Cyfoeth Naturiol Cymru
Natural Resources Wales

Ecological Surveys of Welsh Lakes 2018

Goldsmith B, Stewart NF & Hatton-Ellis TW.

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1. Crynodeb Gweithredol

Aeth y prosiect hwn ati i gasglu, prosesu a chyflenwi data ecolegol ac amgylcheddol i CNC o rwydwaith o 19 o safleoedd llynnoedd ledled Cymru, a hynny er mwyn ategu rhaglen fonitro integredig CNC ar gyfer safleoedd gwarchodedig (Ardaloedd Cadwraeth Arbennig (ACA) a Safleoedd o Ddiddordeb Gwyddonol Arbennig (SoDdGA)), y Gyfarwyddeb Fframwaith Dŵr, y Gyfarwyddeb Nitradau, Cynlluniau Gweithredu Bioamrywiaeth, a sbardunau deddfwriaeth a pholisi eraill, gan gynnwys dyletswydd CNC o ran Rheolaeth Gynaliadwy ar Adnoddau Naturiol. Mae'r arolygon wedi'u hanelu'n arbennig at lywio'r gwaith o reoli ac adfer safleoedd gwarchodedig a hwyluso'r broses o gyflawni Cynlluniau Rheoli Basn Afon, yng nghyd-destun yr Argyfwng Hinsawdd sy'n datblygu.

Gan ddefnyddio dulliau safonol, arolygwyd llynnoedd i asesu rhywogaethau a helaethrwydd planhigion dyfrol sy'n tyfu yn y llynnoedd ac yn syth o'u hamgylch, ac er mwyn mesur claerder y dŵr, ocsigen toddedig a'r tymheredd yn y llynnoedd. Cafodd data cemeg ddŵr a gasglwyd ac a ddadansoddwyd gan CNC hefyd eu tynnu a'u crynhoi i ategu'r data macroffytau.

- Caiff y rhywogaethau planhigion dyfrol eu rhestru yn yr adroddiad a chanlyniadau cyfan yr arolwg a ddarparwyd i CNC ar ffurf taenlenni MS Excel.
- Cyflwynir cyfrifiadau at y defnydd dilynol o ganfod statws ecolegol y llynnoedd yng nghyswllt y Gyfarwyddeb Fframwaith Dŵr (LEAFPACS).

Mae canlyniadau'r arolygon o blanhigion dyfrol yn addas er mwyn asesu cyflwr safleoedd o safbwynt nodweddion dŵr llonydd y Gyfarwyddeb Gynefinoedd a statws SoDdGA. Mae metrigau'r llyn yn gymwys ar gyfer cynhyrchu cymarebau ansawdd ecolegol, y gellir eu defnyddio i ddosbarthu'r llynnoedd yn unol â gofynion y Gyfarwyddeb Fframwaith Dŵr (2000/60/EC).

Cafodd cyfanswm o 67 o rywogaethau planhigion dyfrol eu cofnodi o'r 19 o safleoedd llynnoedd, gan gynnwys nifer o rywogaethau prin a gwarchodedig. Mae'r adroddiad hwn yn cadarnhau sefydlogrwydd poblogaethau llyriad-y-dŵr arnofiol *Luronium natans* yn Llyn Cwellyn a Llyn Padarn, ac mae'n nodi manylion yr arolwg strwythuredig cyntaf o'r rhywogaeth hon yn Llyn Cwmorthin. Caiff dau gofnod newydd eu hychwanegu ynghylch rhawn yr ebol *Nitella gracilis*. Cofnodwyd gwybybyr wythfrigerog *Elatine hydropiper* mewn 3 safle yn y Gogledd Orllewin a chadarnhawyd gwair merllyn bychan *Isoetes echinospora* mewn dau lyn na chawsant eu harolygu'n flaenorol yng Ngheredigion (Llyn Rhosgoch a Llyn Blaenmelindwr).

O'r deuddeng safle llyn gwarchodedig (SoDdGA ac ACA) a arolygwyd, roedd hanner yn cynnal y niferoedd a dargedir o rywogaethau nodweddiadol, ond dim ond mewn dau safle (sef Llyn Cwellyn a Llyn Hîr) yr oedd y rhywogaethau hyn wedi'u cynrychioli â dwysedd ffafriol yn y safleoedd. Pan fu i safleoedd fethu â chyrraedd y targedau o ran macroffytau, yn aml roedd hynny i'w briodoli i oruchafiaeth rhywogaethau estron goresgynnol (e.e. Llyn Syfaddan, Llyn Padarn a Llyn Maelog) neu rywogaethau mwy cyffredinol fel cyrnddail *Ceratophyllum demersum* (e.e. Llyn Dinam, Pwll Cynffig a Llyn Glasfryn); rhywogaethau a hyrwyddir gan lefelau uwch o faethynnau yn y dŵr.

