *Pilularia globulifera* (listed as a BAP priority species), recorded by Jones *et al.* in 1997 (BSBI 2001) and confirmed as present in 2006 (ECUS 2007).

Condition Assessment and Discussion

Table 44 Condition Assessment Summary Table for Llyn Gwyddior

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | None |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise) | ✓ | 5 characteristic *Littorelletea* spp in 2013: *Isoetes lacustris, Littorella uniflora, Lobelia dortmanna, Luronium natans & Sparganium angustifolius.* |
| | No loss of characteristic species (see Box 2) | **?** | Similar species list recorded by ECUS in 2006 – but no *Pilularia globulifera* in 2013 |
| | ≥ 6/10 vegetated sample spots (boat / wader survey) have ≥ 1 characteristic spp. | ✓ | Only 80% of vegetated sample spots comply (82% wader, 75% boat) |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | None recorded |
| | Benthic and epiphytic filamentous algae <10%. | **X** | Filamentous algal was estimated to exceed 10 % cover. |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (site specific) | ✓ | Good zonation present. *L . uniflora* to 1.6 m, *L. dortmanna* to c. 2.0 m, *I. lacustris* to 2.5 m – *Nitella spp* to c. 2.9 m. *L. natans* 0.2 - 1.3 m. |
| | Maximum depth distribution should be maintained | **-** | $Z_{max}$ (recorded) = 10.65 m, $Z_s$ = 3.40 m, $Z_v$ = 2.9 m. |
| | At least present structure should be maintained | **-** | No evidence of change |
| **Water quality** | Stable nutrients levels: TP target / limit: Oligotrophic = 10 $\mu g l^{-1}$ | ✓ | TP (mean 2012/13) = 8.8 $\mu g\ l^{-1}$ (range 4.2 - 27.1 $\mu g\ l^{-1}$). TON = <0.03 $mg\ l^{-1}$ |
| | Stable pH values: pH ~ 5.5 – circumneutral | ✓ | Mean pH 2012/13 = 7.10 (Range 6.70 - 7.89). ANC = 85 $\mu eq\ l^{-1}$ |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 $mg l^{-1}$) | ✓ | > 10 $mg\ l^{-1}$ from 0 - 8.5 m. Water column mixed July 2013 |
| | No excessive growth of cyanobacteria / green algae | ✓ | None noted, and low Chl a values (mean 3.52 $\mu g\ l^{-1}$, range <0.5 - 20.6 $\mu g\ l^{-1}$) |

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Hydrology** | Natural hydrological regime | ✓? | Under natural control, but possibly influenced by forestry drainage |
| **Lake substrate** | Natural shoreline maintained | ✓ | Appears natural |
| | Natural and characteristic substrate maintained | X? | Sediment core analysis shows an increase in organic material since afforestation |
| **Sediment load** | Natural sediment load maintained | X? | Sedimentation rates have increased since afforestation |
| **Indicators of local distinctive-ness** | Distinctive elements maintained at current extent / levels / locations | ✓? | *Luronium natans* is present, but rare. *Nitella flexilis* present and fairly common. *Pilularia globulifera* was not recorded in 2013. |
| **Disturbance** | No introduced species | ✓ | None recorded |
| | Minimal negative impacts from recreation and navigation. No fish farming | ✓ | Occasional shore angling. Minimal impact. |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | ✓ | Diatom flora indicates moderate species turnover but little change in water quality. |

**Status: ✓ = favourable; X = unfavourable; - = unable to assess**

## Extent

The surface area of the lake is 13.7 ha. There is no evidence of any recent loss of extent of open water.

## Macrophyte community composition and structure

Llyn Gwyddior has a species rich flora with many elements being typical for oligo/mesotrophic lakes. A total of 16 aquatic plant species were recorded in 2013, 5 of which were characteristic oligotrophic species (Table 45). Furthermore, 80% of the vegetated sample points had one or more characteristic species present and the vegetation showed characteristic species zones. *Littorella uniflora* and *Lobelia dortmanna* were recorded most commonly in shallower water (1.6 m and 2.0 m respectively) with *Isoetes lacustris* overlapping in shallow water but extending to a maximum depth of 2.5 m. Both *Nitella opaca* and *N. flexilis* sensu stricto were present in the site (determinations confirmed by Nick Stewart), and while it was not always possible to split these two species in the field, it appears both were relatively widespread within the site up to depths of 2.2 m.

*Myriophyllum alterniflorum* was common, but the frequency was below that considered to be indicative of enrichment within the CSM guidelines (JNCC 2005). A large stand of *Equisetum fluviatile* occupied the shallower water (up to 1.5 m) around

the southwest margin, often with significant cover of filamentous green algae growing among the stems and little else. Other species were relatively rare in the site. The maximum recorded depth was for *Chara virgata* at 2.6 m (Table 45 and Figure 35).

*Luronium natans* was confirmed in the lake, and although only recorded at three points in the CSM survey (in Sections 1 and 3), the plant mapping revealed it to be relatively common, with 5 separate beds being recorded in total, the largest being approximately 50 m x 20 m located near the outflow on the southeast side. A dense bed was recorded in the outflow channel (approximately 5 m x 1 m). Other sparse beds were found along the south shore and a few individuals were recorded in shallow water on the north shore (Figure 35). Total numbers of plants were estimated to be in excess of 1000 and the population therefore assumed not to be under immediate risk within the site.

| Submerged and floating vegetation | TRS | PLEX | % occurrence (n=123) | DAFOR abundance[10] | Min depth (cm) | Max depth (cm) |
|---|---|---|---|---|---|---|
| *Callitriche hamulata* | 6.3 | 6.15 | 2 | R | 220 | 220 |
| *Chara virgata* | 7.3 | 7.69 | 7 | O | 75 | 260 |
| *Equisetum fluviatile* | | | 20 | F | 0 | 150 |
| *Fontinalis antipyretica* | 6.3 | 5.38 | 5 | R | 25 | 110 |
| *Glyceria fluitans* | 7 | 6.54 | 1 | **R** | 20 | 25 |
| ***Isoetes lacustris*** | **5** | **4.23** | 58 | D | **20** | **250** |
| ***Littorella uniflora*** | **6.7** | **4.23** | 41 | **A** | **0** | **160** |
| ***Lobelia dortmanna*** | **5** | **3.08** | 49 | A | **20** | **200** |
| ***Luronium natans*** | | | 2 | **R** | **20** | **130** |
| *Myriophyllum alterniflorum* | 6.7 | 4.23 | 30 | **A** | 25 | 220 |
| *Nitella flexilis* | 6.7 | 5.38 | 8 | O | 90 | 220 |
| *Nitella flexilis* agg. | 6.7 | 5.38 | 32 | A | 25 | 160 |
| *Nitella opaca* | 6.7 | 5.38 | 8 | O | 70 | 220 |
| *Potamogeton natans* | 7 | 4.23 | 3 | R | 50 | 120 |
| *Potamogeton polygonifolius* | 3.7 | 3.08 | 3 | R | 25 | 50 |
| ***Sparganium angustifolium*** | **4** | **4.23** | 1 | R | **80** | **80** |
| *Sphagnum sp.* | 2.5 | 1.54 | 1 | **R** | 25 | 25 |
| **Average score** | **5.8** | **4.72** | | | | |
| **Species richness** | | | | 16 | | |

Table 45 Aquatic macrophyte community composition for Llyn Gwyddior in July 2013. Characteristic oligotrophic species are highlighted in **bold**.

