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Ecological Surveys of Welsh Lakes 2015

Goldsmith, B., Turner, S., Shilland, E. and Goodrich, S.
ENSIS Ltd. London

NRW Evidence Report No. 145

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Contents

1. Crynodeb Gweithredol	9
Executive Summary	10
2. Introduction.....	11
2.1. Background.....	11
2.2. Aim of the Report	11
3. Methods.....	12
3.1. Sites	12
3.2. Aquatic Macrophyte Surveys – JNCC	12
3.3. Physico-Chemical Survey and Other Data Sources.....	14
3.4. Bathymetric Survey.....	15
4. Survey Results and Metrics.	16
4.1. Lake metrics.....	16
4.2. Site Overviews	16
4.2.1. Ysceifiog Lake	16
4.2.2. Llyn Cwellyn 34002	18
4.2.3. Llyn Cwmffynnon 33974	21
4.2.4. Llyn Arenig Fawr 34864.....	24
4.2.5. Llyn Hesgyn 34531	26
4.2.6. Llyn Hiraethlyn 34928.....	28
4.2.7. Llyn y Garn 34895	31
4.2.8. Ffynnon Lloer 33736.....	33
4.2.9. Llyn Hir 34928	35
4.2.10. Llyn y Gader	37
4.2.11. Llyn Nantlle Uchaf.....	39
4.2.12. Llyn Dinam.....	42
4.2.13. Llyn Coron	44
4.2.14. Llyn Traffwl.....	46
4.2.15. Llyn Penrhyn.....	49
4.2.16. Llyn Glasfryn.....	51
4.2.17. Llangorse Lake	54
4.2.18. Kenfig Pool	57
4.2.19. Llandegfedd Reservoir	60
4.3. Bathymetric Surveys	62
4.3.1. Llyn Nantlle Uchaf.....	62
4.3.2. Llyn y Gader	63
4.3.3. Bathymetric data.....	64
5. References	66
6. Appendices.....	68
6.1. Appendix I: Aquatic species data for all sites	68
6.2. Appendix II: Data Archiving.....	72

6.3.	Appendix III: Structure of Bathymetric Data.....	73
6.3.1.	Folder structure for bathymetric maps.....	73
6.3.2.	Bathymetric data folders.....	73

List of Figures

Figure 1 Map of Wales showing the location of the lakes.	13
Figure 2 Site map and aerial photograph of Ysceifiog Lake	16
Figure 3 Ysceifiog Lake site photo; from west shore looking east	17
Figure 4 Dissolved oxygen and temperature profiles at Ysceifiog Lake (07/09/2015)	18
Figure 5 Site map and aerial photograph of Llyn Cwellyn	18
Figure 6 Llyn Cwellyn site photo; looking east towards Snowdon	19
Figure 7 Distribution of Luronium natans in Llyn Cwellyn (From: Goldsmith <i>et al.</i> 2014a).....	20
Figure 8 Dissolved oxygen and temperature profiles at Llyn Cwellyn (08/09/2015)	21
Figure 9 Site map and aerial photograph of Llyn Cwmffynnon.....	21
Figure 10 Llyn Cwmffynnon site photo; looking west towards Snowdon	22
Figure 11 Dissolved oxygen and temperature profiles at Llyn Cwmffynnon (09/09/2015)	23
Figure 12 Site map and aerial photograph of Llyn Arenig Fawr	24
Figure 13 Llyn Arenig Fawr site photo; looking northwest towards Arenig Fawr peak.....	24
Figure 14 Dissolved oxygen and temperature profiles at Llyn Arenig Fawr (10/09/2015).....	25
Figure 15 Site map and aerial photograph of Llyn Hesgyn	26
Figure 16 Llyn Hesgyn site photo; looking southwest	27
Figure 17 Dissolved oxygen and temperature profiles at Llyn Hesgyn (11/09/2015).....	28
Figure 18 Site map and aerial photograph of Llyn Hiraethlyn.....	29
Figure 19 Llyn Hiraethlyn site photo; from the southeast shore looking northwest	29
Figure 20 Dissolved oxygen and temperature profiles at Llyn Hiraethlyn (12/09/2015).....	30
Figure 21 Site map and aerial photograph of Llyn y Garn.....	31
Figure 22 Llyn y Garn site photo; taken from the west shore looking east	31
Figure 23 Dissolved oxygen and temperature profiles at Llyn y Garn (13/09/2015)	32
Figure 24 Site map and aerial photograph of Ffynnon Loer	33
Figure 25 Ffynnon Lloer site photo; from the southeast shore looking northwest.....	33
Figure 26 Dissolved oxygen and temperature profiles at Ffynnon Loer (14/09/2015)	34
Figure 27 Site map and aerial photograph of Llyn Hîr.....	35
Figure 28 Llyn Hîr site photo; from the southeast shore looking northwest	35
Figure 29 Dissolved oxygen and temperature profiles at Llyn Hîr (15/09/2015)	36
Figure 30 Site map and aerial photograph of Llyn y Gader.....	37
Figure 31 Llyn y Gader site photo; bathymetric survey, looking northeast towards Snowdon	38
Figure 32 Dissolved oxygen and temperature profiles at Llyn y Gader (16/09/2015)	39
Figure 33 Site map and aerial photograph of Llyn Nantlle Uchaf	39
Figure 34 Llyn Nantlle Uchaf site photo; macrophyte survey, looking east towards Snowdon	40
Figure 35 Dissolved oxygen and temperature profiles at Llyn Nantlle (17/09/2015).....	41
Figure 36 Site map and aerial photograph of Llyn Dinam	42
Figure 37 Llyn Dinam site photo; typical marginal zone (southeast shore)	42
Figure 38 Dissolved oxygen and temperature profiles at Llyn Dinam (31/07/2016).....	44

Figure 39 Site map and aerial photograph of Llyn Coron.....	44
Figure 40 Llyn Coron site photo; typical marginal zone (southeast shore).....	45
Figure 41 Dissolved oxygen and temperature profiles at Llyn Coron (01/08/2016).....	46
Figure 42 Site map and aerial photograph of Llyn Traffwll.....	46
Figure 43 Llyn Traffwll site photo; taken from the north shore looking south.....	47
Figure 44 Dissolved oxygen and temperature profiles at Llyn Traffwll (02/08/2016).....	48
Figure 45 Site map and aerial photograph of Llyn Penrhyn.....	49
Figure 46 Llyn Penrhyn site photo; typical marginal zone (southwest shore).....	49
Figure 47 Dissolved oxygen and temperature profiles at Llyn Penrhyn (03/08/2016).....	51
Figure 48 Site map and aerial photograph of Llyn Glasfryn.....	51
Figure 49 Llyn Glasfryn site photo; typical marginal zone (east shore looking west).....	52
Figure 50 Dissolved oxygen and temperature profiles at Llyn Glasfryn (04/08/2016).....	53
Figure 51 Site map and aerial photograph of Llangorse Lake.....	54
Figure 52 Llangorse Lake site photo; from northeast shore looking south (<i>Butomus umbellatus</i> flowering).....	54
Figure 53 <i>Elodea nuttallii</i> (top) and <i>E. canadensis</i> (below) from Llangorse Lake.....	55
Figure 54 Dissolved oxygen and temperature profiles at Llangorse Lake (05/08/2015).....	56
Figure 55 <i>Potamogeton lucens</i> growing in Llangorse Lake.....	57
Figure 56 Site map and aerial photograph of Kenfig Pool.....	57
Figure 57 Kenfig Pool site photo; east shore looking north.....	58
Figure 58 <i>Myriophyllum alterniflorum</i> (top) and <i>M. spicatum</i> (below) in Kenfig Pool.....	59
Figure 59 Dissolved oxygen and temperature profiles at Kenfig Pool (06/08/2015).....	60
Figure 60 Site map and aerial photograph of Llandegfedd Reservoir.....	60
Figure 61 Llandegfedd Reservoir site photo; southeast shore looking northwest.....	61
Figure 62 Dissolved oxygen and temperature profiles at Kenfig Pool (06/08/2015).....	62
Figure 63 Bathymetric map of Llyn Nantlle Ucaf.....	63
Figure 64 Depth / volume and depth / area curves for Llyn Nantlle Uchaf.....	63
Figure 65 Bathymetric map of Llyn y Gader.....	64
Figure 66 Depth / volume and depth / area curves for Llyn y Gader.....	65

List of Tables

Table 1 Details of the lakes included in this report.....	12
Table 2 Summary of the LEAFPACS lake metrics, typical taxa, non-native species and maximum depth of macrophyte colonisation for the 19 lakes.....	16
Table 3 CSM Survey results from Ysceifiog Lake 2015	17
Table 4 CSM Survey results from Llyn Cwellyn 2015	20
Table 5 CSM Survey results from Llyn Cwmffynnon 2015.....	23
Table 6 CSM Survey results from Llyn Arenig Fawr 2015.....	25
Table 7 CSM Survey results from Llyn Hsegyn 2015.....	27
Table 8 CSM Survey results from Llyn Hiraethlyn 2015.....	30
Table 9 CSM Survey results from Llyn y Garn 2015	32
Table 10 CSM Survey results from Ffynnon Lloer 2015.....	34
Table 11 CSM Survey results from Llyn Hîr 2015	36
Table 12 CSM Survey results from Llyn y Gader 2015	38
Table 13 CSM Survey results from Llyn Nantlle Uchaf 2015	41
Table 14 CSM Survey results from Llyn Dinam 2015	43
Table 15 CSM Survey results from Llyn Coron 2015	45
Table 16 CSM Survey results from Llyn Traffwll 2015	48
Table 17 CSM Survey results from Llyn Dinam 2015	50
Table 18 CSM Survey results from Llyn Glasfryn 2015.....	53
Table 19 CSM Survey results from Llangorse Lake 2015.....	55
Table 20 CSM Survey results from Kenfig Pool 2015	58
Table 21 Summary statistics derived from the bathymetric survey of L. Nantlle Uchaf.....	62
Table 22 Summary statistics derived from the bathymetric survey of Llyn y Gader.....	64
Table 23 Summary of all aquatic and macrophyte species for the 19 lakes.	68

1. Crynodeb Gweithredol

Nod y prosiect hwn oedd casglu, prosesu a chyflenwi data ecolegol ac amgylcheddol i Cyfoeth Naturiol Cymru o rwydwaith o 19 o safleoedd llynnoedd ledled Cymru, i ategu rhaglen fonitro integredig Cyfoeth Naturiol Cymru ar gyfer safleoedd gwarchoddedig (ACA a SoDdGA), y Gyfarwyddeb Fframwaith Dŵr, y Gyfarwyddeb Nitradau, Cynlluniau Gweithredu Bioamrywiaeth a sbardunau deddfwriaethol a pholisi eraill. Yn arbennig, nod yr arolygon yw llywio gwaith i reoli ac adfer safleoedd gwarchoddedig a hwyluso'r broses o gyflawni Cynlluniau Rheoli Basn Afon.

Gan ddefnyddio dulliau safonol, arolygwyd llynnoedd er mwyn asesu rhywogaethau a chyflenwad y planhigion dyfrol sy'n tyfu oddi mewn i'r llynnoedd ac yn uniongyrchol o'u cwmpas, a mesur gloywder y dŵr, ocsigen toddedig a'r tymheredd yn y llynnoedd. Mewn dau safle, sef Llyn y Gader a Llyn Nantlle Uchaf, cynhaliwyd arolygon bathymetrig hefyd a chaiff y canlyniadau eu cyflwyno mewn fformatau safonedig.

- Mae'r rhywogaethau planhigion dyfrol wedi eu rhestr yn yr adroddiad a chyflenwyd canlyniadau cyflawn yr arolwg i Cyfoeth Naturiol Cymru ar ffurf cronfa ddata MS Access.
- Caiff cyfrifiadau eu cyflwyno i'w defnyddio o hyn ymlaen i bennu statws ecolegol y llynnoedd mewn perthynas â'r Gyfarwyddeb Fframwaith Dŵr.
- Caiff data bathymetrig ei gyflenwi mewn fformat GIS yn ogystal â'i gyflwyno'n graffigol ochr yn ochr â mesuriadau metrig a gyfrifwyd ar gyfer y llynnoedd.

Mae canlyniadau'r arolygon planhigion dŵr yn addas at ddibenion asesu cyflwr safle ar gyfer nodweddion merddwr y Gyfarwyddeb Cynefinoedd a statws SoDdGA. Mae mesuriadau metrig y llynnoedd yn berthnasol ar gyfer cynhyrchu cymarebau ansawdd ecolegol y gellir eu defnyddio i ddsbarthu'r llynnoedd, yn unol â gofynion y Gyfarwyddeb Fframwaith Dŵr (2000/60/EC).

Executive Summary

This project set out to collect, process and supply to NRW ecological and environmental data from a network of 19 lake sites across Wales, in support of NRW's integrated monitoring programme for protected sites (SACs and SSSIs), the Water Framework Directive, Nitrates Directive, Biodiversity Action Plans and other legislative and policy drivers. In particular the surveys are aimed at informing management and restoration of protected sites and facilitating delivery of River Basin Management Plans.

Using standard methods, lakes were surveyed to assess the species and abundance of aquatic plants growing within and directly around the lake and to measure water clarity, dissolved oxygen and temperature within the lakes. At two sites, Llyn y Gader and Llyn Nantlle Uchaf, bathymetric surveys were also undertaken and the results presented in standardised formats.

- The aquatic plant species are listed within the report and the complete survey results supplied to NRW as an MS Access database.
- Calculations are presented for the onward use of determining the ecological status of the lakes with respect to the Water Framework Directive (LEAFPACS).
- Bathymetric data are supplied in GIS format as well as graphically presented alongside calculated metrics.

The results of the aquatic plant surveys are suitable for the purposes of assessing site condition for Habitats Directive standing water features and SSSI status. The lake metrics are applicable for the production of ecological quality ratios from which the lakes may be classified in accordance with the requirements of Water Framework Directive (2000/60/EC).

2. Introduction

2.1. Background

Natural Resources Wales (NRW) is the organisation that has taken on the functions of the Countryside Council for Wales, Forestry Commission Wales and the devolved functions of Environment Agency Wales. These functions include the management and monitoring of the freshwater environment including protected sites designated under UK and European legislation (SSSIs and SACs) and environmental monitoring for the Water Framework (WFD) and Nitrates Directives.

Eutrophication is one of the key drivers of freshwater quality in the UK (Bennion *et al* 2014) and, in addition to chemical monitoring, a number of biological methods have been used to determine the status of freshwaters in terms of both eutrophication (e.g. Willby *et al.* 2010, Bennion *et al* 2014) and more generally for conservation (see JNCC 2015). One of these methods, LEAFPACS (Willby *et al.* 2010), has been developed to detect the impact of nutrient enrichment in lakes on the plants that grow there and is now used routinely by the UK Environment Agencies (NRW, EA, SEPA and NIEA) to monitor and evaluate the status of standing waters. Using standard methods to collect the data (JNCC 2005, 2015), the lake sites can be assessed against their type and location to derive site condition status and also to calculate metrics which allow WFD classification.

2.2. Aim of the Report

The aim of the project is to collect, process and supply to NRW ecological and limnological data from a network of 19 lake sites across Wales, in support of NRW's integrated monitoring programme for protected sites (SACs and SSSIs), the Water Framework Directive, Nitrate Directive and other legislative and policy drivers and conservation priorities (e.g. Biodiversity Action Plan species and habitats).

3. Methods

3.1. Sites

The data presented in Table 1 provides details of the 19 lakes included in this report, detailing the primary purpose for survey and CSM aquatic macrophyte survey dates. All sites were subject to aquatic macrophyte surveys using standard methods based on the original JNCC guidelines (JNCC 2005) with updates incorporated from the new guidance (JNCC 2015). During the macrophyte surveys, dissolved oxygen and temperature profiles were undertaken from the deepest point.

Table 1 Details of the lakes included in this report

Lake Name	WBID	Grid ref.	Purpose of survey*	Survey date	Lake Type**
Ysceifiog Lake	33239	SJ147716	BAP interest	07/09/2015	NE
Llyn Cwellyn	34002	SH559549	SAC / WFD-S	08/09/2015	OML-O
Llyn Cwmffynnon	33974	SH649562	SAC	09/09/2015	OML-O
Llyn Arenig Fawr	34864	SH847380	SAC / WFD-O	10/09/2015	OML-O
Llyn Hesgyn	34531	SH884442	SAC	11/09/2015	OML-O
Llyn Hiraethlyn	34928	SH743370	SAC	12/09/2015	OML-O
Llyn y Garn	34895	SH761377	SAC	13/09/2015	OML-O
Ffynnon Lloer	33736	SH662621	SAC	14/09/2015	OML-O
Llyn Hîr	38394	SN789676	SAC / WFD-S	15/09/2015	OML-O
Llyn y Gader	34147	SH568521	SSSI /SAC	16/09/2015	OML-O
Llyn Nantlle Uchaf	34099	SH514529	BAP interest	17/09/2015	OML-M
Llyn Dinam	32948	SH310775	ND / SAC / WFD-S	31/07/2015	NE
Llyn Coron	33337	SH378700	ND / SAC / WFD-S	01/08/2015	NE
Llyn Traffwll	32964	SH325769	ND / SSSI	02/08/2015	NE
Llyn Penrhyn	32968	SH313768	SAC / WDF-O	03/08/2015	NE
Llyn Glasfryn	34622	SH402421	SSSI	04/08/2015	OML-M
Llangorse Lake	40067	SO132264	ND / SAC / WFD-S	05/08/2015	NE
Kenfig Pool	42170	SS796815	SAC / WFD-S	06/08/2015	HC
Llandegfedd Res.	41363	ST328986	ND / WDF-O	07/08/2015	OML-M

* SAC = Special Area Conservation; SSSI = Site of Special Scientific Interest; WFD-S = WFD Surveillance; WFD-O = WFD Operational; ND = Nitrates Directive; BAP = Priority Biodiversity Action Plan habitat

** Habitats Directive type or equivalent: HC = Hard oligo-mesotrophic waters, NE = Naturally eutrophic, OML = Oligo-mesotrophic waters, O = Oligotrophic, M = Mesotrophic.

3.2. Aquatic Macrophyte Surveys – JNCC

The full description of the survey methods used to collect macrophyte data are detailed in the Joint Nature Conservation Committee publications for the CSM guidance for standing waters (see JNCC, 2005 and 2015). In brief, the plant surveys consisted of four components; a “strandline survey” of species uprooted and washed to the shore, a survey of the emergent and marginal species, a “wader survey” of the shallow littoral zone to approximately 1.0 m and a “boat survey” encompassing species in open water and extending to the point of maximum colonization. These

were carried out at each site on up to four discrete 100 m sections of shoreline which were considered representative of the lake and gave good geographical coverage. In order to reduce disturbance, a maximum of 25% of the shoreline was surveyed, resulting in less than four sections being selected at smaller lakes. Where possible, surveying was performed using a bathyscope, but a double-headed rake was used in deeper water or where poor water clarity restricted visibility. The locations of all survey sections and boat transects were recorded using a Global Positioning System (GPS), backed up with digital photographs where necessary.

Figure 1 Map of Wales showing the location of the lakes.



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

The CSM aquatic macrophyte surveys, upon which the data assessments in this report are based, were carried out between June and September 2015. *In-situ* macrophyte identifications were made by Ben Goldsmith (JNCC accredited) or Ewan Shilland. Sites where *Luronium natans* is present were surveyed under Protected Species Licence 59401:OTH:SP:2014 (B. Goldsmith with E. Shilland as accredited agent). Voucher specimens were collected for all taxonomically ambiguous species, unless very rare, and identifications confirmed either from fresh materials (usually in the evening of the survey) or at a later date from pressed specimens by Ben Goldsmith. Vouchers of charophytes and *Utricularia* were preserved in alcohol and sent to Nick Stewart for confirmation. Quality control was performed in-house with reference to previously collected herbaria specimens. Botanical nomenclature follows Stace (1997).