Cafodd tair cronfa ddŵr fawr ar gyfer cyflenwi dŵr eu harolygu. Oherwydd cyfanswm isel o law yn 2018, roedd llawer o alw am dynnu dŵr yn y safleoedd hyn ac roedd pob un ohonynt fwy na 10 m yn is na lefel uchaf y dŵr. Golyga hynny eu bod yn anaddas ar gyfer twf planhigion dyfrol ac felly nad yw'r data'n addas at ddibenion dosbarthu o dan y Gyfarwyddeb Fframwaith Dŵr.

2. 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 including NRW's Sustainable Management of Natural Resources (SMNR) duty. In particular the surveys are aimed at informing management and restoration of protected sites and facilitating delivery of River Basin Management Plans, in the context of the developing Climate Emergency.

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. Water chemistry data collected and analysed by NRW was also extracted and summarised in support of the macrophyte data.

- The aquatic plant species are listed within the report and the complete survey results supplied to NRW as MS Excel spreadsheets.
- Calculations are presented for the onward use of determining the ecological status of the lakes with respect to the Water Framework Directive (LEAFPACS).

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).

A total of 67 aquatic plant species were recorded from the nineteen lakes sites including a number of rare and protected species. This report confirms the stability of floating water-plantain *Luronium natans* populations at Llyn Cwellyn and Llyn Padarn and details the first structured survey of this species at Llyn Cwmorthin. Two new records are added for the Slender stonewort *Nitella gracilis*. Eight-stamened water wort *Elatine hydropiper* was recorded at 3 sites in north-west Wales and spring quillwort *Isoetes echinospora* confirmed at two previously un-surveyed lakes in Ceredigion (Llyn Rhosgoch and Llyn Blaenmelindwr).

Of the twelve protected lake sites (SSSI and SAC) surveyed, half supported target numbers of typical species, but at only two sites (Llyn Cwellyn, Llyn Hîr) were these species represented at favourable density within the sites. Where sites failed to meet the macrophytes target, it was often due to the dominance of non-native invasive species (e.g. Llangorse Lake, Llyn Padarn and Llyn Maelog) or more generalist species such as Rigid hornwort *Ceratophyllum demersum* (e.g. Llyn Dinam, Kenfig Pool and Llyn Glasfryn); species that are promoted by increased nutrient levels in the water.

Three large water-supply reservoirs were surveyed. Low rainfall in 2018 resulted in high abstraction demand at these sites and all were in excess of 10 m below top water level, making them unsuitable for aquatic plant growth and hence the data are not suitable for WDF classification.

3. Introduction

3.1. Background

Natural Resources Wales (NRW) is responsible for the management and monitoring of the freshwater environment in Wales including protected sites designated under UK and European legislation (SSSIs and SACs) and environmental monitoring for the Water Framework (WFD) and Nitrates Directives. This includes monitoring of lakes.

A key aspect of the structure and function of lakes is their aquatic plant community. Lake plant communities are considered defining aspects when identifying lake types (e.g. European Community 1992; Duigan *et al.* 2006; Hatton-Ellis 2014) and play an important role in providing habitat structure for other biota (Jeppesen *et al.* 1998). Lake plants are also important indicators of pressures on the freshwater environment, especially eutrophication (Willby *et al.* 2010; WFD-UKTAG 2014) and to a lesser extent acidification (Shilland & Monteith 2010). For these reasons, aquatic plants are widely used in Britain for monitoring against several different drivers, notably the Habitats Directive and Water Framework Directive. Although data are analysed differently, monitoring for the two Directives uses a single standardised protocol (JNCC 2015).

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) to monitor and evaluate the status of standing waters. Using standard methods to collect the data (JNCC 2005; 2015), lakes can be assessed against their type and location to derive site condition status and also to calculate metrics which allow WFD classification. The same data is also used to assess the condition of the plant community for nature conservation (JNCC 2015).

3.2. 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 lakes. Other relevant data (notably water chemistry) is being collected separately and will be used in combination with the data collected here to generate condition assessment reports for protected sites and classification data for Water Framework Directive monitoring. Indicative element level classifications based on the LEAFPACS tool have been generated, although it is possible that these may be amended following internal checks and / or combining survey data, so these should not be seen as final classification results.