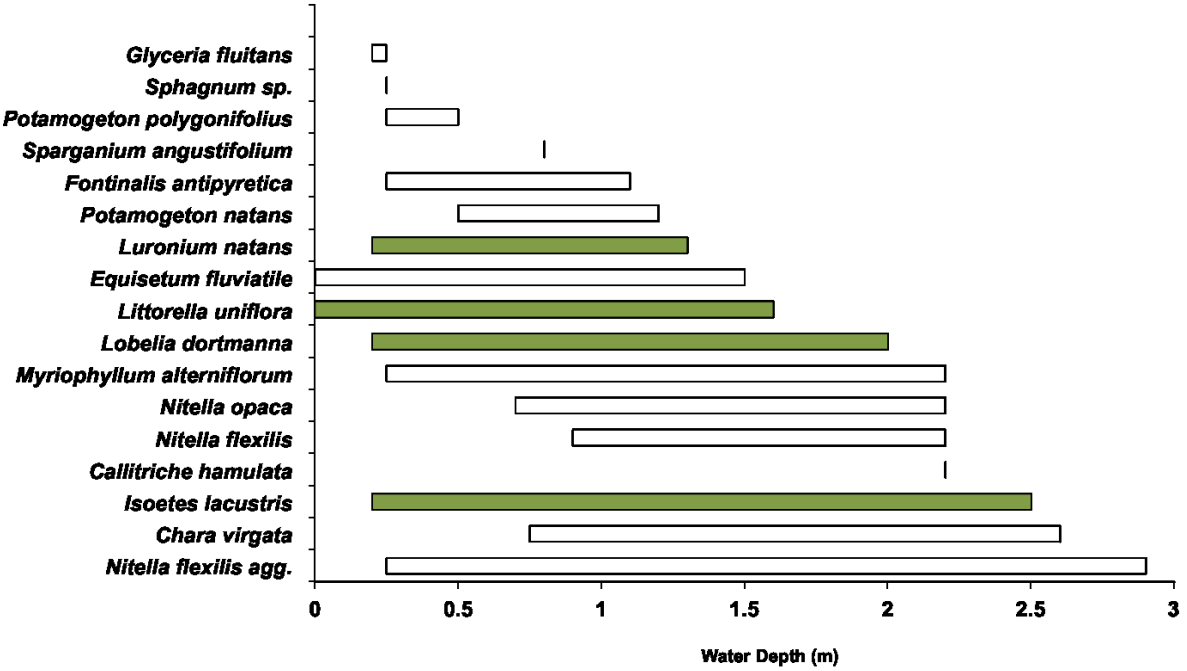
*Pilularia globulifera* was not recorded in the 2013 survey. Previous records show it to have been present in the western margins (ECUS 2007) and growing at depths of up

[10] Based on presence / absence data from all vegetated plots in the wader and boat based surveys. DAFORs are calculated from the total number of occurrences across the wader and boat surveys as a proportion of the total number of vegetated wader and boat survey points.

to 1.6 m (Lockton 2010). Due to its creeping rhizomes, underwater plants are normally easy to detect with a double-headed rake where present, and therefore its absence is of concern. The small area at the west of the lake where it was recorded by ECUS (2007) did not coincide with any of the 2013 survey points and therefore its presence at the site cannot be ruled out.

The current assemblage places the lake into Group D as defined by Duigan *et al*. (2006) which is typified by oligo/mesotrophic lakes with high species richness. The TRS (5.8) and PLEX (4.72) scores are consistent with oligotrophic lakes and the overall character of the flora is typical of lakes with peat-rich catchments and slightly brown water. Llyn Gwyddior is favourable with respect to its aquatic macrophyte composition and distribution. Concern regarding the possible decline or loss of *Pilularia globulifera* requires further investigation.

Figure 34 Depth range of the aquatic macrophytes recorded from Llyn Gwyddior; characteristic oligotrophic species are shaded green.




## Negative indicator species

*Myriophyllum alterniflorum* (30%) was below the frequency considered to be a potential indicator of increased trophic status in oligotrophic lakes (JNCC 2005). Filamentous algae was recorded at scores of 2 (25-75% cover) or 3 (>75% cover) at 36% of sample points, most prevalent within the *Equisetum fluviatile* beds. Only 8% of points had no filamentous algae recorded and although rather patchy, it is estimated that the site exceeded the 10% cover threshold.

No non-native invasive species were present.

Figure 35 Distribution maps of the aquatic plant species recorded in Llyn Gwyddior

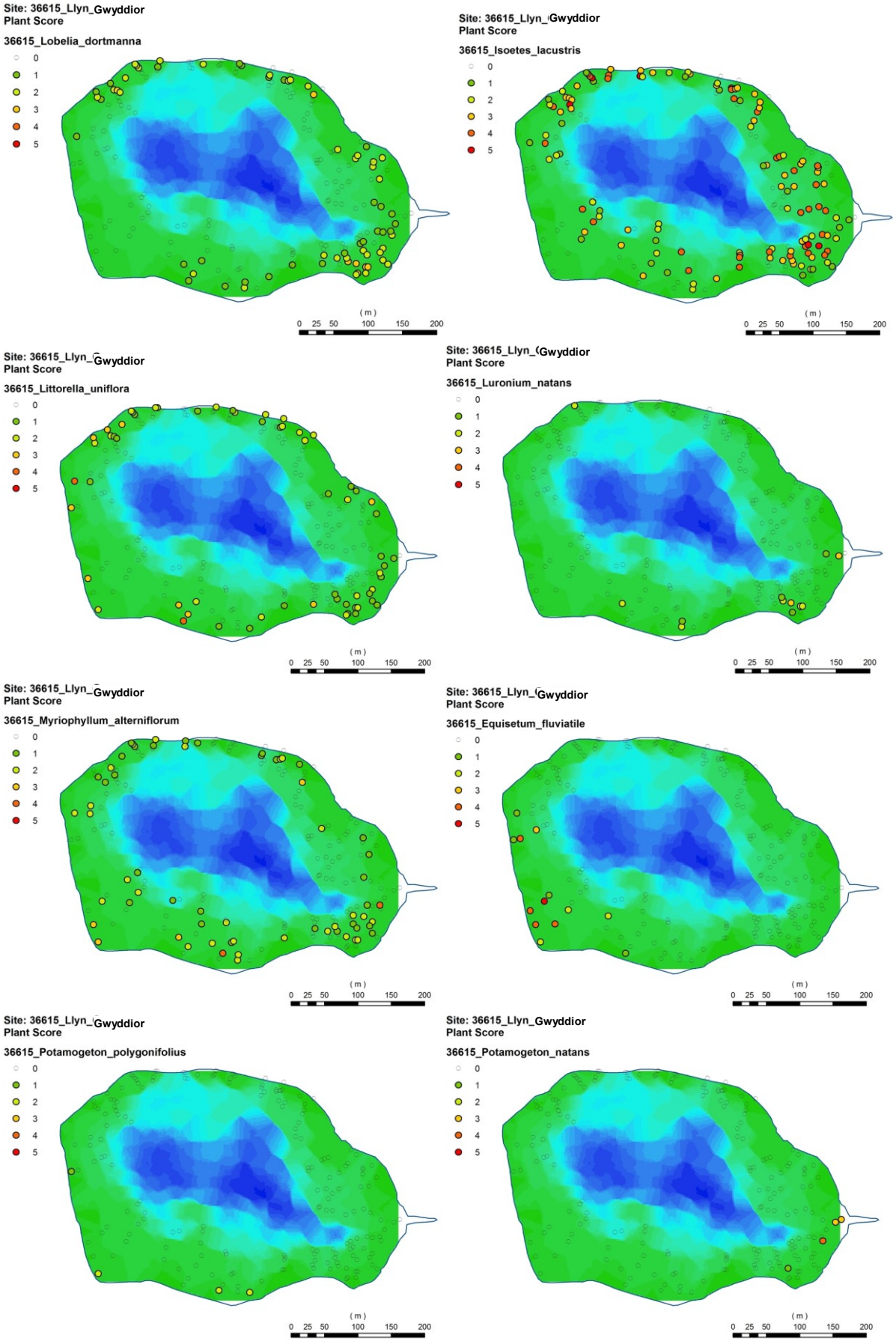
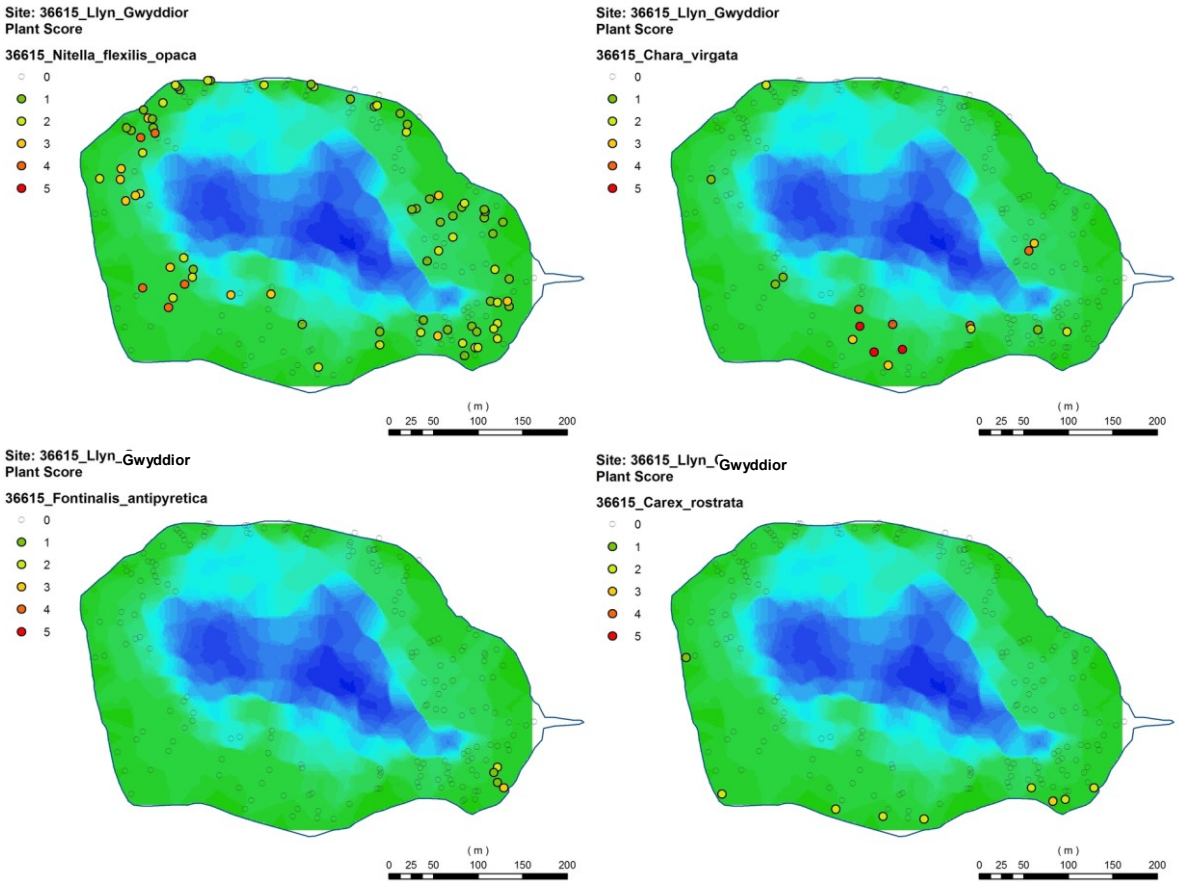


