Site Condition Assessments of Welsh SAC and SSSI Standing Water Features.

**Amy Burgess, Ben Goldsmith and Tristan Hatton-Ellis**

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# Executive Summary

This report was commissioned by the Countryside Council for Wales (CCW) in 2005 and provides an assessment of the conservation status of Welsh Special Areas of Conservation (SACs) and Sites of Special Scientific Interest (SSSIs). It details the site condition assessments of 43 individual standing water features and provides overall assessments of the 13 SACs and 11 SSSIs in which they lie.

Site condition is assessed using Common Standards Monitoring (CSM) methods, where specific habitat feature attributes are assessed against targets corresponding to 'favourable' condition. To make these assessments, data from CCW Contract Science Report no. 704 (Goldsmith *et al*. 2006) is employed, alongside further chemical and biological data collected by ENSIS Ltd. and the Environment Agency (EA) between 2003-2005. Data from previous reports and surveys is also utilised where available to provide a longer-term perspective and possible evidence of trends.

The results of the site condition assessments are discussed in terms of general categories of impact (e.g. acidification or eutrophication). Where sites were in unfavourable condition, recommendations for further investigation and / or management are made. Reference is also made to Water Framework Directive (WFD) Risk Assessments and some attempt is made to relate condition assessment outcomes to the probability of sites failing to meet good ecological status by 2015 in accordance with the objectives of Article 4 of the WFD.

Condition assessments for the oligotrophic to mesotrophic Welsh lake SACs (23 lakes) and SSSIs (7 lakes) with vegetation of the *Littorelletea uniflorae* and / or of the *Isoëto-Nanojuncetea*, indicate that approximately 80 % of lakes of this type are currently in 'unfavourable' (60 %) or 'unfavourable, recovering' (20 %) condition. Only one SAC - Cadair Idris (3 lakes) – and three lakes within two other SACs are classified as 'favourable'. Acidification is the primary reason for failure to meet favourable condition targets, particularly for SAC lakes. The recovery trends observed at a number of acid-impacted lakes most likely relate to reductions in atmospheric deposition of sulphur and nitrogen. It is expected that alkalinisation trends will continue provided that atmospheric deposition stabilises or continues to decrease. Nutrient enrichment, grazing pressure, sediment inwash, forestry operations and drawdown are further pressures that result in unfavourable condition assessment outcomes. Eutrophication is of particular concern amongst SSSI lakes of this type.

All eleven Welsh lake SACs and SSSIs of the naturally eutrophic type (with *Magnopotamion* or *Hydrocharition*-type vegetation) or hard oligo-mesotrophic *Chara* spp. type are classified as 'unfavourable' (70 %) or 'unfavourable, recovering' (20 %), with one lake classified as 'unfavourable, declining'. Eutrophication is the primary reason for failure to meet favourable condition targets. However, unlike acidification, eutrophication may come from both point and diffuse sources, and its effects may be exacerbated by local management practices such as grazing and fish stocking.

For many eutrophied lakes there is scope to identify and reduce diffuse sources of nutrients within the catchment. However, residual sediment nutrient concentrations may be problematic, as may inappropriate fish communities resulting from past stocking practices. Eutrophication can dramatically alter the structure and function of a lake ecosystem; therefore

carefully constructed management plans must be implemented if favourable condition is to be a realistic future target for impacted naturally eutrophic and hard-water Welsh lake SACs and SSSIs.

Only one SAC in Wales is notified for the dystrophic lakes feature (2 lakes). This feature was provisionally classified as unfavourable. However, the targets for this habitat type may require refinement.

The report concludes by discussing uncertainty in lake classification, data confidence concerns, CSM issues relating to survey methodology and the appropriateness of targets used for condition assessment. Comparisons between the CSM approach and other lake assessment methodologies are also considered. Overall recommendations for future monitoring and assessment are provided.

# Crynodeb Gweithredol

Comisiynwyd yr adroddiad hwn gan Gyngor Cefn Gwlad Cymru (CCW) yn 2005 ac fe ddarpara asesiad o statws cadwraethol Ardaloedd Cadwraeth Arbennig (ACAoedd) a Safleoedd o Ddiddordeb Gwyddonol Arbennig (SoDdGAoedd) yng Nghymru. Dyry fanylion asesiadau o gyflwr y safleoedd yn achos 43 o nodweddion dŵr llonydd ac asesiadau cyffredinol o'r 13 ACA ac11 SoDdGA sy'n eu cynnwys.

Asesir cyflwr safle gan ddefnyddio dulliau Monitro Safonau Cyffredin (CSM), trwy ba rai y cymerir priodoleddau penodol nodweddion cynefin â thargedau sy'n cyfateb i 'gyflwr ffafriol'. Er mwyn gwneud yr asesiadau hyn, defnyddir data o Adroddiad Gwyddonol Cytundeb CCW rhif. 704 (Goldsmith *et al*. 2006), ynghyd â data cemegol a biolegol eraill a gasglwyd gan ENSIS Ltd. ac Asiantaeth yr Amgylchedd rhwng 2003 a 2005. Defnyddir hefyd ddata o adroddiadau ac arolygon blaenorol, lle maent ar gael, er mwyn rhoi persbectif tymor hwy ac, o bosibl, dystiolaeth ynghylch tueddiadau.

Trafodir canlyniadau asesiadau cyflwr y safleoedd yn ôl categorïau cyffredinol o effaith (e.e. asideiddio neu ewtroffeiddio). Lle'r oedd safleoedd mewn cyflwr anffafriol, gwneir argymhellion ar gyfer archwilio pellach a / neu reoli. Cyfeirir hefyd at Asesiadau Risg y Gyfarwyddeb Fframwaith Dŵr a gwneir rhyw ymdrech i gysylltu canlyniadau asesiadau cyflwr â'r tebygrwydd y bydd safleoedd yn methu cyrraedd statws ecolegol da erbyn 2015 yn unol ag amcanion Erthygl 4 y Gyfarwyddeb Fframwaith.

Dengys asesiadau cyflwr ACAoedd a SoDdGAoedd llynnoedd Cymru sy'n oligotroffig neu'n fesotroffig (23 o lynnoedd a 7 o lynnoedd yn ôl eu trefn), gyda llystyfiant megis *Littorelletea uniflorae* ac / neu *Isoëto-Nanojuncetea*, fod rhyw 80 % o lynnoedd o'r math hwn ar hyn o bryd mewn cyflwr 'anffafriol' (60 %) neu 'anffafriol, yn gwella' (20 %) . Nid ystyrir ond un ACA - Cadair Idris (tri llyn) - a thri llyn mewn dwy ACA arall yn 'ffafriol'. Asideiddio yw'r prif reswm dros fethu cyrraedd targedau ar gyfer cyflwr ffafriol, yn enwedig yn achos llynnoedd ACA. Sylwyd bod nifer o lynnoedd dan effaith asid yn tueddu i ymadfer; mae'n debygol iawn bod hyn yn ymwneud â'r lleihad ym maint y sylffwr a'r nitrogen sy'n cael eu dyddodi o'r atmosffer. Disgwylir y bydd tueddiadau i alcalineiddio'n parhau, os bydd dyddodi o'r atmosffer yn sefydlogi neu'n parhau i ostwng. Pwysau eraill sy'n arwain at asesiad cyflwr anffafriol yw maethlonni, pwysau gan bori, golchi gwaddod i mewn *(sediment inwash)*, gweithgareddau coedwigaeth a gostyngiad yn lefel y dŵr *(drawdown)*. Mae ewtroffeiddio'n bryder arbennig yn achos llynnoedd SoDdGA o'r math hwn.

Mae pob un o'r un ar ddeg ACA a SoDdGA llynnoedd yng Nghymru sy'n ewtroffig naturiol (gyda llystyfiant megis *Magnopotamion* neu *Hydrocharition*) neu'n oligo-mesotroffig caled *Chara* spp. yn 'anffafriol' (70 %) neu 'anffafriol, yn gwella' (20 %), heblaw un llyn a ystyrir yn 'anffafriol, yn gwaethygu'. Ewtroffeiddio yw'r prif reswm dros fethu cyrraedd targedau ar gyfer cyflwr ffafriol. Er hynny, yn wahanol i asideiddio, gall ewtroffeiddio godi o ffynhonnell unigol ac o ffynonellau gwasgarog, a gall arferion rheoli lleol megis pori a stocio pysgod waethygu ei effeithiau.

Yn achos sawl llyn ewtroffig mae modd adnabod a lleihau ffynonellau gwasgarog maetholion yn y dalgylch. Er hynny, gall crynodiadau maetholion sydd ar ôl yn y gwaddod fod yn broblem, fel y gall cymunedau o bysgod amhriodol o ganlyniad i arferion stocio yn y

gorffennol. Gall ewtroffeiddio newid yn ddramatig adeiladwaith a gweithrediad ecosystem llyn; gan hynny, rhaid gweithredu cynlluniau rheoli a lunnir yn ofalus er mwyn gwneud ymgais realistig i gyrraedd cyflwr ffafriol o hyn ymlaen yn achos ACAoedd a SoDdGAoedd llynnoedd naturiol ewtroffig a llynnoedd dŵr caled yng Nghymru a ystyrir ar hyn o bryd yn anffafriol.

Nid oes ond un ACA yng Nghymru a ddynodwyd oherwydd nodwedd ei llynnoedd dystroffig (dau lyn). "Anffafriol" fu dosbarthiad dros dro'r nodwedd hon. Er hynny, efallai y bydd yn rhaid mireinio'r targedau ar gyfer y math hwn o gynefin.

Daw'r adroddiad i ben trwy drafod ansicrwydd wrth ddosbarthu llynnoedd, amheuon ynghylch y data, materion Monitro Safonau Cyffredin yn ymwneud â methodoleg arolygu a phriodoldeb y targedau a ddefnyddir i asesu cyflwr. Rhoddir ystyriaeth hefyd i gymariaethau rhwng y dull Monitro Safonau Cyffredin a methodolegau eraill ar gyfer asesu llynnoedd. Darperir argymhellion cyffredinol ar gyfer monitro ac asesu o hyn ymlaen.

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# 1. Introduction

The Habitats and Species Directive 1992 (92/43/EEC) requires the UK government to select Special Areas of Conservation (SACs) for certain protected habitats (Annex 1) and species (Annex 2) in Europe. Among these are four standing water features that occur naturally in Wales (Table 1.1).

**Table 1.1: Permanent Standing Water Habitats for which Wales has internationally important sites**

| Code | Feature |
|---|---|
| 3130 | Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and / or of the *Isoëto-Nanojuncetea* |
| 3140 | Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp. |
| 3150 | Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation |
| 3160 | Natural dystrophic lakes and ponds |

Once designated as an SAC, Article 11 of the Habitats Directive obliges member states to undertake surveillance and assess whether a site is in "favourable conservation status".

The UK also has a national series of protected sites, Sites of Special Scientific Interest (SSSIs). These sites are designated under the Wildlife and Countryside Act 1981 (as amended). SAC and SSSI selection and management is devolved to regional conservation agencies. In Wales, the Countryside Council for Wales (CCW) is responsible for carrying out the monitoring and reporting on SAC/SSSI site condition. All Welsh freshwater SACs are also designated as SSSIs.

The UK Conservation Agencies have devised a common standards monitoring (CSM) protocol (JNCC, 2005a) to assess the condition of the Annex 1 habitat features (as listed in Table 1.1). This document sets out the standardised field methods for data collection and details the targets to be used for site condition assessments of protected water bodies. The CSM lake monitoring method is based on previous survey protocols used by the conservation agancies, and aims to gather the maximum amount of information about the ecology of each water body in the most efficient way possible. The protocol makes use of a combination of shoreline walks to identify marginals, waded transects to describe the shallow water vegetation, and boat-based survey to identify plants in deeper water. In addition, physicochemical data are collected for each lake. The protocol is described in full in JNCC (2005a).

When assessing site condition, consideration is given to the major characteristics (attributes) that define the Annex I habitat features. In the CSM protocol there are specified targets for each attribute detailed under the respective feature type. These targets correspond to

'favourable' condition. For each lake, the attribute data are assessed against the targets, thus enabling determination of site condition.

The attributes used in CSM for assessment of habitat features are listed below. It is: mandatory to use all of these attributes in condition assessment

- Lake extent
- Composition of macrophyte community (including presence of introduced species)
- Macrophyte community structure
- Water quality
- Lake hydrology
- Lake substrate
- Sediment load
- Indicators of local distinctiveness

In a few cases, the primary reason for SAC designation is not the standing water feature (e.g. Migneint-Arenig-Dduallt SAC is primarily designated for its large extent of high quality blanket bog habitat). However, the Annex I standing water lake habitats and Annex II aquatic vascular plant species are generally listed as "other qualifying features" and as such require a similar assessment procedure.

During 2003-2005, ENSIS Ltd., under contract to CCW and the Environment Agency (EA) collected a large limnological dataset (physical, chemical and biological data) using the CSM protocol methodology, thereby providing monitoring data for the majority of Welsh SAC permanent standing water sites. Much of the data are compiled in Goldsmith *et al*. (2006) and this report constitutes the principal data source for the current project.

# 2. Project Objectives

To determine the current conservation status of Welsh lake protected habitats, this project seeks to analyse field survey data collected using CSM methods and assess it against habitat feature attribute targets detailed in CSM favourable condition tables.

For Work Package 1 (SACs), site condition assessments are made for i) 32 individual lakes and ii) for the 13 SACs in which they lie (see Figure 3.1 for SAC lake locations and Table 3.1 for further site details). This study will thereby produce draft condition assessments for Welsh standing water bodies selected as SACs, completing the current round of SAC standing waters monitoring in Wales. Where there is more than one lake site within an SAC, an assessment of the overall condition of the SAC is provided.

A number of standing waters are also selected as (candidate) Sites of Special Scientific Interest (SSSI) for their conservation importance. A secondary objective of this project (Work Package 2) is to apply the condition assessment criteria to 11 (c)SSSI lakes (see Figure 3.1 for SSSI lake locations and Table 3.2 for further sites details).

# 3. Methods and Generic Targets

## *3.1 Study sites*

The locations of all SAC and SSSI lakes included in this report are illustrated in Figure 3.1. Tables 3.1 (SAC lakes) and 3.2 (SSSI lakes) provide further details of the individual lakes, including Annex I standing water feature type and WFD lake typologies.

**Table 3.1: SAC Lakes: Lakes surveyed during 2003-4, showing SAC name, lake name, lake typology and the feature for which the sites are notified (for notation see key at bottom of table.)**

| SAC Name | Lake Name | NGR | WFD Typology[$] | HD Feature[#] |
|---|---|---|---|---|
| Afon Gwyrfai a Llyn Cwellyn | Llyn Cwellyn [1] | SH560550 | LA, D | OML |
| Afon Teifi** | Llyn Egnant [2 and 4] | SN793671 | LA, S | OML |
| | Llyn Hîr [2 and 4] | SN789675 | LA, V | OML |
| | Llyn Teifi [2 and 4] | SN783676 | LA, S/D? | OML |
| Cadair Idris | Llyn Gafr [1] | SH711141 | MA, V | OML |
| | Llyn Arran [1] | SH735139 | LA, V | OML |
| | Llyn Cau [1] | SH715123 | LA, D | OML |
| Corsydd Môn / Anglesey Fens | Llyn Cadarn [1] | SH492811 | HA, S | HC |
| | Llyn yr Wyth Eidion [1] | SH474819 | HA, S | HC |
| Elenydd | Llyn Cerrigllwydion Isaf [1] | SN843700 | LA, S | OML |
| | Llyn Fyrddon Fawr [1] | SN800707 | LA, S | OML |
| | Llyn Gwyngu [1] | SN838729 | LA, V | OML |
| | Llyn Gynon [1] | SN800645 | LA, V | OML |
| Eryri / Snowdonia | Llyn Cwmffynnon [1] | SH648563 | LA, V | OML |
| | Llyn Coch [1] | SH598545 | LA, V | OML |
| | Llyn Idwal [1] | SH645595 | LA, V/S | OML |
| | Llyn Ogwen [1] | SH660605 | LA, V | OML |
| Kenfig / Cynffig | Kenfig Pool [1] | SS796815 | HA, V | HC |
| Llyn Dinam | Llyn Dinam [1] | SH310775 | HA, V | NE |
| Llyn Syfaddan / Llangorse Lake | Llangorse Lake [2] | SO132264 | HA, V | NE |

| SAC Name | Lake Name | NGR | WFD Typology[$] | HD Feature[#] |
|---|---|---|---|---|
| Migneint-Arenig-Ddualllt | Llyn Conglog-Mawr [1] | SH758387 | LA, V | OML |
| | Llyn y Dywarchen [1] | SH763420 | LA, V | DY |
| | Llyn y Garn [1] | SH761377 | LA, S | OML |
| | Llyn Hesgyn [3] | SH884443 | LA, V | OML |
| | Llyn Hiraethlyn [3] | SH742370 | LA, V | OML |
| | Llyn Tryweryn [3] | SH788385 | LA, V | DY |
| Pembrokeshire Bat Sites and Bosherton Lakes / Safleoedd Ystlum Sir Benfro a Llynnoedd Bosherton | Bosherston Lily Ponds [1] | SR973946 | HA, S | HC |
| Rhinog | Llyn Cwm Bychan [1] | SH640313 | LA, S | OML |
| | Llyn Eiddew-Mawr [1] | SH646337 | LA, S | OML |
| | Llyn Perfeddau [1] | SH659264 | LA, V | OML |
| | Gloyw Lyn [1] | SH646300 | LA, V | OML |
| Y Twyni o Abermenai i Aberffraw / Abermenai to Aberffraw Dunes | Llyn Coron [1] | SH379700 | HA, V | NE |

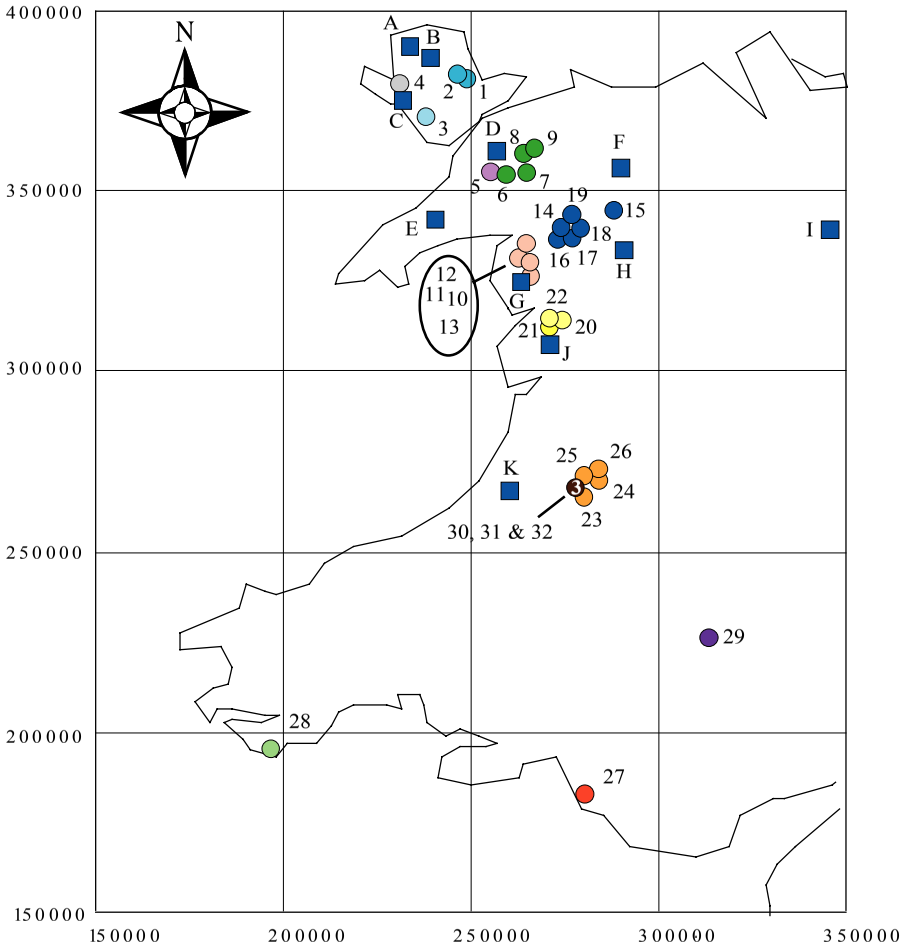
**[$] LA, MA and HA = low, medium and high alkalinity respectively. D = deep ($Z_{mean}$ > 15 m); S = shallow ($Z_{mean}$ 3 – 15 m); V = very shallow ($Z_{mean}$ < 3 m).**
**[#] OML = Oligotrophic to mesotrophic lake with *Littorelletea*; HC = Hard lake with *Chara*; NE = Natural eutrophic lake; DY = Dystrophic lake.**
**[1] Surveyed during 2003-04 by ENSIS Ltd. See Goldsmith *et al.* (2006).**
**[2] Surveyed during 2003-04 by ENSIS Ltd.**
**[3] Surveyed during 2002 by CEH. See Carvalho *et al.* (2003).**
**[4] Surveyed during 2003 by Scott Wilson Associates. See Southey & Broughton (2004).**

**Table 3.2: Lakes within SSSIs: Lakes surveyed during 2003-4 showing SSSI name, lake name, lake typology and the feature for which the sites are notified (for notation, see key at bottom of table).**

Features here are indicative, since they are not defined by Habitats Directive criteria. Llyn Bodlyn is not inside a protected site, but an assessment of its quality against SSSI criteria is required as it is under consideration for protection in the future.

| SSSI Name | Lake Name | NGR | Typology* | SSSI Feature | # Feature for assessment |
|---|---|---|---|---|---|
| Hanmer Mere | Hanmer Mere | SJ452392 | HA, V | Eutrophic Cheshire mere. | NE |
| Llyn Alaw | Llyn Alaw | SH391867 | MA, V | Not notified for standing water | OML Meso |
| Mynydd Hiraethog | Llyn Alwen | SH898356 | LA, S | Natural oligotrophic lake with *Isoetes* and *Lobelia* | OML Oligo |
| - | Llyn Bodlyn | SH648239 | LA, S | Not currently notified | OML Oligo |
| Llyn Eiddwen | Llyn Eiddwen | SN605670 | LA, V | Oligo-mesotrophic lake | OML Meso |
| Llyn Glasfryn | Llyn Glasfryn | SH402421 | MA, V | Shallow lowland oligotrophic to mesotrophic lake | OML Meso |
| Llyn Llygeirian | Llyn Llygeirian | SH346899 | MA, V | Moderately base-rich lake | OML Meso |
| Llyn Padarn | Llyn Padarn | SH573612 | LA, S | *Isoetes echinospora*, *Luronium natans* | OML Oligo |
| Llynnau y Fali / Valley Lakes | Llyn Penrhyn | SH313768 | HA, V | Mesotrophic lakes with base-rich influence. | NE |
| Llyn Tegid | Llyn Tegid | SH910335 | LA, D | Oligotrophic to mesotrophic lake | OML Oligo |
| Cadair Idris | Tal-y-llyn Lake | SH717099 | LA, V | No detail. | OML Oligo |

*** LA, MA and HA = low, medium and high alkalinity respectively. D = deep ($Z_{mean}$ > 15 m); S = shallow ($Z_{mean}$ 3 – 15 m); V = very shallow ($Z_{mean}$ < 3 m).**
**All lakes were surveyed during 2003-04 by ENSIS Ltd.**
**[#] OML = Oligotrophic to mesotrophic lake with *Littorelletea*; HC = Hard lake with *Chara*; NE = Natural eutrophic lake; DY = Dystrophic lake.**




**Corsydd Môn / Anglesey Fens SAC**
1. Llyn Cadarn
2. Llyn yr Wyth Eidion

**Y Twyni o Abermenai i Aberffraw / Abermenai to Aberffraw Dunes SAC**
3. Llyn Coron

**Llyn Dinam SAC**
4. Llyn Dinam

**Afon Gwyrfai a Llyn Cwellyn SAC**
5. Llyn Cwellyn

**Eryri / Snowdonia SAC**
6. Llyn Coch
7. Llyn Cwmffynnon
8. Llyn Idwal
9. Llyn Ogwen

**Rhinog SAC**
10. Gloyw Lyn
11. Llyn Cwm Bychan
12. Llyn Eiddew-mawr
13. Llyn Perfeddau

**Migneint-Arenig-Dduallt SAC**
14. Llyn Conglog-Mawr
15. Llyn Hesgyn
16. Llyn Hiraethlyn
17. Llyn y Garn
18. Llyn Tryweryn
19. Llyn y Dywarchen

**Cadair Idris SAC**
20. Llyn Cau
21. Llyn Gafr
22. Llyn Arran

**Elenydd SAC**
23. Llyn Gynon
24. Llyn Cerrigllwydion Isaf
25. Llyn Fyrddon Fawr
26. Llyn Gwngu

**Kenfig / Cynffig SAC**
27. Kenfig Pool

**Safleoedd Ystlum Sir Benfro a Llynnoedd Bosherston SAC**
28. Bosherston Lily Ponds (Central Arm)

**Llangorse Lake / Llyn Syfaddan SAC**
29. Llangorse Lake

**Afon Teifi SAC**
30. Llyn Teifi
31. Llyn Hir
32. Llyn Egnant

**SSSI Lakes**
- **A.** Llyn Llygeirian
- **B.** Llyn Alaw
- **C.** Llyn Penrhyn
- **D.** Llyn Padarn
- **E.** Llyn Glasfryn
- **F.** Llyn Alwen
- **G.** Llyn Bodlyn
- **H.** Llyn Tegid
- **I.** Hanmer Mere
- **J.** Tal-y-llyn
- **K.** Llyn Eiddwen

**Figure 3.1: Map of Wales locating the SAC and SSSI Welsh protected sites included in this report**

## 3.2 Data used to assess site condition

For the majority of SAC lakes (28 lakes in 11 SACs), condition assessments are prepared using macrophyte and physico-chemical data from the EA / ENSIS Ltd. surveys carried out between 2003 and 2005 (Goldsmith *et al*. 2006). For assessment of the remaining 4 SAC lakes (Llyn Egnant, Llyn Hir, Llyn Teifi and Llangorse Lake) and all 11 (c)SSSI lakes, reference is made to macrophyte survey data and limited physico-chemical data collected during 2003 and 2004 by ENSIS Ltd. Further physical and chemical data for these sites was obtained from the database of GB lakes compiled from a variety of sources (predominantly from EA WFD monitoring data) by the EA and the Centre for Ecology and Hydrology (CEH) (Carvalho *et al.*, October 2005 release).

Unless otherwise stated, limnological data detailed in the site condition assessment tables in Section 4 are derived from Goldsmith *et al.* (2006). There are some reliability issues with the alkalinity and phosphorus data described in Goldsmith *et a*l. (2006). Where this is problematic in relation to the condition assessments; notes are made in the text. In particular, bicarbonate alkalinity and not total alkalinity was measured - inappropriate for soft-water lakes. Total phosphorus (TP) measurements are also unreliable for most seasons because detection limits were too high. Fortunately, the June 2005 TP data are reliable, although use of only one seasonal measure of TP is not recommended for assessment purposes. A supplementary data report will be produced by ENSIS Ltd. in April 2006, where further seasonal TP and alkalinity data from winter 2005 and spring 2006 will be presented.

Where available for individual lakes, palaeolimnological evidence is used to assist with the assessment of current site condition. Sedimentary diatom remains (usually top and bottom core samples) 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 both changes in total phosphorus (Di-TP) and acidity (Di-pH), and hence to compare the current status of the lake with conditions in the past. Although diatoms constitute the dominant source of palaeolimnological evidence for this report, a few lakes also have data for other proxies (e.g. plant macrofossils and cladocera). Data sources are referenced in the text and where necessary, data reliability issues are highlighted.

For background information and to fill gaps in the data, previous reports and journal papers have been consulted e.g. Carvalho *et al*., 2003; Southey & Broughton, 2004; Monteith ed., 1995; Monteith ed., 1996; Monteith ed., 1997; Allott *et al*., 1994; Bennion *et al*., 1997; Davidson & Appleby, 2003; Davidson *et al*., 2002; Burgess *et al*., 2005; Haworth *et al*., 1996.

## 3.3 Assessment of site condition using CSM methods

### 3.3.1 Water quality attributes

For assessment of the total phosphorus (TP) water quality attribute, Table 1 (Total Phosphorus targets for designated lakes) in the CSM guidance (JNCC, 2005a) is employed. This table is duplicated in Table 3.3 in the current report.

Implementation of the EU Water Framework Directive (WFD) has led to the development of new biological classification and predictive tools, both in the UK and across Europe, for the assessment of lake ecological status. Although the majority of tools are in the early stages of development and have yet to be fully tested, some preliminary data are available. Preliminary environmental standards for dissolved oxygen, acidity and phosphorus from the WFD UK TAG Report (January 2006) are presented in Tables 3.5a-f. Chlorophyll boundary values for different ecological states derived from the REBECCA project (http://www.environment.fi/syke/rebecca) and detailed in Phillips (2005) are presented in Table 3.4. Although the WFD and Habitats Directive have different overall objectives, the use of biological quality elements in lake classifications is of direct relevance to habitat conservation. For this reason, reference is occasionally made to the likely corresponding WFD status classification of individual protected lakes based on the data in Table 3.4 and Tables 3.5a-f.

### *3.3.2 Trophic Scores*

Trophic Ranking Scores (TRS – Palmer 1992) were calculated, both using presence / absence and additionally, weighted by DAFOR cover score. Species-specific TRS scores were weighted using DAFOR values calculated for the entire lake. DAFOR values were first converted to numeric values on a 1-5 scale, with D (dominant) having a weighting of 5, and R (rare) a weighting of 1. A weighted TRS for each lake was then calculated using the formula below:

$$\text{Weighted TRS} = \frac{\sum \text{TRS}_{(\text{Species})} \times \text{Cv}_{(\text{species})}}{\sum \text{Cv}}$$

where TRS is the TRS value, and Cv the cover value.

We consider this approach to have some significant advantages over using unweighted TRS values. These are:

- The ability to detect cover-based changes in nutrient status.
- Greater sensitivity to environmental change
- The weighted TRS value tends to reflect the dominant plant cover rather than the species composition. This measure is likely to be more sensitive to changes in trophic status, since changes in nutrient status are more likely to be exploited by shifts in the existing community composition. Moreover, a weighted TRS may be able to give earlier warning of deteriorating environmental conditions.
- Weighted TRS values give less prominence to rare species than presence/absence
- Rare species cannot be reliably detected in field survey, and so may cause error between surveys. By weighting against these species, this error is reduced.

In additions to TRS scores, Plant Lake Ecosystem Index (PLEX) scores (Duigan *et al*. in press) and Ellenberg Fertility Scores 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 is as yet largely untested, but could prove useful both for comparing different sites and for detecting change over time at individual sites. Ellenberg Fertility Scores are a scoring system primarily developed for terrestrial use (Hill *et al*., 1999), but which is being used in the development of LEAFPACS, the UK's Water Framework Directive macrophytes classification tool (Willby *et al*., 2006). Both indices have been weighted using the same procedure as for the TRS scores. Once the LEAFPACS project is completed, CCW hopes to use it as a monitoring tool for freshwaters, and we hope that the results presented here will contribute to its development.

### *3.3.3 Overall assessment*

The current site condition assessments are baseline surveys within the contect of the CSM methods. Where limited previous information is available, it is only possible to state whether a SAC/SSSI lake/site is in favourable or unfavourable condition, not whether the conservation interest is being maintained, recovering, declining or destroyed. Where confidence in the data is low, the qualifier "at risk", is included, where biological attributes indicate that features are in favourable condition, but other habitat factors suggest that the features may be adversely affected in the future. A favourable "at risk" is also used where conditions are considered unsuitable for the long-term maintenance of the habitat.

The condition assessments identify general categories of impact (e.g. acidification or eutrophication) and in the case of a site being in unfavourable condition or "at risk", make recommendations for further investigation and / or management. Reference is also made to Water Framework Directive (WFD) Risk Assessments (Table 3.6). The risk assessments relate to risk of impact from human activity on water body status. Sites determined to be "at risk" have a high probability of failing to meet good ecological status according to objectives of Article 4 of the WFD (by 2015). WFD Risk Assessments are not definitive and will be refined by the EA where necessary. Diffuse pollution includes both acidification and eutrophication.

Where multiple water bodies have been surveyed within an SAC, recommendations are provided as to which lake might be most appropriate as a long-term monitoring site.

**Table 3.3: Total Phosphorus targets for designated lakes (SAC, SSSI/ASSI, Ramsar), as detailed in Table 1 of the CSM guidance (JNCC, 2005a).**

| Lake Type | Approximate corresponding feature type | Depth Category* | Maximum allowable TP target (µg P $l^{-1}$) | TP Range** (µg P $l^{-1}$) |
|---|---|---|---|---|
| Peat | dystrophic | Deep | 10 | na |
| | | Shallow | 10 | na |
| Low Alkalinity | oligotrophic | Deep | 10 | na |
| | | Shallow | 10 | na |
| Medium Alkalinity | mesotrophic | Deep | 15 | na |
| | | Shallow | 20 | na |
| High Alkalinity | eutrophic | Deep | 35 | na |
| | | Shallow | 50 | 35-100 |
| Marl | hard water | Deep | 20 | na |
| | | Shallow | 35 | 20-50 |
| Brackish | brackish | Deep | 35 | na |
| | | Shallow | 35 | na |

*** Depth categories used are the same as WFD categories. 'Shallow' includes both shallow and very shallow lakes.**

**Table 3.4: Range of possible GM boundary criteria for chlorophyll a and resulting TP boundaries (Phillips, 2005) derived from REBECCA (http://www.environment.fi/syke/rebecca) grouped lake regressions**

| Lake Type | Range possible GM boundaries for Chlorophyll µg/l | Range resulting GM boundaries for TP µg/l (Values rounded to nearest 5µg) |
|---|---|---|
| HAD | | |
| HASh | 9-15 | 26-48 (25-50) |
| HAvSh | 15-23 | 46-75 (45-75) |
| MAD | 4-6 | 14-22 (15-20) |
| MASh | 7-11 | 16-26 (15-25) |
| MAvSh | 12-26 | 28-54 (30-55) |
| LAD | 3-6 | 9-22(10-20) |
| LASh | 4-9 | 10-20 |
| LAvSh | 6-20 | 15-44 (15-45) |

**Table 3.5: Tables for dissolved oxygen, acidity and phosphorus from WFD UK TAG Report (January 2006): UK Environmental Standards and Conditions. Draft for Stakeholder Review (SR1–2006). Release 3 February 2006.**

## Tables 3.5a and b: Dissolved oxygen

| Standards for dissolved oxygen | | |
|---|---|---|
| Status | Proposed boundary (all UK lakes) | |
| | Mean in July – August (mg/l) | |
| | Salmonid | Cyprinid |
| High | 9 | 8 |
| Good | 7 | 6 |
| Moderate | 4 | 4 |
| Poor | 1 | 1 |

| Existing standards | |
|---|---|
| From the Swedish Environment Protection Agency | |
| mg/l | |
| Oxygen rich | ≥ 7 |
| Moderately rich | 5 |
| Moderately deficient | 3 |
| Oxgen deficient | 1 |
| Almost no oxygen | < 1 |

## Tables 3.5c and d: Acidity

| Standards for acidity for lakes | | |
|---|---|---|
| Type | High | Good |
| | Acid neutralising capacity (micro equivalents per litre) | |
| All UK lakes | > 40 | > 20 |

| Existing standards | |
|---|---|
| Defra's proposal for 2004 critical loads | Norwegian standard set for salmonid fish |
| Acid Neutralising Capacity (micro equivalents per litre) | |
| > 20 | > 20 |

## Tables 3.5e and f: Phosphorus (TP)

| Standards for phosphorus for lakes | | | | |
|---|---|---|---|---|
| | Class boundaries | | | |
| Type of lake | High | | Good | |
| | Range | Type | Range | Type |
| | Annual mean (µgl) | | | |
| HA - D | There are too few lakes of this type | | | |
| HA - S | 16-23 | 20 | 28-40 | 34 |
| HA – VS | 20-36 | 28 | 33-56 | 43 |
| MA - D | 6-8 | 7 | 10-14 | 13 |
| MA - S | 9-15 | 12 | 13-21 | 17 |
| MA – VS | 15-25 | 20 | 21-36 | 28 |
| LA – D | 4-6 | 5 | 6-11 | 9 |
| LA – S | 5-9 | 7 | 7-13 | 10 |
| LA – VS | 6-15 | 11 | 8-21 | 15 |
| MA – D | As for Moderate Alkalinity | | | |
| Marl – VS | | | | |
| Peat | To be agreed | | | |

| Existing standards | | | | |
|---|---|---|---|---|
| Habitats Directive[1] | Other Member States[2] | | | |
| | High | | Good | |
| | Range | Median | Range | Median |
| | Annual mean (µgl) | | | |
| 50 | | | | |
| | 8-63 | 30 | 20-93 | 46 |
| 50 | 10-100 | 42 | 33-56 | 65 |
| 15 | | | | |
| | 10-34 | 14 | 20-35 | 23 |
| 20 | | | | |
| 10 | | | | |
| | | | | |
| 10 | | | | |
| 15 | | | | |
| 20 | | | | |
| 10 | | | | |

**Table 3.6: Water Framework Directive (WFD) Risk Assessment outcomes: SACs and SSSIs: Available at:** http://maps.environment-agency.gov.uk/

| SAC / SSSI Name | Lake Name | Risk category | Risk source |
|---|---|---|---|
| Afon Gwyrfai a Llyn Cwellyn | **Llyn Cwellyn** | **At risk** | **Diffuse pollution** |
| Afon Teifi | **Llyn Egnant** | **Probably at risk** | **Physical / morphological alteration** |
| | **Llyn Hîr** | **At risk** | **Diffuse pollution** |
| | Llyn Teifi | Probably *not* at risk | |
| Cadair Idris | Llyn Gafr | - | |
| | Llyn Arran | - | |
| | **Llyn Cau** | **At risk** | **Diffuse pollution** |
| Corsydd Môn / Anglesey Fens | Llyn Cadarn | - | |
| | Llyn yr Wyth Eidion | - | |
| Elenydd | Llyn Cerrigllwydion Isaf | Probably *not* at risk | |
| | Llyn Fyrddon Fawr | Probably *not* at risk | |
| | Llyn Gwyngu | - | |
| | Llyn Gynon | Probably *not* at risk | |
| Eryri / Snowdonia | **Llyn Cwmffynnon** | **At risk** | **Diffuse pollution** |
| | Llyn Coch | - | |
| | Llyn Idwal | Probably *not* at risk | |
| | **Llyn Ogwen** | **At risk** | **Diffuse pollution** |
| Kenfig / Cynffig | Kenfig Pool | Probably *not* at risk | |
| Llyn Dinam | **Llyn Dinam** | **At risk** | **Point source pollution (*and* probably at risk from diffuse pollution & alien species)** |
| Llyn Syfaddan / Llangorse Lake | **Llangorse Lake** | **At risk** | **Point source *and* diffuse pollution** |
| Migneint-Arenig-Dduallt | Llyn Conglog-Mawr | - | |
| | Llyn y Dywarchen | - | |
| | **Llyn y Garn** | **At risk** | **Diffuse pollution** |
| | Llyn Hesgyn*** | - | |
| | **Llyn Hiraethlyn*** ** | - | |
| | Llyn Tryweryn*** | - | |

| SAC / SSSI Name | Lake Name | Risk category | Risk source |
|---|---|---|---|
| Pembrokeshire Bat Sites and Bosherton Lakes / Safleoedd Ystlum Sir Benfro a Llynnoedd Bosherton | Bosherston Lily Ponds | - | |
| Rhinog | **Llyn Cwm Bychan** | **At risk** | **Diffuse pollution** |
| | Llyn Eiddew-Mawr | Probably *not* at risk | |
| | Llyn Perfeddau | - | |
| | Gloyw Lyn | - | |
| Y Twyni o Abermenai i Aberffraw / Abermenai to Aberffraw Dunes | **Llyn Coron** | **At risk** | **Diffuse pollution** |
| Hanmer Mere SSSI | Hanmer Mere | Probably *not* at risk | |
| Llyn Alaw | **Llyn Alaw** | **At risk** | **Diffuse pollution and physical / morphological alteration** (probably at risk of alien species) |
| Mynydd Hiraethog | Llyn Alwen | - | |
| - | Llyn Bodlyn | Probably *not* at risk | |
| Llyn Eiddwen SSSI | Llyn Eiddwen | - | |
| Llyn Glasfryn SSSI | Llyn Glasfryn | - | |
| Llyn Llygeirian SSSI | Llyn Llygeirian | - | |
| Llyn Padarn SSSI | **Llyn Padarn** | **At risk** | **Physical / morphological alteration** |
| Llynnau y Fali / Valley Lakes SSSI | **Llyn Penrhyn** | - | |
| Llyn Tegid SSSI | **Llyn Tegid** | **Probably at risk** | **Physical / morphological alteration** |
| Cadair Idris SSSI | **Tal-y-llyn Lake** | **Probably at risk** | **Diffuse pollution** |

**Key:**

- Risk categories are: a) at risk; b) probably at risk; c) probably *not* at risk; d) *no*t at risk.
- A dash indicates that no WFD risk assessments have been completed for these sites.
- Sites in **bold** are those that have been classified as 'at risk' by WFD risk assessments

## *3.4 Notation used in the site condition assessment tables and text*

**Depths**
$Z_{max}$ = Maximum water depth
$Z_{mean}$ = Mean water depth
$Z_s$ = Secchi depth
$Z_v$ = Maximum macrophyte colonisation depth

**Limnological data**
TP = total phosphorus
SRP = soluble reactive phosphorus
TN = total nitrogen
$NO_3^-N$ = nitrate nitrogen
Chl *a* = chlorophyll *a*
Alk = alkalinity
DOC = dissolved organic carbon

**Habitats Directive standing water body feature types**
OML = Oligotrophic to mesotrophic lake with *Littorelletea*
HC = Hard lake with *Chara*
NE = Natural eutrophic lake
DY = Dystrophic lake

**Water Framework Directive (WFD) lake typologies**
***Alkalinity***
LA = low alkalinity
MA = medium alkalinity
HA = high alkalinity
***Depth***
D = deep ($Z_{mean}$ > 15 m)
S = shallow ($Z_{mean}$ 3 – 15 m)
V = very shallow ($Z_{mean}$ < 3 m)

# 4. Site Assessments

## *4.1 Afon Gwyrfai a Llyn Cwellyn SAC*

### 4.1.1 Llyn Cwellyn (LA, D)

Annex 1 type: H3130: Oligotrophic to mesotrophic standing water with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea* – Favourable Condition Table 4.

**Table 4.1.1: Condition Assessment Summary Table for Llyn Cwellyn**

| 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 species present: *L. uniflora, L. dortmanna, I. lacustris, L. natans, S. aquatica* |
| | No loss of characteristic species (see Box 2) | ✓ | Similar to those recorded in 1993 (see Allott *et al*. 1994) |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) have ≥ 1 characteristic species | ✓ | 82 % of vegetated sample spots comply (wader 76%; boat 93%). |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | No non-natives |
| | Benthic and epiphytic filamentous algal cover <10% | ✓**?** | Mean cover score = 1.1<br>17% (20/120) of sample spots have cover values of 3. |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (see Table 4) | ✓ | *L. uniflora / L. dortmanna* → *I. lacustris* (to 5 m depth) |
| | Maximum depth distribution should be maintained | - | Baseline survey:<br>$Z_{max}$ = 36.0 m, $Z_{mean}$ = 22.6 m,<br>$Z_s$ = 7.25 m, $Z_v$ = 5.0 m |
| | At least the present structure should be maintained | - | Comparable structure to that reported in 1993 survey (see Allott *et al*. 1994) |

**Table 4.1.1 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels:<br>TP target/limit = 10µgP $l^{-1}$ | **X?** | TP annual mean 9 $\mu gl^{-1}$ (range: 4-17$\mu gl^{-1}$)<br>TN = 0.39 $\mu gl^{-1}$;<br>Chl *a* = 2.7 $\mu gl^{-1}$ |
| | Stable pH / ANC values:<br>pH ~ 5.5 – 7.0; ANC > 20 | ✓**?** | pH = 6.9 (range = 6.8 - 7.6)<br>ANC data unavailable<br>Alk = 58-82 $\mu eql^{-1}$ (bicarb);<br>DOC = 1-2 $mgl^{-1}$ |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 $mgl^{-1}$) | ✓ | 9-10 $mgl^{-1}$ from 0-15 m (from 15m thermocline, falls to 5 $mgl^{-1}$ by 30m) |
| | No excessive growth of cyanobacteria or green algae | ✓ | No algal blooms |
| **Hydrology** | Natural hydrological regime | **X?** | Raw water abstraction for supply, although not directly from lake (see licence for abstraction limits) |
| **Lake substrate** | Natural shoreline maintained | ✓ | Shoreline modification index = 1.32 |
| | Natural and characteristic substrate maintained | **?** | *J. bulbosus* / filamentous algae may indicate substrate enrichment / inwash |
| **Sediment load** | Natural sediment load maintained | **X?** | -Felling of coniferous trees on southern slopes may be increasing sediment load.<br>-Liming of catchment (in past) may have increased mineralogenic inwash. |
| **Indicators of local distinctiveness** | Distinctive elements maintained | ✓**?** | *L. natans* & *N. gracilis* present (*N. gracilis* not recorded in 1993). Arctic charr, *Salvelinus alpinus* population in the lake. |
| | Minimal negative impacts and no fish farming | ✓**?** | Hotel, slipway & weir at W end. Mature coniferous forest plantation adjacent to S shore. Limited angling. No fish farming. |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | **X?** | Bennion *et al*. (1997) & Bennion ed. (2004): 0-24 cm core: Sq chord distance = 0.803: significant floristic change - acidification post 1860s |

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

Extent
The surface area of the lake is 90.1 ha, with a volume of 20,360 x$10^3$$m^3$.

Macrophyte community composition
The aquatic vegetation of Llyn Cwellyn keys out as a Type 3 "oligotrophic" assemblage (Palmer, 1992). The site is rich in submerged and floating-leaved aquatic macrophytes, with 15 species recorded during a survey on 01/10/2003. Based on the submerged and floating leaved vegetation only (Table 4.1.2), the average Trophic Rank Score (TRS) for the lake is 5.12 (71.7/14). This is comparable to the TRS of 5.32 calculated for Llyn Cwellyn from a 1993 macrophyte survey reported in Allott *et al*. (1994).

**Table 4.1.2 Macrophyte Community Composition for Llyn Cwellyn, including trophic scores. Figures in brackets indicate calculated values for 1993 survey (Allott *et al.* 1994).**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Callitriche hamulata* | 5.0 | F |
| *Elatine hexandra* | 6.0 | Strandline only |
| *Fontinalis antipyretica* | 6.3 | F |
| *Isoetes lacustris* | 5.0 | A |
| *Juncus bulbosus* | 3.7 | A |
| *Littorella uniflora* | 6.7 | A |
| *Lobelia dortmanna* | 5.0 | A |
| *Luronium natans* | - | R |
| *Myriophyllum alterniflorum* | 5.5 | O |
| *Nitella flexilis* agg. | 5.5 | O |
| *Nitella gracilis* | 5.5 | R |
| *Potamogeton berchtoldii* | 7.3 | R |
| *Potamogeton polygonifolius* | 3.7 | Strandline only |
| *Sphagnum auriculatum* | 2.5 | O |
| *Subularia aquatica* | 4.0 | R |
| **SiteTRS (unweighted)** | **5.12 (5.32)** | |
| **Weighted TRS** | **5.68 (5.46)** | |
| **Weighted PLEX** | **4.31 (4.06)** | |
| **Mean Ellenberg Fertility Score** | **4.21 (4.12)** | |

Five characteristic *Littorelletea* species for the Annex I interest feature type are present in Llyn Cwellyn. The characteristic species present are: *Littorella uniflora*, *Lobelia dortmana*, *Isoetes lacustris*, *Subularia aquatica* and *Luronium natans*. 77/97 (79 %) of the vegetated boat and wader sample spots (83 % and 77 % respectively) have at least one of the characteristic species listed above, with a number of sample spots presenting more than one species. Since this is more than 6/10 (60 %) of the sample spots having at least 1 characteristic species, the site passes the macrophyte community composition criteria.

*Luronium natans*, *Nitella* spp. (*Nitella gracilis* and *Nitella flexilis* agg.) and *Elatine hexandra* are present and may indicate that the site is at the interface between oligotrophic and mesotrophic according the CSM guidance. The presence of *Subularia aquatica* indicates that the site is not so enriched as to prevent the growth of this species. However, high cover of *Juncus bulbosus* (mainly) and *Sphagnum* spp. (present in 60 % of the vegetated wader transect points) may indicate that the lake is slightly acidified. The macrophyte species and their abundances recorded in 2003 are similar to those recorded in 1993 (Allott *et al*., 1994), although no *Nitella* spp. or *L. natans* were recorded then. The absence of *Nitella* spp. and *L. natans* in 1993 may simply reflect interannual variation in abundance and/or the patchiness of populations.

The three trophic indices show very little change in trophic status between 1993 and 2003.

Macrophyte community structure

The maximum depth of Llyn Cwellyn ($Z_{max}$) is 36 m. During the 2003 macrophyte survey, Secchi depth ($Z_s$) was 7.25 m and the maximum depth of macrophyte colonisation ($Z_v$) was 5.0 m. This could suggest that the lake is often less clear than recorded during the survey, although a more likely explanation is that other factors (e.g. water pressure and angle of slope) prevent higher plant colonisation at water depths of greater than 5 m (Monteith pers. comm.). Llyn Cwellyn shows the characteristic vegetation zones typical of its oligotrophic macrophyte interest feature, indicating that the site is in favourable condition. With increasing depth, the macrophyte community structure consists of *L. uniflora*, overlapping zones of *Littorella* with *L. dortmana*, then *I. lacustris*. *I. lacustris* is present to a depth of 5.0 m, dominating the assemblage between 2.0 and 5.0 m. The site supports macrophyte species of a number of different growth forms - isoetids (*I. lacustris*, *L. uniflora*, *L. dortmanna*), charophytes (*Nitella* spp.), mosses (*F. antipyretica*, *Sphagnum* spp.), submerged fine/strap-leaved plants (*J. bulbosus, M. alterniflorum, P. berchtoldii*), floating-leaved plants (*Potamogeton polygonifolius*) and emergents (*Phalaris arundinacea*), suggesting that the macrophytes provide a diverse range of habitats within the lake and indicating that Llyn Cwellyn meets its feature type targets for macrophyte community structure.

Negative indicator species

No non-native macrophyte species are present in Llyn Cwellyn. Benthic/epiphytic filamentous algae cover is very variable across the boat and wader transects, with 2 transects presenting no filamentous algal cover and the remaining transects having on average, low to moderate coverage. The mean coverage score across all boat and wader transects is 1.08, with less than 50% (20/120 = 17%) of wader and boat transect sample points having cover values of 3. Overall, the site is probably not enriched, but the abundance of filamentous algae in certain areas of the lake may indicate localised sources of enrichment.

Water quality

Annual mean pH (6.9) is supportive of the feature type and alkalinity is relatively high (> 50 $\mu eq^{-1}$), suggesting that the lake is reasonably well buffered against acidification. DOC concentrations are low (1-2 $mgl^{-1}$) since there is limited peat within the catchment. 10 $\mu gl^{-1}$ is the TP target/limit for LA, D lakes according to Table 1, section 2.1.2.2 of the CSM guidance for standing waters (JNCC, 2005a). With mean annual TP concentrations ranging from 10.05 $\mu gl^{-1}$ to 12.75 $\mu gl^{-1}$ (according to EA data from Autumn 2003 to Summer 2005), Llyn Cwellyn's TP concentrations are slightly above those expected under favourable conditions. It

is worth noting that the mean TP concentration calculated from Spring 1993 – Winter 1993-94 (Allott *et al*., 1994), is only 7 $\mu gl^{-1}$, suggesting that Llyn Cwellyn has experienced nutrient enrichment between 1993 and 2005. If spring TP data only were used for the assessment, Llyn Cwellyn would meet its feature type TP target because all spring TP data are < 10 $\mu gl^{-1}$. NB: Goldsmith *et al*. (2006) data report figure = 9 $\mu gl^{-1}$ (annual mean TP) and the UK TAG draft TP standard for the good / moderate boundary is 9 $\mu gl^{-1}$ and the reference value is 5 $\mu gl^{-1}$ (annual mean TP) for LA, deep lakes.

Hydrology

Llyn Cwellyn's water level is maintained by a concrete weir at the outflow and water is abstracted for raw drinking supply. There are tight controls on the volume of water that can be abstracted and the extent of drawdown permissible. Licence number 23/65/15/24 issued by the EA on 5th May 1994 details the quantities of water authorised to be abstracted from the Afon Gwyrfai at Llyn Cwellyn. Water may only be abstracted when the water level in Llyn Cwellyn is ≥ 138.55 m AOD and only during the period 16th September to 15th November inclusive. Maximum volumes abstracted per day are dependant upon the water level of Llyn Cwellyn and the rate of abstraction should not exceed 300 litres per second.

Lake substrate

Sediment quality and quantity may be enriched, causing the excessive growths of *J. bulbosus*, *Sphagnum* spp. and filamentous algae (see below).

Sediment load

The lake's catchment land use is dominated by unimproved acid grassland. The high cover of *J. bulbosus*, *Sphagnum* spp. and the frequent growths of filamentous algae in some areas of the lake, may indicate an increase in siltation. Planted coniferous woodland accounts for only 6% of catchment land use, however the gradual removal of mature coniferous forest from the slopes around the south shore could potentially be the source of increased sediment loads in a localised area of the lake. Bennion *et al*. (1997) observed the application of lime within Llyn Cwellyn's catchment in 1993. Liming alters soil pH, which in turn improves nutrient availability to the sward for sheep grazing. Brundrud (2002) reported a dramatic increase in populations of *J. bulbosus* following catchment liming, suggesting that the high abundance of *J. bulbosus* in the marginal areas of Llyn Cwellyn may be related to mineral inwash linked to past catchment land-use practices.

Indicators of local distinctiveness

The Red Data Book species, *L. natans* and *N. gracilis* are present in Llyn Cwellyn. During the 2003 sampling, both species were found in only one boat transect at a depth of 3.2 m.

Palaeolimnological evidence

Fossil diatom data presented in Bennion *et al*. (1997) indicates that Llyn Cwellyn has experienced progressive acidification since c.1860 (24 cm depth in central lake sediment core). Diatom inferred pH reconstructions show a decline of 0.7-0.8 pH units over this time period. The squared chord distance dissimilarity score from core bottom (AD 1860) sample to core top sample (AD 1997) is 0.803 (Bennion (ed.), 2004), with the shift in the diatom species assemblage indicating moderate acidification of the lake (Bennion *et al*., 1997). The rate of acidification appears to have increased during the 1940s either as a result of background increases in the rates of acid deposition or as a result of afforestation within the lake's

catchment. From the 1980s to 1995, subtle changes in the diatom flora are interpreted as indicating a slight reversal in the acidification trend, probably brought about through a decline in sulphur deposition within the catchment (Bennion *et al*., 1997).

Summary

Llyn Cwellyn is an oligotrophic lake that appears to be in overall **unfavourable** condition. Shifts in the lake's macrophyte community composition, moderate TP concentrations and palaeolimnological data suggest that the lake has experienced moderate acidification over the last century and perhaps slight nutrient enrichment and increased sediment loading in recent years. Llyn Cwellyn has also been identified in WFD risk assessments as being at risk of diffuse pollution, therefore the site has the potential to deteriorate further unless appropriate management measures are taken.

Future condition assessments should examine whether *J. bulbosus* and *Sphagnum* spp. continue to increase in abundance as a result of nutrient enrichment and sedimentation or whether they decline in abundance, perhaps as a result of a continuing reversal in the historic acidification trend or a reduction in mineral inwash. The extent of sediment inwash to the lake from grassland improvement (liming) and the felling of trees within the catchment should be monitored.

The Red Data Book and Annex II species, *L. natans* and *N. gracilis* should be monitored to ensure that these rare plants are not lost.

## Overall condition of the Afon Gwyrfai SAC

Overall, Llyn Cwellyn and therefore the Afon Gwyrfai a Llyn Cwellyn SAC should be classified as **unfavourable,** with the palaeo evidence suggesting recovery from a period of acidification. The lake's condition should be closely monitored.

**Table 4.1.3: Afon Gwyrfai a Llyn Cwellyn SAC: Overview**

| Water Body | Status | Reason(s) for Failure | Comments |
|---|---|---|---|
| Llyn Cwellyn | Unfavourable (recovering) | Acidification | Seems to be recovering from acidification. Also concerns over nutrients, sediment load and abstraction. |
| **Overall SAC Status** | **Unfavourable** | | |

## *4.2 Afon Teifi SAC*

### 4.2.1 Llyn Egnant (LA, S)

Annex 1 type: H3130: Oligotrophic to mesotrophic standing water with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*. Favourable Condition Table 4.

**Table 4.2.1: Condition Assessment Summary Table for Llyn Egnant**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓? | None, but water-supply reservoir so water level can be drawn down (not during 2004 survey) |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise) | ✓ | 3 species present: *L. uniflora, L. natans, S. angustifolium* *J. bulbosus* and *Sphagnum* spp. present in 92 % of vegetated sample spots |
| | No loss of characteristic species (see Box 2) | **X** | *Lobelia dortmanna* lost – last recorded in 1972 by Seddon. |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) have ≥ 1 characteristic species | **X** | Only 20 % of wader and 15 % of boat vegetated sample spots comply |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | No non-natives. |
| | Benthic and epiphytic filamentous algal cover <10% | ✓? | Mean cover = 0.7. Median = 1.0 No sample spots with cover scores of 3 |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (see Table 4) | **X** | No *L. dortmanna* or *Isoetes* spp. *L. natans* / *J.bulbosus* / *C.hamulata* → *M.alterniflorum* / *C.hamulata* / *S.auriculatum* |
| | Maximum depth distribution should be maintained | ✓ | $Z_{max}$ = 14.2 m, $Z_{mean}$ = ??, $Z_s$ = 1.8 m, $Z_v$ = 2.8 m |
| | At least the present structure should be maintained | - | |

**Table 4.2.1 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels: TP target/limit = 10 µg P $l^{-1}$ | **X** | TP = 20-30 µg$l^{-1}$ (EA data, 04 & 05) |
| | Stable pH / ANC values: pH ~ 5.5–7.0; ANC > 20 | **✓?** | pH = 6.02 (EA data '04) no ANC data; Alk = 38 µeq$l^{-1}$ (EA data '04) |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 mg$l^{-1}$) | ✓ | 9-10 mg$l^{-1}$ from 0 - 14 m (Sept'04) |
| | No excessive growth of cyanobacteria or green algae | ✓ | No blooms seen |
| **Hydrology** | Natural hydrological regime | **X** | Water level regulated by dam – EA abstraction licence no. 22/62/1/87 |
| **Lake substrate** | Natural shoreline maintained | **✓?** | Road along part of shoreline and dam on southern shore |
| | Natural and characteristic substrate maintained | **✓?** | Peat dominant in marginal areas, some of which is eroded |
| **Sediment load** | Natural sediment load maintained | **?** | Surrounding land use dominated by sheep-grazed acid grassland, with small areas of blanket bog and heather moorland |
| **Indicators of local distinctiveness** | Distinctive elements maintained | ✓ | *L. natans* uncommon in survey sections, but frequent across site to ~1.5 m depth |
| | Minimal negative impacts and no fish farming | **X?** | Road along part of shoreline and dam on southern shore. Public water supply reservoir |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | **X?** | 0-31 cm: 1.113 sq chord dist significant floristic change - acidification |

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

Extent

The surface area of the lake is 17.4 ha. No data are available for the lake volume.

Macrophyte community composition

The aquatic vegetation of Llyn Egnant keys out as a Type 3 "oligotrophic" assemblage (Palmer, 1992). Based on submerged and floating leaved vegetation only (Table 4.2.2), the lake has an average Trophic Rank Score (TRS) of 4.70 (32.7/7). Surveys were carried out on 20/09/2004 & 24/09/2004. Llyn Egnant supports relatively few submerged and floating-

leaved macrophyte species in comparision with the other sites in the Afon Teifi SAC and is therefore considered to be species-poor.

**Table 4.2.2: Macrophyte Community Composition for Llyn Egnant, including trophic scores.**

| Submerged and floating vegetation | Trophic Rank Score (TRS) |
|---|---|
| *Callitriche hamulata* | 5.0 |
| *Glyceria fluitans* | 6.3 |
| *Juncus bulbosus* | 3.7 |
| *Littorella uniflora* | 6.7 |
| *Luronium natans* | - |
| *Myriophyllum alterniflorum* | 5.5 |
| *Sparganium angustifolium* | 3.0 |
| *Sphagnum auriculatum* | 2.5 |
| **Average TRS (unweighted)** | **4.70** |
| **PLEX (unweighted)** | **4.29** |
| **Ellenberg Fertility Score (unweighted)** | **4.43** |

The typical characteristic species composition for this lake type is not seen in Llyn Egnant. Although *L. uniflora* is present, it is infrequent and unaccompanied by *L. dortmanna* and *Isoetes* spp. *Sparganium angustifolium* and *L. natans* are the characteristic non-*Littorelletea* species occurring alongside *L. uniflora*. *Callitriche hamulata, Myriophyllum alterniflorum, J. bulbosus* and *Potamogeton poly*gonifolius are associates. *J. bulbosus* is common in peaty marginal areas, as are *C. rostrata*, *C. hamulata* and *Glyceria fluitans*. Although Llyn Egnant supports 4 characteristic *Littorelletea* species, the low representation (15-20% of wader/ boat transect sample spots) of these and other characteristic species results in overall failure of the macrophyte community composition targets. Seasonal draw-down of Llyn Egnant for water supply may inhibit colonisation of unstable / exposed substrates by macrophytes, in turn lowering the coverage of individual species.

Negative indicator species

No non-native macrophyte species are present. *J. bulbosus* and *Sphagnum* spp. are present in 92% of the shore sample spots, which may indicate negative environmental impact. The presence of these species may however be more indicative of areas of peaty, unconsolidated substrate. Filamentous algal cover is low across the four wader and boat transects, with an overall mean score of 0.7 and a median score of 1, equivalent to <25% cover. No sample spots have filamentous algal cover scores of 3. No blue-green algal blooms were seen during the field survey in September 2004.

Macrophyte community structure

As described above, the species association typical for the habitat feature is not present, therefore the typical zonation pattern cannot be seen in Llyn Egnant. Instead, *J. bulbosus*, *Callitriche hamulata* and *L. natans* occur in the shallower water (to ~1.5 m) and *M. alterniflorum*, *C. hamulata*, *Sphagnum auriculatum* and *Sparganium angustifolium* grow in the deeper water (up to 2-3 m depth). Secchi depth was 1.8 m and the maximum depth of macrophyte colonisation was 2.8 m (*S. auriculatum*). Beyond a depth of ~2.0 m, aquatic plant volume was low. The lack of a typical macrophyte zonation pattern may be due to the exposed nature of the site, particularly around the western shore, thus limiting the growth of the shallow water species due to wind stress and poor water clarity resulting from turbulence. The site supports macrophyte species of a number of different growth forms - isoetids (*L. uniflora*), mosses (*Sphagnum auriculatum*), submerged fine/strap-leaved plants (*J. bulbosus, M. alterniflorum, C. hamulata, L. natans, G. fluitans*), floating-leaved plants (*P. polygonifolius*, *S. angustifolium*) and emergents (*C. rostrata*).

Water quality

Annual mean pH (6.02) lies within the target range for the habitat type. Although no ANC data is available, alkalinity is relatively high ($37\mu eql^{-1}$), suggesting that Llyn Egnant is well-buffered. The mean annual DOC concentration is relatively low ($4.4mgl^{-1}$). Nutrient concentrations are high ($20\text{-}30\mu gl^{-1}$ (mean EA data for 2004 & 2005)) compared with the target/limit for the lake type ($10\mu gl^{-1}$ (JNCC, 2005a)), suggesting that the lake has been enriched and placing the site in unfavourable condition.

Hydrology

The hydrological regime of Llyn Egnant is unnatural since a dam on the southern shore regulates the water level. Welsh Water utilises the lake as a public water supply reservoir and under EA abstraction licence number 22/62/1/87, not more than 1,100,000 $m^3$ of water can be abstracted annually. Despite water levels being high during the September 2004 field survey, the restricted macrophyte community composition and structure may arise from seasonal drawdown exposing and destabilising substrates, thus suppressing macrophyte colonisation in these areas. Wind exposure could be an additional factor inhibiting plant growth in the littoral zone, since drawdown exposes marginal plants to wind stress where once they would have been submersed and protected. Macrophyte species vulnerable to these pressures include *Isoetes* spp.

Lake substrate

Within the wader survey sections, the dominant substrate in the marginal areas is peat. Peat substrates are also present to depths of 1.9 m, although silt is more common at water depths >1 m. The marginal areas of the western and northern shores are dominated by cobbles.

Sediment load

Catchment land-use is predominantly sheep-grazed upland grassland (dominated by *Molinia caerulea* and *Juncus* spp.) with small areas of blanket bog and heather moorland (Southey & Broughton, 2004). In some areas (eastern shore) the peat hags are eroded.

Indicators of local distinctiveness

The Annex II species, *L. natans* is present in Llyn Egnant. Although it was uncommon in the survey sections, during the 2004 sampling season this plant was frequently encountered across the site, growing to a depth of ~1.5 m.

Palaeolimnological evidence

Fossil diatom data for Llyn Egnant presented in Burgess *et al*. (2005) indicates that the lake has experienced significant floristic change in its diatom species assemblage from bottom to top of a 31 cm sediment core (squared chord distance dissimilarity score = 1.113). Species typical of circumneutral to mildly acid conditions (*Achnanthes minutissima*, *Cyclotella rossii*, *Fragilaria exigua* and *Eunotia incisa*) have been replaced by an increasing percentage abundance of species associated with moderatedly acid conditions (*E. incisa*, *Cymbella perpusilla* and *Tabellaria flocculosa*) accompanied by the elimination of *A. minutissima* from the assemblage. The species shifts are indicative of progressive acidification of the lake.

Summary

Overall, Llyn Egnant is in **unfavourable** condition.

*L. natans* is an integral component of the lake's macrophyte community; therefore the abundance and distribution of this plant should be monitored to ensure that it is not lost from the lake in the future. *L. dortmanna* has already been lost from the site. The loss may be due to fluctuating water levels from seasonal draw-down of the lake for public water supply, although the effect of other impact factors should be investigated.

The abundance and distribution of *J. bulbosus* and *Sphagnum* spp. should also be monitored to determine whether these species decrease in abundance perhaps as a result of a reversal in acidification, or whether they are expanding through increased sedimentation from accelerated peatland erosion due to climate change and/or continued poaching of the shoreline by livestock increasing mineralogenic sediment loading.

Although DOC concentrations are relatively low at present, they should be monitored to examine whether concentrations are increasing, perhaps as a result of recovery from acidification (Monteith *et al*., 2005). Since palaeolimnological evidence suggests that the lake has been acidified, values for ANC should also be obtained from regular water quality monitoring over the coming years, to better determine the lake's acidity and to track any changes in response to reductions in acid deposition.

## 4.2.2 Llyn Hîr (LA, S)

Annex 1 type: H3130: Oligotrophic to mesotrophic standing water with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*. Favourable Condition Table 4.

**Table 4.2.3: Condition Assessment Summary Table for Llyn Hîr.**

| 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) | ✓ | 6 present: *L. uniflora, L. dortmanna, I. echinospora, L. natans, S. aquatica, S. angustifolium* |
| | No loss of characteristic species (see Box 2) | - | Baseline survey |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) have ≥ 1 characteristic species | ✓ | 97% of vegetated sample spots comply (boat 92% and wader 100%) |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | No non-natives. *J. bulbosus* present but at low abundance |
| | Benthic and epiphytic filamentous algal cover <10% | **?** | Mean = 1.9; Median = 2<br>20/120 sample spots have cover values of 3. |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (see Table 4) | ✓ | *L.uni / L.dort / S.aqu → I.ech / M.alt / L.nat / N.flex* |
| | Maximum depth distribution should be maintained | **-** | $Z_{max}$ = 7.8 m, $Z_{mean}$ = 2.8 m, $Z_s$ = 3.4 m, $Z_v$ = 3.7 m |
| | At least the present structure should be maintained | **-** | Baseline survey |
| **Water quality** | Stable nutrients levels:<br>TP target / limit = 10 µg P $l^{-1}$ | **X?** | TP = 12 µg$l^{-1}$ (EA annual mean 2004) |
| | Stable pH / ANC values:<br>pH ~ 5.5 – 7.0; ANC > 20 | **✓?** | pH = 6.45; No ANC data<br>Alk = 54 µeq$l^{-1}$ (EA data '04 mean) |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 mg$l^{-1}$) | ✓ | 9-10 mg$l^{-1}$ from 0-7 m depth |
| | No excessive growth of cyanobacteria or green algae | ✓ | No algal blooms |
| **Hydrology** | Natural hydrological regime | ✓ | No dam. Not used for water supply. |

**Table 4.2.3 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Lake substrate** | Natural shoreline maintained | ✓? | Margins dominated by steep boulder and gravel shore. Wide shallow bay around northern inflow. Poaching of shore by sheep in survey section 1. |
| | Natural and characteristic substrate maintained | ? | Boulders = dominant substrate. Gravel and peat areas common |
| **Sediment load** | Natural sediment load maintained | ? | Catchment landuse dominated by rough upland grazing. Some heavily grazed upland pasture (survey section 1). Poaching of shore by sheep in survey section 1. |
| **Indicators of local distinctiveness** | Distinctive elements maintained | ✓ | *L. natans* and *I. echinospora* common across transects |
| | Minimal negative impacts and no fish farming | ✓? | Poaching of shore by sheep in survey section 1.<br>Lake and catchment have been limed in the past. Lake limed in 1985. |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | X? | 0-16 cm: 0.904 sq chord dist significant floristic change - acidification |

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

Extent

Llyn Hîr lies at an altitude of 435 m. It has a surface area of 5.1 ha and a volume of 140 $x10^3m^3$.

Macrophyte community composition

The aquatic vegetation of Llyn Hîr keys out as a Type 3 "oligotrophic" assemblage (Palmer, 1992). Based on the submerged and floating leaved vegetation only (Table 4.2.4), the average Trophic Rank Score (TRS) of this site is 4.29 (42.9/10). The site is particularly species rich, with 13 submerged / floating-leaved macrophyte species found during the late summer 2004 field survey.

6 characteristic *Littorelletea* species are present - *L. uniflora, L. dortmanna, I. echinospora, L. natans, S. aquatica* and *S. angustifolium*. Overall across all transects, 97 % of the vegetated wader and boat sample spots have at least one characteristic species. Llyn Hîr is consequently determined to be in favourable condition according to its macrophyte community composition. It should be noted that although *I. lacustris* has been recorded from Llyn Hîr in

the past (Monteith (ed.), 1995), all specimens collected from the site in September 2004 were confirmed as *I. echinospora*.