All field data were recorded onto standard forms printed onto waterproof paper and transferred onto a Microsoft Access database specifically designed to hold CSM records (Mike Hughes, UCL). Macrophyte data from each site were then transcribed into standard MS Excel spreadsheets designed to calculate values for the following metrics (see Willby *et al.* 2010 and WFD-UKTAG 2009):

- Lake Macrophyte Nutrient Index (LMNI)
- Number of typical taxa for habitat type (NTYP) based on JNCC CSM guidance (2015)
- Number of Functional Groups (NFG)
- Number of Macrophyte Taxa (NTAXA)
- Mean % cover of hydrophytes (COV)
- Relative per cent cover of filamentous algae (ALG)
- Maximum depth of macrophyte colonisation (MAXD)

An additional calculation was made for the relative % cover of non-native species (NNS) recorded; expressed relative to the overall COV score. In the case of Llangorse Lake, *Nymphoides peltata* is scored as being non-native (locally absent) with its native range in the UK generally considered to be restricted to central and eastern England (Preston & Croft 1997).

3.3. Physico-Chemical Survey and Other Data Sources

Dissolved oxygen concentration and temperature profiles were taken at the deepest recorded point of each site on the same dates as the macrophyte surveys, using a YSI 550 meter. These data were used to assess oxygen availability within the water. Secchi disc depths were recorded at the time of the macrophyte surveys from the deepest point of all lakes and further measurements taken at each survey section at

sites where variability in water clarity was observed. A standard 20 cm diameter Secchi plate was used and the Secchi depth (Z_s) expressed in metres. These data are integral with the MS Access database (see Appendix **Error! Reference source not found.**).

Catchment data, land cover and general lake data that are quoted in the text are taken from the original UK Lakes database (Hughes *et al.* 2004) and the pre-release Beta version of the new UK Lakes administered by CEH (CEH 2016). Ordnance Survey maps are taken from OS OpenData™ (© Crown copyright 2016) and Aerial photographs from Google Maps (© Google 2016).

3.4. Bathymetric Survey

At two sites, Llyn Nantlle Uchaf and Llyn y Gader, bathymetric surveys were required. These were conducted on the same dates as the plant surveys using a boat-mounted, combined GPS receiver and echo sounder (Lowrance LMS240). Many thousands of geo-referenced depths are recorded from the lake by rowing or motoring along evenly spaced transects across the entire lake surface. These data are stored electronically and can be used in various GIS packages to calculate lake volume and to produce high resolution contour maps (bathymetric maps) of the lakes. Protocols for the standardisation of bathymetric data collection, interpretation and output were developed by Turner *et al.* (2011) in line with NRW requirements.

4. Survey Results and Metrics.

4.1. Lake metrics

The following table summarises the results of the aquatic macrophyte-derived metrics and limnological data. A full list of species for each site is given in Appendix 6.1.

Table 2 Summary of the LEAFPACS lake metrics, typical taxa, non-native species and maximum depth of macrophyte colonisation for the 19 lakes

Site	LMNI	NTAXA	NFG	COV	ALG	NNS	MAXD	NTYP	Secchi
Ysceifiog Lake	6.85	14	8	7.56	0.27	0.01	3.0	2	3.00
Llyn Cwellyn	3.40	14	8	7.11	0.28	0.00	35.6	6	5.10
Llyn Cwmffynnon	3.46	13	8	6.55	0.32	0.00	10.1	5	4.65
Llyn Arenig Fawr	3.67	6	2	5.67	0.69	0.00	35.5	2	7.60
Llyn Hesgyn	3.93	11	8	5.11	0.13	0.00	5.0	1	0.85
Llyn Hiraethlyn	2.91	12	6	7.28	0.30	0.00	8.9	6	3.10
Llyn y Garn	3.73	12	7	2.95	0.39	0.00	17.7	4	6.20
Ffynnon Lloer	3.87	8	5	13.94	0.55	0.00	6.6	2	>6.60
Llyn Hîr	3.29	17	8	6.79	0.50	0.00	7.9	7	2.90
Llyn y Gader	4.00	28	14	4.69	0.16	0.00	2.3	9	>2.30
Llyn Nantlle Uchaf	4.75	19	10	5.66	0.20	0.07	8.2	7	5.12
Llyn Dinam	6.62	30	15	2.02	0.00	0.05	1.9	7	0.75
Llyn Coron	6.97	22	11	2.89	0.33	0.07	3.8	7	1.10
Llyn Traffwll	7.22	19	11	4.63	0.57	0.03	4.1	5	2.10
Llyn Penrhyn	7.19	21	11	3.39	0.53	0.03	2.7	4	1.25
Llyn Glasfryn	5.85	15	10	8.69	0.33	0.00	1.0	3	0.70
Llangorse Lake	6.80	26	11	3.44	0.21	0.27*	7.3	5	1.20
Kenfig Pool	5.69	22	11	3.82	0.00	0.17	2.4	2	2.00
Llandegfedd Res.	7.88	3	2	2.79	0.68	0.00	30.3	0	1.95

* This value is 0.24 if not including *Nymphoides peltata* as non-native.

It should be noted that Llandegfedd Reservoir was drawn down by approximately 3.8 m at the time of survey and had almost no aquatic vegetation recorded.

4.2. Site Overviews

4.2.1. Ysceifiog Lake

Figure 2 Site map and aerial photograph of Ysceifiog Lake



Figure 3 Ysceifiog Lake site photo; from west shore looking east



Ysceifiog Lake is a small (6 ha), very shallow (max. depth 3.0 m) lowland lake located on alkaline geology in Flintshire, North Wales. The site is surrounded by mixed woodland. The aquatic macrophytes flora was dominated by a mixed mosaic of species that are most typical of eutrophic waters (Table 3).

Table 3 CSM Survey results from Ysceifiog Lake 2015

Submerged and floating vegetation	% occurrence (n=77)
<i>Chara globularis</i>	3.3
<i>Callitriche brutia</i>	25.0
<i>Ceratophyllum demersum</i>	25.0
<i>Elodea canadensis</i>	10.0
<i>Enteromorpha sp.</i>	20.0
<i>Fontinalis antipyretica</i>	83.3
<i>Hippuris vulgaris</i>	31.7
<i>Hottonia palustris</i>	48.3
<i>Lemna minor</i>	21.7
<i>Lemna trisulca</i>	46.7
<i>Mosses aquatic</i>	10.0
<i>Potamogeton pusillus</i>	6.7
<i>Zannichellia palustris</i>	5.0
Species richness	13

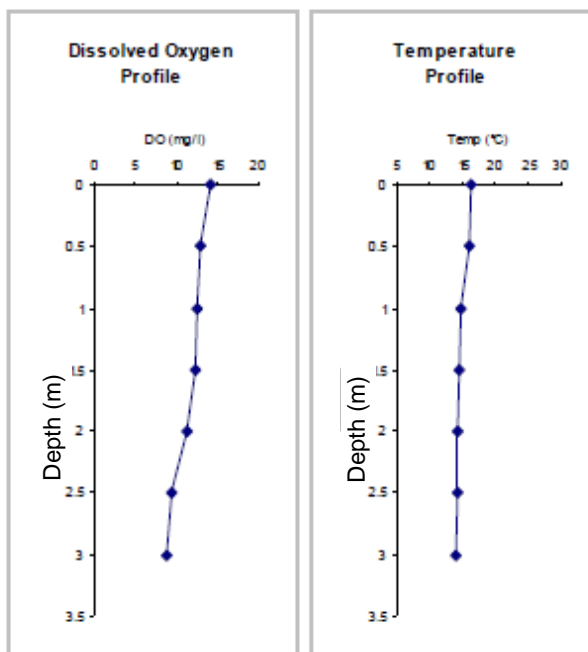
Of particular interest at Ysceifiog Lake is the extensive cover of Water violet *Hottonia palustris*; a species more commonly found in very small ponds and ditches (Preston & Croft 1997). This species probably benefits from the shelter afforded by the surrounding woodland. Although maintaining a relatively species rich flora, the site lacks any broad-leaf *Potamogeton* species and the high abundance of *Fontinalis antipyretica* and *Ceratophyllum demersum* and presence of *Enteromorpha* sp. suggests the site to suffer from eutrophication. At the time of survey, the water was well oxygenated throughout the water column (Figure 4).

Figure 4 Dissolved oxygen and temperature profiles at Ysceifiog Lake (07/09/2015)

Dissolved Oxygen Profile

GPS Location SJ14548 71594
 Maximum Depth (m) 3 m
 Secchi Depth (cm) 3 cm
 Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	14.26	16.3
0.5	13.02	16
1	12.58	14.8
1.5	12.29	14.6
2	11.36	14.4
2.5	9.4	14.2
3	8.89	14.1



4.2.2. Llyn Cwellyn 34002

Figure 5 Site map and aerial photograph of Llyn Cwellyn



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Llyn Cwellyn is a deep (36 m) oligotrophic lake of glacial origin situated at an altitude of 142 m in the Nant y Betws valley in Gwynedd. The site forms part of the Afon

Gwyrfai a Llyn Cwellyn SAC and lies within the Snowdonia National Park. Llyn Cwellyn is a WFD surveillance site. The current lake level is maintained by a low concrete weir on the outflow and water from the site is used as a raw drinking water supply. The slopes above the southern shore are predominantly managed as commercial coniferous forest plantation, much of which has been clear-felled in recent years. Vegetation types adjacent to the lake include rough grassland, some improved pasture and a wetland area. A public road runs adjacent to much of the northern shore.

Figure 6 Llyn Cwellyn site photo; looking east towards Snowdon



The aquatic macrophyte flora is typical of low alkalinity, clear water lakes with extensive populations of *Littorella uniflora*, *Lobelia dortmanna* and *Isoetes lacustris* forming overlapping zones to a depths of up to 5.3 m (Table 4). In addition of particular interest to the SAC feature is the population of Floating water plantain *Luronium natans*. This species is not particularly well represented within the CSM sections, but we know from a recent snorkel survey of the site conducted by ENSIS (Goldsmith *et al.* 2014a) that it occurs in at least three separate populations within the site (Figure 7). The current species assemblage would place the site in favourable condition with respect to its flora under JNCC CSM Guidelines (JNCC 2015)

Dissolved oxygen and temperature profiles show the lake to be stratified during summer with a thermocline at approximately 12.5 m, below which temperatures fall to 8.4 °C. Dissolved oxygen concentrations remain relatively stable throughout the profile (Figure 8).

Table 4 CSM Survey results from Llyn Cwellyn 2015

Submerged and floating vegetation	% occurrence (n=133)
<i>Callitriche hamulata</i>	7.5
<i>Elatine hexandra</i>	2.3
<i>Fontinalis antipyretica</i>	5.3
<i>Isoetes lacustris</i>	60.2
<i>Juncus bulbosus</i>	34.6
<i>Littorella uniflora</i>	36.8
<i>Liverworts unid.</i>	2.3
<i>Lobelia dortmanna</i>	65.4
<i>Luronium natans</i>	2.3
<i>Myriophyllum alterniflorum</i>	20.3
<i>Nitella flexilis</i> agg.	12.8
<i>Potamogeton polygonifolius</i>	0.8
<i>Sphagnum</i> sp.	10.5
<i>Subularia aquatica</i>	3.8
Species richness	14

Figure 7 Distribution of *Luronium natans* in Llyn Cwellyn (From: Goldsmith *et al.* 2014a)

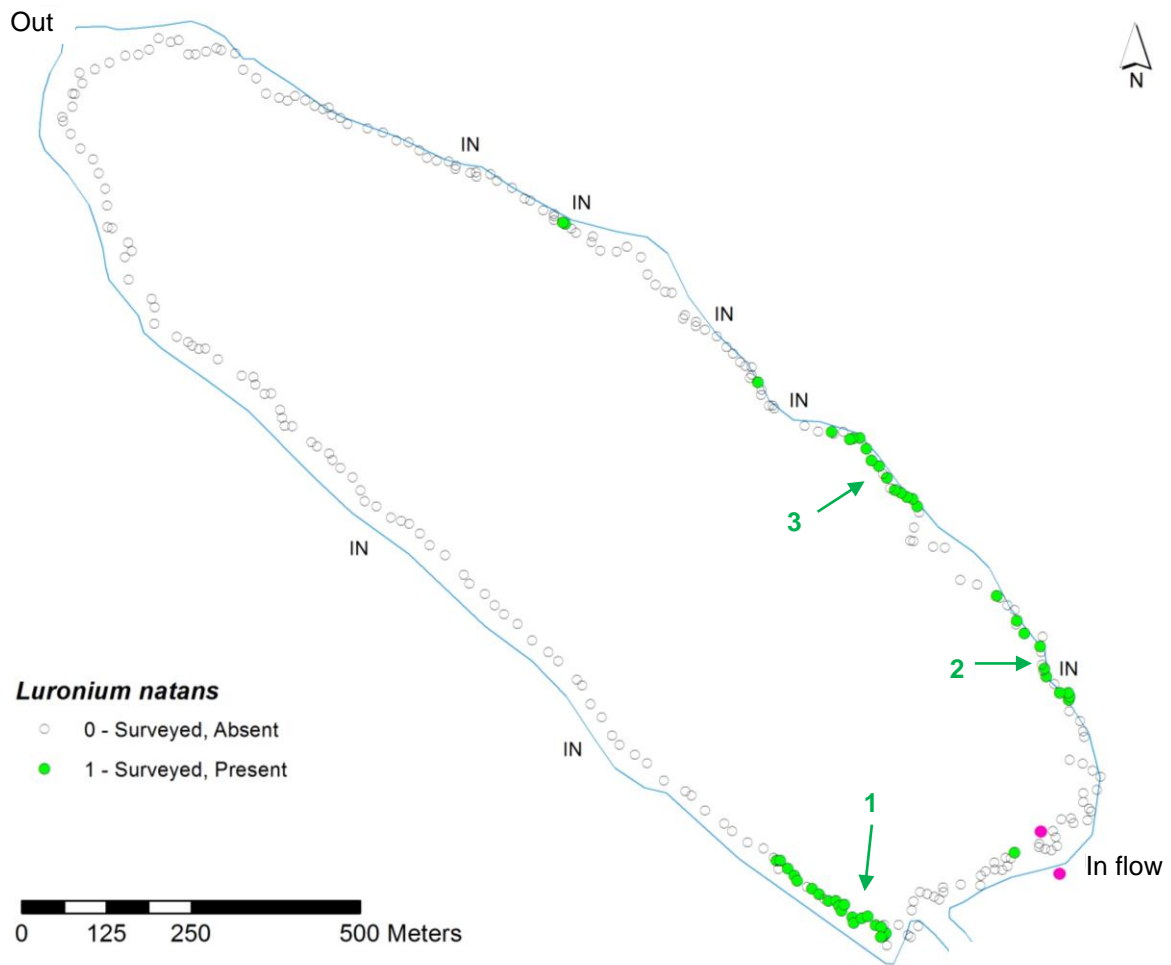
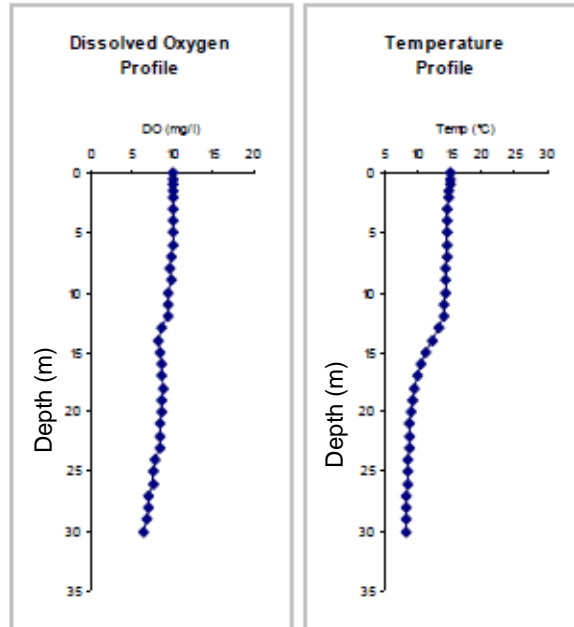


Figure 8 Dissolved oxygen and temperature profiles at Llyn Cwellyn (08/09/2015)

Dissolved Oxygen Profile

GPS Location SH5554455222
 Maximum Depth (m) 35.6 m
 Secchi Depth (cm) 510 cm
 Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	10.14	15.1
0.5	10.16	15.1
1	10.07	15
1.5	10.11	14.9
2	10.07	14.8
3	10.1	14.7
4	10.05	14.7
5	10.04	14.7
6	10	14.6
7	9.9	14.5
8	9.77	14.4
9	9.81	14.3
10	9.53	14.3
11	9.54	14.1
12	9.5	14.1
13	8.83	13.3
14	8.35	12.2
15	8.45	11.2
16	8.83	10.6
17	8.75	10
18	8.85	9.5
19	8.75	9.2
20	8.78	9.1
21	8.49	8.9
22	8.49	8.8
23	8.41	8.7
24	7.91	8.6
25	7.72	8.5
26	7.7	8.5
27	7.17	8.4
28	7.1	8.4
29	6.91	8.4
30	6.48	8.4



4.2.3. Llyn Cwmffynnon 33974

Figure 9 Site map and aerial photograph of Llyn Cwmffynnon



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Llyn Cwmffynnon is a relatively shallow (max. recorded depth 10.1 m) oligotrophic lake situated at an altitude of 358 m below the Glyder mountains in Gwynedd. The site forms part of the Eryri / Snowdonia SAC and is within the Snowdonia National Park. Llyn Cwmffynnon has a relatively small catchment area (c. 80 ha) dominated by acid heath and acid grassland. Palaeoecological evidence from the site suggests it to have acidified (Goldsmith *et al.* 2006), which is typical for poorly buffered sites in this region.

Figure 10 Llyn Cwmffynnon site photo; looking west towards Snowdon



The aquatic macrophyte flora is typical of a low alkalinity, oligotrophic lake with minor humic influence (Table 5). *Littorella uniflora*, *Lobelia dortmanna* and *Isoetes lacustris* are abundant throughout much of the littoral zone, with *I. lacustris* reaching a maximum depth of 3.5 m and *Nitella flexilis* agg. extending slightly deeper to 3.9 m. The maximum depth of colonisation appears limited by the slightly brown water draining from the overlying peat in the catchment. Other characteristic oligotrophic species present were *Utricularia vulgaris* agg. and *Elatine hexandra*, the latter possibly being a new record for the site. The current survey did not record *Sparganium angustifolium*, which has in the past been present, albeit relatively rare in the site. The current species assemblage would place the site in favourable condition with respect to its flora under JNCC CSM guidelines (JNCC 2015), but the possible loss of a characteristic species (*S. angustifolium*) requires further investigation and evidence from previous palaeoecological work suggests the lake to be impacted by acidification.

Table 5 CSM Survey results from Llyn Cwmffynnon 2015

Submerged and floating vegetation	% occurrence (n=123)
<i>Batrachospermum</i> sp.	5.7
<i>Elatine hexandra</i>	0.8
<i>Isoetes lacustris</i>	53.7
<i>Juncus bulbosus</i>	23.6
<i>Littorella uniflora</i>	45.5
<i>Liverworts unid</i>	13.8
<i>Lobelia dortmanna</i>	76.4
<i>Myriophyllum alterniflorum</i>	7.3
<i>Nitella flexilis</i> agg.	13.8
<i>Potamogeton polygonifolius</i>	2.4
<i>Sphagnum</i> sp.	7.3
<i>Utricularia vulgaris</i> agg.	3.3
Species richness	12

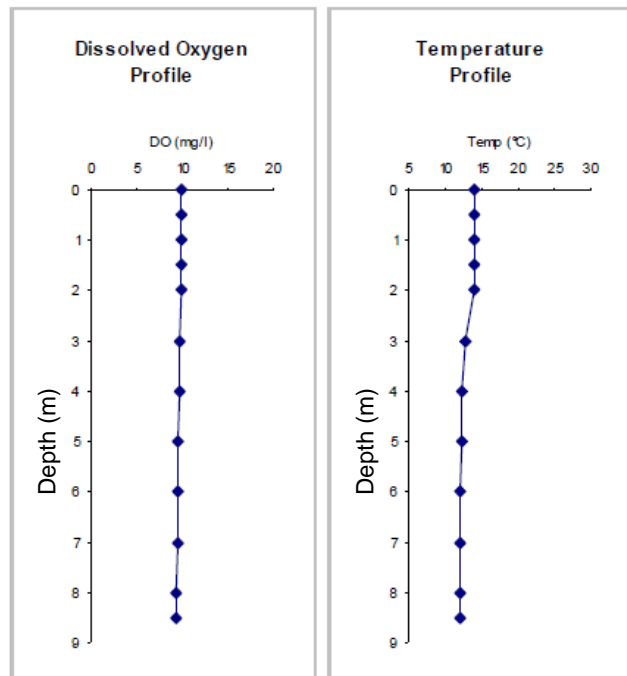
Dissolved oxygen and temperature profiles showed the lake to be mixed during summer. Given that the majority of the lake is relatively shallow (< 5 m), with only a small area of deeper water, this situation is typical for a wind-stress upland lake (Figure 11).