Figure 35 (contd.)




## Water quality

The collection of monthly water chemistry data for Llyn Gwyddior was organised by NRW staff, with samples being sent for analysis by NLS. Despite the remote situation of the lake, NRW staff succeeded in collecting a full set of 12 water samples between May 2012 and May 2013. A faulty pH meter resulted in some loss of data points and reduces data confidence for pH.

The data show Llyn Gwyddior to be a low alkalinity lake with peat-influenced water (Table 46). The mean colour value (excluding an outlier from August 2012) is 37.27 mg $l^{-1}$ Pt units, placing it just inside the 'humic' lake category as used by UKTAG. The MEI model for lake phosphorus predicts a reference TP of 5 µg $l^{-1}$, a H/G boundary of 7 µg $l^{-1}$ and a G/M boundary of 10 µg $l^{-1}$; however these values apply to clear lakes, with humic lakes expected to have slightly higher TP. The CSM boundary for oligotrophic lakes is 10 µg $l^{-1}$ and we have therefore used this figure. Mean total phosphorus concentrations are 8.78 µg $l^{-1}$ and so fall just within the upper limit for oligotrophic lakes of 10 µg $l^{-1}$ and suggest the site to be favourable with respect to trophic status.

Nitrogen is very low at the site, with total oxidized nitrogen being below or close to detection limits throughout the growing season suggesting the site to be nitrogen limited. High values for TP, Chl *a,* and DOC were recorded in August 2012, possibly the result of inwashed nutrients after a period of warm dry weather facilitating oxidation of the catchment peats.

| Determinand | Min. | Max | Mean |
|---|---|---|---|
| pH | 6.7 | 7.89 | 7.10 |
| Cond | 27.3 (July 2013 only) | | |
| Colour ($mgl^{-1}$ Pt) | 21 | 56 (169) | 37.4 |
| Alk (Gran) | 1.9 | 4.08 | 3.27 |
| SRP | 1.02 | 2.70 | 1.78 |
| TP | 4.2 | 27.1 | 8.78 |
| Chl a | 0.72 | 20.60 | 3.35 |
| TON | 0.01 | 0.06 | 0.03 |
| $Na^+$ | 2.71 | 3.65 | 3.26 |
| $K^+$ | 0.06 | 0.24 | 0.21 |
| $Mg^{2+}$ | 0.63 | 1.00 | 0.91 |
| $Ca^{2+}$ | 1.20 | 1.49 | 1.37 |
| $Cl^-$ | 4.00 | 6.30 | 5.48 |
| $SO4^{2-}$ | 1.72 | 2.75 | 2.39 |
| $SiO_2$ | No data | | |
| Sus. Solids | No data | | |
| Labile Al | No data | | |
| DOC | 3.94 | 16.1 | 6.16 |
| ANC-I (ionic) | | | 84.9 |
| ANC-C (Cantrell) | | | 93.2. |

Table 46 Water chemistry data for Llyn Gwyddior (for units see methodology). Based on 11 monthly values from May 2012 – May 2013

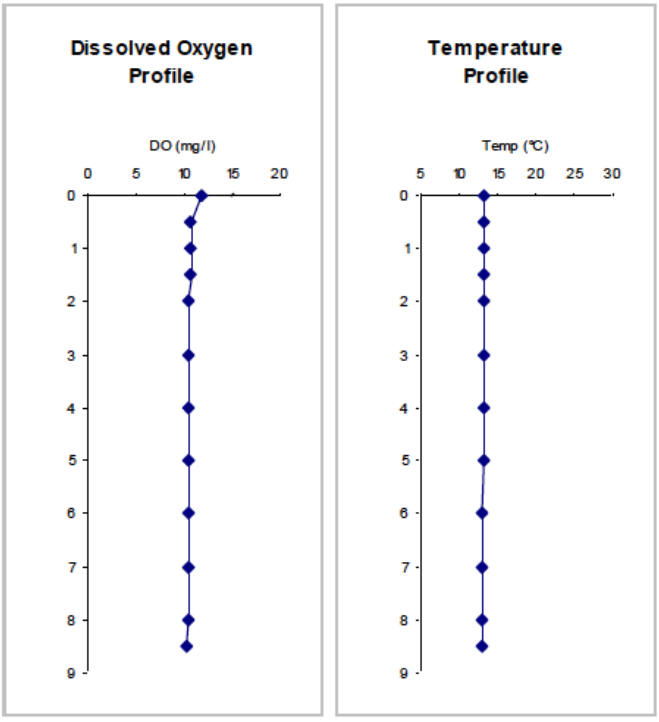
Figure 36 Dissolved oxygen (DO) profile for Llyn Gwyddior (02/07/2013).