**Table 4.2.4: Macrophyte community composition for Llyn Hîr, including trophic scores.**

| Submerged and floating vegetation | Trophic Rank Score (TRS) |
|---|---|
| *Isoetes echinospora* | - |
| *Juncus bulbosus* | 3.7 |
| *Littorella uniflora* | 6.7 |
| *Lobelia dortmanna* | 5.0 |
| *Luronium natans* | - |
| *Myriophyllum alterniflorum* | 5.5 |
| *Nitella flexilis* agg. | 5.5 |
| ***Potamogeton polygonifolius*** | 3.0 |
| *Sparganium angustifolium* | 3.0 |
| *Sphagnum auriculatum* | 2.5 |
| *Subularia aquatica* | 4.0 |
| *Utricularia minor* | 4.0 |
| **Average TRS (unweighted)** | **4.29** |
| **PLEX (unweighted)** | **3.78** |
| **Ellenberg Fertility Score (unweighted)** | **3.76** |

Negative indicator species

There are no non-native aquatic macrophyte species in Llyn Hîr. *J. bulbosus* and *Sphagnum* spp. are present at low abundance (present in ~10% of all vegetated sample spots). No blue-green algal blooms were observed.

Macrophyte community structure

The macrophyte community structure consists of *L. uniflora, L. dortmanna* and *S. aquatica* to water depths of ~ 2.0 m, with *Isoetes echinospora*, *M. alterniflorum*, *L. natans* and *N. flexilis* growing in deeper water. *N. flexilis* was only found in boat transect 3, growing at depths of 3.2 to 3.6 m. The maximum depth of macrophyte colonisation was 3.7 m (*L. natans*).

Water quality

Llyn Hîr's pH is 6.45 (EA mean annual data, 2004), which is within the expected range for the feature type. Prior to liming of the lake by the Welsh Water Authority in 1985, lake pH was only 4.8 (Battarbee *et al.,* 1988). Although no ANC data are available, alkalinity is relatively high (55 $\mu eql^{-1}$), suggesting that the lake is well-buffered. DOC is relatively low, at 3.3 $mgl^{-1}$. The mean annual TP concentration is 12 $\mu gl^{-1}$ (EA data, 2004), which is marginally higher than the 10 $\mu gl^{-1}$ target/limit for the lake type (JNCC, 2005a). Llyn Hîr has been identified in WFD risk assessments as being at risk of diffuse pollution, therefore both nutrient concentrations and acidity should be monitored.

Hydrology

Unlike Llyn Egnant and Llyn Teifi, Llyn Hîr has a natural hydrological regime since it is not used for water abstraction. As such, water levels remain relatively stable, favourable to the growth of *L. dortmanna*.

Lake substrate

The shoreline retains its natural character. Boulders are the dominant substrate around the margins of the lake, with silt being dominant in deeper water areas. The lake is relatively sheltered in comparison with Llyn Egnant and Llyn Teifi, which may explain the proliferation of *L. dortmanna*, a species intolerant of both wind stress and fluctuating water levels.

Sediment load

Llyn Hîr's catchment is dominated by rough upland sheep grazing. In some locations the shoreline is steep and rocky, with little or no vegetation covering the bare rock. One survey section (section 1) was heavily grazed, with the shoreline poached, possibly increasing the sediment load to the lake through erosion.

Indicators of local distinctiveness

*L. natans* is present in Llyn Hîr, growing at water depths of between 0.75 m and 3.7 m, with most specimens growing in association with *M. alterniflorum* at depths of 2-3 m. *I. echinospora* is also present.

Palaeolimnological evidence

Fossil diatom data for Llyn Hîr displayed in Battarbee *et al*. (1988) indicates that the lake experienced a significant shift in its diatom species composition between 1850 and 1988 (squared chord dissimilarity distance = 0.904 (Bennion (*ed.*), 2004)). Diatom-inferred pH (DI-pH) decreased by ~1 unit (Allott *et al.,* 2001) indicating acidification of Llyn Hîr over this time period. Since no recent sediments are available for analysis, it is not known whether the lake is currently recovering from past acidification. In 1985 the Welsh Water Authority limed Llyn Hîr. Prior to liming the pH was only 4.8; therefore since 1985 the lake pH has increased significantly.

Summary

Llyn Hîr is a small, natural oligotrophic lake that is in overall **unfavourable** condition. The site has been identified in WFD risk assessments as being at risk of diffuse pollution and could deteriorate further from its current condition. The annual average TP concentration of >10 $\mu gl^{-1}$ may indicate that the site is experiencing slight nutrient enrichment. It is recommended that nutrient concentrations be monitored. The palaeolimnology evidence indicates that Llyn Hîr has been acidified, although due to reductions in acid deposition across the UK it is likely that the lake is now recovering. Regular water quality monitoring should be carried out to determine the ANC value and therefore the current acidity of the lake. The positive alkalinity of the lake waters suggests that the Llyn Hîr is not in the highest risk category for acid impact.

We recommend that a short sediment core covering the period 1988 to 2005 is extracted and diatom assemblages examined to determine whether the site has experienced recent eutrophication and/or a reversal of the acidification trend.

Populations of *L. dortmanna* should be monitored. Although this species is still present in much of western Britain, it is vulnerable to eutrophication and sites have been lost at the eastern edge of its range (Preston & Croft, 1997). *L. dortmanna* is also vulnerable to fluctuating water levels. Llyn Hîr is the only site in the Afon Teifi SAC that supports *L. dortmanna*, although in the past it has been recorded from Llyn Egnant (last record by Seddon in 1972 (Southey & Broughton, 2004)). Llyn Hîr should therefore be considered an important component of the Afon Teifi SAC and it should be monitored accordingly.

## 4.2.3 Llyn Teifi (LA, D)

Annex 1 type: H3130: Oligotrophic to mesotrophic standing water with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*. Favourable Condition Table 4.

**Table 4.2.5: Condition Assessment Summary Table for Llyn Teifi.**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | None, but water-supply reservoir so water level can be drawn down (not during 2004 survey, but drawn down in autumn 2003) |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise) | ✓ | 4 present: *L. uniflora* / *I. lacustris* / *L. natans* / *S. angustifolium* |
| | No loss of characteristic species (see Box 2) | - | |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) have ≥ 1 characteristic species | **X** | Only 22% of shore transect sample spots comply (no boat survey undertaken) |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | No non-native species |
| | Benthic and epiphytic filamentous algal cover <10% | **✓?** | Mean and median scores = 1 No sample spots have cover values of 3 |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (see Table 4) | **?** | No boat survey data, but *I.lacustris* and *L. natans* present at >75 cm depth. *L. uniflora*, *J. bulbosus* & *C. hamulata* dominant at <75 cm |
| | Maximum depth distribution should be maintained | **?** | No boat survey data $Z_{max}$ = ?? m, $Z_{mean}$ = ?? m, $Z_s$ = ?? m, $Z_v$ = ?? m |
| | At least the present structure should be maintained | - | |

**Table 4.2.5 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels:<br>TP target/limit = 10 µg P $l^{-1}$ | **X** | TP = 15 $\mu g l^{-1}$ (EA 2004 annual average data) |
| | Stable pH / ANC values:<br>pH ~ 5.5 – 7.0; ANC > 20 | **✓?** | pH = 6.41; no ANC data<br>Alk = 52 $\mu eql^{-1}$ (EA 04 mean)<br>no DOC data |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 $mgl^{-1}$) | **?** | No data available |
| | No excessive growth of cyanobacteria or green algae | **✓** | No algal blooms |
| **Hydrology** | Natural hydrological regime | **X** | Reservoir - water level artificially raised and regulated by dam – EA abstraction licence no. 22/62/1/57 |
| **Lake substrate** | Natural shoreline maintained | **✓?** | modification code = 1 throughout |
| | Natural and characteristic substrate maintained | **✓?** | Dominant substrate = boulders |
| **Sediment load** | Natural sediment load maintained | **?** | Rough upland grazing around lake. Heavily grazed along transect 4. |
| **Indicators of local distinctiveness** | Distinctive elements maintained | **✓** | *L. natans* present |
| | Minimal negative impacts and no fish farming | **✓?** | - Public water supply reservoir<br>- Heavily grazed along transect 4 |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | - | No palaeo data available |

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

Extent

The surface area of the lake is 24.1 ha. No data are available for lake volume.

Macrophyte community composition

The aquatic vegetation of Llyn Teifi keys out as a Type 3 "oligotrophic" assemblage (Palmer, 1992). Based on the submerged and floating leaved vegetation only (Table 4.2.6), the average Trophic Rank Score (TRS) of this site is 4.48 (26.9/6). The site is not particularly species rich, although further species may be present in deeper areas of the lake, inaccessible by wading alone.

**Table 4.2.6: Macrophyte community composition for Llyn Teifi, including trophic scores.**

| Submerged and floating vegetation | Trophic Rank Score (TRS) |
|---|---|
| *Callitriche hamulata* | 5.0 |
| *Juncus bulbosus* | 3.7 |
| *Littorella uniflora* | 6.7 |
| *Luronium natans* | - |
| *Myriophyllum alterniflorum* | 5.5 |
| *Potamogeton polygonifolius* | 3.0 |
| *Sparganium angustifolium* | 3.0 |
| **Average TRS** | **4.48** |
| **PLEX (unweighted)** | **4.17** |
| **Ellenberg Fertility Score (unweighted)** | **4.31** |

The lake meets part of its target for macrophyte community composition. It supports 4 characteristic *Littorelletea* species: *L. uniflora*, *I. lacustris*, *L. natans* and *S. angustifolium*, however only 22 % of vegetated wader transect sample spots have at least one characteristic species. No boat transects were completed, therefore it is not possible to fully assess the representation of characteristic species.

Negative indicator species

No non-native macrophyte species are present in Llyn Teifi and no blue-green algal blooms were seen during sampling. Filamentous algae occurs at low abundance (mean cover = 1, median cover = 1) within the wader transects, with no sample spots having coverage scores of 3. *J. bulbosus* is common, with almost all vegetated wader sample spots recording this species and reflecting the dominance of peat and silt in the vegetated marginal areas.

Macrophyte community structure

Since there is no boat survey data (due to high winds and fog during sampling), it is not possible to assertain the maximum depth distribution of macrophytes in Llyn Teifi, nor to determine Secchi depth for the site. However, *J. bulbosus, C. hamulata* and *L. uniflora* were commonly found growing in the shallowest areas, with *I. lacustris* and *L. natans* only found at depths of > 75 cm.

Water quality

The EA annual average (2004) pH value of 6.41 (based on 11 seasonal measurements) is stable for the lake type. Although no ANC data is available, alkalinity is relatively high (~50 $\mu eql^{-1}$), suggesting that Llyn Teifi is well-buffered. DOC concentrations are relatively low, at 4.7 $mgl^{-1}$. TP concentrations are higher than the target/limit for the feature type (~15 $\mu gl^{-1}$ based on EA annual average data for 2004).

Hydrology

Llyn Teifi is dammed on its western shore as it serves as a reservoir for public water supply operated by Welsh Water. A maximum volume of 2,200,000 $m^3$ per annum can be abstracted from Llyn Teifi to maintain the public water supply under EA abstraction licence number 22/62/1/57. Although the water level was raised by ~10 cm following heavy rain during the ENSIS Ltd survey (September 2004), Southey & Broughton (2003) noted that there was high draw down at the time of their survey in October 2003. The draw down meant that extensive beds of vegetation typically under shallow water were exposed and grazed by sheep.

Lake substrate

The lake margins are generally gently shelving with substrates comprising cobble, pebble and finer material. In some steeper areas that occur along the eastern shore, thick layers of lakeside shingle quickly give way to thick, unconsolidated silt in the shallow. The bays along the eastern and northern shores are wide, extensive and contain thick, unconsolidated fines and occasional old peat hags. The more exposed western and norther shores are characterised by steep, unconsolidated boulders and cobbles (Southey & Broughton, 2004).

Sediment load

The land surrounding the lake consists of sheep grazed grassland, small areas of blanket bog and heather moorland. The abundance of *J. bulbosus* in marginal areas may indicate increased levels of mineralogenic sediment inwash to the lake.

Indicators of local distinctiveness

*L. natans* is present in Llyn Teifi. In the wader survey of September 2004, this species was most commonly found at depths of >0.75 cm. Southey & Broughton (2003) found that within the Afon Teifi SAC lakes, *L. natans* was most widespread and abundant in Llyn Teifi. They commented that it appears to rely on the thick silty margins of the lake for its survival. Preston & Croft (1997) note that *L. natans* "populations in natural habitats appear to be greatest when water-levels are low and much bare mud is exposed", perhaps explaining why fewer plants were recorded when water levels were high in September 2004.

Palaeolimnological evidence

There is no palaeolimnological evidence available for Llyn Teifi.

Summary

Llyn Teifi is in overall **unfavourable** status. The hydrological modifications combined with wind stress appear to have damaged the lake's macrophyte community and lake ecology. Although draw-down of the water level may support the growth of *L. natans*, the extent of draw down should be monitored to ensure that it does not negatively impact upon other components of the lake's macrophyte assemblage and in turn cause damage to the lake ecosystem. We recommend further boat surveys to assertain overall diversity and zonation of the site's macrophyte assemblages. We also recommend further water quality monitoring to assess acidification of the lake. An ANC value should be obtained and a palaeolimnological study should be carried out to determine whether diatom assemblages have changed over time and indicate acidification of the lake.

## Overall condition of the Afon Teifi SAC

The Afon Teifi SAC appears to be in overall **unfavourable** condition. Llyn Egnant and Llyn Teifi are dammed and utilised as public water supply reservoirs. Their water levels fluctuate widely, which may be favourable to some macrophyte species e.g. *L. natans*, but unfavourable to others e.g. *L. dortmanna*. Both Llyn Egnant and Llyn Teifi are exposed, wind-stressed sites, which may further restrict the growth and distribution of a number of macrophyte species. Although wind stress reflects habitat quality and not condition, it could be an important factor if exacerbated by drawdown, for example, by making isoetids vulnerable to uprooting by wind. The raised TP concentration in Llyn Egnant may result in the absence of some macrophyte species, particularly those that are sensitive to nutrient enrichment e.g. *L. dortmanna*.

All lakes support the growth of *L. natans*, an internationally protected species (Annex II and Red Data Book) with a restricted distribution in the UK. Populations of *L. natans* should be monitored to ensure that this rare plant is not lost from any of the Afon Teifi SAC lakes.

Llyn Hîr is the only site within the Afon Teifi SAC to support the growth of *I. echinospora* and *S. aquatica*. Llyn Hîr also supports the highest diversity of aquatic plant species. We suggest that future monitoring should focus on Llyn Hîr.

We recommend that Llyn Teifi be surveyed by boat to better determine the diversity of macrophyte species in the lake and to assertain zonation of the macrophyte assemblages.

Global warming may pose a threat to the Afon Teifi lakes through accelerated erosion of peat within the catchments, subsequent increases in sedimentation and in turn, changes in macrophyte composition and structure. Conversely, reductions in sulphur deposition and consequent increases in lake pH, ANC and DOC may lead to increased diversity in lake macrophyte species assemblages.

**Table 4.2.7: Afon Teifi SAC: Overview**

| Water Body | Status | Reason(s) for Failure | Comments |
|---|---|---|---|
| Llyn Teifi | Unfavourable | Acidification, abstraction, eutrophication. Few characteristic species. | |
| Llyn Egnant | Unfavourable | Acidification, abstraction, eutrophication. Loss of characteristic species. Characteristic zonation absent. | |
| Llyn Hîr | Unfavourable (recovering) | Acidification. | Possible slight eutrophication, but apparently healthy macrophyte community |
| **Overall SAC Status** | **Unfavourable** | | |

## *4.3 Cadair Idris SAC*

### 4.3.1 Llyn Gafr (LA, V)

Annex 1 type: H3130: Oligotrophic to mesotrophic standing water with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*. Favourable Condition Table 4.

**Table 4.3.1: Condition Assessment Summary Table for Llyn Gafr**

| 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 present: *I. lacustris, L. dortmanna*, *S. angustifolium* |
| | No loss of characteristic species (see Box 2) | - | |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) have ≥ 1 characteristic species | **X** | Only 36 % of vegetated sample spots comply (55 % wader, 0 % boat) |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | No non-natives |
| | Benthic and epiphytic filamentous algal cover <10% | ✓**?** | Mean cover = 1.5; Median = 2<br>No sample spots with scores of 3 |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (see Table 4) | ✓**?** | Mosaic flora - no clear zonation pattern. |
| | Maximum depth distribution should be maintained | ✓ | $Z_{max}$ = 1.5 m, $Z_{mean}$ = 0.8 m, $Z_s$ = > $Z_{max}$, $Z_v$ = 1.5 m<br>Plants growing to $Z_{max}$ |
| | At least the present structure should be maintained | - | |
| **Water quality** | Stable nutrients levels:<br>TP target / limit = 10 µg P $l^{-1}$ | ✓**?** | TP = 1 µg$l^{-1}$ in Jun'05<br>TN = 0.26 mg$l^{-1}$<br>Chl *a* = 0.6 µg$l^{-1}$ |
| | Stable pH / ANC values:<br>pH ~ 5.5 – 7.0; ANC > 20 | ✓ | pH = 6.7 (range 6.2 – 7.5); ANC=276 µeq$l^{-1}$; Alk=349 µeq$l^{-1}$(bicarb) DOC=0.84mg$l^{-1}$ |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 mg$l^{-1}$) | ✓ | ~10 mg$l^{-1}$ from 0-1 m depth |
| | No excessive growth of cyanobacteria or green algae | ✓ | No algal blooms |

**Table 4.3.1 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Hydrology** | Natural hydrological regime | ✓ | Appears to be natural |
| **Lake substrate** | Natural shoreline maintained | ✓ | Shoreline modification index = 1.18 |
| | Natural and characteristic substrate maintained | ✓ | Cobbles and boulders dominate in marginal areas. Silt in deeper water |
| **Sediment load** | Natural sediment load maintained | ✓ | Catchment land use dominated by dry acid heath, some grazed |
| **Indicators of local distinctiveness** | Distinctive elements maintained | ✓? | Mosaic flora |
| | Minimal negative impacts and no fish farming | ✓? | |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | ? | Goldsmith *et al*. (2006): 0-26 cm: 1.002 sq chord dist significant floristic change – increasing lake water pH |

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

Extent
The surface area of the lake is 2.7 ha, with a volume of 21.6 x$10^3$m$^3$.

Macrophyte community composition
The aquatic vegetation of Llyn Gafr keys out as a Type 3 "oligotrophic" assemblage (Palmer, 1992). Based on the submerged and floating leaved vegetation only (Table 4.3.2), the average Trophic Rank Score (TRS) of this site is 4.68 (37.4/8). The site is reasonably species rich.

Data are based on the results from 2 wader and 2 boat transects only. Llyn Gafr is in favourable condition according to its macrophyte community composition. This site supports the growth of 3 characteristic *Littorelletea* species – *I. lacustris*, *L. dortmanna*, *S. angustifolium* – and one other characteristic species - *N. flexilis* (agg.). Associated species include *P. polygonifolius*, *Equisetum fluviatile*, *Potamogeton natans*, *M. alterniflorum* and *J. bulbosus*. 55 % of the vegetated wader transect sample spots were found to have at least 1 characteristic species present, whereas 0 % of boat transect sample spots. Since only 4 transects were completed, it is not known whether the absence of characteristic species from the vegetated sample spots is related to low confidence in the data or to unfavourable growth conditions such as boulder substrate.

Negative indicator species
No non-native macrophyte species and no blue-green algal blooms were present during field survey in September 2004. Filamentous algal cover is relatively low (mean cover score = 1.5; median cover score = 2), with no wader or boat sample spots having cover scores of 3.

**Table 4.3.2: Macrophyte community composition for Llyn Gafr, including trophic scores.**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Juncus bulbosus* | 3.7 | F |
| *Lobelia dortmanna* | 5.0 | O |
| *Isoetes lacustris* | 5.0 | A |
| *Myriophyllum alterniflorum* | 5.5 | A |
| *Nitella flexilis* (agg.) | 5.5 | O |
| *Potamogeton natans* | 6.7 | F |
| *Potamogeton polygonifolius* | 3.0 | O |
| *Sparganium angustifolium* | 3.0 | R |
| **Unweighted Site TRS** | **4.68** | |
| **Weighted TRS** | **5.70** | |
| **PLEX** | **3.97** | |
| **Ellenberg Fertility Score** | **4.16** | |

Macrophyte community structure

During sampling in September 2004, the water clarity was excellent. $Z_s$ extended to $Z_{max}$ (1.4 m) and macrophytes were found growing to $Z_{max}$, although aquatic plant volume biomass was generally only moderate. There was no clear pattern of zonation, instead a mosaic of different macrophyte species was found growing together. Structure provided by the aquatic macrophytes is good, with a number of different growth forms represented – isoetids (*I. lacustris*, *L. dortmanna*); charophytes (*Nitella flexilis* (agg.)); submerged fine/strap-leaved plants (*J. bulbosus, M. alterniflorum*); floating-leaved plants (*S. angustifolium* & *P. polygonifolius & P. natans*) and emergents (*Equisetum fluviatile*).

Water quality

According to 2004-05 seasonal data, pH for the site ranges between 6.2 and 7.5 (mean = 6.7), which is within the range expected for the feature type. ANC is high at 276, suggesting that the site is well-buffered and reflecting the influence of the mixed catchment geology (igneous (~60%) and sedimentary (~40%)). TP is very low (1 $\mu gl^{-1}$), although it should be noted that this value relates only to one measurement taken in June 05 and hence uncertainty is high. Dissolved $O_2$ from 0-1 m is sufficient to support the fauna of the lake (~10 $mgl^{-1}$). Water quality data for the site suggest favourable condition.

Hydrology

The lake appears to have a natural hydrological regime.

Lake substrate

Cobble and boulder substrates dominate the shallow marginal areas and two banks of the lake have steep rocky sides. The deeper water areas (>80 cm) have a silty substrate. Lake substrates appear to be natural.

Sediment load

The catchment is predominantly covered by upland *Calluna*-dominated dry acid heath, some of which is grazed by livestock. It is not thought that land cover and use has changed significantly over time.

Indicators of local distinctiveness

The mosaic flora (as opposed to zonation) is possibly a feature of local distinctiveness.

Palaeolimnological evidence

The fossil diatom stratigraphy of a sediment core from Llyn Gafr suggests that lake water pH has increased from core bottom (26 cm) to core top (present day) and the shift in the diatom species assemblage (*Aulacoseira lirata* var. *alpigena* & *Denticula rainerensis* to *A. minutissima* & *B. vitrea*) may be indicative of recovery from acidification. The squared chord distance dissimilarity score between the top and bottom samples is high (1.002).

Summary

Llyn Gafr is a small, oligotrophic lake thought to be in overall **favourable** condition, with high water clarity, extensive macrophyte growth across the lake bottom and appropriate supporting water quality conditions. Both the lake and its catchment experience little disturbance and are in a relatively natural state, although stocking levels should be monitored to ensure that sediment loadings to the lake do not increase, threatening the lake's current favourable condition.

No WFD risk assessment has been completed for comparison because the surface area of Llyn Gafr is less than 1 ha.

## 4.3.2 Llyn Arran (LA, V)

Annex 1 type: H3130: Oligotrophic to mesotrophic standing water with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*. Favourable Condition Table 4.

**Table 4.3.4: Condition Assessment Summary Table for Llyn Arran**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise) | ✓ | 4 species present: *L. uniflora, L. dortmanna, I. lacustris* & *S. angustifolium* |
| | No loss of characteristic species (see Box 2) | - | |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) have ≥ 1 characteristic species | ✓ | 90% of vegetated sample spots comply (95% wader, 80% boat) |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | No introduced species |
| | Benthic and epiphytic filamentous algal cover <10% | ✓**?** | Mean cover = 1.6, median = 2.0<br>No sample spots have scores of 3 |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (see Table 4) | ✓**?** | Small lake with no clear zonation pattern. Mosaic of plant communities |
| | Maximum depth distribution should be maintained | ✓ | $Z_{max}$ = 2.0 m, $Z_{mean}$ = 1.2 m, $Z_s$ = > $Z_{max}$, $Z_v$ = 2.0 m<br>Plants growing to $Z_{max}$ |
| | At least the present structure should be maintained | - | |
| **Water quality** | Stable nutrients levels:<br>TP target / limit = 10µg P $l^{-1}$ | ✓ | TP = 4.6µg$l^{-1}$ (Jun'05 data only; TN = 0.22mg$l^{-1}$ |
| | Stable pH / ANC values:<br>pH ~ 5.5 – 7.0; ANC > 20 | ✓**?** | pH = 6.4 (range = 6.1-6.7)<br>ANC=3.46µeq$l^{-1}$ = sensitive<br>Alk = 58 µeq$l^{-1}$ (bicarb, Jun '05); DOC = 1.66 mg$l^{-1}$ |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 mg$l^{-1}$) | ✓ | ~ 10.5 mg$l^{-1}$ from 0-2 m depth |
| | No excessive growth of cyanobacteria or green algae | ✓ | No algal blooms |

**Table 4.3.4 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Hydrology** | Natural hydrological regime | ✓ | Appears natural |
| **Lake substrate** | Natural shoreline maintained | ✓ | Shoreline modification index = 1.06 |
| | Natural and characteristic substrate maintained | ✓ | Boulders = dominant substrate |
| **Sediment load** | Natural sediment load maintained | ✓ | Little disturbance in catchment. Land cover predominatly dry acid heath |
| **Indicators of local distinctiveness** | Distinctive elements maintained | ✓ | Mosaic flora |
| | Minimal negative impacts and no fish farming | ✓ | Little disturbance in catchment, although possibly overgrazed. |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | **?** | Goldsmith *et al*. (2006): 0-30 cm: 0.837 sq chord dist significant floristic change – stable pH – change in habitat availability? |

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

Extent
The surface area of the lake is 0.8ha, with a volume of 9.6 x$10^3$$m^3$.

Macrophyte community composition
The aquatic vegetation of Llyn Arran keys out as a Type 3 "oligotrophic" assemblage (Palmer, 1992). Based on the submerged and floating leaved vegetation only (Table 4.3.5), the average Trophic Rank Score (TRS) of this site is 4.6 (45.7/10). The site is reasonably species rich.

Negative indicator species
Neither introduced macrophyte species nor blue-green algal blooms were observed during sampling. Filamentous algal cover scores are low to moderate (mean = 1.6; median = 2), with no wader or boat sample spots having cover scores of 3.

Macrophyte community structure
Structure of the aquatic macrophytes is good, with a number of different growth forms represented – isoetids (*I. lacustris*, *L. uniflora*, *L. dortmanna*), mosses (*F. antipyretica*, *Sphagnum* spp.), submerged fine/strap-leaved plants (*J. bulbosus, M. alterniflorum, C. hamulata*) and floating-leaved plants (*S. angustifolium* & *P. polygonifolius*). Macrophyte zonation is limited, instead, there is a mosaic flora with most species recorded as growing at most depths. In the September 2004 survey, *M. alterniflorum* and *P. polygonifolius* only occurred at depths of 1.8 - 2.0 m, whereas *I. lacustris*, *L. uniflora* and *L. dortmanna* were not

found at depths of > 1.8 m. However, since only 1 wader and 1 boat transect were completed, uncertainty in these figures is high. Since the site is shallow, vegetation is likely to be patchy as opposed to vertically zoned and distribution patterns may show considerable interannual variation.

**Table 4.3.5: Macrophyte community composition for Llyn Arran, including trophic scores.**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Callitriche hamulata* | 5.0 | D |
| *Isoetes lacustris* | 5.0 | D |
| *Juncus bulbosus* | 3.7 | D |
| *Littorella uniflora* | 6.7 | D |
| *Lobelia dortmanna* | 5.0 | D |
| *Myriophyllum alterniflorum* | 5.5 | F |
| *Fontinalis antipyretica* | 6.3 | O |
| *Potamogeton polygonifolius* | 3.0 | F |
| *Sparganium angustifolium* | 3.0 | F |
| *Sphagnum* spp. | 2.5 | F |
| **Unweighted Site TRS** | **4.6** | |
| **Weighted TRS** | **5.25** | |
| **PLEX** | **3.94** | |
| **Ellenberg Fertility Score** | **4.06** | |

Water quality

Mean annual average pH is 6.4, which is within the expected range for the feature type. ANC is calculated to be 3.46, suggesting that the lake is poorly buffered and therefore susceptible to acid deposition, although alkalinity measured in June 2005 is relatively high for the feature type (58 $\mu eql^{-1}$) as is calcium. The TP concentration for the site (4.6 $\mu gl^{-1}$) is within the limit/target for the feature type, although since this value is based only on one measurement in Jun'05, uncertainty in the data is high.

Hydrology

The lake appears to have a natural hydrological regime. At the time of sampling, the water level was ~15 cm higher than normal after heavy rain.

Lake substrate

Boulders are the dominant substrate around the lake margins. Silt predominates at water depths >80 cm.

Sediment load

The lake catchment is dominated by dry acid heathland, which supports rough upland grazing. There are some areas of exposed rock.

Indicators of local distinctiveness

The shape of Llyn Arran is unusual, with a large alluvial fan on the inflow (visible on an aerial photo of the lake). The site has a mosaic flora (as opposed to zonation), which could be considered a feature of local distinctiveness.

Palaeolimnological evidence

The fossil diatom stratigraphy of a sediment core from Llyn Arran suggests that from core bottom (30 cm) to core top (present day) there has been a significant degree of floristic change (squared chord distance dissimilarity score = 0.837). However the species shift is indicative of neither acidification nor recovery, instead both top and bottom assemblages point to moderately acid waters. The shift may indicate a change in habitat availability within the lake basin. It may be useful to examine the plant macrofossil profile of the lake to determine whether shifts in macrophyte species have occurred over time.

Summary

Llyn Arran is a small, shallow, high altitude (488 m) lake that receives little disturbance and appears to be in overall **favourable** condition, although catchment stocking levels should be monitored to ensure that the land is not overgrazed and sediment loadings to the lake are not allowed to increase.

No WFD risk assessment has been completed due to the small size of the lake (< 1 ha).

A low ANC value suggests that the lake is susceptible to acid deposition, although alkalinity and calcium concentrations are relatively high for the feature type and fossil diatom data suggest that the lake waters have always been moderately acid. Mid-core diatom samples should be analysed to determine whether Llyn Arran has been impacted by acidification in the past and whether the current assemblage represents recovery, but not to the pre-impact diatom assemblage. Plant macrofossil analysis may also provide clues as to why diatom species composition has changed over time.

## 4.3.3 Llyn Cau (LA, D)

Annex 1 type: H3130: Oligotrophic to mesotrophic standing water with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*. Favourable Condition Table 4.

**Table 4.3.6: Condition Assessment Summary Table for Llyn Cau**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise) | **X** | Only 2 present: *L. uniflora* & *I. lacustris* (*L. dortmanna* may be absent due to the deep, exposed site situation, altitude or temperature restrictions). |
| | No loss of characteristic species (see Box 2) | - | |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) have ≥ 1 characteristic species | ✓ | 72 % of wader and boat vegetated sample spots comply (wader = 69%, boat = 80%) |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | No introduced species |
| | Benthic and epiphytic filamentous algal cover <10% | ✓ | Mean cover score = 1.6; median = 2<br>No sample spots with scores of 3 |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (see Table 4) | ✓ | < 2.5 m: J. *bulbosus, C. hamulata*, *L. uniflora, I. lacustris* →<br>2.5 - 4 m: *C. hamulata* →<br>4 – 6 m: *I. lacustris* only |
| | Maximum depth distribution should be maintained | ✓ | $Z_{max}$ = 49 m, $Z_{mean}$ = 20.1 m, $Z_s$ = 12 m, $Z_v$ = 6 m |
| | At least the present structure should be maintained | - | |

**Table 4.3.6 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels:<br>TP target / limit = 10 µg P $l^{-1}$ | ✓? | TP = 2.8 µg$l^{-1}$ (Jun'05 data only)<br>TN = 0.25 mg$l^{-1}$; $NO_3^-$-N = 0.83 mg$l^{-1}$<br>Chl *a* = 2.0 µg$l^{-1}$ |
| | Stable pH / ANC values:<br>pH ~ 5.5 – 7.0 and ANC > 20 | X? | pH = 6.1 (range = 5.8 – 6.4)<br>ANC = -25.99 µeq$l^{-1}$ = acid sensitive; Alk=32µeq$l^{-1}$ (bicarb: Jun'05 only) |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 mg$l^{-1}$) | ✓ | ~ 10 mg$l^{-1}$ from 0-17 m depth<br>~ 11 mg$l^{-1}$ from 18-30 m depth |
| | No excessive growth of cyanobacteria or green algae | ✓ | No algal blooms |
| **Hydrology** | Natural hydrological regime | ✓ | |
| **Lake substrate** | Natural shoreline maintained | ✓ | Shoreline modification index = 1.20 |
| | Natural and characteristic substrate maintained | ✓ | Boulders = dominant substrate |
| **Sediment load** | Natural sediment load maintained | ✓? | Catchment land cover = unimproved acid grassland and dry acid heath. Some grazing. |
| **Indicators of local distinctiveness** | Distinctive elements maintained | ✓ | One of the deepest natural lakes in Wales |
| | Minimal negative impacts and no fish farming | ✓ | |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | ? | Goldsmith *et al*. (2006)<br>0-32 cm: 0.247 sq chord dist floristic change low – plankton-dominated - stable circumneutral pH |

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

Extent

The surface area of the lake is 13.5 ha, with a volume of 2,693 x$10^3$$m^3$.

Macrophyte community composition

The aquatic vegetation of Llyn Cau keys out as a Type 3 "oligotrophic" assemblage (Palmer, 1992). Based on the submerged and floating leaved vegetation only (Table 4.3.7), the average Trophic Rank Score (TRS) of this site is 4.6 (22.9/5). The site is species poor.

**Table 4.3.7: Macrophyte community composition for Llyn Cau, including trophic scores. Figures in brackets are calculated values for 1996 survey (Monteith *et al*., 1997).**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Callitriche hamulata* | 5.0 | A |
| *Isoetes lacustris* | 5.0 | A |
| *Juncus bulbosus* | 3.7 | F |
| *Littorella uniflora* | 6.7 | A |
| *Sphagnum* spp. | 2.5 | R |
| **Average TRS (unweighted)** | **4.6** | |
| **PLEX (unweighted)** | **3.85 (4.03)** | |
| **Ellenberg fertility score (unweighted)** | **4.08 (4.11)** | |

Only 2 characteristic *Littorelletea* species are present – *L. uniflora* and *I. lacustris*, although they are present in 72 % of all vegetated sample spots across 1 boat and 4 wader transects (69 % wader and 80 % boat). Associated species include *C. hamulata* and *J. bulbosus*. There is no evidence of species loss and the deep, exposed nature of the site provides unfavourable habitat for *L. dortmanna*.

Negative indicator species

No introduced species were recorded and no blue-green algal blooms were noted during sampling in September 2004. Filamentous algal cover was low (mean = 1.6, median = 2), with no sample spots having cover scores of 3.

Macrophyte community structure

Structure provided by the aquatic macrophyte community is limited due to the low number of species growing in the lake. The representation of different growth forms includes only isoetids (*I. lacustris*, *L. uniflora*), mosses (*Sphagnum* spp.) and submerged fine/strap-leaved plants (*J. bulbosus, C. hamulata*). In many areas of the lake (transects 1-3), the sides are steeply shelving and no plants were found growing below 1.0 m depth. In transect 4, macrophyte zonation was typified by *J. bulbosus, C. hamulata* and *L. uniflora* predominating in the shallower water (< 2.0 m) alongside some *I. lacustris*. *C. hamulata* and *I. lacustris* co-occurred to ~ 4.0 m and from 4.0 – 6.0 m, *I. lacustris* grew alone.

Water quality

Water transparency is very high, with a Secchi depth of 12.0 m being recorded during sampling in September 2004. The water has a distinctive blue colour. pH is within the range expected for the feature type (6.1) and alkalinity and calcium levels are moderate, but with a negative ANC value (- 25.99), Llyn Cau has probably been impacted by acid deposition. TP concentrations are low (2.8 $\mu gl^{-1}$ according to Jun'05 data), although further seasonal TP measurements are required for greater confidence in the data. Both TN and $NO_3^-$-N concentrations are similar to those for Llyn Gafr and Llyn Cau and in all cases, $NO_3^-$-N concentrations higher than TN concentrations, which is difficult to explain.

Hydrology
The lake appears to have a natural hydrological regime.

Lake substrate
Boulders, cobbles and bedrock are the dominant substrates, with some areas of peat and gravels.

Sediment load
Catchment geology consists of both igneous (60%) and sedimentary (40%) rocks and land cover is predominantly unimproved acid grassland and dry acid heath. Catchment land use is dominated by rough upland grazing. There is almost certainly overgrazing in the catchment, which may have increased the sediment load of Llyn Cau.

Indicators of local distinctiveness
Brown trout, *Salmo trutta* are present in the lake. It is possible that these are a glacial relict stock; however, stocking of upland lakes was common practice in the 19$^{th}$ century. Further work may be needed to determine the importance of this trout population.

Palaeolimnological evidence
The fossil diatom stratigraphy of a sediment core from Llyn Cau suggests that from core bottom (32 cm) to core top (present day) there has been little floristic change (squared chord distance dissimilarity score = 0.247). The lake continues to support a plankton-dominated diatom flora (*Cyclotella comensis*), which is associated with circumneutral conditions. It is recommended that monitoring be carried out to ensure early detection of any negative disturbance to the lake. It is also recommended that mid-core samples be analysed to determine whether Llyn Cau has been impacted by acidification in the past and whether the current assemblage is representive of recovery.

Summary
Llyn Cau is a very deep, mountain lake with a conical basin that reaches a water depth of almost 50 m. It is one of the deepest natural lakes in Wales. The site appears to be in **favourable** condition, despite the low diversity and coverage of macrophytes that result from the steeply shelving sides of the basin.

Overgrazing in the catchment could be increasing sediment loading to the lake. We recommend that stocking levels be reviewed.

The surface sediment diatom species assemblage may reflect a return to pre-impact populations following a period of dominance by species more typically associated with acid conditions, although the lake's present day circumneutral pH suggests that the lake may never have been acidified. We recommend that mid-core diatom samples be analysed to determine any former acidification of Llyn Cau.

Regular monitoring should be carried out to ensure early detection of negative disturbance (e.g. acidification / eutrophication). ANC values should be monitored to track changes in the lake's acidity and recovery from any acidification impact. The presence and abundance of the elodeid macrophyte species *C. hamulata*, suggests either that the lake has not been severely impacted by acid deposition, or that it is recovering from a previous period of impact

(Monteith *et al*., 2005). The absence of L. dortmanna from Llyn Cau is probably related to an altitudinal or temperature restriction as opposed to acidification or nutrient enrichment.

## Overall condition of the Cadair Idris SAC

All lakes assessed in the Cadair Idris SAC are considered to be in **favourable** condition, although stocking levels on Cadair Idris should be monitored and controlled to ensure that sediment and nutrient loadings to the lakes do not increase as a result of overgrazing. It is recommended that all lakes surveyed within this SAC continue to be monitored. Llyn Gafr and Llyn Arran are relatively similar in terms of morphology, macrophyte species composition and their mosaic flora, although ANC values are very different. Llyn Cau is distinct within the Cadair Idris SAC in that it is very deep, with steeply shelving sides and consequently supports lower species diversity and a more marked depth zonation pattern. Llyn Cau also supports a population of Brown Trout, although it is not known whether these fish have been stocked.

If funds are limited, then it is recommended that Llyn Arran and Llyn Cau receive greatest attention since both sites are sensitive to acid deposition and may be useful sites to monitor with respect to post-acidification recovery trends in both biological and chemical elements.

WFD risk assessments have not been completed for Llyn Gafr and Llyn Arran because they are too small to be considered as 'water bodies' under the WFD. However, limited disturbance within the catchments of these lakes suggests a low risk of impact. Llyn Cau has been classified as being at risk from diffuse pollution, further supporting the recommendation that this site should be included in future monitoring programmes. The sources of diffuse pollution should be determined and monitored accordingly in order to protect the lake from deterioration to unfavourable condition.

**Table 4.3.8: Cadair Idris SAC: Overview**

| Water Body | Status | Reason(s) for Failure | Comments |
|---|---|---|---|
| Llyn Gafr | Favourable | | |
| Llyn Arran | Favourable | | |
| Llyn Cau | Favourable | | At some risk of acidification, but not a major concern at present |
| **Overall SAC Status** | **Favourable** | | |

## *4.4 Corsydd Môn / Anglesey Fens SAC*

### 4.4.1 Llyn Cadarn (HA, S - Marl)

Annex 1 type: H3140: Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp. Favourable Condition Table 5.

**Table 4.4.1: Condition Assessment Summary Table for Llyn Cadarn**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | Characteristic species (see Box 3) should be present: *Chara* spp. (excluding *Chara vulgaris*) | **X** | No charophytes |
| | ≥ 7/10 vegetated sample spots (boat or wader survey) should have ≥ 1 characteristic species | **X** | See above |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | No non-natives |
| | Benthic and epiphytic filamentous algal cover <10% (non-*Chara*) | ✓ | Mean cover = 0.3, median = 0<br>No sample spots have scores of 3 |
| **Macrophyte community structure** | Characteristic vegetation zones should be present. *Chara* beds should cover >50% of photic zone | **X** | Fringing reedbed to 0.75 m<br>Band of water lilies to 4.0 m<br>*F. antipyretica* & *L. trisulca* to 5.7m<br>No charophytes |
| | Maximum depth distribution should be maintained | **X?** | $Z_{max}$ = 6.7m, $Z_{mean}$ = 4.8m, $Z_s$ = 4.7m, $Z_v$ = 5.7m (thermoclime) |
| | At least the current structure should be maintained | **-** | Similar structure to that recorded by Stewart (2003). |

**Table 4.4.1 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels:<br>TP target / limit = 20 µg $l^{-1}$ | ✓? | TP = 19.6µg$l^{-1}$ (Jun'05 data only)<br>TN = 0.67mg$l^{-1}$; $NO_3^-$-N = 1.64mg$l^{-1}$ |
| | Stable pH / ANC values:<br>pH ~7.00–8.50 / ANC >20 | ✓ | pH = 8.0<br>ANC = 3888 µeq$l^{-1}$ (well buffered) |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 mg$l^{-1}$) | ✓? | ~ 7.5 mg$l^{-1}$ from 0-4 m depth<br>~ 0-1 mg$l^{-1}$ from 5-6 m depth<br>(below 4-5 m deep thermocline) |
| | No excessive growth of cyanobacteria or green algae | ✓ | No algal blooms |
| **Hydrology** | Natural hydrological regime | ✓ | Appears natural – aquifer-fed |
| **Lake substrate** | Natural shoreline maintained | ✓ | Shoreline modification index = 1.1<br>Lake surrounded by dense reedbed |
| | Natural and characteristic substrate maintained (marl production desirable) | ✓ | Silt is the dominant substrate |
| **Sediment load** | Natural sediment load maintained | ✓ | Quarry within the lake's catchment. Catchment land cover dominated by improved grassland. Some rough grazing around lake. |
| **Indicators of local distinctiveness** | Distinctive elements maintained at current levels and/or in current locations | ✓ | Natural kettle-hole lake, with excellent fringing fen development.<br>Situated in Cors Goch nature reserve. |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | X | Goldsmith *et al.* (2006) :<br>0-25 cm core. Sq chord dist = 1.503 = significant change. Shift from non-planktonic to planktonic assemblage, indicative of nutrient enrichment.<br>Poor diatom preservation. |

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

Extent

The surface area of the lake is 1.0 ha, with a volume of 48 x$10^3$$m^3$.

Macrophyte community composition

To minimise disturbance at this small site survey data are based on only one wader and one boat transect. The aquatic vegetation of Llyn Cadarn keys out as a Type 9 "eutrophic"

assemblage. Components of type 8 and 10 eutrophic assemblages are also present (Palmer, 1992). Based on the submerged and floating leaved vegetation only (Table 4.4.2), the average Trophic Rank Score (TRS) for this site is 7.67 (46/6). The site is species rich, however the greatest diversity is seen amongst the emergents and marginals, with few submerged and floating leaved macrophytes present. No charophytes were recorded from Llyn Cadarn during either the ENSIS 2004 field survey or by Nick Stewart in September 2003 (see Stewart, 2004 for details).

**Table 4.4.2: Macrophyte community composition for Llyn Cadarn, including trophic scores.**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Fontinalis antipyretica* | 6.3 | A |
| *Lemna minor* | 9.0 | F |
| *Lemna trisulca* | 10.0 | O |
| *Nuphar lutea* | 8.5 | A |
| *Nymphaea alba* | 6.7 | A |
| *Utricularia vulgaris* agg. (cf. *australis)* | 5.5 | F |
| **Average TRS (unweighted)** | **7.67** | |
| **TRS (weighted)** | **7.40** | |
| **PLEX (weighted)** | **5.92** | |
| **Ellenberg fertility index (weighted)** | **6.23** | |

Negative indicator species

No introduced species were recorded and no blue-green algal blooms were observed. Filamentous algal cover was low (mean = 0.3, median = 0), with no sample spots having cover scores of 3. Stewart (2004) suggests that "*Fontinalis* dominance is a sign that the water is somewhat enriched" but that the water is not sufficiently enriched to cause algal blooms.

Macrophyte community structure

The lake is fringed with sedges (*Carex acutiformis, Carex rostrata, Carex riparia*) and reeds (*Typha angustifolia*, *Schoenoplectus lacustris*, *Phragmites australis*, *Cladium mariscus*) The lakebed shelves off steeply beyond the outer edge of the reed bed. A 5 - 10 m wide band of *Nymphaea alba* and *Nuphar lutea* grow in water depths of ~1.0 – 4.0 m. The maximum depth of macrophyte colonisation is 4.0 m. Secchi depth is 4.7 m. The absence of charophytes reduces the macrophyte community structure in Llyn Cadarn, leaving much of the lake bottom (4.0 – 8.1 m depth) unvegetated. It is thought that under favourable conditions, charophytes would grow in the currently unvegetated deeper water areas. Despite the poor representation of charophytes and submerged species (only *U. vulgaris* agg.), other macrophyte growth forms are well represented in the lake - floating-leaved species (*N. lutea, N. alba*), free-floating species (*L. trisulca, L. minor*), mosses (*F. antipyretica*) and emergents (*T. angustifolia, S. lacustris, C. mariscus, P. australis, Carex* spp*., Menyanthes trifoliata, E. fluviatile*).

Water quality

Llyn Cadarn is a well buffered, calcium rich lake, with pH values consistently above 7.5 (mean = 8.0), which is within the expected range for the lake's feature type. ANC is very high (3888) and the lake is not sensitive to acid deposition because the underlying rock in the catchment is base-rich carboniferous limestone. Llyn Cadarn's TP concentration is 19.6 $\mu gl^{-1}$. Although the TP measurement lies within the target range for the feature type (< 50 $\mu gl^{-1}$), confidence in the data is low since it is based on a single sample taken in June 2005. Further TP measurements are required to enable calculation of an annual average value. Nitrogen concentrations are low to moderate (TN mean = 0.7 $mgl^{-1}$; $NO_3^-$-N mean = 1.64 $mgl^{-1}$) and Chl *a* concentrations are relatively high (mean = 14.2 $\mu gl^{-1}$). Overall, the nutrient data suggest that Llyn Cadarn has a slightly elevated nutrient status (mesotrophic) consistent with the low-lying nature of the site and high percentage of improved agricultural land in the lake's catchment. The dissolved oxygen profile shows that the lake is stratified, with a sharp decline in oxygen between 4 and 5 m. This corresponds with the maximum light penetration (4.7 m); the water being completely anoxic below 6 m. Anoxic waters and sediments will impact upon the range of organisms that can survive at or near the lake bottom.

Hydrology

The lake is aquifer-fed and appears to have a natural hydrological regime.

Lake substrate

Silt is the dominant substrate.

Sediment load

Llyn Cadarn's catchment geology consists predominantly of carboniferous limestone, the remainder comprises basal conglomerate. Land cover within the catchment is dominated by improved grassland, which may be a source of nutrient inwash. Lowland heath, bracken and rough grazing occur around the lake shores.

Indicators of local distinctiveness

Llyn Cadarn is a natural kettle-hole lake, with excellent fringing fen development. It is situated within the Cors Goch nature reserve owned by the North Wales Wildlife Trust.

Palaeolimnological evidence

The fossil diatom stratigraphy of a sediment core from Llyn Cadarn suggests that from core bottom (25 cm) to core top (present day) there has been significant floristic change (squared chord distance dissimilarity score = 1.503). The diatom assemblage from the core bottom is dominated by small non-planktonic *Fragilaria* taxa, whereas the core top sample is dominated by the planktonic taxon, *Aulacoseira granulata*. The species shift suggests that the lake has experienced nutrient enrichment and has become increasingly turbid. However, poor preservation of diatom frustules means that the data should be interpreted with caution. We recommended that CCW examine further biological indicators e.g. plant macrofossils to better elucidate the nutrient history of Llyn Cadarn.

Summary

Due to the absence of charophytes from Llyn Cadarn, the lake is currently determined to be in **unfavourable** condition. The fringing reedbed and marginal band of water lilies provide an extensive habitat and are important components of the lake, but the absence of charophytes

means that the lake does not support the characteristic species for the feature type. Restoration of the lake to favourable status through re-establishment of charophyte populations is highly desirable.

*Chara rudis* (Rugged stonewort) was recorded from the lake in 1937. This is a deep water species of calcareous lakes and very sensitive to raised nutrient levels. It is "near threatened" and is now extinct in Wales (and much of southern England) (Stewart, 2004). Pollution incidents involving the quarry upstream of the lake are known to have occurred in the 1970s (C. Wynne, pers com, in Stewart, 2004), which may explain the current absence of charophytes from Llyn Cadarn. The improved nature of the grassland in Llyn Cadarn's catchment may also be a source of nutrients, however, Stewart (2004) considers that since there is a buffer of unimproved land around much of the site and the pools and seepages near the edges of the site seem to have better water quality than those in the middle, pollution problems may be historic and residual rather than ongoing. We recommended that a sediment core (dated) is extracted from the lake and that plant macrofossil profiles are examined to determine when charophytes disappeared from Llyn Cadarn. We also recommend that water quality at the site should be monitored and potential sources of pollution identified.

No WFD risk assessment is available for Llyn Cadarn due to the small size of the lake (< 1 ha).

## 4.4.2 Llyn yr Wyth Eidion (HA, S - Marl)

Annex 1 type: H3140: Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp. Favourable Condition Table 5.

**Table 4.4.3: Condition Assessment Summary Table for Llyn yr Wyth Eidion.**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | Characteristic species (see Box 3) should be present: *Chara* spp. (excluding *Chara vulgaris*) | ✓ | *Chara virgata* abundant (*Chara vulgaris* also present) |
| | ≥ 7/10 vegetated sample spots (boat or wader survey) should have ≥ 1 characteristic species | **X** | Only 30 % of sample spots comply (20% wader, 40% boat) – although only 1 transect completed |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | No non-natives present |
| | Benthic and epiphytic filamentous algal cover <10% (non-*Chara*) | ✓ | Low cover scores |
| **Macrophyte community structure** | Characteristic vegetation zones should be present. *Chara* beds should cover >50% of photic zone | **X** | *Chara virgata* grows to 1.2 m depth. *N. alba* grows to a depth of 1.7 m and *N. lutea* grows to a depth of 3 m. Lake bed shelves steeply from 3 m. |
| | Maximum depth distribution should be maintained | ✓**?** | $Z_{max}$ = 9.1 m, $Z_{mean}$ = 6.0 m, $Z_s$ = 4.2 m, $Z_v$ = 3.0 m. Lake bed shelves steeply from 3–9m |
| | At least the current structure should be maintained | ✓ | Greater diversity of submerged macrophyte species recorded in 2003 than in 1996 (see Monteith *et al.,* 1997). |

**Table 4.4.3 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels:<br>TP target / limit = 20 $\mu gl^{-1-1}$ | **X?** | TP = 24.5 $\mu gl^{-1}$<br>TN = 3.21 $mgl^{-1}$; $NO_3^-$-N = 2.21 $mgl^{-1}$<br>Chl a = 4.0 $\mu gl^{-1}$ |
| | Stable pH / ANC values:<br>pH ~ 7.00–8.50 & ANC > 20 | ✓ | pH = 7.7<br>Alkalinity = 3432$\mu eql^{-1}$ |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 $mgl^{-1}$) | ✓ | 6 - 7.5 $mgl^{-1}$ from 0 - 8.5 m |
| | No excessive growth of cyanobacteria or green algae | ✓ | No blooms present |
| **Hydrology** | Natural hydrological regime | ✓ | Appears natural – spring-fed |
| **Lake substrate** | Natural shoreline maintained | ✓ | Shoreline development index = 1.31.<br>Lake surrounded by valley mire and dense *Carex elata*-dominated wet fen. |
| | Natural and characteristic substrate maintained (marl production desirable) | ✓ | Small, marl-producing lake situated on sedimentary deposits of lacustrine shell mud |
| **Sediment load** | Natural sediment load maintained | **✓?** | Quarry within the lake's catchment. Catchment land cover dominated by improved grassland, with some valley mire. Rough grazing around lake. |
| **Indicators of local distinctiveness** | Distinctive elements maintained at current levels and/or in current locations | **X?** | Scarce habitat type in the UK. Active marl-producing lake on limestone.<br>*Chara pedunculata* and *Chara rudis* previously recorded, but absent from 1996 and 2003 macrophyte surveys. |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | **✓?** | Bennion (ed.) (1996) recorded no significant change from core bottom to top, but bottom sample only from 5cm depth – dissolution below. |

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

Extent

The surface area of the lake is 1.31 ha, with a volume of 78.9 $x10^3m^3$.

Macrophyte community composition

Since Llyn yr Wyth Eidion is a small lake, only one transect was completed to minimise disturbance. The survey section was considered characteristic for the site. The aquatic vegetation of keys out as a Type 9 "mainly eutrophic, sometimes marl" assemblage. Components of type 8 and 10 eutrophic assemblages are also present (Palmer, 1992). Based on the submerged and floating leaved vegetation only (Table 4.4.4), the average Trophic Rank Score (TRS) for this site is 7.7 (92.3/12). Monteith et al. (1997) reported a TRS of 7.4 from a macrophyte survey in July 1996, suggesting that the nutrient status of the site increased slightly between 1996 and 2003. Species richness has also increased, which may be a function of nutrient enrichment and/or a reflection of survey timing / transect locations. The appearance of *Fontinalis antipyretica* in Llyn yr Wyth Eidion since 1996, plus its frequent occurrence in 2003, suggests that the lake has become slightly enriched - Stewart (2004) suggests that *Fontinalis* dominance is a sign that the water is somewhat enriched, although not enough to cause algal blooms.

**Table 4.4.4: Macrophyte community composition for Llyn yr Wyth Eidion, including trophic scores. Figures in brackets indicate calculated values for 1996 survey (Monteith *et al.*, 1997).**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Callitriche* sp. (cf. *obtusangula*) | 8.5 | Strandline only |
| *Chara virgata* | 8.5 | A |
| *Chara vulgaris* | 8.5 | A |
| *Fontinalis antipyretica* | 6.3 | F |
| *Lemna minor* | 9.0 | F |
| *Nuphar lutea* | 8.5 | A |
| *Nymphaea alba* | 6.7 | F |
| *Potamogeton berchtoldii* | 7.3 | Strandline only |
| *Potamogeton crispus* | 8.5 | R |
| *Potamogeton perfoliatus* | 7.3 | Strandline only |
| *Sparganium natans* | 5.5 | R |
| **Average TRS** | **7.69 (7.4)** | |
| **TRS (weighted)** | **6.09** | |
| **PLEX (weighted)** | **5.26 (4.80)** | |
| **Ellenberg fertility score** | **5.43 (6.32)** | |

Although charophytes are present in the lake, the characteristic species, *C. virgata* is only present in 30 % of vegetated wader and boat transect spots (wader = 20 %, boat = 40 %). Furthermore, *C. virgata* only grows to a depth of 1.2 m and it does not cover > 50 % of the photic zone, consequently failing the macrophyte community composition target.

Negative indicator species

No non-native species are present and filamentous algal cover is low.

Macrophyte community structure

Llyn yr Wyth Eidion is surrounded by the extensive calcareous valley mire of Cors Erddreiniog National Nature Reserve, a large area of swampy fen with scattered *Salix* spp. and *Alnus glutinosa*. The marginal swamp vegetation extends to a depth of approximately 75 cm and is dominated by *Carex elata*, *Cladium mariscus*, *Phragmites australis* and *Typha latifolia*. Water lilies (mainly *N. lutea*) extended in a band around the section to a depth of 3 m. A number of submerged species were present under and among the lilies between 75 cm and 150 cm, including 2 species of *Chara (C. virgata and C. vulgaris), Potamogeton crispus* and *Sparganium natans.*

The lakebed shelves steeply away from shore and no plants were found growing beyond a water depth of 3 m, despite water clarity ($Z_s$ = 4.2 m) suggesting that the maximum depth of colonisation should extend to a greater water depth. $Z_v$ has remained the same since the 1996 survey and *N. lutea* continues to be abundant within the marginal zone. Reduced substrate stability on the sides of the steeply shelving lake basin may explain the lack of plant colonisation at water depths greater than 3 m.

Different macrophyte growth forms are well represented in the lake - charophytes (*C. virgata, C. vulgaris*), submerged fine/strap-leaved species (*P. berchtoldii)*, submerged broad-leaved species (*P. crispus*, *P. perfoliatus*), floating-leaved species (*N. lutea, N. alba, S. natans*), free-floating species (*L. minor*), mosses (*F. antipyretica*) and emergents (*Carex elata, C. mariscus, P. australis, T. latifolia, H. vulgaris*).

Water quality

Llyn yr Wyth Eidion is a well-buffered, high alkalinity lake with pH values consistently above 7.5, reflecting the mixed geology with Carboniferous limestone in the catchment. Phosphorus concentrations (25 $\mu gl^{-1}$) are moderate and slightly above the feature type target of 20 $\mu gl^{-1}$ (Marl, deep lakes) They appear to have increased since 1996-7, when mean annual TP was reported as 17 $\mu gl^{-1}$ (Monteith *et al*., 1997). Nitrate concentrations are rather high (and higher than in Llyn Cadarn). The source of nitrate seems most likely to result from agricultural contamination via groundwater. The particularly low levels of $NO^{3-}$-N during the macrophyte growth season suggest that, in common with Llyn Cadarn, the lake is nitrogen limited.

Chlorophyll a concentrations are moderately low throughout the year, but perhaps reflect zooplankton activity rather than low primary productivity. Overall, Llyn yr Wyth Eidion has a slightly elevated nutrient status (mesotrophic), consistent with the low-lying nature of the site and high percentage of improved agricultural land in the catchment.

Hydrology

The hydrological regime of the lake appears natural and the lake is aquifer-fed. Monteith *et al*. (1997) reported that *Salix* trees ringing the shoreline of the lake had died since an increase in water level at the site.

Lake substrate

Llyn yr Wyth Eidion is an active marl-producing lake and silt/marl is the dominant substrate.

Sediment load

Surrounding Llyn yr Wyth Eidion is the extensive calcareous valley mire of Cors Erddreiniog, which overlies limestone bedrock. Improved grassland is the dominant land cover within the lake's catchment and there is some grazing of this grassland.

Indicators of local distinctiveness

Hedgehog stonewort *Chara pedunculata* and the rare rugged stonewort *C. rudis* have previously been recorded at this site, however neither species was recorded in 1996/7 or during the September 2003 survey.

Palaeolimnological evidence

Bennion (ed.) (1996) reported that there was no significant change in diatom assemblages between the top and bottom of an undated sediment core from Llyn yr Wyth Eidion (squared chord distance = 0.319). Although the percentage of the planktonic taxon, *Aulacoseira granulata* (fine form) was greater in the surface sample, this was probably a seasonal artefact, particularly if the sediment core was taken during / directly following a bloom of *A. granulata*. The presence of *A. granulata* and other planktonic diatom taxa commonly found in enriched waters (e.g. *Stephanodiscus parvus* and *Asterionella formosa*), suggest that the lake is currently enriched. However the core bottom sample was from only 5 cm depth (dissolution below this depth), and therefore it is not possible to determine past diatom assemblages or to infer past lakewater nutrient concentrations.

Summary

Situated in a large calcareous valley mire on deposits of lacustrine shell mud, Llyn yr Wyth Eidion forms a small but steeply shelving circular water body. Despite water clarity being favourable to macrophyte colonisation to deeper depths, the steep sides of the lake appear to prevent macrophyte growth below a depth of 3 m. Charophyte colonisation is patchy and many vegetated sample spots did not record the presence of the characteristic charophyte species, *C. virgata*.

Hedgehog stonewort *Chara pedunculata* and the rare rugged stonewort *C. rudis* have previously been recorded at this site (1880s and 1890s (*C. rudis* also in 1977 (Ratcliffe, 1977)) (Stewart, 1997), however neither species was recorded in either July 1996 (Monteith *et al*., 1997) or in the September 2003 survey. *C. pedunculata* and *C. rudis* are very sensitive to raised nutrient levels and Stewart (1997) suggests that they have been lost due to eutrophication. It is recommended that further palaeoecological work, particularly plant macrofossil analysis, be carried out at Llyn yr Wyth Eidion to determine past plant communities at the site. This may elucidate when *C. pedunculata* and *C. rudis* disappeared.

The appearance of *Fontinalis antipyretica* in Llyn yr Wyth Eidion since 1996 and its frequent occurrence in 2003, in addition to the increase in TRS and overall macrophyte species richness may provide evidence that the lake has become slightly enriched. Furthermore, surface sediment diatom assemblages contain species commonly observed in the phytoplankton of enriched waters. We recommend that nutrient concentrations in the lake be monitored on a regular basis and possible catchment nutrient sources pin-pointed and appropriately managed to reduce lakewater nutrient concentrations.

Since Llyn yr Wyth Eidion appears to be slightly enriched, has lost nutrient sensitive charophyte species and currently supports a relatively low coverage of charophytes, overall site condition is deemed to be **unfavourable**.

## Overall condition of the Corsydd Môn / Anglesey Fens SAC

Hard oligo-mesotrophic waters with benthic stoneworts (*Chara* spp.) are scarce in the UK, and the best examples of this habitat type are restricted to the north and west. Unfortunately, both Llyn Cadarn, and to a lesser extent, Llyn yr Wyth Eidion, are considered to be damaged examples of the Annex I feature type because they have a lack of charophytes (absent from Llyn Cadarn). Since the presence and colonisation extent of characteristic charophyte species is a key requirement for the Annex I habitat feature type, the overall condition of the Anglesey Fens SAC must be deemed **unfavourable**. Both lakes are relatively deep so are vulnerable even to small impacts, but several rare taxa have been reported and the lakes still have some features that are worth conserving e.g. good fringing development.

Both lakes have slightly raised nutrient levels and we recommend that water quality is monitored on a regular basis and that the source and extent of nutrient enrichment is determined and managed appropriately. We recommend that palaeoecological work, particularly plant macrofossil analysis, be carried out at both Llyn Cadarn and Llyn yr Wyth Eidion to determine past plant communities at the sites and elucidate when / why previously recorded charophyte species disappeared.

**Table 4.4.5: Corsydd Môn SAC: Overview**

| Water Body | Status | Reason(s) for Failure | Comments |
|---|---|---|---|
| Llyn Cadarn | Unfavourable | Eutrophication. No charophytes. | Relatively deep lake is especially sensitive to eutrophication |
| Llyn yr Wyth Eidion | Unfavourable | Eutrophication. Little *Chara*. | Relatively deep lake is especially sensitive to eutrophication. |
| **Overall SAC Status** | **Unfavourable** | | |

## *4.5 Elenydd SAC*

### 4.5.1 Llyn Cerrigllwydion Isaf (LA, V)

Annex 1 type: H3130: Oligotrophic to mesotrophic standing water with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*. Favourable Condition Table 4.

**Table 4.5.1: Condition Assessment Summary Table for Llyn Cerrigllwydion Isaf.**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise) | ✓ | 5 species present: *L. uniflora, L. dortmanna, I. lacustris, S. angustifolium, L. natans* |
| | No loss of characteristic species (see Box 2) | - | |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) have ≥ 1 characteristic species | ✓ | 76% of vegetated sample spots comply (76% wader; 80% boat)<br>NB: Only 1 boat transect completed |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | No non-natives present |
| | Benthic and epiphytic filamentous algal cover <10% | ✓? | Mean cover score = 1.5; median = 2<br>No sample spots have scores of 3 |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (see Table 4) | ✓? | Margins: *C. rostrata* and *S. angustifolium*<br>25–80cm: *L. uni / J. bulb / L. dort*<br>> 220 cm: *C. hamulata / M. alterniflorum* |
| | Maximum depth distribution should be maintained | ✓? | $Z_{max}$ = 10.2 m, $Z_{mean}$ = 3.4 m, $Z_s$ = 2.4 m, $Z_v$ = 2.2 m<br>(based on only 1 boat survey) |
| | At least the present structure should be maintained | - | |

**Table 4.5.1 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels:<br>TP target / limit = 10 µg P $l^{-1}$ | ✓ | TP = 6.4 µg$l^{-1}$ (Jun'05 data only)<br>TN = 0.39 mg$l^{-1}$; $NO_3^-$-N = 0.91 mg$l^{-1}$<br>Chl *a* = 3.8 µg$l^{-1}$ |
| | Stable pH / ANC values:<br>pH ~ 5.5 – 7.0 & ANC > 20 | **X** | pH = 5.5 (range = 5.3–5.9);<br>DOC = 4.49; ANC = -35.99µeq$l^{-1}$ (acid impacted)<br>Alk = 25 (bicarb, June '05 only); |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 mg$l^{-1}$) | ✓ | ~ 10 mg$l^{-1}$ from 0-10 m depth |
| | No excessive growth of cyanobacteria or green algae | ✓ | No algal blooms |
| **Hydrology** | Natural hydrological regime | ✓? | Water level raised by low rock dam |
| **Lake substrate** | Natural shoreline maintained | ✓? | Shoreline development index = 1.42 |
| | Natural and characteristic substrate maintained | ✓? | Bedrock, pebbles and peat |
| **Sediment load** | Natural sediment load maintained | ✓? | Catchment largely comprises wet modified bog vegetation with some blanket bog. Areas of unimproved acid grassland (*Molinia*-dominated) around lake used for rough grazing. |
| **Indicators of local distinctiveness** | Distinctive elements maintained | ✓? | *Luronium natans* present in 2004 – small bed at 110-180 cm water depth in sheltered area close to inflow (section 1) |
| | Minimal negative impacts and no fish farming | ? | Rock dam raises water level slightly |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | ✓? | 0-20cm: Sq chord distance=0.505<br>Moderate degree of floristic change but waters always moderately acid.<br>Goldsmith *et al*. (2006). |

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

Extent

Llyn Cerrigllwydion Isaf lies at an altitude of 498 m. Its surface area is 5.5 ha and its volume is 187 x$10^3$$m^3$.

Macrophyte community composition

Due to high winds at the time of survey, only one boat transect and three wader transects were completed. The aquatic vegetation of keys out as a Type 2 / 3 "oligotrophic" assemblage (Palmer, 1992). Based on the submerged and floating leaved vegetation only (Table 4.5.2), the average Trophic Rank Score (TRS) for this site is 5.08 (45.7/9). The site is relatively species rich.

**Table 4.5.2: Macrophyte community composition for Llyn Cerrigllwydion Isaf, including trophic scores.**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Callitriche hamulata* | 5.0 | O |
| *Fontinalis antipyretica* | 6.3 | R |
| *Glyceria fluitans* | 6.7 | R |
| *Isoetes lacustris* | 5.0 | A |
| *Littorella uniflora* | 6.7 | A |
| *Lobelia dortmanna* | 5.0 | F |
| *Luronium natans* | - | R |
| *Myriophyllum alterniflorum* | 5.5 | A |
| *Sparganium angustifolium* | 3.0 | F |
| *Sphagnum auriculatum* | 2.5 | R |
| **Average TRS (unweighted)** | **5.08** | |
| **TRS (weighted)** | **5.61** | |
| **PLEX** | **4.28** | |
| **Ellenberg Fertility Index** | **4.18** | |

Negative indicator species

No non-native macrophyte species are present in Llyn Cerrigllwydion Isaf. *J. bulbosus* is present, but occurs at low frequency. Filamentous algal cover is is low to moderate, with no sample spots having cover scores of 3. *M. alterniflorum* is abundant, suggesting that the site may be slightly enriched.

Macrophyte community structure

*Sphagnum* sp., *J. bulbosus* and *J. effusus* are commonly encountered growing around the lake perimeter. The lake's marginal areas are dominated by bedrock and boulders, with no transitional zone between the water and the adjacent vegetation. However, at the south-west end, *C. rostrata* is common in the shallow peaty areas and *S. angustifolium* grows to a depth of 1.1 m. The deeper water areas are colonised by *M. alterniflorum* and *C. hamulata*, growing to a maximum depth of 2.2 m. Since only one boat transect was completed, it is not possible to fully describe macrophyte community structure. A range of different macrophyte growth forms are represented in the lake – isoetids (*I. lacustris, L. uniflora, L. dortmanna*); submerged fine/strap-leaved species (*M. alterniflorum, J. bulbosus)*, floating-leaved species

(*S. angustifolium, G. fluitans*), mosses (*F. antipyretica, S. auriculatum*) and emergents (*C. rostrata, J. effusus*).

Water quality

Llyn Cerrigllwydion Isaf has low pH and its negative ANC value (-35.99), indicates that the lake is poorly buffered and has been impacted by acidification, although alkalinity is positive (but this is bicarbonate alkalinity, not total alkalinity). At the time of survey, the lake was well mixed and had a high dissolved oxygen concentration (~ 10 $mgl^{-1}$) throughout the water column. Phosphorus data is unreliable because data are only available for one month. However, the June 2005 TP measurement was below the target / limit for the lake feature type and in combination with the relatively low chlorophyll *a* concentrations throughout the year, suggests that the lake is oligotrophic. There is sufficient dissolved oxygen throughout the water column to support a healthy aquatic fauna.

Hydrology

The lake's water level has been raised slightly by the construction of a low rock dam. This dam has apparently been in place for many years. Inspection of the 1890 OS map indicates that the lake has not changed substantially in shape since then, suggesting that either the dam was already in place then, or else its effects have been minimal.

Lake substrate

The shoreline is dominated by bedrock and boulders although there are some areas of peaty substrate, particularly at the south-western end of the lake.

Sediment load

The lake's catchment is dominated by wet modified bog (66%) and blanket bog (17%), with some unimproved acid grassland and marshy *Molinia*-dominated grassland. Land use in the catchment is predominantly rough upland grazing. The shoreline development index is 1.42, indicating that the shoreline is relatively undisturbed, although overgrazing could be an issue.

Indicators of local distinctiveness

*L. natans* occurs in the lake. This species was only found in one boat transect, growing at a water depth of 110 - 180 cm in a relatively sheltered area of the lake.

Palaeolimnological evidence

The squared chord distance dissimilarity distance between core top and bottom (20 cm) samples is 0.505, suggesting that there has been a moderate degree of floristic change in diatom species assemblages at Llyn Cerrigllwydion Isaf. However, the lake has been acid for the whole of the period represented by the sediment core and the diatom species; *Eunotia incisa, Frustulia rhomboides, Cymbella perpusilla* and *Tabellaria flocculosa* occur in both the top and bottom samples.

Summary

Llyn Cerrigllwydion Isaf is a high altitude (498 m) lake that is sensitive to, and probably impacted by, acid deposition. However, the lake's diatom profile suggests that the lake waters have always been moderately acidic. We tentatively propose that Llyn Cerrigllwydion Isaf should be classified as **unfavourable** until its ANC value increases to at least zero. Monteith *et al*. (unpublished) note that for sites with an ANC of <0, there is a 60% probability that a

site is at least substantially acidified. However, the negative ANC values are at odds with the macrophyte survey data; the abundance of the elodeids *M. alterniflorum* and *C. hamulata*, alongside the presence of *F. antipyretica*, suggest that the lake is either slightly mesotrophic (Palmer, 1992), and/or that the lake is recovering from the effects of historic acidification (Monteith *et al*., 2005). Old macrophyte survey records or plant macrofossil profiles would need to be examined to assertain whether these species have always been present in Llyn Cerrigllwydion Isaf or whether they are more recent additions.