Figure 11 Dissolved oxygen and temperature profiles at Llyn Cwmffynnon (09/09/2015)

Dissolved Oxygen Profile

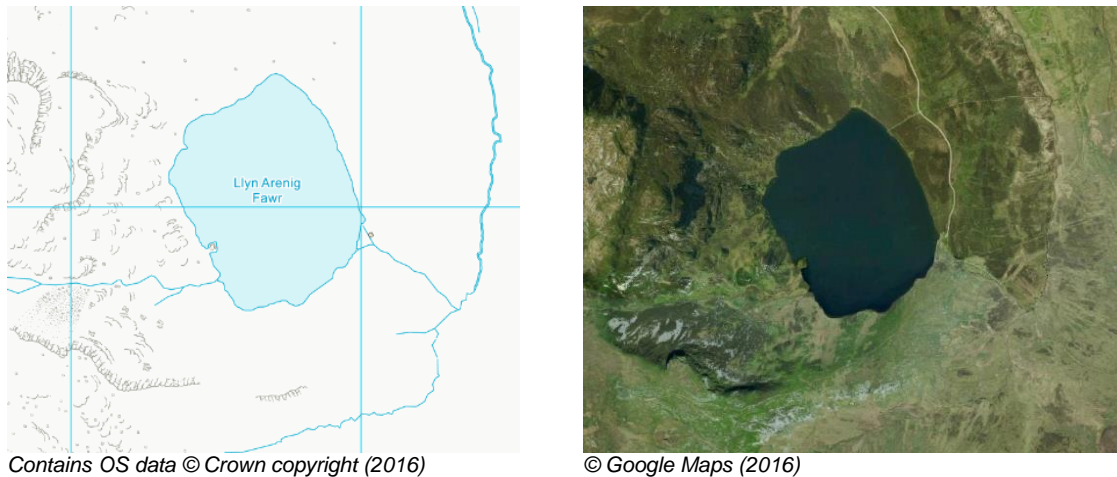
GPS Location SH6489756223
 Maximum Depth (m) 9.1 m
 Secchi Depth (cm) 465 cm
 Notes: 10.1 at SH6490156225

Depth (m)	DO (mg/l)	Temp (°C)
0	9.87	13.9
0.5	9.85	13.9
1	9.81	13.9
1.5	9.85	13.9
2	9.82	13.9
3	9.75	12.8
4	9.79	12.3
5	9.54	12.2
6	9.49	12.1
7	9.48	12.1
8	9.31	12
8.5	9.25	12



4.2.4. Llyn Arenig Fawr 34864

Figure 12 Site map and aerial photograph of Llyn Arenig Fawr



Llyn Arenig Fawr is a deep (max. recorded depth 35.5 m) oligotrophic lake situated at an altitude of 405 m and lying below the peak of Arenig Fawr to the west of Bala in Gwynedd. The lake level was raised in the nineteenth century and altered again in the twentieth century to provide potable water to Bala. Llyn Arenig Fawr forms part of the Migneint–Arenig–Dduallt SAC and is a WDF Operational site. The relatively small catchment (c. 154 ha) is dominated by acid heath and upland acid grassland. The low alkalinity ($10 \mu\text{Eq l}^{-1}$, CEH 2016) indicates that the lake is poorly buffered and likely to have been susceptible to acidification.

Figure 13 Llyn Arenig Fawr site photo; looking northwest towards Arenig Fawr peak



Table 6 CSM Survey results from Llyn Arenig Fawr 2015

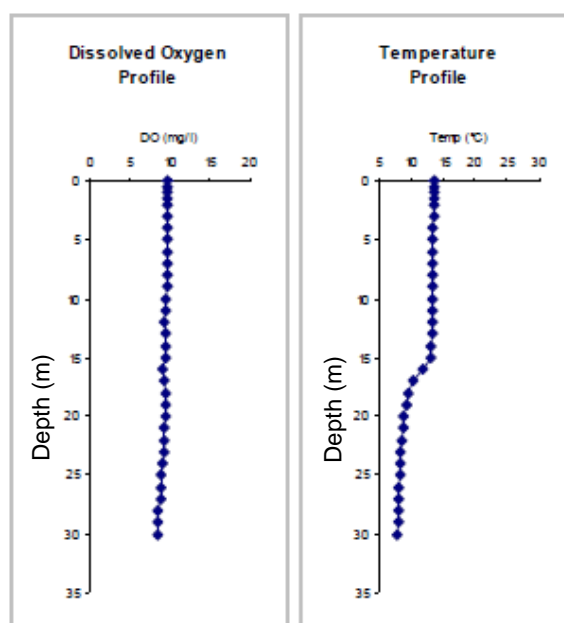
Submerged and floating vegetation	% occurrence (n=74)
<i>Fontinalis antipyretica</i>	1.4
<i>Isoetes lacustris</i>	60.8
<i>Juncus bulbosus</i>	2.7
<i>Littorella uniflora</i>	8.1
<i>Liverworts aquatic</i>	41.9
<i>Mosses aquatic</i>	1.4
<i>Sphagnum</i> sp.	5.4
Species richness	7

Figure 14 Dissolved oxygen and temperature profiles at Llyn Arenig Fawr (10/09/2015)

Dissolved Oxygen Profile

GPS Location SH8475737978
 Maximum Depth (m) 35.5 m
 Secchi Depth (cm) 7.6 cm
 Notes: Windy, overcast and bright.

Depth (m)	DO (mg/l)	Temp (°C)
0	9.79	13.5
0.5	9.77	13.5
1	9.78	13.5
1.5	9.74	13.5
2	9.73	13.5
3	9.76	13.5
4	9.74	13.4
5	9.67	13.4
6	9.7	13.4
7	9.71	13.4
8	9.72	13.4
9	9.6	13.3
10	9.5	13.3
11	9.47	13.3
12	9.36	13.3
13	9.47	13.3
14	9.49	13.2
15	9.46	13.2
16	9.15	11.9
17	9.36	10.3
18	9.46	9.5
19	9.47	9.2
20	9.45	8.9
21	9.37	8.8
22	9.3	8.6
23	9.22	8.4
24	9.05	8.2
25	8.92	8.2
26	8.88	8.1
27	8.84	8.1
28	8.57	8
29	8.49	8
30	8.39	7.9



The aquatic macrophyte flora is typical of a low alkalinity, oligotrophic lake in that it is relatively species poor and dominated by *Isoetes lacustris* (Table 6). The majority of the littoral zone shelves off steeply however and comprises large boulders and

course substrates with very little available suitable habitat for *Littorella uniflora*, which is scarce in the site and no *Lobelia dortmanna* was recorded, The boulders have an abundance of liverwort cover however and a relatively high abundance of filamentous algae was recorded at the site.

The current aquatic flora places the site outside the typical assemblage required for favourable condition under JNCC CSM guidelines (JNCC 2015), but further evidence is required to confirm whether there has been any deterioration at the site since designation, or if its species-poor flora simply reflects the exposed location and lack of suitable littoral habitat for plants.

Dissolved oxygen and temperature profiles show the lake to be stratified during summer with a thermocline at approximately 15 m, below which temperatures fall to 8 °C. Dissolved oxygen concentrations remain relatively stable throughout the profile (Figure 14).

4.2.5. Llyn Hesgyn 34531

Figure 15 Site map and aerial photograph of Llyn Hesgyn



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Llyn Hesgyn is a shallow (max. recorded depth 5.2 m) oligotrophic lake situated at an altitude of 425 m to the east of Carnedd y Filias (669 m) in Gwynedd. The lake forms part of the Migneint-Arenig-Dduallt SAC and is within the Snowdonia National Park. Llyn Hesgyn drains an area to the north (c. 170 ha) dominated by acid heath and grassland. Palaeoecological evidence from the site suggests it to have remained relatively stable in terms of acidification (Goldsmith *et al.* 2006), and water chemistry from the site suggests it to have adequate buffering (Carvalho *et al.* 2003, Goldsmith *et al.* 2006). Although the lake is classified as being Oligotrophic within the HD typology, it shows strong influences from the peat in the catchment and has very brown water and relatively high DOC (Goldsmith *et al.* 2006). The Secchi depth in September 2015 was only 85 cm due to the brown colour of the water. This contrasts with 1.7 m in August 2002 (Carvalho *et al.* 2003) and 1.0 m in 2004 (Goldsmith *et al.* 2006).

Figure 16 Llyn Hesgyn site photo; looking southwest



Table 7 CSM Survey results from Llyn Hesgyn 2015

Submerged and floating vegetation	% occurrence (n=46)
<i>Batrachospermum</i> sp.	4.3
<i>Callitriche hamulata</i>	32.6
<i>Fontinalis antipyretica</i>	6.5
<i>Littorella uniflora</i>	32.6
<i>Liverworts aquatic</i>	4.3
<i>Myriophyllum alterniflorum</i>	26.1
<i>Nuphar lutea</i>	30.4
<i>Sparganium angustifolium</i>	+
<i>Sphagnum</i> sp.	23.9
Species richness	9

The aquatic macrophyte flora is relatively poor, but typical of a low alkalinity, oligotrophic lake with humic influence (Table 7). *Littorella uniflora* is common around the east shore where suitable firm substrates occur, but it rarely grows beyond 80 cm depth. *Myriophyllum alterniflorum* and *Callitriche hamulata* were frequent and the site supports sparse beds of *Nuphar lutea*. *Isoetes lacustris* was recorded as being frequent in 2002 by Carvalho *et al.* (2003), but was only recorded as rare in 2004

(Goldsmith *et al.* 2006) and was not recorded in subsequent surveys by the author in 2009 or this survey in 2015. Similarly, *Sparganium angustifolium* was frequent in 2002 and 2004, but appears to have declined within the fixed survey transects with it rare in 2009 and recorded only in the strandline in 2015. *Nitella flexilis* agg. was recorded in previous surveys, but not seen in 2015.

The maximum depth of colonisation also appears to have declined with respect to *C. hamulata* and *M. alterniflorum*, which were common to 1.5 m in 2002, but were restricted to less than 1.0 m in the 2015 survey.

The decline and possible loss of “typical” characteristic species and decreasing maximum depth of colonisation places the site in unfavourable condition with respect to its flora under JNCC CSM guidance (2015). It is recommended that a more extensive survey of the vegetation is conducted and further monitoring undertaken to support the current evidence and determine the reason for the observed decline.

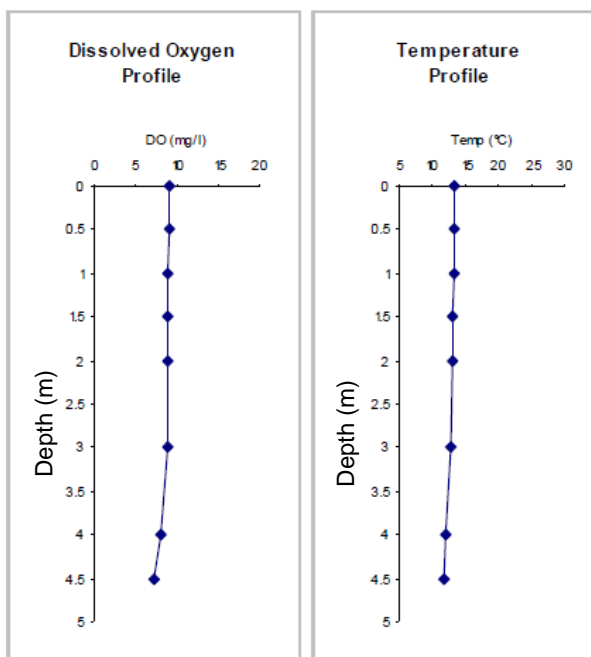
Dissolved oxygen and temperature profiles showed the lake to be mixed during summer with no thermocline evident and only a slight decline in dissolved oxygen with increasing depth (Figure 17).

Figure 17 Dissolved oxygen and temperature profiles at Llyn Hesygn (11/09/2015)

Dissolved Oxygen Profile

GPS Location SH8852844269
 Maximum Depth (m) 5 m
 Secchi Depth (cm) 85 cm
 Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	8.99	13.3
0.5	8.98	13.2
1	8.93	13.2
1.5	8.92	13.1
2	8.84	13.1
3	8.8	12.8
4	8.05	12
4.5	7.16	11.6



4.2.6. Llyn Hiraethlyn 34928

Llyn Hiraethlyn is a relatively shallow (max. recorded depth 8.9 m) oligotrophic lake situated to the east of Twsfynedd, Gwynedd at an altitude of 309 m. The site forms part of the Migneint-Arenig-Dduallt SAC and is within the Snowdonia National Park. The lake has a relatively small catchment area (c. 47 ha) dominated by acid grassland and areas of acid heathland. Palaeoecological evidence from the site suggests it to have become only slightly acidified (Goldsmith *et al.* 2006) and water quality data from the same study show the site to have a mean annual ANC of 25

μEq^{-1} , which falls below the target limit of $40 \mu\text{Eq}^{-1}$ set out in the new JNCC guidance (JNCC 2015), the previous limit being only $20 \mu\text{Eq}^{-1}$ (JNCC 2005). A previous mean annual calculation for ANC was $65 \mu\text{Eq}^{-1}$ (Carvalho *et al.* 2003) and therefore further monitoring is recommended.

Figure 18 Site map and aerial photograph of Llyn Hiraethlyn

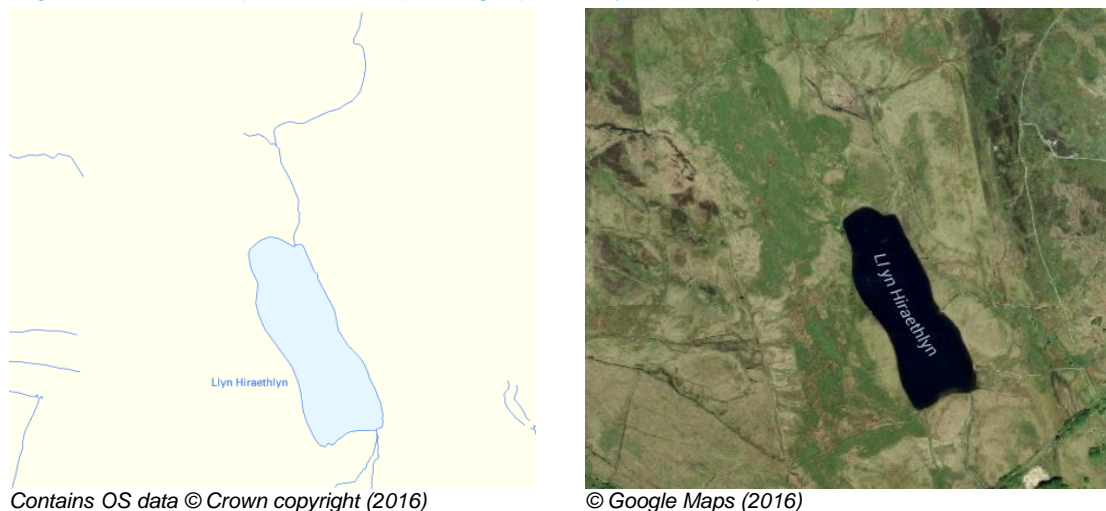


Figure 19 Llyn Hiraethlyn site photo; from the southeast shore looking northwest



Llyn Hiraethlyn has a typical aquatic macrophyte flora for a low alkalinity, oligotrophic lake (Table 8). *Isoetes lacustris*, *Littorella uniflora* and *Lobelia dortmanna* and present at increasing abundance and the site supports a small but apparently stable population of *Luronium natans*. Of possible concern is an areas where *Juncus*

bulbosus occurs at high abundance (mainly restricted to the north end) which can be indicative on increased nutrients. Past surveys (e.g. Carvalho *et al.* 2003) have recorded *Isoetes echinospora* at the site, but all fertile material examined in 2015 was confirmed as *I. lacustris*.

The current species assemblage would place the site in favourable condition with respect to its flora under JNCC CSM Guidelines (JNCC 2015), but additional monitoring is recommended to assess water quality criteria with particular attention to nutrient inputs and ANC.

Table 8 CSM Survey results from Llyn Hiraethlyn 2015

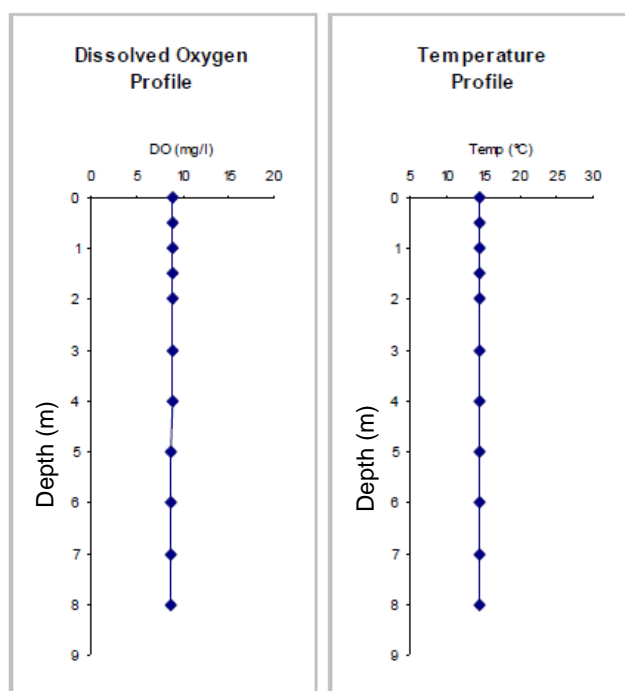
Submerged and floating vegetation	% occurrence (n=80)
<i>Batrachospermum</i> sp.	3.8
<i>Isoetes lacustris</i>	15.0
<i>Juncus bulbosus</i>	36.3
<i>Littorella uniflora</i>	45.0
<i>Lobelia dortmanna</i>	86.3
<i>Luronium natans</i>	3.8
<i>Myriophyllum alterniflorum</i>	15.0
<i>Potamogeton polygonifolius</i>	3.8
<i>Sparganium angustifolium</i>	1.3
<i>Sphagnum</i> sp.	3.8
<i>Utricularia minor</i>	1.3
Species richness	11

Figure 20 Dissolved oxygen and temperature profiles at Llyn Hiraethlyn (12/09/2015)

Dissolved Oxygen Profile

GPS Location SH7434337015
 Maximum Depth (m) 8.9 m
 Secchi Depth (cm) 310 cm
 Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	8.94	14.5
0.5	8.94	14.5
1	8.86	14.5
1.5	8.89	14.5
2	8.91	14.5
3	8.85	14.5
4	8.85	14.5
5	8.81	14.5
6	8.78	14.5
7	8.82	14.5
8	8.72	14.5



Dissolved oxygen and temperature profiles showed the lake to be mixed during the survey period with stable temperature and DO values throughout the water column (Figure 20).