**Dissolved Oxygen Profile**

| | |
|---|---|
| GPS Location | SH9352607440 |
| Maximum Depth (m) | 8.8 m |
| Secchi Depth (cm) | 3.41 cm |

Notes:

| Depth (m) | DO (mg/l) | Temp (°C) |
|---|---|---|
| 0 | 11.83 | 13.2 |
| 0.5 | 10.66 | 13.2 |
| 1 | 10.64 | 13.2 |
| 1.5 | 10.63 | 13.2 |
| 2 | 10.44 | 13.2 |
| 3 | 10.55 | 13.2 |
| 4 | 10.49 | 13.2 |
| 5 | 10.44 | 13.2 |
| 6 | 10.44 | 13.1 |
| 7 | 10.46 | 13.1 |
| 8 | 10.41 | 13 |
| 8.5 | 10.32 | 13 |



At the time of survey in July 2013, the lake was well oxygenated throughout with DO from 0 - 8.5 m was >10 mg $l^{-1}$ (Figure 36). This would place it in High status and therefore the lake passes the DO target.

Due to equipment problems pH data could not be used for assessing acidity. The ANC of 93.2 is well above both value in the updated CSM guidelines (JNCC in draft), and the 40 µeq $l^{-1}$ high/good boundary for lakes (UKTAG 2006). Llyn Gwyddior is therefore considered to be well buffered and not at risk of acidification.

## Hydrology

The lake has no permanent surface inflow streams but is surrounded by wet peat and areas of bog. The surface and sub-surface flow from the surrounding peats was observed at a number of points around the lake. There is a single outflow at the eastern end of the lake which flows east to join the Afon Cannon, a tributary of the Afon Gam which eventually joins the River Severn between Welshpool and Shrewsbury. Small areas of plantation forestry occur within the catchment, including a 250 m wide strip running down to the south shore. The plantation has a network of drains cut into the peats and it is thought likely that these, along with the forest trees, will impact the natural hydrology of the lake, but to what extent is unknown.

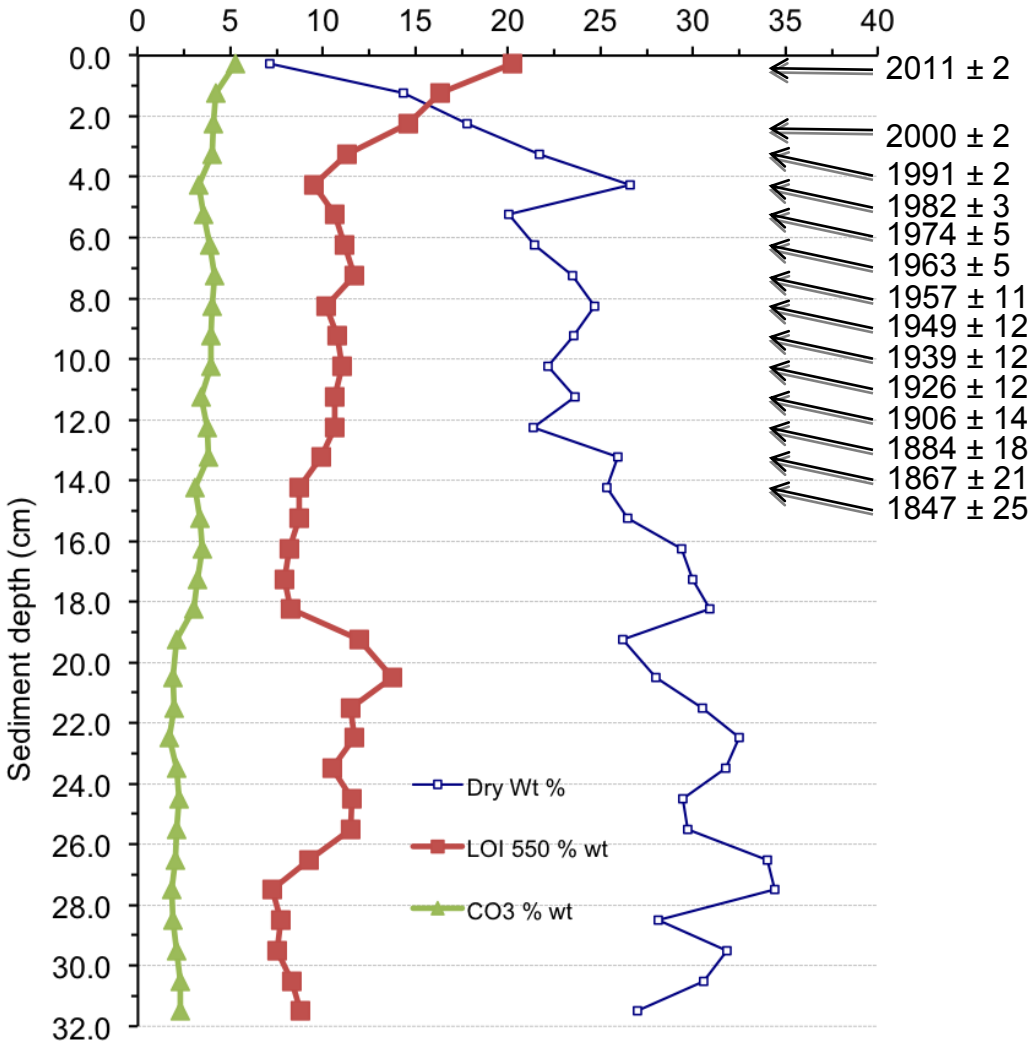
## Lake substrate and sediment loads

The littoral substrates are comprised of mainly pebbles, cobbles, some areas of peat and also sands. In open water there are finer sediments as well as sands and pebbles to depth of 1.5 - 2.0 m, beyond which finer silts predominate.

A 31 cm sediment core (GWYD2) was collected from deep water (9.7 m at SH 93424 07464) and subject to radiometric dating, dry weight and organic content analysis (Figure 37). Prior to recent (c. 1985) afforestation, the organic content of the sediments appears to have been stable for at least 150 years. Following afforestation however, the organic content has approximately doubled along with a significant decline in dry weight (mainly mineral content). The increase in organic matter most likely the reflects increased inwash of catchment peats, forest decay and potentially increased internal productivity due to nutrient release during catchment disturbance.

Although there have been changes to the lake sediment composition pre-1850, the data show relatively stability in more recent years with major changes coinciding with afforestation. The environmental impact of any future forest operations in the catchment should therefore be fully assessed in relation to potential increases in sedimentation and release of nutrients to the lake.

Figure 37 Physical characteristics from core GWYD2 DW = dry weight; LOI = loss on ignition, CO3 = (carbonate content)




## Indicators of local distinctiveness

The presence of *Luronium natans* is of importance. Five separate locations were recorded in the site, the largest bed being approximately 50 m x 20 m located near the outflow on the southeast side. A dense bed was recorded in the outflow channel (approximately 5 m x 1 m). Other sparse beds were found along the south shore and an few individuals recorded in shallow water on the north shore (Figure 35). Total numbers of plants were estimated to be in excess of 1000 and the extent of the population was slightly greater than recorded in 2006 (ECUS 2007).