We recommend that water chemistry, macrophyte and diatom assemblages are monitored to track any recovery in ANC values and acidification pressure.

The population of the Annex II species, *L. natans* should be monitored and further boat surveys completed to determine the population extent and dynamics of this species in Llyn Cerrigllwydion Isaf.

According to WFD risk assessments, Llyn Cerrigllwydion Isaf is 'probably *not* at risk' from either diffuse / point source pollution, physical / morphological alteration or alien species.

## 4.5.2 Llyn Fyrddon Fawr (LA, S)

Annex 1 type: H3130: Oligotrophic to mesotrophic standing water with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*. Favourable Condition Table 4.

**Table 4.5.3: Condition Assessment Summary Table for Llyn Fyrddon Fawr.**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise) | **X** | No *Littorelletea* species |
| | No loss of characteristic species (see Box 2) | **-** | |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) have ≥ 1 characteristic species | **X** | No characteristic species |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | No non-natives present |
| | Benthic and epiphytic filamentous algal cover <10% | ✓**?** | Mean score = 1.3; median = 1<br>1 sample spot has a score of 3 |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (see Table 4) | | *C. rostrata* = emergent<br>*F. antipyretica* growing to ~ 1.0m in bay (and flush) on NW shore |
| | Maximum depth distribution should be maintained | **X?** | $Z_{max}$ = 13.4 m, $Z_{mean}$ = 6.5 m, $Z_s$ = 1.2 m, $Z_v$ = ~1.0 m |
| | At least the present structure should be maintained | **-** | |
| **Water quality** | Stable nutrients levels:<br>TP target / limit = 10 µg P $l^{-1}$ | ✓ | TP = 7.3 µg$l^{-1}$ (Jun'05 data only)<br>TN = 0.33 mg$l^{-1}$; $NO_3^-$-N = 0.53 mg$l^{-1}$ |
| | Stable pH / ANC values:<br>pH ~ 5.5 – 7.0 &ANC > 20 | **X?** | pH = 5.4 (range = 5.3 – 5.9)<br>ANC = -12.09 µeq$l^{-1}$ (acid impacted); Alk = 29 µeq$l^{-1}$ (bicarb, Jun 05 data only) |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 mg$l^{-1}$) | ✓ | ~ 10 mg$l^{-1}$ from 0-11 m depth |
| | No excessive growth of cyanobacteria or green algae | ✓ | No algal blooms |

**Table 4.5.3 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Hydrology** | Natural hydrological regime | **X?** | Water level raised by ~ 3.5 m by old stone dam on outflow |
| **Lake substrate** | Natural shoreline maintained | **✓?** | Shoreline development index = 1.42 |
| | Natural and characteristic substrate maintained | **✓?** | Mainly large boulders and cobbles, with some areas of peat |
| **Sediment load** | Natural sediment load maintained | **?** | - Areas of exposed and eroding peat around the lake.<br>- Some rough grazing in catchment |
| **Indicators of local distinctiveness** | Distinctive elements maintained | **-** | None to note |
| | Minimal negative impacts and no fish farming | **?** | - Rock dam has raised water level by ~ 3.5 m, although this is old.<br>- Some rough grazing in catchment |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | **✓?** | Goldsmith *et al*. (2006). 0-25cm: Sq chord distance=1.064. *A. ralfsii* → *T. flocculosa, E. incisa, C. perpusilla, F. rhomboides*. Possible recovery from acidification, although lake waters always acid. |

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

Extent

Llyn Fyrddon Fawr lies at an altitude of 519 m. Its surface area is 14 ha with a volume of 910 $x10^3m^3$.

Macrophyte community composition

Due to high winds at the time of survey, no boat transects were completed. The aquatic vegetation of Llyn Fyrddon Fawr keys out as a Type 3 "oligotrophic" assemblage (Palmer, 1992). Based on the submerged and floating leaved vegetation only (Table 4.5.4), the average Trophic Rank Score (TRS) for this site is 6.3 (6.3/1). The site is very species poor; the only submerged plant being *F. antipyretica*. Slightly greater diversity is seen amongst the emergents and marginals, with a number of *Carex* and *Juncus* species present.

Negative indicator species

No non-native macrophyte species are present. Filamentous algal cover scores are low and only one sample spot had a cover score of 3.

Macrophyte community structure

Very few macrophyte growth forms in the lake, with only mosses (*F. antipyretica*) and emergents (numerous *Carex* spp (including *C. rostrata*), *J. effusus, J. squarrosus*) represented. The moss, *S. auriculatum* was also found, although its origin was probably terrestrial. *C. rostrata* grows to 0.5 m and *F. antipyretica* grows in water depths greater than 0.75 m in a bay on the north-west shore.

**Table 4.5.4: Macrophyte community composition for Llyn Fyrddon Fawr, including trophic scores.**

| **Submerged and floating vegetation** | **Trophic Rank Score (TRS)** | **DAFOR** |
|---|---|---|
| *Fontinalis antipyretica* | 6.3 | A |
| **Average TRS** | **6.3** | |
| **PLEX** | **5.4** | |
| **Ellenberg Fertility Index** | **5.2** | |

Water quality

Llyn Fyrddon Fawr is an acid lake that is poorly buffered with a negative ANC. Low confidence is afforded to the phosphorus data since only one value is available for June 2005. However, this value is low, and along with the low chlorophyll *a* and nitrate values suggests that the lake is oligotrophic to mildly dystrophic.

Hydrology

The lake's water level has been raised slightly by the construction of a low rock dam. This dam is not of recent construction. It is not thought that the dam is negatively impacting upon the lake ecosystem.

Lake substrate

The dominant substrates in the marginal areas are boulders and cobbles, with some areas of exposed peat. The substrates appear to be natural.

Sediment load

Eroded peat is exposed on the north-east and north-west shores of the lake. Peat erosion may be increasing the lake's sediment load. Rough grazing within the catchment may also be increasing sediment loading.

Indicators of local distinctiveness

None

Palaeolimnological evidence

Although the lake has been acid for the whole of the period represented by the sediment core, the core top and bottom (25 cm) diatom samples are significantly different in terms of floristic composition (squared chord distance dissimilarity score = 1.064). The change in diatom species from core bottom to top indicates an increase in pH and suggests a recovery from

acidification. *Asterionella ralfsii*, an indicator of strongly acid waters, is abundant at 25 cm. In the surface sediment sample, *A. ralfsii* is absent, replaced by increasing percentage abundances of *Tabellaria flocculosa, Cymbella perpusilla, Eunotia incisa* and *Frustulia rhomboides* var. *viridula*; all taxa indicative of moderately to strongly acid waters. *A. ralfsii* is a species characteristic of peatland disturbance and nutrient enrichment (Monteith & Evans eds., 2000), therefore its decrease at the core top may also be related to a decrease in catchment disturbances such as a decrease in peat erosion in recent years.

Summary
Llyn Fyrddon Fawr is an exposed upland lake set within a catchment consisting mainly of blanket bog. The large expanses of peat are exposed and eroding in some areas, possibly increasing sediment loading and rough grazing within the catchment may also be impacting upon the sediment load.

The lake is devoid of submerged macrophytes and is therefore a very poor example of its feature type with respect to its aquatic plant community. The nature of the catchment and macrophyte community suggests that Llyn Fyrddon Fawr may be better classified as mildly dystrophic, although DOC concentrations are not sufficiently high for a dystrophic classification.

Llyn Fyrddon Fawr's surface sediment diatom assemblage shows signs that the lake is recovering from acidification. However, it remains moderately acidic, with both pH and ANC below the targets set for the lake's feature type. Although DOC levels are relatively low, these may increase as the water become less acidic (Evans *et al*., 2005).

The lake's water level has been raised by approximately 3.5 m by an old stone dam on the outflow. This dam has been in place for many years and is not thought to impact upon habitat quality.

Overall Llyn Fyrddon Fawr is determined to be in **unfavourable** condition largely because it has a history of acidification (and it currently has a negative ANC) and an underdeveloped submerged macrophyte flora. However, surface sediment diatoms assemblage suggests a decrease in acidity and/or a decrease in catchment disturbance in recent years.

There is no evidence that characteristic oligotrophic species have ever occurred in the lake, therefore the lake may be better classified as an acidified dystrophic lake with low DOC levels. Further investigation into Llyn Fyrddon Fawr's classification is required.

According to WFD risk assessments, Llyn Fyrddon Fawr is 'probably *not* at risk' from either diffuse / point source pollution, physical / morphological alteration or alien species. Although this contradicts the results of the current assessment, WFD risk assessments are largely generic.

## 4.5.3 Llyn Gwngu (LA, S)

Annex 1 type: H3130: Oligotrophic to mesotrophic standing water with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*. Favourable Condition Table 4.

**Table 4.5.5: Condition Assessment Summary Table for Llyn Gwngu.**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise) | **X** | No *Littorelletea* species. |
| | No loss of characteristic species (see Box 2) | **-** | Baseline survey |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) have ≥ 1 characteristic species | **X** | Only 24 % of vegetated sample spots comply<br>(28% wader, 10% boat) |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | No non-natives present |
| | Benthic and epiphytic filamentous algal cover <10% | **✓?** | Mean score =1.3; median= 2<br>No sample spots have scores of 3 |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (see Table 4) | **X?** | 0–0.75m: *C. rostrata, P. australis, E. fluviatile, E. fluitans, N. lutea*<br>0.75–2.0m: *N. lutea, E. fluviatile, E. fluitans, M. alterniflorum*, *C. hamulata*<br>2.0-2.5 m: *M. alterniflorum* |
| | Maximum depth distribution should be maintained | **-** | $Z_{max}$ = 6.7 m, $Z_{mean}$ = 2.5 m, $Z_s$ = 2.3 m, $Z_v$ = 2.5 m |
| | At least the present structure should be maintained | **-** | Baseline survey |

**Table 4.5.5 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels:<br>TP target / limit = 10 µg P $l^{-1}$ | ✓? | TP = 6.9 µg$l^{-1}$ (Jun'05 data only)<br>TN = 0.34 mg$l^{-1}$; $NO_3^-$-N = 0.30 mg$l^{-1}$<br>Chl *a* = 1.6 µg$l^{-1}$ |
| | Stable pH / ANC values:<br>pH ~ 5.5 – 7.0 & ANC > 20 | ✓ | pH = 5.6 (range = 5.2 – 6.7)<br>ANC = 32.70 µeq$l^{-1}$; Alk = 82 µeq$l^{-1}$ (bicarb, Jun '05 data only) |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 mg$l^{-1}$) | ✓ | 9 - 10 mg$l^{-1}$ from 0 - 6 m depth |
| | No excessive growth of cyanobacteria or green algae | ✓ | No algal blooms |
| **Hydrology** | Natural hydrological regime | ✓? | Appears natural |
| **Lake substrate** | Natural shoreline maintained | ✓? | Shoreline development index = 1.06 |
| | Natural and characteristic substrate maintained | ✓? | Silt is the dominant lake substrate both in the margins and at depth. Areas of peat are also common. |
| **Sediment load** | Natural sediment load maintained | ✓? | - Wet modified bog, blanket bog and unimproved acid grassland are the dominant catchment land covers.<br>- Wet upland grazing is common. |
| **Indicators of local distinctiveness** | Distinctive elements maintained | ✓? | Highest altitude site in Wales (and joint highest in the UK) to record the growth of *Eleogiton fluitans* |
| | Minimal negative impacts and no fish farming | ✓? | Wet upland grazing in catchment |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | X | Goldsmith *et al*. (2006)<br>0-31cm: Sq chord dist = 0.621.<br>*T. flocculosa, E. incisa, B. vitrea* → *E. incisa, T. quadriseptata, P. fibula* = Acidification (moderately acid-strongly acid) |

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

**Extent**

Llyn Gwngu lies at an altitude of 438 m. It has a surface area of 2.9 ha and a volume of 72.5 x$10^3$$m^3$.

Macrophyte community composition

The aquatic vegetation of keys out as a Type 2/3 "oligotrophic" assemblage (Palmer, 1992) although the site does not support any of the *Littorelletea* species typical of this type of assemblage. The macrophyte flora includes elements of a more mesotrophic Type 5 assemblage (*Nuphar lutea* and *Callitriche hamulata*) and elements of a more dystrophic Type 1 assemblage (*Sphagnum auriculatum* and *Potamogeton polygonifolius*). Based on the submerged and floating leaved vegetation only (Table 4.5.6), the average Trophic Rank Score (TRS) for this site is 5.0 (35.2/7).

**Table 4.5.6: Macrophyte community composition for Llyn Gwngu, including trophic scores.**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Callitriche hamulata* | 5.0 | R |
| *Myriophyllum alterniflorum* | 5.5 | A |
| *Nuphar lutea* | 8.5 | D |
| *Potamogeton natans* (strandline only) | 6.7 | - |
| *Potamogeton polygonifolius* | 3.0 | F |
| *Sphagnum auriculatum* | 2.5 | A |
| *Utricularia minor* | 4.0 | A |
| **Average TRS** | **5.0** | |
| **TRS (weighted)** | **5.44** | |
| **PLEX (weighted)** | **4.07** | |
| **Ellenberg Fertility Index (weighted)** | **4.65** | |

Negative indicator species

No non-native species are present in Llyn Gwyngu and the coverage of filamentous algae is low.

Macrophyte community structure

The lake margins are mainly peat and grade into Juncus effusus marsh. The emergents; *Carex rostrata, Equisetum fluviatile* and *Phragmites australis* (an unusually high altitude for this species) are locally abundant around the margins, growing in water depths of up to 75 cm. Extensive beds of *Nuphar lutea* grow around much of the lake between depths of 25 and 230 cm. The shading effect of *N. lutea* may help explain the absence of characteristic *Littorelletea* species throughout the shallow water zone. *Eleogiton fluitans* is the dominant submerged plant, growing between the depths of 25 – 200 cm on the north side of the lake. The growth of *Utricularia minor* and *Myriophyllum alterniflorum* is patchier, with both species occurring across a range of water depths to 1.5 m and 2.3 m respectively.

Although no isoetids occur in the lake, a reasonable range of other macrophyte growth forms are represented - submerged fine/strap-leaved species (*M. alterniflorum, U. minor, J. bulbosus, C. hamulata)*, floating-leaved species (*N. lutea*, *E. fluitans, P. natans, P.*

*polygonifolius*), mosses (*S. auriculatum*) and emergents (*C. rostrata, E. fluviatile, M. trifoliata, P. australis*).

Water quality

Llyn Gwyngu is a mildly acid lake with a positive ANC (33) that is both above the threshold value considered necessary for adequate buffering against acidification and above the target for the feature type (> 20). DOC concentrations are moderate (5.50 $mgl^{-1}$) and probably reflect the high coverage of peat within the catchment. The lake is well mixed and has high dissolved oxygen concentrations throughout the water column and is therefore likely to support a healthy aquatic fauna. Confidence in the TP data is low because only one value is available. However, the June 2005 TP measurement is below the limit for the feature type and in tandem with low SRP, chlorophyll *a* and nitrogen concentrations suggests that Llyn Gwyngu is oligotrophic.

Hydrology

The hydrological regime of the lake appears natural.

Lake substrate

The dominant lake substrate is silt, both in the marginal and deep-water areas. Peat is locally common, particularly in the marginal areas. The lake substrates appear natural.

Sediment load

Wet upland grazing occurs in the catchment and could potentially be increasing the sediment load to the lake.

Indicators of local distinctiveness

At 438 m, Llyn Gwyngu is the joint highest recorded site in the UK and the highest site in Wales to support the growth of *Eleogiton fluitans*.

Palaeolimnological evidence

Goldsmith *et al*. (2006) describe results from the analysis of diatom samples from the top and bottom of a 31 cm sediment core. There is a significant degree of floristic change between core top and bottom (squared chord distance dissimilarity score = 0.621). The bottom sample is diverse and includes taxa indicative of moderately acid water conditions (*Tabellaria flocculosa, Eunotia incisa* and *Brachysira vitrea*), whereas the top sample is less diverse and comprises taxa more indicative of strongly acid waters (*E. incisa, Tabellaria quadriseptata, Peronia fibula*). Results indicate that the lake has further acidified from an already acid state, probably as a result of acid deposition from fossil fuel burning.

Summary

Since Llyn Gwyngu only supports one macrophyte species that is characteristic of the habitat feature type (*Utricularia minor*) and this species is only present in 28% of wader and 10% of boat vegetated sample spots. However, the dominance of the floating leaved species, *N. lutea* in the shallow areas of the lake (25 – 230 cm) may provide too much shade for the growth of *Littorelletea* species, preventing their establishment in the lake. It would be useful to determine whether *Littorelletea* species have ever been an important component of the macrophyte flora of Llyn Gwyngu and if so, when/why they disappeared from the site. To

assess the past flora of the site, we recommend that sediment cores be extracted and examined for plant macrofossils and aquatic pollen.

Given the mildly acidic pH, the abundance of *Sphagnum auriculatum* is unlikely to be indicative of a site, but more likely reflects the slightly dystrophic nature of the site.

The status of the lake as the highest altitude site in Wales to record the growth of *Eleogiton fluitans* is significant and the environmental conditions that favour this species should be maintained, whilst at the same time avoiding the compromisation of overall habitat feature condition.

Overall, Llyn Gwyngu appears to be in **favourable** condition and is of conservation interest as part of the Elenydd SSSI Standing Water feature. However, it is not a typical example of the Habitats Directive 'Oligotrophic to Mesotrophic lakes with *Littorelletea'* feature.

No WFD risk assessment has been completed for comparison.

## 4.5.4 Llyn Gynon (LA, V)

Annex 1 type: H3130: Oligotrophic to mesotrophic standing water with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*. Favourable Condition Table 4.

**Table 4.5.7: Condition Assessment Summary Table for Llyn Gynon.**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise) | ✓ | 6 present: *L.uniflora, L. dortmanna, I. lacustris, S. angustifolium, L. natans, S. aquatica* |
| | No loss of characteristic species (see Box 2) | - | |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) have ≥ 1 characteristic species | ✓ | 99% of vegetated sample spots comply (99% wader, 100% boat) |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | No non-natives present |
| | Benthic and epiphytic filamentous algal cover <10% | ✓**?** | Mean cover score = 1.5; median = 2<br>No sample spots have scores of 3 |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (see Table 4) | ✓ | < 1.4 m: *J. bulbosus L. uniflora, L. dortmanna, I. lacustris*,<br>1.0 – 2.2 m: *I. lacustris, U. minor, M. alterniflorum, L. natans*<br>2.0 – 3.4 m: *N. flexilis* |
| | Maximum depth distribution should be maintained | ✓ | $Z_{max}$ = 11.7 m, $Z_{mean}$ = 2.3 m, $Z_s$ = 3.05 m, $Z_v$ = 3.4 m |
| | At least the present structure should be maintained | - | |

**Table 4.5.7 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels:<br>TP target / limit = 10 µg P $l^{-1}$ | ✓? | TP = 13µg$l^{-1}$ (Dec'03 – Sep'04)<br>TN = 0.38mg$l^{-1}$; $NO_3^-$-N = 0.14mg$l^{-1}$ |
| | Stable pH / ANC values:<br>pH ~ 5.5 - 7.0 & ANC > 20 | ✓? | pH = 6.0 (range = 5.3 – 6.6)<br>No ANC data |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 mg$l^{-1}$) | ✓ | ~ 9 mg$l^{-1}$ from 0 - 8 m depth, then drops to ~ 6 mg$l^{-1}$ at 10 m depth |
| | No excessive growth of cyanobacteria or green algae | ✓ | No algal blooms |
| **Hydrology** | Natural hydrological regime | ✓? | Appears natural. Lake fed chiefly by a stream from the north, and groundwater flows. |
| **Lake substrate** | Natural shoreline maintained | ✓? | Shoreline development index = 1.43 |
| | Natural and characteristic substrate maintained | ✓? | |
| **Sediment load** | Natural sediment load maintained | ✓? | Catchment land cover mainly wet *Molinia* flushes and unimproved acid grassland used for rough grazing. Some areas of peat bog. |
| **Indicators of local distinctiveness** | Distinctive elements maintained | ✓? | - *L. natans* present<br>- *Pilularia globulifera* recorded in 1964 by Seddon, but not recorded at the site since.<br>- Remote site – shallow depression on highland plateau |
| | Minimal negative impacts and no fish farming | ✓? | - Used occasionally by fly fishermen. Wild Brown Trout.<br>- Some rough upland grazing in catchment |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | X? | Battarbee et al. (1988) and Bennion ed. (2004 ):<br>0-32 cm: Sq chord dist = 0.651. Slight acidification. |

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

Extent

The surface area of the lake is 25.3 ha, with a volume of 582 x$10^3$$m^3$.

Macrophyte community composition

The aquatic vegetation of keys out as a Type 3 "oligotrophic" assemblage (Palmer, 1992). Based on the submerged and floating leaved vegetation only (Table 4.5.8), the average Trophic Rank Score (TRS) for this site is 4.92 (68.9/14). The site supports a high diversity of macrophytes, with 14 different submerged and floating leaved species present.

**Table 4.5.8: Macrophyte community composition for Llyn Gynon, including trophic scores.**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Callitriche hamulata* | 5.0 | R |
| *Elatine hexandra* | 6.0 | R |
| *Fontinalis antipyretica* | 6.3 | R |
| *Glyceria fluitans* | 6.7 | O |
| *Isoetes lacustris* | 5.0 | D |
| *Juncus bulbosus* | 3.7 | A |
| *Littorella uniflora* | 6.7 | D |
| *Lobelia dortmanna* | 5.0 | D |
| *Luronium natans* | - | O/R |
| *Myriophyllum alterniflorum* | 5.5 | F |
| *Nitella flexilis* | 5.5 | F |
| *Sparganium angustifolium* | 3.0 | R |
| *Sphagnum auriculatum* | 2.5 | F |
| *Subularia aquatica* | 4.0 | R |
| *Utricularia minor* | 4.0 | O |
| **Average TRS (unweighted)** | **4.92** | |
| **TRS (weighted)** | **5.42** | |
| **PLEX (weighted)** | **3.98** | |
| **Ellenberg Fertility Index (weighted)** | **4.03** | |

Negative indicator species

No non-native macrophyte species have been recorded and filamentous algal cover is low.

Macrophyte community structure

The submerged flora is typical of an upland oligotrophic lake with *Littorella uniflora, Lobelia dortmanna* and *Isoetes lacustris* abundant from shallow water depths to depths of 1.6 m, 1.6 m and 2.5 m respectively. *Juncus bulbosus* was locally abundant from shallow water to approximately 1.4 m. *Luronium natans* was recorded throughout the lake between 1.2 – 2.2 m. *Nitella flexilis* was the only species growing between depths of 2.2 – 3.4 m throughout the lake. A wide range of different macrophyte growth forms are represented in the lake – isoetids (*I. lacustris, L. uniflora, L. dortmanna*); charophytes and mosses (*N. flexilis*, *F. antipyretica, S. auriculatum*); submerged fine/strap-leaved species (*M. alterniflorum, L. natans, C. hamulata, S. aquatica, E. hexandra, U. minor, J. bulbosus)*; floating-leaved species (*S.*

*angustifolium, L. natans, G. fluitans*) and emergents (*J. effusus, C. rostrata, E. fluviatile*). The numerous macrophyte growth forms afford structure and complexity to the lake ecosystem, providing a wide range of habitat niches for aquatic organisms.

Water quality

Annual mean pH of the lake waters (6.0) indicates mildly acid conditions. No data are available for ANC, although it is not thought that the lake is sensitive to acid deposition. Mean annual TP concentrations (12 $\mu gl^{-1}$) are slightly higher than the feature type target and are also higher than the 7.7 $\mu gl^{-1}$ annual mean concentration reported by Monteith (ed.) (1995). The slightly elevated nutrient levels may explain the rich macrophyte flora of the site and the presence of some species more characteristic of mesotrophic waters.

Hydrology

The hydrological regime of the lake appears natural. At the time of the 2004 macrophyte survey, the lake level was slightly low and macrophyte species tolerant of exposure such as *L. uniflora, C. hamulata* and *E. hexandra* were recorded as growing on the shore.

Lake substrate

The lake lies within a shallow depression on a highland plateau composed exclusively of sedimentary rocks. Silt is the dominant sediment in the deeper water areas, with coarser substrates, generally boulders and cobbles more frequent in the marginal areas. There are no peaty areas.

Sediment load

Land cover within the catchment comprises a mix of unimproved acid grassland and *Molinia* dominated marshy grassland, which is used for rough grazing. Fly fishermen use the lake occasionally, but overall there is little human disturbance of the site.

Indicators of local distinctiveness

*L. natans* is recorded throughout the lake between 120-220 cm, but rarely occurred in abundance. Monteith ed. (1995) recorded *L. natans* growing in similar localities, at similar water depths and in similar abundances, suggesting that populations of *L. natans* have remained relatively stable in Llyn Gynon.

Palaeolimnological evidence

A sedimentary diatom profile is presented in Battarbee *et al*. (1988) and Bennion (ed.) (2004) reports a squared chord distance dissimilarity score of 0.651 between core top and bottom diatom assemblages.

Summary

Llyn Gynon is a remote upland site that has become moderately acidified as a consequence of the deposition of atmospherically derived pollutants. No ANC data are available, although palaeolimnological evidence suggests acidification, but alkalinity is positive. Overall Llyn Gynon is determined to be in **favourable** condition, mainly because it is a relatively undisturbed lake supporting a well structured, species rich macrophyte assemblage.

According to WFD risk assessments, Llyn Gynon is 'probably *not* at risk' from either diffuse / point source pollution, physical / morphological alteration or alien species. The current

assessment suggess that the lake has been impacted by diffuse pollution in the form of acid deposition, although this risk may no longer be significant following reductions in sulphur deposition across the UK.

## Overall condition of the Elenydd SAC

Overall, the Elenydd SAC is determined to be in **unfavourable** condition.

Prior to this survey, the Elenydd lakes were relatively poorly surveyed, so there is relatively little prior data against which to compare results. Two of the lakes surveyed (Llyn Fyrddon Fawr and Llyn Gwyngu) do not contribute to the Habitats Directive 'Oligotrophic to mesotrophic lakes with *Littorelletea*' interest feature. Llyn Fyrddon Fawr is probably a dystrophic lake (itself a Habitats Directive Annex 1 feature), and Llyn Gwyngu is an oligotrophic lake lacking isoetids.

Although all four lakes are acidic, palaeolimnological evidence shows that two of the lakes (Llyn Cerrigllwydion Isaf and Llyn Fyrddon Fawr) have been severely impacted by acidification and the other two lakes (Llyn Gwyngu and Llyn Gynon) are less sensitive to acidification and have only been moderately impacted. We recommend that the diatom floras and associated water chemistries of all Elenydd SAC sites be monitored to track any recovery trends from acidification.

The macrophyte communities of the lakes are generally species poor. This reflects both the acidity of the lake waters and the exposed nature of the sites. Llyn Fyrddon Fawr has a particularly peat-rich catchment, is more dystrophic than the other Elenydd SAC lakes and supports no submerged macrophytes. Llyn Gynon is set on sedimentary rock and has less acidic waters and greater macrophyte species diversity and characteristic species representation than the other Elenydd SAC lakes. Llyn Gwngu is also relatively species rich, although no characteristic *Littorelletea* species are present.

Llyn Gwyngu is the highest site in Wales and the joint highest lake in the UK to support the growth of *Eleogiton fluitans* (Preston & Croft 1997). Llyn Gynon supports the growth of the Annex II species, *Luronium natans*, as does Llyn Cerrigllwydion Isaf, although it is more abundant in Llyn Gynon.

Llyn Cerrigllwydion Isaf and Llyn Fyrddon Fawr are lakes with artificially raised water levels, although water levels were raised approximately 100 years ago. It is not thought that these artificial features currently affect habitat condition.

### Recommendations for Further Work

- Of the four sites monitored here, Llyn Cerrigllwydion Isaf and Llyn Gynon are the most appropriate sites for future SAC monitoring of the oligotrophic lakes feature. The two lakes complement one another, as Cerrigllwydion Isaf is vulnerable to acidification, whereas Gynon is more susceptible to eutrophication. At present, acidification seems to be a greater concern.

- Although not forming part of the SAC feature, Llyn Gwyngu is of conservation interest as part of the SSSI Standing Water feature, and SSSI monitoring should consider using this site as well.
- Llyn Fyrddon Fawr is potentially a dystrophic lake. Further investigation of this site may be warranted to establish whether the current absence of macrophytes is natural or due to human impact.

**Table 4.5.9: Elenydd SAC: Overview**

| Water Body | Status | Reason(s) for Failure | Comments |
|---|---|---|---|
| Llyn Cerrigllwydion Isaf | Unfavourable | Acidification | No other significant impacts. |
| Llyn Fyrddon Fawr | N/A | No macrophytes | Peaty – a possible dystrophic lake? Affected by acidification (and peatland disturbance?) |
| Llyn Gwyngu | N/A | | No *Littorelletea*. Appears to be otherwise favourable. |
| Llyn Gynon | Favourable | | Has suffered acidification in the past |
| **Overall SAC Status** | **Unfavourable** | | |

## *4.6 Eryri / Snowdonia SAC*

### 4.6.1 Llyn Cwmffynnon (LA, V)

Annex 1 type: H3130: Oligotrophic to mesotrophic standing water with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*. Favourable Condition Table 4.

**Table 4.6.1: Condition Assessment Summary Table for Llyn Cwmffynnon.**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise) | ✓ | 4 present*: L. uniflora*, *L. dortmanna*, *I. lacustris, S. angustifolium* |
| | No loss of characteristic species (see Box 2) | - | Baseline survey |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) have ≥ 1 characteristic species | ✓ | 96 % of vegetated sample spots comply (wader = 97%, boat = 95%) |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | No introduced species |
| | Benthic and epiphytic filamentous algal cover <10% | ✓? | Mean cover = 2.2; median = 2<br>37% (44/120) sample spots have cover scores of 3 |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (see Table 4) | ✓ | <1.5 m: *L. uniflora, L. dortmanna*<br>>1.5 m: *I. lacustris* / *M. alterniflorum* |
| | Maximum depth distribution should be maintained | ✓ | $Z_{max}$ = 11.2 m, $Z_{mean}$ = 2.7 m, $Z_s$ = 3.6 m, $Z_v$ = 3.8 m |
| | At least the present structure should be maintained | - | Baseline survey |

**Table 4.6.1 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels:<br>TP target / limit = 10 µg P $l^{-1}$ | ✓? | TP = 4.1 µg$l^{-1}$ (Jun'05 data only)<br>TN=0.26mg$l^{-1}$; $NO_3^-$-N=0.29mg$l^{-1}$<br>Chl *a* = 3.0µg$l^{-1}$ |
| | Stable pH / ANC values:<br>pH ~ 5.5 – 7.0 & ANC > 20 | ✓ | pH = 6.2 (range = 6.0 – 6.5)<br>ANC = 0 µeq$l^{-1}$ (acid sensitive)<br>DOC = 1.97, Alk = 31 µeq$l^{-1}$ (bicarb, Jun'05 data only), |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 mg$l^{-1}$) | ✓ | 8-9 mg$l^{-1}$ from 0-10 m depth |
| | No excessive growth of cyanobacteria or green algae | ✓ | No algal blooms |
| **Hydrology** | Natural hydrological regime | ✓? | Appears to be natural |
| **Lake substrate** | Natural shoreline maintained | ✓? | Shoreline development index = 1.29 |
| | Natural and characteristic substrate maintained | ✓ | Catchment geology composed predominantly of sedimentary rocks. Boulders are the dominant lake substrate. |
| **Sediment load** | Natural sediment load maintained | ✓ | Dominant land cover is *Calluna*-dominated unimproved acid grassland, used predominantly for rough upland grazing |
| **Indicators of local distinctiveness** | Distinctive elements maintained | ✓? | *Luronium natans*<br>*Lycopodiella inundata* |
| | Minimal negative impacts and no fish farming | ✓? | |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | X | Goldsmith *et al*. (2006).<br>0-25 cm sq chord distance = 0.976<br>Moderate acidification<br>Shift from periphytic circumneutral to moderately acid taxa. |

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

Extent

The surface area of the lake is 9.9 ha, with a volume of 267.3 x$10^3$$m^3$.

Macrophyte community composition

The aquatic vegetation of Llyn Cwmffynnon keys out as a Type 2/3 "oligotrophic" assemblage (Palmer, 1992). Based on the submerged and floating leaved vegetation only (Table 4.6.2), the average Trophic Rank Score (TRS) for this site is 4.51 (45.1/10).

**Table 4.6.2: Macrophyte community composition for Llyn Cwmffynnon, including trophic scores.**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Isoetes lacustris* | 5.0 | A |
| *Juncus bulbosus* | 3.7 | F |
| *Littorella uniflora* | 6.7 | A |
| *Lobelia dortmanna* | 5.0 | D |
| *Myriophyllum alterniflorum* | 5.5 | O |
| *Potamogeton natans* | 6.7 | F |
| *Potamogeton polygonifolius* | 3.0 | F |
| *Sphagnum* (cf. *auriculatum*) | 2.5 | R |
| *Sparganium angustifolium* | 3.0 | R |
| *Utricularia vulgaris* agg. | 4.0 | R |
| **Average TRS** | **4.51** | |
| **TRS (weighted)** | **5.41** | |
| **PLEX (weighted)** | **3.68** | |
| **Ellenberg fertility score (weighted)** | **3.94** | |

The submerged flora of Llyn Cwmffynnon is typical for a low alkalinity, nutrient-poor upland lake and it meets its feature type targets for macrophyte community composition. The lake supports four characteristic *Littorelletea* species: *Littorella uniflora, Lobelia dortmanna, Isoetes lacustris* and *Sparganium angustifolium*, which together with another characteristic species, *Utricularia vulgaris* agg., occur in 96% of vegetated wader and boat sample spots.

Negative indicator species

No non-native, introduced macrophyte species are present. Filamentous algal coverage is moderate to high across all wader survey sections and some boat transects. The overall mean filamentous algae coverage score is 2.2 and 44 out of 120 sample spots (37 %) have cover scores of 3 (in August 2004). High coverage of filamentous algae may indicate nutrient enrichment and/or increased sedimentation rates, although equally, transect locations may be unintentionally biased towards areas of filamentous algal growth.

Macrophyte community structure

With the exception of survey section 2, which has sparse *Phragmites* and *Carex rostrata* beds as well as *Equisetum fluviatile,* much of the lake margins have little or no transitional zone between the lake and terrestrial habitats. The submerged flora is typical for a low alkalinity, nutrient-poor upland lake, having mainly *Littorella* and *Lobelia* to a depth of 120-150 cm, interspersed with *Juncus bulbosus* and *Isoetes lacustris.* Beyond this zone *I. lacustris* is dominant to a maximum depth of 380 cm, but its distribution is patchy, with few dense stands. *Myriophyllum alterniflorum* is locally common to a depth of 380 cm and a dense bed of *Potamogeton natans* was present in the bay at the south end of the lake. The site supports macrophyte species of a number of different growth forms - isoetids (*I. lacustris*, *L. uniflora*, *L. dortmanna*), mosses (*Sphagnum* spp.), submerged fine/strap-leaved plants (*J. bulbosus, M.*

*alterniflorum, U. vulgaris* agg.), floating-leaved plants (*S. angustifolium, P. natans, P. polygonifolius*) and emergents (*Carex* spp. including *C. rostrata, Juncus* spp*., P. australis, M. trifoliata*), suggesting that the macrophytes provide a diverse range of habitats within the lake.

Water quality

Although reaching a maximum depth of 11.2 m, the deep area is confined to a relatively small region of the lake and the water was well mixed and oxygenated throughout the water column in August 2004. Although Llyn Cwmffynnon has a mean pH of 6.2, a very low ANC value indicates poor buffering and impact by acidification. Uncertainty in the phosphorus and alkalinity data is high, since only one data value for each determinand is available (2005 / 2006 data to follow), however low SRP and chlorophyll *a* concentrations and a reliable TP value obtained in June 2005 suggest that the site meets its feature type targets for nutrients and is currently oligotrophic. Nitrogen concentrations are low and indicate that the lake is probably nitrogen-limited.

Hydrology

The hydrological regime of the lake appears to be natural.

Lake substrate

Boulders are the dominant substrate along the lake margins and in most of the littoral zone to water depth of approximately 75 cm. Silt is the dominant substrate in the deeper (> 75 cm) areas of the lake. The lake substrates appear to be natural.

Sediment load

Unimproved acid grassland is the dominant land cover in Llyn Cwmffynnon's catchment, with smaller areas of dry acid heath and blanket bog. The predominant land use is rough upland grazing.

Indicators of local distinctiveness

*Luronium natans* was not found in the current survey, although it has been previously recorded from the lake. The uncommon clubmoss *Lycopodiella innundata* is known from the lake margins.

Palaeolimnological evidence

The squared chord distance dissimilarity score between the core top and bottom (25 cm) samples is high (0.976), indicating that there has been a significant degree of floristic change in Llyn Cwmffynnon. The diatom assemblage of the bottom sample comprises numerous non-planktonic species typical of circumneutral, relatively nutrient-poor waters, the most abundant being *Achnanthes minutissima, Fragilaria brevistriata,* and *Navicula seminulum* var. *intermedia.* The top sample is also diverse but markedly different, comprising *Fragilaria virescens* var. *exigua*, *Navicula leptostriata* and *Brachysira vitrea,* diatoms more typically found in moderately acid waters, occurring in the highest abundances. Palaeolimnological evidence indicates moderate acidification of the lake (Goldsmith *et al*., 2006).

Summary

Overall, Llyn Cwmffynnon is determined to be in **unfavourable** (recovering?) condition. Although its macrophyte community composition and structure is characteristic of the lake's feature type, the palaeolimnological evidence and a present day low ANC (-0.04), suggests

that the lake has been impacted by acid deposition. Monteith *et al*. (unpublished) note that for sites with an ANC of <0, there is a 60% probability that a site is at least substantially acidified. Llyn Cwmffynnon currently has a positive alkalinity, although it is not known whether alkalinity has recently increased, perhaps following some degree of recovery from acidification as atmospheric sulphur deposition has decreased.

As Llyn Cwmffynnon recovers from acidification and alkalinity increases, the lake's water chemistry and macrophyte community should be monitored to examine in detail any recovery trend and to determine whether macrophyte populations, particularly of acid-sensitive elodeid species such as *M. alterniflorum* (which derive their inorganic carbon directly from the water column in the form of bicarbonate) increase in abundance alongside the acid tolerant, low-growing isoetid taxa (which derive their inorganic carbon from sedimentary sources) (Monteith *et al*., 2005).

Although filamentous algal coverage is moderate to high, it is not thought that the lake is currently undergoing enrichment or experiencing increased sediment loading. However any catchment addition of either phosphorus or nitrogen, particularly from agricultural sources, should be monitored to ensure that nutrient and chlorophyll *a* levels are maintained at low levels.

## 4.6.2 Llyn Coch (LA, V)

Annex 1 type: H3130: Oligotrophic to mesotrophic standing water with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*. Favourable Condition Table 4.

**Table 4.6.3: Condition Assessment Summary Table for LlynCoch.**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise) | ✓ | 3 present: *L. uniflora, I. lacustris* and *S.angustifolium.* |
| | No loss of characteristic species (see Box 2) | - | Baseline survey |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) have ≥ 1 characteristic species | ✓ | 95 % of wader and boat vegetated sample spots comply (wader = 100%, boat = 90%) |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | No introduced species |
| | Benthic and epiphytic filamentous algal cover <10% | ✓ | Mean cover score = 0.2; median = 0<br>No sample spots with scores of 3 |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (see Table 4) | ✓? | 25-75 cm: *L. uniflora*<br>75-90 cm: *L. uniflora* and *I. lacustris*<br>1.1 m: *M. alterniflorum* |
| | Maximum depth distribution should be maintained | ✓ | $Z_{max}$ = 1.1 m, $Z_{mean}$ = 0.5 m, $Z_s$ = > $Z_{max}$, $Z_v$ = 1.1 m<br>Macrophytes growing to $Z_{max}$ |
| | At least the present structure should be maintained | - | Baseline survey |

**Table 4.6.3 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels: TP target / limit = 10 µg P $l^{-1}$ | ✓? | TP = 3.0 µg$l^{-1}$ (Jun'05 data only) TN = 0.32 mg$l^{-1}$; $NO_3^-$-N = 1.17 mg$l^{-1}$ Chl *a* = 0.51 µg$l^{-1}$ |
| | Stable pH / ANC values: pH ~ 5.5 – 7.0 & ANC > 20 | ✓ | pH = 7.0 (range = 6.8 – 7.2) ANC = 31µeq$l^{-1}$ (bicarb) DOC = 0.51, Cond = 35 |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 mg$l^{-1}$) | ✓ | ~10 mg$l^{-1}$ from 0-0.5 m depth |
| | No excessive growth of cyanobacteria or green algae | ✓ | No algal blooms |
| **Hydrology** | Natural hydrological regime | ✓? | Appears natural |
| **Lake substrate** | Natural shoreline maintained | ✓ | Shoreline development index = 1.21 |
| | Natural and characteristic substrate maintained | ✓ | Boulders, gravel and silt |
| **Sediment load** | Natural sediment load maintained | ✓ | Igneous geology. Catchment land cover is entirely unimproved acid grassland with some rough grazing |
| **Indicators of local distinctiveness** | Distinctive elements maintained | ✓? | Small, very shallow upland lake with low hydraulic residence time |
| | Minimal negative impacts and no fish farming | ✓? | Undisturbed site apart from rough grazing in catchment |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | ✓? | 0-10 cm, sq chord distance = 0.676 Moderate degree of floristic change, although circumneutral diatom taxa throughout. No evidence of acidification. Possible change in habitat availability. |

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

Extent

Llyn Coch lies at an altitude of 528 m. The surface area of the lake is 1.2 ha, with a volume of 6 x$10^3$$m^3$.

Macrophyte community composition

The aquatic vegetation of keys out as a Type 2/3 "oligotrophic" assemblage (Palmer, 1992). Based on the submerged and floating leaved vegetation only (Table 4.6.4), the average Trophic Rank Score (TRS) for this site is 4.8 (28.9/6). The site is species poor, although altitude and exposure may explain this.

**Table 4.6.4: Macrophyte community composition for Llyn Coch, including trophic scores.**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Callitriche hamulata* (strandline only) | 5.0 | - |
| *Isoetes lacustris* | 5.0 | D |
| *Juncus bulbosus* (strandline only) | 3.7 | - |
| *Littorella uniflora* | 6.7 | D |
| *Myriophyllum alterniflorum* | 5.5 | R |
| *Sparganium angustifolium* | 3.0 | F |
| **Average TRS** | **4.80** | |
| **TRS (weighted)** | **5.55** | |
| **PLEX** | **4.28** | |
| **Ellenberg Fertility Index (weighted)** | **4.09** | |

Only one 100 m shoreline transect was carried out in order to minimize the disturbance to this small site (as per method, Appendix 1). The submerged flora consists predominantly of only *Littorella uniflora* and *Isoetes lacustris.* A strandline survey recorded the presence of *Callitriche hamulata* and the submerged form of *Juncus bulbosus*. No *Lobelia dortmanna* is present, perhaps because this species has a low competitive ability (Preston & Croft, 1997) and cannot compete with *L. uniflora* or *I. lacustris* in the lake's exposed location. Alternatively the species may have been lost to eutrophication. This may seem unlikely given the relatively undisturbed nature of the lake's catchment, although there is a discharge from the Snowdon café near to the lake and this potential pollution source should be investigated..

Negative indicator species

No non-native macrophyte species are present and filamentous algal cover scores are low.

Macrophyte community structure

The marginal habitats of Llyn Coch are typical of the surrounding terrestrial habitats, with no transitional wetland zone. The submerged flora extends across the entire lakebed consisting only of *Littorella uniflora* (dominant between 25–50 cm) and *Isoetes lacustris* (co-occurring with *L. uniflora* between 70-90 cm), except for a small area of *Myriophyllum alterniflorum* at the deepest point of the lake (110 cm).

Water quality

Llyn Coch is circum-neutral, with moderate alkalinity and ANC. Confidence in the phosphorus data is low since only one TP measurement is available from June 2005. However, this summer value was low (3.2 $mgl^{-1}$) and in tandem with very low chlorophyll *a* levels and clear water, water quality is considered typical for an upland oligotrophic lake. Llyn Coch is too shallow to record a meaningful DO / temperature profile, however surface water temperature was 10.5 °C and dissolved oxygen 9.6 $mgl^{-1}$ in August 2004, suggesting that there is sufficient dissolved oxygen available to support a healthy aquatic fauna.

Hydrology
The lake appears to have a natural hydrological regime.

Lake substrate
The lake margins are dominated by boulders, with gravels and silty substrates common in the wader survey and silt dominant in the deeper water areas.

Sediment load
There is some rough upland grazing in the lake catchment, although overall catchment disturbance is low.

Indicators of local distinctiveness
Llyn Coch is a small, exposed, very shallow upland lake with a very low hydraulic residence time.

Palaeolimnological evidence
Results of diatom analysis of core top and bottom (10 cm) samples are presented in Goldsmith *et al.* (2005). Both top and bottom samples had a high mineral content and many frustules were badly broken. The squared chord distance dissimilarity score between the two samples is 0.676, indicating that there has been a moderate degree of floristic change. The assemblages of both the bottom and top samples are comprised of non-planktonic taxa typically associated with the substrates of circumneutral waters. There is no evidence of acidification. The observed species shifts are more likely to be explained by alterations in habitat availability such as changes in the host plant community.

Summary
Llyn Coch is considered to be in **favourable** condition and although no WFD risk assessment has been completed (because the lake is < 1 ha in size), it is not thought that the lake is at risk of failing to meet the WFD good ecological status target. ANC data suggest that the lake is not sensitive to acid deposition and palaeolimnological evidence implies that the lake has not been acidified - although changes in diatom floristic composition suggest that there may have been a change in habitat availability. Although there is grazing in the lake catchment, the site is otherwise undisturbed.

## 4.6.3 Llyn Idwal (LA, V)

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

**Table 4.6.5: ConditionAssessment Summary Table for Llyn Idwal.**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise) | ✓ | 4 species present: *L. uniflora, L. dortmanna*, *I. lacustris, S. aquatica* |
| | No loss of characteristic species (see Box 2) | **X** | *S. angustifolium* extensive in southern bay in 1994 - absent from 2004 survey |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) have ≥ 1 characteristic species | ✓ | 70 % of wader and boat vegetated sample spots comply (wader = 73%, boat = 65%) |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | No introduced species |
| | Benthic and epiphytic filamentous algal cover <10% | ✓ | Mean score = 1.3; median = 1<br>2/119 sample spots with scores of 3 |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (see Table 4) | ✓ | < 2.0 m: *L. uniflora, L. dortmanna, J. bulbosus, E. hexandra, S. aquatica,*<br>2.0 –5.9 m: *I. lacustris, M. alterniflorum, P. berchtoldii* |
| | Maximum depth distribution should be maintained | ✓ | $Z_{max}$ = 13.0 m, $Z_{mean}$ = 2.9 m, $Z_s$ = 5.4 m, $Z_v$ = 5.9 m |
| | At least the present structure should be maintained | ✓**?** | Fewer floating leaved species than in 1994. $Z_v$ has increased (2.5 to 5.9 m) |

**Table 4.6.5 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels: TP target / limit = 10 µg P $l^{-1}$ | **X?** | TP = 12 µg$l^{-1}$ (range = 7-19 µg$l^{-1}$) SRP = 5 µg$l^{-1}$; Chl *a* = 0.7 µg$l^{-1}$ TN = 0.31 mg$l^{-1}$; $NO_3^-$-N = 0.10 mg$l^{-1}$ |
| | Stable pH / ANC values: pH ~ 5.5 – 7.0 & ANC > 20 | ✓ | pH = 6.4 (range = 6.2 – 7.1) ANC = 26 µeq$l^{-1}$ (Oct – Apr only) DOC=1.00, Alk=71µeq$l^{-1}$ (bicarb) |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 mg$l^{-1}$) | ✓ | 8-9 mg$l^{-1}$ from 0-11 m depth |
| | No excessive growth of cyanobacteria or green algae | ✓ | No algal blooms |
| **Hydrology** | Natural hydrological regime | ✓? | Catchment drains to lake via series of steep streams and falls. 3 small upland tarns lie above the lake. |
| **Lake substrate** | Natural shoreline maintained | ✓? | Shoreline development index = 1.55 Visitor access / erosion around lake |
| | Natural and characteristic substrate maintained | ✓ | Complex catchment geology - mix of igneous and sedimentary rocks. |
| **Sediment load** | Natural sediment load maintained | ✓ | Catchment landcover dominated by unimproved acid grassland and dry acid heath - used for rough upland grazing. Some *Juncus* dominated wetland. |
| **Indicators of local distinctiveness** | Distinctive elements maintained | **X?** | *Pilularia globulifera* reported in 1998 (JNCC), but not found in 2004 survey. *I. echinospora* reported previously. |
| | Minimal negative impacts and no fish farming | **X?** | Significant recreational pressure - hill walkers, climbers, visitors - erosion of lake / stream margins and paths |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | ✓? | 0-25 cm: Sq chord distance = 0.314. No significant floristic change and no acidification. Circumneutral, nutrient-poor diatom taxa throughout core. |

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

Extent
The surface area of the lake is 13.6 ha, with a volume of 394.4 x$10^3$$m^3$.

Macrophyte community composition
The aquatic vegetation of Llyn Idwal keys out as a Type 3 "oligotrophic" assemblage (Palmer, 1992). Based on the submerged and floating leaved vegetation only (Table 4.6.6), the average Trophic Rank Score (TRS) for this site is 5.12 (51.2/10). Allott *et al.* (1994) reported a similar macrophyte species list, but a slightly higher TRS of 5.6. Species present in the 1993 survey but absent from the 2004 survey included the floating-leaved species; *Potamogeton natans, Sparganium angustifolium* and *Glyceria fluitans*, all recorded as occasional or rare at the southern end of the lake only in 1993. *Elatine hexandra* was not recorded in 1994, but was occasional in 2004.

**Table 4.6.6: Macrophyte community composition for Llyn Idwal, including trophic scores. Figures in brackets indicate calculated values for 1996 survey (Allott *et al*., 1994).**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Callitriche hamulata* | 5.0 | O |
| *Elatine hexandra* | 6.0 | O |
| *Isoetes lacustris* | 5.0 | D |
| *Juncus bulbosus* | 3.7 | F |
| *Littorella uniflora* | 6.7 | A |
| *Lobelia dortmanna* | 5.0 | A |
| *Myriophyllum alterniflorum* | 5.5 | O |
| *Potamogeton berchtoldii* | 7.3 | O |
| *Potamogeton polygonifolius* | 3.0 | R |
| *Subularia aquatica* | 4.0 | F |
| **Average TRS** | **5.12** | |
| **TRS (weighted)** | **5.64 (5.46)** | |
| **PLEX (weighted)** | **4.37 (4.33)** | |
| **Ellenberg Fertility Score (weighted)** | **4.20 (4.24)** | |

Survey section 2, in the sheltered southern end of Llyn Idwal, has a mixed emergent flora dominated by *Phragmites australis* with *Carex rostrata* and *Menyanthes trifoliata* beds along the shore. The submerged species in this section are limited to dense beds of *Juncus bulbosus*. The three survey sections in the north basin show a more typical low-nutrient, upland-lake flora, with the shallow water dominated by *Littorella uniflora, Lobelia dortmanna* and *Isoetes lacustris. Subularia aquatica* is also common in shallow water on the east and west shore sections (sections 1 & 3), and *Elatine hexandra, Juncus bulbosus* and *Callitriche hamulata* are encountered sporadically in all three sections. *Nitella* spp. is not found in Welsh lakes where pH < 6.4 (Allott *et al*., 1994). The absence of *Nitella* from Llyn Idwal (pH 6.4) in 2004

when it was present in 1994 may therefore be of concern, although its absence may be explained by interannual population dynamics and not a decrease in lake water pH.

The weighted indices of plant community all show very little change in status between 1993 and 2004. Weighted TRS increased by less than 0.2, and weighted PLEX and Ellenberg scores changed by less than 0.05 units.

Negative indicator species

No non-native macrophyte species occur in Llyn Idwal and filamentous algal cover scores are low (mean = 1.3; median = 1), with only 2 sample spots having scores of 3.

Macrophyte community structure

The more open area to the north of the lake (section 2) has almost no transitional vegetation between the water and the terrestrial habitats and the submerged macrophyte flora is limited to dense beds of *Juncus bulbosus* to the maximum depth of the bay (150 cm). The three survey sections in the north basin (sections 1, 3 and 4) show the characteristic vegetation zones typical of Llyn Idwal's oligotrophic feature type. With increasing depth, macrophyte community structure consists of *L. uniflora*, overlapping zones of *Littorella* with *L. dortmanna* (140–230 cm), then *I. lacustris*. *I. lacustris* is present to a depth of 560 cm, dominating the assemblage alongside *P. berchtoldii* between 200 and 500 mm on the north and west shores (sections 1 and 4). In addition, *Callitriche hamulata* is present in both shallow and deeper water whereas *Subularia aquatica* is common in shallower water (25-100 cm) on the east and west shore sections (sections 1 & 3). The site supports macrophyte species of a number of different growth forms - isoetids (*I. lacustris*, *L. uniflora*, *L. dortmanna*), mosses (*Sphagnum* spp.), submerged fine/strap-leaved plants (*J. bulbosus, M. alterniflorum, P. berchtoldii, S. aquatica, C. hamulata, E. hexandra*), floating-leaved plants (*P. polygonifolius*) and emergents (*Carex* spp.*, Juncus* spp.*, P. australis, M. trifoliata*), suggesting that the macrophytes provide a diverse range of habitats within the lake and indicating that the lake is in favourable status.

Water quality

Llyn Idwal has a relatively high pH (mean 6.4) and although data are limited the ANC appears to show the site to be well buffered for an upland lake, probably due to several areas of base-rich bedrock underlying the catchment, resulting in relatively high lake water calcium concentrations. Furthermore, Allott *et al.* (1994) determined that the critical load of Llyn Idwal had not been exceeded. At the time of sampling, the lake was fully mixed and well oxygenated throughout the water column. Phosphorus levels in Llyn Idwal appear to have increased. Allott *et al.* (1994) reported a mean annual (1993-94) TP concentration of 5.3 $\mu gl^{-1}$ (range 3.8-6.9), whereas in 2004-05 mean annual TP had increased to 12 $\mu gl^{-1}$ (range 7-19). On the other hand, the site has very clear water and consistently low nitrate and chlorophyll *a* concentrations, comparable to the values reported by Allott *et al.* (1994). Analyses of longer-term records are recommended to assess any recent trends in trophic status.

Hydrology

The catchment drains to the lake via a series of steep streams and falls. Three small upland tarns lie high above Llyn Idwal (Allott *et al*., 1994). The lake's hydrological regime is natural.

Lake substrate

The dominant marginal substrates are gravels and pebbles, with some areas of coarser cobbles and boulders. The deeper areas are dominated by silt, as is the bay in the southern area of the lake (section 2). All substrates appear to be natural.

Sediment load

Llyn Idwal is surrounded by moorland vegetation that is used for rough grazing by sheep. There is also significant recreational pressure on the lake catchment from large numbers of hill walkers, climbers and visitors. Allott *et al*. (1994) considered erosion of paths, lake and stream margins to be a problem. The catchment of Llyn Idwal is steeply draining and erosional activity is common. Bennion et al. (1997) reported two major catchment erosion events – a major slope failure in 1964 following a violent thunderstorm and a major period of erosional activity by the inflow stream, the Afon Clyd, between 1971 and 1974. Erosional events and human / livestock activities in the steeply sloping catchment have the potential to significantly increase the lake's sediment load, although no data are available to support this assertion. Recent CCW / National Trust initatives to reduce grazing pressure in the catchment are likely to encourage the development of upland woodland in the lake's catchment, with beneficial consequences for the lake.

Indicators of local distinctiveness

*Pilularia globulifera* reported in the 1998 (JNCC) survey was not recorded in either the 1993 macrophyte survey (Allott *et al*., 1994) or the 2003 survey sections. However, this species is very cryptic and is unlikely to be reliably detectable in a standard lake survey. *Isoetes echinospora* has previously been reported at this site. Many individual *Isoetes* plants found at the site in the 2003 survey resembled *I. echinospora*, with rather flaccid leaves, but all specimens carrying megaspores were confirmed as *I. lacustris*. Other notable aquatic species recorded in previous surveys, which were not found during the 1993 or 2003 surveys include: *Callitriche brutia* (1972, 1976), *Scirpus lacustris* (1976), *Sparganium natans* (1980) and *Sparganium erectum* (Allott *et al*., 1994). *S. natans* and *S. lacustris* are considered rare for Wales (Palmer & Newbold, 1983).

Palaeolimnological evidence

The core top and bottom (25 cm) samples show no significant change in floristic composition (squared chord distance = 0.314) (Bennion (ed.), 2004). The lake has always supported diatom taxa indicative of circumneutral, nutrient-poor conditions, although the middle of the core (mid-1900s) sees an increase in the planktonic taxon, *Cyclotella comensis*, but the abundance of other common taxa remain stable. The fact that Llyn Idwal has not acidified is significant, as there are few examples of upland, nutrient-poor lakes in high acid deposition areas of Britain that have not acidified (Bennion *et al.*, 1997).

Summary

Overall Llyn Idwal is in **favourable** condition. WFD risk assessments have determined that the lake is 'probably *not* at risk' of either diffuse / point source pollution or alien species. Palaeolimnological evidence indicates that the lake has not been affected by acid deposition and macrophyte species composition and structure has not changed significantly since 1994. However, the impact from recreational pursuits and grazing should be monitored to ensure that lake habitat quality does not deteriorate. Analyses of longer-term water chemistry records are recommended to better establish the recent trends in trophic status. Regular water quality monitoring should be carried out to track future phosphorus trends.

## 4.6.4 LlynOgwen (LA, V)

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

**Table 4.6.7: ConditionAssessment Summary Table for Llyn Ogwen.**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise) | ✓ | 5 species present: *L. uniflora, L. dortmanna, I. lacustris, S. angustifolium, S. aquatica* |
| | No loss of characteristic species (see Box 2) | - | Baseline survey |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) have ≥ 1 characteristic species | ✓ | 100% of both wader and boat vegetated sample spots comply |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | No introduced species |
| | Benthic and epiphytic filamentous algal cover <10% | ✓**?** | Mean cover score = 1.5; median = 2<br>No sample spots with scores of 3 |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (see Table 4) | ✓ | < 1.3 m: *L. uni* dominant (*L. dort, I. lac, J. bulb, S. aqu, E. hex* present)<br>1.3 – 1.8 m: *L. dort & I. lac*<br>>2 m: *I. lacustris* dominant (to 3.1 m) |
| | Maximum depth distribution should be maintained | ✓ | $Z_{max}$ = 3.1 m, $Z_{mean}$ = 2.2 m, $Z_s$ = 2.1 m, $Z_v$ = 3.1 m<br>Macrophytes growing to $Z_{max}$ |
| | At least the present structure should be maintained | - | Baseline survey |

**Table 4.6.7 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels: TP target / limit = 10 µg P $l^{-1}$ | ✓ | TP = 9 µg$l^{-1}$ (Jul'04-Apr'05 mean) TN = 0.33 mg$l^{-1}$; $NO_3^-$-N = 0.08 mg$l^{-1}$; Chl *a* = 1.9 µg$l^{-1}$ |
| | Stable pH / ANC values: pH ~ 5.5 – 7.0 & ANC > 20 | **X?** | pH = 6.6 (range = 6.0 – 6.9) ANC = 6 µeq$l^{-1}$ (Apr-Oct) - acid sensitive DOC=1.45, Alk=55µeq$l^{-1}$ (bicarb) |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 mg$l^{-1}$) | ✓ | 8-9 mg$l^{-1}$ from 2.5 m depth |
| | No excessive growth of cyanobacteria or green algae | ✓ | No algal blooms |
| **Hydrology** | Natural hydrological regime | ✓ | Appears natural |
| **Lake substrate** | Natural shoreline maintained | **X?** | Shoreline development index = 1.75. Wall and A5 road running along shore of survey section 4 |
| | Natural and characteristic substrate maintained | ✓ | Catchment geology = mixed sedimentary and igneous. Dominant lake substrate = boulders |
| **Sediment load** | Natural sediment load maintained | ✓ | Catchment vegetation mainly unimproved acid grassland and dry acid heath - used for rough grazing |
| **Indicators of local distinctiveness** | Distinctive elements maintained | **✓?** | |
| | Minimal negative impacts and no fish farming | **✓?** | Wall and A5 road running along shore of survey section 4. |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | ✓ | Burgess *et al.* (2005) 0-25 cm significant floristic change (sq chord distance = 0.641). Acidification? |

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

Extent

The surface area of the lake is 38.9 ha, with a volume of 855.8 x$10^3$$m^3$.

Macrophyte community composition

The aquatic vegetation of keys out as a Type 2/3 "oligotrophic" assemblage (Palmer, 1992). Based on the submerged and floating leaved vegetation only (Table 4.6.8), the average Trophic Rank Score (TRS) for this site is 5.05 (65.7/13). The site is species rich.

**Table 4.6.8: Macrophyte community composition for Llyn Ogwen, including trophic scores.**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Callitriche hamulata* | 5.0 | R |
| *Elatine hexandra* | 6.0 | O |
| *Fontinalis antipyretica* | 6.3 | O |
| *Glyceria fluitans* | 6.3 | R |
| *Isoetes lacustris* | 5.0 | D |
| *Juncus bulbosus* | 3.7 | A |
| *Littorella uniflora* | 6.7 | D |
| *Lobelia dortmanna* | 5.0 | D |
| *Myriophyllum alterniflorum* | 5.5 | F |
| *Potamogeton natans* | 6.7 | R |
| *Sphagnum* sp. (and *auriculatum*) | 2.5 | R |
| *Subularia aquatica* | 4.0 | R |
| *Sparganium angustifolium* | 3.0 | R |
| **Average TRS** | **5.05** | |
| **TRS (weighted)** | **5.69** | |
| **PLEX (weighted)** | **4.10** | |
| **Ellenberg fertility score (weighted)** | **4.15** | |

The submerged macrophyte community composition is typical of a nutrient-poor site with *Littorella uniflora, Lobelia dortmanna and Isoetes lacustris* dominant. *Juncus bulbosus,* is also common across all survey sections, whereas *Elatine hexandra* and *Subularia aquatica* are found only in survey section 4, on the south shore towards the western end. A number of large beds of *Potamogeton natans* occur along the south side of the lake and several beds of *Sparganium angustifolium* are present at the western end.

Negative indicator species

No non-native macrophyte species are present. Filamentous algal cover scores are low (mean = 1.5, median = 2), with no sample spots recording scores of 3.

Macrophyte community structure

The lake margin has no transitional zone between the water and the adjacent terrestrial habitat. No emergent species are present, although *Carex* spp. and *Juncus* spp. are common around the margins in the terrestrial flora. The submerged macrophyte community structure is typical of a nutrient-poor site with *Littorella uniflora* dominant to a depth of approximately 130 cm with *Lobelia dortmanna, Isoetes lacustris* and *Juncus bulbosus* also present. *Lobelia* is co-dominant with *Isoetes* in a zone between approximately 130-180 cm. *I. lacustris* carpets the lakebed between water depths of ~2 - 3 m.

The overall macrophyte community structure is reasonably well developed, with a plenty of submerged species (dominated by *L. uniflora, L. dortmanna* & *I. lacustris*, with *C. hamulata,*

*E. hexandra, F. antipyretica, J. bulbosus, M. alterniflorum, Sphagnum auriculatum* & *S. aquatica* occurring alongside). Floating leaved species (*P. natans, S. angustifolium, G. fluitans*) were recorded only as rare in the survey sections, but were more common across the site as a whole.

Water quality

Llyn Ogwen is a large, wind-stressed and relatively shallow lake that is well mixed, with high concentrations of dissolved oxygen throughout the water column. The lake has a relatively high pH (mean 6.6) but has slightly lower alkalinity than Llyn Idwal and although data are limited (October 2004 to April 2005), the low ANC value (6) appears to show the site to be poorly buffered and therefore at risk of acidification. TP and chlorophyll *a* concentrations are relatively low for a large shallow lake and classify it as being on the boundary between oligotrophic and mesotrophic.

Hydrology

The hydrological regime of Llyn Ogwen appears to be relatively natural, although it is not known to what extent hydrology is affected by reservoirs upstream.

Lake substrate

The lake substrate consists predominantly of boulders around the margins, with areas of gravel, pebbles and bedrock. Although silt is dominant in the deeper water areas, small areas of sandy substrate also occur.

Sediment load

Catchment vegetation consists mainly of unimproved grassland and dry acid heath. Adjacent to the lake are areas of rough grazing, bare rock and *Juncus* marsh. The A5 road lies alongside the shore of survey section 4, although a wall separates the lake from the road.

Indicators of local distinctiveness

None to note

Summary

Llyn Ogwen is a large, wind-stressed and relatively shallow lake with submerged macrophytes (*I. lacustris*) growing in extensive mats to the maximum depth of the lake. The lake has been impacted by acid deposition, as indicated by a low ANC (6) and palaeolimnological evidence also indicates that the lake has been acidified. WFD risk assessments have determined the lake to be at risk of diffuse pollution.

Overall, Llyn Ogwen is considered to be in **unfavourable** condition, although it is likely that the lake is now recovering from acidification and the risk of nutrient enrichment is considered low.

## Overall condition assessment of the Eryri / Snowdonia SAC

Since two lakes in this SAC (Llyn Cwmffynnon and Llyn Ogwen) are in unfavourable condition due to the impact of acidification and the other two lakes (Llyn Coch and Llyn Idwal) are in favourable condition, with current ANC and palaeolimnological evidence suggesting that neither lake has suffered from acidification, the overall condition of the SAC

must be **unfavourable**. However, none of the lakes are considered severely impacted, with all lake ecosystems considered sustainable, providing that catchment impacts remain low.

Water chemistry and macrophyte community composition and structure should be monitored in both Llyn Cwmffynnon and Llyn Ogwen to examine any acidification recovery trends and to determine whether macrophyte populations, particularly of acid-sensitive elodeid species such as *M. alterniflorum* (which derive their inorganic carbon directly from the water column in the form of bicarbonate) increase in abundance alongside the acid tolerant, low-growing isoetid taxa (which derive their inorganic carbon from sedimentary sources) (Monteith *et al*., 2005).

Although Llyn Idwal has not been impacted by acidification, the impact from recreational pursuits and grazing should be monitored to ensure that lake habitat quality does not deteriorate. Analyses of longer-term water chemistry records are recommended to better establish the recent trends in trophic status. Regular water quality monitoring should be carried out to track future phosphorus trends.

**Recommendations for Further Work**

- Water chemistry and macrophyte community composition and structure should be monitored in both Llyn Cwmffynnon and Llyn Ogwen to examine any acidification recovery trends.
- All four sites contribute to the SAC 'Oligotrophic to mesotrophic lakes with *Littorelletea'* interest feature. For long-term SAC monitoring, Llyn Idwal, Ogwen and Cwmffynnon are all appropriate sites. Given Llyn Idwal's flagship status, we recommend that CCW continues to monitor this lake plus at least one other. Although it does contain *Littorelletea* vegetation, Llyn Coch is probably too small to use as a long-term SAC monitoring site.
- The impact of recreation and grazing on Llyn Idwal should be investigated.
- Changes to Llyn Coch's sedimentary diatom assemblages should be investigated to determine whether the floristic changes are related to habitat availability and therefore whether parallel changes have occurred in the lake's macrophyte species composition and abundance.

**Table 4.6.9: Eryri SAC: Overview**

| Water Body | Status | Reason(s) for Failure | Comments |
|---|---|---|---|
| Llyn Cwmffynon | Unfavourable | Acidification | No other significant impacts. |
| Llyn Coch | Favourable | | Very small site |
| Llyn Idwal | Favourable | | Some risk of disturbance from walkers |
| Llyn Ogwen | Unfavourable | Acidification | Has suffered acidification in the past |
| **Overall SAC Status** | **Unfavourable** | | |

## *4.7 Kenfig / Cynffig SAC*

### 4.7.1 Kenfig Pool (HA, V)

Annex 1 type: H3140: Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp. Favourable Condition Table 5.

**Table 4.7.1: ConditionAssessment Summary Table for Kenfig Pool.**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | Characteristic species (see Box 3) should be present: *Chara spp.* (excluding *Chara vulgaris*) | ✓ | 2 charophyte species present: *C. aspera* & *C. virgata* (+ *C. contraria* var. *hispidula* in 2005). |
| | ≥ 7/10 vegetated sample spots (boat or wader survey) should have ≥ 1 characteristic species | ✓ | 71 % of vegetated sample spots comply (81% wader, 55% boat). |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓**?** | *E. canadensis* present, but rare. This species was not recorded in 1995. |
| | Benthic and epiphytic filamentous algal cover <10% (non-*Chara*) | ✓ | Mean cover = 1, median = 1<br>No sample spots have scores of 3 |
| **Macrophyte community structure** | Characteristic vegetation zones should be present. *Chara* beds should cover >50% of photic zone | ✓ | *C. aspera & C. virgata* dominant to ~1.2 m → *Chara* spp / *R. circinatus* / *fine-leaved Pots* (~ 1 - 2 m) → *R. circinatus* / *fine-leaved Pots* (> 2 m) |
| | Maximum depth distribution should be maintained | ✓**?** | $Z_{max}$ = 2.6 m, $Z_{mean}$ = 1.8 m, $Z_s$ = 1.7 m, $Z_v$ = 2.1 m<br>Previous survey suggested site was vegetated to $Z_{max}$. |
| | At least the current structure should be maintained | ✓ | Similar / slight improvement to that described in Monteith ed. (1996). |

**Table 4.7.1 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels:<br>TP target / limit = 35 $\mu gl^{-1}$<br>(range 20-50 $\mu gl^{-1}$) | ✓ | TP = 20 $\mu gl^{-1}$<br>TN = 0.59 $mgl^{-1}$;<br>$NO_3^-N$ = 0.16 $mgl^{-1}$<br>Chl a = 3.9 $\mu gl^{-1}$ |
| | Stable pH / ANC values:<br>pH ~ 7.00 – 8.50 & ANC > 20 | ✓ | pH = 7.9 (range = 7.6 – 8.3)<br>Alk = 1558$\mu eql^{-1}$; Cond = 299 |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 $mgl^{-1}$) | ✓ | ~ 8 $mgl^{-1}$ from 0-2 m depth |
| | No excessive growth of cyanobacteria or green algae | ✓ | No algal blooms |
| **Hydrology** | Natural hydrological regime | **✓?** | |
| **Lake substrate** | Natural shoreline maintained | **✓?** | Shoreline development index = 1.28.<br>Poaching by horses in transect 4<br>Bird hide at NW end of lake<br>Beach on south shore used for paddling / bathing |
| | Natural and characteristic substrate maintained (marl production desirable) | ✓ | Sandy substrate around margins and to 1.5 m water depth. Silty substrate in deeper waters. |
| **Sediment load** | Natural sediment load maintained | **✓?** | |
| **Indicators of local distinctiveness** | Distinctive elements maintained at current levels and/or in current locations | ✓ | Important site for over-wintering wildfowl. |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | **?** | No diatom records.<br>*Chara* oospore and cladoceran remains indicate changes in lake ecosystem related to fish stocking practices. See text for details. (Davidson & Appleby, 2003) |

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

Extent

The surface area of the lake is 29.2 ha, with a volume of 525.3 $x10^3m^3$.