4.2.7. Llyn y Garn 34895

Figure 21 Site map and aerial photograph of Llyn y Garn

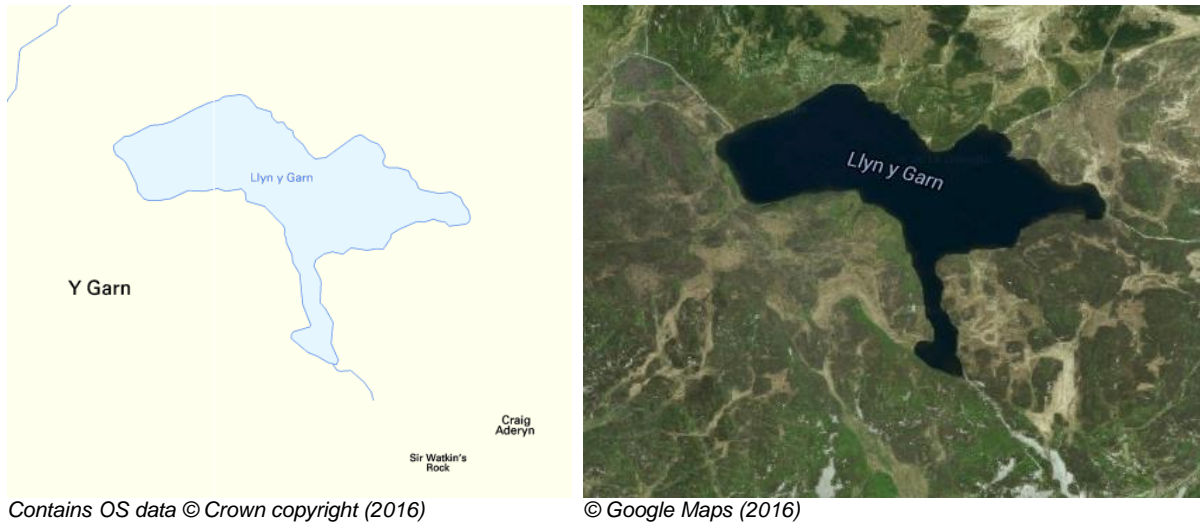


Figure 22 Llyn y Garn site photo; taken from the west shore looking east



Llyn y Garn is an oligotrophic lake of moderate depth (max. recorded depth 18.5 m) situated to the east of Twsfynedd, Gwynedd at an altitude of 448 m. The site forms

part of the Migneint-Arenig-Dduallt SAC and is within the Snowdonia National Park. The lake has a relatively small catchment area (c. 23 ha) dominated by acid upland heath. Palaeoecological evidence from the site suggests it has not suffered any major impacts from acidification despite a relatively low ANC (Goldsmith *et al.* 2006). Mean ANC recorded in 2005 was 26 $\mu\text{Eq l}^{-1}$, which falls below the target limit of 40 $\mu\text{Eq l}^{-1}$ set out in the new JNCC guidance (JNCC 2015). Further monitoring is therefore recommended.

Table 9 CSM Survey results from Llyn y Garn 2015

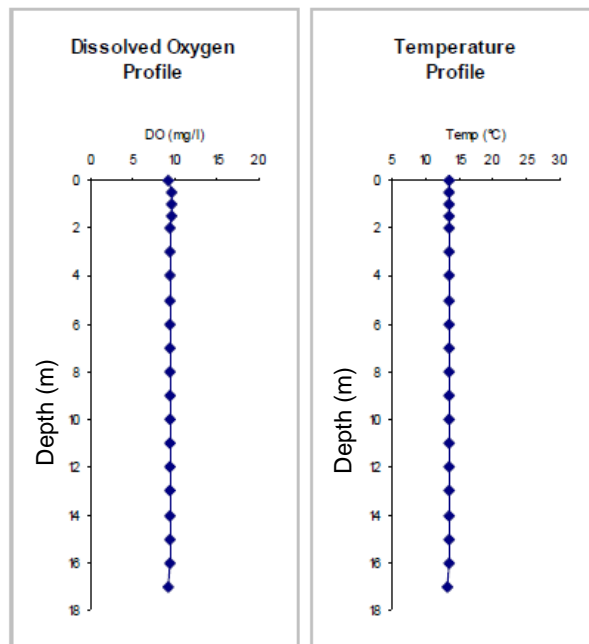
Submerged and floating vegetation	% occurrence (n=41)
<i>Isoetes lacustris</i>	31.7
<i>Juncus bulbosus</i>	9.8
<i>Littorella uniflora</i>	75.6
<i>Lobelia dortmanna</i>	63.4
<i>Luronium natans</i>	17.1
<i>Myriophyllum alterniflorum</i>	36.6
<i>Nitella flexilis</i> agg.	4.9
<i>Nymphaea alba</i>	4.9
Species richness	8

Figure 23 Dissolved oxygen and temperature profiles at Llyn y Garn (13/09/2015)

Dissolved Oxygen Profile

GPS Location SH7620537788
 Maximum Depth (m) 17.7 m
 Secchi Depth (cm) 620 cm
 Notes: 18.5 m max recorded depth

Depth (m)	DO (mg/l)	Temp (°C)
0	9.2	13.6
0.5	9.53	13.6
1	9.5	13.6
1.5	9.5	13.6
2	9.44	13.6
3	9.46	13.5
4	9.44	13.5
5	9.44	13.4
6	9.41	13.4
7	9.41	13.4
8	9.39	13.4
9	9.33	13.4
10	9.33	13.4
11	9.34	13.4
12	9.35	13.4
13	9.34	13.4
14	9.33	13.4
15	9.3	13.4
16	9.32	13.4
17	9.25	13.3



As a result of the site being wind-stressed and having steeply shelving littoral zones around much of the shore, the aquatic flora of Llyn y Garn is relatively sparse (only 34% of the 120 survey points had any aquatic plants). Where available habitat does occur however a number of typical aquatic macrophyte species were recorded (Table 9). *Isoetes lacustris*, *Lobelia dortmanna* and *Littorella uniflora* are present at

increasing abundance and the site supports a stable population of *Luronium natans* in the more sheltered southern arm (section 4). Despite very clear water (Secchi depth = 6.20 m) and what appeared to be suitable substrates in some areas of deeper water, the maximum depth of colonisation was only 2.5 m.

Where plants do grow, the assemblage is favourable with respect to species composition and coverage under JNCC CSM Guidelines (JNCC 2015).

Dissolved oxygen and temperature profiles showed the lake to be mixed during the survey period with stable temperature and DO values throughout the water column (Figure 23).

4.2.8. Ffynnon Lloer 33736

Figure 24 Site map and aerial photograph of Ffynnon Lloer

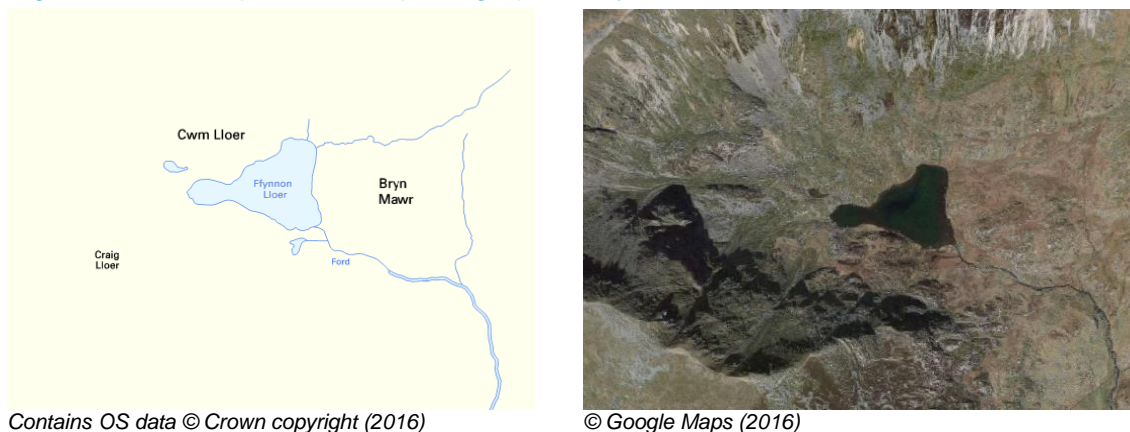


Figure 25 Ffynnon Lloer site photo; from the southeast shore looking northwest



Ffynnon Lloer is a small, shallow (max. recorded depth 6.6 m) oligotrophic lake situated within a corrie depression to the south of to the peak of Carnedd Dafydd (1044 m) in Conwy. The lake lies at an altitude of 650 m making it one of the highest lakes of this size in Wales. Ffynnon Lloer forms part of the Eryri / Snowdonia SAC and is within the Snowdonia National Park. The lake has a catchment area of approximately 100 ha dominated by acid upland heath and bare rock and scree. To the best of our knowledge there have been no previous aquatic surveys at the site.

As a result of the site being wind-stressed and lying within a rocky basin, much of the site is dominated by boulders and hard substrates which are unsuitable for plant

growth. The current flora of Ffynnon Lloer is therefore rather sparse with only 38% of the 80 survey points having any macrophytes recorded. Where available habitat does occur a number of typical aquatic macrophyte species were recorded (Table 10) with just over 60% of vegetated sample points having either *Isoetes lacustris* or *Littorella uniflora*. *Nitella flexilis* agg. was also frequent in the site growing to a depth of 4.2 m. The water was exceptionally clear with the Secchi disc still clearly visible at the deepest point of the lake (6.6 m).

Table 10 CSM Survey results from Ffynnon Lloer 2015

Submerged and floating vegetation	% occurrence (n=30)
<i>Callitriche hamulata</i>	6.7
<i>Isoetes lacustris</i>	46.7
<i>Littorella uniflora</i>	20.0
<i>Nitella flexilis</i> agg.	40.0
<i>Potamogeton polygonifolius</i>	3.3
Species richness	5

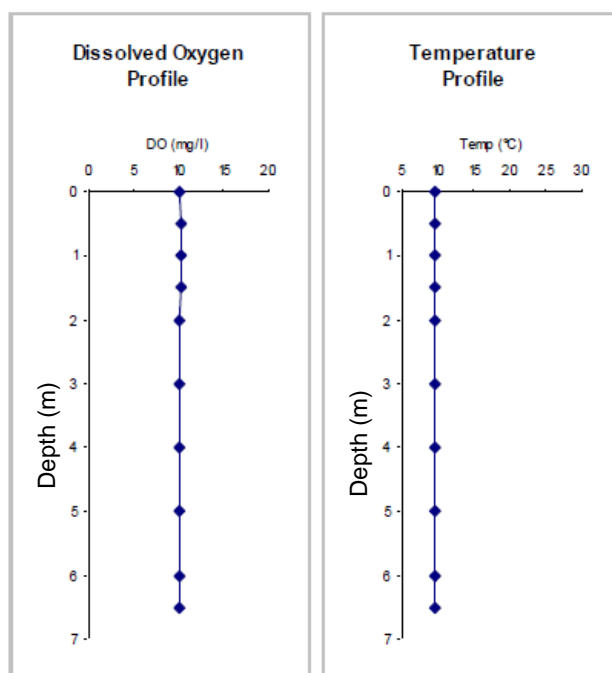
Although not meeting the full CSM target for macrophytes, the lack of species is most likely due to the elevation of the site and therefore it would most likely be favourable in terms of species composition and coverage under JNCC CSM Guidelines (JNCC 2015). Filamentous algal cover was however well above the acceptable target for favourable condition with 38% of sample points scoring a “3” (3 = >75% cover). The reason for the high abundance of filamentous algae was unclear, but potentially it may reflect deposition and availability of atmospheric nitrogen within this high rainfall area. Further monitoring is therefore recommended.

Figure 26 Dissolved oxygen and temperature profiles at Ffynnon Lloer (14/09/2015)

Dissolved Oxygen Profile

GPS Location SH6622862113
 Maximum Depth (m) 6.6 m
 Secchi Depth (cm) -
 Notes: Secchi > 6.6 m - very clear

Depth (m)	DO (mg/l)	Temp (°C)
0	10.13	9.7
0.5	10.21	9.7
1	10.22	9.7
1.5	10.22	9.7
2	10.17	9.7
3	10.17	9.7
4	10.03	9.7
5	10.17	9.7
6	10.17	9.7
6.5	10.18	9.6



Dissolved oxygen and temperature profiles showed the lake to be mixed during the survey period with stable temperature and DO values throughout the water column (Figure 26).

4.2.9. Llyn Hîr 34928

Figure 27 Site map and aerial photograph of Llyn Hîr

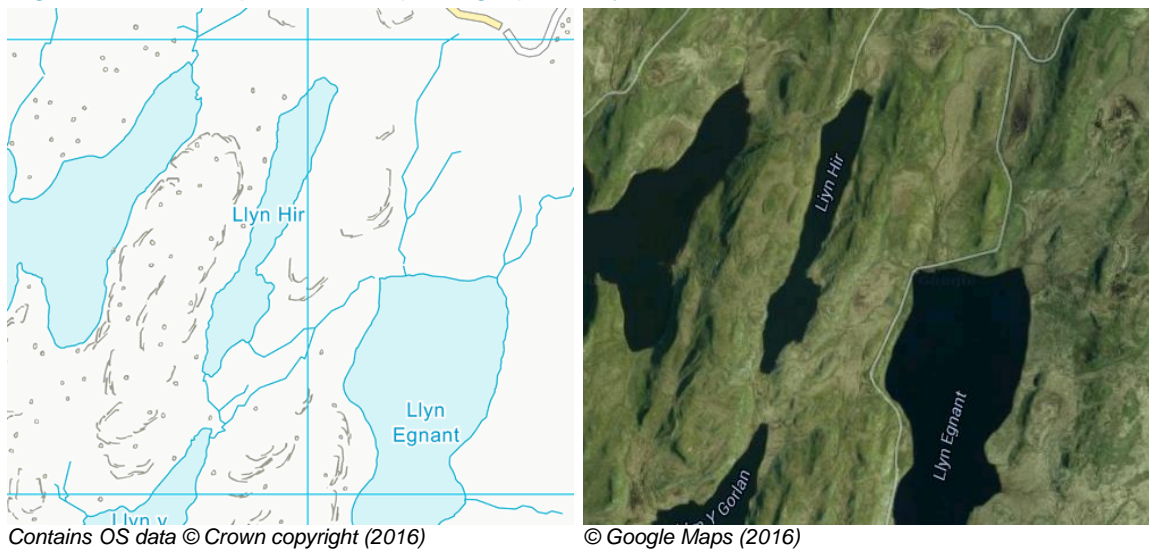


Figure 28 Llyn Hîr site photo; from the southeast shore looking northwest



Llyn Hîr is a relatively shallow (max. recorded depth 7.9 m) oligotrophic lake situated within the Tiefsi Pools at an altitude of 439 m in Ceredigion. The site lies within the headwaters of the Afon Teifi / River Teifi SAC and is a WFD Surveillance site. The

lake has a relatively small catchment area (c. 21 ha) dominated by acid grassland and small areas of acid heathland. Palaeoecological evidence from the site shows it to have undergone significant change due to acidification over the past 150 years (Battarbee *et al.* 1988, Goldsmith *et al.* 2006). Such was the extent of acidification that in 1985 the Welsh Water Authority limed Llyn Hîr, elevating the pH from 4.8 to current levels of approximately 6.4 (Goldsmith *et al.* 2006).

Table 11 CSM Survey results from Llyn Hîr 2015

Submerged and floating vegetation	% occurrence (n=104)
<i>Isoetes echinospora</i>	30.8
<i>Isoetes lacustris</i>	4.8
<i>Juncus bulbosus</i>	15.4
<i>Littorella uniflora</i>	50.0
<i>Lobelia dortmanna</i>	56.7
<i>Luronium natans</i>	11.5
<i>Myriophyllum alterniflorum</i>	15.4
<i>Nitella flexilis</i> agg.	24.0
<i>Potamogeton polygonifolius</i>	6.7
<i>Sparganium angustifolium</i>	1.9
<i>Sphagnum</i> sp.	12.5
<i>Subularia aquatica</i>	23.1
Species richness	12

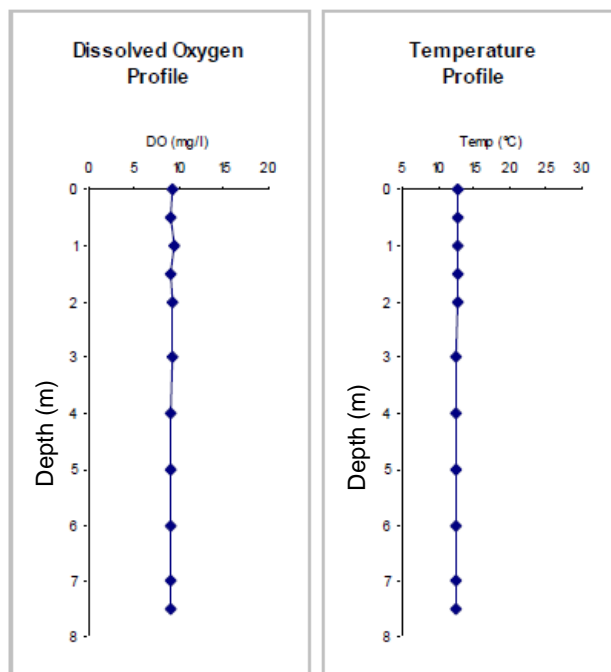
Figure 29 Dissolved oxygen and temperature profiles at Llyn Hîr (15/09/2015)

Dissolved Oxygen Profile

GPS Location SN7902067817
 Maximum Depth (m) 7.9 m
 Secchi Depth (cm) 290 cm

Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	9.26	12.7
0.5	9.2	12.7
1	9.43	12.7
1.5	9.19	12.7
2	9.34	12.7
3	9.39	12.6
4	9.2	12.5
5	9.06	12.5
6	9.07	12.5
7	9.08	12.5
7.5	9.13	12.5



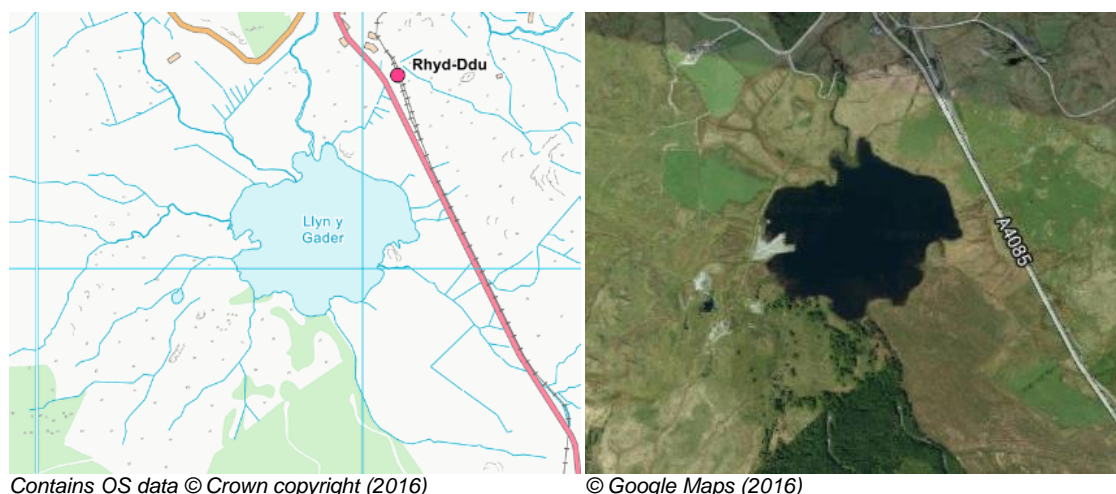
Llyn Hîr has a relatively rich aquatic macrophyte flora typical of low alkalinity, oligotrophic lakes (Table 11). Both species of *Isoetes* were recorded and confirmed in the site with *I. echinospora* more frequent than *I. lacustris*. *Littorella uniflora* and *Lobelia dortmanna* are both abundant and the site supports a stable population of

Luronium natans and *Subularia aquatica*. The current species assemblage would place the site in favourable condition with respect to its flora under JNCC CSM Guidelines (JNCC 2015). The longer-term impact of liming the site is of interest and would warrant further palaeological investigation.