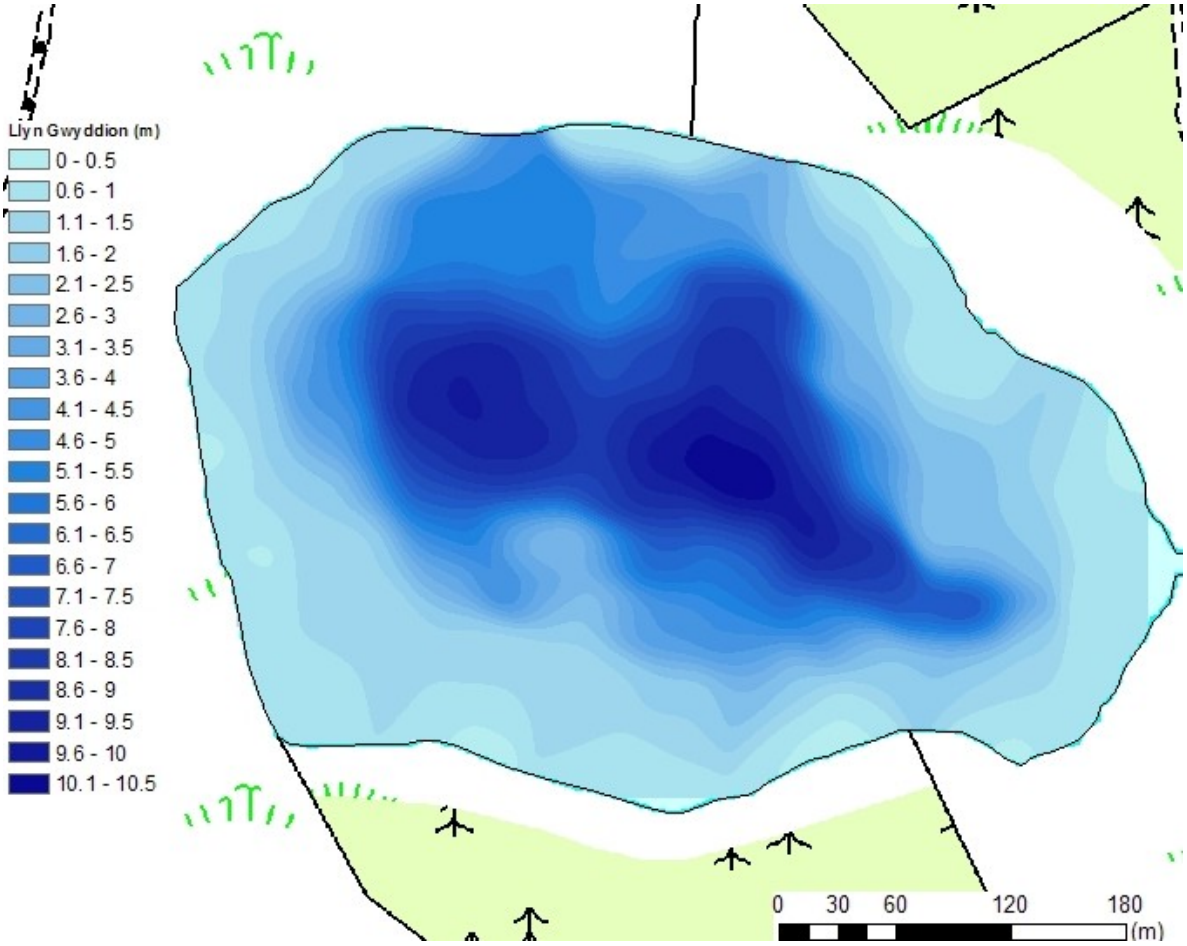
*Nitella flexilis* sensu stricto was confirmed from the site by Nick Stewart. This is a BAP priority species. The extent to which it occurred at the site was not assessed due to it not being possible to separate it from *Nitella opaca* in the field. Unidentified material was all recorded as *Nitella flexilis* agg.

*Pilularia globulifera* was not recorded in the 2013 survey, but was previously recored in the western margins (ECUS 2007). Further survey to confirm the presence of this species is recommended.

## Bathymetry

Llyn Gwyddior is a shallow (mean depth 3.73 m) lake with its deepest point of 10.65 m being towards the centre (Figure 38). The littoral zone is relatively broad and slopes gently from shore, providing ample shallow water habitat for aquatic plant growth.

Figure 38 Bathymetric map of Llyn Gwyddior, December 2012




## Palaeolimnological evidence

A 32 cm sediment core (GWYD2) was taken from 9.7 m at SH 93424 07464 using a Renberg gravity corer. The core was sliced at 1 cm intervals in the field and analysed for dry weight, organic content and carbonate content. A subset of samples were dried and subjected to radiometric dating. The physical analysis and dating of the core are discussed above and presented in Figure 37.

The diatom flora of the surface sediment was dominated by benthic taxa, consistent with the lake having extensive shallow water. *Achnanthes minutissima* (18%) and *Tabellaria flocculosa* (14%) dominated the diatom flora, with a planktonic species, *Cyclotella distinguenda* var. *unipunctata,* also present at 8% abundance. The diatom assemblage of the deepest sediments showed a relatively high degree of species turnover has occurred, but the SCD between the samples was les than 1.00 and therefore not significant (Table 47).

The basal sediments also had *Achnanthes minutissima* (6%), but were dominated by a small *Gomphonema* species (cf. *pumilum*) at 11% and *Eunotia incisa* (8%). *Cyclotella distinguenda* var. *unipunctata* was present at 4.5%. Based on the accumulation rates of c.AD 1850, the age of this sample is likely to be very old (>500 years BP).

| Sample Code | Depth (cm) | 2012/13 mean pH | DI-pH | 2012/13 mean TP | DI-TP | SCD |
|---|---|---|---|---|---|---|
| GWYD2-00 | 0 | 7.30? | 6.16 | 8.7 | 5.3 | 0.85 |
| GWYD2-20 | 31 | | 6.32 | | 8.2 | 0.00 |

Table 47 Results of Llyn Gwyddior sediment core analysis

Reconstructions of diatom-inferred pH (DI-pH) were produced using the SWAP training set (RMSEP = 0.32 pH units). There were some analogue problems between the training set and the GWYD2 31-32 cm sample, primarily due to unresolvable taxonomic issues with the *Gomphonema* species common in the sample, but poorly represented in the training set. The DI-pH results suggest the site has become very slightly more acid over the time period covered by the core, but the difference is within the error of the model and not therefore considered to be significant. The current surface sediment assemblage estimates current pH to be lower than measured pH which is probably due to errors in pH measurement resulting from faulty equipment.

Reconstructions of diatom-inferred TP (DI-TP) show low modelled TP from the core bottom and top (8.3 to 5.3 µg $l^{-1}$). A high percentage of the taxa in the fossil samples were present in the NW European training set and there were no major analogue problems. The current annual mean TP based on monthly water samples collected during 2012-13 was 8.7 µg $l^{-1}$ and therefore the diatom model gives a good estimate of current conditions.

In summary, there has been a moderate degree of floristic change in the sediment core diatoms from Llyn Gwyddior, and the fossil diatom assemblages indicates little change in the water quality between the core top and bottom. High resolution diatom analysis of the upper sediments would be beneficial to understanding the impact of atmospheric deposition over the past 150 years and of the forestry on the lake water quality in the last few decades.

## Site condition summary and overview

Llyn Gwyddior is in **favourable condition (at risk)** with **high confidence**. The lake supports a species rich aquatic macrophyte flora, inclusive of a well represented characteristic aquatic macrophyte flora with good depth distribution consistent with the slightly brown water derived from the catchment peats.

The lake supports a population of the UK BAP species *Luronium natans,* with the total numbers of plants estimated to be in excess of 1000 and these were present at a number of different locations within the site. This survey, inclusive of the plant mapping, compares favourably with the survey undertaken in 2006 (ECUS 2007)

which showed, if anything, a slightly lower overall coverage and therefore the current population is considered to be at least stable and possibly increasing. Llyn Gwyddior is therefore an important site for this Annex II (Habitat Directive) and UK BAP species and should be afforded greater protection. While *L. natans* appears to be stable at the site, it is vulnerable due to the potential increases in sedimentation and nutrients that future forestry operations may cause.

*Pilularia globulifera* was not recorded in 2013, and while the confirmed loss of a characteristic taxon is unfavourable, the absence of records in this survey does not confirm it as permanently lost from the site. This species is very sensitive to short-term changes in environmental conditions such as water level fluctuation and desiccation of littoral habitats and is well known to vary greatly in abundance from year to year (Lockton 2010). It is therefore recommended that annual checks are made at Llyn Gwyddior, ideally following drier conditions in summer, to ascertain the presence of *Pilularia globulifera* at the site.

The mean annual TP in 2012/3 lies just within the recommended target limit for oligotrophic lakes and palaeoecologcal evidence suggests there to have been no significant acidification or eutrophication within the site. There is however evidence that afforestation has changed the sediment structure within the lake and previous studies on afforested catchments suggest there is a real risk of the increased availability of phosphorus (as well as nitrogen and DOC) during planting and clear-fell harvesting (Drinan *et al.* 2013). No forest management should be conducted within the catchment without a full appraisal of the risks to the lake. Where perceived risks are identified, these should be mitigated for in consultation with NRW staff with respect to threats to UK BAP and Annex II Habitats Directive species. Hence the site is placed “at risk” despite being in favourable condition.