Macrophyte community composition

The aquatic vegetation of Kenfig Pool keys out as a Type 10A lowland "meso-eutrophic" assemblage (Palmer, 1992), although the site supports aspects of a number of other community types. Based on the submerged and floating leaved vegetation only (Table 4.7.2),

the average Trophic Rank Score (TRS) of this site is 8.92 (133.8/15). The site TRS seems to have remained very similar since 1995 (TRS was then 8.97). However, when TRS values are weighted using cover scores, there has been a detectable decrease in TRS, from 8.9 in 1995 to 8.0 in 2004. There has been considerable species turnover between the surveys, especially among *Potamogetons* (*pectinatus, lucens* and *crispus* not recorded in 2004 and x *nitens* recorded). Charophytes seem to have increased in abundance between 1995 and 2004. However, consideration should be given to the large interannual and seasonal variation in the abundance of different macrophyte species.

**Table 4.7.2: Macrophyte community composition for Kenfig Pool, including trophic scores. Figures in brackets indicate calculated values for 1995 survey (Monteith ed., 1996).**

| Submerged and floating species | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Ceratophyllum demersum* | 10.0 | R |
| *Chara aspera* | 8.5 | D |
| *Chara virgata* | 8.5 | D |
| *Chara contraria* v. *hispidula* (2005) | 8.5 | - |
| *Elodea canadensis* | 8.5 | R |
| *Fontinalis antipyretica* | 6.3 | F |
| *Lemna trisulca* | 10.0 | R |
| *Littorella uniflora* | 6.7 | F/O |
| *Myriophyllum alterniflorum* | 5.5 | O |
| *Myriophyllum spicatum* | 10.0 | F |
| *Nitella flexilis* | 5.5 | R |
| *Potamogeton pusillus* | 8.5 | F |
| *Potamogeton trichoides* | 10.0 | A |
| *Potamogeton gramineus* | 7.3 | R |
| *Potamogeton nitens* | - | O |
| *Ranunculus circinatus* | 10.0 | O/F |
| *Zannichellia palustris* | 10.0 | R |
| **Site TRS** | **8.92 (8.97)** | |
| **TRS (weighted)** | **7.77** | |
| **PLEX (weighted)** | **7.04 (7.49)** | |
| **Ellenberg Fertility Score (weighted)** | **6.37 (7.44)** | |

According to the CSM guidance, Kenfig Pool's macrophyte community should be largely composed of *Chara* spp. *Chara aspera* and *Chara virgata* occur in the lake, both species occurring at high abundance (a survey by ENSIS Ltd in summer 2005 also recorded *Chara contraria* v. *hispidula*). The associates; *F. antipyretica*, *Nitella* spp (*flexilis*) and *Potamogeton gramineus* (and *P. nitens*?) occur alongside. The fringing vegetation is as expected for the habitat type, comprising *Schoenoplectus tabernaemontani*, *Phragmites australis* and *Bolboschoenus maritimus*. Overall, at least 7 out of 10 vegetated sample spots include at least

1 characteristic species (81 % for the wader survey, but only 55 % for the boat survey). Although *Chara* spp. are dominant, Kenfig Pool's macrophyte flora is particularly rich, with 15 submerged /free-floating species represented alongside a wide diversity of emergent and marginal species.

Macrophyte community structure

*Chara* spp. appear to cover at least 50 % of the photic zone. Secchi depth was 1.72 m and *C. virgata* was found growing to a depth of 2.1 m and *C. aspera* to a depth of 1.4 m. The absence of charophytes from the deepest areas of the lake may be a cause for concern. Possible explanations for charophyte absence from the deepest areas include: a) charophytes are outcompeted by other species in the deeper areas b) there are 'holes' in the chara beds, c) charophyte cover is seasonally variable, with *Chara* dominating earlier in the season. Kenfig Pool's surface sediment diatom assemblage described in Monteith (ed.) (1996) is dominated by small *Fragilaria* spp., indicating that light penetration is sufficient to support diatom growth on the lake bottom.

Many different macrophyte growth forms are represented in the lake – isoetids (*L. uniflora*), free-floating species (*L. trisulca*), charophytes (*C. aspera, C. virgata, N. flexilis*), mosses (*F. antipyretica*), submerged fine/strap-leaved species (*M. alterniflorum, M. spicatum, P. gramineus, P. pusillus, P. trichoides, Ranunculus circinatus, Z. palustris*), submerged broad-leaved species (*P. graminaeus, P. nitens*), free-floating species (*L. trisulca*) and emergents (*Alisma plantago-aquatica, Baldellia ranunculoides, Eleocharis palustris, Iris pseudacorus, B. maritimus, S. tabernaemontani*, *P. australis, M. trifoliata*). No floating-leaved species are represented, but *Nymphaea alba* was formerly present at the site (Davidson & Appleby, 2003).

Although several different species capable of exploiting eutrophic conditions are present (*C. demersum, Z. palustris, P. pusillus, M. spicatum*), none are dominant in the lake, and more mesotrophic species such as *P. gramineus* and *L. uniflora* persist. This is reflected by the relatively low TRS and fertility scores for a high alkalinity water body.

Negative indicator species

*E. canadensis* is present, but at low abundance only, although this species was not recorded in the previous survey (Monteith ed., 1996). No other non-natives are present in the lake. Species usually associated with raised nutrient levels (e.g. *Z. palustris, M. spicatum*) are present, but at low abundance only, suggesting that nutrient concentrations are relatively low. Filamentous algal cover is low (mean cover = 1, median = 1), with no sample spots supporting cover scores of 3.

Water quality

The mean annual TP concentration is ~ 20 $\mu gl^{-1}$, which is within the target range for the habitat feature type. Chl *a* levels are low throughout the year (3.9 $\mu gl^{-1}$ annual average). High alkalinity (1558 $mgl^{-1}$) values reflect the proximity of the site to the sea. High calcium concentrations may reflect the marine shell enriched dune sand and also inflow from a deep carbonate-rich aquifer. Annual average pH (7.90) is within the expected range for the feature type. The lake was isothermal and well oxygenated (~ 8 $mgl^{-1}$ from 0-2 m depth) on the September 2003 sampling date. Water quality is supportive of favourable condition.

Hydrology

The lake appears to have a natural hydrological regime. It is fed by dune seepage, three small ephemeral streams, and possibly a deep Carboniferous Limestone aquifer (Davidson & Appleby, 2003). Since the lake is mainly groundwater-fed, it is difficult to estimate the exact catchment area. The extent of the drainage systems leading from the M4 motorway and the town of North Cornelly are also unknown, however it seems likely that most industrial and urban drainage bypasses the site (Monteith (ed.), 1996). Three small streams flowing into the site are thought to be the source of plant nutrients and in 1984 may have received some inputs from waste paper sludge treatment that was spread on adjacent fields. The aquifer may be a threat in that it could convey various pollutants from landfill quarries (ENSIS, 1996).

Lake substrate

The substrate of the lakeshores and margins (to ~ 1.5 m depth) is mostly composed of unconsolidated sand. The lake bottom is silty at water depths of > 1.5 m. The shoreline more or less retains its natural character, although there is public access to a beach area to the south side of the lake, which is used for paddling and bathing.

Sediment load

The solid geology of Kenfig Pool's catchment is sedimentary, consisting of Triassic mudstones. The predominant land cover across catchment is improved grassland (~ 50 %), with arable land accounting for 11 % and dune grassland 12 % of the catchment area. However, as noted above, since the lake is mainly groundwater-fed, it is difficult to estimate the exact catchment area. There is public access to a beach area to the south side of the lake, which is used for paddling and bathing and in close proximity to the lake's southeastern shore there is a caravan site. Radiometric dating results indicate a small but significant increase in sediment accumulation rates over the last 20 years (Davidson & Appleby, 2003), which suggests slightly increased sediment loads.

Indicators of local distinctiveness

Kenfig Pool is Glamorgan's largest natural lake. The site is noted for its aquatic macrophyte flora and is a relatively species rich lake for the UK (see James *et al*., 2005). *Baldellia ranunculoides* occurs at the site, an uncommon species for Wales. A wide range of *Potamogeton* species are recorded close to their range limit (e.g. *P. lucens, P. gramineus* and *P. trichoides*) and the site is one of only two lakes in Wales to record *Potamogeton* x *nitens*. Kenfig Pool is the best example of a 'dune lake' in Wales (the other significant one, Llyn Coron – see section 4.13, suffers from eutrophication). Kenfig Pool is an important site for over-wintering wildfowl, including bittern (Davidson & Appleby, 2003).

Palaeolimnological evidence

Previous palaeolimnological work at Kenfig Pool demonstrated that sedimentary diatom preservation was poor (Allott *et al*., 2001). However Davidson & Appleby (2003) employed alternative palaeolimnological techniques of sedimentary *Characeae* oospore and cladoceran remain analysis. Their results suggest that there has been a reduction in the conservation value of Kenfig Pool in terms of its submerged vegetation. This decline is reported to have occurred in tandem with changes in the cladoceran community that are indicative of an increase in fish predation pressure. Records of fish stocking for this period support this hypothesis.

Summary
Kenfig Pool is an important conservation resource and is a unique habitat type, not only in Wales, but also in the UK as a whole (Davidson & Appleby, 2003). The lake is not a classic example of its Annex I feature type, but rather a hybrid between a hard oligo-mesotrophic water, a dune slack lake and a lowland naturally meso-eutrophic lake.

A WFD risk assessment for Kenfig Pool reported that the site was probably not at risk of either diffuse / point-source pollution or physical / morphological alteration. The site currently supports low nutrient levels (20 $\mu gl^{-1}$), which are within the target range for the feature type, suggesting that nutrient enrichment is not a problem at Kenfig Pool. However, since improved grassland and arable land constitute a large proportion of the catchment area and taking into consideration other potential sources of pollutants within the catchment (e.g. landfill sites / caravan park / visitor recreation), nutrient concentrations should be closely monitored. Data from Monteith (ed.) (1996) report annual average TP and Chl *a* concentrations of 32 $\mu gl^{-1}$ and 17.8 $\mu gl^{-1}$ respectively, suggesting that nutrient levels decreased from 1996 to 2003, which can only be of benefit to safeguarding the lake's ecological functioning.

Palaeolimnological evidence from *Characeae* oospore and cladoceran analysis, in association with fish stocking records, indicates that the lake's conservation value has declined over the last 55 years. Fish stocking practices and manipulation may be implicated in this decline. Although the natural fish population is probably eel and stickleback, the lake has a very long history of fish stocking dating back to at least the 1500s, and has variously supported roach, rudd, pike, bream, carp, tench, perch, rainbow trout and brown trout. Most of these populations seem to have required regular stocking to maintain them. Today there are rudd, tench, pike and possibly perch in the lake. The presence of carp is of greatest concern and CCW are currently initiating a netting programme for their removal (Hatton-Ellis, *pers com*). For furthur recommendations on the site's fishery management and on the future overall management of the site, please refer to Davidson & Appleby (2003) and Giles & Associates (2003).

The current ecological functioning, biological community and water chemistry of the lake appear favourable**.** However, given that Kenfig Pool's ecosystem structure may be highly dependent upon fish stocking practices, it may be pertinent to place the site in **unfavourable, recovering** status until carp populations have been removed.

**Recommendations**

- The removal of the few remaining carp is an essential prerequisite to the site achieving favourable status.
- We recommend that the site is closely monitored and management practices reviewed on a regular basis to ensure that Kenfig Pool's aquatic ecosystem functions at optimal levels.

**Table 4.7.3: Kenfig SAC: Overview**

| Water Body | Status | Reason(s) for Failure | Comments |
|---|---|---|---|
| Kenfig Pool | Unfavourable (recovering) | Introduced fish (carp) | Generally in good ecological condition. If carp removal can be carried out, favourable condition should follow. |
| **Overall SAC Status** | **Unfavourable** | | |

## *4.8 Llyn Dinam SAC*

### 4.8.1 Llyn Dinam (HA, V)

Annex 1 type: H3150: Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation. Favourable Condition Table 5.

**Table 4.8.1: ConditionAssessment Summary Table for Llyn Dinam.**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | ≥ 6 of the characteristic species listed in Box 4 and 1 broadleaved *Potamogeton* species | **X** | No broadleaved *Potamogeton* spp.<br>5-6 characteristic species:<br>3-4 *Magnopotamion* species: *P.berchtoldii*, *C.vulgaris*, *Callitriche* sp. & *N. flexilis*.<br>2 *Hydrocharition* species: *Lemna minor* & *Lemna trisulca.* |
| | No loss of characteristic species | - | |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) should have ≥ 1 characteristic species | ✓ | 90% of shore and 93% of boat vegetated sample spots comply |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | *Elodea canadensis* present, but at low frequency |
| | Benthic and epiphytic filamentous algal cover <10% (non-*Chara*) | **?** | *Hydrodictyon* sp.<br>Mean cover; shore = 1.3, boat = 2.0 |
| **Macrophyte community structure** | Characteristic vegetation zones should be present. Extensive beds of submerged macrophytes should be present | ✓**?** | Extensive macrophyte beds growing across lake bottom. Dense marginal vegetation. Very limited *L. uniflora* lawn. |
| | Maximum depth distribution should be maintained | - | $Z_{max}$ = 1.8 m, $Z_s$ = 1.5 m, *P. berchtoldii, C.demersum* & *N. flexilis* growing to $Z_{max}$. |
| | At least the present structure should be maintained | - | |

**Table 4.8.1 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels: TP target / limit = 50 $\mu gl^{-1}$ (range 35-100 $\mu gl^{-1}$) | **X?** | TP = 58 $\mu gl^{-1}$ (2003/4 mean) Spring = 34 $\mu gl^{-1}$ (2004 mean TP = 76 $\mu gl^{-1}$ in GB lakes database) |
| | Stable pH / ANC values: pH >7.00 and <9.00; ANC > 20 | ✓ | pH = 7.7; ANC = 1790$\mu eql^{-1}$ |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 $mgl^{-1}$) | ✓ | ~ 10 $\mu gl^{-1}$ from 0 - 1 m |
| | No excessive growth of cyanobacteria or green algae | ✓ | No blooms recorded |
| **Hydrology** | Natural hydrological regime | ✓ | |
| **Lake substrate** | Natural shoreline maintained | ✓**?** | Shoreline development index = 1.7 Some areas rough-grazed to shore |
| | Natural and characteristic substrate maintained | ✓ | Predominantly silt |
| **Sediment load** | Natural sediment load maintained | ✓**?** | |
| **Indicators of local distinctiveness** | Distinctive elements maintained at current levels and/or in current locations | ✓ | *Elatine hydropiper* present (O). RSPB reserve – supports a significant wildfowl population |
| **Environmental disturbance** | Note environmental disturbance factors and assess impact | | |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | **X** | Burgess *et al*. (2005) 0-20 cm core: Sq chord dist = 0.830 significant floristic change –eutrophication |

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

Extent

The surface area of the lake is 9.7 ha, with a volume of 136.3 $x10^3 m^3$.

Macrophyte community composition

The aquatic vegetation of Llyn Dinam keys out as a Type 10A "eutrophic" assemblage (Palmer, 1992). Based on the submerged and floating leaved vegetation only (Table 4.8.2), the average Trophic Rank Score (TRS) of this site is 8.4 (134/16).

**Table 4.8.2: Macrophyte community composition for Llyn Dinam, including trophic scores. Figures in brackets indicate calculated values for 1993 survey (Allott *et al*., 1994).**

| Submerged and floating species | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Callitriche hermaphroditica* | 8.5 | F |
| *Ceratophyllum demersum* | 10.0 | D |
| *Chara vulgaris* | 8.5 | R |
| *Elatine hydropiper* | - | O |
| *Eleocharis acicularis* | 8.5 | R |
| *Elodea canadensis* | 8.5 | R |
| *Fontinalis antipyretica* | 6.3 | D |
| *Lemna minor* | 9.0 | F |
| *Lemna trisulca* | 10.0 | D |
| *Littorella uniflora* | 6.7 | R |
| *Myriophyllum spicatum* | 10.0 | F |
| *Nitella flexilis* (agg.) | 5.5 | F |
| *Nuphar lutea* | 8.5 | F |
| *Nymphaea alba* | 6.7 | F |
| *Potamogeton berchtoldii* | 7.3 | O |
| *Potamogeton pectinatus* | 10.0 | R |
| *Zannichellia palustris* | 10.0 | O |
| **Site TRS** | **8.4** | |
| **TRS (weighted)** | **8.27 (8.30)** | |
| **PLEX (weighted)** | **6.90 (7.06)** | |
| **Ellenberg Fertility Index (weighted)** | **6.69 (6.87)** | |

Llyn Dinam is surrounded by dense marginal vegetation of the *Scirpo-Phragmitetum* type, predominantly comprising *P. australis*, *S. lacustris* and *S. erectum*, with *T. latifolia*, *T. angustifolia*, *P. arundinacea* and *A. plantago-aquatica* occurring at lower abundance. In terms of its floating and submerged flora, Llyn Dinam supports a number of *Magnopotamion* and *Hydrocharition*-type species. The characteristic *Magnopotamion* taxa include *P. berchtoldii*, *C. vulgaris* and *Callitriche* spp., with *N. flexilis* (agg.) occurring as a frequent component of the assemblage. *Magnopotamion* associates include *C. demersum, P. pectinatus, Z. palustris* and *M. spicatum*. The only characteristic *Hydrocharition* species occurring in Llyn Dinam are *L. trisulca* and *L. minor*. The *Hydrocharition* associates are *Callitriche* spp., *N. lutea* and *N. alba*. *C. demersum* and *L. trisulca* are the dominant submerged macrophytes. The dominance of *C. demersum* suggests that the lake has raised nutrient levels. The absence of submerged broad-leaved *Potamogeton* species suggests unfavourable condition of the site in terms of macrophyte community composition.

Both the weighted PLEX and fertility indices suggest a slight reduction in trophic status since 1994.

Negative indicator species

The naturalised non-native *E. canadensis* occurs in the lake, but is rare.

Macrophyte community structure

The vegetation of Llyn Dinam is typical for the lake type; a dense marginal reedbed of the *Scirpo-Phragmitetum* type surrounds the lake and the main water body supports extensive beds of macrophytes that grow to the maximum depth of the lake. *C. demersum* is the dominant macrophyte species, and alongside *N. flexilis* (agg.), it grows to a depth of ~ 1.8 m. *P. berchtoldii* also grows to 1.8 m depth, but it was rare at the time of survey. *N. lutea* and *N. alba* are frequently observed growing at depths of 0.75 - 1.1 m. *E. hydropiper* is present to depths of 1.4 m, although it is more common in shallower water. There are no lawns of *L. uniflora* in the shallower water. Many different macrophyte growth forms are represented in the lake – isoetids (*L. uniflora*), free-floating species (*L. trisulca, L. minor*), charophytes (*C. vulgaris, N. flexilis*), mosses (*F. antipyretica*), submerged fine/strap-leaved species (*M. spicatum, P. pectinatus, Z. palustris*), (*P. graminaeus, P.* x *nitens*), free-floating species (*L. trisulca*) and emergents (*Sparganium erectum*, *A. plantago-aquatica, E. palustris, Eleocharis multicaulis, I. pseudacorus, S. lacustris*, *P. australis, P. arundinacea, T. angustifolia, T. angustifolia, M. trifoliata*). No submerged broad-leaved macrophyte species are present.

Water quality

pH (7.7) is within the range expected for the feature type. Llyn Dinam is not sensitive to acid deposition since the ANC of the lake is high (1790), reflecting high alkalinity of the lake waters and the coastal nature of the site. Based on four seasonal measurements (Dec'03, Mar'04, Aug'04 and Oct'04), the mean annual TP concentration for Llyn Dinam is 58 $\mu gl^{-1}$, with the Mar'04 measurement being recorded as 34 $\mu gl^{-1}$. The spring TP concentration lies below the 50 $\mu gl^{-1}$ target for the lake type, whereas the mean annual concentration is > 50 $\mu gl^{-1}$. Allott *et al*. (2001) reported diatom-based estimates of historical change (pre-1850 AD to the present) in TP concentrations of almost 100 $\mu gl^{-1}$. In 1996, the mean annual TP concentration of Llyn Dinam was 112 $\mu gl^{-1}$ (Bennion *et al*., 1996) suggesting that although the current TP of the lake is above the target concentration, the lake may be in the process of recovery from a previous phase of enrichment. With further measures to reduce nutrient inputs to the lake, TP concentrations might be expected to return to favourable conditions in the future. Chl *a* of the site is relatively high (16.2 $\mu gl^{-1}$), suggesting relatively high algal production. TN and $NO_3^-$-N concentrations are also relatively high, at 1.5 and 0.47 mgl-1 respectively. The lake was isothermal and well oxygenated (~ 10 $mgl^{-1}$ from 0-1 m depth) on the September 2003 sampling date. Water quality data suggest unfavourable condition, although as noted above, nutrient levels appear to have decreased in recent years.

Hydrology

Llyn Dinam drains a very low lying catchment area of 377 ha through which flows one minor stream and a series of small artificial drainage channels (Allott *et al*., 1994). The possibility of diffuse pollution entering from the adjacent Llyn Penrhyn (into which RAF Valley Sewage Treatment Works discharges) is the subject of a Review of Consents investigation.

Lake substrate

The substrate of the lake is predominantly silt, although the marginal area in transect 3 consists of a coarser mixture of boulders, cobbles and gravels.

Sediment load

An extensive area of reedbed surrounds the lake, although in the north there is a limited stretch of open shoreline. The small catchment of the lake is underlain almost entirely by sedimentary rocks, and the cambric stagnogley soils are slowly permeable, seasonally waterlogged fine loams. The geology and soils supports agricultural land, which is managed in places for arable and better quality rough grazing utilised for sheep and cattle. Drainage from agricultural land may constitute relevant land-use impacts in the catchment, potentially increasing nutrient inputs Additionally, the small village of Caergeiliog and the A5 road lie in Llyn Dinam's catchment, from which run-off may also be received (Allott *et al*., 1994).

Indicators of local distinctiveness

The site supports *Elatine hydropiper*. In September 2003, this species was found growing in water up to 1.5 m deep. The Valley Lakes are of ornithological interest for over-wintering wildfowl: they are especially important for shoveler; other species include teal, tufted duck, pochard and goldeneye. The vegetation cover also provides breeding habitat for a variety of wetland birds (http://www.ccw.gov.uk/protected_sites) and the site is an RSPB reserve.

Palaeolimnological evidence

Burgess *et al*. (2005) reported that there have been significant changes in the diatom flora from the bottom (20 cm) to the top of a sediment core (squared chord distance dissimilarity score = 0.830). The diatom species shifts are indicative of eutrophication. Similar findings were reported by Haworth *et al*. (1996).

Summary

Overall it would appear that Llyn Dinam is in **unfavourable** condition, principally because broad-leaved *Potamogeton* species are absent from the macrophyte assemblage and the mean annual average TP concentration is above the target/limit for the feature type. However, it appears that nutrient levels have decreased since 1996.

At the time of Llyn Dinam's notification as a component of the Valley Lakes SSSI, the lake was reported to support *Potamogeton gramineus*. This species was not recorded during the 2003 survey and may have been lost through eutrophication. However, its absence from the survey may be a false negative. Further macrophyte surveys are recommended to determine the status of *P. gramineus* in Llyn Dinam. *P. gramineus* is present in Kenfig Pool, which has a similar coastal location, basin morphology, pH and alkalinity, but a sandy substrate and much lower concentrations of both phosphorus and nitrogen. It is not known whether reduction of nutrient levels in Llyn Dinam could lead to recovery of *P. gramineus* populations, or whether contemporary luxuriant growths of *C. demersum* would not afford *P. gramineus* a suitable niche.

*C. demersum* populations should be monitored to ensure that this species does not increase in abundance to the detriment of other less pollution-tolerant macrophyte species.

**Recommendations:**

- The nutrient status of Llyn Dinam appears to be moving towards favourable condition. However, continued management action (including continued reduction of catchment nutrient inputs) is needed to maintain this trajectory.
- Coarse fish populations in the lake should be monitored to ensure that they are no interfering with the recovery of the lake.
- Further survey work to confirm the presence of *P. gramineus* would be beneficial.

**Table 4.8.3: Llyn Dinam SAC: Overview**

| Water Body | Status | Reason(s) for Failure | Comments |
|---|---|---|---|
| Llyn Dinam | Unfavourable (recovering) | Few characteristic species. Eutrophication. | Nutrient levels appear to be decreasing |
| **Overall SAC Status** | **Unfavourable** | | |

## *4.9 Llyn Syfaddan / Llangorse Lake SAC*

### 4.9.1 Llangorse Lake (HA, V)

Annex 1 type: H3150: Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation. Favourable Condition Table 5.

**Table 4.9.1: ConditionAssessment Summary Table for Llangorse Lake.**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | ≥ 6 of the characteristic species listed in Box 4 and 1 broadleaved *Potamogeton* species | ✓ | 9 characteristic species:<br>5 *Magnopotamion* species (including 2 broadleaved *Potamogeton* spp): *P.lucens, P. perfoliatus, P. pusillus, C. globularis, R. circinatus.*<br>4 *Hydrocharition* species: *L. trisulca, L. gibba, L. minor, S. polyrhiza*. |
| | No loss of characteristic species | ✓ | No significant loss since 1994 |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) should have ≥ 1 characteristic species | ✓ | 91 % of vegetated sample spots comply (98% wader, 78% boat) |
| **Negative indicator species** | Non-native species absent or present at low frequency. *Elodea canadensis / nuttallii* < 50% frequency or no new colonisation | **X?** | *E. canadensis* and *E. nuttallii* present in 55% and 90% of vegetated wader and boat sample spots respectively. *E. nuttallii* dominant. |
| | Benthic and epiphytic filamentous algal cover <10% (non-*Chara*) | **✓?** | Mean cover = 0.3, median = 0<br>No sample spots have scores of 3 |
| **Macrophyte community structure** | Characteristic vegetation zones should be present. Extensive beds of submerged macrophytes should be present | **✓?** | Dense fringing emergent reedbeds in some areas. Extensive macrophyte beds growing across lake bottom to depth of 2.3 m |
| | Maximum depth distribution should be maintained | **-** | $Z_{max}$ = 7.5 m, $Z_{mean}$ = 2.0 m, $Z_s$ = 1.2 m, $Z_v$ = 2.3 m |
| | At least the present structure should be maintained | **-** | Baseline survey |

**Table 4.9.1 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels:<br>TP target / limit = 35 $\mu gl^{-1}$ | **X** | TP = 138 $\mu gl^{-1}$ (EA 04 mean)<br>SRP = 60 $\mu gl^{-1}$ (EA 04 mean)<br>TN = 1.95 $mgl^{-1}$; TON = 0.80 $mgl^{-1}$;<br>Chl *a* = 16.7 $\mu gl^{-1}$ (range=7.7–29.0) |
| | Stable pH / ANC values:<br>pH >7.00 and <9.00; ANC > 20 | ✓ | pH = 7.9 (range = 7.3 – 9.0)<br>ANC = 1790 $\mu eql^{-1}$ |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 $mgl^{-1}$) | ✓ | Gradual decrease from 9.5 to 6.0 $mgl^{-1}$ from 0 - 5 m |
| | No excessive growth of cyanobacteria or green algae | ✓ | No blooms recorded |
| **Hydrology** | Natural hydrological regime | ✓ | Appears natural |
| **Lake substrate** | Natural shoreline maintained | **X?** | Shoreline development index = 1.50<br>Dense reedbed / alder carr around lake, backed by grazed improved grassland. Shoreline extensively poached locally |
| | Natural and characteristic substrate maintained | ✓ | Silty substrate in marginal and deeper water areas |
| **Sediment load** | Natural sediment load maintained | **?** | Transect 3 shoreline extensively poached by livestock (sheep and cattle) |
| **Indicators of local distinctiveness** | Distinctive elements maintained at current levels and/or in current locations | **X?** | Site renowned for its flora and recognised for its high biodiversity.<br>Lake used by a variety of wildfowl. |
| **Environmental disturbance** | Note environmental disturbance factors and assess impact | **X** | Watersports (waterskiing, motor boating, sailing) and fishing. Outdoor pursuits.<br>Lake no longer receives partially treated sewage effluent (1992). |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | **X** | Bennion (2004): 0-123 cm dated core: Sq chord distance = 1.193 = significant floristic change: Eutrophication: 1970s -early '80s. Now recovering, but still enriched (Bennion & Appleby, 1999) |

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

Extent

The lake lies at an altitude of 155 m. It has a surface area of 139 ha and a volume of 2780 $x10^3m^3$.

Macrophyte community composition

The aquatic vegetation of Llangorse Lake keys out as a Type 10B "eutrophic" assemblage (Palmer, 1992). Based on the submerged and floating leaved vegetation only (Table 4.9.2), the average Trophic Rank Score (TRS) of this site is 9.13 (146/16). In 1995, Monteith ed. (1996) reported a TRS of 8.36 and described the site as Type 10A, suggesting that the site may have become more enriched over the last decade.

**Table 4.9.2: Macrophyte community composition for Llangorse Lake, including trophic scores. Figures in brackets indicate calculated values for 1995 survey (Monteith ed., 1996).**

| Submerged and floating species | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Ceratophyllum demersum* | 10.0 | A |
| *Chara globularis* | 8.5 | F |
| *Elodea canadensis* | 8.5 | F |
| *Elodea nuttallii* | 10.0 | D |
| *Lemna minor* | 9.0 | F |
| *Lemna trisulca* | 10.0 | D |
| *Lemna gibba* | - | O |
| *Myriophyllum spicatum* | 10.0 | A |
| *Nuphar lutea* | 8.5 | D |
| *Nuphar* x *spenneriana* | - | R |
| *Nymphaea alba* | 6.7 | R |
| *Nymphoides peltata* | - | A |
| *Persicaria amphibia* | 9.0 | R |
| *Potamogeton lucens* | 10.0 | O |
| *Potamogeton pectinatus* | 10.0 | O |
| *Potamogeton perfoliatus* | 7.3 | F |
| *Potamogeton pusillus* | 8.5 | Strandline only |
| *Ranunculus circinatus* | 10.0 | R |
| *Spirodela polyrhiza* | - | F |
| *Zannichellia palustris* | 10.0 | R |
| **Site TRS** | **9.13 (8.36)** | |
| **TRS (weighted)** | **8.84** | |
| **PLEX (weighted)** | **8.09 (7.63)** | |
| **Ellenberg fertility score (weighted)** | **7.70 (7.26)** | |

The lake meets its feature type targets for macrophyte community composition. It supports nine characteristic macrophyte species, including two broad-leaved *Potamogeton* species

(*Potamogeton lucens, Potamogeton perfoliatus*) and a good mix of characteristic *Magnopotamion* (*P. lucens, P. perfoliatus, Potamogeton pusillus*, *Chara globularis*, *Ranunculus circinatus*) and *Hydrocharition* (*Lemna trisulca, Lemna gibba, Lemna minor, Spirodela polyrhiza*) species. The representation of the characteristic species across the survey sections is high, with 91 % of all vegetated sample spots (98 % wader and 78 % boat) having at least one characteristic species.

Almost all characteristic species recorded in 1995 (Monteith ed., 1996) were also recorded in 2003, with the exception that *Potamogeton crispus* was rare in 1995 and absent in 2003 and *P. pusillus* was recorded as occasional in 1994 (the first record since 1973), but was only found on the strandline in 2003. The 2003 survey sections may have missed the small patchs of *P. crispus* and P. pusillus, or the early season *Potamogetons* may have been replaced by late summer species in 2003.

Negative indicator species

The lake supports the naturalised non-native species, *Elodea canadensis* and *Elodea nuttallii* at high frequency. These species occur at > 50% frequency (present in 55 % of wader and 99 % of boat vegetated sample spots (67 % overall)), indicating that the lake is in unfavourable condition. *Elodea nuttallii* was not recorded in 1995 (Monteith ed., 1996), suggesting that it is a recent introduction. Its appearance and rapid population expansion could potentially affect the population dynamics of other characteristic macrophyte species through competition.

Another non-indigenous macrophyte species, *Nymphoides peltata*, was first recorded in the lake in 1936 (Duigan *et al*., 1999) and remains abundant today. The increased abundance of the nutrient-tolerant, highly competitive species *C. demersum* since 1995 could indicate that the lake is becoming more enriched. However, the abundances of *Z. palustris* and *P. pectinatus*, two species indicative of eutrophic, turbid conditions, have remained stable.

Macrophyte community structure

Llangorse Lake is fringed partly by emergent stands of vegetation characteristic of its feature type, of which *Phragmites australis* and *Typha latifolia* are most dominant. These emergent stands are often flanked on the landward side by fen, alder/willow carr and wet grassland communities and on the open water side by floating leaved canopies of waterlilies. The lake also has a diverse submerged flora and supports a full complement of different macrophyte growth forms – charophytes (*C. globularis*), submerged fine/strap-leaved species (*P. pectinatus, Z. palustris*, *P. pusillus*, *E. nuttallii, E. canadensis, M. spicatum, R. circinatus, C. demersum*), submerged broad-leaved species (*P. perfoliatus, P. lucens*) free-floating species (*L. trisulca, L. minor, L. gibba, S. polyrhiza*), floating-leaved species (*N. lutea, N. alba, N. peltata, N,* x *spenneriana*) and emergents (*T. latifolia, P. australis, S. erectum, S. tabernaemontani, B. umbellatus, I. pseudacorus, E. fluviatile, E. palustris, A. plantago-aquatica, P. amphibia*). The diversity of macrophyte growth forms suggests that the lake has a high structural diversity that is of benefit to aquatic macroinvertebrates and other aquatic life. The maximum depth of macrophyte colonisation in September 2003 (230 cm) was similar to that reported in Monteith ed. (1996) during a September 1995 survey (~200 cm) In 2003, the species growing to ~ 200 cm included *E. nuttallii, C. demersum*, *L. trisulca, M. spicatum* and *N. lutea*.

Water quality

Monteith ed. (1996) reported a mean annual (1995-1996) TP concentration of 118 $\mu gl^{-1}$. In 2003, the mean annual TP concentration was similar (120 $\mu gl^{-1}$), but in 2004, the concentration increased to 138 $\mu gl^{-1}$, perhaps indicating that the site was experiencing further nutrient enrichment, that residual sediment-bound phosphorus from an earlier enrichment period was being resuspended into the overlying waters or that climate conditions in 2004 were favourable to increased algal production. In 2005, the mean annual TP concentration decreased to 95 $\mu gl^{-1}$. Between 1995 and 2005, the mean annual chlorophyll *a* concentration has remained relatively constant (1995 = 14.5 $\mu gl^{-1}$; 2003 = 17 $\mu gl^{-1}$; 2004 = 17 $\mu gl^{-1}$; 2005 = 13 $\mu gl^{-1}$). Over the coming years, nutrient concentrations and algal productivity should be monitored in tandem with macrophyte / aquatic organism surveys to determine the impact of any changes in nutrient availability upon lake ecosystem functioning.

Hydrology

The hydrological regime of the lake appears to be natural. It receives water from the Afon Llynfi and from five small streams feeding its north and east shores (Monteith ed., 1996). Sections of the Afon Llynfi have been channelized in the past and it is important to ensure that any similar future works do not affect the seasonality of lake water levels which are important to the lake hydrosere (Duigan *et al*., 1999). The Afon Llynfi drains the lake at the north-west end to the River Wye (Monteith ed., 1996).

Lake substrate

The lake substrate in both the marginal and deeper water areas is entirely silty and appears to be natural.

Sediment load

The large catchment area is mainly used for agriculture and there is potential for the lake to receive sediment-laden run-off. However, the lake is partially surrounded by dense reedbeds, which will reduce the impact of any run-off. Livestock poaching heavily impacts the shoreline of survey section 3 probably increasing the sediment load and water turbidity in this area of the lake. Survey section 1 also receives light poaching.

Indicators of local distinctiveness

Llangorse Lake is the largest lake in South Wales and is located within the Brecon Beacons National Park. It is a shallow, productive lowland lake that is renowned for its rich flora and high biodiversity, including variable damselfly *Coenagrion pulchellum*. The lake is used by a variety of waterfowl.

Environmental disturbance

Llangorse Lake is used for a variety of water and shore-based leisure pursuits. Power boating, water skiing, motor boating, sailing and angling occur on the lake and there are a number of man-made structures including jetties, a sailing clubhouse and an outdoor pursuits centre on or near to the lakeshores. The lake's large catchment is mainly used for agriculture and contains several farms, Llangorse village, caravan sites and other tourist developments. Until the early 1990s, the lake received partially treated sewage effluent, which increased the nutrient loading of the site and contributed to a decrease in water quality. The first diversion of the sewage effluent in the early 1980s resulted in a dramatic improvement in lake water quality (Monteith ed., 1996, Bennion *et al*., 1997).

A number of non-indigenous plant and animal species have colonised Llangorse Lake. Introduced macrophyte species have been discussed above. The benthivorous fish species, bream (*Abramis brama*) was introduced to Llangorse in the early 1970s (Duigan *et al*., 1999). Whilst feeding, bream disturb the benthic sediments, increasing water turbidity and re-suspending nutrient-rich sediments, potentially affecting the ecological functioning of the lake ecosystem. Overall, the lake receives significant anthropogenic pressure both from population, recreation, agricultural use and introduced species, which may at times be in conflict with Llangorse Lake's conservation status.

Palaeolimnological evidence

Bennion ed. (2004) report a squared chord dissimilarity distance of 1.193 between the core top and bottom (123 cm) diatom assemblages of core LLAN3, indicating that there has been a significant degree of floristic change from core bottom to top (c.1830 to 1996). Bennion *et al*. (1997) report the results of diatom analysis of thirteen levels from the same core. The core bottom is dominated by non-planktonic small *Fragilaria* taxa, with the planktonic taxa, *Cyclostephanos dubius, Stephanodiscus parvus* and *Aulacoseira granulata* indicative of nutrient-rich alkaline waters occurring alongside, signifying that the lake has always been eutrophic. From ~1950 and coinciding with the start of agricultural intensification, small benthic *Fragilaria* taxa decrease in relative abundance and there is a corresponding increase in planktonic taxa.

Following the first sewage diversion in the early 1980s, increasing percentage relative abundances of *Aulacoseira subarctica, Aulacoseira ambigua* and *Cyclotella radiosa* occur. These taxa are more typical of mesotrophic waters and there is a corresponding decrease in diatom-inferred TP when these taxa increase in relative abundance, suggesting an improvement in water quality. Using the results of plant macrofossil analysis, Bennion ed. (2004) also reports that the lake has always supported a rich macrophyte flora, including a floating-leaved community. There is some suggestion that the lake originally supported a diverse charophyte community, but that this changed to a macrophyte community dominated by more nutrient-tolerant species such as *M. spicatum* and *C. demersum*. There appears to have been a shift in the functioning of the lake from benthic-littoral to a more pelagic system since ~1850, although as nutrient levels have decreased, the lake may shift back again.

Summary

Llangorse Lake is in **unfavourable**, **recovering** condition. The lake's water quality fails to meet the targets set for naturally eutrophic lakes, although considerable reductions in nutrient concentrations, particularly TP have occurred over the last few decades. The lake is considered to be a risk of both diffuse and point source pollution according to a WFD risk assessment, which is in agreement with the site condition assessment.

The full restoration of the lake to favourable condtion may be difficult to achieve because of residual nutrients stored within the lake's sediments. However, every effort should be made to restore the structure and functioning of the lake to a favourable, sustainable status, with particular attention being paid to the management of environmental factors which could cause the lake to switch from the plant-dominated to phytoplankton-dominated stable state. The removal of benthivorous fish may result in positive changes to lake turbidity, as could a reduction in livestock poaching of the lake margins. Reductions in the application of agricultural chemicals may also be beneficial.

Attention should also be focused on the dominance of the macrophyte community by non-native, highly competitive nutrient-tolerant species such as *E. nuttallii*. This species' continued dominance could result in changes to the native macrophyte community and lead to a macrophyte-poor assemblage due to its competitive advantage in eutrophic waters and the shading effects of its rapidly growing elongate stems (Preston & Croft, 1997). Future macrophyte surveys should closely monitor *E. nuttallii* populations to ensure that the characteristic species of naturally eutrophic lakes are not lost from Llangorse Lake.

**Table 4.9.3: Llangorse Lake SAC: Overview**

| Water Body | Status | Reason(s) for Failure | Comments |
|---|---|---|---|
| Llangorse Lake | Unfavourable (recovering) | Eutrophication. Dominance of alien macrophyte species (*Elodea nuttallii*). Poaching of shoreline. Disturbance from watersports. | Despite numerous pressures, plant community remains of interest. Recovering from past eutrophication. |
| **Overall SAC Status** | **Unfavourable** | | |

## *4.10 Migneint-Arenig-Dduallt SAC*

### 4.10.1 Llyn Conglog-Mawr (LA, V)

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

**Table 4.10.1: ConditionAssessment Summary Table for Llyn Conglog-Mawr.**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise) | **X** | Only 1 present: *L. uniflora* |
| | No loss of characteristic species (see Box 2) | **-** | Baseline survey |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) have ≥ 1 characteristic species | **X** | 8% of vegetated sample spots comply (wader = 9%, boat = 6%) |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | No introduced species |
| | Benthic and epiphytic filamentous algal cover <10% | ✓**?** | Mean score = 0.9; median = 1 1/49 (2%) of sample spots have a score of 3 |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (see Table 4) | **?** | No clear zonation – mosaic of macrophyte communities. |
| | Maximum depth distribution should be maintained | ✓ | $Z_{max}$ = 5.9 m, $Z_{mean}$ = 1.1 m, $Z_s$ = 0.8 m, $Z_v$ = 1.4 m |
| | At least the present structure should be maintained | **-** | Baseline survey |

**Table 4.10.1 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels:<br>TP target / limit = 10 µg P $l^{-1}$ | **X?** | TP = 16.4 µg$l^{-1}$ (Jun'05 data only)<br>TN = 0.24 mg$l^{-1}$; $NO_3^-$-N = 0.24 mg$l^{-1}$; Chl *a* = 4.2 µg$l^{-1}$ |
| | Stable pH / ANC values:<br>pH ~ 5.5 – 7.0 & ANC > 20 | **X** | pH = 6.1 (range = 5.8 – 6.4)<br>ANC = 0.84 µeq$l^{-1}$ - acid sensitive / impacted; DOC = 5.16 |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 mg$l^{-1}$) | ✓ | 8 - 9 mg$l^{-1}$ from 0 - 2.5 m depth |
| | No excessive growth of cyanobacteria or green algae | ✓ | No algal blooms |
| **Hydrology** | Natural hydrological regime | ✓ | Appears to be natural |
| **Lake substrate** | Natural shoreline maintained | ✓ | Shoreline development index = 1.22 |
| | Natural and characteristic substrate maintained | ✓ | Catchment geology predominantly sedimentary (some igneous rocks). Lake substrate mainly silty, with some areas of coarser substrate. |
| **Sediment load** | Natural sediment load maintained | ✓? | Catchment land cover mainly dry acid heath used for rough upland grazing. Significant areas of mire, marshy grassland and blanket bog. |
| **Indicators of local distinctiveness** | Distinctive elements maintained | ✓? | *Nitella gracilis* growing in lake – large bed recorded in section 2 in 2004. |
| | Minimal negative impacts and no fish farming | ✓? | - Lakeside vegetation rough grazed.<br>- *Calluna*-dominated heath partly burnt |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | **?** | Goldsmith *et al.* (2006): 0-30 cm: Bottom sample dissolved. Top sample dominated by non-planktonic taxa indicative of moderately acid waters (*F. exigua, E. incisa, B. vitrea, T. flocculosa, F. rhomboides*) |

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

Extent

Llyn Conglog-mawr lies at an altitude of 425 m. The surface area of the lake is 3.5 ha, with a volume of 38.5 x$10^3$$m^3$.

Macrophyte community composition

The aquatic vegetation of Llyn Conglog-mawr keys out as a Type 3 "oligotrophic" assemblage (Palmer, 1992). The site is rich in submerged and floating-leaved aquatic macrophytes, with 11 species recorded during the August 2004 field survey. Based on the submerged and floating leaved vegetation only (Table 4.10.2), the average Trophic Rank Score (TRS) for the lake is 5.43 (54.3/10).

**Table 4.10.2: Macrophyte community composition for Llyn Conglog-Mawr, including trophic scores.**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Fontinalis antipyretica* | 6.3 | A |
| *Juncus bulbosus* | 3.7 | R |
| *Littorella uniflora* | 6.7 | R |
| *Myriophyllum alterniflorum* | 5.5 | F |
| *Nitella flexilis* agg. | 5.5 | R |
| *Nitella gracilis* | 5.5 | R |
| *Nymphaea alba* | 6.7 | F |
| *Potamogeton natans* | 6.7 | O |
| *Potamogeton polygonifolius* | 3.7 | R |
| *Utricularia minor* | 4.0 | O |
| **Average TRS** | **5.43** | |
| **TRS (weighted)** | **6.13** | |
| **PLEX (weighted)** | **4.17** | |
| **Ellenberg Fertility Score (weighted)** | **4.6** | |

Macrophyte community composition in Llyn Conglog-mawr does not meet the targets for the feature type. Only one characteristic *Littorelletea* species is present (*L. uniflora*) and it is rare. Other characteristic species are present (*Nitella gracilis* (R), *Nitella flexilis* agg. (R) and *Utricularia minor* (O)), but the overall representation of all characteristic species across the survey sections is below target levels.

Negative indicator species

No non-native macrophyte species occur in the lake and the coverage of filamentous algae is low.

Macrophyte community structure

The margins of Llyn Conglog-Mawr are dominated by acid wet heath communities, with an extensive area of *Carex*-dominated swamp around the south shore. *Equisetum fluviatile* is common in many of the shallow areas and to a maximum depth of 140 cm in survey section 1, on the north-west side of the lake. Both *Nuphar lutea* and *Nymphaea alba* are common at the site, but restricted to the more sheltered areas along the southern shore. Submerged vegetation is sparse and mainly restricted to the shallow marginal areas in section 1. *Myriophyllum alterniflorum* is locally abundant while *Littorella uniflora, Utricularia minor* and *Juncus*

*bulbosus* are all present but rare. Survey section 2 is also sparsely vegetated, but has a large bed of the rare stonewort *Nitella gracilis* as well as *N. flexilis* agg. and *M. alterniflorum,* recorded growing to a maximum depth of 140 cm. Much of the peaty sediments are devoid of any vegetation. The water is fairly brown, explaining the shallow Secchi depth (0.8 m) recorded in August 2004, although the maximum depth of macrophyte colonization is almost double the Secchi depth.

Water quality

Llyn Conglog-mawr is a mildly acidic lake (mean pH 6.1) with low ionic content and a very low ANC value (0.84), suggesting it is poorly buffered and impacted by acid deposition. Although not considered as dystrophic, the lake shows strong influences of the peat soils in the catchment with elevated DOC values (5.16 $mgl^{-1}$) and resultant increases in iron mobility (mean annual Fe concentration 514 $\mu gl^{-1}$). Further phosphorus data are required for an objective assessment of nutrient levels to be made, however the relatively high TP value obtained in June 2005 (16.5 $\mu gl^{-1}$) and the slightly elevated mean annual chlorophyll *a* concentration (4.2 $\mu gl^{-1}$) suggests the site is moderately enriched, although the source of this enrichment is unclear. Nitrate concentrations are consistently low, indicating that the lake is nitrogen, not phosphorus limited, a character typical of dystrophic lakes.

Hydrology

The hydrological regime of the lake appears to be natural.

Lake substrate

The dominant lake substrates are silt, with some peaty areas and some areas of coarser substrates. The substrates appear to be natural.

Sediment load

Catchment landcover is predominantly dry acid heath, which is subject to rough grazing. There are also significant areas of peat-rich valley mires and blanket bog, the erosion of which could increase organic input to the lake.

Indicators of local distinctiveness

Llyn Conglog-mawr supports the rare charophyte species, *Nitella gracilis*. This species is classified as endangered in Britain and is afforded general protection under the Wildlife and Countryside Act, 1981. Some *Calluna* heath adjacent to the lake shows evidence of burning, although this is not thought to negatively impact upon the lake ecosystem.

Palaeolimnological evidence

Palaeolimnological data are presented in Goldsmith *et al*. (2006). Diatom analysis of a short sediment core was unable to establish any historical changes in water quality owing to poor preservation of diatoms down-core. However, the surface sediment diatom assemblage comprises periphytic diatom taxa typical of moderately acid water, the most abundant being *Fragilaria exigua, Eunotia incisa, Brachysira vitrea*, *Frustulia rhomboides* and *Tabellaria flocculosa*.

Summary

Llyn Conglog-Mawr is currently in **unfavourable** condition, supporting the growth of only one *Littorelletea* species, *L. uniflora* and a very low overall representation of other

characteristic species for the feature type. The lake has a low ANC (0.84) and has almost certainly been impacted by acid deposition. Since downcore diatom preservation is poor, it would be informative to examine plant macrofossil remains to determine the macrophyte history of the lake and assertain whether the lake previously supported a richer characteristic *Littorelletea* flora. In the absence of a rich natural *Littorelletea* flora, the lake may be better placed in the dystrophic feature type. Aside from its acid sensitivity, Llyn Conglog-Mawr could be considered a good example of a dystrophic lake. Further investigation is required.

Llyn Conglog-mawr supports the growth of the rare charophyte species, *Nitella gracilis*. Although the overall abundance of this species was low in 2004, it was locally abundant, with a large bed found growing in survey section 2 on a silty substrate. The extent of *N. gracilis* populations should be monitored over a long time scale, since interannual variation in population size is likely.

Llyn Conglog-mawr would be a good candidate site for long-term monitoring and experimental work to further elucidate patterns and processes of DOC release, transport and fate in upland systems.

## 4.10.2 Llyn y Dywarchen (LA, V - Peat)

Annex 1 type: H3160: Natural dystrophic lakes and ponds. Favourable Condition Table 7.

**Table 4.10.3: ConditionAssessment Summary Table for Llyn y Dywarchen.**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | No loss of characteristic species (see Box 5) | - | Characteristic species present: *C. rostrata, Sphagnum* sp. |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | No non-native species present Filamentous algal cover scores: Mean = 0; median = 0. No sample spots have a score of 3 |
| **Macrophyte community structure** | Characteristic zones of vegetation should be present (site-specific) | ? | No submerged higher plants, only emergent / marginal zone comprising some *J. effusus* and *C. rostrata*. |
| | Maximum depth distribution should be maintained | X? | $Z_{max}$ = 2.3 m, $Z_{mean}$ = 1.6 m, $Z_s$ = 0.8 m, $Z_v$ (higher plants) = 0.5 m<br>Brown-water lake with no submerged higher plants. |
| | At least the present structure should be maintained | - | |
| **Water quality** | Stable nutrients levels: Nutrient-poor<br>TP target / limit = 10 µg P $l^{-1}$ | X? | TP = 22.3 µg$l^{-1}$ (Jun'05 data only)<br>TN = 0.27 mg$l^{-1}$; $NO_3^-$-N = 0.19 mg$l^{-1}$<br>Chl *a* = 17.4 µg$l^{-1}$ |
| | Stable pH / ANC values:<br>pH <5.0 and ANC > 20<br>DOC > 6.0 mg$l^{-1}$ | X? | pH = 5.5 (range = 5.2 – 5.9)<br>ANC = -35.35µeq$l^{-1}$ = acid impacted; DOC = 4.33, Cond=22 |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 mg$l^{-1}$) | ✓ | ~ 9 mg$l^{-1}$ from 0 - 2 m depth |
| | No excessive growth of cyanobacteria or green algae | ✓ | No algal blooms |

**Table 4.10.3 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Hydrology** | Natural hydrological regime | ✓ | Appears natural |
| **Lake substrate** | Natural shoreline maintained | ✓ | Shoreline development index = 1.17 |
| | Natural and characteristic substrate maintained | ✓ | Lake catchment situated entirely on Upper Cambrian sedimentary rock. |
| **Sediment load** | Natural sediment load maintained | ✓ | - Lake has small catchment with land cover dominated by blanket bog.<br>- Peat is the dominant lake substrate, with some areas of boulders / bedrock |
| **Indicators of local distinctiveness** | Distinctive elements maintained at current extent / levels and / or in current locations | ✓? | - High altitude, exposed dystrophic brown-water lake surrounded by blanket bog<br>- No submerged higher plants |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | X | Goldsmith *et al*. (2006): 0-20 cm: Sq chord distance = 1.373 Significant floristic change. Acidification (*E. incisa* → *A. ralfsii* ) |

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

Extent

The lake lies at an altitude of 503 m. The surface area of the lake is 3.2 ha, with a volume of 51.2 x$10^3$m$^3$.

Macrophyte community composition

The aquatic vegetation of Llyn y Dywarchen keys out as a Type 1 "dystrophic" assemblage (Palmer, 1992). No submerged higher plants were recorded from the site in August 2004 and only one submerged species, *Sphagnum* sp. was used to calculate the average Trophic Rank Score (TRS) for the lake. Based on this one species only, the site TRS is 2.5 (2.5/1).

Only two wader and two boat transects were completed because the site was small and few macrophytes were seen. The only characteristic species growing at the site in 2004 were *Sphagnum* spp. and *Carex rostrata*. These species were present in 67 % of the wader survey vegetated sample spots, although only 6/40 sample spots were vegetated. No boat transect sample spots were vegetated.

**Table 4.10.4: Macrophyte community composition for Llyn y Dywarchen, including trophic scores.**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Sphagnum* sp. | 2.5 | R, but D in marginal area |
| **Average TRS** | **2.5** | |
| **PLEX** | **1.54** | |
| **Ellenberg Fertility Score** | **2.9** | |

Negative indicator species
No non-native macrophyte species were recorded in August 2004.

Macrophyte community structure
The margins were dominated by *Juncus effusus,* with occasional areas of sparse emergent *Carex rostrata*, which was recorded growing in water depths up to 50 cm. No submerged higher plants were recorded, but liverworts (including *Marsupella emarginata*), were locally common in the splash zone and to a depth of 10 cm.

Water quality
Llyn y Dywarchen is an exposed, shallow lake that is mixed throughout the water column and has high concentrations of dissolved oxygen. Lying within a small catchment and almost entirely surrounded by blanket bog, Llyn y Dywarchen has the appearance of a classic dystrophic brown-water lake The chemistry however is less typical of a dystrophic lake, with a mean pH of only 5.5 (dystrophic lake target is pH < 5.0) and a relatively low mean DOC concentration of only 4.33 $mgl^{-1}$ (target > 6 $mgl^{-1}$). Low ionic strength and the absence of high concentrations of weak organic acids which often help buffer dystrophic lakes, results in the site having a negative ANC, indicating that it has been impacted by acid deposition. More typical were the relatively low nitrogen concentrations and high TP concentrations, suggesting nitrogen is most likely to be the limiting nutrient (2005 / 2006 TP data report to follow). Chlorophyll *a* concentrations were higher than expected for a dystrophic upland lake.

Hydrology
The hydrological regime appears to be natural.

Lake substrate
Most of the lake margin comprises vertical peat to between 25 and 100 cm depth. The area of shore to the northeast of the lake is more gently sloping with boulders and exposed bed-rock as well as peat.

Sediment load
No information is available

Indicators of local distinctiveness
Llyn y Dywarchen is a dystrophic lake - a rare lake type in Wales.

Palaeolimnological evidence
Sediment core analysis suggests the site has always been acid, although it has become more acid over time. The squared chord dissimilarity distance between the core top and bottom samples is 1.373, indicating a significant change in the diatom flora between the two samples. The core bottom sample (20 cm) is dominated by acid water taxa – *Eunotia incisa*, *Aulacoseira perglabra*, *Pinnularia* spp. and *Frustulia rhomboides* var. *viridula*, whereas the core top sample is dominated by *Asterionella ralfsii*, an indicator of strongly acid waters. The presence of *A. ralfsii* is also indicative of peatland disturbance and nutrient enrichment (Monteith & Evans eds., 2000).

Summary
Llyn y Dywarchen is a relatively small, shallow, high altitude dystrophic lake, a rare lake type in Wales. Lake water chemistry is not however particularly characteristic for the lake type and no submerged higher plants were recorded growing in the lake in 2004. The lack of macrophytes does not necessarily indicate unfavourable condition for dystrophic lakes Enrichment of the site seems unlikely, particularly since the catchment is small and unimpacted. Furthermore, no filamentous algal growth has been recorded and water transparency is sufficient to enable macrophyte colonisation to a depth of at least 1 - 1.5 m. The site is located at a high altitude and in an exposed location, which may partly explain the scant macrophyte colonisation. Acidification of the site through acid deposition is also thought to help explain the lack of macrophytes.

Future condition assessments should examine whether there are any significant decreases in acidity or DOC concentrations, perhaps as a result of decreasing acid deposition. If acid deposition is decreasing and consequentially the impacts of acidification diminish (ANC should increase above zero), then *Sphagnum* spp. abundance may also decline and submerged higher plant species may begin to (re)colonise the site. We recommend that a sediment core is taken from the site and plant macrofossils examined to determine whether submerged macrophytes were ever a component of the lake ecosystem. This should provide evidence as to whether the present lake ecosystem condition is comparable to reference conditions.

At present, Llyn y Dywarchen is therefore considered to be in **unfavourable** status.

## 4.10.3 Llyn y Garn (LA, S)

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

**Table 4.10.5: ConditionAssessment Summary Table for Llyn y Garn.**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise) | ✓ | 4 present: *L. uniflora*, *L. dortmanna*, *I. lacustris, L. natans* |
| | No loss of characteristic species (see Box 2) | - | |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) have ≥ 1 characteristic species | ✓ | 84 % of wader and boat vegetated sample spots comply (wader = 79%, boat = 92%) |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | No introduced species |
| | Benthic and epiphytic filamentous algal cover <10% | ✓ | Mean cover score = 0.9; median = 1<br>No sample spots with scores of 3 |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (see Table 4) | ✓? | Mosaic of macrophyte species.<br>< 1 m: *L. uniflora, L. dortmanna*<br>0.75 – 1.5 m: *I. lacustris, P. natans, N. alba* & *N. flexilis*<br>1.5–1.7m: *M. alterniflorum & L. natans* |
| | Maximum depth distribution should be maintained | X? | $Z_{max}$ = 19.8 m, $Z_{mean}$ = 8.3 m,<br>$Z_s$ = 4.6 m, $Z_v$ = 1.7 m<br>Few plants growing at > 75 cm |
| | At least the present structure should be maintained | - | Baseline survey |

**Table 4.10.5 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels: TP target / limit = 10 µg P $l^{-1}$ | ✓? | TP = 6.0 µg$l^{-1}$ (Jun'05 data only) SRP = 6.0 µg$l^{-1}$ (mean '04-'05) TN=0.27 mg$l^{-1}$; $NO_3^-$-N=0.76 mg$l^{-1}$ Chl *a* = 2.8 µg$l^{-1}$ |
| | Stable pH / ANC values: pH ~ 5.5 – 7.0 & ANC > 20 | ✓ | pH = 6.4 (range = 6.3 - 6.7) ANC = 26 µeq$l^{-1}$ DOC = 3.01 mg$l^{-1}$, Cond = 33 µS$cm^{-1}$ |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 mg$l^{-1}$) | ✓? | ~9 mg$l^{-1}$ to 15 m depth, then sharp drop to 1 mg$l^{-1}$ between 15-18 m. |
| | No excessive growth of cyanobacteria or green algae | ✓ | No algal blooms |
| **Hydrology** | Natural hydrological regime | ✓ | Appears natural |
| **Lake substrate** | Natural shoreline maintained | ✓ | Shoreline development index = 1.73 |
| | Natural and characteristic substrate maintained | ✓ | Mixed igneous / sedimentary catchment geology. Lake substrate generally coarse (boulders / bedrock). |
| **Sediment load** | Natural sediment load maintained | ✓ | Steep slopes down to lakeshore. Small catchment - *Calluna*/*Vaccinium* dry acid heath dominates landcover. |
| **Indicators of local distinctiveness** | Distinctive elements maintained | ✓? | *L. natans* present in section 4 boat survey at water depth of 1.5 - 1.7 m |
| | Minimal negative impacts and no fish farming | ? | |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | ✓ | 0-26 cm: Sq chord distance = 0.388 No evidence of acidification. Planktonic taxa throughout, indicative of oligotrophic, circumneutral to mildly acid water conditions. |

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

Extent

The surface area of the lake is 8.6 ha, with a volume of 713.8 x$10^3$$m^3$.

Macrophyte community composition

The aquatic vegetation of keys out as a Type 2-3 "oligotrophic" assemblage (Palmer, 1992). Based on the submerged and floating leaved vegetation only (Table 4.10.6), the average Trophic Rank Score (TRS) for this site is 5.6 (44.8/8). The site is relatively species rich.

Llyn y Garn meets its feature type targets for macrophyte community composition. The lake supports four characteristic *Littorelletea* species - *Littorella uniflora, Lobelia dortmanna, Isoetes lacustris* and *Luronium natans* and the survey sections record a high coverage of these species as well as the presence of another characteristic species (*Nitella flexilis* agg.). Overall, 84 % of vegeated wader and boat sample spots have at least one characteristic macrophyte species.

**Table 4.10.6: Macrophyte community composition for Llyn y Garn, including trophic scores.**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Fontinalis antipyretica* (marginal only) | 6.3 | R (marginal only) |
| *Isoetes lacustris* | 5.0 | O |
| *Juncus bulbosus* | 3.7 | O |
| *Littorella uniflora* | 6.7 | F |
| *Lobelia dortmanna* | 5.0 | F |
| *Luronium natans* | - | R |
| *Myriophyllum alterniflorum* | 5.5 | R |
| *Potamogeton natans* | 6.7 | F |
| *Potamogeton polygonifolius* (marginal only) | 3.0 | R (marginal only) |
| *Nymphaea alba* | 6.7 | R |
| *Nitella flexilis* agg. | 5.5 | R |
| *Sphagnum* sp. (marginal only) | 2.5 | F (marginal only) |
| **Average TRS** | **5.6 (or 56.6/11 = 5.1)** | |
| **TRS (weighted)** | **5.59** | |
| **PLEX (weighted)** | **3.67** | |
| **Ellenberg Fertility Score (weighted)** | **4.11** | |

Negative indicator species

No non-native macrophyte species are present and the coverage of filamentous algae is low.

Macrophyte community structure

There is very little transitional vegetation on the steeply shelving boulder and cobble-dominated shore. In areas of finer sediment, *Littorella uniflora, Lobelia dortmanna* and *Isoetes lacustris* grow to a depth of 130 cm. The sheltered arm to the south of the main basin (survey section 4) is shallow (170 cm) and relatively species rich. A large bed of *Potamogeton natans* extends over much of the section with a small area of *Nymphaea alba*. Across the rest of this shallow lake, the submerged flora has a somewhat mosaic-like structure, although there is some degree of zonation. The shallow areas (to a depth of 100 cm)

are dominated by *L. uniflora, L. dortmanna* and *Juncus bulbosus* with *Myriophyllum alterniflorum and Nitella flexilis* also present. In deeper water (150-170 cm) there is a relatively dense bed of *Luronium natans* and occasional plants of *M. alterniflorum*.

Considering the water transparency at the site (460 cm), it is surprising that no plants grow beyond a depth of 170 cm and there are few plants growing at > 75 cm water depth. This suggests that either the water clarity at the time of the survey was unusually high, or perhaps that the lake substrate across much of the deeper areas is unsuitable for macrophyte colonisation.

The lake supports a wide range of different macrophyte growth forms – isoetids (*I. lacustris, L. uniflora, L. dortmanna*), charophytes and mosses (*N. flexilis* agg., *Sphagnum* spp*., F. antipyretica*), submerged fine/strap-leaved species including elodeids (*M. alterniflorum, J. bulbosus, L. natans*), floating-leaved species (*N. alba, P. natans, P. polygonifolius*) and emergents (*Juncus* spp*., Carex* spp.) – suggesting that the vegetation structure is good, providing a diversity of habitats within the lake, although as noted previously, the deeper areas of the lake are unvegetated.

Water quality

Being a relatively deep site, Llyn y Garn stratifies and there is a marked reduction in both dissolved oxygen and temperature at 15 m. The lake is circumneutral to mildly acidic (mean pH 6.4) with low ionic content. With an ANC value of 26, meeting its feature type target of 20, Llyn y Garn is considered sufficiently buffered and is not thought to have acidified. Palaeolimnological evidence (see below) further supports this conclusion. Uncertainty in the phosphorus data is low, with further data required to make a more objective assessment. However the June 2005 TP concentration (6 $\mu gl^{-1}$) and mean annual chlorophyll *a* concentration (2.8 $\mu gl^{-1}$) are both low and consistent with the site being oligotrophic.

Hydrology

The hydrological regime of the lake appears to be natural.

Lake substrate

The majority of the shore around the main lake basin shelves steeply and is dominated by boulders and cobbles, although there are some areas of finer sediment, particularly in the sheltered basin of the lake's southern arm.

Sediment load

Further information is required.

Indicators of local distinctiveness

In deeper water (150-170 cm) there is a relatively dense bed of *Luronium natans* (SH7617537502).

Palaeolimnological evidence

Fossil diatom data presented in Goldsmith *et al*. (2005) and Roebuck (2005) suggest that Llyn y Garn has not been acidified. Both the core top and bottom (25 cm) samples (Goldsmith *et al*., 2005) and the mid-core (5, 10 and 15 cm) samples (Roebuck, 2005) are dominated by small planktonic *Cyclotella* taxa typical of oligotrophic, circumneutral to mildly acid waters.

The squared chord distance dissimilarity score between core top and bottom samples is low (0.388), further supporting the inference of low floristic change in sedimentary diatom assemblages at Llyn y Garn.

Summary

Llyn y Garn is in overall **favourable** condition, supporting a macrophyte community composition typical of its feature type, with good representation of characteristic species. However, the abundance of the characteristic species across the lake is patchy and the maximum depth of colonisation is rather shallow considering the high water transparency at the time of survey. Macrophyte colonisation may therefore be limited by unsuitable substrates, particularly in deeper water areas.

A WFD risk assessment determined that Llyn y Garn is at risk of diffuse pollution, but probably not at risk of point source pollution or alien species. The lake has a small catchment that is steeply shelving with little vegetation cover; therefore potential sources of enrichment are limited, excepting nitrogen derived from atmospheric deposition.

The lake supports the growth of a relatively dense bed of *Luronium natans* on finer silty sediments in deeper water (150-170 cm) in the sheltered arm to the south of the main basin, Suitable conditions for the sustainable growth of *L. natans* should be maintained.

## 4.10.4Llyn Hesgyn (LA, V)

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

**Table 4.10.7: ConditionAssessment Summary Table for Llyn Hesgyn.**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise) | ✓ | 3 species present: *L. uniflora*, *S. angustifolium, I. lacustris* |
| | No loss of characteristic species (see Box 2) | ✓ | Similar species to those recorded in 2002 by Carvalho *et al*. (2003). |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) have ≥ 1 characteristic species | **X** | 42% of wader and boat vegetated sample spots comply (wader = 40%, boat = 46%) |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | No introduced species |
| | Benthic and epiphytic filamentous algal cover <10% | ✓ | Mean cover score = 1.0; median = 1<br>1 sample spot with a score of 3 |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (see Table 4) | ✓**?** | 25-75 cm: *L. uniflora, C. rostrata, C. hamulata,* mosses<br>75-180 cm: *S. angustifolium, C. hamulata, N. lutea, M. alterniflorum*<br>*I. lacustris* rare – growing at 50-75 cm |
| | Maximum depth distribution should be maintained | ✓ | $Z_{max}$ = 5.2 m, $Z_{mean}$ = 1.8 m, $Z_s$ = 1.0, $Z_v$ = 2.0 m |
| | At least the present structure should be maintained | ✓ | Similar structure to that recorded in 2002 by Carvalho *et al*. (2003). |

**Table 4.10.7 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels:<br>TP target / limit = 10 µg P $l^{-1}$ | **X?** | TP = 15.5 µg$l^{-1}$ (Jun'05 data only)<br>TN = 0.33 mg$l^{-1}$; $NO_3^-$-N = 0.28 mg$l^{-1}$<br>Chl *a* = 4.2 µg$l^{-1}$ |
| | Stable pH / ANC values:<br>pH ~ 5.5 – 7.0 & ANC > 20 | ✓ | pH = 6.2 (range = 6.0 – 6.6)<br>ANC = 77.45µeq$l^{-1}$<br>DOC=7.90 mg$l^{-1}$, Cond=34µS$cm^{-1}$ |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 mg$l^{-1}$) | ✓ | ~8 – 8.5 mg$l^{-1}$ from 0 - 4.5 m water depth, falling to 6.4 mg$l^{-1}$ at 5.0 m |
| | No excessive growth of cyanobacteria or green algae | ✓ | No algal blooms |
| **Hydrology** | Natural hydrological regime | ✓ | Appears natural |
| **Lake substrate** | Natural shoreline maintained | ✓ | Shoreline development index = 1.01 |
| | Natural and characteristic substrate maintained | ✓ | Underlying geology = mixed. Some igneous lava and tuff (36%), but predominantly sedimentary (64%).<br>Peat is the dominant substrate in the lake's marginal zone. Silty at depth. |
| **Sediment load** | Natural sediment load maintained | ✓**?** | Catchment land cover dominated by blanket bog. Grazed *Calluna*-dominated dry acid heath surrounds lake. |
| **Indicators of local distinctiveness** | Distinctive elements maintained | ✓**?** | |
| | Minimal negative impacts and no fish farming | ✓**?** | Livestock grazing in catchment<br>Lake privately fished<br>Some burning of dry acid heath |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | **X?** | Goldsmith *et al*. (2006) and Roebuck (2005). 0-26 cm: Sq chord distance = 0.620. Slight acidification, but evidence for recovery in top 5 cm. |

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

Extent

Llyn Hesgyn lies at an altitude of 425 m. The surface area of the lake is 3.1 ha, with a volume of 55.8 x$10^3$$m^3$.

Macrophyte community composition

The aquatic vegetation of keys out as a Type 3 "oligotrophic" assemblage (Palmer, 1992) with the characteristic taxa, *L. uniflora* and *I. lacustris*. The presence of *I. lacustris, M. alterniflorum* and *S. angustifolium* place it in the more oligotrophic type. The site is reasonably species rich and includes elements of a more mesotrophic "Type 5" assemblage (*N. lutea, F. antipyretica, C. hamulata*) and elements of a more dystrophic "Type 1" assemblage (*S. auriculatum, P. polygo*nifolius). Based on the submerged and floating leaved vegetation only (Table 4.10.8), the average Trophic Rank Score (TRS) for this site is 5.06 (45.5/9).

**Table 4.10.8: Macrophyte community composition for Llyn Hesgyn, including trophic scores.**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Callitriche hamulata* | 5.0 | D |
| *Fontinalis antipyretica* | 6.3 | R |
| *Isoetes lacustris* | 5.0 | R |
| *Littorella uniflora* | 6.7 | F |
| *Myriophyllum alterniflorum* | 5.5 | A |
| *Nuphar lutea* | 8.5 | A |
| *Potamogeton polygonifolius* | 3.0 | O |
| *Sphagnum auriculatum* | 2.5 | A |
| *Sparganium angustifolium* | 3.0 | A |
| **Average TRS** | **5.06** | |
| **TRS (weighted)** | **5.59** | |
| **PLEX (weighted)** | **4.53** | |
| **Ellenberg Fertility Score (weighted)** | **4.78** | |

Llyn Hesgyn partially meets its feature type target for macrophyte community composition. The lake supports three characteristic *Littorelletea* species: *L. uniflora, I. lacustris* and S. *angustifolium*, however the representation of these species across the survey sections is below the target for both the wader and boat transects.