Dissolved oxygen and temperature profiles showed the lake to be mixed during the survey period with stable temperature and DO values throughout the water column (Figure 29).

4.2.10. Llyn y Gader

Figure 30 Site map and aerial photograph of Llyn y Gader



Llyn y Gader is a very shallow (2.26 m) oligotrophic lake situated upstream and to the southeast of Llyn Cwellyn at an altitude of 185 m in the Nant y Betws valley in Gwynedd. The outflow from the site is the start of the Afon Gwyrfai a Llyn Cwellyn SAC and the lake itself lies within the SSSI boundary and is inside the Snowdonia National Park. The catchment is a mix of acid and neutral grassland and although there is no chemistry available for the site it is classified as having “moderate alkalinity” based on the geological character of the area (UK Lakes).

The aquatic macrophytes flora of Llyn y Gader is exceptional. The site has a very species rich assemblage of typical, clear-water, oligotrophic species (Table 12). There are extensive populations of *Littorella uniflora*, *Lobelia dortmanna* and *Isoetes lacustris* forming overlapping zones throughout the lake to maximum depth. In addition and of particular interest to the SSSI / SAC feature is the population of Floating water plantain *Luronium natans* which occurs throughout the lake from the sheltered margins, growing within *Carex rostrata* beds, to a maximum depth of 2.0 m. It was most abundant within the 1-1.8 m depth zone and present in a total of 33% of the survey points (58% of open water points). Other species of note included *Pilularia globulifera* which was recorded as two separate populations in shallow water, and three species of *Nitella* with Llyn y Gader being a new site for *N. gracilis* (N. Stewart, pers. comm.). *Juncus bulbosus* was recorded at high frequency (and abundance) which may be indicative of enrichment and therefore we would recommend that water quality monitoring be carried out at the site. The current species assemblage

would place the site in favourable condition with respect to its flora under JNCC CSM Guidelines (JNCC 2015).

Figure 31 Llyn y Gader site photo; bathymetric survey, looking northeast towards Snowdon



Table 12 CSM Survey results from Llyn y Gader 2015

Submerged and floating vegetation	% occurrence (n=124)	Submerged and floating vegetation	% occurrence (n=124)
<i>Batrachospermum</i> sp.	11.3	<i>Nitella flexilis</i> agg.	2.4
<i>Callitriche hamulata</i>	23.4	<i>Nitella gracilis</i>	2.4
<i>Callitriche</i> sp.	9.7	<i>Nitella translucens</i>	1.6
<i>Elatine hexandra</i>	32.3	<i>Nymphaea alba</i>	4.8
<i>Eleogiton fluitans</i>	8.9	<i>Pilularia globulifera</i>	3.2
<i>Fontinalis antipyretica</i>	0.8	<i>Potamogeton berchtoldii</i>	0.8
<i>Isoetes lacustris</i>	48.4	<i>Potamogeton natans</i>	13.7
<i>Juncus bulbosus</i>	79.0	<i>Potamogeton polygonifolius</i>	0.8
<i>Littorella uniflora</i>	41.9	<i>Ranunculus aquatilis</i> agg.	0.8
<i>Liverworts aquatic</i>	0.8	<i>Sparganium angustifolium</i>	23.4
<i>Lobelia dortmanna</i>	54.0	<i>Sphagnum</i> sp.	15.3
<i>Luronium natans</i>	33.1	<i>Subularia aquatica</i>	1.6
<i>Menyanthes trifoliata</i>	2.4	<i>Utricularia vulgaris</i> agg.	24.2
<i>Myriophyllum alterniflorum</i>	19.4		
Species richness			27

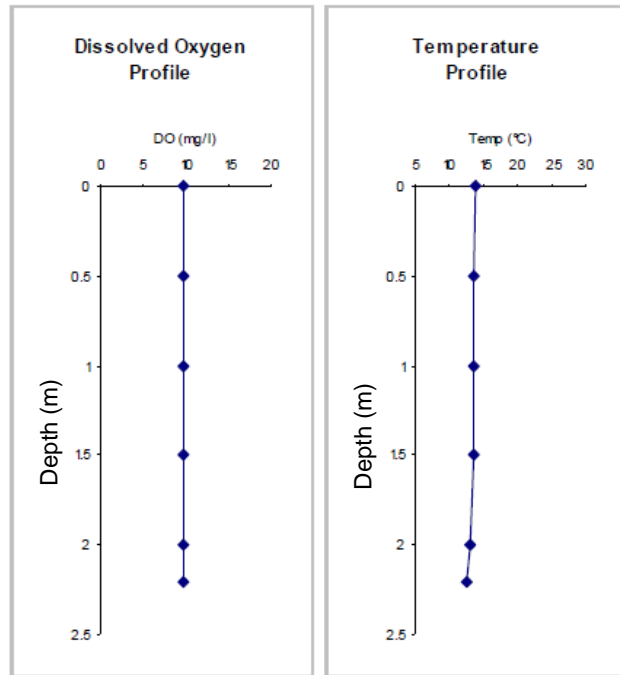
Being very shallow, the dissolved oxygen and temperature profiles show the lake to be well mixed with good oxygen concentration throughout the water column (Figure 32).

Figure 32 Dissolved oxygen and temperature profiles at Llyn y Gader (16/09/2015)

Dissolved Oxygen Profile

GPS Location SH5681152034
 Maximum Depth (m) 2.3 m
 Secchi Depth (cm) -
 Notes: Water clear and secchi > max depth

Depth (m)	DO (mg/l)	Temp (°C)
0	9.74	13.7
0.5	9.69	13.6
1	9.64	13.6
1.5	9.64	13.5
2	9.76	12.9
2.2	9.79	12.6



Results from the bathymetric survey of Llyn y Gader are presented in section 4.3.2 below.

4.2.11. Llyn Nantlle Uchaf

Figure 33 Site map and aerial photograph of Llyn Nantlle Uchaf



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Llyn Nantlle Uchaf is a shallow (8.21 m) oligo-mesotrophic lake situated in the Nantlle Valley to the east of Penygroes. The lake lies at an altitude of 98 m and although it is

outside of any statutory designations, it is just within the western boundary of the Snowdonia National Park. The majority of the upper catchment is acid grassland with areas of acid heath, but there is also small areas of more alkaline grassland and improved pasture close to the lake shore. The primary reason for survey is as a freshwater BAP habitat.

Figure 34 Llyn Nantlle Uchaf site photo; macrophyte survey, looking east towards Snowdon



The aquatic macrophytes flora of Llyn Nantlle is of considerable interest. The site is relatively species rich and dominated by species typical of clear-water, oligotrophic lakes (Table 13). There are typical zone with *Littorella uniflora*, *Lobelia dortmanna* (occasion) and *Isoetes* spp. to a depth of 2.0 m. Based on vegetative characters, it is probable that both *Isoetes lacustris* and *I. echinospora* are present in the lake, but only the latter was confirmed from the voucher specimens collected. A more comprehensive study of the *Isoetes* plants is therefore required to confirm if both are present and the proportion at which they occur.

In additional and of particular BAP (and HD) interest is the population of Floating water plantain *Luronium natans* which is frequent in Llyn Nantlle Uchaf at depths up to 2.5 m (most common < 2.0 m). *Elatine hydropiper* is also relatively common in the site and therefore worthy of note. Seddon (1972) recorded *Potamogeton alpinus* in the lake; this was not recorded in 2015, but would require a more extensive survey to confirm its absence. The non-native invasive species *Elodea canadensis* was present at 21% frequency, which is of concern, although it rarely dominated any of the survey points and at current levels does not appear to be having any major impact on the condition of the site. The current species assemblage would place the

site in favourable condition with respect to its flora under JNCC CSM Guidelines (JNCC 2015), but “at risk” based on the presence of *Elodea canadensis*.

We recommend that this site should be afforded greater protection based on the extensive population of *L. natans* (well established, historic and healthy), in conjunction with a mixed oligotrophic flora containing *Isoetes echinospora* and *Elatine hydropiper*.

Table 13 CSM Survey results from Llyn Nantlle Uchaf 2015

Submerged and floating vegetation	% occurrence (n=143)	Submerged and floating vegetation	% occurrence (n=143)
<i>Callitriche hamulata</i>	23.8	<i>Lobelia dortmanna</i>	4.9
<i>Elatine hydropiper</i>	31.5	<i>Luronium natans</i>	27.3
<i>Eleocharis acicularis</i>	1.4	<i>Mosses aquatic</i>	1.4
<i>Elodea canadensis</i>	21.0	<i>Myriophyllum alterniflorum</i>	13.3
<i>Fontinalis antipyretica</i>	4.9	<i>Nitella flexilis</i> agg.	28.0
<i>Isoetes echinospora</i>	9.1	<i>Potamogeton berchtoldii</i>	4.2
<i>Isoetes</i> sp.	42.7	<i>Ranunculus aquatilis</i> agg.	7.0
<i>Juncus bulbosus</i>	1.4	<i>Sparganium angustifolium</i>	7.0
<i>Littorella uniflora</i>	19.6		
Species richness			17

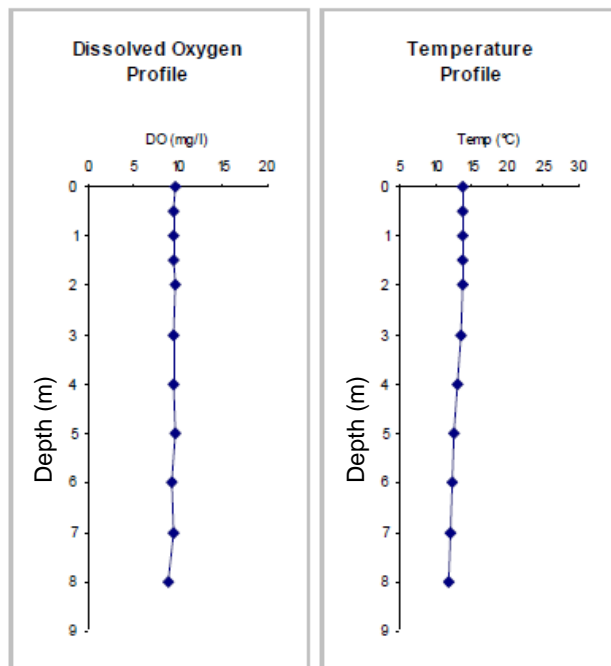
Being very shallow, the dissolved oxygen and temperature profiles show the lake to be well mixed with good oxygen concentration throughout the water column (Figure 35).

Figure 35 Dissolved oxygen and temperature profiles at Llyn Nantlle (17/09/2015)

Dissolved Oxygen Profile

GPS Location SH5134253086
 Maximum Depth (m) 8 m
 Secchi Depth (cm) 512 cm
 Notes:

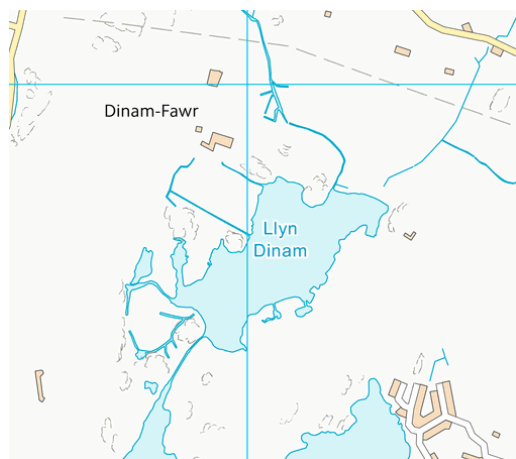
Depth (m)	DO (mg/l)	Temp (°C)
0	9.66	13.8
0.5	9.53	13.8
1	9.54	13.8
1.5	9.57	13.8
2	9.62	13.8
3	9.51	13.5
4	9.57	12.9
5	9.68	12.5
6	9.4	12.3
7	9.51	12.1
8	8.91	11.9



Results from the bathymetric survey of Llyn Nantlle are presented in section 4.3.1 below.

4.2.12. Llyn Dinam

Figure 36 Site map and aerial photograph of Llyn Dinam



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Figure 37 Llyn Dinam site photo; typical marginal zone (southeast shore)



Llyn Dinam is a very shallow (1.9 m), naturally eutrophic lake lying 1.5 km from the coast of western Anglesey within the Llynau y Fali: Valley Lakes SSSI and Llyn Dinam SAC. The site is reed fringed around most of its margin and the wider catchment comprises a mix of a neutral to alkaline grassland with some improved

areas and a number of isolated rural dwellings. Llyn Dinam is an RSPB Reserve and has only very limited access and consequently has low human disturbance. The site receives water from the catchment to the northeast and although very close to Llyn Penrhyn, it shares no obvious hydrological link to this hyper-eutrophic lake.

The aquatic macrophyte flora consists of a species-rich, mixed mosaic of typically eutrophic species (Table 14). Of particular interest is the occurrence of both *Callitriche hermaphroditica* and *C. truncata* together; the latter species being confined to Anglesey in Wales. Other notable species include, *Elatine hydropiper*, *Nitella opaca* s.s. and an isolated patch of *Littorella uniflora* confined to very shallow water next to a rocky outcrop on the north shore (SH3114477726).

Although maintaining a relatively species rich flora, the site is dominated by *Ceratophyllum demersum* and lacks the abundance of broad-leaf *Potamogeton* species one expects to see in natural eutrophic sites in favourable condition. A few plants of *P. crispus* were recorded along with one record for *P. perfoliatus*. The current species assemblage is borderline favourable with respect to CSM guidelines (JNCC 2015), but water quality has previously failed to meet CSM targets (Mean TP 58 µg/l-1 in 2003-4) and water clarity was very poor in July 2015 (Secchi = 75 cm).

Table 14 CSM Survey results from Llyn Dinam 2015

Submerged and floating vegetation	% occurrence (n=114)	Submerged and floating vegetation	% occurrence (n=114)
<i>Alisma plantago-aquatica</i>	8.8	<i>Myriophyllum spicatum</i>	19.3
<i>Callitriche hermaphroditica</i>	36.8	<i>Nitella flexilis</i> agg.	36.0
<i>Callitriche</i> sp.	4.4	<i>Nitella opaca</i>	6.1
<i>Callitriche truncata</i>	21.1	<i>Nuphar lutea</i>	5.3
<i>Ceratophyllum demersum</i>	68.4	<i>Nymphaea alba</i>	17.5
<i>Chara globularis</i>	13.2	<i>Persicaria amphibia</i>	5.3
<i>Elatine hydropiper</i>	31.6	<i>Potamogeton berchtoldii</i>	29.8
<i>Eleocharis acicularis</i>	8.8	<i>Potamogeton crispus</i>	2.6
<i>Elodea canadensis</i>	12.3	<i>Potamogeton natans</i>	2.6
<i>Fontinalis antipyretica</i>	9.6	<i>Potamogeton pectinatus</i>	13.2
<i>Lemna minor</i>	10.5	<i>Potamogeton perfoliatus</i>	0.9
<i>Lemna minuta</i>	5.3	<i>Potamogeton trichoides</i>	0.9
<i>Lemna trisulca</i>	39.5	<i>Ranunculus aquatilis</i> agg.	11.4
<i>Littorella uniflora</i>	1.8	<i>Ranunculus lingua</i>	0.9
<i>Menyanthes trifoliata</i>	8.8		
Species richness			29

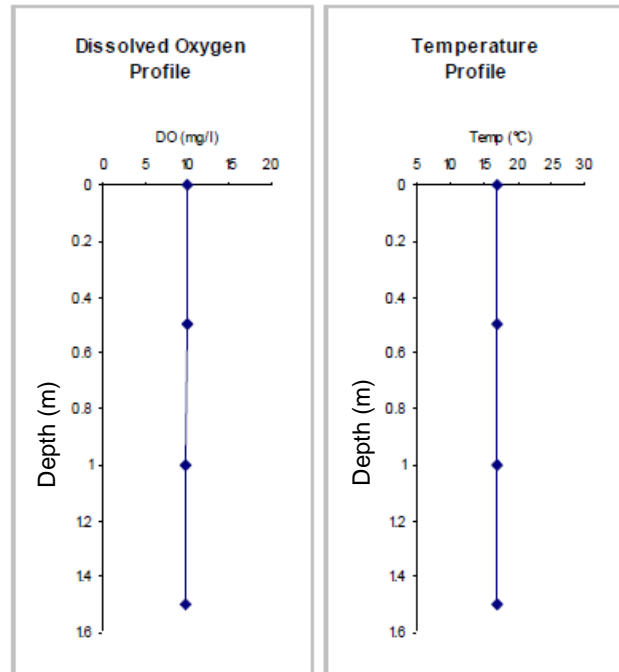
The site is very shallow and exposed and at the time of survey the water was well oxygenated (Figure 38).

Figure 38 Dissolved oxygen and temperature profiles at Llyn Dinam (31/07/2016)

Dissolved Oxygen Profile

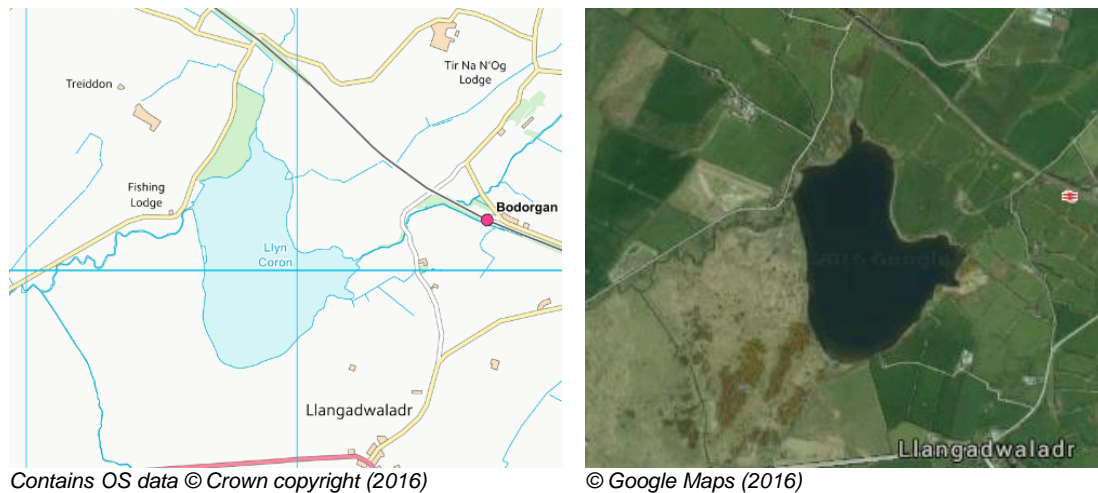
GPS Location
 Maximum Depth (m) 1.85 m
 Secchi Depth (cm) 75 cm
 Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	10	16.9
0.5	10.1	16.9
1	9.7	16.9
1.5	9.7	16.9



4.2.13. Llyn Coron

Figure 39 Site map and aerial photograph of Llyn Coron



Llyn Coron is a very shallow (3.8 m), naturally eutrophic lake lying only 2 km from the southwest coast of Anglesey. The lake forms the northern edge of the Y Twyni o Abermenai i Aberffraw / Abermenai to Aberffraw Dunes SAC and Tywyn Aberffraw SSSI. The site is mainly reed fringed around its south and west margin, but has improved grazing around the eastern side. The wider catchment extends to the northeast of the site and is approximately 75% improved grassland, with areas of unimproved calcareous grassland (CEH 2016). Llyn Coron has a small fishing club with a number of boats moored or hauled out near the outflow.

Figure 40 Llyn Coron site photo; typical marginal zone (southeast shore)



The aquatic macrophyte flora is relatively rich (20 species) and consist of a mixed mosaic of typically eutrophic species (Table 15). Of particular interest is the remnant population of *Littorella uniflora* confined to shallow water on the north shore, often in rocky fissures (SH3781070378). *Elatine hydropiper* is confirmed in the site, possibly also *E hexandra* but this was not verified. Two broad-leaf *Potamogeton* species were recorded; *P. perfoliatus* was most common in the north of the site growing to a depth of 2.0 m, *P. crispus* occurred only sporadically.