Table 48 Llyn Gwyddior overview

| Water Body | Status | Reason(s) for concern | Comments |
|---|---|---|---|
| Llyn Gwyddior | **Favourable – at risk (high confidence)** | Risk of increased sediment and nutrient load during timber harvest | Llyn Gwyddior has a species rich aquatic flora, including good distribution of characteristic isoetid species. *L. natans* populations appear healthy under current conditions and require better protection to prevent damage from increased siltation and nutrients from forest management. *P. globulifera* populations require annual monitoring to assess stability.. Current catchment management is considered to be a threat to the BAP interest within the site. |

The impact of disturbance during forest planting is also well known to rapidly increase sediment loads to lakes within the catchment (Battarbee *et al.* 1985) and it is recommended that the catchment should not be replanted and efforts be made to return drainage patterns to a more natural state and promote conditions for the redevelopment of blanket bog in the region.

## Recommendations for monitoring and management:

The presence of coniferous forest plantation within the catchment of Llyn Gwyddior is considered to be inconsistent with the conservation needs of the lake and likely to place the population of the Annex II (Habitats Directive) *Luronium natans* and UK BAP species *Pilularia globulifera* at increased risk. NRW should be made fully aware of all future forestry operations and full ecological impact assessments made, including assessments of increased sediment loads and nutrient release.

Although current water quality is good, quarterly monitoring (to include colour in addition to the full list of monitored variables in Table 2) is recommended to ascertain any directional change in water quality and provide an early warning of any deterioration to the site. Additional monitoring should be undertaken during any forestry operations within the catchment.

Amenity use at the lake is low and angling is restricted by limited access and controlled ticketing through the Llanbrymair Angling Association. This situation is considered appropriate.

Good water quality and low sedimentation rates are key factors in maintaining the habitat quality of Llyn Gwyddior and preserving the populations of *Luronium natans* and other characteristic oligotrophic plant species within the lake. A change from forestry to low intensity grazing may also be beneficial for *Pilularia globulifera,* which benefits from moderate disturbance within and around lake margins. The site would also benefit from regular (every 3 years recommended) macrophyte surveys to ascertain any shifts in the population of *Luronium natans* and annual monitoring of *P. globulifera* to assess stability of the BAP species populations.

The following recommendations are based on the evidence collected for this report:

- Elevate the conservation status of the site to protect the lake habitat and populations of *L. natans* and *Pilularia globulifera.*
- Ensure all catchment forestry operations are conducted within best practice guidelines and minimise sediment and nutrient inputs to the lake.
- Monitor water quality – minimum of quarterly sampling.
- Increase water quality monitoring during foresty operations.
- Monitor the aquatic flora, including *Luronium natans* populations, every 3 years and make annual assessment of *P. globulifera* populations to ascertain any directional trends.

## CSM Database output

### Site Condition Assessment: Llyn Gwyddior (02/07/2013)

| Lake Details | | Survey Details | | |
|---|---|---|---|---|
| Lake Name | Llyn Gwyddior | Survey Date | 02/07/2013 | |
| SSSI Name | | Surveyors | BG, JoS & ST | |
| SAC Name | | Shore Surveys | 4 | out of |
| Grid Ref | SH935073 | Wader Surveys | 4 | 4 |
| WBID / NI No. | 36615 / | Boat Surveys | 4 | sections |

Site Notes:
Forrestry site - best access from north.

Survey Notes:
pH 6.7, Cond 27.3. Both Nitella opaca and N. flexilis ss confirmed from the site (NS)

#### Section Summaries

| | | |
|---|---|---|
| **Section 1** | Maximum depth of colonisation (cm) | 220 cm |
| | Compass bearing of boat transect (°) | 270 ° |
| | Lateral distance from waters edge to 75cm depth (m) | 10 m |
| | Notes: Plants to mad depth of transect | |
| **Section 2** | Maximum depth of colonisation (cm) | 230 cm |
| | Compass bearing of boat transect (°) | 190 ° |
| | Lateral distance from waters edge to 75cm depth (m) | 5 m |
| | Notes: | |
| **Section 3** | Maximum depth of colonisation (cm) | 220 cm |
| | Compass bearing of boat transect (°) | 5 ° |
| | Lateral distance from waters edge to 75cm depth (m) | 5 m |
| | Notes: | |
| **Section 4** | Maximum depth of colonisation (cm) | 230 cm |
| | Compass bearing of boat transect (°) | 210 ° |
| | Lateral distance from waters edge to 75cm depth (m) | 24 m |
| | Notes: | |

#### Section Locations

| | Shore Survey GPS Co-ords | | Boat Survey GPS Co-ords | |
|---|---|---|---|---|
| | start | end | start (shore) | end (lake) |
| **Section 1** | SH9374907395 | SH9375007309 | SH9374407370 | SH9367907397 |
| **Section 2** | SH9358807564 | SH9350607580 | SH9335007566 | SH9335707553 |
| **Section 3** | SH9341007271 | SH9332907972 | SH9337607293 | SH9341607333 |
| **Section 4** | SH9336407588 | SH9328707515 | SH9331707514 | SH9332907505 |

#### Section Photos

| | Start of Section | Whole Section | End of Section |
|---|---|---|---|
| **Section 1** | 48 | 52 | 51 |
| **Section 2** | 53 | 55 | 54 |
| **Section 3** | 59 | 61 | 60 |
| **Section 4** | 62 | 64 | 63 |

## Species Abundance - Boat Survey

Total number of sample plots 80
Total number of vegetated sample plots 45

| Plant Species | Occurrence n | Occurrence % |
|---|---|---|
| *Callitriche hamulata* | 2 | 4 |
| *Chara virgata* | 8 | 18 |
| *Equisetum fluviatile* | 6 | 13 |
| *Fontinalis antipyretica* | 0 | 0 |
| *Isoetes lacustris* | 31 | 69 |
| *Lobelia dortmanna* | 13 | 29 |
| *Luronium natans* | 1 | 2 |
| *Myriophyllum alterniflorum* | 21 | 47 |
| *Nitella flexilis* | 10 | 22 |
| *Nitella flexilis agg.* | 5 | 11 |
| *Nitella opaca* | 10 | 22 |

## Species Abundance - Wader Survey

Total number of sample plots 80
Total number of vegetated sample plots 78

| Plant Species | Occurrence n | Occurrence % |
|---|---|---|
| *Carex rostrata* | 11 | 14 |
| *Eleocharis palustris* | 4 | 5 |
| *Equisetum fluviatile* | 18 | 23 |
| *Fontinalis antipyretica* | 6 | 8 |
| *Glyceria fluitans* | 1 | 1 |
| *Isoetes lacustris* | 40 | 51 |
| *Littorella uniflora* | 51 | 65 |
| *Lobelia dortmanna* | 47 | 60 |
| *Luronium natans* | 2 | 3 |
| *Myriophyllum alterniflorum* | 16 | 21 |
| *Nitella flexilis agg.* | 34 | 44 |
| *Potamogeton natans* | 4 | 5 |
| *Potamogeton polygonifolius* | 4 | 5 |
| *Sparganium angustifolium* | 1 | 1 |
| *Sphagnum sp.* | 1 | 1 |

Note: Species abundance % = ((number of plots / total number of vegetated sample plots) * 100)