Negative indicator species

No introduced macrophyte species were observed. Filamentous algal cover was low (mean cover score = 1.0, median = 1), with only 1 sample spot having a cover score of 3, indicating that the site is not enriched. Given the lake's pH (see below), the abundance of *S. auriculatum* is unlikely to be indicative of a site in unfavourable condition, but more likely reflects the dystrophic nature of the lake.

Macrophyte community structure

The marginal vegetation on the east of the lake (survey section 1) consists of a narrow band of *Juncus effusus*. Dense beds of *Carex rostrata* with associated *Sphagnum* swamp communities

dominate the remainder of Llyn Hesgyn's marginal zone. The submerged vegetation is found in a band from the shore generally to about 1.5 m depth. Along the rockier eastern shore *Littorella uniflora* is dominant and characteristically found in shallow water (0-0.5 m deep). Although *I. lacustris* was found at 0.5-1.0 m, it is rare at the site. *M. alterniflorum* and *C. hamulata* are dominant to depths of 100 cm and 150 cm respectively, beyond which no plants are found. The submerged flora of the west side is similar but no *Littorella* is found in the peaty sediments. *Nuphar lutea* and *Sparganium angustifolium* are locally common at maximum depths of 195 cm and 150 cm respectively.

The maximum colonisation depth is similar to that reported by Carvalho *et al*. (2003). The lake supports a wide range (particuarly for the feature type) of different macrophyte growth forms – isoetids (*I. lacustris, L. uniflora*), mosses (*S. auriculatum, F. antipyretica*), submerged fine-leaved, elodeids (*M. alterniflorum*), floating-leaved species (*N. lutea, N. alba, P. polygonifolius, S. angustifolium*) and emergents (*J. effusus, C. rostrata*) – suggesting that the vegetation structure is good, providing a diversity of habitats within the lake.

Water quality

Llyn Hesgyn is a mildly acidic lake (mean pH 6.2) with low ionic content. The site has an acceptable ANC value (77.45) however, suggesting it is well-buffered and has a low sensitivity to acidification. Although not considered as dystrophic, the lake shows strong influences of the peat soils in the catchment with high DOC values (7.9) and a corresponding increase in iron concentrations. Phosphorus concentrations require further investigation (2005 / 2006 data to follow), but the relatively high value obtained in June 2005 (above the 10 $\mu g\ l^{-1}$ target / limit for the feature type) suggests the site to be slightly enriched. Low nitrogen concentrations suggest that aquatic macrophyte growth is probably limited by the lack of available nitrogen from the peaty catchment soils.

Lake hydrology

The lake appeared to have a natural hydrological regime.

Lake substrate

The shoreline retained its natural character with lake substrates dominated by peat and boulders.

Sediment load

Although there is some rough upland grazing within the catchment, it is light and is not thought to be of sufficient intensity to cause increased sediment loading to the lake.

Indicators of local distinctiveness

The catchment of Llyn Hesgyn remains predominantly *Sphagnum* bog, which appeared to be in good condition with some heath that appeared to be actively managed by burning. No coniferous forestry plantations are present within the catchment. The lake is fished privately and contains pike, perch and minnows (the latter observed in this survey) (Ward, 1931; Roberts, 1995 in Carvalho *et al*., 2003).

Palaeolimnological evidence

Evidence of significant diatom floristic change and slight acidification from the bottom (26 cm) to the top of a sediment core is presented in Goldsmith *et al.* (2006). The core bottom

sample has a diverse assemblage of non-planktonic diatom species typical of mild to moderately acid waters e.g. *Fragilaria exigua, Achnanthes minutissima* and *Tabellaria flocculosa*. The most marked difference between the bottom and top samples was the increase in *Eunotia incisa* and *Aulacoseira distans* [cf. *septentrionalis*], in the latter. The squared chord distance dissimilarity score between the two samples was 0.620. Further mid-core diatom samples are presented in Roebuck (2005) and suggest that there may be evidence of recovery from acidification at the core top.

Summary

Llyn Hesgyn is a relatively small oligotrophic lake that appears to be in **favourable** condition. The macrophyte assemblage is species rich for this lake type, reflecting the rather mixed geology and soils present within the catchment. Fewer submerged and floating-leaved macrophyte species were recorded in 2004 (Goldsmith *et al.*, 2005) than in 2002 (Carvalho *et al*., 2003), although those that were absent in 2004 were recorded as rarities in 2002 (*P. berchtoldii*, *N. flexilis* agg.) and were only found growing in an area to the NW of the lake which was not covered by the 2004 survey transects. It is not thought therefore that the absence of these species in 2004 indicates negative impacts, rather transect locations and interannual / seasonal variation in macrophyte populations; although future macrophyte surveys are recommended to closely monitor species shifts. *I. lacustris* was recorded as abundant along the rocky eastern shore in 2002, but was rare in 2004, although colonisation depths were similar. Again, populations should be monitored.

Llyn Hesgyn supports a number of elodeid macrophyte species, including *M. alterniflorum* and *C. hamulata*, which suggest that the lake is not impacted by acidification. Monteith *et al.* (2005) reported the appearance of *M. alterniflorum* and *C. hamulata* in the Round Loch of Glenhead and Llyn Llagi respectively to coincide with the exceedance of zero alkalinity and the availability of DIC (dissolved inorganic carbon) for photosynthesis directly from the water column. Also present in Llyn Hesgyn is *F. antipyretica*, which along with other aquatic mosses is linked with non-acid conditions and the increasing availability of DIC (Brandrud, 2002).

Carvalho et al. (2003) reported that the FAB critical load was not exceeded at Llyn Hesgyn, although the critical loads of sulphur and sulphur + nitrogen predicted by the diatom model were exceeded. Diatom evidence from core top and bottom samples displayed in Goldsmith *et al.* (2005) suggests that Llyn Hesgyn has experienced significant floristic change, signifying slight acidification. Further mid-core diatom samples displayed in Roebuck (2005) suggest that although the lake has experienced slight acidification, there appears to be evidence of recovery towards the core top. It is suggested that the lake should be monitored in the future to determine whether this recovery trend continues.

## 4.10.5 Llyn Hiraethlyn (LA, V)

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

**Table 4.10.9: ConditionAssessment Summary Table for Llyn Hiraethlyn.**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise) | ✓ | 3 species present: *L. uniflora*, *L. dortmanna* & *I. lacustris* |
| | No loss of characteristic species (see Box 2) | **X?** | *L. natans* recorded in 2002 (Carvalho *et al.*, 2003). Absent from 2004 survey. Other species similar |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) have ≥ 1 characteristic species | ✓ | 99 % of wader and boat vegetated sample spots comply (wader = 98%, boat = 100%) |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | No introduced species |
| | Benthic and epiphytic filamentous algal cover <10% | ✓ | Mean cover score = 1.8; median = 2<br>14% (11/80) of sample spots have scores of 3 |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (see Table 4) | ✓**?** | 0.25 – 1.0 m: *L. uni, L. dort, J. bulb*<br>1.0 – 2.0m: *U. minor, L. dort, J. bulb*<br>0.8 – 4.0 m: *I. lac*, *M. alt* |
| | Maximum depth distribution should be maintained | ✓ | $Z_{max}$ = 9.0 m, $Z_{mean}$ = 2.8 m, $Z_s$ = 4.2 m, $Z_v$ = 4.0 m |
| | At least the present structure should be maintained | - | Baseline survey |

**Table 4.10.9 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels:<br>TP target / limit = 10 µg P $l^{-1}$ | ✓? | TP = 8.2 $\mu g l^{-1}$ (Jun'05 data only)<br>TN = 0.33 $mgl^{-1}$; $NO_3^-$-N = 0.51 $mgl^{-1}$<br>Chl *a* = 5.8 $\mu gl^{-1}$ |
| | Stable pH / ANC values:<br>pH ~ 5.5 – 7.0 & ANC > 20 | ✓ | pH = 6.3 (range = 6.1 - 6.6)<br>ANC = 25.10 $\mu eql^{-1}$<br>DOC=3.59$mgl^{-1}$; Cond=35$\mu Scm^{-1}$ |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 $mgl^{-1}$) | ✓ | 7 - 9 $mgl^{-1}$ from 0 - 9 m depth |
| | No excessive growth of cyanobacteria or green algae | ✓ | No algal blooms |
| **Hydrology** | Natural hydrological regime | ✓ | Appears natural |
| **Lake substrate** | Natural shoreline maintained | X? | - Shoreline development index = 1.27<br>- Heavy grazing around shoreline |
| | Natural and characteristic substrate maintained | ✓ | - Catchment geology entirely sedimentary (Upper Cambrian).<br>- Cobbles, pebbles and gravels dominate marginal zone, silt beyond |
| **Sediment load** | Natural sediment load maintained | X? | - Catchment landcover = mix of dry acid heath and unimproved to semi-improved acid grassland.<br>- Heavy grazing right to the shore. |
| **Indicators of local distinctiveness** | Distinctive elements maintained | X? | Annex II species, *L. natans* previously recorded (Carvalho *et al.*, 2003). Absent from 2004 survey |
| | Minimal negative impacts and no fish farming | X? | Heavy grazing around shoreline<br>Large numbers of geese observed around lake in 2004. |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | ✓? | Goldsmith *et al*. (2006): 0-26 cm: Sq chord distance=0.471<br>Modest degree of floristic change, indicative of mild acidification.<br>Decline in planktonic *Cyclotella* taxa. |

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

Extent

Llyn Hiraethlyn lies at an altitude of 309 m. The surface area of the lake is 4.6 ha, with a volume of 128.8 x$10^3$$m^3$.

Macrophyte community composition

The aquatic vegetation of Llyn Hiraethlyn keys out as a Type 2 "oligotrophic" assemblage – heavily influenced by peat, according to Palmer (1992) with characteristic taxa of the feature type, *L. uniflora*, *L. dortmanna* and *I. lacustris*. The presence of *L. dortmanna*, *M. alterniflorum* and *I. echinospora*, place it in the more oligotrophic community type. Elements of a more dystrophic "Type 1" assemblage (*Sphagnum* sp., *P. polygonifolius* and *U. minor*) were present, reflecting the peaty influence in the lake. Llyn Hiraethlyn is relatively species rich. Based on the submerged and floating leaved vegetation only (Table 4.10.10), the average Trophic Rank Score (TRS) for this site is 4.4 (35.4/8). This is highly comparable to the TRS of 4.3 reported in Carvalho *et al.* (2003) and based on data from a macrophyte survey undertaken in 2002.

**Table 4.10.10 Macrophyte community composition for Llyn Hiraethlyn, including trophic scores.**

| **Submerged and floating vegetation** | **Trophic Rank Score (TRS)** | **DAFOR** |
|---|---|---|
| *Isoetes lacustris* | 5.0 | A |
| *Juncus bulbosus* | 3.7 | A |
| *Littorella uniflora* | 6.7 | A |
| *Lobelia dortmanna* | 5.0 | D |
| *Myriophyllum alterniflorum* | 5.5 | F |
| *Potamogeton polygonifolius* | 3.0 | R |
| *Sphagnum auriculatum* | 2.5 | F |
| *Utricularia minor* | 4.0 | F |
| **Average TRS** | **4.4** | |
| **TRS (weighted)** | **5.18** | |
| **PLEX (weighted)** | **3.55** | |
| **Ellenberg Fertility Score (weighted)** | **3.71** | |

Negative indicator species

Filamentous algal cover is generally moderate (mean cover score = 1.8; median = 2), with few sample spots (14 %) having cover scores of 3. The moderate coverage of filamentous algae may indicate that the lake is slightly enriched, although the relationship between filamentous algal cover and enrichment requires further investigation. *J. bulbosus* is present in 28 % and 42 % of the vegetated wader and boat sample spots respectively and *Sphagnum* sp. occurs frequently, reflecting either the lake's slightly acidified status, dystrophic elements of the site's character and/or a bias in the location of transects towards areas with high coverage of *J. bulbosus* and *Sphagnum* spp.

Macrophyte community structure

The majority of the shore has very little transitional vegetation between the water and the semi-improved grazing that slopes down to the lake. *J. articulatus* and *J. effusus* were the dominant marginal species.

The submerged vegetation of Llyn Hiraethlyn was found in a band from the shore generally to about 4.0 m depth and was typical of a nutrient-poor upland lake. *L. uniflora* and *L. dortmanna* characteristically dominated the shallow water around the site to a depth of approximately 100cm, the latter reaching 230 cm on the east side of the lake (survey section 1). *Isoetes lacustris* was also abundant on the east side of the lake to a depth of approximately 4.0 m, it was much less common on the north and west shores and only reached a depth of 80 cm. *M. alterniflorum* was locally common and was found in all 3 sections at various depths up to 380 cm in section 1. *Juncus bulbosus* was only abundant in section 2 at the north end of the lake, where it occurred up to 200 cm.

The maximum depth of macrophyte colonisation in 2004 (4.0 m) was greater than that recorded in 2002 (3.0 m, reported in Carvalho *et al*., 2003), suggesting that the water clarity has improved, or simply reflecting interannual variation in macrophyte populations at the site. The lake supports a range of different macrophyte growth forms – isoetids (*I. lacustris, L. uniflora, L. dortmanna*), mosses (*S. auriculatum*), submerged fine-leaved species including elodeids (*M. alterniflorum, U. minor, J. bulbosus*), floating-leaved species (*P. polygonifolius*) and emergents (*J. effusus, J. articulatus*) – suggesting that the vegetation structure provides a reasonable range of habitats within the lake. Llyn Hiraethlyn's macrophytes do not provide as much structure as those found in Llyn Hesgyn.

Water quality

Llyn Hireathlyn is a mildly acidic lake (mean pH 6.3) with low ionic content. The site has an ANC value > 20 (25.10) and should therefore be sufficiently buffered and at low risk of acidification. The presence of dioritic intrusions in the bedrock probably explains the relatively large calcium concentrations and well-buffered lake water, although critical loads predicted by both the diatom and FAB models are exceeded (Carvalho *et al*., 2003).

DOC concentrations are relatively low (3.59), compared with the other five lakes in the SAC, which could be considered favourable for the macrophyte species present. Confidence in phosphorus measurements is low, with only June 2005 data available (2005 / 2006 data to follow), although the June 2005 data (8.2 $\mu gl^{-1}$) suggests that the lake should pass the TP target / limit of 10 $\mu gl^{-1}$ for oligotrophic lakes. Chlorophyll *a* concentrations are higher than would be expected for an oligotrophic lake, perhaps suggesting minor enrichment.

Lake hydrology

The lake appeared to have a more or less natural hydrological regime. The inflow in the south-east corner of the lake appeared to have had its course modified slightly

Lake substrate

The shoreline more or less retained its natural character with lake substrates dominated by pebbles and bedrock. A small stretch of the south-east corner appeared to have been modified slightly by the addition of a rocky 'beach' around an inflow.

Introduced species
No introduced macrophyte species were observed.

Indicators of local distinctiveness
The catchment of Llyn Hiraethlyn is predominantly dry dwarf shrub acid heath and acid grassland, some of which is semi-improved for sheep grazing, although this does not appear to be having any significant influence on nutrient concentrations. The Annex II submerged macrophyte species *L. natans* was recorded from Llyn Hiraethlyn in 2002, a new record for this site in Wales (Carvalho *et al*., 2003). However no plants of *L. natans* were recorded in 2004, which could indicate a loss of the plant from the lake – populations should be monitored to determine its status.

Palaeolimnological evidence
Diatom analysis of the top and bottom samples from a 26 cm sediment core are presented in Goldsmith *et al*. (2005). The core bottom (26 cm) sample was diverse with the presence of both planktonic and non-planktonic species typical of circumneutral to mildly acid waters. The top sample contained many of the same taxa as the bottom sample but the planktonic *Cyclotella* spp. declined markedly and small amounts of taxa commonly found in more moderately acid conditions appeared. The squared chord distance dissimilarity score between the two samples was 0.471, suggesting a modest degree of floristic change in the Llyn Hiraethlyn core, indicative of slight acidification.

Summary
Llyn Hiraethlyn is a reasonably good example of its Annex 1 feature type although it is still considered to be in overall **unfavourable** condition. The macrophyte assemblage contains all the characteristic taxa and both the lake and its catchment appear to be in a relatively natural state. However grazing pressure around the lake is high, with heavy grazing to the shore recorded in a number of transect areas in 2004. Grazing pressure should be monitored to ensure that it does not negatively impact upon the lake ecosystem.

A single plant of *L. natans* was recorded from a water depth of 1.3 m at the northern end of Llyn Hiraethlyn in 2002 (Carvalho *et al*., 2003). This was a new record for this site in Wales and represented an important additional population within Snowdonia, the 'core' natural habitat for this species in the UK. No plants of *L. natans* were recorded in 2004. There is a possibility that the water clarity is lower than that recommended for *L. natans*. Populations of *L. natans* should be monitored to determine whether absence in 2004 reflects a real loss of the species from Llyn Hiraethlyn – further investigation is suggested.

Palaeolimnological evidence suggests that Llyn Hiraethlyn has experienced some acidification, although it may now be recovering. Although the surface sediment diatom assemblage infers slightly higher pH conditions than the 5 cm sample (Roebuck, 2005), pH is not as high as that inferred from the core bottom sample, suggesting that the lake has not yet returned to pre-impact conditions. Reduction scenarios required for safeguarding the lake are either to reduce sulphur or nitrogen deposition.

## 4.10.6Llyn Tryweryn (LA, V - Peat)

Annex 1 type: H3160: Natural dystrophic lakes and ponds. Favourable Condition Table 7.

**Table 4.10.11: ConditionAssessment Summary Table for Llyn Tryweryn.**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | No loss of characteristic species (see Box 5) | ✓? | Characteristic species present in 2004 include: *C. rostrata, I. lacustris, J. bulbosus, P. polygonifolius, N. alba, N. lutea, Sphagnum* sp.*, S. angustifolium*. (Similar to those species recorded in 2002 and reported in Carvalho *et al*. 2003). |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | No non-natives present.<br>Low filamentous algal cover scores: Mean = 0.3; median = 0.<br>No sample spots have a score of 3 |
| **Macrophyte community structure** | Characteristic zones of vegetation should be present (site-specific) | ? | Limited transitional zone vegetation. Water is brown and $Z_v$ limited. |
| | Maximum depth distribution should be maintained | ? | $Z_{max}$ = 8.5 m, $Z_{mean}$ = 2.7 m, $Z_s$ = 1.0 m, $Z_v$ = 1.7 m.<br>$Z_v$ is greater than that reported in Carvalho *et al*. (2003), with *I. lacustris* growing to 1.3 m. |
| | At least the present structure should be maintained | ✓? | Similar structure to that reported in Carvalho *et al*. (2003). |
| **Water quality** | Stable nutrients levels:<br>Nutrient-poor<br>TP target / limit = 10 µg P $l^{-1}$ | X? | TP = 32.8 $\mu gl^{-1}$ (Jun'05 data only)<br>SRP = 13 $\mu gl^{-1}$ (mean annual '04-'05)<br>TN = 0.44 $mgl^{-1}$; $NO_3^-$-N = 0.22 $mgl^{-1}$<br>Chl *a* = 2.5 $\mu gl^{-1}$ |
| | Stable pH / ANC values:<br>pH <5.0 & ANC > 20 $\mu eql^{-1}$<br>DOC = high | ✓ | pH = 4.8 (range = 4.6 – 5.1)<br>ANC = 36.52 $\mu eql^{-1}$<br>DOC=11.87 $mgl^{-1}$<br>Labile Al = 43.7, Fe = 1010 $\mu gl^{-1}$ |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 $mgl^{-1}$) | ✓ | ~ 8 $mgl^{-1}$ from 0-8 m depth |
| | No excessive growth of cyanobacteria or green algae | ✓ | No algal blooms |

**Table 4.10.11 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Hydrology** | Natural hydrological regime | ✓ | Appears to be natural |
| **Lake substrate** | Natural shoreline maintained | ✓ | Shoreline development index = 1.26 |
| | Natural and characteristic substrate maintained | | Catchment geology composed entirely of sedimentary rocks. |
| **Sediment load** | Natural sediment load maintained | | - Recent felling of conifer plantation to the SE of catchment.<br>- Vegetation adjacent to survey sections = *Juncus*-dominated and rough grazed.<br>- 52% of catchment land cover is coniferous plantation. ~20% is blanket bog. |
| **Indicators of local distinctiveness** | Distinctive elements maintained at current extent/levels and/or in current locations | ✓**?** | *Isoetes echinospora* reported from site in 2002, but all *Isoetes* plants confirmed by megaspores in 2004 were *I. lacustris*. |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | **X** | Goldsmith *et al.* (2006): 0-20 cm: Sq chord distance = 1.373 Significant floristic change. Acidification (*E. incisa* → *A. ralfsii*) |

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

Extent

The lake lies at an altitude of 388 m. It has a surface area of 7.9 ha and a volume of 213.3 $x10^3m^3$.

Macrophyte community composition

The aquatic vegetation of Llyn Tryweryn keys out as a Type 1 "dystrophic" assemblage (Palmer, 1992), with elements of a Type 3 "oligotrophic" assemblage (*Glyceria fluitans*). Dystrophic lakes are naturally species-poor, although the presence of *Nymphaea alba*, *Nuphar lutea* indicate a more nutrient rich site for this lake type. The characteristic taxa, *Sphagnum* and *Juncus bulbosus* that dominated the macrophyte assemblage in 2002 (Carvalho *et al*., 2003) were absent from the submerged flora in 2004. Based on the submerged and floating leaved vegetation only, the average Trophic Rank Score (TRS) for this site in 2004 is 5.97 (35.8/6), which is considerably higher than in 2002 (4.6). The decrease in submerged *Sphagnum* spp. and the appearance of *Fontinalis antipyretica* since 2002 may indicate that the site is becoming less acid.

**Table 4.10.12: Macrophyte community composition for Llyn Tryweryn, including trophic scores.**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Fontinalis antipyretica* | 6.3 | R |
| *Glyceria fluitans* | 6.3 | O (submerged)<br>F (floating-leaved) |
| *Isoetes lacustris* | 5.0 | A |
| *Nuphar lutea* | 8.5 | F |
| *Nymphaea alba* | 6.7 | F |
| *Sparganium angustifolium* | 3.0 | F |
| **Average TRS** | **5.97** | |
| **TRS (weighted)** | **6.17** | |
| **PLEX (weighted)** | **4.98** | |
| **Ellenberg Fertility Score (weighted)** | **5.05** | |

Negative indicator species

No non-native macrophyte species were recorded and filamentous algal coverage scores are very low.

Macrophyte community structure

The majority of the southern lake margin comprises eroded peat and the northern shore more gently sloping cobble beaches. These areas have no transitional vegetation between the water and the adjacent *Juncus effusus* dominated terrestrial communities. At the east end, close to the outflow, the margins have emergent beds of *Carex rostrata*. *Sparganium angustifolium* and *Glyceria fluitans* are locally abundant in small beds around the entire lake margin. Larger beds of *Nymphaea alba* flank the southern shore to a maximum depth of 170 cm, with *Nuphar lutea* growing within the patches of *N. alba* and forming smaller beds in the shallower water. The submerged flora is made up of sparse beds of *Isoetes lacustris* to a maximum depth of 130 cm. The maximum depth of macrophyte colonisation is limited by the poor light climate.

Llyn Tryweryn has an atypical macrophyte community for a dystrophic lake, with only *Sparganium angustifolium* being broadly typical of the habitat. *I.lacustris, N. lutea, G.fluitans* and *F.antipyretica* are all very rare in dystrophic lakes, whilst typical 'dystrophic' species such as *Sphagnum*, *Utricularia minor* and *Juncus bulbosus* were absent. *Nymphaea alba* is somewhat unusual in dystrophic lakes.

Water quality

Llyn Tryweryn lies in a catchment dominated by peat soils (100% cover), resulting in water with a high humic acid content and visible brown staining, both target dystrophic lake features. The DOC concentration of 11.9 mg $l^{-1}$ is the highest of the Migneint lakes and above the minimum guideline concentration of 6.0 mg $l^{-1}$ for dystrophic lakes. The lake's mean pH of 4.8 is slightly higher than the dystrophic lake target of <4.5 and in terms of acid sensitivity,

Llyn Tryweryn has an ANC of 37, suggesting that the lake is well buffered and unimpacted by acid deposition.

Nutrient concentrations in Llyn Tryweryn are relatively high compared with the other Migneint lakes. Carvalho *et al*. (2003) suggested that the high TP concentration might be the result of fertilisation of coniferous plantations in the catchment or the improvement of pasture for sheep grazing. Chlorophyll *a* concentrations are relatively low, suggesting that high TP concentrations are not leading to increased phytoplankton abundance. Similarly, no excessive filamentous algal growth was observed. Nitrate concentrations are low and in common with many other dystrophic lakes, nitrogen is the limiting nutrient to plant growth.

Hydrology

The lake appears to have a natural hydrological regime and the water level reduction reported in Carvalho *et al*. (2003) was not seen in 2004. As a precaution, water level changes should be minimised to avoid detrimental effects on the already light-stressed macrophyte assemblages of the lake.

Lake substrate

The majority of the shoreline retains its natural peat character and within the survey sections there are a mix of peat and gravel areas in the shallow marginal zone. Carvalho *et al*. (2003) reported that the north-east corner of the lake was an artificial rocky shore associated with the nearby road construction. There were also signs of artificial substrates along the northern shoreline that were created when the now-disused Great Western Railway line was constructed. This line has been disused since the 1960s (Roberts, 1995).

Sediment load

It is recommended that an assessment should be made of any changes to the lake's sediment load as a consequence of recent coniferous plantation felling operations in the southeast of the catchment. The fact that >50% of the catchment is covered by coniferous plantation and only 22 % remains as *Sphagnum* bog indicates a significant degree of disturbance, or lack of naturalness, with likely consequent impacts on hydrology, water quality (acidity, nutrients and metals) and sediment load. The relatively high concentrations of aluminium are most likely derived from forestry drainage operations exposing mineral soils. Catchment pressures are not necessarily recent, a painting of "Llyn Tryweryn" by Augustus John, completed in 1912, depicts the road along the shore and what may be peat cuttings laid out beside it (http://www.tate.org.uk/) (Carvalho *et al*., 2003).

Indicators of local distinctiveness

None

Palaeolimnological evidence

Core top and bottom (21 cm) samples are not significantly different in terms of diatom floristic composition (squared chord dissimilarity distance = 0.432). Both samples comprise non-planktonic species typical of moderate to strongly acid waters, the most abundant being *Eunotia incisa*, *Cymbella perpusilla* and *Navicula soehrensis*, suggesting that the lake has been acid for the whole of the period represented by the sediment core.

Summary status

Llyn Tryweryn is a relatively large example of a dystrophic lake, a rare lake type in Wales. It retains a characteristic macrophyte assemblage and appropriate targets for water quality. However palaeolimnological evidence suggests that the lake has acidified. Mean annual DOC concentrations have increased slightly and ANC values have decreased slightly since 2002/2003, possibly indicating that the lake is becoming slightly less acid, although inferences are cautionary because of considerable seasonal variation. Aluminium concentrations have remained constantly high since 2002/2003, but iron concentrations have significantly decreased. The reasons for this are unclear, although changes in forestry drainage operations may provide an explanation.

Carvalho *et al*. (2003) suggested that future condition assessments should examine whether *Sphagnum* or *J. bulbosus* increase in abundance. In the 2004 survey, neither species was recorded, although this may have been due to differences in survey methods as opposed to a real loss of these species. However, the significant decline in the abundance of submerged *Sphagnum* spp. may indicate

Carvalho *et al*. (2003) recommended that site management should aim to limit the impact of the coniferous plantation on the lake habitat, since it has the potential to exacerbate acidification, enhance aluminium and nutrient supplies and affect hydrology and sediment load. The recent felling of part of the plantation may also impact upon the lake environment through increased sediment loading. We recommend that as felling opperations proceed, sediment loads should be monitored to ensure minimal negative impact to the lake's conservation interest.

Overall, Llyn Tryweryn is thought to be in **unfavourable, recovering** condition. Full elimination of the coniferous plantation within the lake's catchment should result in attainment of favourable condition, provided sediment loading is not compromised either during or subsequent to felling operations. Furthermore, there should be no sudden water level fluctuations which could result in light stress to submerged macrophyte species in this dystrophic lake.

## Overall condition of the Migneint-Arenig-Ddualt SAC

The lakes in the Migneint-Arenig-Ddualt SAC comprise two different Annex I habitat feature types, dystrophic and oligotrophic. The lakes are determined to be in a range of conditions.

One dystrophic lake, Llyn y Dywarchen supports no higher plants, although this does not indicate unfavourable status for this lake type. However this site also shows evidence of acidification both in its current ANC value and from palaeolimnological evidence. The other dystrophic lake, Llyn Tryweryn shows similar palaeolimnological evidence indicative of acidification (the same diatom species shifts), but its current ANC value is moderate. It also has a very uncharacteristic macrophyte flora.

Based on the above, the dystrophic lakes feature for Migneint is **Unfavourable, Maintained**.

Llyn Hiraethlyn and Llyn Conglog-Mawr have also been impacted by acid deposition and are also in unfavourable condition, although they appear to be recovering. Recovery trends should be monitored from water quality data and regular macrophyte surveys.

Llyn y Garn and Llyn Hesgyn are in favourable condition, with catchment characteristics that are less susceptible to the impact of acid deposition and fairly rich macrophyte assemblages. The macrophyte assemblage in Llyn Hesgyn is particularly species rich for this lake type, reflecting the rather mixed geology and soils present within the catchment. Both the patchy macrophyte species distribution and the shallow maximum depth of macrophyte colonisation may be of concern in Llyn y Garn, although the availability of suitable substrates may explain the distribution, particularly since all other habitat attributes meet the feature type targets.

Llyn y Garn supports the growth of the Annex II species, *Luronium natans* and this species was also recorded in Llyn Hesgyn in 2002 (Carvalho et al., 2003), although no plants were found in 2004. Habitat conditions suitable for the continued survival of *L. natans* should be ensured at both sites.

Based on the above, the condition of the Oligotrophic Lakes feature on Migneint is **Unfavourable, Recovering**.

Recommendations for Further Work (Dystrophic Lakes)

- More detailed investigation of the effects of forestry on Llyn Tryweryn is needed. In the long term, agreements should be sought to replace the coniferous forestry in the catchment with upland habitats such as heath, deciduous woodland and acid grassland.
- Further survey of other potential dystrophic lakes and pools on Migneint is needed.

Recommendations for Further Work (Oligotrophic Lakes)

- The main impacts on oligotrophic lakes on Migneint seem to be atmospheric. Continued effort at a national and international level is needed to ensure that atmospheric sulphur and nitrogen deposition does no result in exceedence of critical loads for these lakes.

**Table 4.10.13: Migneint-Arenig-Dduallt SAC: Overview**

| Water Body | Status | Reason(s) for Failure | Comments |
|---|---|---|---|
| ***Littorelletea* lakes:** | | | |
| Llyn Conglog-Mawr | Unfavourable | Acidification. Eutrophication. Insufficient characteristic speices. | |
| Llyn y Garn | Favourable | | Maximum depth distribution may be a concern. |
| Llyn Hesgyn | Favourable | | Does not meet one of its vegetation targets – this may need monitoring. |
| Llyn Hiraethlyn | Unfavourable | Heavy grazing pressure. Elevated sediment load. | *Luronium* not recorded this time. |
| **Dystrophic lakes:** | | | |
| Llyn y Dywarchen | Unfavourable | Acidification. Eutrophication. | TP values may need revisiting for this lake type. |
| Llyn Tryweryn | Unfavourable (recovering) | Acidification. Eutrophication | |
| **Overall SAC Status** | **Unfavourable** | | |

## *4.11 Pembrokeshire Bat Sites and Bosherston Lakes / Safleoedd Ystlum Sir Benfro a Llynnoedd BosherstonLily Ponds (Central basin only) SAC*

### 4.11.1 Bosherston Lily Ponds - Central arm only (HA, V)

H3140: Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp. Favourable Condition Table 5.

**Table 4.11.1: ConditionAssessment Summary Table for Bosherston Lily Ponds (central).**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | Characteristic species (see Box 3) should be present: *Chara spp.* (excluding *Chara vulgaris*) | ✓ | Extensive growths of *Chara hispida* |
| | ≥ 7/10 vegetated sample spots (boat or wader survey) should have ≥ 1 characteristic species | **X** | 24% wader, 88% boat transect sample spots comply (46% overall) |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | *Elodea canadensis* present on strandline |
| | Benthic and epiphytic filamentous algal cover <10% (non-*Chara*) | **✓?** | Filamentous algal cover scores low Mean = 0.4 (wader = 0.1, boat = 1.0) |
| **Macrophyte community structure** | Characteristic vegetation zones should be present. *Chara* beds should cover >50% of photic zone | **✓?** | ~10 m fringe of *Nymphaea alba*. *Chara hispida* in wedge in lake centre, growing to surface |
| | Maximum depth distribution should be maintained | ✓ | $Z_{max}$ = 1.0 m, $Z_{mean}$ = ?? m<br>$Z_s$ = >1.0 m, $Z_v$ = >1.0 m |
| | At least the current structure should be maintained | **-** | |

**Table 4.11.1 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels:<br>TP target / limit = 35 $\mu gl^{-1}$ | **X?** | TP=62 $\mu gl^{-1}$ (Jun'04 single sample). TP=46 $\mu gl^{-1}$ (GB database, 04 mean - 9 samples) TN=2.5 $mgl^{-1}$(GB database'04 mean) |
| | Stable pH / ANC values:<br>pH ~ 7.00 – 8.50 & ANC > 20 | ✓ | pH = 7.8<br>Alkalinity = 3194 $\mu eql^{-1}$ |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 $mgl^{-1}$) | ✓ | 4.64 $mgl^{-1}$ at surface – *Chara* too dense below to take measurements |
| | No excessive growth of cyanobacteria or green algae | ✓ | No blooms |
| **Hydrology** | Natural hydrological regime | **✓?** | Appears to be natural – fed by springs. Since 1992, no water received from Lower Eastern Arm. |
| **Lake substrate** | Natural shoreline maintained | **✓?** | Generally natural |
| | Natural and characteristic substrate maintained (marl production desirable) | **✓?** | Deeper areas have silty, marl substrate (dead, calcified *Chara*). Margins areas dominated by steep banks of exposed limestone bedrock. Silty substrate only in south |
| **Sediment load** | Natural sediment load maintained | **✓?** | Lake surrounded by deciduous woodland. Catchment land-use largely agricultural (semi) improved grassland and arable land. |
| **Indicators of local distinctiveness** | Distinctive elements maintained at current levels and/or in current locations | **?** | At notification, described as an 'outstanding shallow marl lake system' dominated by '*C. hispida*' and 'variable quantities of *C. virgata C. globularis* and *C. vulgaris*' |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | **✓?** | 0-25cm (2002 - 1930s). Sq chord dist = 0.747. Small benthic *Fragilaria* spp. and epiphytic diatoms dominate throughout. Davidson *et al*. (2002). |

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

Extent
The surface area of the lake is 4.0 ha, with a volume of ?? x$10^3$$m^3$.

Macrophyte community composition
The aquatic vegetation of Bosherston Lily Ponds – Central Arm keys out as a Type 10A?? lowland "meso-eutrophic" assemblage (Palmer, 1992), although the site supports aspects of a number of other community types. Based on the submerged and floating leaved vegetation only (Table 4.11.2), the average Trophic Rank Score (TRS) of this site is 8.0 (40/5).

**Table 4.11.2: Macrophyte community composition for Bosherston Lily Ponds (central), including trophic scores.**

| Submerged and floating species | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Chara hispida* | 8.5 | A |
| *Elodea canadensis* | 8.5 | Strandline only |
| *Fontinalis antipyretica* | 6.3 | R |
| *Lemna trisulca* | 10.0 | D |
| *Nymphaea alba* | 6.7 | D |
| **Site TRS** | **8.0** | |
| **TRS (weighted)** | **7.89** | |
| **PLEX (weighted)** | **6.48** | |
| **Ellenberg Fertility Score (weighted)** | **6.29** | |

According to the CSM guidance, Bosherston Central Lake's macrophyte community should be largely composed of *Chara* spp. *Chara hispida* is the only charophyte species to occur in the lake, although it is abundant and its dense growth (to the surface) restricted boat access in the central lake area.

Overall, only 46 % of the vegetated sample spots include at least 1 characteristic species, therefore the lake does not comply with the macrophyte community composition target for its feature type. However, *C. hispida* is present in 88 % of the boat transect sample spots, but only 24 % of the wader sample spots, highlighting the dominance of *C. hispida* in the central lake area and the dominance of other species around the lake margins. Bosherston's macrophyte flora is not particularly species rich, with only five submerged and free-floating / floating leaved species recorded in 2003.

Negative indicator species
The non-native species, *Elodea canadensis* was recorded on the strandline in 2003 and has previously been recorded growing in the lake (Davidson *et al*., 2002).

Macrophyte community structure
With most of the margins dominated by limestone bedrock sloping steeply into the water, there is a restricted transitional zone between the open water and the adjacent wooded

vegetation. A narrow band of emergent vegetation, typical of the lake's habitat feature type, is dominated by *Phragmites australis*, with *Sparganium erectum* and *Bolboschoenus maritimus* locally common. The entire Central Arm is encircled by an almost continuous bed of *Nymphaea alba*, from the margins to a depth of 100 cm. Under the canopy of *Nymphaea* leaves, *Lemna trisulca* is dominant, with *Chara hispida* common. Beyond the lilies and extending throughout the centre portion of the Central Arm, *C. hispida* is dominant and over past years dead *Chara* has formed a dense calcified mass, on top of which new plants grow.

Water quality

Measured TP data for 1981 to 2000 decrease from 90 to 20 $\mu gl^{-1}$, although intraannual variation is high (Davidson *et al*., 2002). Improvements in water quality have been seen since the 1990s, probably as a result of the implementation of a series of management plans since the mid 1980s, such as diversion of sewage since 1984 and bypass pipeline construction in 1992 to prevent nutrient rich water entering the Central Lake from the Eastern Arm (Davidson *et al*., 2002).

Hydrology

The Central Lake is mainly fed by the limestone aquifer. Since 1992, no water has been received from the Lower Eastern Arm. The hydrological regime of the lake therefore appears to be natural, with the water level fluctuating seasonally, dependent upon input from the aquifer. An Act of Parliament exempts the area from abstraction controls, and there is concern that overabstraction is a problem.

Lake substrate

The lake substrates appear to be natural. Across much of the lake basin and in particular in a 'wedge' in the centre of the lake, the sediment consists of dead and decaying, calcified remains of *Chara*. Around much of the lake, steep limestone bedrock slopes down to the shore except at the southern end where the substrate is silty.

Sediment load

Davidson *et al*. (2002) reported an increase in sediment accumulation rates in the Central Lake since 1980, although further work was recommended in the catchment to establish the sources and quantities of sediment inwash.

Indicators of local distinctiveness

At the time of notification, *C. virgata, C. vulgaris* and *C. globularis* were noted to occur alongside *C. hispida*. These species were not recorded in 2003. The Bosherston Lakes are an active fishery, and fishery management practices may affect overall ecosystem dynamics.

Palaeolimnological evidence

The diatom record for core BOSHC1 exhibits relatively small species shifts from 25 cm (c.1930) to 0 cm (2001), with a squared chord distance dissimilarity score between core top and bottom of 0.747 (Bennion ed., 2004). The core is dominated by non-planktonic taxa associated with clear-water, plant-dominated systems, with no evidence of a turbid, phytoplankton-dominated phase. Subtle changes in the diatom flora are probably related to changes in habitat availability and grazing pressure (Davidson *et al*., 2002). Diatom TP reconstructions indicate slight enrichment prior to the 1960s, followed by a decline in TP levels over the last three or four decades, most markedly since ~1990, perhaps attributable to

the redirection of sewage and the elimination of input from the Eastern Arm. Macrofossil records suggest a significant shift in the lake's macrophyte community since 1900, with a gradual deline in Charophyte abundance and a shift to more nutrient tolerant species and increased plant biomass. The greater proportion of epiphytic diatom taxa towards the core top may be explained by increased plant biomass (Davidson *et al*., 2002) and a reduction in light availability to the sediments from increased plant biovolume may explain the reduction in benthic *Fragilaria* spp. Furthermore, the species shifts include a decline in *Cocconeis placentula* and increasing relative abundances of *Cymbella microcephala* and *Achnanthes minutissima*. Data from the DALES dataset (Burgess, unpublished) suggests that these shifts in periphytic diatom species are indicative of a reduction in phosphorus concentraitons over recent years, which is in agreement with the decline in measured TP.

Summary

Bosherston Cental Lake appears to be in overall **unfavourable** condition. Although characteristic species (charophytes) are present, only one species, *C. hispida* was recorded in 2003. Davidson *et al*. (2002) reported that plant macrofossil remains indicate only recent re-establishment of charophytes (late 1980s) and that the lack of oospores in the recent sediments probably indicates that the charophyte population is not performing at optimum levels. Furthermore, at the time of notification, "variable quantities of *C. globularis*, *C. virgata* and *C. vulgaris*" were reported, suggesting that a number of charophyte species have been lost from the lake.

The 2005 mean annual TP data (GB database) suggests that phosphorus concentrations are declining, however James *et al*. (2005) report that high nitrogen concentrations, particularly winter values are associated with lower macrophyte species diversity. There is a low diversity of macrophyte species in Bosherston Central Lake. Furthermore, the dominance of *Lemna trisulca* in Bosherston Central Lake may reflect enrichment by nitrogen. *Lemna trisulca* is favoured by high nitrogen concentrations and can then rapidly outcompete slower-growing species.

The macrophyte species assemblage of Bosherston is similar to that of Llyn Cadarn, with both lakes supporting an abundance of marginal waterlilies and at least frequent abundances of *Lemna* spp (*L. minor* and/or *L. trisulca*). The major difference between the two lakes is that Llyn Cadarn is significantly deeper and has no charophytes. Cadarn also has a slightly higher winter nitrogen concentration, although Bosherston is moderately enriched with nitrogen, suggesting that continued nitrogen enrichment could potentially eliminate charophytes from Bosherston Central Lake. We recommend that monitoring of water quality be continued and that measures are taken to reduce nitrogen input to the lake.

Davidson *et al*. (2002) reported a proliferation of filamentous algae to be problematic, however only low abundances were recorded across all 2003 macrophyte survey sections, although it is not known whether this is representative of filamentous algal coverage across the lake as a whole. Increased abundances of both filamentous algae and the moss *Fontinalis antipyretica* further suggest eutrophication and a high N:P ratio (Stewart, 2003; Davidson *et al*., 2002; James *et al*., 2005).

**Table 4.11.3: Pembrokeshire Bat Sites and Bosherston Lakes SAC: Overview**

| Water Body | Status | Reason(s) for Failure | Comments |
|---|---|---|---|
| Bosherston Lake (Central Arm) | Unfavourable | Eutrophication. Insufficient *Chara* cover. | *Azolla* recorded in one of the feeder streams during summer 2005. |
| **Overall SAC Status** | **Unfavourable** | | |

## *4.12 Rhinog SAC*

### 4.12.1 Llyn Cwm Bychan (LA, S)

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

**Table 4.12.1: ConditionAssessment Summary Table for Llyn Cwm Bychan.**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise) | ✓ | 5 present: *L. uniflora, L. dortmanna, I. lacustris / echinospora, S. angustifolium, L. natans* |
| | No loss of characteristic species (see Box 2) | - | |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) have ≥ 1 characteristic species | ✓ | 82% of vegetated sample spots comply (87% wader, 74% boat) |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | No non-natives, but *J. bulbosus* and *Sphagnum* spp. present in 70% of all vegetated sample spots. |
| | Benthic and epiphytic filamentous algal cover <10% | ✓? | Mean cover score = 2.0, Median = 2<br>33/119 (28%) of sample spots have cover scores of 3. |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (see Table 4) | ✓ | < 1.5 m: *L. uniflora / L.dort*manna<br>1.5 - 4.0 m: *I. lacustris / echinospora*<br>*U. vulgaris / L. natans / P. berchtoldii / E. fluitans* |
| | Maximum depth distribution should be maintained | - | $Z_{max}$ = 14.6 m, $Z_{mean}$ = 4.9 m, $Z_s$ = 3.1 m, $Z_v$ = 4.6 m<br>*Sphagnum auriculatum* to 8.0 m<br>*I. lacustris / echinospora* to 4.0 m. |
| | At least the present structure should be maintained | - | Previous surveys? |

**Table 4.12.1 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels:<br>TP target / limit = 10 µg P $l^{-1}$ | ✓ | TP = 4.6 µg$l^{-1}$ (Jun'05)<br>SRP = 5 µg$l^{-1}$ (mean annual '04-'05)<br>TN = 0.32 mg$l^{-1}$; $NO_3^-$-N = 0.54 mg$l^{-1}$<br>Chl *a* = 2.7 µg$l^{-1}$ |
| | Stable pH / ANC values:<br>pH ~ 5.5 – 7.0 and ANC > 20 | **X?** | pH = 5.9 (range=5.6–6.2); DOC = 2.88 mg$l^{-1}$<br>ANC = -13.30 µeq$l^{-1}$ = acid impacted |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 mg$l^{-1}$) | ✓ | 7-9 mg$l^{-1}$ from 0-10 m, then drops to ~ 5 mg$l^{-1}$ from 10 m to $Z_{max}$ |
| | No excessive growth of cyanobacteria or green algae | ✓ | No blooms |
| **Hydrology** | Natural hydrological regime | ✓ | Appears to be natural |
| **Lake substrate** | Natural shoreline maintained | **X?** | Shoreline development index = 1.53 |
| | Natural and characteristic substrate maintained | ✓ | Boulders = dominant lake substrate. |
| **Sediment load** | Natural sediment load maintained | ✓ | Catchment landcover predominantly dry acid heath. Bracken, deciduous woodland, steep bedrock around lake. |
| **Indicators of local distinctiveness** | Distinctive elements maintained | ✓**?** | Small beds of *L. natans* present in 2004. |
| | Minimal negative impacts and no fish farming | ✓**?** | Stone embankment in transect 3<br>Catchment used for walking / fishing |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | **X?** | Goldsmith *et al*. (2006): 0-26 cm:<br>Sq chord distance = 0.827:<br>*A. minutissima* → *E. incisa*<br>Acidification: Shift from mildly acid to moderately acid flora. |

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

Extent

The surface area of the lake is 15.4 ha, with a volume of 754.6 x$10^3$$m^3$.

Macrophyte community composition

The aquatic vegetation of keys out as a Type 2/3 "oligotrophic" assemblage (Palmer, 1992). Based on the submerged and floating leaved vegetation only (Table 4.12.2), the average Trophic Rank Score (TRS) for this site is 4.95 (54.5/11). The site is species rich.

**Table 4.12.2: Macrophyte community composition for Llyn Cwm Bychan, including trophic scores.**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Eleogiton fluitans* | - | R |
| *Glyceria fluitans* | 6.3 | R |
| *Isoetes lacustris / echinospora* | 5.0 | A |
| *Juncus bulbosus* | 3.7 | A |
| *Littorella uniflora* | 6.7 | A |
| *Lobelia dortmanna* | 5.0 | A |
| *Luronium natans* | - | R |
| *Myriophyllum alterniflorum* | 5.5 | R |
| *Potamogeton berchtoldii* | 7.3 | R |
| *Sphagnum auriculatum* | 2.5 | A |
| *Sparganium angustifolium* | 3.0 | O |
| *Utricularia minor* | 4.0 | R |
| *Utricularia vulgaris* agg. *(cf. australis)* | 5.5 | O |
| **Average TRS** | **4.95** | |
| **TRS (weighted)** | **5.00** | |
| **PLEX (weighted)** | **3.66** | |
| **Ellebnerg fertility score (weighted)** | **3.85** | |

Five characteristic *Littorelletea* species are present in Llyn Cwm Bychan - *Littorella uniflora* (A), *Lobelia dortmana* (A), *Isoetes lacustris/echinospora* (A), *Luronium natans* (R) and *Sparganium angustifolium* (O). Other characteristic species present are *Utricularia minor* (R) *and Utricularia vulgaris* agg. (cf. *australis*). Overall, 82 % (77/94) of the vegetated boat and wader sample spots (87 % and 74 % respectively) have at least one of the characteristic species listed above, with a number of sample spots presenting more than one species. Since this equates to at least 6/10 (60 %) of the sample spots having at least 1 characteristic species, Llyn Cwm Bychan passes the macrophyte community composition attribute. The macrophyte species assemblage today is similar to that recordednin 1973 (Liddle *et al*., (1979) in Jones, (unpublished)), although no *Nymphaea alba* or *Potamogeton natans* were recorded in the 2004 survey.

Negative indicator species

No non-native species are present in the lake. Filamentous algal cover scores are moderate, with 28 % of sample spots having cover scores of 3, suggesting that the lake may be slightly

enriched. *Sphagnum* spp. and *Juncus bulbosus* are present in 70 % of vegetated sample spots, suggesting that the lake is acidified and/or that sediment loading to the lake has increased.

Macrophyte community structure

The eastern end of the lake is shallow (<100 cm) and extensively populated with *Equisetum fluviatile* with beds of *Schoenoplectus lacustris, Phragmites australis* and *Sparganium angustifolium* also locally common. The submerged flora of this area (survey section 1) is relatively sparse, but dominated by *L. dortmanna,* with *L. uniflora, Isoetes* spp.*, U. minor, U. australis, J. bulbosus* and *S. auriculatum* also present. Much of the remainder of the margins slope steeply into the lake, with boulders dominating the shallow water and *L. dortmanna* and *L. uniflora* growing between the rocks. *L. uniflora* and *L. dortmanna* grow to a depth of 1.5 m and *I. lacustris / echinospora* grows to a depth of 4.0 m. *Sphagnum auriculatum* grows to a depth of 8.0 m. Water clarity is good and the maximum depth of higher plant colonisation (4.6 m) reflects this.

Water quality

The lake is well mixed throughout the majority of the water column, although the 2004 data record a slight decline in dissolved oxygen below 10 m, although concentrations remain above target levels. Llyn Cwm Bychan is a mildly acidic lake with a negative ANC value (-13) suggesting that it has poor buffering capacity and has been impacted by acid deposition. Considerable uncertainty surrounds the TP data since the assessment is based only on one sample taken in June 2005, although TP was low at this time (5 $\mu gl^{-1}$) and in combination with the relatively low chlorophyll *a* and nitrogen levels suggests that the lake should meet its feature type nutrient target.

Hydrology

Llyn Cwm Bychan is a small lake formed in a kettle hole. There are two inflowing streams at the northern end of the lake and outflows at its southern end. The hydrological regime of the lake appears to be natural.

Lake substrate

Much of the marginal area slopes steeply into the lake, with substrates dominated by boulders. The shallow eastern end of the lake (survey section 1) is dominated by a silty substrate, as are the deeper areas of the lake (beyond water depths of 1.5 – 2 m). The lake substrates appear natural, except in survey section 3, where a stone embankment forms part of the shore.

Sediment load

The catchment area of the lake is predominantly rough grazed, dry acid heath. Around the lake edge there are areas of bracken, deciduous woodland and steep bedrock. There is peat development on the waterlogged land immediately adjacent to the lake. Jones, (unpublished) reported that almost half of the lake's catchment area was covered by coniferous forest, but this forested area has since been removed, possibly increasing the sediment loading to the lake during the period of removal. The catchment also has a history of annual burns that may have affected past sediment loads and road building in 1955 has been linked to increased sediment input to the lake at this time (Jones, unpublished). It is not thought that the lake currently receives high sediment loading, although filamentous algal cover is moderately high.

Indicators of local distinctiveness

A small bed of *Luronium natans* was recorded from a depth of 100 cm on the south shore (section 2) and in deeper water (350 cm) off the north-west shore (section 4) in 2004. *Isoetes echinospora* was recorded in 2004, although distinction from *Isoetes lacustris* was not possible on site, therefore all records were noted as *I. lacustris / I. echinospora*. The northwestern shore has been altered to accommodate the road.

Palaeolimnological evidence

Results from the analysis of subfossil diatoms in a 26 cm undated sediment core indicate that Llyn Cwm Bychan has experienced acidification. A squared chord distance dissimilarity score of 0.827 between core bottom and top samples indicates a significant shift in floristic composition. *Achnanthes minutissima*, is dominant at the core bottom, with *B. vitrea*, *E. incisa* and *C. kuetzingiana* occurring alongside; this association of taxa is indicative of mildly acid waters. *Eunotia incisa* is dominant at the core top, with other *Eunotia* spp., *Navicula leptostriat*a, *Navicula tenuicephala* and *Peronia fibula* occurring alongside that indicate Llyn Cwm Bychan is currently moderately acid and has acidified.

Summary

Llyn Cwm Bychan is a lake that appears to be in overall **unfavourable** condition. A WFD risk assessment places the lake at risk of diffuse pollution, most likely relating to acid deposition, although the lake may be slightly enriched from the improved pastures in the catchment. The low ANC (-13) of the lake and the increasing abundance of moderately acid diatom taxa in the lake's surface sediments suggest that the lake has experienced acidification. The relatively high abundances of both filamentous algae and *J. bulbosus* may indicate that the lake is experiencing some degree of disturbance. Furthermore, the rarity of elodeid macrophyte species (e.g. *M. alterniflorum*) suggests that the lake is acidified. The abundance of elodeid species and the lake's acidity should be monitored in future surveys to determine any recovery trends. Catchment stocking levels should also be monitored, as should other potential sources of sediment loading to the lake.

A small bed of *Luronium natans* was recorded from a depth of 100 cm on the south shore (section 2) and in deeper water off the north-west shore (section 4) in 2004. The population of *L. natans* should be monitored and conditions suitable for the continued persistence of this species maintained.

## 4.12.2 Llyn Cwm Eiddew-Mawr (LA, S)

Annex 1 type: H3130: Oligotrophic to mesotrophic standing water with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*. Favourable Condition Table 4.

**Table 4.12.3: ConditionAssessment Summary Table for Llyn Eiddew-Mawr.**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise) | ✓ | 5 present: *L. uniflora, L. dortmanna, I. lacustris , S. angustifolium, S. aquatica* |
| | No loss of characteristic species (see Box 2) | - | Baseline survey |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) have ≥ 1 characteristic species | ✓ | 87% of vegetated sample spots comply (87% wader, 87% boat) (Only x 2 boat surveys completed) |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | No non-natives, but *J. bulbosus* and *Sphagnum* spp. present in 51% of all vegetated sample spots. |
| | Benthic and epiphytic filamentous algal cover <10% | ✓**?** | Mean cover score = 1.8, Median = 2<br>4/96 (4%) of sample spots have cover scores of 3. |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (see Table 4) | ✓ | < 1.5 m: *L. uniflora / L.dort*manna<br>1.5 - 4.6 m: *I. lacustris* dominant<br>4.6 – 6.0 m: *Sphagnum auriculatum* |
| | Maximum depth distribution should be maintained | - | $Z_{max}$ = 13.6 m, $Z_{mean}$ = 3.8 m, $Z_s$ = 2.2 m, $Z_v$ = 4.6 m<br>*I. lacustris* growing to 4.6 m.<br>*Sphagnum auriculatum* to 6.0 m. |
| | At least the present structure should be maintained | - | Baseline survey |

**Table 4.12.3 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels:<br>TP target / limit = 10 µg P $l^{-1}$ | ✓ | TP = 3.7 µg$l^{-1}$ (Jun'05)<br>SRP = 5 µg$l^{-1}$ (mean annual '04-'05)<br>TN = 0.28 mg$l^{-1}$; $NO_3^-$-N = 0.64 mg$l^{-1}$<br>Chl *a* = 5.8 µg$l^{-1}$ |
| | Stable pH / ANC values:<br>pH ~ 5.5 – 7.0 and ANC > 20 | **X** | pH = 5.7 (range = 5.5 – 6.0)<br>ANC = -26.38 µeq$l^{-1}$ = acid impacted |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 mg$l^{-1}$) | ✓ | ~ 10 mg$l^{-1}$ from 0-13 m |
| | No excessive growth of cyanobacteria or green algae | ✓ | No blooms |
| **Hydrology** | Natural hydrological regime | ✓ | Water supply reservoir, but lake ≠ dammed. |
| **Lake substrate** | Natural shoreline maintained | ✓**?** | Shoreline development index = 1.43 |
| | Natural and characteristic substrate maintained | ✓ | Boulders = dominant lake substrate. |
| **Sediment load** | Natural sediment load maintained | ✓ | Catchment landcover predominantly dry *Calluna*-dominated acid heath. Heath and bare rock adjacent to lake. |
| **Indicators of local distinctiveness** | Distinctive elements maintained | ✓**?** | |
| | Minimal negative impacts and no fish farming | **X?** | Water supply reservoir |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | **X?** | 0-20 cm: Sq chord distance = 0.478<br>*F. exigua* → *T. quadriseptata / binalis*<br>Acidification: Shift from moderately acid flora to strongly acid flora. |

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

Extent

The surface area of the lake is 10.3 ha, with a volume of 391.4 x$10^3$$m^3$.

Macrophyte community composition

The aquatic vegetation of Llyn Eiddew-Mawr keys out as a Type 2/3 "oligotrophic" assemblage (Palmer, 1992). Based on the submerged and floating leaved vegetation only (Table 4.12.4), the average Trophic Rank Score (TRS) for this site is 4.49 (40.5/9). The site is moderately species rich, with isoetids dominating the assemblage.

**Table 4.12.4: Macrophyte community composition and trophic scores for Llyn Eiddew-Mawr.**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Callitriche hamulata* | 5.0 | O |
| *Eleogiton fluitans* | - | Strandline only |
| *Isoetes lacustris* | 5.0 | A |
| *Juncus bulbosus* | 3.7 | F |
| *Littorella uniflora* | 6.7 | A |
| *Lobelia dortmanna* | 5.0 | D |
| *Myriophyllum alterniflorum* | 5.5 | R |
| *Sparganium angustifolium* | 3.0 | O |
| *Sphagnum* sp. (and *auriculatum*) | 2.5 | A |
| *Subularia aquatica* | 4.0 | R |
| **Average TRS** | **4.49** | |
| **TRS (weighted)** | **4.93** | |
| **PLEX (weighted)** | **3.59** | |
| **Ellenberg Fertility Score (weighted)** | **3.72** | |

Negative indicator species

The lake does not support any non-native macrophyte species. Filamentous algal cover scores are moderate, although only four sample spots have scores of 3.

Macrophyte community structure

The majority of the shoreline has no transitional zone between the water and the terrestrial habitats. Small areas of *Carex* spp. and *Juncus* spp. dominated swamp occur in bays and adjacent to flushes. The submerged flora is dominated by *Littorella uniflora* and *Lobelia dortmanna* in the shallows and to a depth of ~150 cm, with *Juncus bulbosus* also locally common. *Isoetes lacustris* is common from 25 cm to a maximum recorded depth of 460 cm, which is also the maximum depth of higher plant colonisation. *Sphagnum auriculatum* grows beyond the *Isoetes* zone to a depth of 600 cm. These data are based on four wader transects, but only two boat transects.

Water quality

Dissolved oxygen concentrations were high (~ 10 $mgl^{-1}$) from 0-13 m and the water column was well mixed in September 2004. The lake is moderately acid (mean pH 5.9) and has a negative ANC (-26.38), suggesting that it has poor buffering capacity and has been impacted

by acid deposition. There is low confidence in the phosphorus data because only one measurement is available from June 2005. However the TP concentration at this time was low and chlorophyll *a* and TN concentrations are also low overall, probably suggesting that the lake meets its feature type target for nutrients.

Hydrology
Llyn Eiddew-Mawr is not dammed, although it is used as a public water supply reservoir. The hydrological regime of the lake is therefore modified and water levels may be drawn down via a pipe at the outflow during periods of high demand.

Lake substrate
The dominant lake substrates are boulders and cobbles, with areas of silt in the deeper waters.

Sediment load
Catchment land cover is dominated by dry acid *Calluna* heath and bare rock, as are the areas adjacent to the lake.

Indicators of local distinctiveness
None to note.

Palaeolimnological evidence
Goldsmith *et al.* (2006) describe the results of diatom analysis from core top and bottom (20 cm) samples. The squared chord distance dissimilarity score between top and bottom samples is 0.478, indicating a moderate degree of floristic change. The surface sediment sample is dominated by strongly acid indicators (*Tabellaria quadriseptata, Tabellaria binalis, Navicula tenuicephala*), whereas the bottom sample is dominated by non-planktonic taxa indicative of moderately acid conditions (*Fragilaria exigua, Eunotia incisa, Achnanthes minutissima, Navicula leptostriata, Tabellaria flocculosa*). The species shifts are indicative of acidification.

Summary
Llyn Eiddew-Mawr is currently in **unfavourable** condition, largely due to its negative ANC (-26) indicating acid impact, with the palaeolimnological evidence further suggesting that the lake has been acidified. The macrophyte species assemblage is dominated by isoetid taxa, with elodeids of rare occurrence. This may also be a result of acidification. We recommend that water quality, macrophyte assemblages and diatom assemblages be monitored over the coming years to assertain any recovery trends that may occur as acid deposition declines.

## 4.12.3 Llyn Perfeddau (LA, V)

Annex 1 type: H3130: Oligotrophic to mesotrophic standing water with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*. Favourable Condition Table 4.

**Table 4.12.5: ConditionAssessment Summary Table for Llyn Perfeddau.**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise) | ✓ | 4 present: *L. uniflora, L. dortmanna, I. lacustris , S. aquatica* |
| | No loss of characteristic species (see Box 2) | - | Baseline survey |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) have ≥ 1 characteristic species | ✓ | 72% of vegetated sample spots comply (68% wader, 80% boat) (Only 1 wader and 1 boat survey) |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | No non-natives present |
| | Benthic and epiphytic filamentous algal cover <10% | ✓? | Mean score = 2.0, Median = 2 No sample spots have cover scores of 3. |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (see Table 4) | ✓? | Lake too shallow for clear zonation pattern. Mosaic of macrophyte species. *I. lacustris* growing to 2 m. |
| | Maximum depth distribution should be maintained | - | $Z_{max}$ = 2.2 m, $Z_{mean}$ = 1.0 m, $Z_s$ > 2.2 m, $Z_v$ to 2.2 m (to $Z_{max}$) *M. alt, L. dort, L. uni* to 2.2 m. |
| | At least the present structure should be maintained | - | Baseline survey |

**Table 4.12.5 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels:<br>TP target / limit = 10 µg P $l^{-1}$ | ✓? | TP = 4.6 µg$l^{-1}$ (Jun'05)<br>SRP = 5 µg$l^{-1}$ (mean'04-'05)<br>TN = 0.39 mg$l^{-1}$; $NO_3^-$-N = 1.13 mg$l^{-1}$; Chl *a* = 5.5 µg$l^{-1}$ |
| | Stable pH / ANC values:<br>pH ~ 5.5 – 7.0 and ANC > 20 | X | pH = 6.1 (range = 5.9 – 6.3)<br>ANC = -28.30 µeq$l^{-1}$ = acid impacted |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 mg$l^{-1}$) | ✓ | 10-11 mg$l^{-1}$ from 0-2 m |
| | No excessive growth of cyanobacteria or green algae | ✓ | No blooms |
| **Hydrology** | Natural hydrological regime | ✓ | Appears natural |
| **Lake substrate** | Natural shoreline maintained | ✓ | Shoreline development index = 1.09 |
| | Natural and characteristic substrate maintained | ✓ | Boulders = dominant lake substrate. |
| **Sediment load** | Natural sediment load maintained | ✓ | Catchment landcover mixed dry *Calluna-Vaccinium* upland acid heath and unimproved acid grassland with some areas of bare rock. |
| **Indicators of local distinctiveness** | Distinctive elements maintained | ✓ | Small upland lake with macrophytes covering the lake basin |
| | Minimal negative impacts and no fish farming | ✓? | |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | X? | 0-26 cm: Sq chord distance = 0.820:<br>Acidification: Shift from circumneutral to slightly acid flora:<br>*A. minutissima* → *F. exigua*. |

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

Extent

Llyn Perfeddau lies at an altitude of 469 m. It has a surface area of 0.9 ha and a volume of 9.0 x$10^3$$m^3$.

Macrophyte community composition

The aquatic vegetation of keys out as a Type 2/3 "oligotrophic" assemblage (Palmer, 1992). Based on the submerged and floating leaved vegetation only (Table 4.12.6), the average Trophic Rank Score (TRS) for this site is 4.59 (36.7/8). The site is relatively species rich.

**Table 4.12.6: Macrophyte community composition for Llyn Perfeddau, including trophic scores.**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Callitriche hamulata* | 5.0 | R |
| *Isoetes lacustris* | 5.0 | F |
| *Littorella uniflora* | 6.7 | D |
| *Lobelia dortmanna* | 5.0 | D |
| *Myriophyllum alterniflorum* | 5.5 | F |
| *Potamogeton polygonifolius* | 3.0 | R |
| *Sphagnum* sp. (and *auriculatum*) | 2.5 | R |
| *Subularia aquatica* | 4.0 | A |
| **Average TRS** | **4.59** | |
| **TRS (weighted)** | **5.31** | |
| **PLEX (weighted)** | **3.90** | |
| **Ellenberg Fertility Score (weighted)** | **3.80** | |

Negative indicator species

The lake supports no non-native macrophyte species and filamentous algal cover scores are low to moderate (mean = 2.0), with no sample spots having scores of 3.

Macrophyte community structure

The data to assess macrophyte community structure are based on only one boat and one wader transect. The southern side of Llyn Perfeddau has an extensive bed of *Equisetum fluviatile* to a depth of 90 cm with the marginal areas characterised by *Carex rostrata*, *Juncus articulatus* and *Potamogeton polygonifolius* grading into wet *Calluna* heath community. The submerged flora is dominated by *Littorella uniflora, Lobelia dortmanna* and *Isoetes lacustris* from shallow water to the maximum depth of the lake (220 cm). *Subularia aquatica* is common between 100-130 cm and *Myriophyllum alterniflorum* between 150-220 cm.

Water quality

Llyn Perfeddau is a mildly acidic lake (mean pH 6.1) with positive alkalinity. Negative ANC (-28.30), suggests that the lake has poor buffering capacity and has been impacted by acid deposition. Confidence in the TP data is low because only one value is available from June 2005. However, the TP concentration is low at this time (5 $\mu gl^{-1}$) and chlorophyll *a* concentrations are low throughout the year, suggesting that the lake meets its feature type targets for nutrients. The lake has high oxygen concentrations throughout the water column, which are sufficient to support a healthy aquatic fauna.

Hydrology
The lake appears to have a natural hydrological regime.

Lake substrate
Lake substrates are dominated by boulders and cobbles around the margins and to a water depth of approximately 100 cm. Beyond this depth, substrates are silty.

Sediment load
Catchment impacts are low and sediment loads do not appear enhanced.

Indicators of local distinctiveness
Llyn Perfeddau is a very small, shallow, clear water upland lake with macrophytes covering the lake basin.

Palaeolimnological evidence
There has been a significant degree of floristic change (squared chord distance dissimilarity score 0.820) in diatom assemblages in Llyn Perfeddau, indicative of acidification. The core bottom sample is dominated by *Achnanthes minutissima* and other taxa indicative of circumneutral to slightly acid waters. The top sample is dominated by *Fragilaria exigua* and also records the appearance of *Navicula leptostriata* and *Cymbella gaeumannii*, taxa indicative of mildly to moderately acid waters.

Summary
Llyn Perfeddau is currently in **unfavourable** condition. Although the lake's macrophyte community composition and structure meet the targets for the feature type, the lake is acidified and has a negative ANC and a slightly acid surface sediment diatom flora.

We recommend that future monitoring of both water quality, diatom and macrophyte assemblages are carried out to investigate any recovery trends from acidification and to determine when the site achieves an ANC >20 and can be considered in good ecological status.

## 4.12.4 Gloyw Lyn (LA, V)

Annex 1 type: H3130: Oligotrophic to mesotrophic standing water with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*. Favourable Condition Table 4.

**Table 4.12.7: ConditionAssessment Summary Table for Gloyw Lyn.**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons) | ✓ | 4 present: *L. uniflora, L. dortmanna, I. lacustris , S. angustifolium.* |
| | No loss of characteristic species (see Box 2) | **?** | *Utricularia* spp. recorded as rare in 1997, but absent in 2004. |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) have ≥ 1 characteristic species | ✓ | 66% of vegetated sample spots comply (50% wader, 100% boat) (Only x 3 boat and x 3 wader surveys) |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | No non-natives |
| | Benthic and epiphytic filamentous algal cover <10% | ✓**?** | Mean cover score = 2.0, Median = 2<br>4/77 (5%) of sample spots have cover scores of 3. |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (see Table 4) | ✓ | Patchy vegetation cover. Many areas have no plants @ 1-2 m depth<br>0.25 - 1.0 m: *E. fluviatile, L. uniflora* 0.75 – 2.1 m*: L. uniflora, L. dortmanna, I. lacustris* |
| | Maximum depth distribution should be maintained | ✓**?** | $Z_{max}$ = 7.5 m, $Z_{mean}$ = 1.5 m, $Z_s$ = 3.0 m, $Z_v$ = 2.1 m<br>*I. lacustris* & *L. dortmanna* to 2.1 m. *I. lacustris* recorded growing to depth of 3.8 m in 1996 (Monteith ed., 1997) |
| | At least the present structure should be maintained | ✓**?** | Similar structure in 2004 to that recorded in 1996 (Monteith ed., 1997). |

**Table 4.12.7 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels:<br>TP target / limit = 10 µg P $l^{-1}$ | ✓? | TP = 9.1 $\mu g l^{-1}$ (Jun'05)<br>SRP = 5 $\mu g l^{-1}$ (mean annual 04-05)<br>Chl *a* = 4.3 $\mu g l^{-1}$<br>TN = 0.29 $mg l^{-1}$; $NO_3^-$-N = 0.50 $mg l^{-1}$ |
| | Stable pH / ANC values:<br>pH ~ 5.5 – 7.0 & ANC > 20 | X? | pH = 5.9 (range=5.8–6.2);<br>DOC = 3.96 $mg l^{-1}$<br>ANC = 1.81 $\mu eq l^{-1}$ = acid sensitive/impacted |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 $mg l^{-1}$) | ✓ | 8 - 9 $mg l^{-1}$ from 0 - 7.5 m |
| | No excessive growth of cyanobacteria or green algae | ✓ | No blooms |
| **Hydrology** | Natural hydrological regime | ✓ | Appears natural |
| **Lake substrate** | Natural shoreline maintained | ✓ | Dominant shoreline modification code = 1 (i.e. a relatively natural shore) |
| | Natural and characteristic substrate maintained | ✓ | Boulders = dominant lake substrate. |
| **Sediment load** | Natural sediment load maintained | ✓ | Catchment vegetation sparse and predominantly dry *Calluna*-dominated acid heath. Much steep, bare rock |
| **Indicators of local distinctiveness** | Distinctive elements maintained | ✓ | Small, boulder-dominated lake in a sparsely vegetated catchment<br>Shoreline development index = 1.74 |
| | Minimal negative impacts and no fish farming | ✓? | Little impact in catchment |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | ✓? | 0-26 cm: Sq chord distance = 0.468:<br>*F. exigua* & *B. vitrea* constant components. ↓ *A. minutissima, C. cesatii* and ↑ *E. incisa / N. leptostriata / C. perpusilla*: Minor acidification |

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

Extent

The surface area of the lake is 3.7 ha, with a volume of 55.5 $x10^3 m^3$.