Table 15 CSM Survey results from Llyn Coron 2015

Submerged and floating vegetation	% occurrence (n=112)	Submerged and floating vegetation	% occurrence (n=112)
<i>Callitriche hermaphroditica</i>	2.7	<i>Littorella uniflora</i>	0.9
<i>Ceratophyllum demersum</i>	1.8	<i>Myriophyllum spicatum</i>	43.8
<i>Chara globularis</i>	5.4	<i>Potamogeton berchtoldii</i>	41.1
<i>Chara vulgaris</i> var. <i>papillata</i>	22.3	<i>Potamogeton crispus</i>	2.7
<i>Elatine hydropiper</i>	10.7	<i>Potamogeton pectinatus</i>	18.8
<i>Eleocharis acicularis</i>	11.6	<i>Potamogeton perfoliatus</i>	11.6
<i>Elodea canadensis</i>	9.8	<i>Potamogeton trichoides</i>	18.8
<i>Elodea nuttallii</i>	8.0	<i>Ranunculus aquatilis</i> agg.	3.6
<i>Enteromorpha</i> sp.	13.4	<i>Ranunculus circinatus</i>	32.1
<i>Lemna trisulca</i>	11.6	<i>Zannichellia palustris</i>	9.8
Species richness			20

The flora has a number of characteristic elements but falls short of the 60% frequency target of characteristic species required for favourable condition under CSM guidance (JNCC 2015). Two non-native species were present in the site. *Elodea canadensis* has been present in the site for many years, but *E. nuttallii* is a recent arrival and has the potential to alter the ecology of the site significantly.

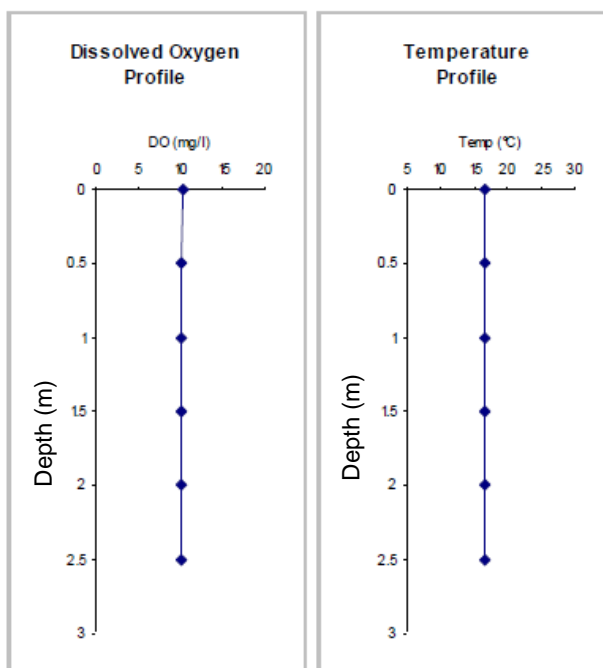
The site is very shallow and exposed and at the time of survey the water was well oxygenated (Figure 41).

Figure 41 Dissolved oxygen and temperature profiles at Llyn Coron (01/08/2016)

Dissolved Oxygen Profile

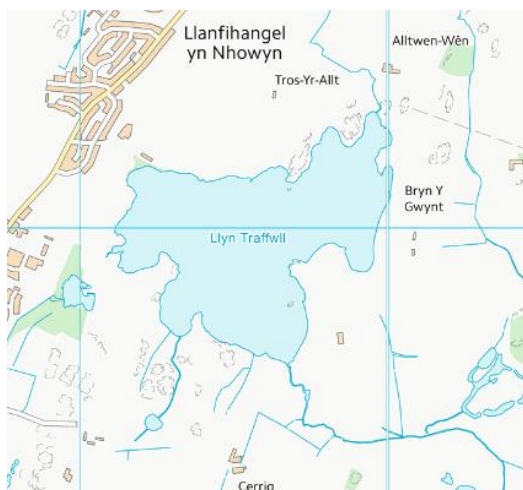
GPS Location SH3784869973
 Maximum Depth (m) 3.8 m
 Secchi Depth (cm) 110 cm
 Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	10.3	16.6
0.5	10.2	16.6
1	10.2	16.6
1.5	10.2	16.6
2	10.1	16.6
2.5	10.1	16.6



4.2.14. Llyn Traffwll

Figure 42 Site map and aerial photograph of Llyn Traffwll



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Figure 43 Llyn Traffwll site photo; taken from the north shore looking south



Llyn Traffwll is a relatively large, base rich, shallow (max. recorded depth 4.1 m) lake lying within the Crigyll catchment. The lake is close to the Valley Lakes SSSI just to the west, but is separated from Llyn Penrhyn by a low ridge on which the village of Llanfihangel yn Nhowyn is located. The entire lake and associated wetland to the south-west and outflow to the south is designated as a SSSI on the basis of biological interest with eight-stamened waterwort (*Elatine hydropiper*) and flowering rush (*Butomus umbelatus*) being of particular interest. The lake is also notable as important site for overwintering wildfowl, particularly shoveler, but also gadwall, widgeon, pochard and goldeneye. The wider catchment extends to the north of the site and comprises approximately 65% improved grassland, with areas of unimproved calcareous grassland (UK Lakes CEH 2016).

The aquatic macrophyte flora is relatively rich, with 17 species recorded, most of which are typical of eutrophic waters (Table 16). Of particular interest is the high frequency of *Elatine hydropiper* which was common in the littoral zone to 1.2 m and also the presence of *Littorella uniflora*, which although not recorded in the transects has been recorded previously in the site (Goldsmith *et al.* 2014b) and was found in the strandline of the current survey. The current species assemblage does not meet the target criteria for favourable condition as set out in the CSM guidelines (JNCC 2015).

The site is very shallow and exposed and at the time of survey the water was well oxygenated (Figure 44).

Table 16 CSM Survey results from Llyn Traffwll 2015

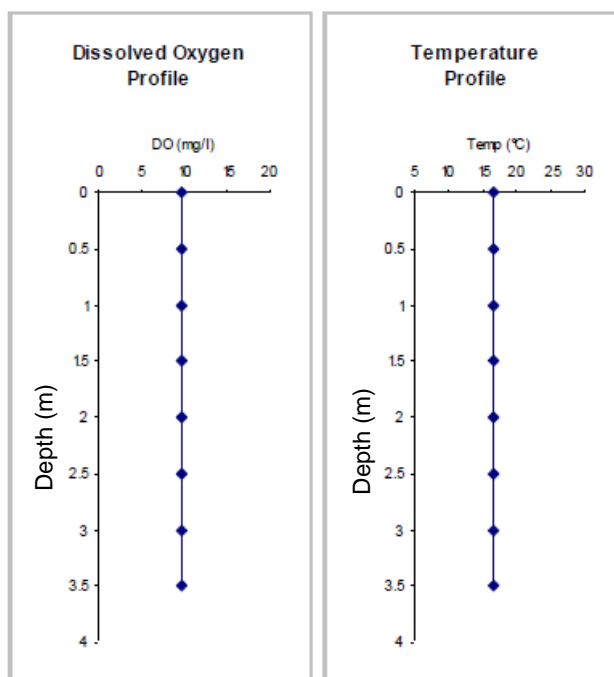
Submerged and floating vegetation	% occurrence (n=123)	Submerged and floating vegetation	% occurrence (n=123)
<i>Alisma plantago-aquatica</i>	0.8	<i>Littorella uniflora</i>	+
<i>Callitriche truncata</i>	52.8	<i>Myriophyllum spicatum</i>	0.8
<i>Ceratophyllum demersum</i>	15.4	<i>Nitella flexilis</i> agg.	4.9
<i>Chara globularis</i>	10.6	<i>Potamogeton berchtoldii</i>	48.8
<i>Elatine hydropiper</i>	40.7	<i>Potamogeton crispus</i>	0.8
<i>Eleocharis acicularis</i>	8.9	<i>Potamogeton pectinatus</i>	30.9
<i>Elodea canadensis</i>	17.1	<i>Potamogeton perfoliatus</i>	17.1
<i>Enteromorpha</i> sp.	6.5	<i>Zannichellia palustris</i>	25.2
<i>Lemna trisulca</i>	4.9		
Species richness			17

Figure 44 Dissolved oxygen and temperature profiles at Llyn Traffwll (02/08/2016)

Dissolved Oxygen Profile

GPS Location SH3244676971
 Maximum Depth (m) 3.75 m
 Secchi Depth (cm) 210 cm
 Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	9.7	16.7
0.5	9.7	16.7
1	9.6	16.7
1.5	9.6	16.7
2	9.6	16.7
3	9.6	16.7
3.5	9.6	16.7
2.5	9.6	16.7



4.2.15. Llyn Penrhyn

Figure 45 Site map and aerial photograph of Llyn Penrhyn

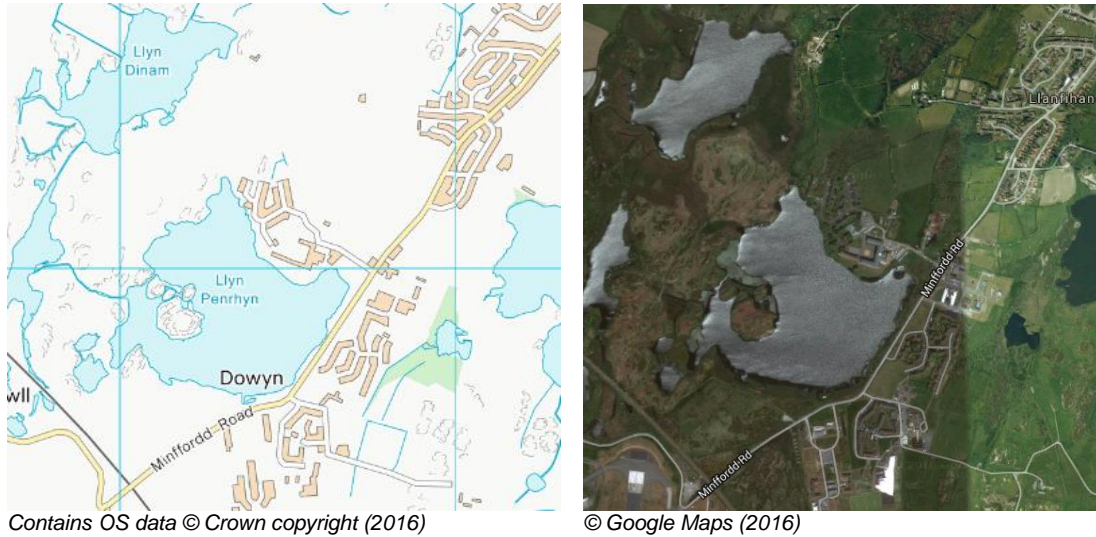


Figure 46 Llyn Penrhyn site photo; typical marginal zone (southwest shore)



Llyn Penrhyn is a very shallow (max. recorded depth 2.7 m), naturally eutrophic lake lying 1.5 km from the coast of southwest Anglesey and within the Llynau y Fali: Valley Lakes SSSI. The site is reed fringed around most of its margin and the wider

catchment comprises a mix of acid and neutral grassland, some of which is improved. There is also a significant proportion of the catchment (11.4%) of urban development which includes RAF Valley accommodation and the village of Llanfihangel yn Nhowyn. Historically, Llyn Penryn has suffered from gross pollution due to sewage effluent from RAF Valley Sewage Treatment Works and the settlement of Llanfihangel yn Nhowyn discharging directly into the lake. The sewage treatment works was enlarged in 1964 but phosphate stripping only came into effect in 1994 (Haworth *et al.* 1996).

Beyond the fringing reeds (dominated by *Phragmites australis* and *Schoenoplectus lacustris*) the aquatic flora was mostly rather sparse. In shallow water, *Callitriche truncata* was most common, but often as dense uprooted clumps and it proved difficult to ascertain where in the site it was growing. *Ceratophyllum demersum* was most frequent throughout the open water, but there were rarely more than one or two plants on a 4 m rake haul and the high frequency does should not therefore be misinterpreted as high abundance. Other species were similarly sparse. Richard Lansdowne undertook a survey of Llyn Penrhyn in 2012 and recorded *Potamogeton lucens* growing in the southwestern arm of the site. This area coincides with survey section four of the 2015 survey (SH3102476897), but despite a thorough search, no *P. lucens* was recorded. The site is notable for supporting a reasonable population of *Elatine hydropiper*, which was mainly restricted to firmer substrates in shallow water..

Table 17 CSM Survey results from Llyn Dinam 2015

Submerged and floating vegetation	% occurrence (n=95)	Submerged and floating vegetation	% occurrence (n=95)
<i>Callitriche truncata</i>	32.6	<i>Myriophyllum spicatum</i>	1.1
<i>Ceratophyllum demersum</i>	47.4	<i>Nitella flexilis</i> agg.	+
<i>Chara globularis</i>	2.1	<i>Nuphar lutea</i>	7.4
<i>Chara virgata</i>	7.4	<i>Nymphaea alba</i>	8.4
<i>Elatine hydropiper</i>	8.4	<i>Persicaria amphibia</i>	2.1
<i>Elodea canadensis</i>	12.6	<i>Potamogeton pectinatus</i>	5.3
<i>Enteromorpha</i> sp.	11.6	<i>Potamogeton perfoliatus</i>	6.3
<i>Lemna minor</i>	5.3	<i>Potamogeton pusillus</i>	32.6
<i>Lemna minuta</i>	5.3	<i>Zannichellia palustris</i>	4.2
<i>Lemna trisulca</i>	5.3		
Species richness			19

The current aquatic flora is sparse and with *Ceratophyllum demersum* most frequently occurring species. The site fails to meet the target of six characteristic species required for favourable condition within the CSM guidance (JNCC 2015) and also lacks the abundance of broad-leaf *Potamogeton* species one expects to see in natural eutrophic sites (and appears to have lost *P. lucens*). The current species assemblage is therefore unfavourable and suggests the site to remain hyper-eutrophic.

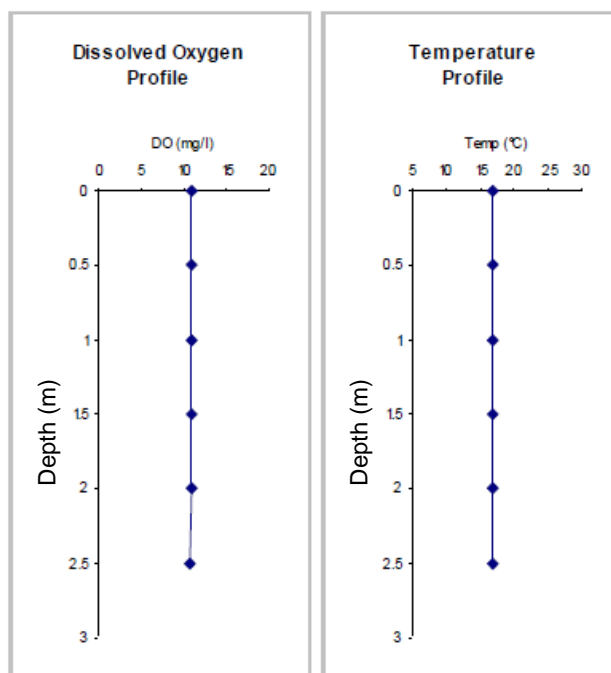
The site is very shallow and exposed and at the time of survey the water was well oxygenated (Figure 47).

Figure 47 Dissolved oxygen and temperature profiles at Llyn Penrhyn (03/08/2016)

Dissolved Oxygen Profile

GPS Location SH3137676776
 Maximum Depth (m) 2.7 m
 Secchi Depth (cm) 125 cm
 Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	10.85	16.9
0.5	10.86	16.9
1	10.88	16.9
1.5	10.86	16.9
2	10.87	16.9
2.5	10.82	16.9



4.2.16. Llyn Glasfryn

Figure 48 Site map and aerial photograph of Llyn Glasfryn



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Llyn Glasfryn is a small, very shallow lake (max. recorded depth 1.0 m) situated on acid soils (Arfon series) within the gently undulating countryside of the Llyn peninsula. The immediate catchment is small and dominated by improved grassland and broadleaf woodland. The hydrology of the site is unclear however and possibly impacted by groundwater from beyond the extent of the surface water catchment. The site was designated as a SSSI in 1989 due to the biological interest within the lake, primarily the aquatic flora, and because open water habitats are scarce on the Llyn peninsula. Previous studies on the site have revealed the lake to be enriched

(Monteith 1997; Burgess *et al.* 2006) and palaeoecological evidence suggested there to have been significant species turnover attributed to eutrophication (Allott *et al.* 2001, Bennion 2004).

Figure 49 Lyn Glasfryn site photo; typical marginal zone (east shore looking west)



Although the lake has continued to support a relatively diverse flora in recent years, including notable rarities such as *Elatine hydropiper* and *E. hexandra*, there have been no records of *Luronium natans* since 1987 (Lockton 2009) and the site no longer supports the isoetid flora that is characteristic of many mesotrophic lakes. Seddon (1972) reports the presence of *Littorella uniflora*, *Isoetes echinospora* and even *Subularia aquatica* from surveys conducted in the early 1960s, although *Luronium natans* was not recorded at that time.

The previous site condition reports (Burgess *et al.* 2006, Goldsmith *et al.* 2014b) recorded a relatively diverse flora, but one that lacked a typical mesotrophic assemblage and the site was classified as being unfavourable with respect to the flora and the poor water quality, the latter has however improved since 1996.

The aquatic flora recorded in 2015 was very different to that seen in 2012. In 2012 *Callitriche hamulata* was dominant (83% frequency), whereas in 2015 *C. hamulata* was far less frequent (11%) and the site dominated instead by *Ceratophyllum demersum* (81%); a species recorded as rare in 2004 and not present in the 2012 survey. This switch in dominance does not however appear to have impacted the other species which remain similar (Table 18 and Goldsmith *et al.* 2013). *Myriophyllum alterniflorum* has increased since 2012 and *Nitella flexilis* agg. was

common. The site is notable for supporting both *Elatine hydropiper* and *E. hexandra* but these were often completely covered by dense growths of *C. demersum*.

Table 18 CSM Survey results from Llyn Glasfryn 2015

Submerged and floating vegetation	% occurrence (n=120)	Submerged and floating vegetation	% occurrence (n=120)
<i>Callitriche hamulata</i>	10.8	<i>Myriophyllum alterniflorum</i>	43.3
<i>Callitriche cf stagnalis</i>	+	<i>Nitella flexilis</i> agg.	43.3
<i>Ceratophyllum demersum</i>	80.8	<i>Nuphar lutea</i>	17.5
<i>Elatine hexandra</i>	14.2	<i>Nymphaea alba</i>	7.5
<i>Elatine hydropiper</i>	15.0	<i>Persicaria amphibia</i>	4.2
<i>Fontinalis antipyretica</i>	2.5	<i>Potamogeton perfoliatus</i>	0.8
<i>Menyanthes trifoliata</i>	14.2		
Species richness			13

The current aquatic flora is more typical of eutrophic waters than the mesotrophic features for which the site was designated and fails to meet the characteristic species targets required for favourable condition within the CSM guidance (JNCC 2015). The site is clearly very dynamic with respect to its flora and would therefore benefit from annual surveys to better understand its ecological function.