## Plant Scores

**Total plant species** 32 **Filamentous algae (%)** 42.2 % WADER 19.4 % BOAT

**Total plant cover (%)** 196.45

**SURVEY SCORES**

| PLANT SPECIES | PERIMETER | WADER | BOAT | COVER % | DAFOR | ABUNDANCE |
|---|---|---|---|---|---|---|
| *Isoetes lacustris* | 0 | 0.1129 | 0.2362 | 29.26 | A | 4 |
| *Juncus effusus* | 0.75 | 0 | 0 | 18.75 | F | 3 |
| *Lobelia dortmanna* | 0 | 0.1404 | 0.1048 | 17.5 | F | 3 |
| *Myriophyllum alterniflorum* | 0 | 0.0479 | 0.1236 | 14.76 | F | 3 |
| *Equisetum fluviatile* | 0.05 | 0.1159 | 0.0497 | 12.02 | F | 3 |
| *Carex rostrata* | 0.275 | 0.0686 | 0 | 10.3 | F | 3 |
| *Nitella flexilis agg.* | 0 | 0.0969 | 0.0526 | 10.1 | F | 3 |
| *Littorella uniflora* | 0 | 0.1896 | 0 | 9.48 | O | 2 |
| *Hydrocotyle vulgaris* | 0.275 | 0 | 0 | 6.88 | O | 2 |
| *Nitella flexilis* | 0 | 0 | 0.0636 | 6.36 | O | 2 |
| *Carex nigra* | 0.25 | 0 | 0 | 6.25 | O | 2 |
| *Eleocharis palustris* | 0.2125 | 0.0166 | 0 | 6.14 | O | 2 |
| *Chara virgata* | 0 | 0 | 0.051 | 5.1 | O | 2 |
| *Sphagnum sp.* | 0.1875 | 0.0041 | 0 | 4.89 | R | 1 |
| *Juncus bulbosus* | 0.1875 | 0 | 0 | 4.69 | R | 1 |
| *Nitella opaca* | 0 | 0 | 0.0454 | 4.54 | R | 1 |
| *Cardamine amara* | 0.15 | 0 | 0 | 3.75 | R | 1 |
| *Ranunculus flammula* | 0.15 | 0 | 0 | 3.75 | R | 1 |
| *Cirsium palustre* | 0.125 | 0 | 0 | 3.12 | R | 1 |
| *Eriophorum vaginatum* | 0.125 | 0 | 0 | 3.12 | R | 1 |
| *Galium palustre* | 0.125 | 0 | 0 | 3.12 | R | 1 |
| *Glyceria fluitans* | 0.0875 | 0.0031 | 0 | 2.34 | R | 1 |
| *Myosotis laxa* | 0.0875 | 0 | 0 | 2.19 | R | 1 |
| *Viola palustris* | 0.0875 | 0 | 0 | 2.19 | R | 1 |
| *Potentilla erecta* | 0.0625 | 0 | 0 | 1.56 | R | 1 |
| *Luronium natans* | 0 | 0.005 | 0.0069 | 0.94 | R | 1 |
| *Fontinalis antipyretica* | 0 | 0.0149 | 0 | 0.74 | R | 1 |
| *Callitriche hamulata* | 0 | 0 | 0.0069 | 0.69 | R | 1 |
| *Potamogeton polygonifolius* | 0 | 0.0135 | 0 | 0.68 | R | 1 |
| *Carex paniculata* | 0.025 | 0 | 0 | 0.62 | R | 1 |
| *Potamogeton natans* | 0 | 0.01 | 0 | 0.5 | R | 1 |
| *Sparganium angustifolium* | 0 | 0.0025 | 0 | 0.12 | R | 1 |

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# 6. Discussion

This section provides a summary and more general interpretation of the results presented in the previous chapter. An overall summary of the current conservation and biodiversity the eight lakes is provided. Consideration is given to the key environmental variables affecting site condition and any site-specific issues affecting confidence in assessment outcomes are highlighted. This section concludes by making overall recommendations for future monitoring and assessment priorities for freshwater BAP habitats in Wales.

## 6.1. Summary status of the eight Welsh lakes

Table 49 summarises the results of the site condition assessments for the eight lakes included in this report.

| Water Body | Status | Issues | Comments |
|---|---|---|---|
| Llyn Cregennen Uchaf | **Favourable (high confidence)** | None | Both lakes have excellent water quality and clarity and support a species-rich characteristic oligotrophic macrophyte flora. The flora shows characteristic zonation with depth and the maximum depth of colonization is approximately 8.0 m. Both lakes show no evidence of any significant degradation and current catchment management poses low threat to the site. |
| Llyn Cregennen Isaf | **Favourable (high confidence)** | None | |
| Llyn Dinas | **Favourable (high confidence)** | None | Llyn Dinas has excellent water quality and clarity and supports a species-rich, oligotrophic flora that shows characteristic zonation with depth. Aquatic plants extend to a maximum depth of 5.2 m. The site shows no evidence of significant degradation and current catchment management poses low threat to the site. |
| Llyn Gwernan | **Unfavourable (high confidence)** | High frequency of *E. canadensis* (50%) Presence of *E. nuttallii* (10%) | Llyn Gwernan has excellent water quality and clarity and supports a species-rich, oligo-mesotrophic macrophyte flora. The flora shows characteristic zonation with depth and aquatic plants extend to a maximum depth of 4 m. The site shows no evidence of significant |

| Water Body | Status | Issues | Comments |
|---|---|---|---|
| | | | degradation and current catchment management poses low threat to the site (risk increased by forestry operations). The invasive *Elodea* spp. require further monitoring to assess population stability. |
| Llyn Mair | **Unfavourable (high confidence)** | Only 2 characteristic spcies, present at low cover.<br>High frequency of *J. bulbosus* (>40%).<br>Evidence of water quality decline | Llyn Mair has reasonable water quality, but would benefit from a decrease in P and N. The lake has a species-poor flora and is dominated by generalist species. There is evidence of significant degradation related to forestry activity in the catchment. |
| Llyn Cerrig-y-Myllt | **Unfavourable (high confidence)** | No characteristic species.<br>Poorly buffered and at risk of acidification from atmospheric deposition. | Llyn Cerrig-y-Myllt has relatively good water quality, and there is no evidence of any decline in quality from the fossil diatom record. The site is naturally acidic and almost certainly acidified. The lake has almost no plants and although unfavourable, there may be natural reasons why plants are not present; primarily due to being very shallow and exposed. |
| Llyn Coch-hwyad | **Unfavourable (low confidence)** | Elevated TP concentrations and some evidence of acidification.<br>> 10% filamentous algae cover<br>High frequency of *M. alterniflorum* (40%)<br>High risk of increased sediment and nutrient load during timber harvest | Llyn Coch-hwyad has a species rich flora, and is a rare example of a dystrophic lake in Wales. *L. natans* populations appear healthy under current conditions and require better protection to prevent damage from increased siltation and nutrients from forest management. Nutrient concentrations remain a concern and should be monitored along with pH. Current catchment management is a threat to the BAP interest within the site. |

| Water Body | Status | Issues | Comments |
|---|---|---|---|
| Llyn Gwyddior | **Favourable – at risk (high confidence)** | Risk of increased sediment and nutrient load during timber harvest | Llyn Gwyddior has a species-rich flora, including good distribution of characteristic species. *L. natans* populations appear healthy but require better protection to prevent damage from increased siltation and nutrients from forest management. *P. globulifera* populations require monitoring to assess stability. Current catchment management is considered to be a threat to the BAP interest within the site. |

Table 49 Overview of the site condition of the eight lakes surveyed 2013.

The primary focus of this report was to gain an understanding of the quality and condition of eight standing water sites with respect to UK Biodiversity Action Plan habitats and species. All eight sites currently lie outside of any statutory protection (SAC or SSSI) and as such have not received any formal condition appraisal in the past.

Four of the sites have been reported to be in favourable condition in terms of their CSM attributes for species composition and water quality. Two sites, Llynnau Cregennen are not only of BAP interest, but represent some of the highest quality standing water habitat in Wales. Both lakes have previously unrecorded populations of *Potamogeton praelongus* (Critically Endangered in Wales (Dines 2008)) and *Nitella flexilis* sensu stricto, which is a BAP priority stonewort species. Llyn Dinas has a large population of the Annex II (Habitats Directive) and UK BAP priority species, *Luronium natans,* for which the UK has an international responsibility. Llyn Gwyddior and Llyn Coch-hywad, also had sizable populations of *L. natans* present; the former is favourable but the latter shows impacts associated with nutrient enrichment and siltation probably caused by forestry. Llyn Gwernan, although not classified favourable due to presence of non-native species, nonetheless supports a good population of *Potamogeton alpinus,* also Critically Endangered in Wales (Dines 2008).