Macrophyte community composition

The aquatic vegetation of keys out as a Type 3 "oligotrophic" assemblage (Palmer, 1992). Based on the submerged and floating leaved vegetation only (Table 4.12.8), the average Trophic Rank Score (TRS) for this site is 4.82 (28.9/6). Based on data from a macrophyte survey in 1996, Monteith ed. (1997) calculated a TRS of 5.3 for Gloyw Llyn. It is not thought that the difference in TRS between 1996 and 2004 is significant because the macrophyte species lists are similar for both survey periods.

**Table 4.12.8: Macrophyte community composition for Llyn Perfeddau. Figures in brackets are calculated from the 1996 survey (Monteith ed., 1997).**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Isoetes lacustris* | 5.0 | F |
| *Littorella uniflora* | 6.7 | A |
| *Lobelia dortmanna* | 5.0 | A |
| *Potamogeton natans* | 6.7 | R |
| *Sphagnum auriculatum* | 2.5 | O |
| *Sparganium angustifolium* | 3.0 | R |
| **Average TRS** | **4.82 (5.30)** | |
| **TRS (weighted)** | **5.02** | |
| **PLEX (weighted)** | **3.44 (3.55)** | |
| **Ellenberg Fertility Score (weighted)** | **3.65 (3.69)** | |

Gloyw Lyn meets its feature type targets for macrophyte community composition, recording four characteristic *Littorelletea* species (*Littorella uniflora, Lobelia dortmanna, Isoetes lacustris* and *Sparganium angustifolium*), which are present in 66 % of the vegetated wader and boat sample spots (50 % wader and 100 % boat). The lower representation of characteristic species in the wader survey sections is probably due to the large expanses of boulders in the marginal areas, providing limited substrate for macrophyte growth.

Negative indicator species

Gloyw Lyn does not support the growth of any non-native macrophyte species. The cover scores of filamentous algae across all wader and boat survey sections are moderate (mean 2.0), with few (5%) sample spots having cover scores of 3.

Macrophyte community structure

The shoreline around the north end of the lake is boulder dominated and there are few locations where suitable substrates have developed to support higher plants. However in some relatively sheltered locations, a shallow water association of *Littorella uniflora* and *Lobelia dortmanna* are locally abundant to a depth of 210 cm, occasionally in association with *Sphagnum auriculatum*.

The main basin of the lake is also boulder-strewn and here only *I. lacustris* is present in limited patches. The shallow, more sheltered southern end of the lake around the inflow (and the small bay around the outflow on the west side) supports emergent vegetation dominated by *Carex rostrata* swamp. In deeper water towards the centre of the lake, the swamp grades into *Equisetum fluviatile* beds to a depth of 100 cm, within which lie small areas of *Sparganium angustifolium* near the outflow.

Monteith (1997) recorded *I. lacustris* growing to a depth of 3.8 m at the southern end of the lake in July 1996. In September 2004, *I. lacustris* was only recorded growing to a depth of 2.1 m., The 2004 survey may not have recorded *Isoetes* growing at deeper depths because the lake has an unusual bathymetry with a 'hole', which the transects probably missed. The characteristic species, *Utricularia* sp. was recorded as rare in 1997, but was not recorded in 2004. This may not correspond to a loss of the species because different survey methods were used in 1996 and 2004; small populations of individual species could have been missed in 2004.

Water quality

Gloyw Lyn is mildly acidic (mean pH 5.9) with a low ANC (2), below target levels and suggestive of acidification. The lake has a positive alkalinity (but low?). DOC concentrations are moderate and reflect the influence of peaty soils and some areas of blanket bog in the catchment. Increased acidity results in low, but detectable concentrations of labile aluminium in the lake. Lake waters are well oxygenated, with sufficient dissolved oxygen throughout the water column to support a healthy aquatic fauna. Although limited TP data are available, the June 2005 TP concentration of 9.1 $\mu gl^{-1}$ is close to the feature type target, although since catchment disturbance is minimal, it is not thought that the lake is enriched.

Hydrology

Gloyw Lyn is mostly shallow although there are two small basins in the north and south. The lake is fed by one steeply incised inflow that enters from the south and it drains via sub-surface channels to the north (Monteith, 1997). The hydrological regime appears to be natural.

Lake substrate

Gloyw Lyn lies in an area of hard, acidic Cambrian grits, where there are numerous cliffs and rocky outcrops. Both the shoreline and main basin of the lake are boulder-strewn. The southern end of the lake around the inflow comprises finer, silty substrates.

Sediment load

Catchment soils are mostly very shallow and acid peaty soils over rock, with bare rock and thick peat in places. Catchment land cover consists almost exclusively of dry acid heath, with some small areas of wet heath at the southern end of the lake. The sparse catchment vegetation is dominated by *Calluna vulgaris* and grazing is largely restricted to a small number of feral goats (Monteith ed., 1997). It is not thought that the lake receives elevated sediment loads.

Indicators of local distinctiveness

Gloyw Lyn is an unusually shaped, small, boulder-dominated lake that lies in a sparsely vegetated catchment.

Palaeolimnological evidence

The top and bottom diatom samples from a 26 cm core from Gloyw Lyn are significantly different in terms of floristic composition (squared chord distance dissimilarity score = 0.468). The core bottom sample has a diverse non-planktonic flora co-dominated by *Achnanthes minutissima*, *Fragilaria exigua* and *Brachysira vitrea*, taxa typical of mildly acid waters. The top sample records a lower relative abundance of *A. minutissima*, an increased abundance of *Eunotia incisa* and low percentage relative abundances of *Tabellaria flocculosa* and *Navicula leptostriata*, a species shift indicative of minor acidification of the lake.

Summary

The macrophyte community composition and structure in Gloyw Lyn meets the targets for the feature type, although aquatic macrophyte assemblages appear to be largely determined by the extent of habitat exposure and the availability of suitable substrates for macrophyte colonisation. Despite favourable biological attributes, the lake cannot be classified to be in overall favourable condition because palaeolimnological evidence and a low ANC (below target levels) reveal that acidification has impacted upon the lake. Until ANC increases to >20 and surface sediment diatom assemblages return to pre-impact assemblages, the lake must be tentatively classified as **unfavourable**, recovering.

## Overall condition of the Rhinog SAC

The extensive Rhinog SAC is considered to be in overall **unfavourable** status, largely because all sites display evidence of at least mild acidification and all lakes have negative or low positive ANC values. Despite the apparent impact of acidification on all Rhinog lakes, deposition of sulphur is declining (Monteith *et al*., 2005) and the future acidity status of the lakes is likely to reduce. Recovery and maintenance of the lake ecosystems in this SAC is therefore considered sustainable under reduced acid deposition scenarios.

The abundance of elodeid macrophyte species and the acidity of all Rhinog SAC lakes should be monitored in future surveys to determine recovery trends.

Llyn Cwm Bychan is the only lake in the Rhinog SAC to support the growth of *Luronium natans*. In 2004, a small bed of this Annex II species was recorded growing at a depth of 100 cm on the south shore (section 2) and in deeper water off the north-west shore (section 4). The population of *L. natans* should be monitored and conditions suitable for the continued persistence of this species maintained.

Of the Rhinog SAC lakes in this study, there are few significant catchment pressures and the lakes remain relatively undisturbed, although stocking levels within the catchment of Llyn Cwm Bychan should be monitored, as should other potential sources of sediment loading to the lake.

**Table 4.12.9: Rhinog SAC: Overview**

| Water Body | Status | Reason(s) for Failure | Comments |
|---|---|---|---|
| Llyn Cwm Bychan | Unfavourable | Acidification | No other significant impacts. |
| Llyn Eiddew-Mawr | Unfavourable | Acidification | Water supply reservoir |
| Llyn Perfeddau | Unfavourable | Acidification | No other impacts |
| Gloyw Lyn | Unfavourable | Acidification | No other impacts |
| **Overall SAC Status** | **Unfavourable** | | |

## *4.13 Y Twyni o Abermenai i Aberffraw / Abermenai to Aberffraw Dunes SAC*

### 4.13.1 Llyn Coron (HA, V)

Annex 1 type: H3150: Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation. Favourable Condition Table 5.

**Table 4.13.1: ConditionAssessment Summary Table for Llyn Coron**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | ≥ 6 of the characteristic species listed in Box 4 and 1 broadleaved *Potamogeton* species | **X** | Only 4 species: *L. minor*, *C. vulgaris*, *C. truncata*, *P. berchtoldii* / *pusillus*. No broad-leaved *Potamogeton* spp. |
| | No loss of characteristic species | **?** | *P. perfoliatus* may have been lost since 1994 survey. *Littorella* rare. |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) should have ≥ 1 characteristic species | ✓ | 77 % (7.7/10) of vegetated wader and boat sample spots comply |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | *E. canadensis* present, but at low frequency. Small patch of non-native *Nymphaea* spp. (pink flowers) near NW edge of lake |
| | Benthic and epiphytic filamentous algal cover <10% (non-*Chara*) | ✓ | Present, but low coverage |
| **Macrophyte community structure** | Characteristic vegetation zones should be present. | **X** | 0.25 – 1.4 m: *C. truncata* (D), *E. hydropiper* (F), *Z. palustris* (A) 0.75 – 2.1 m: *M. spicatum* (D), *E. canadensis* (O). Sparse macrophyte coverage in deeper water areas. |
| | Maximum depth distribution should be maintained | - | $Z_{max}$ = 2.8 m, $Z_{mean}$ = 1.8 m, $Z_s$ = 1.1 m, $Z_v$ = 2.1 m |
| | At least the present structure should be maintained | - | Baseline survey |

**Table 4.13.1 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels:<br>TP target / limit = 50 µg P $l^{-1}$<br>(range 35-100 µg P $l^{-1}$) | **X** | TP = 72 µg$l^{-1}$ (EA mean '04)<br>SRP = 29 µg$l^{-1}$ (mean '03-'04)<br>TN = 0.29 mg$l^{-1}$; $NO_3^-$-N = 0.50 mg$l^{-1}$; Chl *a* = 4.3 µg$l^{-1}$ |
| | Stable pH / ANC values:<br>pH >7.00 and <9.00;<br>ANC > 20 | ✓ | pH = 7.8 (range = 7.4 - 8.3)<br>ANC = 1946 µeq$l^{-1}$ |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 mg$l^{-1}$) | ✓ | ~ 10 mg$l^{-1}$, constant with depth |
| | No excessive growth of cyanobacteria or green algae | ✓ | No blooms (bloom in Sep 2005) |
| **Hydrology** | Natural hydrological regime | ✓ | One principal stream plus minor artificial drainage ditches |
| **Lake substrate** | Natural shoreline maintained | **X** | East shoreline extensively poached by livestock (sheep and cattle) |
| | Natural and characteristic substrate maintained | ✓ | Base-rich geology Mix of lake substrates - pebbles/gravels dominate shallow areas. Sand dominant in wader transect 3. |
| **Sediment load** | Natural sediment load maintained | **?** | Probably increased by livestock poaching of east shore (rough grazing) |
| **Indicators of local distinctiveness** | Distinctive elements maintained at current levels and/or in current locations | ✓ | - *Elatine hydropiper* and *Callitriche truncata* present (rare plant species)<br>- Significant wildfowl population |
| **Environmental disturbance** | Note environmental disturbance factors and assess impact | | - Recreational fishery<br>- Extensive livestock poaching |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | **X?** | 0-80 cm sediment core: 80-25cm = benthic/littoral flora; ~25cm (early 1960s) = increase in small planktonic taxa; ~10cm (late1970s/early 1980s) = hypertrophy: Eutrophication |

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

Extent

The surface area of the lake is 28 ha, with a volume of 504 x$10^3$$m^3$.

Macrophyte community composition

The aquatic vegetation of Llyn Coron keys out as a Type 10A "eutrophic" assemblage (Palmer, 1992). Based on the submerged and floating leaved vegetation only (Table 4.13.2), the average Trophic Rank Score (TRS) of this site is 8.7 (87/10). This is similar to the score of 8.59 reported from a survey in 1993 (Allott *et al*.,1994).

**Table 4.13.2: Macrophyte community composition for Llyn Coron. Figures in brackets are calculated from the 1993 survey (Allott *et al*., 1994).**

| Submerged and floating species | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Callitriche truncata* | 8.5 | D |
| *Chara vulgaris* | 8.5 | R |
| *Elatine hydropiper* | - | F |
| *Eleocharis acicularis* | 8.5 | F |
| *Elodea canadensis* | 8.5 | O |
| *Lemna minor* | 9.0 | R |
| *Littorella uniflora* | 6.7 | R |
| *Myriophyllum spicatum* | 10.0 | D |
| *Potamogeton* cf. *berchtoldii* | 7.3 | R |
| *Potamogeton pectinatus* | 10.0 | R |
| *Zannichellia palustris* | 10.0 | A |
| **Site TRS** | **8.70 (8.59)** | |
| **TRS (weighted)** | **8.33 (7.84)** | |
| **PLEX (weighted)** | **8.25 (7.41)** | |
| **Ellenberg Fertility Score** | **6.44 (6.27)** | |

Llyn Coron does not support 6 characteristic species for its interest feature type. The boat, wader and perimeter surveys recorded only 4 characteristic species – *Lemna minor*, *Chara vulgaris*, *Callitriche truncata* and *Potamogeton berchtoldii* / *pusillus*. The pollution tolerant, negative indicator species, *Potamogeton pectinatus* and *Zannichellia palustris* are present, although they are not dominant. 64/79 (81 %) of the vegetated wader sampling spots and 23/34 (68 %) of the vegetated boat sampling spots included at least 1 of the characteristic species expected in naturally eutrophic lakes. Therefore, although Llyn Coron fails this attribute in terms of both the number of characteristic species present and their representation. The *Magnopotamion* vegetation is poorly developed in Llyn Coron, with no broad-leaved *Potomogeton* species recorded in September 2003. Since *Magnopotamion* vegetation is generally quite sensitive to eutrophication, its absence suggests that the lake is negatively impacted.

A subsequent visit in August 2005 recorded a similar assemblage to that above, but additionally found rare *Potamogeton perfoliatus*, *P. crispus* and *Ranunculus circinatus*. All occurred at frequencies too low to be reliably picked up by a transect. Records from the 1880s

indicate that the lake formerly contained a diverse flora that included *Potamogeton* x *nitens*, *Lobelia dortmanna* and *Chara aspera*.

The indices of trophic status all increased between the 1993 survey (Allott *et al*. 1994) and the present day, suggesting that the lake is continuing to deteriorate. Even when survey error was discounted (by adding in species still known to occur at the lake but not recorded by CSM survey methods), the PLEX score increased by 0.8 and weighted TRS by 0.42, though the Fertility score remained almost unchanged. Increases in cover of *Myriophyllum spicatum*, *Zannichellia palustris* and *Potamogeton pectinatus* are the major causes of this.

Negative indicator species

The naturalised non-native, *Elodea canadensis* is present, but at low frequency, only occurring in 8 % of vegetated wader (and 3 % of vegetated boat) sampling spots. A patch of non-native water lilies with pink flowers was seen growing near to the NW bank near the angler's car park in both 2003 and 2005. The invasive alien species, *Impatiens glandulifera* (Himalayan balsam) was observed growing in the angler's car park to the northwest side of the lake and requires control to prevent spreading.

Macrophyte community structure

With the exception of the eastern shore, which is heavily grazed, Llyn Coron maintains a rich marginal flora typical for its feature type, with *Schoenoplectus tabernaemontani, Iris pseudacorus* and *Phalaris arundinacea* all being locally common. A single stand of *Phragmites australis* is present in a sheltered bay at the south end of the lake.

The submerged flora was dominated in the shallows (25-100 cm (140 cm max.)) by *Callitriche truncata*. In 2003, the deeper central area of the lake had a sparse coverage of macrophytes, with *Myriophyllum spicatum* growing to a depth of 210 cm in transect 3. Other submerged species included *Elodea canadensis* and the stonewort *Chara vulgaris.* The maximum depth of the lake is 2.8 m.

Water quality

The mean annual pH for the site is 7.8, which is within the range expected for the feature type. Llyn Coron lies in an area of base-rich geology, which is reflected in the water chemistry with high pH and alkalinity. The proximity of the site to the sea also results in elevated chloride (and sodium) concentrations. ANC is high (1946), indicating that the lake is well buffered and not at all susceptible to acid deposition. Dissolved oxygen concentrations (~10 $mgl^{-1}$, constant with depth) meet the target.

Phosphorus concentrations are relatively high (meso-eutrophic to eutrophic) throughout the year and result in high summer chlorophyll *a* concentrations. According to Phillips (2005), Llyn Coron's mean annual TP concentration of 72 $\mu gl^{-1}$ places the lake within 'good' status, although the value is very close to the good/moderate boundary (75 $\mu gl^{-1}$). According to the criteria in JNCC 2005a, 50 $\mu gl^{-1}$ is the upper limit to for high alkalinity (HA) very shallow (V) lakes. Therefore, Llyn Coron fails the TP target. A high percentage of improved pasture within the catchment is likely to contribute to the nutrient status of the lake. However, it would appear that nutrient concentrations have decreased over the last decade, since Allott *et al*. (1994) reported a mean annual TP concentration of 156 $\mu gl^{-1}$. The relatively exposed

position of the lake may mean that nutrients in the lake sediments are likely to be easily resuspended in the water column due to wind action (Haworth *et al*. 1996.).

Hydrology

The hydrological regime of Llyn Coron appears to be natural. One principal stream enters the lake in addition to a number of minor artificial drainage ditches. Llyn Coron's catchment is of low relief.

Lake substrate

The lake substrate appears to be natural. Pebbles and gravels are the dominant substrates within the transect areas, with some smaller patches of cobbles, bedrock and silt. Transect 2 is located adjacent to an area of dune slack, and the substrate here is dominated by sand.

Sediment load

Catchment geology predominantly consists of sedimentary rocks, outcropping in places and giving rise to poor agricultural land that has been improved and is utilised for rough grazing for sheep and cattle. Livestock extensively poaches the eastern shore of the lake, probably leading to increased sediment loading and turbidity of the water. Isolated farms and a diffuse rural population are present in the catchment and domestic drainage to septic tanks and production and storage of silage may represent relevant land-uses in terms of their impact on lake water quality and sediment loads. A pig farm is also present within the catchment (Allott *et al*., 1994). Run-off may enter the lake from the small road that runs N-S close to the western edge of the lake. However this is thought unlikely since there is a good buffer strip of vegetation between the road and the lake.

Indicators of local distinctiveness

*Elatine hydropiper* (scarce in the UK) and *Callitriche truncata* (restricted distribution) are present in Llyn Coron. *C. trunc*ata is also a rare species for Wales, occurring only in Anglesey. In the 2003 survey, *E. hydropiper* was of frequent occurrence and was most common along the north and southeast shores to a depth of ~80 cm. *C. truncata* was dominant, occurring in dense mat across many areas of the lake, to depths of ~1.4 m. The lake is also important for wildfowl populations.

Environmental disturbance

Recreational fishing takes place on Llyn Coron, and the lake is regularly stocked with brown trout. There is a small pontoon at the NW end of the lake where a small number of rowing boats are moored. Fishing could inflict negative physical impacts to Llyn Coron through sediment disturbance and boat damage to plant communities. There could be a risk from the introduction of new fish species and/or a change in fish species dynamics through poor fisheries management. However, fishing is small scale and under the current regime probably has a low impact.

Palaeolimnological evidence

Haworth *et al*. (1996) reported "a switch from a sparse flora of benthic and littoral diatoms in a somewhat minerogenic environment to a more productive planktonic succession of centric diatom taxa". The authors suggested that planktonic centric diatoms began to increase *ca* 1963 (*ca* 25 cm) and reached a peak in the late 1970s/early 1980s, coinciding with the maximum period of enrichment of the lake (hypertrophy). This is in good agreement with a

report that diatom plankton was dominated by *Stephanodiscus hantzschii*, cf. *Thalassiosira* and *Cyclotella* sp. in 1980-81 (Priddle & Happey-Wood, 1983).

Bennion *et al*. (1996) reported a diatom-inferred annual mean TP concentration of 166 $\mu gl^{-1}$ for the surface sediment of Llyn Coron, which is in close agreement with the measured annual mean TP concentration of 156 $\mu gl^{-1}$ for the sample time period (Allott *et al*., 1994). The diatom-inferred TP reconstruction for an 80 cm, undated sediment sample is 70 $\mu gl^{-1}$ (Bennion *et al*., 1996), suggesting that current annual mean TP concentrations have decreased since the early 1990s and have returned to concentrations similar to those seen pre-enrichment. However, since the sediment core is not dated, it is not possible to state whether these values represent 'baseline' TP levels. It is clear from the surface sediment diatom data presented in Burgess *et al*. (2005), that despite a decrease in TP concentrations, the lake's diatom assemblage has not yet returned to a pre-enrichment flora.

Summary

WFD risk assessments determined that Llyn Coron is at risk of diffuse pollution, and despite the recent decline in its TP concentrations, the lake is currently considered to be in **unfavourable, maintained** condition. The water chemistry and plant community in Llyn Coron should be monitored regularly to determine whether any improvements in water quality are tracked by the ecological quality of the lake.

TN and $NO_3^-$-N concentrations are high (2.66 and 1.83 $mgl^{-1}$ annual mean concentration respectively). Without further data, it is not known whether a) the lake's high nitrate concentrations are natural for Llyn Coron, b) have decreased from former high levels, or c) whether concentrations remain high due to continued agricultural input.

Further studies are required to examine whether over time, the diatom flora returns to its pre-enrichment assemblage (see Haworth *et al*., 1996), or whether factors aside from TP concentrations (e.g. turbidity, nitrate concentrations) hamper re-establishment of pre-enrichment populations.

The broad-leaved *Potamogeton* species, *Potomogeton perfoliatus* was recorded as 'occasional' in the lake in 1994 (Allott *et al*., 1994). *P. perfoliatus* was absent in the 2003 macrophyte survey and in June 2005 it was present in the strandline survey of transect 1 only. The status of this species should be monitored as its absence from Llyn Coron may be due to a real loss, or instead due to interannual variation in macrophyte populations. Similarly, the absence of *L. uniflora* from the 2005 macrophyte surveys may be a genuine loss of this species from the lake, or in consequence of interannual variation (this species was found growing on the north shore (section 4) in 2003).

Llyn Coron supports several rare macrophyte species: *Elatine hydropiper* (scarce in the UK) and *Callitriche truncata* (restricted distribution). These species were noted to be growing in the same locations in a macrophyte survey conducted in 1994 (Allott *et al*., 1994), and populations of both species appeared healthy. Populations should be monitored to determine whether populations and their distributions remain stable, increase or decline.

Any changes in land-use or land management practices should be monitored to determine the impacts on Llyn Coron's aquatic ecosystem. Similarly, recreational fishing practices should also be monitored to enable early detection of negative impacts on Llyn Coron's ecosystem.

Recommendations for the Abermenai to Aberffraw Dunes SAC

- Llyn Coron is one of a handful of dune lakes in Wales, and is of great conservation importance. Although it has been significantly damaged by eutrophication, many of the characteristic species are still present, such that under good management there is an excellent prospect of returing the lake to favourable status.
- Future management of the lake should concentrate on catchment management measures, especially reducing livestock access to the eastern shore, addressing septic tank discharges, and reducing nutrient input via the inflow stream
- Resuspension of sediments due to wind action is likely to slow recovery of this lake.
- The current fishery regime is appropriate to the lake and should be maintained. Under no circumstances should stocking or introduction of coarse fish to this lake be consented.
- Monitoring data should also be collected for Llyn Rhosddu, a smaller dune lake within this SAC.

**Table 4.13.3: Abermenai to Aberffraw Dunes SAC: Overview**

| Water Body | Status | Reason(s) for Failure | Comments |
|---|---|---|---|
| Llyn Coron | Unfavourable | Eutrophication. Insufficient characteristic species. Sparse macrophyte cover in deeper areas. | Most key elements essential to favourable condition still present in the lake. |
| **Overall SAC Status** | **Unfavourable** | | |

## *4.14 Hanmer Mere SSSI*

### 4.14.1 Hanmer Mere (HA, V)

Annex 1 type: H3150: Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation. Favourable condition table 6.

**Table 4.14.1: Condition Assessment Summary Table for Hanmer Mere**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | No loss |
| **Macrophyte community composition** | ≥ 6 of the characteristic species listed in Box 4 and 1 broadleaved *Potamogeton* species | **X** | 1 broadleaved *Potamogeton* spp.: *P.crispus (??)*<br>3 characteristic species:<br>2 *Magnopotamion* species: *P.crispus* & *P.pusillus*.<br>2 *Hydrocharition* species: *Lemna minor* & *Lemna trisulca* (strandline) |
| | No loss of characteristic species | **?** | Similar species to those recorded at the time of notification (1995) and in 1996 by Monteith ed. (1997). |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) should have ≥ 1 characteristic species | **X** | 38% of vegetated sample spots comply (wader 37%; boat 38%) |
| **Negative indicator species** | Non-native species absent or present at low frequency | **X** | *Elodea canadensis* dominant (57% of vegetated sample spots) – not recorded in 1996. |
| | Benthic and epiphytic filamentous algal cover <10% (non-*Chara*) | ✓ | Mean cover = 0.3; median = 0.0<br>1% (1/83) of sample spots have cover scores of 3 |
| **Macrophyte community structure** | Characteristic vegetation zones should be present. Extensive beds of submerged macrophytes should be present | ✓**?** | *Typha* / *Lemna* 0 – 0.75 m<br>Waterlilies 0.75m - 1.0 m<br>*C.demersum* / *E. canadensis* →1.8m |
| | Maximum depth distribution should be maintained | **X** | $Z_{max}$ = 5.7 m, $Z_{mean}$ = 3.0 m, $Z_s$ = 1.2 m, $Z_v$ = 1.8 m<br>$Z_v$ less than in 1996 (3.0 m) |
| | At least the present structure should be maintained | **X** | Similar structure to 1996, but see comment above |

**Table 4.14.1 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels:<br>TP target / limit = 50 µg P $l^{-1}$ | **X** | TP = 1074µg$l^{-1}$; SRP = 828 µg$l^{-1}$; TN = 3.1mg$l^{-1}$; $NO_3^-$-N = 0.4mg$l^{-1}$; Chl *a* = 15.6µg$l^{-1}$ |
| | Stable pH / ANC values:<br>pH >7.00 and <9.00;<br>ANC > 20 | **✓?** | pH = 8.2 (range 7.4 - 10.7)<br>ANC data unavailable<br>Alk = 1600 µeq$l^{-1}$; DOC = 13.2 mg$l^{-1}$ |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 mg$l^{-1}$) | **?** | No data available |
| | No excessive growth of cyanobacteria or green algae | **X** | No blooms recorded in 2003, but thick cyanobacterial bloom in 2005 |
| **Hydrology** | Natural hydrological regime | **✓** | No surface inflows. Outflows underground at northern end |
| **Lake substrate** | Natural shoreline maintained | **✓?** | Shoreline modification code = 1 - 2<br>Poached by cattle in transect 2 |
| | Natural and characteristic substrate maintained | **✓** | Predominantly silt |
| **Sediment load** | Natural sediment load maintained | **✓?** | Probably increased during 1990s when lake enriched |
| **Indicators of local distinctiveness** | Distinctive elements maintained at current levels and/or in current locations | **✓** | *Nationally scarce Circuta virosa (Cowbane) recorded in 2003* (present at time of notification) |
| **Environmental disturbance** | Note environmental disturbance factors and assess impact | **X** | Sewage smell noted at northern end of lake near village in 2003. Overflow from cesspits / septic tanks in catchment in 1990s |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | **X** | Bennion ed. (2004):<br>0-26 cm core (undated): Sq chord dist = 0.540 significant floristic change: eutrophication |

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

Extent

The surface area of the lake is 17.0 ha, with a volume of 510 x$10^3$$m^3$ (Monteith ed. 1997).

Macrophyte community composition

The aquatic vegetation of Hanmer Mere keys out as a Type 10A "eutrophic" assemblage (Palmer, 1992). Based on the submerged and floating leaved vegetation only (Table 4.14.2), the average Trophic Rank Score (TRS) of this site is 8.71 (69.7/8), which is similar to the score of 8.8 reported from a survey in 1996 (Monteith ed., 1997). In terms of its floating and submerged flora, Hanmer Mere supports few *Magnopotamion* and *Hydrocharition*-type species. The characteristic *Magnopotamion* taxa include *P. pusillus* and *P. crispus*. The only characteristic *Hydrocharition* species occurring in the lake are *L. trisulca* (strandline only) and *L. minor*. The dominance of *Elodea canadensis* and the abundance of *Zanichellia palustris* indicate raised nutrient levels. The absence of submerged broad-leaved *Potamogeton* species (except P. crispus??) suggests unfavourable condition of the site in terms of macrophyte community composition.

**Table 4.14.2: Macrophyte community composition for Hanmer Mere, including trophic scores. Numbers in brackets are back-calculated scores for July 1996 (Monteith ed. 1997)**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Ceratophyllum demersum* | 10.0 | O |
| *Elodea canadensis* | 8.5 | D |
| *Lemna minor* | 9.0 | F |
| *Nuphar lutea* | 8.5 | A |
| *Nymphaea alba* | 6.7 | F |
| *Potamogeton crispus* | 8.5 | F |
| *Potamogeton pusillus* | 8.5 | O |
| *Zannichellia palustris* | 10.0 | A |
| **Average TRS** | **8.71 (8.8)** | |
| **PLEX (weighted)** | **7.54 (7.56)** | |
| **Ellenberg Fertility Score (weighted)** | **6.27 (7.22)** | |

Negative indicator species

The naturalised non-native, *Elodea canadensis* occurs in the lake and is recorded as dominant. This species is present in 57% of the vegetated sample spots. In 1996, *E. canadensis* was less common and instead, *Ceratophyllum demersum* was recorded as the dominant submerged macrophyte species. This difference may simply be due to interannual variation in macrophyte populations or may indicate a longer term shift in the dominant macrophyte taxa.

Macrophyte community structure

Hanmer Mere is surrounded by marginal woodland comprising stands of wet alder carr (*Alnus glutinosus*) and locally with crack willow (*Salix fragilis*). Trees overhang the lake in places (e.g. transect 1). There are some areas of fen vegetation beyond the alder carr, including species such as *Cicuta virosa, Carex elata* and *Iris pseudacorus*. The marginal emergent vegetation succeeding the fen vegetation comprises *Typha angustifolia*, with *Typha latifolia*

and *Sparganium erectum*, extending to a depth of approximately 0.75 m, with *Lemna minor* commonly found floating on the surface amongst the stems. A patchy zone of water lilies grows between depths of 0.75 – 1.0 m. Both within and beyond this zone, submerged aquatic species are present and include *Zannichellia palustris*, *Potamogeton pusillus / crispus, Ceratophyllum demersum and Elodea canadensis*. Both *C. demersum* and *E. canadensis* grow to a depth of 1.8 m, with E. canadensis dominant. The maximum depth of colonisation in 2003 was almost half that recorded in 1996 by Monteith ed. (1997), suggesting a deterioration of the lake's light climate. A limited number of macrophyte growth forms are represented in the lake – free-floating species (*L. trisulca, L. minor*), floating-leaved species (*N. lutea, N. alba*), submerged fine/strap-leaved species (*Z. palustris, P. pusillus*), submerged broad-leaved species (*P. crispus??*) and emergents (*Sparganium erectum*, *I. pseudacorus, T. angustifolia, T. latifolia, E. palustris, C.virosa*).

Water quality

The water chemistry of Hanmer Mere is indicative of a nutrient rich, alkaline lake. pH (8.2) is within the range expected for the feature type and Hanmer Mere is not sensitive to acid deposition Based on data from Carvalho et al. (2005), mean annual TP for 2004 was 1074 $\mu gl^{-1}$ (range 655 – 1910 $\mu gl^{-1}$), which is considerably higher than the target concentration of 50 $\mu gl^{-1}$. Allott *et al*. (2001) reported a diatom-inferred increase (pre-1850 AD to the present) in TP concentrations of at least 150 $\mu gl^{-1}$. In 1996, Monteith ed. (1997) reported a maximum TP concentration of 2382 $\mu gl^{-1}$ (mean 1806 $\mu gl^{-1}$), suggesting that although the current TP of the lake is above the target concentration, the lake may be in the process of recovery from a previous phase of enrichment. With further measures to reduce nutrient inputs to the lake, TP concentrations might be expected to return to favourable conditions some time in the future, although residual phosphorus in the sediments is likely to be significant if it is recycled into the water column. Chlorophyll *a* is high (mean 15.6 $\mu gl^{-1}$; range 2.8 – 53.5 $\mu gl^{-1}$), suggesting moderate to high algal production. TN concentrations are high (mean 3.1 $mgl^{-1}$; range 0.8 – 11.2 $mgl^{-1}$), although $NO_3^-$-N concentrations are constantly < 1 $mgl^{-1}$, indicating that the lake is nitrogen limited. No data are available for dissolved oxygen, although Monteith ed. (1997) reported deoxygenation of the bottom waters. If dense cyanobacterial blooms occur, as in 2005, their decay will most likely result in anoxia at the lake bottom. Hanmer Mere fails the targets for water quality. Water quality data suggest unfavourable condition, although as noted above, nutrient levels appear to have decreased in recent years.

Hydrology

Hanmer Mere has no surface inflows, but overflows underground at its northern end. The lake's hydrological regime appears to be more or less natural.

Lake substrate

The lake substrate is predominantly silty, which is thought to be natural since the lake is underlain by boulder-clay.

Sediment load

In damper areas adjacent to the mere there is a zone of grazed fen pasture, whilst at the northern end there is an area of drier grassland. The marginal area of transect 2 is poached by cattle. Drainage from agricultural land and cattle poaching may constitute relevant land-use impacts in the catchment, potentially increasing sediment loads and nutrient inputs.

Additionally, the small village of Hanmer lies adjacent to the lake from which run-off and cesspit overflow may also be received.

Indicators of local distinctiveness

Hanmer Mere is the largest of the meres in the former county of Clwyd and most probably the deepest. At the time of notification in 1994, Hanmer Mere was described as a 'mesotrophic mere', although the current water chemistry of the site suggests that this is no longer the case. The nationally scarce cowbane *Circuta virosa* was present in the marginal fen vegetation at the time of notification and was also recorded in 2003. The site supports good numbers of wildfowl, particularly during winter and at the time of notification, supported the nationally scarce variable damselfly *Coenagrion pulchellum*.

Environmental disturbance

At the time of survey (September 2003) a smell of sewage was noted at the north end of the Mere near the village. Monteith ed. (1997) considered that the lake had undergone considerable enrichment in the mid-to-late 1990s, possibly due to the effect of overflow from cesspits or septic tanks within the catchment. Increased phosphorus loading from the sediments resulting from higher water temperatures and longer periods of anoxia are also possibilities.

Palaeolimnological evidence

Bennion ed. (2004) reported that there have been significant changes in the diatom flora from the bottom (26 cm) to the top of a sediment core (squared chord distance dissimilarity score = 0.540). The diatom species shifts are indicative of eutrophication.

Summary

Overall Hanmer Mere SSSI is in **unfavourable** condition, principally because the lake's mean annual TP concentration is more than an order of magnitude higher than the target/limit for its feature type. Nutrient levels appear to have decreased since 1996, although they remain extremely high. Chlorophyll *a* and TN concentrations are also high. The lake's water chemistry has deteriorated significantly since the site's notification as a SSSI in 1994, when it was described as a 'mesotrophic mere'. It therefore seems contradictory that a WFD risk assessment determined the lake was *not* at risk of either diffuse or point source pollution.

Nutrient loads to Hanmer Mere should be monitored and the extent of residual sediment sources of nutrients should be determined

**Table 4.14.3: Hanmer Mere SSSI: Overview**

| Water Body | Status | Reason(s) for Failure | Comments |
|---|---|---|---|
| Hanmer Mere | Unfavourable | Eutrophication | Nutrient concentrations very high. |
| **Overall SSSI Status** | **Unfavourable** | | |

## *4.15 Llyn Alaw SSSI*

### 4.15.1 Llyn Alaw (MA, V)

Annex 1 type: H3150: Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation. Favourable condition table 6.

**Table 4.15.1: Condition Assessment Summary Table for Llyn Alaw**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | **X?** | 2-10m between HW mark and waters edge at time of 2003 survey – reservoir seasonally drawn down |
| **Macrophyte community composition** | ≥ 6 of the characteristic species listed in Box 4 and 1 broadleaved *Potamogeton* species | **X** | 1 broadleaved *Potamogeton* species: *P.perfoliatus*<br>3 characteristic species present: *P.perfoliatus, Chara virgata.*, *P. berchtoldii. (Nitella opaca, L. uniflora)* |
| | No loss of characteristic species | **-** | Baseline survey. Species list is similar to Garnett & Blackstock (1983). |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) should have ≥ 1 characteristic species | **X** | 38% of vegetated sample spots comply (wader 48%; boat 0%) |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | *Elodea canadensis* present, but rare (3% of vegetated sample spots) |
| | Benthic and epiphytic filamentous algal cover <10% | ✓ | Mean cover = 0.8; median = 0<br>18% (15/85) of sample spots have scores of 3 |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (see Table 4) | ✓**?** | Submerged macrophytes patchy and sparse below 1.0m depth.<br>*E. hexandra / L. uniflora* → 1.2m<br>*N. opaca* → 1.8m |
| | Maximum depth distribution should be maintained | **X?** | $Z_{max}$ = 3.8 m, $Z_{mean}$ = ?? m, $Z_s$ = 1.2 m, $Z_v$ = 1.8 m |
| | At least the present structure should be maintained | **-** | Baseline survey |

**Table 4.15.1 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels:<br>TP target / limit = 20 $\mu gl^{-1}$ for mesotrophic MA, S lakes | **X?** | TP = 39.5 $\mu gl^{-1}$; SRP = 14.8 $\mu gl^{-1}$; TN = 1.4 $mgl^{-1}$; $NO_3^-$-N = 0.6 $mgl^{-1}$; Chl a = 10.8 $\mu gl^{-1}$ |
| | Stable pH / ANC values:<br>pH >7.00 and <9.00;<br>ANC > 20 | ✓ | pH = 7.7 (range 7.0 – 8.2)<br>ANC data unavailable<br>Alk=850$\mu eql^{-1}$; DOC=7.6$mgl^{-1}$ |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 $mgl^{-1}$) | ✓ | 9 - 12 $mgl^{-1}$ from 0 – 3.5 m depth |
| | No excessive growth of cyanobacteria or green algae | **X** | Blue-green algal bloom present during sampling |
| **Hydrology** | Natural hydrological regime | **X** | Reservoir |
| **Lake substrate** | Natural shoreline maintained | **X** | Shoreline modification code = 2-3 |
| | Natural and characteristic substrate maintained | ✓ | Silty substrate dominant in deeper areas. Patches of cobbles, gravel, sand and clay in marginal area. |
| **Sediment load** | Natural sediment load maintained | ✓**?** | Lake surrounded mainly by Salix scrub, with improved grassland adjacent to transect 2. |
| **Indicators of local distinctiveness** | Distinctive elements maintained at current levels and/or in current locations | ✓**?** | *Eleocharis acicularis* recorded in margins in 2003 and recorded at time of site notification. |
| **Environmental disturbance** | Note environmental disturbance factors and assess impact | **X** | - Reservoir, with periodic draw down – may be favourable to some macrophyte species.<br>- Site used for angling. Stocked with Rainbow Trout. Rudd and Brown Trout also reported |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | **?** | Burgess *et al.* (2005).<br>0-20 cm: Surface sediment dominated by small centric diatoms indicative of (meso)eutrophic conditions (*S. parvus, C. invisitatus, A. subarctica*). Poor diatom preservation at core bottom. |

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

Extent

Llyn Alaw lies at an altitude of 42 m. The surface area of the lake is 308 ha, with a volume of ???? x$10^3 m^3$.

Macrophyte community composition

According to Palmer (1992), the aquatic vegetation of Llyn Alaw keys out as a Type 5A "mesotrophic" assemblage, an uncommon type in the UK, mainly found in the north and west. Based on the submerged and floating leaved vegetation only (Table 4.15.2), the average Trophic Rank Score (TRS) for this site is 7.28 (72.8/10). Llyn Alaw is a relatively species rich lake, although it fails the targets both for the presence of characteristic species (only 3 characteristic macrophyte species present in 2003) and the representation of these species across the survey sections (only 38% of vegetated sample spots have at least one characteristic species). The lake also supports fewer broadleaved *Potamogeton* species than might be expected in a high quality mesotrophic site, although *Potamogeton perfoliatus* is abundant in the wader survey sections. The presence of *Littorella uniflora* and *Eleocharis acicularis* in the marginal area is typical of northern lakes of this type.

**Table 4.15.2: Macrophyte community composition for Llyn Alaw, including trophic scores.**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Chara virgata* | 8.5 | O |
| *Elatine hexandra* | 6.0 | A |
| *Eleocharis acicularis* | 8.5 | A |
| *Littorella uniflora* | 6.7 | A |
| *Myriophyllum alterniflorum* | 5.5 | O |
| *Nitella flexilis* (agg.) | 5.5 | A |
| *Persicaria amphibia* | 9.0 | R |
| *Potamogeton berchtoldii* | 7.3 | O |
| *Potamogeton perfoliatus* | 7.3 | F |
| *Ranunculus peltatus* | 8.5 | A |
| **Average TRS** | **7.28** | |
| **PLEX (weighted)** | **5.91** | |
| **Ellenberg Fertility Score (weighted)** | **6.01** | |

Negative indicator species

Filamentous algal cover is low (mean cover score = 0.8; median = 0), with few sample spots (18 %) having cover scores of 3. The patches of denser algal cover may indicate areas of localised enrichment, although the relationship between filamentous algal cover and enrichment requires further investigation. The naturalised non-native species, *E. canadensis* is present in Llyn Alaw, but was only recorded in 3 % of the vegetated wader (and none of the boat) sample spots in 2004. No other introduced macrophyte species were observed.

Macrophyte community structure

The majority of the shore is surrounded by emergent stands of *Phalaris arundinacea* that are backed by Salix scrub. The submerged vegetation of Llyn Alaw comprises dense but patchy growths of *L. uniflora, E. hexandra, Elatine hexandra* and *Ranunculus peltatus* in a band from the shore to between 1.0 and 1.3 m water depth. The *Phalaris-Littorella-Eleocharis* association is typical of northern shorelines of this feature type. The maximum depth of macrophyte colonisation in 2004 was 1.8 m (*Nitella opaca*), although few macrophytes were found growing beyond a water depth of approximately 1.0 m. The maximum depth distribution of macrophytes appears restricted by relatively low water clarity. This probably resulted from the cyanobacterial bloom at the time of survey and indicates nutrient enrichment and a shift in ecological functioning from periphyton to phytoplankton dominance. The lake supports a range of different macrophyte growth forms – isoetids (*L. uniflora*), charophytes (*C. virgata, N. flexilis, N. opaca*), submerged fine-leaved species (*E. hexandra*, *R. peltatus*, *M. alterniflorum, E. canadensis, P. berchtoldii, E. acicularis*) and emergents (*J. effusus, J. articulatus*) – suggesting that the vegetation structure provides a good range of habitats within the lake. No free-floating or floating-leaved species were recorded, perhaps reflecting the relatively exposed nature of the site and the periodic draw down. The lake margins appear to favour good colonizers and species tolerant of exposure and changes in water level.

Water quality

Llyn Alaw is a circumneutral to alkaline lake (mean pH 7.7) that is well buffered and not considered at risk of acidification. Dissolved oxygen concentrations are adequate to support the health of aquatic fauna and the lake was well mixed at the time of survey in August 2004. Data from Carvalho *et al*. (2005) indicate that TP concentrations are above the range expected for the lake type (mean 39.5 $\mu gl^{-1}$; range 12 - 64 $\mu gl^{-1}$) and the lake therefore fails the TP target / limit of 20 $\mu gl^{-1}$ for mesotrophic, shallow, medium alkalinity lakes. Furthermore, according to the UK TAG Report (January 2006), Llyn Alaw's mean annual TP concentration is slightly higher than the range limit (36 $\mu gl^{-1}$) for good ecological status, therefore placing the lake in moderate status only. Chlorophyll *a* concentrations suggest that the lake is at good ecological status according to preliminary boundaries derived from REBECCA (Phillips, 2005). There was a cyanobacterial bloom at the time of survey, suggesting deterioration in water quality due to enrichment. Longer-term nutrient data are required to assess the enrichment trends.

Lake hydrology

Llyn Alaw is a large lowland reservoir and as such it has a modified hydrological regime.

Lake substrate

Lake substrates are dominated by silt in the deeper water areas, whereas both silt, clay, sand and cobble substrates are commonly encountered in the marginal areas.

Sediment load

The lake is surrounded predominantly by *Salix* scrub, which probably helps to reduce sediment inflow from the surrounding catchment. Llyn Alaw is a water supply reservoir that can be periodically drawn down. Draw-down could increase sediment loads as exposed marginal sediments are re-worked and washed into the lake.

Indicators of local distinctiveness

The uncommon slender spike-rush *Eleocharis acicularis* was present at the time of notification and was recorded as abundant during the 2004 survey. *Pilularia globulifera* was noted as a marginal specie in section 5 in 2004, although this record has not been verified.

Palaeolimnological evidence

Sediment samples from the top and bottom of a 20 cm sediment core have been analysed for diatoms (Burgess *et al*., 2005). Unfortunately there was no preservation of diatom frustules in the core bottom sample so it is not possible to assess the degree of environmental change. However, the surface sediment diatom sample comprises mostly small centric planktonic taxa indicative of eutrophic conditions (mainly *Stephanodiscus parvus, Cyclostephanos invisitatus, Stephanodiscus hantzschii*) and moderate enrichment (*Aulacoseira subarctica*), with some periphytic taxa alongside (e.g. *Achnanthes minutissima* and *Navicula* spp.)

Summary

Llyn Alaw is a large, shallow, base-rich lowland reservoir on the Isle of Anglesey, described as 'mesotrophic' at the time of its notification as a SSSI. The site does not fall neatly into one of the SAC feature types and therefore it is difficult to assess its current condition using CSM methods, although it is probably best considered a naturally eutrophic lake type. However, the lake does not meet the favourable condition criteria for any of the three feature types to which it could potentially correspond, suggesting that it is in **unfavourable** condition.

For a naturally eutrophic lake, Llyn Alaw does not support a sufficient number of characteristic macrophyte species to pass the macrophyte community composition target. Furthermore, the characteristic species are poorly represented in the survey sections. Aquatic macrophytes are sparsely distributed, although they are locally abundant, particularly in the marginal areas, where low growing species tolerant of fluctuating water levels are common (e.g. *L. uniflora, E. hexandra, E. acicularis*).

The site is a modified water body that is used for water supply and may therefore be subjected to periodic draw down, potentially affecting the range of macrophyte species capable of colonizing the marginal areas. Although silt is the dominant substrate in the deeper water areas, the margins have a diversity of substrates, which appear to create an important habitat for macrophyte growth.

Current phosphorus concentrations are above the target/limit for the lake's habitat feature type and according to WFD criteria, the lake may only be in moderate status. Furthermore, WFD risk assessments have determined that Llyn Alaw is at risk from diffuse pollution, physical and morphological alteration and is probably at risk of alien species. The surface sediment diatom assemblage of Llyn Alaw comprises predominantly planktonic taxa that are indicative of (meso)eutrophic conditions, suggesting that the lake has been enriched.

We recommend that nutrient concentrations and macrophyte populations be monitored in Llyn Alaw to enable rapid detection of any further deterioration in water and habitat quality. We also recommend that water levels be monitored to ensure that draw down remains favourable to colonization of the marginal areas by macrophytes. Fish stocking should also be regulated to ensure that negative impacts to water quality and native fish populations are minimized.

**Table 4.15.3: Llyn Alaw SSSI: Overview**

| Water Body | Status | Reason(s) for Failure | Comments |
|---|---|---|---|
| Llyn Alaw | Unfavourable | Eutrophication.<br>Insufficient characteristic species.<br>Sparse macrophyte cover in deeper areas.<br>Reservoir. | Concerns over nutrients, cyanobacterial blooms and reservoir draw-down.<br>Many key elements essential to favourable condition still present, but depth distribution of macrophytes compromised |
| **Overall SSSI Status** | **Unfavourable** | | |

## *4.16 Mynydd Hiraethog SSSI*

### 4.16.1 Llyn Alwen (LA, S)

Annex 1 type: H3130: Oligotrophic to mesotrophic standing water with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*. Favourable Condition Table 4.

**Table 4.16.1: Condition Assessment Summary Table for Llyn Alwen**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise) | ✓ | 3 species present: *L. uniflora*, *L. dortmanna* & *I. lacustris* |
| | No loss of characteristic species (see Box 2) | ✓ | Same species as those recorded in 1996 (Monteith ed. 1996) |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) have ≥ 1 characteristic species | ✓ | 82 % of vegetated sample spots comply (wader 91%, boat 25%) |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | No introduced species |
| | Benthic and epiphytic filamentous algal cover <10% | ✓ | Mean cover = 1.7; median = 2<br>27% (25/92) of sample spots have scores of 3 |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (see Table 4) | ✓**?** | 0 – 1.0 m: *I. lacustris* dominant (*L. uniflora* & *L. dortmanna* sparse, with mosses / liverworts*)*<br>1.0 – 2.1 m: *Sphagnum* / mosses |
| | Maximum depth distribution should be maintained | ✓**?** | $Z_{max}$ = 13.5 m, $Z_{mean}$ = 6.0 m, $Z_s$ = 2.1 m, $Z_v$ = 2.1 m |
| | At least the present structure should be maintained | **-** | Baseline survey |

**Table 4.16.1 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels: TP target / limit = 10 µg P $l^{-1}$ | **X** | TP = 36.2 µg$l^{-1}$; SRP = 9.4 µg$l^{-1}$; TN = 0.68 mg$l^{-1}$; $NO_3^-$-N=0.28 mg$l^{-1}$; Chl *a*=1.62µg$l^{-1}$ |
| | Stable pH / ANC values: pH ~ 5.5 – 7.0 and ANC > 20 | **X?** | pH = 4.7 (range 4.0 – 5.1)<br>ANC data unavailable<br>Alk = 20 µeq$l^{-1}$; DOC = 7.3 mg$l^{-1}$ |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 mg$l^{-1}$) | ✓ | 8 - 9 mg$l^{-1}$ from 0 - 11 m depth |
| | No excessive growth of cyanobacteria or green algae | ✓ | No algal blooms recorded |
| **Hydrology** | Natural hydrological regime | ✓ | Appears natural. Small inflow to NE; outflow to SE via Afon Alwen. High annual rainfall and impeded drainage. |
| **Lake substrate** | Natural shoreline maintained | ✓ | Shoreline modification code: 1<br>Rough grazing around shoreline. |
| | Natural and characteristic substrate maintained | ✓ | Cobbles, pebbles and gravels dominate marginal zone, silt beyond. |
| **Sediment load** | Natural sediment load maintained | ✓**?** | Catchment landcover = dry ericaceous heath, used for rough grazing. Acid wet blanket bog vegetation around lake perimeter. |
| **Indicators of local distinctiveness** | Distinctive elements maintained | ✓**?** | Catchment important for diverse upland breeding bird community |
| | Minimal negative impacts and no fish farming | ✓**?** | Rough grazing around shoreline. Traditional grouse moor management in catchment. Derelict farmhouse on north shore. |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | **X** | Bennion ed. (2004):<br>0-25 cm core:<br>Sq chord distance = 0.830<br>Significant floristic change, indicative of acidification. |

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

Extent

Llyn Alwen lies at an altitude of 384 m. The surface area of the lake is 26.3 ha, with a volume of 1560 x$10^3$$m^3$.

Macrophyte community composition

The aquatic vegetation of Llyn Alwen keys out as a Type 2 "oligotrophic" assemblage according to Palmer (1992). Characteristic taxa of the feature type, *Isoetes lacustris*, *Lobelia dortmanna* and *Littorella uniflora* are present alongside elements of a more dystrophic assemblage (*Sphagnum* sp.), reflecting the peaty influence in the lake. Based on the submerged and floating leaved vegetation only (Table 4.16.2), the average Trophic Rank Score (TRS) for this site is 5.1 (25.5/5). This is highly comparable to the TRS of 5.2 reported by Monteith ed. (1997), indicating that macrophyte assemblages have remained stable.

**Table 4.16.2: Macrophyte community composition for Llyn Alwen, including trophic scores. Numbers in brackets are back-calculated scores for July 1996 (Monteith ed., 1997).**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Fontinalis antipyretica* | 6.3 | F |
| *Isoetes lacustris* | 5.0 | D |
| *Littorella uniflora* | 6.7 | F |
| *Lobelia dortmanna* | 5.0 | O |
| *Sphagnum auriculatum* | 2.5 | A |
| **Average TRS** | **5.10 (5.2)** | |
| **PLEX (weighted)** | **3.66 (3.73)** | |
| **Ellenberg Fertility Index (weighted)** | **3.75 (3.68)** | |

Negative indicator species

Filamentous algal cover is generally moderate (mean cover score = 1.7; median = 2), with 27 % of sample spots having cover scores of 3. The moderate coverage of filamentous algae may indicate that the lake is slightly enriched, although the relationship between filamentous algal cover and enrichment requires further investigation. *Sphagnum auriculatum* occurs frequently, probably reflecting the lake's acidified status and/or the peaty nature of catchment soils. The frequent occurrence of *Fontinalis antipyretica* may reflect nutrient enrichment. No introduced macrophyte species are present.

Macrophyte community structure

The perimeter of Llyn Alwen is entirely surrounded by a stand of *Juncus effusus* flanked by *Polytrichum commune* hummocks. The lake littoral is dominated by *I. lacustris*, either growing on its own (to the north), in association with liverworts on cobbles (to the east), or in association with *L. dortmanna* and *L. uniflora* (to the west and south) to a depth of 0.9 m. No aquatic vegetation was found beyond a water depth of 2.1 m, although no higher plants were found growing beyond a depth of 0.9 m (*I. lacustris*). Monteith ed. (1997) reported a

maximum depth of macrophyte colonization of 2.2 m, suggesting that water clarity has remained stable over the last ten years. The lake supports a limited range of different macrophyte growth forms – isoetids (*I. lacustris, L. uniflora, L. dortmanna*), mosses (*Sphagnum auriculatum*), liverworts (*Nardia compressa, Scapania undulata*) and emergents (*J. effusus, J. articulatus*) – suggesting that the vegetation structure provides a restricted range of habitats within the lake. Trophic indices suggest that there has been very little change in the plant community since 1996.

Water quality

Llyn Alwen is a permanently acid lake (mean pH 4.7) with low ionic content. Although no ANC data are available, the site has a low alkalinity (20 $\mu eql^{-1}$) and is therefore poorly buffered and at risk of acidification. In 1996, alkalinity was -20 $\mu eql^{-1}$ and critical loads were exceeded under both the Henriksen and diatom models (Monteith ed., 1997). The current positive alkalinity value may indicate that the lake is recovering from an earlier period of acidification. The water transparency of Llyn Alwen is relatively poor and results from the significant concentration of dissolved organic carbon derived from the peaty catchment soils. Phosphorus concentrations are high and above the target/limit for the lake's feature type (mean TP = 36 $\mu gl^{-1}$; range = 10 – 63 $\mu gl^{-1}$). Concentrations are also higher than those measured in 1996 (16 $\mu gl^{-1}$) by Monteith ed. (1997). Nitrate and chlorophyll a concentrations are generally low. The water chemistry data for Llyn Alwen should be treated with some caution since all data are from winter 2004.

Lake hydrology

The lake appeared to have a more or less natural hydrological regime. Two main inflows enter the lake to the north east and north west. The outflow is to the south east.

Lake substrate

The shoreline appears to retain its natural character, with lake substrates dominated by cobbles, pebbles and gravels.

Sediment load

The lake is predominantly surrounded by dry acid heath and there is some rough grazing to the shore, which could potentially increase lake sediment loads.

Indicators of local distinctiveness

None to note in relation to the lake itself, although the Mynydd Hiraethog SSSI is important for its diverse upland breeding bird community.

Palaeolimnological evidence

Diatom analysis of the top and bottom samples from a 25 cm sediment core are presented in Bennion ed. (2004). The squared chord distance dissimilarity score between the two samples was 0.830, indicating a significant degree of floristic change in the Llyn Alwen core, indicative of acidification. Surface sediment samples from both 1996 (Monteith ed., 1997) and 2004 (Burgess, unpublished) are dominated by *Eunotia incisa*, a diatom taxon associated with moderately acid conditions.

Summary

Llyn Alwen is considered to be in overall **unfavourable** condition. The macrophyte assemblage contains all the characteristic *Littorelletea* taxa of the lake's feature type, although *L. uniflora* and *L. dortmanna* populations are sparse and *I. lacustris* only grows to a depth of 0.9 m – considerably shallower than the site's water clarity would suggest. Mosses and liverworts are the only plants growing between 0.9 and 2.2 m depth. The water transparency of Llyn Alwen is relatively poor and results from the significant concentration of dissolved organic carbon, reflecting the peaty catchment soils. Phosphorus concentrations are higher than the target for the feature type and indicate nutrient enrichment. However, both the lake and its catchment appear to be in a relatively natural state, although the extent of grazing pressure around the lake should be monitored to ensure that it does not negatively impact upon the lake ecosystem.

Palaeolimnological evidence suggests that Llyn Alwen has been acidified, although following reductions in emissions of nitrogen and sulphur, lake alkalinisation is probably occurring and the lake may now be recovering. This is suggested by the current positive alkalinity values. Recovery trends should be monitored.

No WFD risk assessment is available for comparison.

**Table 4.16.3: Mynydd Hiraethog SSSI: Overview**

| Water Body | Status | Reason(s) for Failure | Comments |
|---|---|---|---|
| Llyn Alwen | Unfavourable | Acidification and eutrophication.<br>Sparse macrophyte cover in deeper water areas and restricted distribution of most characteristic *Littorelletea* species. | Recovery from acidification in progress - alkalinity values higher than in 1996.<br>Concerns over high TP concentrations.<br>Site is exposed, probably affecting macrophyte species distributions.<br>Many key elements essential to favourable condition still present, but depth distribution of macrophytes restricted. |
| **Overall SSSI Status** | **Unfavourable** | | |

## *4.17 Llyn Bodlyn (currently unnotified)*

### 4.17.1 Llyn Bodlyn (LA, S)

Annex 1 type: H3130: Oligotrophic to mesotrophic standing water with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*. Favourable Condition Table 4.

**Table 4.17.1: Condition Assessment Summary Table for Llyn Bodlyn**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise) | ✓ | 4 species present: *L. uniflora*, *L. dortmanna, S. angustifolium* & *I. lacustris* |
| | No loss of characteristic species (see Box 2) | - | Baseline survey |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) have ≥ 1 characteristic species | ✓ | 92 % of vegetated sample spots comply (wader 92%, boat 95%) |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | No introduced species |
| | Benthic and epiphytic filamentous algal cover <10% | ✓ | Mean cover = 1.7; median = 2<br>16% (16/99) of sample spots have scores of 3 |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (see Table 4) | ✓ | 0 – (1.5) 2.0 m: *L. uniflora, L. dortmanna, I. lacustris, C. hamulata*<br>2.0 - 4.5 m: *I. lacustris*, *N. flexilis, M. alterniflorum* |
| | Maximum depth distribution should be maintained | ✓ | $Z_{max}$ = 20.0 m, $Z_{mean}$ = ?? m, $Z_s$ = 3.9 m, $Z_v$ = 4.5 m |
| | At least the present structure should be maintained | - | Baseline survey |

**Table 4.17.1 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels: TP target / limit = 10 µg P $l^{-1}$ | **X?** | TP = 20.6 $\mu g l^{-1}$; SRP = 8.5 $\mu g l^{-1}$ TN = 0.56 $mg l^{-1}$; $NO_3^-$-N = 0.28 $mg l^{-1}$; Chl *a* = 3.1 $\mu g l^{-1}$ |
| | Stable pH / ANC values: pH ~ 5.5 – 7.0 and ANC > 20 | ✓ | pH = 6.8 (range 5.7 – 7.9) ANC data unavailable Alk= 45$\mu eq l^{-1}$; DOC=2$mg l^{-1}$ |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 $mg l^{-1}$) | ✓ | 9 - 10 $mg l^{-1}$ from 0 - 20 m depth |
| | No excessive growth of cyanobacteria or green algae | ✓ | No algal blooms recorded |
| **Hydrology** | Natural hydrological regime | **X** | Water supply reservoir – water level regulated |
| **Lake substrate** | Natural shoreline maintained | **✓?** | Shoreline modification code: 1 Wall beyond lake buffer zone |
| | Natural and characteristic substrate maintained | ✓ | Coarse natural substrates – dominate marginal zone, silt beyond. |
| **Sediment load** | Natural sediment load maintained | **✓?** | Catchment landcover dominated by rough upland grazing. |
| **Indicators of local distinctiveness** | Distinctive elements maintained | - | Contains Britain's southernmost population of Arctic charr (present in 2003). |
| | Minimal negative impacts and no fish farming | **✓?** | |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | **X** | Burgess et al. (2005): 0-22 cm core: Sq chord distance = 0.707: Modest diatom species floristic change, indicative of moderate acidification. Decline in *C. comensis* and *A. minutissima*. Increase in *E. incisa, P. fibula* and *T. flocculosa*. |

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

Extent

Llyn Bodlyn lies at an altitude of 385 m. The surface area of the lake is 16.5 ha, with a volume of ?? $x10^3 m^3$.

Macrophyte community composition

The aquatic vegetation of Llyn Bodlyn keys out as a Type 3 "oligotrophic" assemblage according to Palmer (1992). The assemblage is dominated by characteristic taxa of the feature type, *Littorella uniflora*, *Lobelia dortmanna* and *Isoetes lacustris*, with *Sparganium angustifolium* recorded as occasional. Llyn Bodlyn is relatively species rich and passes the macrophyte community composition target for its feature type, both in terms of the number of *Littorelletea* species present and the representation of these and other characteristic species across the survey sections. Based on the submerged and floating leaved vegetation only (Table 4.17.2), the average Trophic Rank Score (TRS) for this site is 5.08 (45.7/9).

**Table 4.17.2: Macrophyte community composition for Llyn Bodlyn, including trophic scores.**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Callitriche hamulata* | 5.0 | F |
| *Eleogiton fluitans* | - | R |
| *Fontinalis antipyretica* | 6.3 | F |
| *Isoëtes lacustris* | 5.0 | D |
| *Juncus bulbosus* | 3.7 | O |
| *Littorella uniflora* | 6.7 | D |
| *Lobelia dortmanna* | 5.0 | A |
| *Myriophyllum alterniflorum* | 5.5 | A |
| *Nitella flexilis* (agg.) | 5.5 | R |
| *Sparganium angustifolium* | 3.0 | O |
| **Average TRS** | **5.08** | |
| **PLEX (weighted)** | **4.31** | |
| **Ellenberg Fertility Score (weighted)** | **4.24** | |

Negative indicator species

Filamentous algal cover is generally moderate (mean cover score = 1.7; median = 2), with few sample spots (16 %) having cover scores of 3. The moderate coverage of filamentous algae may indicate that the lake is slightly enriched, although the relationship between filamentous algal cover and enrichment requires further investigation. No introduced macrophyte species are present in the lake.

Macrophyte community structure

*Juncus effusus* is the dominant marginal species along with *Sphagnum* spp. The submerged vegetation of Llyn Bodlyn is well developed and is found in a band from the shore generally to about 4.5 m depth, with the zonation of species typical of a nutrient-poor upland lake. *L. dortmanna* and *L. uniflora* characteristically dominate the shallow water around the site to depths of 1.5 m and 2.0 m respectively. *I. lacustris* is also abundant in the shallow water areas, but more commonly found in deeper waters to 4.5 m. *M. alterniflorum* and *N. flexilis* (agg.) are also typical deep water species, predominantly growing at depths of 2.0 – 4.5 m.

The lake supports a range of different macrophyte growth forms – isoetids (*I. lacustris, L. uniflora, L. dortmanna*), charophytes (*Nitella flexilis* agg.), mosses (*S. auriculatum*), submerged fine-leaved species including elodeids (*M. alterniflorum, J. bulbosus*), floating-leaved species (*S. angustifolium*) and emergents (*J. effusus, J. articulatus, Carex* spp.) – suggesting that the vegetation structure provides a good range of habitats within the lake.

Water quality

Llyn Bodlyn is a mildly acidic lake (mean pH 6.8) with low ionic content. Although no ANC data are available, alkalinity is moderate (45 $\mu eql^{-1}$), suggesting that the lake is reasonably well buffered. DOC concentrations are relatively low (~ 2), which could be considered favourable for the macrophyte species present. Phosphorus concentrations are relatively high (mean TP 20 $\mu gl^{-1}$) and above the target/limit for the feature type, suggesting that the lake has been enriched. However, nutrient sources are not easily determined. Both chlorophyll *a* and nitrate concentrations are generally low.

Lake hydrology

Llyn Bodlyn is a water supply reservoir and therefore has a modified hydrological regime.

Lake substrate

The shoreline more or less retains its natural character, with marginal and shallow water areas dominated by coarse substrates including boulders, cobbles, pebbles and gravels. Silt predominates in the deeper water areas.

Sediment load

The lake is predominantly surrounded by dry acid heath and there is some rough grazing, which could potentially increase lake sediment loads. Llyn Bodlyn is a water supply reservoir that can be periodically drawn down. Draw-down could increase sediment loads as exposed marginal sediments are re-worked and washed into the lake.

Indicators of local distinctiveness

None to note

Palaeolimnological evidence

Diatom analysis of the top and bottom samples from a 22 cm sediment core are presented in Burgess *et al*. (2005). The core bottom (22 cm) sample was diverse with the presence of both planktonic and non-planktonic species typical of circumneutral to mildly acid waters. The top sample contained some of the same taxa as the bottom sample but both *Achnanthes minutissima* and *Cyclotella comensis* declined markedly and increasing amounts of taxa commonly found in moderately to strongly acid conditions appeared (*Eunotia incisa, Peronia fibula, Frustulia rhomboides* and *Tabellaria flocculosa*). The squared chord distance dissimilarity score between the two samples was 0.707, suggesting significant diatom floristic change in the Llyn Bodlyn core, indicative of acidification.

Summary

Llyn Bodlyn is considered to be in overall **unfavourable** condition. This is largely due to the lake's acidification history and current concentrations of phosphorus that are higher than the feature type targets. However, the lake's macrophyte assemblage comprises all the characteristic taxa expected and their representation across the survey sections is high.

Furthermore, the lake and its catchment appear to be relatively unimpacted aside from the lake's use as a water supply reservoir and the presence of some degree of rough grazing pressure in the catchment. Reservoir water levels and catchment grazing pressure should be managed to ensure minimal negative impact upon the lake ecosystem.

A WFD risk assessment considers that Llyn Bodlyn is probably *not* at risk from either diffuse or point source pollution. This appears contrary to palaeolimnogical evidence that suggests the lake has acidified. However, following reductions in atmospheric concentrations of nitrogen and sulphur over the last few decades, the pH of Llyn Bodlyn has increased. In the late 1980s, mean pH was 5.4 (Stevenson *et al*., 1991), whereas in 2004, mean pH was 6.8. Furthermore, alkalinity values increased over the same period, indicating recovery from acidification. With this in mind, Llyn Bodlyn should probably be classified as **unfavourable, recovering**.

**Table 4.17.3: Llyn Bodlyn: Overview**

| Water Body | Status | Reason(s) for Failure | Comments |
|---|---|---|---|
| Llyn Bodlyn | Unfavourable, recovering? | Acidification and eutrophication.<br>Water supply reservoir | Recovery from acidification in progress - alkalinity and pH higher than in the late 1980s.<br>Concerns over high TP concentrations – source unknown.<br>Many key elements essential to favourable condition still present. |
| **Overall SSSI Status** | **Unfavourable, recovering?** | | |

## *4.18 Llyn Eiddwen SSSI*

### 4.18.1 Llyn Eiddwen (LA, V)

Annex 1 type: H3130: Oligotrophic to mesotrophic standing water with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*. Favourable Condition Table 4.

**Table 4.18.1: Condition Assessment Summary Table for Llyn Eiddwen**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise) (Mesotrophic?) | ✓ | 6 species present: *L. uniflora*, *L. dortmanna, S. aquatica*, *I. lacustris, I. echinospora* & *L. natans* |
| | No loss of characteristic species (see Box 2) | ✓ | Similar species in 2003 and 2004 to those recorded in 1994 (Monteith ed., 1995) |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) have ≥ 1 characteristic species | ✓ | 99% of vegetated sample spots comply (wader 99%, boat 100%) – calculated from 2003 data |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | No introduced species |
| | Benthic and epiphytic filamentous algal cover <10% | ✓ | Mean cover = 1.8; median = 2<br>4% (4/97) of sample spots have scores of 3 (2003 data) |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (see Table 4) | ✓? | 0–1m: *L. uniflora, L. dortmanna, S. aquatica*<br>1–2m: *I. lacustris, C. hamulata, L. natans, N. translucens*<br>2–3m: *N. translucens* (in 2003) |
| | Maximum depth distribution should be maintained | ✓? | $Z_{max}$ = 7.5 m, $Z_{mean}$ = 2.6 m,<br>$Z_s$=1.7m 2004 (0.4m in 2003)<br>$Z_v$=1.9m 2004 (3.0m in 2003) |
| | At least the present structure should be maintained | ✓ | Similar structure to that reported in 1994 (Monteith ed., 1995) |

**Table 4.18.1 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels:<br>TP target / limit = 10 – 20??<br>µg P $l^{-1}$ | **X** | TP = 28 $\mu g l^{-1}$; SRP = 12 $\mu g l^{-1}$<br>TN = 0.6 $mg l^{-1}$; $NO_3^-$-N = 0.3 $mg l^{-1}$; Chl *a* = 10.4 $\mu g l^{-1}$ |
| | Stable pH / ANC values:<br>pH ~ 5.5 – 7.0 and ANC > 20 | ✓ | pH = 6.5 (range 4.4 – 8.0)<br>ANC data unavailable<br>Alk= 120$\mu eq l^{-1}$; DOC= 6.4$mg l^{-1}$ |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 $mg l^{-1}$) | ✓ | 9 - 10 $mg l^{-1}$ from 0 - 7 m depth |
| | No excessive growth of cyanobacteria or green algae | **X?** | Blue green algal bloom recorded in 2003, but none noted in 2004 |
| **Hydrology** | Natural hydrological regime | ✓ | Appears natural |
| **Lake substrate** | Natural shoreline maintained | **X?** | Shoreline modification code: 0-2 |
| | Natural and characteristic substrate maintained | ✓ | Cobbles, pebbles and gravels dominate marginal zone, silt beyond. |
| **Sediment load** | Natural sediment load maintained | **X?** | Catchment landcover comprises dry acid heath used for rough upland grazing.<br>Livestock poaching of the shoreline. |
| **Indicators of local distinctiveness** | Distinctive elements maintained | **✓?** | - Annex II species, *L. natans* recorded in 2004 and 1994 Absent from 2003 survey.<br>- *I. echinospora* recorded in section 1 in 2003.<br>- One of most southerly sites for *S. aquatica.* |
| | Minimal negative impacts and no fish farming | **X?** | Livestock poaching of shoreline |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | **X?** | Bennion *et al*. (1998) & Bennion ed. (2004):<br>0-40 cm core: Sq chord distance = 0.774: Moderate floristic change = alkalinization and slight eutrophication. Increase in planktonic taxa at core top. |

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

Extent

Llyn Eiddwen lies at an altitude of 305 m. The surface area of the lake is 10.1 ha, with a volume of 260 x$10^3$$m^3$.