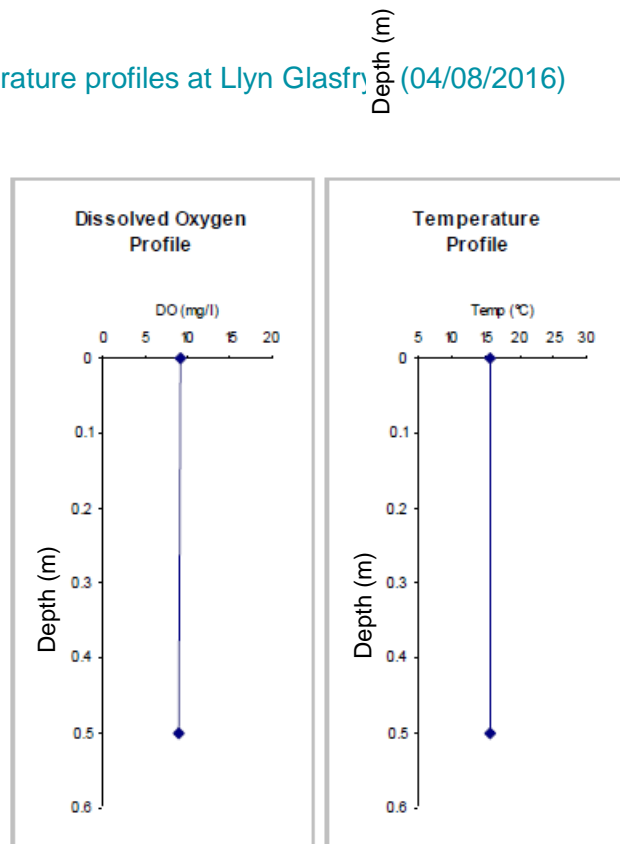
The site is very shallow and exposed and at the time of survey the water was well oxygenated (Figure 50).

Figure 50 Dissolved oxygen and temperature profiles at Llyn Glasfryn (04/08/2016)

Dissolved Oxygen Profile

GPS Location SH4022642144
 Maximum Depth (m) 1 m
 Secchi Depth (cm) 70 cm
 Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	9.08	15.8
0.5	8.87	15.8



4.2.17. Llangorse Lake

Figure 51 Site map and aerial photograph of Llangorse Lake



Figure 52 Llangorse Lake site photo; from northeast shore looking south (*Butomus umbellatus* flowering)



Llangorse Lake is a large (140 ha), shallow (max. recorded depth 7.5 m) lowland lake located on alkaline geology in Powys, south Wales. The site was designated as a SSSI in 1954 and is a HD Annex I site (SAC) for its Natural Eutrophic lake feature. The lake is surrounded by a variety of habitats including wet, broadleaf and mixed woodland and improved grassland and the wider catchment is dominated by improved grassland.

The previous CSM condition assessment indicated the site to be unfavourable and provided palaeoecological evidence to show that although the lake is naturally eutrophic, there has been ecological shifts in the site coincidental with agricultural improvements since approximately 1950 (Burgess *et al.* 2006), but the trophic status has since improved following the diversion of sewage from the site in the 1980s (May *et al.* 2008). Since the diversion of sewage from the site there has also been a recovery in the number of macrophyte species recorded in the site from only 4 in 1979 to 14 in 1998 (Wade 1999) and over 20 currently present (Table 19).

Table 19 CSM Survey results from Llangorse Lake 2015

Submerged and floating vegetation	% occurrence (n=128)	Submerged and floating vegetation	% occurrence (n=128)
<i>Ceratophyllum demersum</i>	25.8	<i>Nuphar lutea</i>	45.3
<i>Chara globularis</i>	25.0	<i>Nymphaea alba</i>	10.9
<i>Eleocharis acicularis</i>	0.8	<i>Nymphoides peltata</i>	19.5
<i>Elodea canadensis</i>	21.1	<i>Persicaria amphibia</i>	0.8
<i>Elodea nuttallii</i>	71.1	<i>Potamogeton lucens</i>	14.1
<i>Lemna minor</i>	10.2	<i>Potamogeton pectinatus</i>	17.2
<i>Lemna trisulca</i>	46.1	<i>Potamogeton perfoliatus</i>	5.5
<i>Menyanthes trifoliata</i>	3.1	<i>Potamogeton pusillus</i>	3.9
<i>Myriophyllum spicatum</i>	28.1	<i>Ranunculus circinatus</i>	0.8
<i>Nitella</i> sp.	4.7	<i>Sparganium emersum</i>	2.3
<i>Nitellopsis obtusa</i>	0.8	<i>Spirodela polyrhiza</i>	15.6
Species richness			22

The current species composition is typical of eutrophic waters. The site has extensive reed fringes giving way to both white and yellow water lilies as well as the locally absent fringed water lily *Nymphoides peltata*. Among the water lilies and growing to a maximum depth of 2.5 m, *Elodea nuttallii* was abundant and in places co-occurring with *E. canadensis* (Figure 53). *Lemna trisulca* was also frequent, often forming an understory within the reeds and growing within the dense *Elodea* beds. In places, *Myriophyllum spicatum* and *Ceratophyllum demersum* were frequent, but they rarely reached high abundance and mainly occurred subordinate to *Elodea* spp.

Figure 53 *Elodea nuttallii* (top) and *E. canadensis* (below) from Llangorse Lake



Despite the dominance of *Elodea* spp. in the site, the overall species richness was high and included five characteristic eutrophic species (JNCC 2015). Notable species included *Potamogeton lucens* (Figure 55) which appears relatively stable at the site since 2003 ranging in frequency from 6.7 – 19.6 % (based on 6 surveys by ENSIS). *Chara globularis* was present in three transects and mainly occurring at depths of 1-1.5 m. *Spirodela polyrhiza* was frequent within the sheltered marginal areas, mainly restricted to areas within the reeds. A single record of *Nitellopsis obtusa* was recorded from 1.9 m water depth at (SO1295526348). This stonewort species was first detected in Llangorse Lake in 2014 (N. Stewart, *pers. comm.*); it is classified as endangered (IUCN) and is a BAP priority species and NERC Species of Principal Importance in Wales. Its presence in the site should therefore be monitored and it should be included in any future conservation strategy at the site.

The current flora, although greatly improved since the site was grossly polluted in the 1970s and now with a number of notable elements, remains unfavourable with respect to the CSM targets (JNCC 2015). The site having only five characteristic eutrophic species and an abundance of *Elodea* spp. being the primary reason for failure.

There was a strong breeze during the survey and as a consequence the water column was well mixed to maximum depth and with no appreciable decline in dissolved oxygen concentration (Figure 54).

Figure 54 Dissolved oxygen and temperature profiles at Llangorse Lake (05/08/2015)

Dissolved Oxygen Profile

GPS Location SO1341826623
 Maximum Depth (m) 7.3 m
 Secchi Depth (cm) 120 cm
 Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	8.31	17.1
0.5	8.17	17.1
1	8.17	17.1
1.5	8.04	17.1
2	8.1	17.1
3	8.08	17.1
4	8.16	17.1
5	8.04	17.1
6	8.2	17.1
7	7.93	17.1

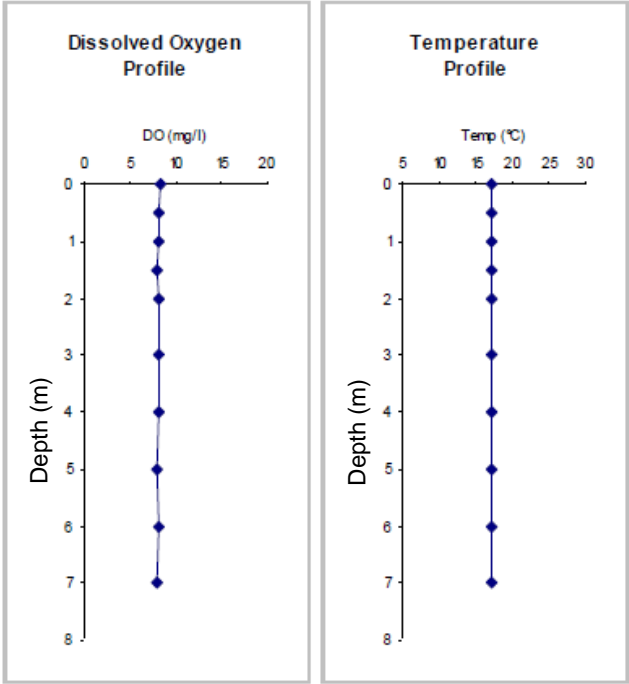


Figure 55 *Potamogeton lucens* growing in Llangorse Lake

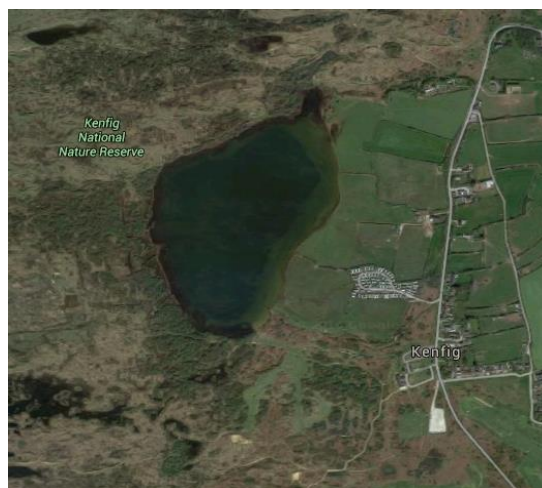


4.2.18. Kenfig Pool

Figure 56 Site map and aerial photograph of Kenfig Pool



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Kenfig Pool is a very shallow (2.4 m) lake situated towards the landward side of the Kenfig Burrows in Bridgend, South Wales. The area was designated as a SSSI in 1953 and Kenfig Pool forms part of the Kenfig SAC and is designated as a lake with “Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp.”. The surface water catchment of the lake is relatively small and comprises improved grassland and sand dunes as well as the urban area of Kenfig village to the east of the site..

Figure 57 Kenfig Pool site photo; east shore looking north



Table 20 CSM Survey results from Kenfig Pool 2015

Submerged and floating vegetation	% occurrence (n=123)	Submerged and floating vegetation	% occurrence (n=123)
<i>Ceratophyllum demersum</i>	42.3	<i>Persicaria amphibia</i>	6.5
<i>Chara aspera</i>	28.5	<i>Potamogeton berchtoldii</i>	4.1
<i>Chara virgata</i>	18.7	<i>Potamogeton gramineus</i>	0.8
<i>Elodea canadensis</i>	39.8	<i>Potamogeton x angustifolius</i>	3.3
<i>Fontinalis antipyretica</i>	8.1	<i>Potamogeton natans</i>	3.3
<i>Lemna trisulca</i>	31.7	<i>Potamogeton pectinatus</i>	2.4
<i>Littorella uniflora</i>	12.2	<i>Potamogeton perfoliatus</i>	7.3
<i>Menyanthes trifoliata</i>	4.1	<i>Potamogeton trichoides</i>	26.0
<i>Myriophyllum alterniflorum</i>	13.0	<i>Ranunculus circinatus</i>	5.7
<i>Myriophyllum spicatum</i>	42.3	<i>Zannichellia palustris</i>	0.8
<i>Nitella flexilis</i> agg.	1.6		
Species richness			21

The aquatic macrophytes flora of Kenfig Pool is relatively species rich and notable for a number of reasons, albeit not typical of the SAC feature for which it is classified. The site does have *Chara* beds, but these are mostly restricted to the sandy substrates around the margins and rarely extend beyond 1.5 m depth. The 2015 survey showed a reduced frequency of *Chara* spp. which was due to their absence along the western shore, where in the past they have been abundant in a narrow band in front of the reed edge. The reason for the decline in this area is unclear,

Chara beds in the north and east of the lake appeared stable and healthy. In open water there was also a change from previous surveys. *Ceratophyllum demersum* was dominant in 2015, whereas it was only occasional in 2009 and 2011 when *Potamogeton trichoides* dominated the open water areas to maximum depth. *Potamogeton trichoides* was present in 2015, but at much lower frequency. *Elodea canadensis* remains frequent in the site and was locally abundant.

The site is notable for supporting six *Potamogeton* species and one hybrid (Table 20). *Potamogeton gramineus* and its *P. lucens* hybrid (*P. x angustifolius*) are mainly confined to the sheltered areas at the back of the reed fringed north shore; the small bay at the northern extent of the lake being particularly rich. *Littorella uniflora* is locally abundant in the sandy substrates along the north shore and occasional just above the waterline where it was seen in flower. Kenfig Pool is rather unusual in that it supports both *Myriophyllum spicatum* and *M. alterniflorum* (Figure 58). These two species are normally ecologically distinct, with the latter favouring more oligotrophic, low alkalinity sites and *M. spicatum* being a typical eutrophic species of more alkaline waters.

Figure 58 *Myriophyllum alterniflorum* (top) and *M. spicatum* (below) in Kenfig Pool



This site is atypical for of its HD designation as a hard water lake. The current flora fails to reach the CSM targets for favourable condition with respect to its flora under JNCC CSM Guidelines (JNCC 2015). The dominance of *C. demersum* in 2015 is of concern and we would recommend regular monitoring of the flora and water quality to help inform site management.

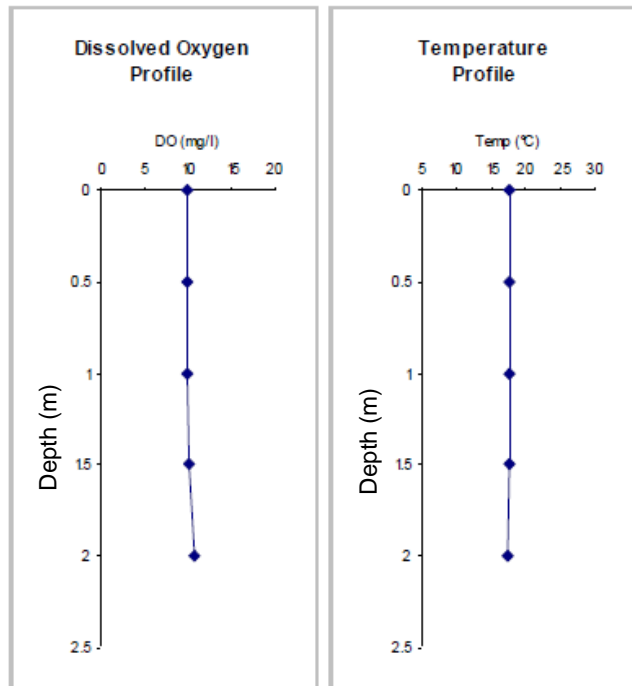
Being very shallow, the dissolved oxygen and temperature profiles show the lake to be well mixed with good oxygen concentration throughout the water column (Figure 59).

Figure 59 Dissolved oxygen and temperature profiles at Kenfig Pool (06/08/2015)

Dissolved Oxygen Profile

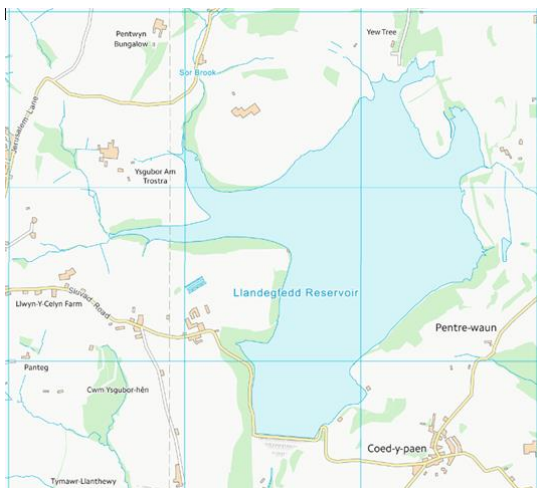
GPS Location SS7965581482
 Maximum Depth (m) 2.4 m
 Secchi Depth (cm) 200 cm
 Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	9.98	17.5
0.5	9.84	17.5
1	9.86	17.5
1.5	10	17.5
2	10.73	17.4

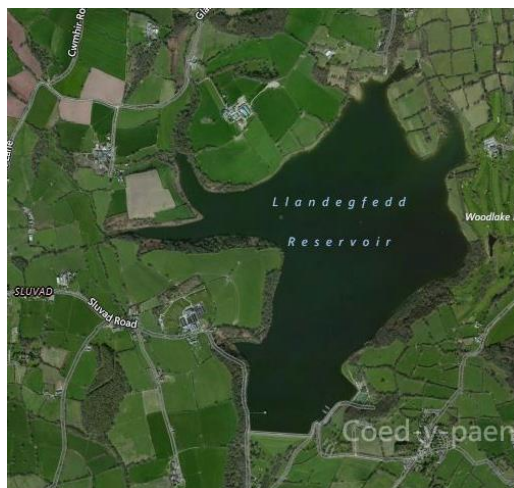


4.2.19. Llandegfedd Reservoir

Figure 60 Site map and aerial photograph of Llandegfedd Reservoir



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Llandegfedd Reservoir is a large (176 ha), reservoir with a maximum recorded depth of 34 m situated in Torfean, South Wales. The area was designated as a SSSI in 1971, primarily for its interest for waterfowl. The reservoir is managed by Dŵr Cymru as a potable water supply as well as for leisure activities and angling (rainbow and brown trout stocked). The catchment is relatively small (650 ha) and predominantly improved grassland interspersed with broadleaf and mixed woodland.

Figure 61 Llandegfedd Reservoir site photo; southeast shore looking northwest



In August 2015, Llandegfedd reservoir was drawn down by approximately 3.8 m and as a consequence there was almost no submerged aquatic flora present in the site. In 2012, an ENSIS survey showed the site to support *Chara globularis*, *Persicaria amphibia*, *Ranunculus aquatilis*, *Potamogeton pusillus* and *Zannichellia palustris* after a prolonged period without any major draw-down. In 2015, only *Z. palustris* was recorded growing in one small area of the reservoir, and a single plant of *Potamogeton pectinatus* was recorded from the strandline.

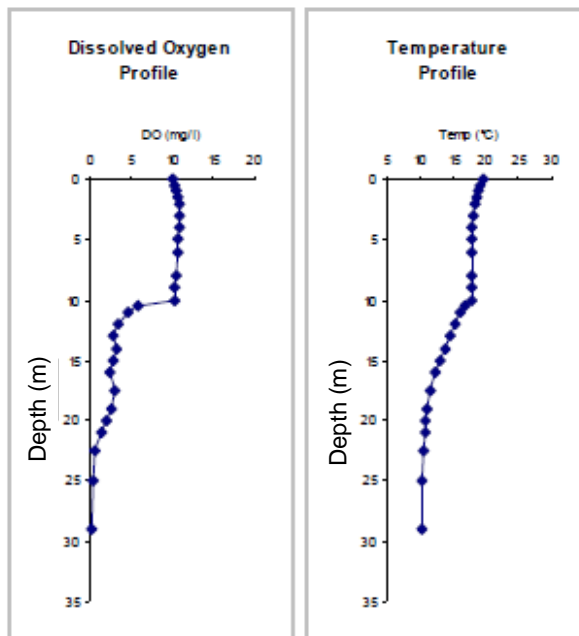
The dissolved oxygen and temperature profiles shows the reservoir to stratify with a thermocline at 10 m, below which there was a sharp drop off in dissolved oxygen concentration (Figure 62).

Figure 62 Dissolved oxygen and temperature profiles at Kenfig Pool (06/08/2015)

Dissolved Oxygen Profile

GPS Location ST3257698756
 Maximum Depth (m) 30.3 m
 Secchi Depth (cm) 195 cm
 Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	10.2	19.6
0.5	10.32	19.2
1	10.53	18.8
1.5	10.71	18.6
2	10.93	18.3
3	10.95	18.2
4	10.93	18
5	10.68	18
6	10.63	17.9
8	10.49	17.9
9	10.35	17.8
10	10.4	17.8
10.5	5.94	16.8
11	4.61	16.1
12	3.38	15.3
13	2.73	14.6
14	3.23	13.9
15	2.88	13
16	2.5	12.3
17.5	3.06	11.6
19	2.71	11.1
20	2.02	10.9
21	1.33	10.8
22.5	0.66	10.6
25	0.38	10.4
29	0.2	10.2



4.3. Bathymetric Surveys

4.3.1. Llyn Nantlle Uchaf

The summary statistics for Llyn Nantlle Uchaf are given in Table 21. The lake has a mean depth of 2.02 m and reaches a maximum of 8.2 m towards the north-west side (Figure 63). With clear water and plants growing to a depth of 3.9 m in 2015, this approximates to 87% of the lake area available for colonisation (Figure 64), although in reality, not all areas of the lake bed between 2.9-3.9 m had plants present.