Of the four sites failing to achieve favourable condition, the main reasons are mostly linked to inappropriate catchment management causing increased sedimentation and eutrophication at sites. Coniferous afforestation in particular is demonstrated to cause major perturbations by altering the hydrology of catchments and increasing sediment loads as well as nutrients to lakes.

These eight lakes demonstrate that where catchment inputs remain low, Welsh standing waters have excellent potential for biodiversity. The report also clearly demonstrates the need for well informed management to protect standing waters at a catchment scale to ensure these habitats and biodiversity are safeguarded for the future.

Management intervention, as recommended in this report, needs to be accompanied by a renewed effort to establish the past baseline condition of the sites to properly inform site specific targets which can be used to review their current condition. These reports also highlights the importance of continuous water quality monitoring at standing water habitats where biodiversity and conservation are of interest. More comprehensive monitoring will allow for changes in condition to be tracked and also provide assessments for the effectiveness of any management interventions.

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# 9. Appendices

## 9.1. Data Archive Appendix

Data outputs associated with this project are archived as Project Number 450, media 1493, metadata number 115704 on server–based storage at Natural Resources Wales.

The data archive contains:

[A] The final report in Microsoft Word and Adobe PDF formats.

[B] A database named [sca_database_v2.1_NWR_Macrophytes_2014.db] in Microsoft Access 2000 format with explanatory notes described in a Microsoft Word document.

[C] A full set of site and transect photographs produced in JPEG format.

[D] Bathymetric data in Excel format and bathymetric maps in JPEG format.

[E] Plant mapping data in Excel a full set of plant maps produced in JPEG format.

[F] A series of GIS layers on which the maps in the report are based with a series of word documents detailing the data processing and structure of the GIS layers.

[G] Water Chemistry data in Excel fomat [BAP Lakes Chemistry 2013.xls]

Metadata for this project is publicly accessible through Natural Resources Wales' Library Catalogue http://194.83.155.90/olibcgi by searching 'Dataset Titles'. The metadata is held as record no 115704.

## 9.2. Collection and structure of Bathymetric Data

Bathymetric data were collected from the selected lakes using the standardised methods detailed in Turner *et al*. (2011), CCW Contract Science Report No. 955. To improve monitoring and effect of lake level change on bathymetries, details of water level during the survey were also recorded – primarily the measurement of water level to a temporary bench mark (TBM). Due to the remoteness of the lakes and absence of OS bench marks, absolute level above sea level was not recorded and all depths are presented as depth below surface in metres. Site details are found in the _docs folder in the GIS folder structure. Depth data was also collected independently at each of the plant survey point using an hand held echo sounder or measuring staff in shallow, plant rich areas.

### Folder structure for bathymetric maps

The data are within folder: **NRW_2012_13**
All bathymetric data returned to CCW are stored in separate sub-folders named accordingly: **WBID_Name,** e.g. 36615_Llyn_Gwyddior, where WBID is the UKLakes (www.UKLakes.net) water body ID and Name is the accepted UKLakes water body name. Lakes not included in the WBID database (Hughes *et al.* 2004) are numbered sequentially starting at **99999_Name** to allow a future update (e.g. in this report one did not have an assigned WBID number: 99999_Llyn Coch-hywad)

### Bathymetric data folders

The bathymetric data folder follows the same format including raw data, interpolated grids, basic ARCMap (.mxd) files and morphometric statistical outputs:

- **d<datasetid>_<WBID>_xyz.csv** - Raw data (comma delimited). Column headings Index, OS_X, OS_Y, Depth where depth is in metres (m).
- **d<datasetid>_<WBID>_xyz.shp** - Shape file collection (with .prj files) from .csv data.
- **<foldername>_lake_polyline.shp -** Lake outline polyline (derived from OS raster data, required for confining bathymetric raster).
- **<foldername>.mxd** - Basic ArcGIS project file. Document set to relative path names.
- **b<bathygridid>_WBID** - ESRI grid folder, bathygridid relates to individual bathymetric grid outputs. May be multiple folders. This allows flexibility to have multiple outputs dependent on settings inputted for grid calculation.
- **b<bathygridid>_WBID.asc** - ASCII export of ESRI grid. Standard export format of raster data. Used for R: software outputs.

Also included in the separate bathymetric lake folders are the morphometric statistic outputs:

- **b<bathygridid>_WBID_hypsographic_curve.pdf** - Hypsographic curve (Depth; %area, m2)
- **b<bathygridid>_WBID_depth_-_volume_curve.pdf** - Depth volume curve (Depth; %volume, m3)

- **b<bathygridid>_WBID_composite_display.pdf** - Composite diagram from R: script output
- **b<bathygridid>_WBID_curve_data.csv** - Volume (m3), Area (m2) values for 0.5m depth intervals calculated from raster grid.
- **Shapefiles** - Folder containing polygon shapefiles for individual 0.5m depth intervals generated from the raster grid.

In the _Doc folder there is an Excel file summarising the lake morphometry, bathymetry and grid details for the lakes.

## 9.3. Structure of macrophyte mapping data

### Plant data folders

Plant data for each lake is contained in separate sub-folders **WBID_Name_plants,** e.g. 32964_Llyn_Traffwl_plants. Within these folders are found subfolders:

- **WBID_name_plant_jpegs** - Folder containing simple jpeg images of plant species using the File>Export Map> procedure in ArcMap. This allows multiple formats to be exported depending on output requirements.
- **WBID_name_plants_xyz** - Folder containing text files of the raw plant species data in rows and columns with the following headings; Object_ID, Waypoint, OS Grid Ref, X coordinate (6 fig OS), Y coordinate (6 fig OS), Depth_m and plant species (plant score). Also included is an 'All plant' text file.
- **WBID_name_plant_shapefiles -** Folder containing shapefiles of the plant species data.

## 9.4. Macrophyte Database – MS Access

**File name:** sca_database_v2.1_Macrophytes_NRW_2014.db

The database is saved as MS Access 2000 and MS Access 2007 and contains all Welsh Sites surveyed by ENSIS from 2007 to 2013.

### Basic guidance on use.

- Copy the database to a trusted location on to your computer (it will have limited / no functionality if run from a CD)
- You may receive a "Security warning" message saying "Certain content in the database has been disabled" - This is because the db contains macros. These are safe, and you will need to click on options and "Enable content". If you click on "Open the trust centre" you can then click on "Trusted locations" and "Add new location" and browse for the directory where the database is stored. Click OK and exit the Trust centre and now the db should start without the warning message.

Open database and find a site

- You will be presented with the "Main Switchboard"
- Click "View survey list and edit survey data"
- You can now either scroll through the survey data or better still search for a site using the "binoculars" button – search by Look in: "SCA Survey Selector" and Match: "Any part of Field" – you can then type in the name (or part of) and click Find Next.
- The SCA Survey Selector should now show the required site – you can cancel the find tool.
- To open the site information click on the bottom right (Open Form) button – you should now have a form entitled "Survey Details"

You can now add, edit or view data – all changes you make will be live – i.e. automatically saved.

- Within the initial page there are 4 tabs "Pressures", "Shoreline", "DO/Temp" and "Sections"
- Click "Sections" to take you to all the plant data.
- Note the big "1" – all data below refers to **section 1** – until you click the arrow to show a big "2" – all data will now be for **section 2**.
- Below the big "1" there are another series of tabs which are hopefully self explanatory (with the exception of "Shore Survey Submerged – which is strandline data)
- To export data – open the database and repeat the find process to get back to the required site in the SCA Survey Selector – but no need to open the forms this time.
- This time click on the left-hand button of the two bottom right icons – the "Mail Report" button.
- A text report should leap out on to the screen.

- To get the data – In pre 2007 versions of Access - go to the file menu and select “Export” and export it as “file type” rich text format (*.rtf). In MS Access 2007 and later, simply click the MS Word icon in the “Data” menu. This produces all the data in a summary format where it can (mostly) be copies into both word and Excel for any additional data manipulation.

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