Macrophyte community composition

The aquatic vegetation of Llyn Eiddwen keys out as a Type 2-3 "oligotrophic" assemblage according to Palmer (1992). The macroflora of Llyn Eiddwen is rich and characteristic of a nutrient poor but not strongly acid lake. Six characteristic *Littorelletea* taxa are present - *Littorella uniflora*, *Lobelia dortmanna, Isoetes lacustris, Isoetes echinospora, Subularia aquatica* and *Luronium natans*. These and other characteristic taxa are well represented across the survey sections and are present in almost all vegetated sample spots (in both 2003 and 2004). Based on the submerged and floating leaved vegetation only (Table 4.18.2), the average Trophic Rank Score (TRS) for this site is 4.76 (57.1/12). This is lower than the TRS of 5.7 reported from a macrophyte survey undertaken in 1996 and reported in Monteith ed. (1997). This may be because a couple of species with low TRSs were recorded as submerged taxa in 2003/4, but were not recorded in 1996 (including *Juncus bulbosus, Sphagnum auriculatum* and *Utricularia minor*).

**Table 4.18.2: Macrophyte community composition for Llyn Eiddwen, including trophic scores. Numbers in brackets are back-calculated scores for summer 1996 (Monteith ed., 1997)**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Callitriche hamulata* | 5.0 | R |
| *Elatine hexandra* | 6.0 | R |
| *Isoëtes lacustris* | 5.0 | A |
| *Isoëtes echinospora* | - | R |
| *Juncus bulbosus* | 3.7 | R |
| *Littorella uniflora* | 6.7 | D |
| *Lobelia dortmanna* | 5.0 | D |
| *Luronium natans* | - | R |
| *Nitella translucens* | 5.5 | A |
| *Potamogeton natans* | 6.7 | F |
| *Potamogeton polygonifolius* | 3.0 | R |
| *Sphagnum auriculatum* | 2.5 | R |
| *Subularia aquatica* | 4.0 | O |
| *Utricularia minor* | 4.0 | O |
| **Average TRS** | **4.76 (5.7)** | |
| **PLEX (weighted)** | **4.05 (4.51)** | |
| **Ellenberg Fertility Score (weighted)** | **3.97 (4.26)** | |

Negative indicator species

Filamentous algal cover is generally moderate (mean cover score = 1.8; median = 2), with few sample spots (4 %) having cover scores of 3. The moderate coverage of filamentous algae may indicate that the lake is slightly enriched, although the relationship between filamentous algal cover and enrichment requires further investigation. No introduced macrophyte species were observed in Llyn Eiddwen.

Macrophyte community structure

A broad swathe of wetland vegetation dominated by *Juncus* sp. circles the lake. The southern end of the lake is marshy, comprising a *Carex rostrata* swamp community.

Much of the shallow water (< 1.0 m) is dominated by *L. uniflora* and *L. dortmanna*. The deeper water areas are dominated by *N. translucens*, which grows to a depth of 2 - 3 m. The maximum depth of macrophyte colonisation in 2003 was 3.0 m, which was similar to that reported in 1994 by Monteith ed. (1995). The maximum colonization depth in 2004 was only 1.9 m, perhaps reflecting interannual variation in macrophyte populations at the site. The lake supports a good range of different macrophyte growth forms – isoetids (*I. lacustris, I. echinospora, L. uniflora, L. dortmanna*), charophytes (*N. translucens*), mosses (*S. auriculatum*), submerged fine-leaved species (*U. minor, J. bulbosus, L. natans, C. hamulata, E. hexandra, S. aquatica*), floating-leaved species (*P. polygonifolius, P. natans*) and emergents (*J. effusus, J. articulatus, C. rostrata, E. fluviatile*) – suggesting that the vegetation structure provides a wide range of habitats within the lake.

Water quality

Llyn Eiddwen is a mildly acidic lake (mean pH 6.5) with relatively low ionic content. The lake appears to be well buffered and at low risk of acidification. Monteith ed. (1995) reported that critical loads had not been exceeded. DOC concentrations are moderate (6.39), reflecting the influence of peaty soils in the lake's catchment. TP Mean annual phosphorus concentrations are relatively high (28 $\mu gl^{-1}$) and are above the 10 $\mu gl^{-1}$ target/limit for oligotrophic lakes. Chlorophyll *a* concentrations are higher than would be expected for an oligotrophic lake. In September 2003, a cyanobacterial bloom was reported producing a thick scum at the northern end of the lake. This evidence, combined with a mean TP concentration of 28 $\mu gl^{-1}$ (above the attribute target/limit of 10 $\mu gl^{-1}$) and a mean chlorophyll *a* concentration of 10 $\mu gl^{-1}$, suggests nutrient enrichment of the lake. Similar signs of enrichment were recorded from a survey undertaken in 1994 and reported in Monteith ed. (1995).

Lake hydrology

The lake appears to have a more or less natural hydrological regime. The main inflow to the lake drains the most steeply sloping area of the catchment.

Lake substrate

The shoreline retains its natural character. Cobbles and pebbles dominate the marginal substrates with some areas of peat. Substrates in the deeper water areas are predominantly silts.

Sediment load

The lake is predominantly surrounded by dry acid heath and there is some rough grazing, which could potentially increase lake sediment loads, although the marginal areas of the lake have been continuously grazed by livestock for many years. Bennion *et al.* (1998) reported

extensive evidence of peat cutting in the catchment, which could lead to increased sediment loading to the lake if exposed peat cuttings are subject to heavy rainfall. Conversely, Bennion *et al*. (1998) also reported apparent decreases in percentage organic matter and sediment accumulation rates at the top of a sediment core from the lake and interpreted this as indicative of a recent decrease in catchment disturbance.

Indicators of local distinctiveness

The catchment of Llyn Eiddwen is predominantly sheep grazed pasture (some improved), which extends to the lake shores and results in moderate poaching impact to marginal areas. The Annex II submerged macrophyte species, *L. natans* was recorded from Llyn Eiddwen in both 1996 and 2004 – populations should be monitored to determine its status. *Isoetes echinospora* was confirmed from megaspores to be growing in section 1 in 2004. All other *Isoetes* records from the 2003/4 surveys are of *I. lacustris*.

Palaeolimnological evidence

Diatom analysis of selected samples from a 40 cm sediment core are presented in Bennion *et al*. (1998). The squared chord distance dissimilarity score between the top and bottom samples is 0.774 (Bennion ed., 2004), suggesting a moderate degree of floristic change in the Llyn Eiddwen core, indicative of slight alkalinization. There is also an increase in planktonic taxa towards the core top, suggestive of a change in lake ecosystem functioning from periphyton to phytoplankton dominance, perhaps resulting from recent nutrient enrichment.

Summary

Llyn Eiddwen is a reasonably good example of a mesotrophic lake of its Annex 1 feature type although it is still considered to be in overall **unfavourable** condition.

The macrophyte assemblage contains many characteristic *Littorelletea* taxa of mesotrophic waters (*L.uniflora*, *L.dortmanna, S.aquatica*, *I. lacustris, L.natans*)**.** The representation of these and other characteristic species (*N. translucens, U. minor, E. hexandra*) across the survey sections is high (99 % of vegetated sample spots have at least one characteristic species).

At the time of the 2003 macrophyte survey, water clarity was poor, although this was probably only temporary because the maximum depth of macrophyte colonization was considerably deeper than would be expected under such turbid conditions. Furthermore, Secchi depth was significantly greater during the 2004 survey, although maximum colonization depth was similar to that recorded in 2003. Reduced water clarity most likely resulted from the cyanobacterial bloom present at the time of the 2003 survey.

Palaeolimnological evidence suggests that Llyn Eiddwen has experienced a slight post-1950s increase in TP concentrations, although the dominant change has been in the increased alkalinity of the lake waters as inferred from a change in the lake's diatom flora. Alkalization of lowland waters is relatively common, but trends of alkalization are unusual for relatively low alkalinity surface waters. Alkalization is most likely related to changes in catchment land-use practices such as agricultural improvement and may have protected the lake from surface water acidification due to acid deposition (Bennion *et al*., 1998).

We recommend that nutrient concentrations are closely monitored in Llyn Eiddwen to track enrichment trends. Cyanobacterial blooms should also be monitored to ascertain any increase in their frequency and/or extent. Surface sediment and/or epilithic diatom assemblages could also provide a useful indication of ecologically significant lake ecosystem change in relation to eutrophication.

The impact of grazing around the lake is relatively high, with significant poaching of the lake's marginal areas around all shores. Although some grazing of marginal areas may be beneficial, grazing pressure should be monitored to ensure that it does not negatively impact upon the lake ecosystem. Catchment stocking densities and agricultural practices should be investigated to identify possible nutrient sources.

The Annex II species, *Luronium natans* was recorded from the lake in both 2004 and 1994. It was locally abundant, growing at water depths of between 1.0 – 1.6 m. No plants of *L. natans* were recorded in 2003, when water clarity was lower than that recommended for *L. natans* and the patchy distribution of *L. natans* meant that it was missed from the survey. Populations of *L. natans* should be monitored to ensure that this species is not lost from the lake, particularly if water clarity decreases and/or nutrient levels increase.

No WFD risk assessment is available for Llyn Eiddwen for comparison.

**Table 4.18.3: Llyn Eiddwen: Overview**

| Water Body | Status | Reason(s) for Failure | Comments |
|---|---|---|---|
| Llyn Eiddwen | Unfavourable | Eutrophication?<br>Grazing pressure? | Relatively high TP concentrations for feature type. Chemical survey evidence suggests stable nutrient levels for at least the last 20 years, although there may be a recent slight increase in TP.<br>Poaching of the shoreline may increase sediment loads.<br>Many key elements essential to favourable condition still present. |
| **Overall SSSI Status** | **Unfavourable** | | |

## *4.19 Llyn Glasfryn SSSI*

### 4.19.1 Llyn Glasfryn (MA, V)

Annex 1 type: H3130: Oligotrophic to mesotrophic standing water with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*. Favourable Condition Table 4.

**Table 4.19.1: Condition Assessment Summary Table for Llyn Glasfryn**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | Mesotrophic: ≥ 3 characteristic *Potamogeton* species and ≥ 8 characteristic species listed in Box 2 (unless valid reasons suggest otherwise) | **X** | No characteristic *Potamogeton* species present<br>2 other characteristic species present:<br>*E.hexandra* & *N.flexilis* (agg.) |
| | No loss of characteristic species (see Box 2) | **X** | *P.perfoliatus* & *L.natans* lost since SSSI notification – *P.perfoliatus* recorded as rare in 1996 (Monteith ed., 1997)<br>*L. uniflora* recorded in 1996, but absent in 2004. |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) have ≥ 1 characteristic species | **X** | Only 4% of vegetated sample spots comply (wader 5%, boat 3%) |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | No introduced species |
| | Benthic and epiphytic filamentous algal cover <10% | ✓ | Mean cover = 1.3; median = 1<br>3% (4/116) of sample spots have scores of 3 |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (see Table 4) | ✓**?** | ~0.25m: *E. hexandra, E. hydropiper, E. acicularis*<br>0.5-1.0m: *N. alba, N. lutea*<br>0.0-1.1m: *M. alterniflorum*<br>0.8-1.1m: *P. obtusifolius* |
| | Maximum depth distribution should be maintained | ✓ | $Z_{max}$ = 1.1 m, $Z_{mean}$ = 0.7 m, $Z_s$ = 0.9 m, $Z_v$ = 1.1 m |
| | At least the present structure should be maintained | ✓ | Similar depth distribution to that recorded in 1996 (Monteith ed., 1997) – although different species. |

**Table 4.19.1 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels: TP target / limit = 20 µg P $l^{-1}$ | **X?** | TP = 42 µg$l^{-1}$; SRP = 18 µg$l^{-1}$ TN = 0.9 mg$l^{-1}$; $NO_3^-$-N = 0.03 mg$l^{-1}$; Chl *a* = 7.1 µg$l^{-1}$ |
| | Stable pH / ANC values: pH ~ 5.5 – 7.0 and ANC > 20 | ✓ | pH = 7.1 (range 5.7 – 7.9) Alkalinity = 430 µeq$l^{-1}$ DOC = 6.7 mg$l^{-1}$ |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 mg$l^{-1}$) | - | No data available |
| | No excessive growth of cyanobacteria or green algae | ✓ | No algal blooms recorded |
| **Hydrology** | Natural hydrological regime | **✓?** | Appears largely natural. Small surface catchment. Some input derived from underground springs and drains. |
| **Lake substrate** | Natural shoreline maintained | **X?** | Shoreline modification code: 2 Crenate shoreline and islands give lake habitat diversity. |
| | Natural and characteristic substrate maintained | ✓ | Silt, cobbles & gravels dominate marginal zone. Silt beyond. |
| **Sediment load** | Natural sediment load maintained | **X?** | Catchment landcover: *Alnus* & deciduous wood to east. Improved, extensively grazed grassland to east. |
| **Indicators of local distinctiveness** | Distinctive elements maintained | **X?** | *L. natans* absent in 2004. Rare vascular plants *E. hexandra, E. hydropiper* and *E. acicularis* still present. |
| | Minimal negative impacts and no fish farming | **X?** | Stocked with Brown trout. Mallard ducks reared for shooting at site. |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | **?** | Bennion ed. (2004): 0-23 cm: Sq chord distance = 0.938: Significant floristic change, indicative of alkalinisation and slight eutrophication. |

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

Extent

Llyn Glasfryn lies at an altitude of 129 m. The surface area of the lake is 5.8 ha, with a volume of 42 x$10^3$$m^3$.

Macrophyte community composition

The aquatic vegetation of Llyn Glasfryn keys out as a Type 5 "mesotrophic" assemblage according to Palmer (1992), although the vegetation characteristics span a number of other types - Monteith ed. (1997) defined the site as Type 9 "eutrophic". Llyn Glasfryn is relatively species rich. Based on the submerged and floating leaved vegetation only (Table 4.19.2), the average Trophic Rank Score (TRS) for this site is 7.12 (78.3/11). This is highly comparable to the TRS of 7.5 reported in Monteith ed. (1997) and based on data from a macrophyte survey undertaken in 1996.

**Table 4.19.2: Macrophyte community composition for Llyn Glasfryn, including trophic scores. Numbers in brackets are back-calculated scores for July 1996 (Monteith ed., 1997)**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Callitriche hamulata* | 5.0 | R |
| *Ceratophyllum demersum* | 10.0 | R |
| *Elatine hexandra* | 6.0 | R |
| *Elatine hydropiper* | - | O |
| *Eleocharis acicularis* | 8.5 | O |
| *Fontinalis antipyretica* | 6.3 | R |
| *Myriophyllum alterniflorum* | 5.5 | D |
| *Nitella flexilis (agg.)* | 5.5 | R |
| *Nuphar lutea* | 8.5 | F |
| *Nymphaea alba* | 6.7 | F |
| *Persicaria amphibia* | 9.0 | R |
| *Potamogeton obtusifolius* | 7.3 | F |
| **Average TRS** | **7.12 (7.5)** | |
| **PLEX (weighted)** | **5.72 (5.96)** | |
| **Ellenberg Fertility Score (weighted)** | **6.17 (6.18)** | |

Negative indicator species

Filamentous algal cover is low to moderate (mean cover score = 1.3; median = 1), with few sample spots (3 %) having cover scores of 3. No introduced macrophyte speciesare present in Llyn Glasfryn. In August 2004, *Myriophyllum alterniflorum* dominated the submerged macrophyte assemblage across all water depths and survey sections. This species was not recorded in 1996 (Monteith ed., 1997). Similarly, *Ceratophyllum demersum* was absent in 1996, but was present (rare) in 2004. Both *Litorella uniflora* and *Potamogeton perfoliatus* were recorded in 1996, but were absent from the 2004 survey. These species shifts may simply reflect interannual variation in macrophyte populations, or may provide evidence of increasing trophic status. In particular, the dominance of *M. alterniflorum* in mesotrophic waters is indicative that a lake is not in favourable condition. Interannual shifts in macrophyte species abundances should be monitored to determine directional change in lake ecosystem functioning.

Macrophyte community structure

Llyn Glasfryn is a shallow lowland lake with macrophytes growing to the maximum depth of the site (1.1 m). Fringing vegetation is mixed: *Juncus* marsh to improved grazing in section 1, a buffer strip to improved ley grassland in section 2 (west side), *Salix* scrub in section 3 and overhanging *Alnus* grading to deciduous woodland on the east side (section 4). The August 2004 survey recorded *E. hexandra, E. hydropiper* and *E. acicularis* as common in the shallowest water areas (~0.25 m). Water lilies (*N. lutea, N. alba*) grow in patches around the lake between depths of 0.5-1.0 m. *M. alterniflorum* is dominant throughout the lake. *P. obtusifolius* is common in deeper water areas (0.8-1.1 m) with small amounts of *N. flexilis* agg. growing alongside. The lake supports a range of different macrophyte growth forms – charophytes (*N. flexilis* agg.), mosses (*F. antipyretica*), submerged fine-leaved species (*M. alterniflorum, P. obtusifolius, E. acicularis, C. demersum, E. hexandra, E. hydropiper, C. hamulata*), floating-leaved species (*N. lutea, N. alba, P. amphibia*) and emergents (*Juncus* spp.*, Carex* spp.*, I. pseudacorus, P. arundinacea, A. plantago-aquatica, M. trifoliata, E. palustris, E. cf. multicaulis*). No isoetids are present. The diversity of growth forms suggests that the lake's vegetation structure provides a wide range of habitats for aquatic fauna.

Water quality

Llyn Glasfryn is a lowland, circumneutral lake (mean pH 7.11). It is at very low risk of acidification due to its moderate alkalinity and high buffering capacity. Phosphorus data indicate that the lake is enriched, with concentrations above the target/limit for the feature type, although data from 1996 (Monteith ed., 1997) indicate that nutrient and productivity levels have decreased since 1996 (from 146 $\mu gl^{-1}$ to 42 $\mu gl^{-1}$ mean annual TP and from 101 $\mu gl^{-1}$ to 7 $\mu gl^{-1}$ mean annual chlorophyll *a*).

Lake hydrology

The lake appeared to have a more or less natural hydrological regime. The surface catchment of the lake is small, but underground springs and drains contribute to the lake's inflow.

Lake substrate

The shoreline more or less retains its natural character with lake substrates dominated by silts, pebble and cobbles.

Sediment load

There may be increased sediment loads due to runoff from grazed pasture, although around much of the lake there is marginal vegetation that should prevent significant sediment inwash. There is a buffer strip between the area of improved grassland and the lake shore and the area of *Salix* scrub adjacent to the shore in section 3 should prevent significant impact from any road runoff.

Indicators of local distinctiveness

The surface catchment of Llyn Glasfryn is small and predominantly covered with extensively grazed grassland, some of which is improved (seeded ley). The Annex II submerged macrophyte species, *L. natans* was noted from Llyn Glasfryn at the time of SSSI notification, however no plants of *L. natans* were recorded in 2004, which could indicate a loss of the plant from the lake – populations should be monitored to determine its status.

Palaeolimnological evidence

Diatom analysis of the top and bottom samples from a 22 cm sediment core are presented in Allott *et al*. (2001) and Bennion ed. (2004). The squared chord distance dissimilarity score between the top and bottom samples is 0.938, suggesting significant floristic change. Floristic change is indicative of alkalinization and eutrophication. In 1996, the surface sediment diatom assemblage was dominated by small benthic *Fragilaria* spp., the periphytic taxon *Achnanthes minutissima* and the epiphytic taxon *Cocconeis placentula*. Similar species were recorded in seasonal periphyton samples from 2004 (Burgess *et al*., unpublished), suggesting little change in habitat structure over the period 1996-2004. Nutrient enrichment probably pre-dated 1996.

Summary

Llyn Glasfryn is in overall **unfavourable** condition. The site may be recovering from a period of significant eutrophication, since phosphorus concentrations and lake productivity have decreased significantly since 1996. However, feature type TP limits are currently exceeded and must decline further for the site to attain favourable condition. The macrophyte assemblage contains some characteristic species, although in 2004 the lake flora was dominated by *M. alterniflorum*, suggesting nutrient enrichment. The macrophyte species, *L. uniflora*, *L. natans* and *P. perfoliatus* may have been lost through increased trophic status, although their absence from the 2004 survey may also reflect interannual variation in populations and/or their patchy distribution and hence absence from survey section locations. Regular macrophyte surveys should be carried out to further investigate any species losses.

Populations of the Annex II species, *L. natans* should be monitored to determine whether absence in both 1996 and 2004 reflects a real loss of the species from Llyn Glasfryn in response to eutrophication – further investigation is suggested.

Grazing pressure around the lake and the improvement of grassland through application of fertilizers should be monitored and managed to ensure that it does not negatively impact upon the lake ecosystem. Feeding of mallard ducks at or near the lake may result in raised nutrient levels.

Palaeolimnological evidence from a core taken in the mid-1990s presented in Allott *et al*. (2001) and Bennion ed. (2004) suggests that Llyn Glasfryn had experienced some degree of eutrophication, although it may now be recovering.

No WFD risk assessment is available for Llyn Glasfryn for comparison.

**Table 4.19.3: Llyn Glasfryn: Overview**

| Water Body | Status | Reason(s) for Failure | Comments |
|---|---|---|---|
| Llyn Glasfryn | Unfavourable | Eutrophication | High TP concentration, but TP & productivity less than in 1996. Buffer strip between improved grassland and lake. Possible loss of nutrient sensitive macrophyte species – further investigation required |
| **Overall SSSI Status** | **Unfavourable** | | |

## *4.20 Llyn Llygeirian SSSI*

### 4.20.1 Llyn Llygeirian (MA, V – moderately base-rich lowland lake)

Annex 1 type: H3150: Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation. Favourable condition table 6.

**Table 4.20.1: Condition Assessment Summary Table for Llyn Llygeirian**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | ≥ 6 of the characteristic species listed in Box 4 and 1 broadleaved *Potamogeton* species | ✓? | 1 broadleaved *Potamogeton* species present: *P.perfoliatus*<br>6? characteristic species present: *Magnopotamion*: *P.perfoliatus, P. pusillus, C. aspera, C. globularis*<br>*Hydrocharition: L. minor, L. trisulca.* |
| | No loss of characteristic species | **X?** | *E.hexandra, I.echinospora & P.globulifera* lost since SSSI notification. Fine-leaved *Potamogeton* spp. populations crashed in late summer . |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) should have ≥ 1 characteristic species | ✓ | 71% of vegetated sample spots comply (wader 61%, boat 85%) - although fine-leaved *Pots* dead |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | *E.canadensis* present, but rare (4% of vegetated samples) |
| | Benthic and epiphytic filamentous algal cover <10% | ✓ | Mean score = 0.7; median = 1<br>1% (1/118) of sample spots have scores of 3 |
| **Macrophyte community structure** | Characteristic vegetation zones should be present. Extensive beds of submerged macrophytes should be present | **X?** | Few submerged macrophytes living in September 2003 (really too late for survey), but dense cover of *P. pectinatus* and *P. pusillus* in July 2002. |
| | Maximum depth distribution should be maintained | ✓ | $Z_{max}$ = 1.1? m, $Z_{mean}$ = ?? m, $Z_s$ = 1.1 m, $Z_v$ = 1.1 m |
| | At least the present structure should be maintained | - | Baseline survey |

**Table 4.20.1 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels: TP target / limit = 20 µg P $l^{-1}$ (meso shallow lake target) | **X** | TP = 77 $\mu gl^{-1}$; SRP = 32 $\mu gl^{-1}$ TN = 1.9 $mgl^{-1}$; $NO_3^-$-N = 1.1 $mgl^{-1}$; Chl *a* = 8.4 $\mu gl^{-1}$ |
| | Stable pH / ANC values: pH >7.00 and <9.00; ANC > 20 | ✓ | pH = 7.5 (range 6.9 – 7.9) ANC data unavailable Alk=950µeq$l^{-1}$; DOC=11.6$mgl^{-1}$ |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 $mgl^{-1}$) | - | No data available |
| | No excessive growth of cyanobacteria or green algae | ✓ | No algal blooms recorded |
| **Hydrology** | Natural hydrological regime | ✓ | Appears natural |
| **Lake substrate** | Natural shoreline maintained | ✓? | Shoreline modification code: 1-2 (5 in section 4 – old causeway). |
| | Natural and characteristic substrate maintained | ✓ | Silt, cobbles and boulders dominate marginal zone, silty substrate in deeper water areas. |
| **Sediment load** | Natural sediment load maintained | ✓ | Reedswamp, willow carr and mire communities surround lake |
| **Indicators of local distinctiveness** | Distinctive elements maintained at current levels and/or in current locations | **X?** | -Lake with *Littorelletea*, charophytes and *Magnopotamion* vegetation – very unusual.<br>-*E.hexandra, I.echinospora & P.globulifera* lost from main lake since SSSI notification.<br>-*I. echinospora* and *H. morsus-ranae* (only record for N.Wales) present in small basin separated from main lake (also *E. hydropiper* and *U. australis*?)<br>-*P. filiformis* recorded in 1978 (not found today, but survey rather late in year for *Potamogeton* spp.)<br>-*C. rostrata* in lowland situation. |
| **Environmental disturbance** | Note environmental disturbance factors and assess impact | **?** | -Small area of coniferous forest at northern end of lake.<br>-Put and take trout fishery. |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification / eutrophication | ✓? | Bennion ed. (2004): 0-20 cm: Sq chord distance = 0.340 Little floristic change |

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

Extent

Llyn Llygeirian lies at an altitude of 45 m. The surface area of the lake is 11.1 ha, with a volume of ?? x$10^3$$m^3$.

Macrophyte community composition

The aquatic vegetation of Llyn Llygeirian keys out as a Type 10 "eutrophic" assemblage. Based on the submerged and floating leaved vegetation only (Table 4.20.2), the average Trophic Rank Score (TRS) for this site is 8.01 (112.2/14).

**Table 4.20.2: Macrophyte community composition and trophic scores for Llyn Llygeirian.**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Chara aspera* | 8.5 | A |
| *Chara globularis* | 8.5 | F |
| *Elatine hydropiper* | - | F |
| *Eleocharis acicularis* | 8.5 | F |
| *Elodea canadensis* | 8.5 | R |
| *Lemna minor* | 9.0 | F |
| *Lemna trisulca* | 10.0 | A |
| *Littorella uniflora* | 6.7 | O |
| *Myriophyllum alterniflorum* | 5.5 | O |
| *Nitella flexilis* (agg.) | 5.5 | D |
| *Nymphaea alba* | 6.7 | R |
| *Persicaria amphibia* | 9.0 | O |
| *Potamogeton* fragments *cf pectinatus* | 10.0 | F |
| *Potamogeton perfoliatus* | 7.3 | R |
| *Potamogeton pusillus* | 8.5 | R |
| *Potamogeton* fragments *cf pusillus* | - | A |
| **Average TRS** | **8.01** | |
| **PLEX (weighted)** | **7.27** | |
| **Ellenberg Fertility Score (weighted)** | **6.62** | |

[Other species noted during a field visit in 2005, but not recorded in the survey include *Hydrocharis morsus-ranae*, *Isoetes echinospora*, *Ranunculus* aff. *peltatus* and *Utricularia vulgaris* / *australis* agg. It is not clear whether these species were all recorded from the small basin adjacent to (but separated from) the main lake.]

Negative indicator species

Filamentous algal cover is generally low (mean cover score = 0.7; median = 1), with very few sample spots (1 %) having cover scores of 3. The naturalised non-native macrophyte taxon, *Elodea canadensis* was recorded from Llyn Llygeirian in 2003, but its abundance across the

survey sections was low (present in only 4 % of vegetated sample spots). No other introduced macrophyte species were observed.

Macrophyte community structure

Areas of reedswamp, mire and willow carr communities dominate the margins of Llyn Llygeirian. Both the shallow and deeper water areas comprise a mosaic of different submerged and floating leaved macrophyte species. In September 2003 the deeper areas of the main waterbody of Llyn Llygeirian was devoid of living submerged macrophytes, however many degraded vegetative fragments of fine-leaved *Potamogeton* species were recovered, suggesting that populations of these species had crashed prior to the survey. Further support for this hypothesis is derived from a macrophyte survey undertaken in July 2002, when dense cover of *Potamogeton pectinatus* and *Potamogeton pusillus* was recorded. The die-back of fine-leaved *Potamogeton* species is a frequent observation in nutrient enriched lakes, where algal biomass increases in late summer, resulting in increased water turbidity, decreased water clarity and consequently a reduction in the maximum depth of macrophyte colonization. The site is species rich, supporting macrophytes with a wide range of different growth forms – isoetids (*L. uniflora, I. echinospora* (small basin), charophytes (*C. aspera, C. globularis, N. flexilis* agg.), submerged fine/strap-leaved species (*E. hydropiper, E. acicularis, E. canadensis, M. alterniflorum, P. pectinatus, P. pusillus*), submerged broad-leaved species (*P. perfoliatus*), free-floating species (*H. morsus-ranae* (small basin), *L. minor, L. trisulca*), floating-leaved species (*P. amphibia, N. alba*) and emergent species (*P. arundinacea, T. latifolia*, *S. lacustris, Juncus* spp*., M. trifoliata, C. rostrata, I. pseudacorus, E. fluviatile, E. palustris, S. erectum*).

Water quality

Llyn Llygeirian is a moderately base-rich lowland lake, with a mean pH of 7.5 - within the range of values expected for the lake's feature type. The mean annual TP concentration for Llyn Llygeirian is 76 $\mu gl^{-1}$ (range 27-214 $\mu gl^{-1}$), which is significantly higher than the targe/limit of 20 $\mu gl^{-1}$ for shallow mesotrophic lakes and much higher than the suggested boundary value between good and moderate ecological status (28 $\mu gl^{-1}$) for medium alkalinity, very shallow lakes (WFD UK TAG January 2006). TN concentrations are also consistently high, although biologically available nitrogen concentrations fluctuate seasonally and suggest nitrogen limitation in the summer. Chlorophyll *a* concentrations are generally low to moderate, suggesting that although the lake is enriched, productivity is largely kept in check by zooplanktivorous grazing of algal populations.

The lake is managed as a low intensity put and take trout fishery. This management regime is thought to have minimal impact on the lake ecology. Coarse fish are thought to be absent from the lake.

Lake hydrology

The lake appears to have a natural hydrological regime.

Lake substrate and shoreline

The shoreline more or less retains its natural character, with marginal lake substrates dominated by silt in survey sections 1 and 2, and by cobbles and boulders in sections 3 and 4 respectively. Deeper water areas are dominated by silt. However, the morphology of the lake has been significantly altered by the construction of a stone causeway, originally built for

access to the now-disused quarry at Llanfflewyn (SH346891) and cutting off a section of the lake from the main body. Historic Ordnance Survey maps show this causeway to have existed since at least 1890.

Sediment load

The catchment of Llyn Llygeirian is predominantly improved grassland used for sheep and cattle grazing. There are smaller amounts of marshy grassland (mostly fringing the lake) acid grassland / heathland mosaic, and bracken. Sediment loads are not thought to be significant because there are no major inflow streams and a fringing reedswamp community borders the lake in many areas.

Indicators of local distinctiveness

Llyn Llygeirian is probably the last remaining Anglesey Lake of any size that remains relatively unimpacted by eutrophication.

There is a small basin separated from the main lake by a causeway. In 2005, Andy Jones confirmed the presence of *H. morsus-ranae* (as far as we know, the only population in N Wales) and *I. echinospora* in this basin, along with a larger *Utricularia* sp (*vulgaris* / *australis*?).. *P. globulifera* was also mentioned in the site notification but has not been recently recorded, although it is unlikely to be detected in generic monitoring such as this.

Palaeolimnological evidence

Diatom analyses of sediment core samples from depths of 0, 5, 10 and 20 cm are presented in Bennion ed. (2004). The squared chord distance dissimilarity score between the core top and bottom samples is 0.340, suggesting little floristic change from bottom to top. All samples are dominated by small benthic *Fragilaria* spp. However, this inference should be treated with caution because the sediment core was short and undated, with 20 cm probably not extending back in time to pre-disturbance conditions. Furthermore, the appearance of small percentage relative abundances of the planktonic taxa *Aulacoseira subarctica* and *Stephanodiscus parvus* at the core top indicate a shift in lake ecosystem functioning towards phytoplankton dominance, despite a non-significant chord distance suggesting no change.

Summary

Llyn Llygeirian is generally a good example of its Annex 1 feature type. The lake's macrophyte assemblage comprises many characteristic taxa and their representation across the survey sections is high. However, both the current measured nutrient concentrations and the palaeolimnological evidence suggest that the lake has undergone enrichment. Furthermore, the tendancy for populations of fine-leaved *Potomogeton* species to crash in late summer as algal populations increase provides further evidence that the lake is in **unfavourable** condition. Catchment sources of nutrients should be identified and appropriately managed to ensure that no further deterioration of Llyn Llygeirian's aquatic ecosystem occurs.

No WFD risk assessment is available for Llyn Llygeirian for comparison.

**Table 4.20.3: Llyn Llygeirian: Overview**

| Water Body | Status | Reason(s) for Failure | Comments |
|---|---|---|---|
| Llyn Llygeirian | Unfavourable | Eutrophication | - High phosphorus and nitrogen concentrations – catchment sources should be identified and reduced.<br>- Late summer crashes in fine-leaved *Potomogeton* species populations.<br>- Possible loss of nutrient sensitive macrophyte species – further investigation required |
| **Overall SSSI Status** | **Unfavourable** | | |

## *4.21 Llyn Padarn SSSI*

### 4.21.1 Llyn Padarn (LA, S)

Annex 1 type: H3130: Oligotrophic to mesotrophic standing water with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*. Favourable Condition Table 4.

**Table 4.21.1: Condition Assessment Summary Table for Llyn Padarn**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise) | ✓ | 4 species present: *L. uniflora, S.aquatica, I.lacustris* & *L.natans* |
| | No loss of characteristic species (see Box 2) | ✓? | SSSI notification mentions *I.echinospora*, rather than *I.lacustris* |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) have ≥ 1 characteristic species | ✓ | 89 % (71% w/o *Nitella*) of vegetated sample spots comply (wader 88%, boat 92%) |
| **Negative indicator species** | Non-native species absent or present at low frequency | ? | *E.nuttallii* frequent (present in 17% of vegetated samples) |
| | Benthic and epiphytic filamentous algal cover <10% | ✓? | Mean score = 0.8; median = 0<br>3% (3/110) of sample spots have scores of 3 |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (see Table 4) | ✓? | < 1.5 m: *L. uniflora, I. lacustris, S. aquatica, E. hexandra*<br>1 - 5 m: *N. flexilis, E. nuttallii, P. berchtoldii*, *M. alterniflorum* |
| | Maximum depth distribution should be maintained | ✓ | $Z_{max}$ = 27 m, $Z_{mean}$ = ?? m, $Z_s$ = 3.7 m, $Z_v$ = 5.2 m |
| | At least the present structure should be maintained | - | Baseline survey |

**Table 4.21.1 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels:<br>TP target / limit = 10 µg P $l^{-1}$ | **X** | TP = 16.2 µg$l^{-1}$; SRP = 6.8 µg$l^{-1}$<br>TN = 0.4 mg$l^{-1}$; $NO_3^-$-N = 0.2 mg$l^{-1}$; Chl *a* = 5.1 µg$l^{-1}$ |
| | Stable pH / ANC values:<br>pH ~ 5.5 – 7.0 and ANC > 20 | **✓?** | pH = 7.5 (range 6.4 – 9.3)<br>ANC data unavailable<br>Alk=170µeq$l^{-1}$; DOC=1.34mg$l^{-1}$ |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 mg$l^{-1}$) | - | No data available |
| | No excessive growth of cyanobacteria or green algae | ✓ | No algal blooms recorded |
| **Hydrology** | Natural hydrological regime | ✓ | Appears natural |
| **Lake substrate** | Natural shoreline maintained | **✓?** | Shoreline modification code: 1-2 |
| | Natural and characteristic substrate maintained | ✓ | - Coarse substrates are dominant (boulders and cobbles). Gravels and silts in section 1, Silty substrate in deeper water areas. |
| **Sediment load** | Natural sediment load maintained | **X?** | -Catchment landcover mix of urban, deciduous woodland, wetland and rough pasture<br>-Grazing to shore in section 1. |
| **Indicators of local distinctiveness** | Distinctive elements maintained | ✓ | -*Luronium natans* present in lake<br>-One of only 3 sites in Wales with natural Arctic charr *Salvelinus alpinus* L. (genetically different from populations in Llyn Cwellyn and Llyn Bodlyn)<br>-Geological site of national importance |
| | Minimal negative impacts and no fish farming | **X?** | -Town along S lake shore.<br>-Lake used for watersports / tourist pleasure boats |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | **X?** | Burgess *et al.* (2005): 0-25 cm: Sq chord distance = 0.761: Modest degree of floristic change, indicative of eutrophication - shift in planktonic flora: ↓ *C. comensis* ↑ *A. subarctica, A. formosa* |

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

Extent

Llyn Padarn lies at an altitude of 105 m. The surface area of the lake is 97.6 ha, with a volume of ?? x$10^3$$m^3$.

Macrophyte community composition

The aquatic vegetation of Llyn Padarn keys out as a Type 2 "oligotrophic" assemblage. Llyn Padarn passes the macrophyte community composition attribute targets, both in terms of the number of *Littorelletea* taxa present (4 species – *Littorella uniflora, Isoetes lacustris, Subularia aquatica, Luronium natans*) and the representation of these and other characteristic species across the survey sections (89 % of vegetated sample spots have at least one characteristic species). Based on the submerged and floating leaved vegetation only (Table 4.21.2), the average Trophic Rank Score (TRS) for this site is 6.13 (61.3/10).

**Table 4.21.2: Macrophyte community composition and trophic scores for Llyn Padarn**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Callitriche hamulata* | 5.0 | R |
| *Elatine hexandra* | 6.0 | A |
| *Elodea nuttallii* | 10.0 | F |
| *Fontinalis antipyretica* | 6.3 | A |
| *Isoëtes lacustris* | 5.0 | D |
| *Littorella uniflora* | 6.7 | D |
| *Luronium natans* | - | R |
| *Myriophyllum alterniflorum* | 5.5 | F |
| *Nitella flexilis* (agg.) | 5.5 | A |
| *Potamogeton berchtoldii* | 7.3 | O |
| *Subularia aquatica* | 4.0 | F |
| **Average TRS** | **6.13** | |
| **PLEX (weighted)** | **5.22** | |
| **Ellenberg Fertility Score (weighted)** | **5.04** | |

Negative indicator species

Filamentous algal cover is generally low (mean cover score = 0.8; median = 0), with few sample spots (3 %) having cover scores of 3. The naturalised non-native species, *Elodea nuttallii* is present in Llyn Padarn, recorded as locally abundant in the deeper water areas in 2003. The abundance of this species may indicate unfavourable condition. No other introduced macrophyte species are present in the lake.

Macrophyte community structure

Some of Llyn Padarn's shoreline has very little transitional vegetation between the water and the marginal areas due to the steeply sloping lakeshores. Where marginal areas are more shallowly shelving, the submerged vegetation zonation is fairly typical for an oligotrophic lake, although no *L. dortmanna* is present. *L. uniflora* and *I. lacustris* dominate the shallow

water to a depth of approximately 1.5 m, with *E. hexandra and S. aquatica* occurring in association. The deeper water areas (1.0 - 5.0 m) are dominated by *N. flexilis* (agg.), with *E. nuttallii, P. berchtoldii* and *M. alterniflorum* also present. The maximum depth of macrophyte colonisation in 2003 was 5.2 m. The lake supports a range of different macrophyte growth forms – isoetids (*I. lacustris, L. uniflora*), charophytes and mosses (*N. flexilis, F. antipyretica*), submerged fine-leaved species (*M. alterniflorum, J. bulbosus*), floating-leaved species (*P. polygonifolius*) and emergents (*J. effusus, J. articulatus, P. arundinacea, Carex* spp.) – suggesting that the vegetation structure provides a reasonable range of habitats within the lake.

Water quality

Llyn Padarn is a circumneutral to mildly alkaline lake (mean pH 7.53) that is not at risk of acidification. Phosphorus concentrations are moderate (mean TP 16 $\mu gl^{-1}$) and above the 10 $\mu gl^{-1}$ target/limit for the lake's feature type, suggesting that Llyn Padarn has been eutrophied. However nitrate concentrations are relatively low and stable, indicating that enrichment by nitrates is not a problem in Llyn Padarn, probably because little agricultural land occurs within the lake's catchment.

Lake hydrology

The lake appears to have a more or less natural hydrological regime.

Lake substrate

The shoreline more or less retains its natural character with steeply shelving banks in some areas, where substrates are coarse, dominated by boulders and cobbles.

Sediment load

Catchment landcover is varied. The town of Llanberis lies on the …. lake shore, from which urban drainage (and sewage?) may enter the lake. A tourist railway runs along the steep ….. shore, although this not thought to affect sediment loads. The marginal area adjacent section 1 comprises a small area of *Juncus* dominated wetland to rough pasture, where visitors can also walk. Trampling of the shoreline in this area could potentially increase sediment loads and lead to increased water turbidity. Visitors can also walk along the …. shore on a raised footpath.

Indicators of local distinctiveness

The Annex II species *Luronium natans* is present in Llyn Padarn. It was listed as a notable aquatic plant feature at the time of SSSI notification and in both 2003 and 2005 this species was recorded from section 1, growing at a water depth of ~2 - 3 m. Llyn Padarn is one of only three remaining sites in Wales for Arctic charr *Salvelinus alpinus* L. The race present in Llyn Padarn is genetically different from populations in Llyn Cwellyn and Llyn Bodlyn. Spawning in Llyn Padarn occurs locally in shallow, marginal waters, notably along Afon y Bala. The lake outflow, Afon Rhythallt is one of the most important spawning sites for salmon and sea-trout in north Gwynedd.

Palaeolimnological evidence

Diatom analysis of the top, middle and bottom samples from a 25 cm sediment core are presented in Burgess *et al*. (2005). All samples are dominated by planktonic taxa typical of circumneutral waters. The squared chord distance dissimilarity score between the two samples

was 0.761, indicating significant floristic change in the Llyn Padarn core The most notable difference from core bottom to top is the marked decline in relative abundance of the oligotrophic taxon *Cyclotella comensis* and the increase in taxa more indicative of mesotrophic waters (e.g. *Asterionella formosa, Aulacoseira subarctica* and *Cyclotella pseudostelligera*). The diatom species shifts are indicative of eutrophication.

Summary

Llyn Padarn is determined to be in overall **unfavourable** condition. Although it passes the attribute targets for macrophyte species composition and structure, water clarity is not as high as might be expected for an oligotrophic lake and phosphorus concentrations are above the recommended level for the lake's Annex I feature type, suggesting enrichment. Palaeolimnological evidence provides further support for the increasing trophic status of Llyn Padarn.

A small patch of the Annex II species, *Luronium natans* was recorded from survey section 1 growing at water depths of between 2 –3 m in both 2003 and 2005. Populations of *L. natans* should be monitored to determine the status of this species in Llyn Padarn and to identify any decrease in abundance.

A WFD risk assessment for Llyn Padarn determined that the lake was at risk from physical / morphological alteration, but *not* at risk from either diffuse / point-source pollution or alien species. This is contrary to the results from the current study which suggest that the lake has experienced eutrophication.

**Table 4.21.3: Llyn Padarn SSSI: Overview**

| Water Body | Status | Reason(s) for Failure | Comments |
|---|---|---|---|
| Llyn Padarn | Unfavourable | Eutrophication – TP concentration above feature type limit and palaeo evidence suggests eutrophication | Assess impact on lake ecosystem from town, tourism and watersports |
| **Overall SSSI Status** | **Unfavourable** | | |

## *4.22 Llynnau y Fali / Valley Lakes SSSI*

### 4.22.1 Llyn Penrhyn (HA, V) - Mesotrophic lake with base-rich influence

Annex 1 type: H3150: Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation. Favourable condition table 6.

**Table 4.22.1: Condition Assessment Summary Table for Llyn Penrhyn**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | ≥ 6 of the characteristic species listed in Box 4 and 1 broadleaved *Potamogeton* species | **X** | No broadleaved *Potamogetons.* 5 characteristic species: 4 *Magnopotamion* spp: *P.berchtoldii*, *C.globularis*, *Callitriche* sp. & *P.pusillus* 1 *Hydrocharition* spp: *L.minor.* |
| | No loss of characteristic species | **X** | -No loss since 1993, but at least 7 species lost since 1895 (Griffith, 1895). See text. -SSSI notification records *L.trisulca*, but absent in 2003. |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) should have ≥ 1 characteristic species | **X** | 56% of vegetated sample spots comply (shore 65%, boat 36%) |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | *E.canadensis* present at frequent level (11% of vegetated samples) |
| | Benthic and epiphytic filamentous algal cover <10% (non-*Chara*) | ✓ | Mean cover = 0.8; median = 0 7.5% (9/120) of sample spots have scores of 3 |
| **Macrophyte community structure** | Characteristic vegetation zones should be present. Extensive beds of submerged macrophytes should be present | **✓?** | Species poor macrophyte beds growing across lake to 2.5 m depth – patchy. 0-2.5m mainly *C. demersum, C. hermaphroditica, E. canadensis,* fine-leaved *Potamogetons* frequent. |
| | Maximum depth distribution maintained | **✓?** | $Z_{max}$ = 3.0 m, $Z_{mean}$ = 2.2 m, $Z_s$ = 2.5 m, $Z_v$ = 2.5 m. Turbid |
| | At least present structure should be maintained | - | Similar macrophyte species structure to that recorded in 1993 (Allott *et al*., 1994) |

**Table 4.22.1 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels: TP target/limit: 50µgPl$^{-1}$ | **X** | TP=425µgl$^{-1}$; SRP=388µgl$^{-1}$ TN=1.0mgl$^{-1}$; $NO_3^-N$ = 0.2mgl$^{-1}$; Chl *a* = 13.4 µgl$^{-1}$. |
| | Stable pH / ANC values: pH >7.00 and <9.00; ANC > 20 | ✓ | pH = 7.3 (range 6.8 - 7.7) No ANC data; Alk=1860µeql$^{-1}$; DOC=13.2mgl$^{-1}$ |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 mgl$^{-1}$?) | - | No data available |
| | No excessive growth of cyanobacteria or green algae | **X** | Scum present in sheltered bays and reedbeds 28/9/03 |
| **Hydrology** | Natural hydrological regime | **✓?** | Appears to be natural. No discrete drainage from poorly distinguished catchment. Long residence time. |
| **Lake substrate** | Natural shoreline maintained | **X** | Shoreline modification code: 1-3. Many areas modified by artificial structures. Some areas grazed to shore |
| | Natural and characteristic substrate maintained | ✓ | Predominantly silt |
| **Sediment load** | Natural sediment load maintained | **X** | -Small catchment – mix of intensively farmed land, some rough grazing and housing estates / RAF Valley airbase. -Small STW discharges into lake (water phosphate stripped). |
| **Indicators of local distinctiveness** | Distinctive elements maintained at current levels and/or in current locations | ✓ | -*Elatine hydropiper* occasional -RSPB reserve – supports a significant wildfowl population |
| **Environmental disturbance** | Note environmental disturbance factors and assess impact | **X** | -Small STW discharges to lake. Phosphate stripping post-1994. -RAF runway adjacent to site. -Housing estates / RAF base. -North American Ruddy ducks (*Oxyura jamaicensis*) present |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | **X** | Poor diatom preservation. Surface sediment diatom assemblage dominated by eutrophic taxa e.g. *S. parvus* |

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

Extent

Llyn Penrhyn lies at an altitude of 4.0 m. The surface area of the lake is 22.3 ha and the volume is 420 x$10^3$ $m^3$.

Macrophyte community composition

The aquatic vegetation of Llyn Penrhyn keys out as a Type 10A "eutrophic" assemblage (Palmer, 1992). Based on the submerged and floating leaved vegetation only (Table 4.22.2), the average Trophic Rank Score (TRS) of this site is 8.5 (119.3/14), which is highly comparable to the TRS of 8.68 reported by Allott *et al*. (1994) from a survey undertaken in 1993, when similar macrophyte species were recorded. Llyn Penrhyn's macrophyte assemblage is typical of a eutrophic base-rich lowland lake, comprising species tolerant of high nutrient loads.

**Table 4.22.2: Macrophyte community composition for Llyn Penrhyn, including trophic scores. Figures in brackets are from a survey in 1993 (Allott *et al.*, 1994).**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Callitriche hermaphroditica* | 8.5 | A |
| *Ceratophyllum demersum* | 10.0 | D |
| *Chara globularis* | 8.5 | R |
| *Elatine hydropiper* | - | R |
| *Eleocharis acicularis* | 8.5 | R |
| *Elodea canadensis* | 8.5 | F |
| *Fontinalis antipyretica* | 6.3 | R |
| *Lemna minor* | 9.0 | R |
| *Nuphar lutea* | 8.5 | R |
| *Nymphaea alba* | 6.7 | R |
| *Persicaria amphibia* | 9.0 | R |
| *Potamogeton berchtoldii* | 7.3 | R |
| *Potamogeton pectinatus* | 10.0 | R |
| *Potamogeton pusillus* | 8.5 | R |
| *Zannichellia palustris* | 10.0 | F |
| **Average TRS** | **8.52 (8.68)** | |
| **PLEX (weighted)** | **7.91** | |
| **Ellenberg Fertility Score (weighted)** | **6.46** | |

The flora of Llyn Penrhyn shows evidence of severe environmental change during the late 20th century. Griffith (1895) recorded a diverse aquatic macrophyte community in Llyn Penrhyn, including species characteristic of oligo-mesotrophic waters (*Lobelia dortmanna* and *Potamogeton obtusifolius*) and clear, base-rich waters (*Potamogeton lucens, Potamogeton perfoliatus, Hottonia palustris, Myriophyllum verticillatum* and *Utricularia australis*). With the exception of *L. dortmanna* and *M. verticillatum*, all of these were recorded again in 1983 (Garnett & Blackstock 1983). This diverse range of species was absent in both 1993 (Allott *et*

*al*, 1994) and in 2003 (ENSIS survey), replaced by a less diverse, nutrient tolerant flora comprising *Ceratophyllum demersum* (not found in 1983)*, Callitriche hermaphroditica, E. canadensis,* fine-leaved *Potamogeton* spp. *and Zannichellia palustris*. *C. demersum* appears to be more abundant than in 1993, although this may simply reflect interannual variation in macrophyte populations.

Two visits to the site were also carried out by CCW staff during summer 2005, during which plant species were recorded. Although the survey was not to CSM specifications, no submerged macrophytes were found at all in late July. In late August, some macrophytes (mainly *C. demersum*) were apparent, but cover throughout much of the lake was relatively sparse, and no macrophytes at all were recorded below a depth of around 2m.

Negative indicator species

In September 2003, a blue-green algal bloom was observed, producing scums within bays and amongst the reedbeds. 45 blue-green algal blooms were noted between 1994 and 1998 (Millband, 1999) and an aerial photo taken in 2001 shows a dense blue-green algal bloom. Filamentous algal cover score are generally low (mean 0.8; median 0), with few sample spots having cover scores of 3 (8 %). The naturalised non-native macrophyte species, *E. canadensis* is frequent and across all survey sections it occurs in 11 % of vegetated sample spots. The dominance of the nutrient tolerant taxon, *C. demersum* is indicative of unfavourable condition, as is the frequent occurance of other nutrient tolerant taxa such as *Z. palustris* and *E. canadensis*.

Macrophyte community structure

Llyn Penrhyn appears to have switched from a stable, clear water, macrophyte dominated lake, to an unstable, turbid, plankton-dominated system. Macrophytes are still extensive in shallow water, dominated by *C. demersum* (0 - 2.5 m), but in deeper areas they are absent, with populations of fine-leaved *Potamogetons* tending to crash in the late summer as increased phytoplankton biomass reduces water clarity. Light levels in the deepest areas of the lake (2.5 - 3.0 m) are limiting, since no submerged macrophytes were found in these areas in September 2003. The site is relatively species rich, supporting macrophytes with a number of different growth forms – charophytes (*C. globularis*), mosses (*F. antipyretica*), submerged fine/strap-leaved species (*C. demersum, C. hermaphroditica, Z. palustris, E. canadensis, P. berchtoldii, P. pectinatus, P. pusillus, E. hydropiper, E. acicularis*), free-floating species (*L. minor*), floating-leaved species (*N. lutea, N. alba, P. amphibia*) and emergent species (*P. australis, S. lacustris, T. latifolia*, *Carex* spp.*, B. umbellatus, I. pseudacorus, A. plantago-aquatica*). However, many of the more sensitive species grow only in a few sheltered, shallow bays where they are less susceptible to shading from phytoplankton.

Water quality

The water chemistry of Llyn Penrhyn is indicative of a highly alkaline, highly eutrophic lowland lake and the exposed, shallow nature of the site leads to regular mixing of the water column. pH is stable for the lake type (annual average for 2003 = 7.58). No ANC data are available for Llyn Penrhyn, although it is very unlikely that the lake would be affected by acidification. Llyn Penrhyn's annual average TP concentration appears to have decreased from 1215 $\mu gl^{-1}$ in 1993 (CCW data), to 537 $\mu gl^{-1}$ in 2003, 374 $\mu gl^{-1}$ in 2004 and 237 $\mu gl^{-1}$ in 2005. This data indicates that the lake is recovering from a period of severe nutrient enrichment in the early 1990s. However, current TP is still very high and indicative of

hypertrophic conditions and the high conductivity values probably result from sewage input. Considerable amounts of phosphorus probably remain within the sediments of this shallow lake. Re-suspension of lake sediments and therefore phosphorus into the water column is likely to stimulate algal growth, and the very long residence time means that recovery is likely to be slow.. Annual average TN concentrations between 2003 and 2005 are between 1.0 and 1.4 $mgl^{-1}$. The low nitrogen to phosphorus ratio suggests that the lake is nitrogen-limited, particularly during the summer months, when algal production is high and biologically available nitrogen concentrations are often barely detectable.

Hydrology

The hydrological regime of the lake appears to be relatively natural. The lake lies adjacent to Llyn Dinam and its catchment area is difficult to distinguish. The lake is probably groundwater-fed, as there appears to be no discrete drainage into Llyn Penrhyn, except for input of treated water from the RAF base STW. The lake has a long residence time.

Lake substrate

The dominant marginal lake substrates are silts and sands, with localised areas of coarser substrates including cobbles and bedrock. The deeper water areas are dominated by silts. Lake substrates appear to be largely natural.

Sediment load

RAF Valley airbase covers half Llyn Penrhyn's catchment area. Domestic sewage effluent has enriched Llyn Penrhyn for several decades. The sewage treatment works was enlarged in 1964 but phosphate has been stripped from this since 1994 before treated water enters the lake (Haworth *et al*., 1996). Survey section 1 lies in an area where livestock can access the lakeshore; consequently there is some poaching of the marginal areas, which could lead to bankside erosion, sediment inwash and increased turbidity. Section 2 (eastern shore) lies very close to a public road and in this area the lake's banks are artificial in places, with fences and a pipeline to the water's edge. Run-off from the road may enter the lake. There is a small housing estate to the north east of the lake, which is a potential source of urban drainage. The remains of old scaffolding structures are present in Section 3, whereas in Section 4 steep banks of bedrock rise out of the water and there is no access to the shore. A railway embankment was built in the 1840s, which may have stabilised the local sand-dunes sufficiently for there to be a more orderly, less minerogenic accumulation of sediment. This may also explain why dissolution of diatom frustules is greatest below 24 cm sediment depth.

Indicators of local distinctiveness

*Elatine hydropiper* (eight-stamened waterwort) is present in the lake and is a SSSI feature attribute for which a generic favourable condition table is available (see p. 20, JNCC, 2005). Llyn Penrhyn is an RSPB reserve.

Palaeolimnological evidence

Bennion (1995), Haworth *et al*. (1996) and Bennion *et al*. (1996) present the results of diatom analysis from Llyn Penrhyn. Diatom frustules are poorly preserved in older sediments, but more recent sedimentary diatom assemblages indicate eutrophication.

Summary

The Valley Lakes SSSI, of which Llyn Penrhyn is one feature and Llyn Dinam (now an SAC in its own right) the other, was notified because of its biological interest. The aquatic macrophyte communities were described as being largely composed of species associated with mesotrophic conditions and base-rich water. At present however, Llyn Penrhyn cannot be considered mesotrophic, since current measured nutrient concentrations are well above the target/limit for the lake's feature type, signifying hypertrophy. Diatom inferred nutrient enrichment of the lake has also been well documented. Despite improvements to the STW and the reduction in phosphorus concentrations, Llyn Penrhyn is determined to be in **unfavourable, declining** condition, No WFD risk assessment has been completed for this site for comparison.

There is a possibility that under continuing trends of phosphorus reduction, the lake may recover. However there is likely to be considerable residual phosphorus retained in the lake's sediments and resuspension of these nutrient-rich sediments into the water column will provide a source of nutrients for some time to come, particularly since the lake has such a long residence time. Fish populations should be managed to ensure that no benthivorous species are introduced (e.g. carp), which would exacerbate phosphorus release from the lake sediments through foraging activities. Furthermore, populations of zooplanktivorous fish species (e.g. roach) should also be minimised to reduce the likelihood of promoting a phytoplankton-dominated system. There are currently a few perch, rudd and roach in the lake, but recruitment is poor due to poor water quality causing sags in dissolved oxygen, resulting in poor survival of young (White, 2000). Wildfowl numbers, especially larger phytophagous species such as Canada geese should be monitored to ensure that they do not contribute to nutrient enrichment.

**Table 4.22.3: Llynnau y Fali / Valley Lakes SSSI: Overview**

| Water Body | Status | Reason(s) for Failure | Comments |
|---|---|---|---|
| Llyn Penrhyn | Unfavourable | Eutrophication – TP concentration considerably higher than feature type limit | TP concentrations lower than in 1993. Identify sources and reduce nutrient inputs. Long water residence time and residual nutrients in sediments may prevent full recovery. Continued persistence of submerged macrophytes suggests that if a carefully constructed management plan is instigated, long-term restoration of Llyn Penrhyn is feasible. |
| **Overall SSSI Status** | **Unfavourable** | | |

## *4.23 Llyn Tegid SSSI*

### 4.23.1 Llyn Tegid (LA, D)

Annex 1 type: H3130: Oligotrophic to mesotrophic standing water with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*. Favourable Condition Table 4.

**Table 4.23.1: Condition Assessment Summary Table for Llyn Tegid**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise) | ✓ | 3 species present: *L. uniflora*, *L. natans* & *I. lacustris* |
| | No loss of characteristic species (see Box 2) | ✓ | Same characteristic species recorded in 2003 as those present in 1996 (Monteith ed., 1997). |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) have ≥ 1 characteristic species | ✓ | 100% of vegetated sample spots comply (wader = 100%, boat = 100%) |
| **Negative indicator species** | Non-native species absent or present at low frequency | ✓ | *E.nuttallii* present but rare (1% of vegetated samples) |
| | Benthic and epiphytic filamentous algal cover <10% | ✓ | Mean cover score=1.3; median=1<br>7% (8/110) of sample spots have scores of 3 |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (see Table 4) | ✓? | < 1.0m: *L. uniflora, I. lacustris, E. hexandra, C. hamulata, F. antipyretica, E. acicularis*<br>1.0–2.0m: *N. flexilis, I. lacustris, C. hamulata, L. natans* |
| | Maximum depth distribution should be maintained | ✓? | $Z_{max}$ = 43 m, $Z_{mean}$ = 24 m, $Z_s$ = 2.0 m, $Z_v$ = 1.9 m<br>Poor water clarity, although $Z_v$ the same as recorded in 1996. |
| | At least the present structure should be maintained | - | Baseline survey |

**Table 4.23.1 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels:<br>TP target / limit = 10 µg P $l^{-1}$ | **X** | TP = 22 µg$l^{-1}$; SRP = 9.7 µg$l^{-1}$<br>TN = 0.9 mg$l^{-1}$; $NO_3^-$-N = 0.4 mg$l^{-1}$; Chl *a* = 3.37 µg$l^{-1}$ |
| | Stable pH / ANC values:<br>pH ~ 5.5 – 7.0 and ANC > 20 | ✓ | pH = 7.1 (range 6.1 – 8.6)<br>ANC data unavailable<br>Alk=160µeq$l^{-1}$; DOC=4.9mg$l^{-1}$ |
| | Adequate dissolved $O_2$ for health of characteristic fauna (> 5 mg$l^{-1}$) | - | No data available, although 1996 data indicated deoxygenated conditions below thermoclime |
| | No excessive growth of cyanobacteria or green algae | ✓ | No algal blooms recorded |
| **Hydrology** | Natural hydrological regime | **X** | Managed since 1955 as part of the River Dee regulation scheme. The lake can receive water from the Afon Tryweryn, effectively increasing its catchment area and leading to unnaturally fluctuating water levels. |
| **Lake substrate** | Natural shoreline maintained | **X?** | -Shoreline modification code: 2<br>-Boat slipways and clubhouses<br>-Some poaching of shoreline. |
| | Natural and characteristic substrate maintained | ✓ | Cobbles, pebbles and gravels dominate marginal zone, silt beyond |
| **Sediment load** | Natural sediment load maintained | **X?** | Catchment landcover predominantly agricultural – nutrient / sediment runoff? |
| **Indicators of local distinctiveness** | Distinctive elements maintained | ✓ | -Largest natural lake in Wales.<br>-RAMSAR site<br>-Annex II species, *L. natans* locally abundant.<br>-Unique fish species – the Gwyniad (*Coregonus lavaretus*). |
| | Minimal negative impacts and no fish farming | **X?** | -Used for watersports<br>-Agricultural land in catchment |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | **X** | Bennion *et al.* (1997) and Bennion ed. (2004):<br>0-36 cm core: Sq chord distance = 0.771: Modest floristic change - eutrophication. |

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

Extent

Llyn Tegid lies at an altitude of 158 m. The surface area of the lake is 415.2 ha, with a volume of 85,000 x$10^3 m^3$.

Macrophyte community composition

According to Palmer (1992), the aquatic vegetation of Llyn Tegid keys out as a Type 3 boulder dominated "oligotrophic" assemblage. Based on the submerged and floating leaved vegetation only (Table 4.23.2), the average Trophic Rank Score (TRS) for this site is 6.63 (53/8). This is similar to the TRS of 7.1 reported in Monteith ed. (1997) and calculated from a macrophyte survey undertaken in 1996. Similar macrophyte species assemblages were recorded in both 1996 and 2003.

**Table 4.23.2: Macrophyte community composition for Llyn Tegid, including trophic scores. Numbers in brackets indicate back-calculated scores for July 1996 (Monteith (ed.) 1997).**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Callitriche hamulata* | 5.0 | A |
| *Elatine hexandra* | 6.0 | A |
| *Eleocharis acicularis* | 8.5 | F |
| *Elodea nuttallii* | 10.0 | R |
| *Fontinalis antipyretica* | 6.3 | F |
| *Isoetes lacustris* | 5.0 | D |
| *Littorella uniflora* | 6.7 | D |
| *Luronium natans* | - | A |
| *Nitella flexilis* (agg.) | 5.5 | A |
| **Average TRS** | **6.63 (7.1)** | |
| **PLEX (weighted)** | **5.44 (5.60)** | |
| **Ellenberg Fertility Score (weighted)** | **5.06 (5.12)** | |

Negative indicator species

Filamentous algal cover is generally low to moderate (mean cover score = 1.3; median = 1), with few sample spots (7 %) having cover scores of 3. The non-native species, *Elodea nuttallii* was absent from the 1996 macrophyte survey, but was present and recorded as rare in 2003. This may signify a recent introduction of *E. nuttallii*, perhaps indicative of nutrient enrichment. The appearance of this species may be significant in terms of competitive interactions between macrophyte species.

Macrophyte community structure

A marginal association in which *Phalaris arundinacea, Oenanthe crocata* and J*uncus effusus* are commonly encountered encircles much of the shoreline of Llyn Tegid. The perimeter of the lake is largely composed of exposed, boulder dominated littoral substrates, unsuitable for the development of sediments and the establishment of much aquatic vegetation. These areas

are characterised by *Fontinalis antipyretica* and occasional patches of *I. lacustris*. The more sheltered bays in the south of the lake support a more diverse aquatic flora, in which there is marked vertical zonation. *Littorella uniflora, Elatine hexandra* and *Eleocharis acicularis* tend to dominate the shallow zone (< 1.0 m), with *Nitella flexilis, Callitriche hamulata* and *Luronium natans* growing in deeper waters (> 1.0 m). The maximum depth of macrophyte colonisation in 2003 (1.9 m) was similar to that recorded in 1996 (2.0 m), suggesting that water clarity has remained turbid but stable. The lake supports a range of different macrophyte growth forms – isoetids (*I. lacustris, L. uniflora*), charophytes and mosses (*N. flexilis* (agg.)*, F. antipyretica*), submerged fine-leaved species including elodeids (*C. hamulata, E. hexandra, E. nuttallii, E. acicularis*) and emergents (*P. arundinacea, J. effusus*) – suggesting that the vegetation structure provides a reasonable range of habitats within the lake to support the aquatic fauna.

Water quality

Llyn Tegid is a circumneutral to mildly acidic lake (mean pH 7.1). Lake acidity appears to have decreased since 1996, with both pH and alkalinity values increasing. Phosphorus concentrations (mean TP 22 $\mu gl^{-1}$) are higher than the 10 $\mu gl^{-1}$ TP target / limit for oligotrophic lakes, suggesting that the lake is enriched. Nitrate concentrations are similarly high for an oligotrophic lake and probably reflect inputs from the predominantly agricultural catchment. The first observation of a cyanobacterial bloom was made in 1995.

Lake hydrology

The lake is fed by numerous inflows that drain a large hydrological catchment. The main inflows are the Afon Twrch and Afon Lliw and the lake is drained at its northern end by the Afon Dyfrdwy (River Dee). Llyn Tegid has been hydrologically managed since 1955 as part of the River Dee regulation scheme. Sluice gates 1 km downstream of the lake are used at times to divert water from the Afon Tryweryn into Llyn Tegid, The water level of Llyn Tegid was lowered in 1995 due to hydrological management and may have been responsible for a decline in the Brown Trout population of the lake (Monteith ed., 1997).

Lake substrate

The shoreline more or less retained its natural character with lake substrates dominated by cobbles pebbles and gravels. There are some areas of silt, although these are generally restricted to the deeper water areas.

Sediment load

The catchment of Llyn Tegid is predominantly agricultural, with the potential for increased sediment loads. Runoff from the town of Bala to the north and from roads surrounding the lake could potentially increase sediment loading.

Indicators of local distinctiveness

Llyn Tegid is a RAMSAR site and it is the largest natural lake in Wales both by area and volume. The Annex II submerged macrophyte species; *Luronium natans* is abundant and has been recorded from the lake since the early 1800s. The unique Gwyniad (*Coregonus lavaretus*), a subspecies of European whitefish is present in the lake. The catchment of Llyn Tegid is predominantly agricultural, providing a likely source of nutrients.

Palaeolimnological evidence

Diatom analysis of samples from a 36 cm sediment core are presented in Bennion et al. (1997) and Bennion ed. (2004). The squared chord distance dissimilarity score between the core top and bottom samples is 0.771, suggesting a modest degree of floristic change. The core bottom is dominated by small planktonic *Cyclotella* taxa associated with oligotrophic conditions, whereas since the mid-1970s the assemblage has seen the expansion of *Asterionella formosa* and *Aulacoseira subarctica*, planktonic taxa associated with oligo-mesotrophic conditions. The diatom species shifts are therefore indicative of eutrophication.

Summary

Llyn Tegid is considered to be in overall **unfavourable** condition. The macrophyte assemblage comprises a number of characteristic taxa, but the lake's current nutrient chemistry, alongside palaeolimnological evidence suggest eutrophiciation. The likely source of nitrate is from the predominantly agricultural land within the lake's catchment. Phosphorus may be derived from diffuse catchment sources (e.g. septic tanks), or more directly from urban drainage. Catchment sources of nutrients should be determined and managed appropriately to ensure that concentrations to the lake are reduced so that further enrichment is avoided and negative impacts upon the lake ecosystem are minimised.

The Annex II species, *Luronium natans* is locally abundant in Llyn Tegid. Populations of *L. natans* should be monitored to ensure that lake habitat conditions remain favourable to this species and to make sure that it is not lost from the lake if nutrient levels increase.

A WFD risk assessment has determined that Llyn Tegid is probably at risk of physical / morphological alteration, but probably not at risk of alien species or point source / diffuse pollution. This is contrary to the results of the current study, indicating that the lake has been eutrophied and that current TP concentrations are above the lake's feature type limits for favourable condition.

**Table 4.23.3: Llyn Tegid SSSI: Overview**

| Water Body | Status | Reason(s) for Failure | Comments |
|---|---|---|---|
| Llyn Tegid | Unfavourable | Eutrophication – current TP concentration above feature type limit and diatom palaeo evidence indicates nutrient enrichment | Reduce catchment (agricultural) input of nutrients to lake. |
| **Overall SSSI Status** | **Unfavourable** | | |

## *4.24 Cadair Idris SSSI*

### 4.24.1 Tal-y-llyn Lake (LA, V)

Annex 1 type: H3130: Oligotrophic to mesotrophic standing water with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*. Favourable Condition Table 4.