Table 21 Summary statistics derived from the bathymetric survey of L. Nantlle Uchaf

Bathy ID	WBID	Mean depth (m)	Max. depth (m)	Surface Area (m ²)	Volume (m ³)
b194	34099	2.023	8.21	323960	655367

Figure 63 Bathymetric map of Llyn Nantlle Ucaf

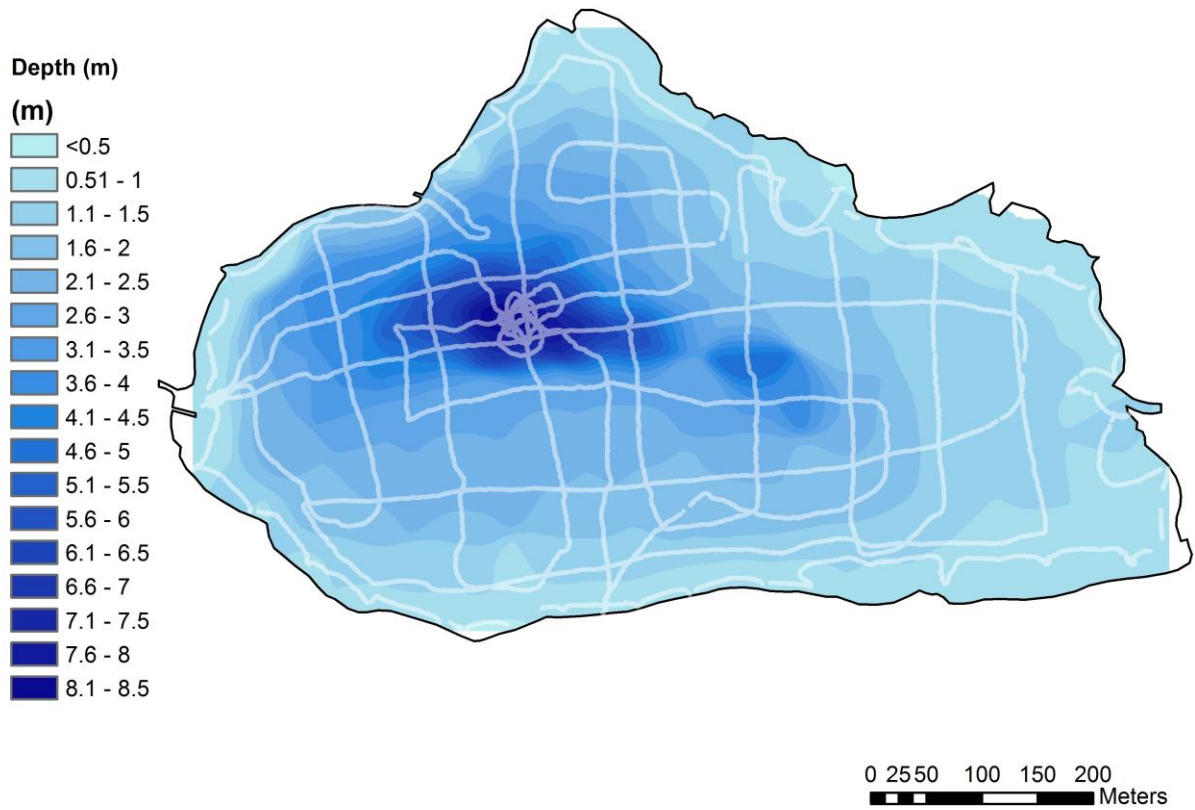
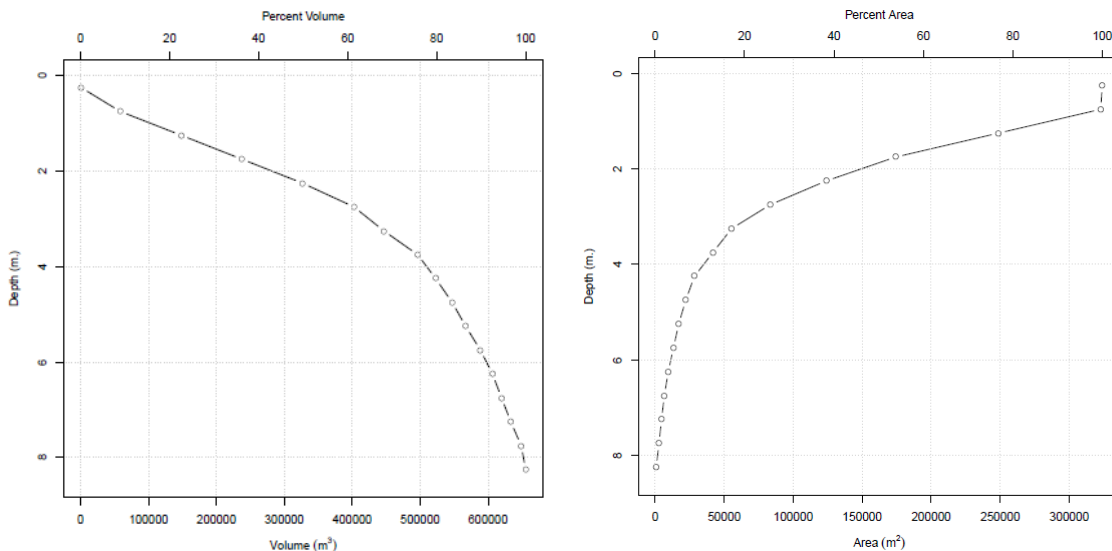


Figure 64 Depth / volume and depth / area curves for Llyn Nantlle Ucaf



4.3.2. Llyn y Gader

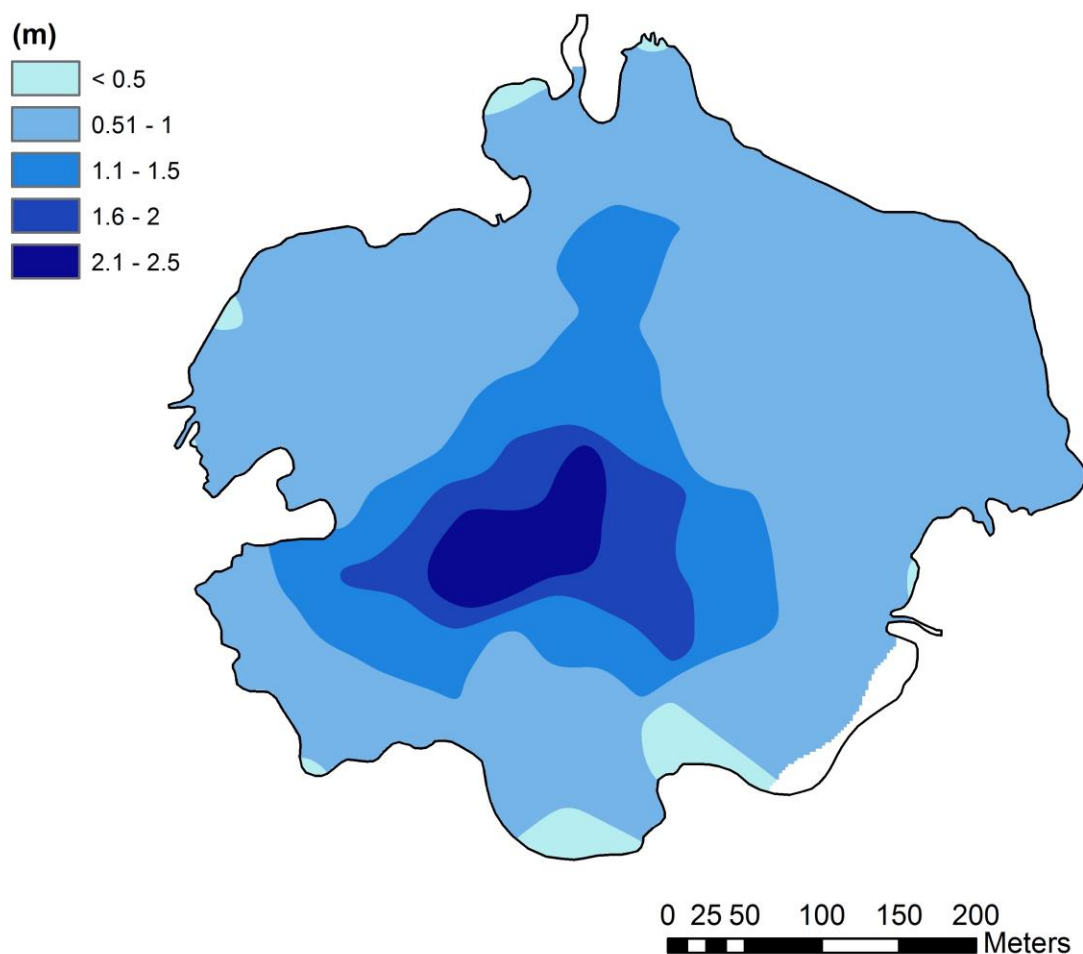
The summary statistics for Llyn y Gader are given in Table 22. The lake is shallow with a mean depth of only 0.91 m and maximum of 2.26 m (Figure 65). The water was very clear at the time of survey and macrophyte growth extended across the entire lake bed. *Luronium natans* was most common within the open water between

0.8 – 1.9 m, thus approximately 40% of total area of the lake provides suitable depth habitat for this species making it an important site for this species.

Table 22 Summary statistics derived from the bathymetric survey of Llyn y Gader

Bathy ID	WBID	Mean depth (m)	Max. depth (m)	Surface Area (m ²)	Volume (m ³)
b195	34147	0.91	2.26	187852	171065

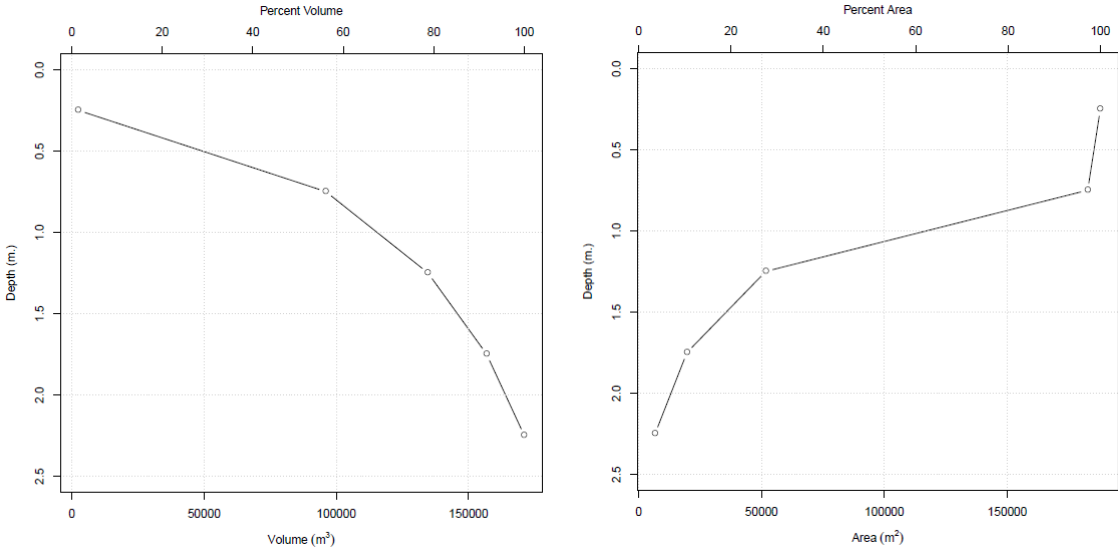
Figure 65 Bathymetric map of Llyn y Gader



4.3.3. Bathymetric data

The data collation, processing and mapping was achieved using the standard techniques set out in Turner *et al.* (2011). Data archiving is detailed in Appendix 6.2

Figure 66 Depth / volume and depth / area curves for Llyn y Gader



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6. Appendices

6.1. Appendix I: Aquatic species data for all sites

Table 23 Summary of all aquatic and macrophyte species for the 19 lakes.

Figures represent per cent frequency at a site based on the CSM method; typical species are shaded green (Based on JNCC 2015) and NNS / locally absent species in orange

	Fynnon Lloer	Kenfig	Llangeford Res.	Llangorse	Llyn Arenig Fawr	Llyn Coron	Llyn Cwellyn	Llyn Cwmffynnon	Llyn Dinam	Llyn Glasfryn	Llyn Hsegyn	Llyn Hfir	Llyn Hiraethlyn	Llyn Nantlle Uchaf	Llyn Penrhyn	Llyn Traffwl	Llyn y Gader	Llyn y Garn	Ysceifiog Lake
<i>Alisma plantago-aquatica</i>								9							1				
<i>Batrachospermum</i> sp.							6			4		4					11		
<i>Callitriche brutia</i>																			25
<i>Callitriche hamulata</i>	7					8			11	33			24				23		
<i>Callitriche hermaphroditica</i>					3			37											
<i>Callitriche</i> sp.								4									10		
<i>Callitriche truncata</i>								21							33	53			
<i>Ceratophyllum demersum</i>		42	26		2			68	81						47	15			25
<i>Chara aspera</i>		28																	
<i>Chara globularis</i>			25		5			13							2	11			3
<i>Chara virgata</i>		19													7				
<i>Chara vulgaris</i> var. <i>papillata</i>					22														
<i>Elatine hexandra</i>						2	1		14										32
<i>Elatine hydropiper</i>					11			32	15				31	8	41				
<i>Eleocharis acicularis</i>			1		12			9					1		9				
<i>Eleogiton fluitans</i>																	9		

	Fynnonn Lloer	Kenfig	Llangeford Res.	Llangorse	Llyn Arenig Fawr	Llyn Coron	Llyn Cwellyn	Llyn Cwmffynnon	Llyn Dinam	Llyn Glasfryn	Llyn Hespyn	Llyn Hir	Llyn Hiraethlyn	Llyn Nantlle Uchaf	Llyn Penrhyn	Llyn Traffwll	Llyn y Gader	Llyn y Garn	Ysceifiog Lake
<i>Elodea canadensis</i>		40		21		11			12					21	13	16			10
<i>Elodea nuttallii</i>				71		8													
<i>Enteromorpha</i> sp.						13									12	7			20
<i>Fontinalis antipyretica</i>		8			1		5		10	3	7			5			1		83
<i>Hippuris vulgaris</i>																			32
<i>Hottonia palustris</i>																			48
<i>Isoetes echinospora</i>												31		9					
<i>Isoetes lacustris</i>	47				61		60	54				5	15				48	32	
<i>Isoetes</i> sp.														43					
<i>Juncus bulbosus</i>					3		35	24				15	36	1			79	10	
<i>Lemna minor</i>				10					11						5				22
<i>Lemna minuta</i>									5						5				
<i>Lemna trisulca</i>		32		46		12			39						5	5			47
<i>Littorella uniflora</i>	20	12			8	1	37	46	2		33	50	45	20		+	42	76	
Liverworts aquatic					42		2	14			4							1	
<i>Lobelia dortmanna</i>							65	76				57	86	5			54	63	
<i>Luronium natans</i>							2					12	4	27			33	17	
<i>Menyanthes trifoliata</i>		4		3					9	14								2	
Mosses aquatic					1									1					10
<i>Myriophyllum alterniflorum</i>		13					20	7		43	26	15	15	13			19	37	
<i>Myriophyllum spicatum</i>		42		28		44			19						1	1			
<i>Nitella flexilis</i> agg.	40	2		5			13	14	36	43		24		28		5	2	5	
<i>Nitella gracilis</i>																		2	
<i>Nitella opaca</i>									6										
<i>Nitella translucens</i>																	2		

	Fynnonn Lloer	Kenfig	Llangeford Res.	Llangorse	Llyn Arenig Fawr	Llyn Coron	Llyn Cwellyn	Llyn Cwmfynnon	Llyn Dinam	Llyn Glasfryn	Llyn Hsegyn	Llyn Hir	Llyn Hiraethlyn	Llyn Nantlle Uchaf	Llyn Penrhyn	Llyn Traffwl	Llyn y Gader	Llyn y Garn	Ysceifiog Lake
<i>Nitellopsis obtusa</i>				1															
<i>Nuphar lutea</i>				45					5	18	30				7				
<i>Nymphaea alba</i>				11					18	5					8		5	5	
<i>Nymphoides peltata</i>				20															
<i>Persicaria amphibia</i>		7		1					5	4					2				
<i>Pilularia globulifera</i>																	3		
<i>Potamogeton berchtoldii</i>		4			41				30					4	49	1			
<i>Potamogeton crispus</i>					3				3						1				
<i>Potamogeton gramineus</i>		1																	
<i>Potamogeton lucens</i>				14															
<i>Potamogeton x angustifolius</i>		3																	
<i>Potamogeton natans</i>		3							3									14	
<i>Potamogeton pectinatus</i>		2		17	19				13						5	31			
<i>Potamogeton perfoliatus</i>		7		5	11				1	1					6	17			
<i>Potamogeton polygonifolius</i>	3					1	2					7	4				1		
<i>Potamogeton pusillus</i>				4											33				7
<i>Potamogeton trichoides</i>		26			19				1										
<i>Ranunculus aquatilis</i> agg.					4				11					4			1		
<i>Ranunculus circinatus</i>		6		1	32														
<i>Ranunculus lingua</i>									1						1				
<i>Sparganium angustifolium</i>												2	1	9			23		
<i>Sparganium emersum</i>				2															
<i>Sphagnum</i> sp.					5	18	7				26	13	4				15		
<i>Spirodela polyrhiza</i>				16															
<i>Subularia aquatica</i>						4						23					2		

	Fynnonn Lloer	Kenfig	Llangeford Res.	Llangorse	Llyn Arenig Fawr	Llyn Coron	Llyn Cwellyn	Llyn Cwmffynnon	Llyn Dinam	Llyn Glasfryn	Llyn Hsegyn	Llyn Hir	Llyn Hiraethlyn	Llyn Nantlle Uchaf	Llyn Penrhyn	Llyn Traffwll	Llyn y Gader	Llyn y Garn	Ysceifiog Lake
<i>Utricularia minor</i>													1						
<i>Utricularia vulgaris</i> agg.								3									24		
<i>Zannichellia palustris</i>		1	+			10									4	26			5

6.2. Appendix II: Data Archiving

Data outputs associated with this project are archived in our document management system on server-based storage at Natural Resources Wales.

The data archive contains:

[A] The final report [NRW_Ecological_Surveys_of_Welsh_Lakes_2015_Final.doc] in Microsoft Word and Adobe PDF formats.

[B] Leafpacs calculator files within folder [NRW_2015_Leafpacs_Data] in Microsoft Excel format [Lake_name_LEAFPACS 2 0_metriccalculator_Month_Year] and summary information in MS Excel format [Site_metrics_Summary_2015.xls]

[C] A series of GIS layers and associated files in folder [NRW_2015_Bathymetry_Data] on which the bathymetric maps and data are based. A full description is given in Appendix 6.3.

[D] A full set of digital photographs from the surveys in [jpg] format.

[E] A species list for all sites in MS Excel format suitable for upload to Recorder [NRW_2015_Lake_Species_Data_Recorder.xls].

Metadata for this project is publicly accessible through Natural Resources Wales' Library Catalogue <http://194.83.155.90/olibcgi> by searching 'Dataset Titles'. The metadata is held as record no 116480.

6.3. Appendix III: Structure of Bathymetric Data

Bathymetric data were collected from Llyn Nantlle Uchaf and Llyn y Gader using the standardised methods detailed in Turner *et al.* (2011), CCW Contract Science Report No. 955.

6.3.1. Folder structure for bathymetric maps

The data are within folder: NRW_2015_Bathymetry_Data

All bathymetric data returned to NRW are stored in separate sub-folders named accordingly: **WBID_Name**, e.g. 34099_Llyn_Nantlle_Uchaf, where WBID is the UKLakes water body ID and Name is the accepted UKLakes water body name.

6.3.2. Bathymetric data folders

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

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

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

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



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