**Table 4.24.1: Condition Assessment Summary Table for Tal-y-llyn Lake**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Extent** | No loss of extent of standing water | ✓ | |
| **Macrophyte community composition** | Oligotrophic: ≥ 3 characteristic *Littorelletea* species listed in Box 2 (≥ 2 if valid reasons suggest otherwise) | **X** | 2 species present: *L. uniflora* & *I. lacustris* |
| | No loss of characteristic species (see Box 2) | - | Baseline survey |
| | ≥ 6/10 vegetated sample spots (boat or wader survey) have ≥ 1 characteristic species | ✓ | 85% (64% w/o *Nitella*) of vegetated sample spots comply (wader 81%, boat 95%) |
| **Negative indicator species** | Non-native species absent or present at low frequency | **X?** | *E. nuttallii* present and abundant (49% of vegetated sample spots) |
| | Benthic and epiphytic filamentous algal cover <10% | ✓ | Mean score = 1.6; median = 2<br>2% (2/120) of sample spots have scores of 3 |
| **Macrophyte community structure** | Characteristic vegetation zones should be present (see Table 4) | **✓?** | < 1.0 m: *L. uniflora, I. lacustris, E. hexandra, E. nuttallii*<br>> 1.0 m: *N. flexilis, E. nuttallii, C. hamulata, P. berchtoldii, M. alterniflorum.* |
| | Maximum depth distribution should be maintained | ✓ | $Z_{max}$ = 3.5 m, $Z_{mean}$ = ?? m,<br>$Z_s$ = 3.5 m, $Z_v$ = 3.5 m |
| | At least the present structure should be maintained | - | Baseline survey |

**Table 4.24.1 continued**

| Attribute | Target | Status | Comment |
|---|---|---|---|
| **Water quality** | Stable nutrients levels:<br>TP target/limit: 10µg $Pl^{-1}$ | **X** | TP = 28 $\mu gl^{-1}$; SRP = 8.7 $\mu gl^{-1}$<br>TN = 0.6 $mgl^{-1}$; $NO_3^-$-N = 0.2 $mgl^{-1}$; Chl *a* = 5.7 $\mu gl^{-1}$ |
| | Stable pH / ANC values:<br>pH ~ 5.5 – 7.0<br>ANC > 20 | **✓?** | pH = 7.3 (range 6.9 – 7.9)<br>ANC data unavailable<br>Alk=120$\mu eql^{-1}$; DOC=13.2$mgl^{-1}$ |
| | Adequate dissolved $O_2$ for health of characteristic fauna<br>(> 5 $mgl^{-1}$) | - | No data available |
| | No excessive growth of cyanobacteria or green algae | ✓ | No algal blooms recorded |
| **Hydrology** | Natural hydrological regime | **✓?** | |
| **Lake substrate** | Natural shoreline maintained | **X?** | Shoreline modification cores: 2-4. Rough grazing and improved grazing to shore in some areas. Section 4 – wall and busy main road along shore. Section 3 – trackway. |
| | Natural and characteristic substrate maintained | **✓?** | Mixed marginal substrates (cobbles, pebbles, silt) with silt in deeper water areas. |
| **Sediment load** | Natural sediment load maintained | **X?** | Improved and rough grazing to shore in some areas.<br>Potentially increased sediment loads from road/track run-off. |
| **Indicators of local distinctiveness** | Distinctive elements maintained | **✓?** | Rivers up/downstream of lake are spawning grounds for Atlantic salmon *Salmo salar*. |
| | Minimal negative impacts and no fish farming | **X?** | - Site used for shore and boat angling – stocked with trout ??<br>- Agricultural land surrounding lake – grazing to shore<br>- Road adjacent to lake. |
| **Palaeo evidence** | No evidence of significant environmental change e.g. acidification or eutrophication | **✓?** | Burgess *et al*. (2005): 0-20 cm: Sq chord distance = 0.359: Non-significant floristic change. |

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

Extent

Tal-y-llyn Lake lies at an altitude of 85 m. The surface area of the lake is 50.7 ha, with a volume of ?? x$10^3$$m^3$.

Macrophyte community composition

The aquatic vegetation of Tal-y-llyn Lake keys out as a Type 2 "oligotrophic" assemblage, although the presence of *Nitella flexilis* and *Elodea nuttallii*, and the absence of *Lobelia dortmanna* suggest nutrient enrichment. Recording only two characteristic *Littorelletea* species, Tal-y-llyn fails its feature type target for macrophyte community composition. However the representation of these and other characteristic species (*Elatine hexandra, Callitriche hamulata, Potamogeton berchtoldii* and *Nitella flexilis*) across the survey sections is high - 85 % of vegetated sample spots have one or more characteristic species. Based on the submerged and floating leaved vegetation only (Table 4.24.2), the average Trophic Rank Score (TRS) for this site is 6.60 (72.5/11).

**Table 4.24.2: Macrophyte community composition for Tal-y-llyn Lake, including trophic scores.**

| Submerged and floating vegetation | Trophic Rank Score (TRS) | DAFOR |
|---|---|---|
| *Callitriche hamulata* | 5.0 | O |
| *Elatine hexandra* | 6.0 | F |
| *Eleocharis acicularis* | 8.5 | R |
| *Elodea nuttallii* | 10.0 | A |
| *Fontinalis antipyretica* | 6.3 | R |
| *Isoëtes lacustris* | 5.0 | D |
| *Littorella uniflora* | 6.7 | A |
| *Myriophyllum alterniflorum* | 5.5 | R |
| *Nitella flexilis* (agg.) | 5.5 | A |
| *Nymphaea alba* | 6.7 | R |
| *Potamogeton berchtoldii* | 7.3 | F |
| **Average TRS** | **6.60** | |
| **PLEX (weighted)** | **5.64** | |
| **Ellenberg Fertility Score (weighted)** | **5.56** | |

Negative indicator species

Filamentous algal cover is generally moderate (mean cover score = 1.6; median = 2), and few sample spots (2 %) have cover scores of 3. The moderate coverage of filamentous algae may indicate that the lake is slightly enriched, although the relationship between filamentous algal cover and enrichment requires further investigation. The naturalised non-native species, *E. nuttallii* is present in Tal-y-llyn, occurring in 49 % of vegetated sample spots. Its high abundance in the lake is indicative of unfavourable condition according to CSM criteria.

Macrophyte community structure

The marginal emergent vegetation is dominated in all survey sections by *Juncus effusus*. Water clarity at Tal-y-llyn is excellent and the submerged vegetation extends to the maximum depth of the lake (3.5 m). In the shallower waters (> 1.0 m), *L. uniflora* and *I. lacustris* are dominant, with *E. hexandra* frequently occurring alongside. These species all grow to a maximum depth of 1.7 m. In the deeper water areas (> 1.0 m), *E. nuttallii* and *N. flexilis* are dominant, *C. hamulata* is frequent and both *P. berchtoldii* and *M. alterniflorum* are rare. The lake supports a wide range of different macrophyte growth forms – isoetids (*I. lacustris, L. uniflora*), charophytes and mosses (*N. flexilis* (agg.)*, F. antipyretica*), submerged fine-leaved species including elodeids (*E. nuttallii, C. hamulata, P. berchtoldii, E. hexandra, M. alterniflorum, E. acicularis*), floating-leaved species (*N. alba*) and emergents (*J. effusus, J. articulatus, E. palustris, M. trifoliata, P. arundinacea, C. rostrata*) – suggesting that the vegetation structure provides a diversity of habitats for aquatic fauna.

Water quality

Tal-y-llyn Lake is circumneutral (mean pH 7.3). Although no ANC data are available, alkalinity is sufficiently high to suggest that the lake is well buffered and at low risk of acidification. Phosphorus concentrations (mean TP 28 $\mu gl^{-1}$; range 14-59 $\mu gl^{-1}$) are above the TP target / limit of 10 $\mu gl^{-1}$ for oligotrophic lakes. Furthermore, TP levels are above the range of concentrations drafted for 'good' ecological status in the UK WFD TAG report (January 2006). Chlorophyll *a* concentrations are not excessive, suggesting that perhaps efficient zooplankton grazing is keeping lake productivity in check. Nitrate concentrations are generally low, particularly during the growth season, suggesting that the lake may be nitrogen limited.

Lake hydrology

The lake appears to have a more or less natural hydrological regime.

Lake substrate

Lake substrates are varied. Marginal areas are dominated either by cobbles, pebbles or silt. Silt is dominant in deeper water areas.

Sediment load

The lake may receive increased sediment loads from run-off associated with both the adjacent road and agricultural land. However, sediment loads are not thought to be excessive since water clarity is excellent and the maximum depth of macrophyte colonisation extends to the lake bottom.

Indicators of local distinctiveness

The catchment of Tal-y-llyn is dominated by rough grazing, although there is some improved grazing to the lake shore in survey section 2. Adjacent to survey section 4 there is an artificial wall backed by a busy main road and a rough track runs beside survey section 3.

Palaeolimnological evidence

Diatom analysis of the top and bottom samples from a 20 cm sediment core are presented in Burgess *et al*. (2005). The squared chord distance dissimilarity score between the top and bottom samples was non-significant at 0.359, suggesting minimal floristic change in diatom assemblages in Tal-y-llyn Lake. Both top and bottom samples were floristically diverse, with

periphytic taxa typical of circumneutral waters (e.g. *Achnanthes minutissima*) dominating the assemblages.

Summary

Although palaeolimnological evidence suggests that Tal-y-llyn Lake is a reasonably good example of its Annex 1 feature type, the lake is still considered to be in **unfavourable** condition. Tal-y-llyn's macrophyte assemblage comprises two characteristic *Littorelletea* taxa, but the absence of *L. dortmanna* probably indicates nutrient enrichment. The presence of *E. nuttallii* is also indicative of unfavourable condition and its continued dominance may ultimately lead to the loss of other less competitive native macrophyte species. Macrophyte assemblages should be monitored regularly to track both interannual and long term trends in species distributions and abundances.

Phosphorus concentrations in Tal-y-llyn are above the limit for the lake's feature type. Possible catchment nutrient sources (e.g. run-off from agricultural land) should be identified and managed appropriately. Grazing pressure should also be monitored to ensure that it does not negatively impact upon the lake ecosystem.

**Table 4.24.3: Cadair Idris SSSI: Overview**

| Water Body | Status | Reason(s) for Failure | Comments |
|---|---|---|---|
| Tal-y-llyn Lake | Unfavourable | Eutrophication?<br>TP concentration above target.<br>Insufficient characteristic species.<br>Dominance of naturalised non-native *E. nuttallii* | Many key elements essential to favourable condition still present in the lake – water clarity excellent<br>Palaeo-evidence suggests little change, but longer core required. |
| **Overall SSSI Status** | **Unfavourable** | | |

# 5. Discussion

This section provides an interpretation and discussion of results presented in the previous section. An overall summary of the status of Welsh protected standing waters is provided and consideration is given to the key environmental factors affecting their condition. Since the standing waters monitoring protocol has only recently been developed (JNCC, 2005), the discussion also provides suggestions for modifications to both the Common Standards Monitoring (CSM) survey methodology and the favourable condition attribute targets used for condition assessment. Uncertainties in lake classifications and data confidence issues are discussed and comparisons between the CSM approach and other lake assessment methodologies are also considered. The discussion concludes by making overall recommendations for future monitoring and assessment priorities at Welsh SAC and SSSI lakes.

## *5.1 Summary status of protected standing waters in Wales and the major environmental factors affecting them*

Table 5.1 summarises the results of site condition assessments for 32 lakes within SACs and 11 SSSI lakes. The majority of lakes are in unfavourable condition (18 SAC and 9 SSSI lakes), although a reasonable number appear to be in the process of recovery (8 SAC lakes and 1 SSSI lake). Six lakes are classified as favourable and one lake is in unfavourable, declining condition.

Condition assessments for the oligotrophic to mesotrophic Welsh lake SACs (23 lakes) and SSSIs (7 lakes) with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*, indicate that approximately 80 % of lakes of this type are currently in 'unfavourable' (60 %) or 'unfavourable, recovering' (20 %) condition. Only one SAC - Cadair Idris (3 lakes) – and three lakes within two other SACs are classified as 'favourable'. Acidification is the primary reason for failure to meet favourable condition targets, particularly for SAC lakes. Nutrient enrichment, grazing pressure, sediment inwash, forestry operations and drawdown are further pressures that result in unfavourable condition assessment outcomes. Eutrophication is of particular concern amongst SSSI lakes of this type.

All eleven Welsh lake SACs and SSSIs of the naturally eutrophic type (with *Magnopotamion* or *Hydrocharition*-type vegetation) or hard oligo-mesotrophic *Chara* spp. type are classified as 'unfavourable' (70 %) or 'unfavourable, recovering' (20 %), with one lake classified as 'unfavourable, declining'. Eutrophication is the primary reason for failure to meet favourable condition targets. However, unlike acidification, eutrophication may come from both point and diffuse sources, and its effects may be exacerbated by local management practices such as grazing and fish stocking.

Only one SAC in Wales is notified for the dystrophic lakes feature (2 lakes). This feature was provisionally classified as unfavourable. However, the targets for this habitat type may require refinement.

**Table 5.1: Summary table illustrating the site condition assessment outcomes of Welsh SAC and SSSI standing water features.**

| SAC / SSSI Name | Lake Name | Feature[#] | Condition* | Impact^ |
|---|---|---|---|---|
| Afon Gwyrfai a Llyn Cwellyn | Llyn Cwellyn | OML | UR<br>Recovery from acidification only | A (E/S?) |
| Afon Teifi | Llyn Egnant | OML | U | A (D?) |
| | Llyn Hîr | OML | U | A (E?) |
| | Llyn Teifi | OML | U | A? / D? |
| Cadair Idris | Llyn Gafr | OML | F | Monitor grazing |
| | Llyn Arran | OML | F | |
| | Llyn Cau | OML | F | |
| Corsydd Môn / Anglesey Fens | Llyn Cadarn | HC | U | E |
| | Llyn yr Wyth Eidion | HC | U | E |
| Elenydd | Llyn Cerrigllwydion Isaf | OML | U | A |
| | Llyn Fyrddon Fawr | OML | U | A |
| | Llyn Gwyngu | OML | U | A |
| | Llyn Gynon | OML | U | A |
| Eryri / Snowdonia | Llyn Cwmffynnon | OML | UR | A |
| | Llyn Coch | OML | F | Monitor grazing |
| | Llyn Idwal | OML | F | Monitor grazing and recreation |
| | Llyn Ogwen | OML | UR | A |
| Kenfig / Cynffig | Kenfig Pool | HC | UR | F<br>remove remaining carp |
| Llyn Dinam | Llyn Dinam | NE | U | E |
| Llyn Syfaddan / Llangorse Lake | Llangorse Lake | NE | UR | E/F?/S? |
| Migneint-Arenig-Dduallt | Llyn Conglog-Mawr | OML / DY? | U? | A? |
| | Llyn y Dywarchen | DY | U | A/S? |
| | Llyn y Garn | OML | F | |
| | Llyn Hesgyn | OML | F? (UR?) | A |
| | Llyn Hiraethlyn | OML | U | A/S? |
| | Llyn Tryweryn | DY | UR | A/FO |

**Table 5.1 continued**

| SAC / SSSI Name | Lake Name | Feature[#] | Condition* | Impact^ |
|---|---|---|---|---|
| Pembrokeshire Bat Sites and Bosherton Lakes / Safleoedd Ystlum Sir Benfro a Llynnoedd Bosherton | Bosherston Lily Ponds | HC | U | E (high N concentration) |
| Rhinog | Llyn Cwm Bychan | OML | U | A/S?/G? |
| | Llyn Eiddew-Mawr | OML | U | A |
| | Llyn Perfeddau | OML | U | A |
| | Gloyw Lyn | OML | UR | A |
| Y Twyni o Abermenai i Aberffraw / Abermenai to Aberffraw Dunes | Llyn Coron [1] | NE | U | E / G |
| Hanmer Mere SSSI | Hanmer Mere | NE | U | E |
| Llyn Alaw | Llyn Alaw | NE | U | E |
| Mynydd Hiraethog | Llyn Alwen | OML | U | A / E |
| - | Llyn Bodlyn | OML | UR | A (E↑) |
| Llyn Eiddwen SSSI | Llyn Eiddwen | OML | U | E |
| Llyn Glasfryn SSSI | Llyn Glasfryn | OML | U | E |
| Llyn Llygeirian SSSI | Llyn Llygeirian | NE | U | E |
| Llyn Padarn SSSI | Llyn Padarn | OML | U | E |
| Llynnau y Fali / Valley Lakes SSSI | Llyn Penrhyn | NE | UD | E |
| Llyn Tegid SSSI | Llyn Tegid | OML | U | E |
| Cadair Idris SSSI | Tal-y-llyn Lake | OML | U | E |

**[#] OML = Oligotrophic to mesotrophic lake with *Littorelletea*; HC = Hard lake with *Chara*; NE = Natural eutrophic lake; DY = Dystrophic lake.**
*** F = favourable; U = unfavourable; UR = unfavourable, recovering; UD = unfavourable declining.**
**^ Impact: A = acidification; E = eutrophication; G = overgrazing; FI = fish stocking; FO = forestry; S = sediment loading; D = drawdown.**

Table 5.2 provides a summary of the conservation status of Welsh SAC and SSSI standing water features. Where there is more than one lake within a feature, overall site condition has been determined by examination of the assessments for individual lakes. The oligo-mesotrophic *Littorelletea* feature type has two unfavourable SACs, four unfavourable, recovering and one favourable. There is one unfavourable dystrophic SAC. All hard-water and naturally eutrophic sites are in either unfavourable or unfavourable, recovering condition. All SSSI lakes are in unfavourable condition, with one recovering and one declining.

**Table 5.2: Summary of the conservation status of Welsh SAC and SSSI lakes. F = favourable; U = unfavourable; UR = unfavourable, recovering; UD = unfavourable, declining. No features reported as destroyed or partially destroyed.**

| SAC / SSSI name | | Feature | | | |
|---|---|---|---|---|---|
| | | **Dystrophic** | **Oligotrophic with *Littorelletea*** | **Hard water with *Chara*** | **Eutrophic with *Magnopotamion*** |
| Abermenai to Aberffraw Dunes | | - | - | - | U |
| Afon Gwyrfai & Llyn Cwellyn | | - | UR | - | - |
| Afon Teifi | | - | U | - | - |
| Cadair Idris | | - | F | - | - |
| Corsydd Môn / Anglesey Fens | | - | - | U | - |
| Elenydd | | - | U | - | - |
| Eryri / Snowdonia | | - | UR | - | - |
| Kenfig / Cynffig | | - | - | UR | - |
| Llangorse Lake / Llyn Syfaddan | | - | - | - | UR |
| Llyn Dinam | | - | - | - | U |
| Migneint-Arenig-Dduallt | | U | UR | - | - |
| Bosherston Lakes | | - | - | U | - |
| Rhinog | | - | UR | - | - |
| **Total SACs** | **F** | **0** | **1** | **0** | **0** |
| | **UR** | **0** | **4** | **1** | **1** |
| | **U** | **1** | **2** | **2** | **2** |
| Hanmer Mere | | - | - | - | U |
| Llyn Alaw | | - | - | - | U |
| Mynydd Hiraethog (Llyn Alwen) | | - | U | - | - |
| Llyn Bodlyn | | - | UR | - | - |
| Llyn Eiddwen | | - | U | - | - |
| Llyn Glasfryn | | - | U | - | - |
| Llyn Llygeirian | | - | - | - | U |
| Llyn Padarn | | - | U | - | - |
| Llynnau y Fali / Valley Lakes (Llyn Penrhyn) | | - | - | - | UD |
| Llyn Tegid | | - | U | - | - |
| Cadair Idris (Tal-y-llyn Lake) | | - | U | - | - |
| **Total SSSIs** | **F** | - | **0** | - | **0** |
| | **UR** | - | **1** | - | **0** |
| | **U** | - | **6** | - | **3** |
| | **UD** | - | **0** | - | **1** |

**Table 5.3: Summary of environmental impacts on Welsh protected lakes. Numbers in brackets indicate lakes that have multiple pressures and that have already been accounted for under their dominant pressure.**

| Lake type | Impact | Number of lakes | |
|---|---|---|---|
| | | **SAC** | **SSSI** |
| **Dystrophic**<br>SAC = 2 lakes<br>SSSI = 0 lakes | Acidification<br>(ANC <20 or palaeo evidence) | **2** | - |
| **Oligotrophic / mesotrophic**<br>SAC = 23 lakes<br>SSSI = 7 lakes | Acidification<br>(ANC <20 or palaeo evidence) | **17** | **(2)** |
| | Overgrazing / sediment loading / drawdown | **(7)** | **0** |
| | Eutrophication | **(3)** | **7** |
| **Eutrophic / hard-water**<br>SAC = 7 lakes<br>SSSI = 4 lakes | Eutrophication | **6** | **4** |
| | Fish stocking | **1** | **0** |
| **TOTALS** | | **25**<br>**out of 32** | **11**<br>**out of 11** |

## *5.2 Detailed analysis of the environmental impacts on Welsh lakes*

### 5.2.1 Acidification

Acid Neutralising Capacity or ANC is used as a summary chemical indicator of current acidity status, integrating geological sensitivity to acidification with the current acid deposition pressure, whilst also taking into account the buffering effect of organic acids. A change in ANC may occur without an accompanying change in pH in well-buffered systems as a result of acid deposition, ANC therefore provides a useful complement to pH data. A large number of the low alkalinity Welsh lake SACs and some SSSIs have been impacted by acidification. Many have low or negative ANC values, indicating both acid sensitivity and impact. Supporting evidence for acidification is provided in the palaeolimnological record (discussed later).

The WFD UK TAG Report (SR1-2006) on environmental standards and conditions (UK TAG, 2006) tentatively proposed 40 $\mu eql^{-1}$ ANC as the boundary between high and good lake

ecological status and 20 μeql$^{-1}$ ANC as the good and moderate status boundary. The WFD stipulates that all UK waterbodies should be in good ecological status by 2015, therefore in relation to acidification, the key aim of CCW should be to increase the ANC of all lakes to greater than 20 μeql$^{-1}$.

Lakes with available ANC data that have been acidified and currently have an ANC < 20 μeql$^{-1}$ include: Cadair Idris - Llyn Arran (4), Llyn Cau (-26); Elenydd - Llyn Cerrigllwydion Isaf (-36), Llyn Fyrddon Fawr (-12); Eryri / Snowdonia - Llyn Cwmffynnon (0), Llyn Ogwen (6 (Apr-Oct)); Migneint-Arenig-Dduallt - Llyn Conglog-Mawr (1), Llyn y Dywarchen (-35); Rhinog - Llyn Cwm Bychan (-13), Llyn Eiddew-Mawr (-26), Llyn Perfeddau (-28), Gloyw Llyn (2).

Lakes where ANC lies between 20-40 μeql$^{-1}$ include Llyn Tryweryn (37), Llyn Hiraethlyn (25), Llyn y Garn (26), Llyn Idwal (26), Llyn Coch (31), Llyn Gwngu (33),

Monteith ed. (2005) report that Acid Waters Monitoring Network (AWMN) sites have seen significant biological change in recent years, with appearances of acid-sensitive species that are consistent with observed chemical change. We recommend that all lakes with negative or low positive (<40) ANC values (and particularly those where ANC is less than 20 μeql$^{-1}$) should be closely monitored both chemically and biologically, so that recovery trends from acid deposition can be determined. Cation and anion data, obtained through regular water chemistry monitoring, should be collected for all acid sensitive sites, so that reliable ANC values can be calculated. To complement the ANC data, total alkalinity should also be determined at least seasonally. To enable the comparison of data from different sites, years and seasons, consistency in the methods of alkalinity determination and ANC calculation are essential.

The recovery trends tentatively observed fo ra number of acid-impacted protected Welsh protected most likely relates to reductions in atmospheric deposition of sulphur. Monteith ed. (2005) report that since 1996, the UK has experienced a sharp downturn in sulphur deposition, in part due to emissions abatement strategies. It is expected that alkalinisation trends will continue, provided that atmospheric deposition stabilises or continues to decrease in response to national and international policies. Regional scale climate variation will also be important.

## 5.2.2 Eutrophication

#### *5.2.1.1 Lowland naturally eutrophic and hard water lakes*

Eutrophication has impacted almost all naturally eutrophic and hard water SAC lakes in Wales - Llyn Cadarn, Llyn yr Wyth Eidion, Llyn Dinam, Llyn Coron and Bosherston Central Lake. All naturally eutrophic SSSI lakes; Hanmer Mere, Llyn Alaw, Llyn Llygeirian and Llyn Penrhyn have also been eutrophied.

For many artificially enriched lakes, there is scope to identify and reduce point and diffuse catchment sources of nutrients. However, some eutrophied lakes have relatively low or moderate but declining TP concentrations and at these sites nutrient enrichment may be

historic. Residual concentrations of phosphorus in profundal lake sediments can be released into the water column if sediments are disturbed by wind or bioturbation. Increased concentrations of nutrients in the water column fertilise the growth of planktonic algae and shallow lake ecosystems in particular can switch from clear-water macrophyte dominated systems to turbid, algal dominated lakes. Stocking of inappropriate fish species such as carp can exacerbate the problem, with knock-on effects throughout the trophic cascade.

The composition and structure of macrophyte assemblages can be severely impacted by eutrophication. Once the more competitive, nutrient-tolerant macrophyte species (e.g. *E. canadensis* / *E. nuttallii* / *M. spicatum* and *Z. palustris*) come to dominate the macrophyte assemblage, it is difficult to re-establish species that favour lower nutrient status.

Since eutrophication can dramatically alter the structure and function of a lake ecosystem, carefully constructed management plans must be implemented if favourable condition is to be a realistic future target for impacted naturally eutrophic and hard-water Welsh lake SACs and SSSIs.

#### *5.2.1.2 Upland soft-water lakes – nitrogen enrichment*

In contrast to the decreasing trends reported for sulphate in upland lakes, Monteith ed. (2005) report that there has been no such decrease in the flux of deposited nitrogen species ($NO_3^-$ and $NH_4^+$). There is growing recognition that nitrogen enrichment is occurring in upland lakes. To date, most attention has been focussed on phosphorus, however it has been shown that nitrogen concentrations are increasing (Curtis *et al*., 2005). At present, the CSM methodology does not really consider nitrogen enrichment. Setting of appropriate targets for nitrogen would require further investigation.

The impacts on lake biology remain unclear, although for lakes where primary production is limited by the availability of nitrogen, increased nitrogen input from both terrestrial and atmospheric sources (e.g. agricultural chemicals and ammonium from fossil fuel combustion) could instigate significant changes to aquatic ecosystem dynamics.

Schuurkes *et al*. (1985) linked the increase in acid-tolerant macrophyte species such as *J. bulbosus* and *Sphagnum* spp. to increased ammonium concentrations. Acid-tolerant species have ammonium-dominated nitrogen utilisation, with the leaves of the plants constituting the major uptake site. Conversely, soft-water species have nitrate-dominated uptake and the roots are the major uptake site. An increase in acid-tolerant species could indicate increased availability of ammonium through atmospheric deposition or agricultural run-off.

### 5.2.3 Grazing pressure and increased sediment loads

In preparing the current site condition assessments, grazing pressure has generally been determined by field observation. Further examination of stocking levels and livestock access to lake shorelines would be informative, particularly at sites where extensive poaching of marginal areas has been noted on field survey sheets. Some degree of poaching may be beneficial to littoral macrophyte species, but if poaching pressure is excessive, species

favouring disturbance may increase in abundance at the expense of taxa tolerant of only minimal disturbance.

High stocking levels also have the potential to increase lake sediment loads. Trampling can denude catchment vegetation, exposing underlying soils and increasing their vulnerability to erosion during periods of heavy rainfall, thus increasing sediment loads. This problem may be more pronounced in upland catchments where slope angles are steeper. Sites at which grazing pressure and catchment stocking levels should be further investigated are detailed in Table 5.5.

Increased sediment loads can also arise from forestry operations within lake catchments At Llyn Cwellyn, macrophyte surveys revealed relatively high cover of *J. bulbosus* and *Sphanum* spp. The expansion of *J. bulbosus* and *Sphanum* spp. has been linked to elevated levels of mineralogenic material derived from the inwash of catchment sediments and Brundrud (2002) reported an sharp increase in *J. bulbosus* following liming.

### 5.2.4 Fish stocking and fisheries management practices

Overstocking of fish and the introduction of non-native fish species to individual lakeses has the potential to significantly modify lake ecosystem function. Although few lakes in the current round of assessments appear to be affected by inappropriate fisheries management practices, the introduction of carp to Kenfig Pool is thought to have lowered the lake's conservation value. Carp are of particular concern in shallow lake ecosystems where benthic foraging for food disturbs sediments and increases lake turbidity to the detriment of macrophyte populations. This can lead to a switch in lake ecosystem structure and function towards a phytoplankton-dominated state (Moss *et al*., 2002). This problem can be exacerbated where zooplanktivorous fish predation pressure leads to low zooplankton numbers and in turn, increased algal populations. High nutrient levels can further exacerbate this problem, stimulating high levels of algal productivity. Limited fish stocking data are available for most lakes, so it can be difficult to identify problems and manage impacts .

## *5.3 Use of Trophic Indices*

Trophic indices showed a broad relationship with lake nutrient status. However, this relationship is complex and reflects the tendency of different lake types to overlap.

Detailed analysis of the effectiveness of trophic indices is not possible for most Welsh lake types, because there are too few examples in each category. However, *Littorelletea* lakes are reasonably widespread, and further analysis is presented for this group.

Figure 5.1 shows the relationship between pressure (as identified by diatom inferred changes to pH and / or TP), PLEX score, and Ellenberg fertility score. Not surprisingly, there is a relationship between PLEX and fertility score, since lake types are themselves related to trophic status (Duigan *et al*. in press). Table 5.4 illustrates that *Littorelletea* lakes in favourable condition spanned a moderate range of PLEX scores (mean PLEX = 4.00 ± 0.31),

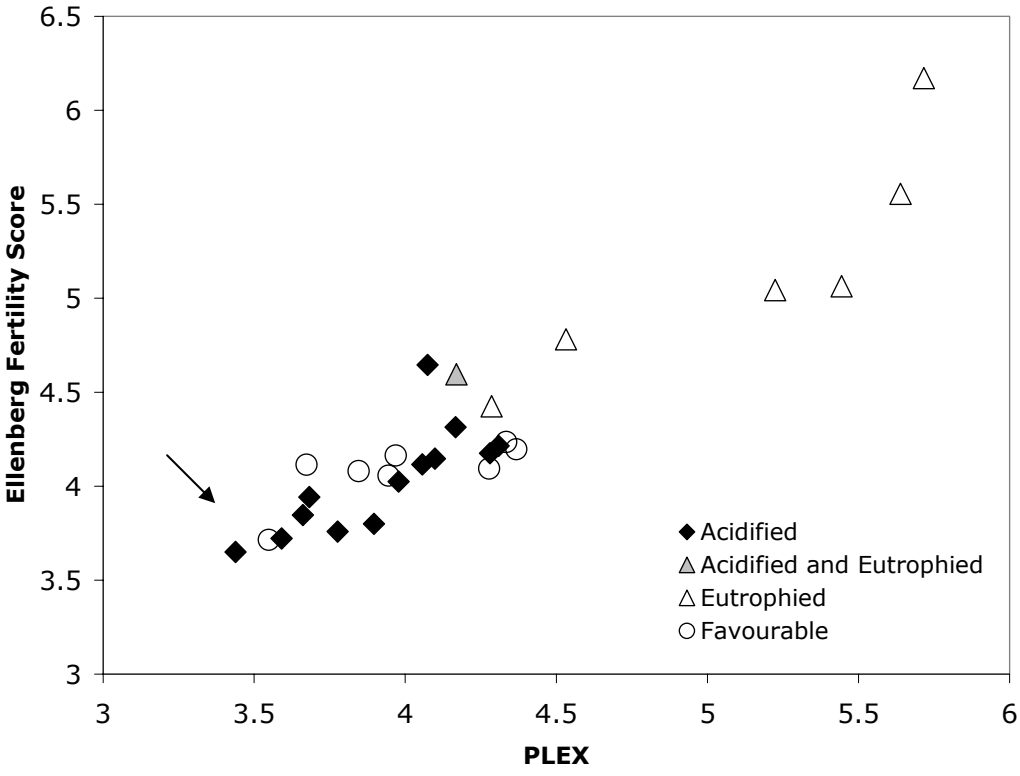
reflecting ecological variation across Wales. However, there was much less variation in fertility scores for lakes in favourable condition (mean Fertility Score = 4.13 ± 0.07).

Lakes impacted by acidification had slightly lower PLEX and fertility scores, but both indices showed greater variance. For lakes affected by eutrophication, both PLEX and fertility scores were on average, markedly higher.

**Table 5.4: Mean PLEX and Fertility Scores for *Littorelletea* lakes.**

| Status | Mean PLEX ± Stdev | Mean Fertility Score ± Stdev |
|---|---|---|
| Favourable | 4.00 ± 0.31 | 4.13 ± 0.07 |
| Acidified | 3.92 ± 0.27 | 4.03 ± 0.28 |
| Eutrophied | 5.00 ± 0.66 | 5.09 ± 060 |

**Figure 5.1: Status of *Littorelletea* Lakes in Wales, showing the response to main pressures. Apart from the peat-influenced Llyn Hiraethlyn (arrowed), all sites classed as being in favourable condition have fertility scores of between 4.0 and 4.5.**



## *5.4 Common Standards Monitoring Guidance Survey and Assessment Issues:*

### 5.4.1 Uncertainty in lake classification

Given that all lakes are unique, their classification into broad 'types' can create problems for condition assessment using CSM methods, although targets do reflect some degree of within-type ecological variability. Although many lakes fit relatively neatly into feature types, there is often overlap between types e.g. peaty oligotrophic lakes in the Elenydd and Migneint SACs. Considerable overlap also exists between hard-water *Chara* lakes and naturally eutrophic lake types, such as Llyn Llygeirian, a lake that supports *Littorelletea*, *Chara* and *Magnopotamion* vegetation. There is some degree of uncertainty in the classification of such lakes and a consequent risk of assessing their condition against inappropriate targets.

A potential option for SSSIs is to assess lakes against generic targets. Generic targets are given to ensure a minimum standard, since site-specific targets may require too much investigation for individual lakes. However, generic targets are less stringent than type-specific targets and as such a lake may be classified as favourable when a more thorough analysis would show it to be impacted. Lakes spanning a number of feature types could be assessed under individual feature type targets and the different assessments compared. Based on the balance of evidence, the most appropriate assessment could be reported. Alternatively, if time and resources allowed, assessments made using all potential feature type targets could be reported. Perhaps a combined approach is favoured, where generic targets are used to set a minimum level (or limits) and then site-specific targets can then be used to modify this. The CSM methods as they stand cannot overcome problems of uncertainty in lake classification, therefore we suggest that methods such as palaeolimnology might be usefully employed to provide further elucidation of site-specific features such as macrophyte history and naturalness, particularly for sites at the oligotrophic - dystrophic boundary.

### 5.4.2 Macrophyte survey methods

#### *5.4.2.1 Transects versus whole- lake surveys*

The macrophyte survey methods do not require full lake surveys to be undertaken. Instead, sampling (ideally) comprises four wader and four boat transects. In future years, the same transects must be monitored to ensure comparability. Previous surveys e.g. the integrated classification and assessment of lakes in Wales (Allott *et al*., 1994; Monteith ed., 1995; Monteith ed., 1996; Monteith ed., 1997), used whole-lake macrophyte surveys. The CSM approach standardises the survey methods so that surveys from different years and undertaken by different personnel are directly comparable. Surveys can also be completed more efficiently. However, the use of transects cannot by its very nature encompass all areas of the lake. Therefore in lakes where vegetation is patchy or localised, some species will invariably be omitted. This must be taken into account when reporting on 'species loss', since some cryptic species (e.g. *Pilularia globulifera, Luronium natans*), it may not be realistic to expect their detection by the transect survey method – specialist species-specific methods may be required.

When data from whole-lake surveys was compared with data generated using the transect-based CSM approach, there were remarkably few compatibility issues. The majority of differences such as species absences could be explained by the positioning of transects, or identification issues (e.g. distinguishing between charophyte species). However, caution should be exercised when comparing results and inferring trends from surveys where data has been obtained using different sampling methodologies.

The baseline site condition assessment outcomes may be highly dependent upon the original choice of transect sampling locations. CSM guidance suggests that survey sections should "focus on areas where characteristic macrophyte communities or species features are likely to occur (i.e. not random)" and "if macrophyte data are not available locations should be chosen to represent the potential range of habitats or species." These prescriptions are logical, although choice of transect locations are consequently biased.

#### *5.4.2.2 The necessity of boat surveys*

The CSM guidance stipulates that results of wader surveys alone can be used for site condition assessment, although it is preferable that complementary boat surveys be carried out. In the absence of boat survey data, maximum colonisation depths cannot be recorded and no assessment can be made of the macrophyte structure attribute. This is particularly pertinent in oligotrophic systems, where deep-water species such as *Isoetes* may not appear in wader transects. Furthermore, there is a high risk of underrecording or missing rare deep-water species such *L. natans* - an important species in Wales – and *N. gracilis* – a scarce species –if boat transects are not completed. We strongly recommend that boat surveys be an integral and necessary component of the CSM methods.

### 5.4.3 Macrophyte species compositional and structural targets

#### *5.4.3.1 Data obtained from wader and boat surveys*

In assessing macrophyte species compositional targets, there are issues to consider in relation to the use of wader and/or boat survey data. For the assessment of vegetation composition, the CSM guidance stipulates that for e.g. Hard oligo-mesotrophic waters, "7 out of 10 vegetated sample spots (boat or wader) should include at least 1 characteristic species". In the case of Kenfig Pool, 81 % of wader sample spots include at least 1 characteristic species (result = pass target), whereas this is true for only 55 % of the boat sampling points (result = fail target). When shore and boat sample points are combined, the overall score is 71% (result = just favourable). As such, the choice to employ boat OR wader data (or both combined) can result in different condition assessment outcomes. In the current report, the combined score is used for assessments.

#### *5.4.3.2 Seasonal bias and interannual variability in macrophyte species composition and structure*

Seasonal bias can be very marked, especially in unfavourable lakes. The timing of surveys in any one year can significantly influence the range of macrophyte species recorded and hence

those species used for site condition assessment. For example, in unfavourable sites, where eutrophication has altered the structure and function of the lake ecosystem, large populations of fine-leaved *Potamogeton* species may crash in mid-late summer as the system switches to phytoplankton dominance. In July 2005, CCW region staff found almost no macrophytes in Llyn Penrhyn, whereas in mid August of the same year, a repeat visit found reasonable, though generally sparse macrophyte cover (mainly *Ceratophyllum demersum*).

Interannual variability also has the potential to significantly influence site condition assessments. For example, in September 2003 few living submerged macrophytes were recorded in Llyn Llygeirian, whereas in July 2002 there was a dense cover of *Potamogeton pectinatus* and *Potamogeton pusillus*. Contrasting assessment outcomes could potentially be derived from survey data from the two different years.

Caution should therefore be exercised when comparing macrophyte survey data from different years / different seasons and in inferring long-term trends without first accounting for seasonal or interannual survey bias. Regular monitoring (e.g. 3-yearly, is recommended to gain the fullest possible understanding of individual sites.

#### *5.4.3.3 Presence/absence data versus weighted abundances and DAFOR abundances.*

The macrophyte presence/absence data could be weighted according to the abundance of each species. i.e. biomass scores (0-3) could be used when assessing vegetation composition against the CSM guidance criteria. The recording of biomass scores in the field has been trialed and comparisons made. The use of DAFOR scores (as here) is another approach. However, a tailored analytical method based directly on transect data might constitute a better approach.

The data generated from wader and boat transects is inherently different and should perhaps be weighted to account for these differences. Some suggestions are made in Appendix 1 of Goldsmith *et al*. (2006), although the current report makes no attempt to use weighting methods to this end. The extra calculations involved are protracted and further detailed consideration is necessary if weightings are to be suitably applied.

The CSM targets for macrophyte species composition do not take account of the abundances of the individual characteristic species. For example, the target; “6 out of 10 sample spots should have at least one characteristic species”, does not stipulate the number of characteristic species that should make up this total. As such, the total could be dominated by only one characteristic species. In assessing the macrophyte composition target; “presence of at least 3 *Littorelletea* species”, the assemblage might have 3 *Littorelletea* species, but this could comprise 90% of one species and only 10% of the other two species. Consequently, small percentage abundances of the two rare species could easily be lost if environmental conditions in the lake were to change.

Despite fulfilment of CSM feature type targets, a lake’s macrophyte assemblage could be shifting towards a monoculture. We recommend that future assessments make use of abundance scores in preference to simple presence / absence data.

#### *5.4.3.4 Negative indicator species: Filamentous algal cover*

The objective assessment of benthic / filamentous algal cover is problematical. CSM targets for all feature types state that there should be "less than 10 % cover". Data available for assessment of this attribute comprises algal biomass scores in the range 0-3, recorded for every sample spot across both the wader and boat transects (where 0 = absent, 1 = <25 % cover, 2 = 25-50 % cover and 3 = >50 % cover). The attribute target and the available data are therefore incompatible. Further consideration is required to develop objectively assessable targets that are compatible with the survey methods employed.

One suggestion for target amendment is: "no more than 50 % of sample spots to have scores of 3" (CSM review meeting, November 2005). Using this target, none of the SAC or SSSI sites would have failed the filamentous algae element of the negative indicator species attribute. The revised target may therefore be set too low.

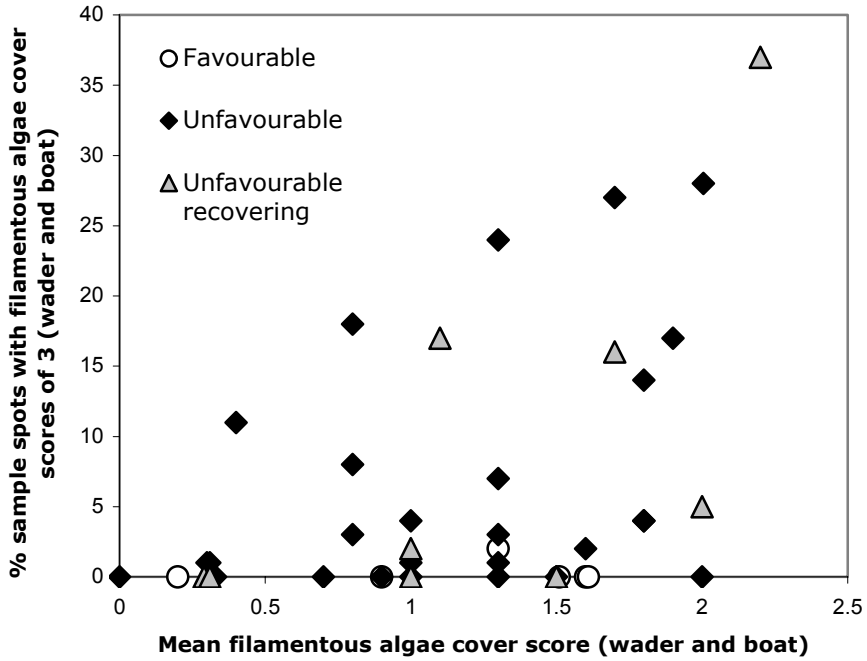
Figure 5.2 illustrates that all lakes in favourable condition have a very low percentage (< 5 %) of sample spots with filamentous algae cover scores of 3. Mean filamentous algae cover scores at these sites show greater variation (ranging from 0.3 to 1.6). Although the sample size for favourable sites is very small (n = 7) and cover scores are to some extent arbitrary, results suggest that a cut-off of < 5 % of sample spots with filamentous algae cover scores of 3 (across both wader and boat transects) could be used as a target for favourable status. Further investigation into filamentous algae targets is recommended, particularly since it is clear from Figure 5.2 that there is significant variability in filamentous algae cover scores for lakes within each condition status. It may be sufficient to stipulate in the CSM guidance that there should simply be a *low coverage* of filamentous algae at favourable status, and leave the definition of 'low' to expert judgement.

The composition of the filamentous / benthic algae should also be considered. Different field surveyors may have different perceptions of what constitutes 'filamentous / benthic algae' e.g. a thick covering of green slime, or a relatively thin covering of periphytic diatoms. Species composition should ideally be recorded to make a full assessment of filamentous/benthic algae coverage, although this may be beyond the scope of the CSM methods.

#### *5.4.3.5 Chara species coverage in hard-water lakes*

An estimation of *Chara* spp. coverage is required for the condition assessment of hard-water lakes. Using the CSM methods (transects) it is difficult to objectively assess whether coverage across the entire lake amounts to >50% of the photic zone. We cannot simply assume that the transect data can be converted to an overall score for the entire lake. A re-assessment of the methods and of the target may be required, although since the attribute target is itself to some extent subjective, perhaps it is sufficient to stipulate that there should simply be a *high coverage* of *Chara* spp. and leave the definition of 'high' to expert judgement. Alternatively for these hard-water lakes, percentage vegetation infestation (PVI) scores for *Chara* spp. could be obtained for the entire water body using a bathyscope. This may be feasible for small, shallow, clear-water sites and where time and resources allow.

**Figure 5.2: Relationship between the condition of SAC and SSSI lakes (all feature types) and the coverage of filamentous algae.**




### *5.4.3.6 Characteristic species listed as 'spp.' in the favourable condition tables*

When characteristic species are listed in the favourable condition tables as 'spp.' e.g. *Chara* spp. or *Lemna* spp., and more than one species from a genera is present, no CSM guidance is provided as to whether all individual species should be counted separately towards the compositional targets. In the current assessments, all individual species have been counted i.e. *Lemna minor* and *Lemna trisulca* have been counted separately, as have all individual *Chara* species. We think that this is a reasonable interpretation of the CSM guidance, although perhaps counting separate species is more appropriate for charophytes than for *Lemna* species. Further analysis of the favourable condition indicator value of different macrophyte genera is required, although in the interim, where possible all taxa should be recorded to species level unless there are good ecological reasons to suggest otherwise.

## 5.4.4 Palaeoecological data – diatoms, plant macrofossils and other proxies

In the absence of historical chemical and biological data, palaeo-data provides a valuable long-term perspective. In the CSM methodology, clearer guidance on the use of this type of data is required. Palaeoecological data should be interpreted with caution, particularly where only a limited number of stratigraphic levels have been analysed.

#### *5.4.4.1* Diatoms

For the majority of lakes in the current report, diatom data are only available for core top and bottom samples. To enable a more robust assessment of trends, analysis of approximately five stratigraphic levels is recommended. Roebuck (2005) analysed mid-core diatom samples from two SACs included in the current report (Rhinog and Migneint). Diatom data from core top and bottom samples presented in Goldsmith *et al*. (2006) was complemented by the mid-core samples of Roebuck (2005). The mid-core samples better elucidated acidification and recovery trends, in particular providing evidence of recent recovery.

Diatom inferred pH (DI-pH) and TP (DI-TP) values are usefully employed in the assessment of trends. However, robustness of inferences and problems such as domination of small, ubiquitous *Fragilaria* spp. in shallow lakes (Sayer, 2001) can be problematic. In Goldsmith *et al*. (2006), DI-pH was consistently underestimated when compared to current measured pH. Preliminary evidence from work in the UK (Monteith pers comm.) suggests that this may be because the diatoms are responding to changes in alkalinity (bicarbonate) as opposed to pH.

#### *5.4.4.2 Plant macrofossils*

Further palaeo work is recommended at the hard-water SAC lakes, Llyn Cadarn and Llyn yr Wyth Eidion. Plant macrofossil analysis should help to establish the composition and extent of former macrophyte communities and in particular, to ascertain trends in charophyte species composition, abundance and distribution. Recent macrophyte surveys at Llyn Cadarn recorded no charophyte species, but historical records suggest that charophytes were previously an important component of the macrophyte flora. Plant macrofossil analysis may also be usefully exploited in lakes where current macrophyte assemblages are sparse or species poor, to determine if assemblages were formerly richer, and if so, the approximate species composition.

Complementary palaeo information may also be obtained from pollen and cladoceran analysis.

### 5.4.5 Historic macrophyte data

Historic macrophyte data constitutes a valuable information resource on former plant communities. The current assessments do not take account of all available data principally due to time constraints. However, since the current assessments are to some extent baseline surveys, this is not considered significantly problematical. There are a number of issues associated with old survey data that should be considered when comparing past and present data. Most notably, there may be bias towards the recording of rarities, or the inclusion of only those species that could be surveyed from the lakeshores. Present day absence of previously recorded rarities may be informative, but full species lists for individual lakes are unusual. The CSM guidance details the methods that should be used to carry out macrophyte surveys to make site condition assessments, however it is not thought that most amateur naturalists used any such standard methodologies, with surveys performed more ad-hoc.

## 5.4.6 Environmental data and targets

### *5.4.6.1 Frequency of measurements used to calculate seasonal / annual averages*

The GB chemistry typology database (Carvalho *et al*. October 2005 version) has been used extensively as the source of environmental data for the assessment of all SSSI and some SAC lakes. For many variables, the database comprises monthly data, from which seasonal and annual means can be calculated. This should result in more accurate/realistic average values from which to make site condition assessments as opposed to single seasonal measurements for each of 4 seasons detailed in Goldsmith *et al*. (2006). However, the use of Carvalho *et al.*'s database for the assessment of lake SSSI condition (and some SAC lakes) raises some issues concerning the range of seasonal data available for the calculation of annual means.

### *5.4.6.2 Favourable condition targets for environmental variables*

There is considerable work being undertaken at present to set environmental standards and conditions for the assessment of lake ecological status under the requirements of the EU WFD. The WFD and Habitats Directive have different objectives, but it may be pertinent to explore integration into the CSM favourable condition tables of current thinking with respect to nutrient (TP) targets. Examination of Tables 3.5e and 3.5f indicate that the TP ranges and maxima indicative of good ecological status / favourable condition are broadly similar. However, cross-referencing issues arise where lake typologies have changed i.e. the WFD typology now includes a 'very shallow' category. The existing Habitats Directive standards could potentially be brought in line with WFD standards over the coming years, particularly since WFD standards are currently being developed from biological quality elements of direct relevance to habitat conservation.

It is well established that TP is generally a good predictor of chlorophyll in lakes. However, it is also well known that there is considerable scatter in this relationship, caused by a variety of factors including lake depth, grazing and limitation by other nutrients. There is scope for further nutrient and productivity targets (aside from TP) to be incorporated into the CSM favourable condition tables. The REBECCA project (http://www.environment.fi/syke/rebecca) is exploring relationships between the ecological and chemical status of surface waters. A range of possible type-specific good / moderate boundary criteria for chlorophyll *a* have been proposed (Table 3.4), corresponding to changes in depth distribution of macrophytes. Draft targets for chlorophyll *a* are reported in the TAG/LTT_95a paper (Phillips, 2005). It is recognised that there are uncertainties in determination of boundary values, although these uncertainties will be explored and reported over the coming months, particularly by the WFD phytoplankton classification tool project (Carvelho *et al*., in progress).

### *5.4.6.2 The seasonal / mean environmental data used to assess lake water quality*

The CSM guidance stipulates that TP data should be based on a minimum of 4 quarterly measurements, or alternatively only spring data can be used. For many lakes, the TP

concentration will be at its lowest in the spring. Therefore the decision as to whether 'mean annual' or 'spring only' environmental data are employed has the potential to significantly affect assessments of water quality against attribute targets.

In the medium term, improved water quality data should become available via the Environment Agency's routine WFD lake water quality monitoring. These data will be invaluable in deriving condition assessments. In Wales, EA and CCW should work together to ensure that appropriate water quality data are available for all SSSI and SAC lakes. This is vital to ensure data integrity and ultimately derive robust and meaningful condition assessments.

#### *5.4.6.3 Lake-specific chemical and biological targets*

Since each lake is unique, there is an argument for lake-specific chemical and biological targets. This may be particularly relevant to shallow eutrophic lakes, where the structure and function of the lake ecosystem can be complex and there can be significant seasonal and interannual variability in chemical and biological elements. Although specific standards for individual lakes may be the favourable approach, type specific standards should be applied in cases where insufficient data are available.

### 5.4.7 Comparison of the CSM approach with other assessment methods

The CSM methodology (JNCC, 2005) prescribes a standardised approach to biological monitoring of standing water habitats that are notified as qualifying features on SAC and SSSI sites. CSM guidance stipulates that; "a site should be classed as being in unfavourable condition if any individual attribute fails to meet its targets". This is equivalent to 100 % compliance. There is some scope for expert judgement in the overall assessment of sites, but this should be justified.

The ECOFRAME project (Moss *et al*., 2003) also uses a standardised approach to monitoring (comparable, but different methods), but the ecological quality of lakes is assessed by means of lake ecotypes and status classifications using a confidence-based approach. Expectations of 100 % or 50 % compliance are deemed unreliable, but 75 % compliance gives a pattern that is not significantly different to that expected from the range of sites included in the assessment.

Differences in the stringency of the two different assessment methods would most likely result in different condition assessment outcomes. If the ECOFRAME project's 75 % compliance level were applied to the current assessments, it is thought that many more Welsh lake SACs and SSSIs would be classified as unfavourable recovering, or favourable. Consideration should be given to the ultimate purpose of the assessments and therefore the relevance of a lower level of compliance.

Moss *et al*. (2003) suggests that the ECOFRAME assessments could be made more sophisticated by giving different weightings to some variables compared to others. This approach could also be considered for inclusion in the CSM methods, particularly where the general impact category (e.g. eutrophication or acidification) has been identified and therefore

some attributes may be of greater relevance and importance than others in deriving the condition assessment.

### 5.4.8 Long-term sustainability of Welsh lake SAC and SSSI habitats

Under Article 1 of the Habitats Directive (Council of the European Communities, 1992: 92/43/EEC), member states are required to take into account the long-term sustainability of protected habitats. This is particularly pertinent to aquatic habitats where restoration from unfavourable condition is often difficult and costly.

The long-term sustainability of most oligo-mesotrophic Welsh lake SACs and SSSIs is considered viable if atmospheric deposition of both nitrogen and sulphur continue to decrease as a result of international policies. Under conditions of decreasing emissions, it is expected that the majority of upland lakes previously impacted by acid deposition should see continued recovery trends. Recovery should be monitored to investigate whether over time a return to pre-impact conditions is achieved. Alongside contemporary chemical and biological data, palaeolimnological evidence will be valuable in examining these trends.

The long-term sustainability of most naturally eutrophic and hard-water Welsh lake SACs and SSSIs is also possible. However, residual sediment nutrient concentrations and continued inwash of nutrients from diffuse catchment sources are significant obstacles that must be overcome if recovery from eutrophication is to occur. Furthermore, eutrophication can dramatically alter the structure and function of lake ecosystems; therefore carefully constructed management plans must be implemented if favourable condition is to be a realistic future target for impacted naturally eutrophic and hard-water lakes. Llyn Penrhyn SSSI is the only lake in the current study that is considered to be in unfavourable, declining condition. The long-term sustainability of this site is debatable and the habitat feature may have been largely destroyed. It is vital that action is taken immediately and restoration efforts sustained, to prevent the decline of other protected Welsh lake habitats.

Regular water quality monitoring and macrophyte surveys are recommended at all naturally eutrophic and hard-water Welsh lake SACs and SSSIs. Ideally, monthly water samples should be taken and analysed (minimum quarterly) from all sites selected for further monitoring. Certain sites may require more intensive monitoring. CSM guidance recommends that biological attribute surveys (i.e. macrophyte surveys) should be spaced at least four years apart. Although annual surveys might be optimal, this level of sampling frequency is unrealistic for the majority of sites. Comparison of surveys carried out at two-yearly intervals is not recommended as an appropriate strategy because many species have alternate ‘good’ and ‘bad’ years. Natural population dynamicss could under these circumstances be misinterpreted as directional change. A sampling frequency of three years is recommended as an appropriate strategy for naturally eutrophic and hard-water lakes.

Palaeolimnological work is recommended at sites where ecological structure and function appears to have altered through eutrophication. Plant macrofossil and cladoceran analysis is recommended, so as to reconstruct past macrophyte assemblages and zooplankton populations. This should be combined with contemporary chemical and biological data, alongside efforts to reduce catchment nutrient inputs and sustainably manage fish populations.

## *5.5 Overall recommendations for future monitoring and assessments*

Table 5.5. details the recommended data and monitoring requirements for Welsh lake SACs and SSSIs. These recommendations are intended to address data uncertainty issues and to provide a focus for future survey work. Practical suggestions are provided to facilitate attainment of favourable condition at sites currently classified as unfavourable, and to maintain the favourable condition of sites currently classified as favourable.

**Table 5.5: Further data requirements, monitoring recommendations and actions required for Welsh lake SACs and SSSIs. Bolded sites are recommended for future monitoring.**

| SAC Name | Lake Name | Data / monitoring requirements | Actions required |
|---|---|---|---|
| Afon Gwyrfai a Llyn Cwellyn | **Llyn Cwellyn** | -ANC (cations and anions), alkalinity and TP/TN data.<br>-Sediment loading data / catchment nutrient and liming history<br>-Monitor *L. natans* and *N. gracilis* populations (also *S. aquatica*) | -Continued reductions in atmospheric deposition of N and S.<br>-Reductions in nutrient / sediment inwash.<br>-Continued gradual removal of coniferous trees in catchment. |
| Afon Teifi | Llyn Egnant | -ANC (cations and anions), alkalinity and TP/TN data.<br>-Monitor *L. natans* populations.<br>-Monitor abundance and distribution of *J. bulbosus* and *Sphagnum* spp. | -Appropriate management of reservoir water levels.<br>-Continued reduction of atmospheric deposition of N and S.<br>-Regular water quality / macrophyte surveys.<br>-Reduction in nutrient concentrations.<br>-Maintain conditions favourable to *L. natans*. |
| | **Llyn Hîr** | -ANC (cations and anions), alkalinity and TP/TN data.<br>-Short sediment core (1998-2005) to assess recent eutrophication / alkalinisation trends.<br>-Monitor populations of *L. dortmanna* , *L. natans* and *I. echinospora*. | -Continued reduction of atmospheric deposition of N and S.<br>-Regular water quality monitoring.<br>-Slight reduction in nutrient concentrations.<br>-Maintain conditions favourable to *L. natans*, *I. echinospora*. |

| SAC Name | Lake Name | Data / monitoring requirements | Actions required |
|---|---|---|---|
| | Llyn Teifi | -ANC and alkalinity data and a DO profile.<br>-Data on macrophyte community structure.<br>-Monitor *L. natans* populations. | -Appropriate management of reservoir water levels.<br>-Continued reduction of atmospheric deposition of N and S.<br>-Regular water quality / macrophyte surveys.<br>-Reduction in nutrient concentrations.<br>-Maintain conditions favourable to *L. natans*.<br>-Boat survey using CSM methods. |
| Cadair Idris | **Llyn Gafr** | -Further TP data.<br>-Monitor catchment stocking levels. | -Regular macrophyte / water quality surveys.<br>-Manage catchment stocking levels appropriately. |
| | **Llyn Arran** | -Further TP and alkalinity data (seasonal/mean).<br>-Monitor ANC.<br>-Monitor catchment stocking levels.<br>-Diatom analysis of further levels to examine any acidification trends.<br>-Macrofossil analysis to examine any macrophyte species shifts. | -Regular macrophyte / water quality surveys.<br>-Continued reductions in atmospheric deposition of N and S.<br>-Manage catchment stocking levels appropriately. |
| | **Llyn Cau** | -Further alkalinity and TP data. (seasonal/mean).<br>-Monitor ANC.<br>-Monitor catchment stocking levels.<br>-Diatom analysis of further levels to examine any acidification trends. | -Regular macrophyte / water quality surveys.<br>-Continued reductions in atmospheric deposition of N and S.<br>-Manage catchment stocking levels appropriately. |

| SAC Name | Lake Name | Data / monitoring requirements | Actions required |
|---|---|---|---|
| Corsydd Môn / Anglesey Fens | **Llyn Cadarn** | -Macrophyte survey data.<br>-Macrofossil analysis of a dated sediment core, to determine former charophyte assemblages.<br>-Catchment nutrient budget. | -Regular macrophyte / water quality surveys.<br>-Identify catchment nutrient sources and reduce nutrient loading.<br>-Re-establish charophyte populations. |
| | **Llyn yr Wyth Eidion** | -Macrophyte survey data.<br>-Macrofossil analysis (as for Llyn Cadarn.<br>-Catchment nutrient budget. | -Identify catchment nutrient sources and reduce nutrient loading.<br>-Regular macrophyte / water quality surveys. |
| Elenydd | **Llyn Cerrigllwydion Isaf** | -Further TP and alkalinity data (seasonal/mean).<br>-Monitor ANC.<br>-Further boat transects.<br>-Diatom / macrofossil analysis of further levels to examine acidification trends.<br>-Monitor populations of *L. natans*.<br>-Monitor catchment stocking levels. | -Regular macrophyte / water quality surveys and surface sediment sampling.<br>-Analysis of catchment stocking data.<br>-Maintain conditions favourable to *L. natans*.<br>-Continued reductions in atmospheric deposition of N and S. |
| | Llyn Fyrddon Fawr | -Further TP and alkalinity data (seasonal/mean).<br>-Monitor ANC.<br>-Plant macrofossil and aquatic pollen analyses to examine former flora.<br>-Monitor peat erosion.<br>-Monitor catchment stocking levels. | -Potentially change feature type from oligotrophic to dystrophic.<br>-Investigate whether present-day absence of macrophytes is natural.<br>-Continued reductions in atmospheric deposition of N and S. |

| SAC Name | Lake Name | Data / monitoring requirements | Actions required |
|---|---|---|---|
| | Llyn Gwyngu | -Further TP and alkalinity data (seasonal/mean).<br>-Plant macrofossil and aquatic pollen analyses to examine former flora.<br>-Monitor peat erosion.<br>-Monitor catchment stocking levels.<br>-Monitor *E. fluitans* populations<br>-Investigate absence of *Littorelletea* species. | -Continued reduction of atmospheric deposition of N and S.<br>- Maintain favourable habitat for *E. fluitans*. |
| | **Llyn Gynon** | -Further TP, ANC and alkalinity data required.<br>-Monitor populations of *L. natans*.<br>-Monitor catchment stocking levels. | -Continued reduction of atmospheric deposition of N and S.<br>-Regular macrophyte / water quality surveys.<br>-Maintain conditions favourable to *L. natans*. |
| Eryri / Snowdonia | **Llyn Cwmffynnon** | -Further TP and alkalinity data (seasonal/mean).<br>-Monitor ANC.<br>-Monitor catchment stocking levels. | -Continued reduction of atmospheric deposition of N and S.<br>-Regular macrophyte / water quality surveys. |
| | Llyn Coch | -Monitor ANC.<br>-Monitor catchment stocking levels.<br>-Plant macrofossil and diatom analysis of at least five levels, to examine changes in habitat availability. | -Regular macrophyte / water quality surveys. |
| | **Llyn Idwal** | -Monitor ANC.<br>-Further alkalinity data.<br>-Monitor catchment stocking levels.<br>-Monitor catchment recreational pressure. | -Regular macrophyte / water quality surveys. |
| | **Llyn Ogwen** | -Monitor ANC.<br>-Further alkalinity data.<br>-Monitor catchment stocking levels. | -Regular macrophyte / water quality surveys.<br>-Continued reduction of atmospheric deposition of N and S. |

| SAC Name | Lake Name | Data / monitoring requirements | Actions required |
|---|---|---|---|
| Kenfig / Cynffig | **Kenfig Pool** | -Establish potential catchment nutrient sources and monitor. | -Regular macrophyte / water quality surveys.<br>-Removal of remaining carp. |
| Llyn Dinam | **Llyn Dinam** | -Monitor coarse fish populations.<br>-Further survey work to confirm the presence of *P. gramineus*.<br>-Monitor populations of *C. demersum*. | -Regular macrophyte / water quality surveys.<br>-Reduce TP levels.<br>-Continued management action to maintain trajectory towards favourable condition. |
| Llyn Syfaddan / Llangorse Lake | **Llangorse Lake** | -Monitor coarse fish populations.<br>-Monitor populations of *E. nuttallii*. | -Reduce TP levels.<br>-Regular macrophyte / water quality surveys. |
| Migneint-Arenig-Dduallt | **Llyn Conglog-Mawr** | -Further TP and alkalinity data (seasonal/mean).<br>-Monitor ANC.<br>-Plant macrofossil and aquatic pollen analyses to examine former flora.<br>-Monitor populations of *N. gracilis*. | -Regular macrophyte / water quality surveys.<br>-Change feature type from oligotrophic to dystrophic?<br>-Continued reduction of atmospheric deposition of N and S. |
| | **Llyn y Dywarchen** | -Further TP and alkalinity data (seasonal/mean).<br>-Monitor ANC.<br>-Plant macrofossil and aquatic pollen analyses to examine former flora.<br>-Further survey of other potential dystrophic lakes on Migneint is needed. | -Regular macrophyte / water quality surveys – examine trends in ANC.<br>-Continued reduction of atmospheric deposition of N and S.<br>-Investigate whether present-day absence of macrophytes is natural. |
| | **Llyn y Garn** | -Further TP and alkalinity data (seasonal/mean).<br>-Monitor populations of *L. natans*. | -Regular macrophyte / water quality surveys.<br>-Maintain conditions favourable to *L. natans*. |
| | **Llyn Hesgyn** | -Further TP and alkalinity data (seasonal/mean). | -Regular macrophyte / water quality surveys. |

| SAC Name | Lake Name | Data / monitoring requirements | Actions required |
|---|---|---|---|
| | **Llyn Hiraethlyn** | -Further TP and alkalinity data (seasonal/mean).<br>-Monitor populations of *L. natans*.<br>-Monitor grazing pressure. | -Regular macrophyte / water quality surveys.<br>-Continued reduction of atmospheric deposition of N and S. |
| | **Llyn Tryweryn** | -Further TP and alkalinity data (seasonal/mean).<br>-Monitor labile aluminium concentrations.<br>-Investigate possible reasons for atypical dystrophic macrophyte flora.<br>-Investigate effects of forestry on lake ecosystem. | -Regular macrophyte / water quality surveys.<br>-Continued reduction of atmospheric deposition of N and S.<br>-Managed felling of coniferous trees – replace with natural landcover. |
| Pembrokeshire Bat Sites and Bosherton Lakes / Safleoedd Ystlum Sir Benfro a Llynnoedd Bosherton | **Bosherston Lily Ponds (Central)** | -Monitor nutrient concentrations, particularly nitrogen. | -Regular macrophyte / water quality surveys.<br>-Reduce nitrogen input.<br>-Ensure that *Azolla* does not enter the lake from the feeder streams. |
| Rhinog | **Llyn Cwm Bychan** | -Further TP and alkalinity data (seasonal/mean).<br>-Monitor ANC<br>-Monitor populations of *L. natans*.<br>-Monitor relative abundance of isoetid and elodeid species.<br>-Monitor catchment stocking levels and sediment loading. | -Regular macrophyte / water quality surveys.<br>-Continued reduction of atmospheric deposition of N and S.<br>-Maintain conditions favourable to *L. natans.* |
| | **Llyn Eiddew-Mawr** | -Further TP and alkalinity data (seasonal/mean).<br>-Monitor ANC<br>-Monitor relative abundance of isoetid and elodeid species. | -Regular macrophyte / water quality surveys.<br>-Continued reduction of atmospheric deposition of N and S. |

| SAC Name | Lake Name | Data / monitoring requirements | Actions required |
|---|---|---|---|
| | **Llyn Perfeddau** | -Further TP and alkalinity data (seasonal/mean).<br>-Monitor ANC<br>-Monitor relative abundance of isoetid and elodeid species. | -Regular macrophyte / water quality surveys.<br>-Continued reduction of atmospheric deposition of N and S. |
| | **Gloyw Lyn** | -Further TP and alkalinity data (seasonal/mean).<br>-Monitor ANC.<br>-Monitor relative abundance of isoetid and elodeid species. | -Regular macrophyte / water quality surveys.<br>-Continued reduction of atmospheric deposition of N and S. |
| Y Twyni o Abermenai i Aberffraw / Abermenai to Aberffraw Dunes | **Llyn Coron** | -Monitor nutrient and productivity levels.<br>-Monitor populations of *E. hydropiper* and *C. truncata* (rarities in UK).<br>-Monitor populations of broad-leaved *Potomogeton* spp. and *L. uniflora*.<br>-Monitor sediment loading.<br>-Also collect monitoring data from Llyn Rhos-ddu, a smaller lake within this SAC. | -Regular macrophyte / water quality surveys.<br>-Catchment management measures required -reduce livestock poaching, addess septic tank discharges and reduce nutrient input via inflow stream.<br>-Maintain fishery regime – **do not** allow stocking of coarse fish / carp. |
| Hanmer Mere SSSI | **Hanmer Mere** | -Monitor nutrient and productivity levels. | -Regular macrophyte / water quality surveys.<br>-Reduce nutrient concentrations. |
| Llyn Alaw | **Llyn Alaw** | -Monitor nutrient concentrations.<br>-Monitor populations of *E. acicularis*. | -Regular macrophyte / water quality surveys.<br>-Reduce nutrient input.<br>-Manage reservoir draw-down appropriately.<br>-Ensure that fishery management is appropriate to overall aquatic ecosystem health. |

| SAC Name | Lake Name | Data / monitoring requirements | Actions required |
|---|---|---|---|
| Mynydd Hiraethog | **Llyn Alwen** | -ANC data required.<br>-Monitor ANC, alkalinity and pH.<br>-Monitor nutrient concentrations and identify sources. | -Regular macrophyte / water quality surveys.<br>-Continued reduction of atmospheric deposition of N and S.<br>-Reduce nutrient input.<br>-Maintain grazing in catchment at appropriate levels. |
| - | **Llyn Bodlyn** | -ANC data required.<br>-Monitor ANC, alkalinity and pH.<br>-Monitor nutrient concentrations and identify sources. | -Regular macrophyte / water quality surveys.<br>-Continued reduction of atmospheric deposition of N and S.<br>-Manage reservoir draw-down appropriately.<br>-Maintain grazing in catchment at appropriate levels. |
| Llyn Eiddwen SSSI | **Llyn Eiddwen** | -ANC data required.<br>-Monitor nutrient concentrations / algal blooms and identify nutrient sources.<br>-Monitor populations of *L. natans* and *S. aquatica*. | -Regular macrophyte / water quality surveys.<br>-Maintain grazing in catchment at appropriate levels – reduce poaching of shoreline.<br>-Reduce nutrient input.<br>-Maintain conditions favourable to a rich aquatic flora. |
| Llyn Glasfryn SSSI | **Llyn Glasfryn** | -Monitor nutrient concentrations and identify sources of nutrients.<br>-Monitor populations of rare / nutrient sensitive macrophyte species. | -Regular macrophyte / water quality surveys.<br>-Reduce nutrient input.<br>-Ensure that fishery management is appropriate to overall aquatic ecosystem health.<br>-Ensure livestock grazing and improvement of agricultural land is appropriately managed. |

| SAC Name | Lake Name | Data / monitoring requirements | Actions required |
|---|---|---|---|
| Llyn Llygeirian SSSI | **Llyn Llygeirian** | -Monitor nutrient concentrations and identify sources of nutrients.<br>-Monitor late summer population crashes of fine-leaved *Potamogeton* spp..<br>-Monitor populations of rare / nutrient sensitive macrophyte species. | -Regular macrophyte / water quality surveys.<br>-Reduce nutrient input.<br>-Ensure livestock grazing is appropriately managed. |
| Llyn Padarn SSSI | **Llyn Padarn** | -ANC data required.<br>-Monitor nutrient concentrations and identify nutrient sources – assess impact from town, tourism and watersports.<br>- Monitor populations of Arctic charr.<br>- Monitor populations of *L. natans*. | -Regular macrophyte / water quality surveys.<br>-Reduce nutrient input.<br>-Manage recreational use of lake appropriately.<br>-Ensure lake management is appropriate for *L. natans* and Arctic charr. |
| Llynnau y Fali / Valley Lakes SSSI | **Llyn Penrhyn** | -Monitor nutrient concentrations.<br>-Monitor populations of *E. hydropiper*. | -Regular macrophyte / water quality surveys.<br>-Reduce nutrient input.<br>-Instigate carefully constructed management plan for lake restoration. |
| Llyn Tegid SSSI | **Llyn Tegid** | -ANC data required.<br>-Monitor nutrient concentrations and identify nutrient sources – prepare a nutrient budget<br>- Monitor populations of Gwyniad.<br>- Monitor populations of *L. natans*. | -Regular macrophyte / water quality surveys.<br>-Reduce catchment nutrient input, particularly from agricultural land.<br>-Manage hydrological regime of lake appropriately to ensure aquatic ecosystem health.<br>-Maintain habitat conditions favourable to *L. natans* / Gwyniad. |

| SAC Name | Lake Name | Data / monitoring requirements | Actions required |
|---|---|---|---|
| Cadair Idris SSSI | **Tal-y-llyn Lake** | -Monitor nutrient concentrations and identify nutrient sources – prepare a nutrient budget.<br>-Monitor populations of naturalised non-native macrophyte, *E. nuttallii.* | -Regular macrophyte / water quality surveys.<br>-Reduce catchment nutrient input.<br>-Ensure livestock grazing is appropriately managed.<br>-Ensure that fishery management is appropriate to overall aquatic ecosystem health. |

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