Detailed descriptions of most of the lakes surveyed including water chemistry, environmental history and other parameters of interest can be found in Burgess *et al.*

(2006, 2009, 2013) and Goldsmith *et al.* (2006, 2010, 2014) and are not repeated here.

Of the 19 lakes surveyed for this report, all but four have had at least one CSM survey conducted in the past, thus allowing for comparisons to be drawn and possible improvement or decline in the aquatic flora of a site. At Llyn Cwmorthin, Llyn Rhosgoch, Llyn Syfydrin and Llyn Blaenmelindwr no previous structured data exists, the surveys provide a valuable insight into the current status of the lakes and a baseline against which future surveys can be compared. It should be stressed that data presented here are based only on macrophytes and additional information on water quality is required to fully assess the condition of the lakes under CSM guidance (JNCC 2015).

4. Methods

4.1. Sites

Table 1 provides details of the 19 lakes included in this report (See Figure 1 for locations), 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 current JNCC guidance (JNCC 2015).

Lake Name	WBID	Grid ref.	Purpose of survey*	Survey date	Lake Type**
Llyn Cadarn	32792	SH492811	HD	17/09/2018	HC
Llyn yr Wyth Eidion	32761	SH474819	HD	17/09/2018	HC
Llyn Dinam	32948	SH311776	HD & WFD	19/09/2018	NE
Llyn Traffwll	32964	SH326770	SSSI	20/09/2018	NE
Llyn Maelog	33160	SH326730	SSSI	18/09/2018	NE
Llyn Cwellyn	34002	SH560549	HD & WFD	28/09/2018	OML
Llyn Padarn	33730	SH569615	SSSI	30/09/2018	OML
Llyn Cwmorthin	34397	SH677464	BIO	29/09/2018	Unknown
Llyn Glasfryn	34622	SH403422	SSSI	21/09/2018	OML
Llyn Hîr	38394	SN789676	HD & WFD	01/10/2018	OML
Llangorse Lake	40067	SO132264	HD & WFD	03/10/2018	NE
Llyn Pencarreg	39303	SN537456	SSSI	02/10/2018	OML
Kenfig Pool	42170	SS797816	HD & WFD	03/10/2018	HC
Llyn Blaenmelindwr	37777	SN715836	BIO	30/09/2018	Unknown
Llyn Rhosgoch	37793	SN713831	BIO	28/09/2018	Unknown
Llyn Syfydrin	37743	SN723847	BIO	29/09/2018	Unknown
Caban-Coch Reservoir	38419	SN917633	WFD	02/10/2018	AWB
Claerwen Reservoir	38427	SN851651	WFD	01/10/2018	AWB
Llandegfedd Reservoir	41363	ST329997	WFD	04/10/2018	AWB

Table 1 Details of the lakes included in this report.

*Purpose: HD = Habitats Directive; SSSI = Site of Special Scientific Interest; WFD = Water Framework Directive; BIO = Priority Biodiversity habitat.
**Lake Type: HC = Hard oligo-mesotrophic waters, OML = Oligo-mesotrophic waters, NE = Natural eutrophic waters, D = Dystrophic, AWB = Artificial water body (Reservoirs).

4.2. Aquatic Macrophyte Surveys

The full description of the survey methods used to collect macrophyte data are detailed in the Joint Nature Conservation Committee publication for the CSM guidance for standing waters (JNCC 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 macrophyte colonisation. 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. To reduce disturbance, a maximum of 25% of the shoreline was surveyed, resulting in fewer than four sections being surveyed at smaller lakes and conversely, larger lakes had up to six sections completed to ensure representative coverage was achieved.

Where possible, surveying was performed using a bathyscope, but a double-headed rake was used in deeper water, where material needed to be collected for identification, or where poor water clarity restricted visibility. Where lakes had previously been surveyed, transect locations used in the past were re-surveyed in order to maximise comparability between surveys. The locations of all survey sections and boat transects were recorded using a Global Positioning System (GPS), backed up with digital photographs where necessary. In 2017 representative underwater digital photographs were also taken in each section where possible. The grid references and photo numbers of survey sections are listed in Appendix 7.2.

Figure 1. Map of Wales showing the location of the 2018 survey 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. Although they do not produce a complete species list for a lake, comparison with a more thorough mapping approach generally show that the transect method consistently detects >90% of the macrophyte species richness within a lake (e.g. Burgess *et al.* 2009). Additional efforts such as sampling drift line flora were made to record species which did not occur in the survey sections.

The CSM aquatic macrophyte surveys, upon which the data assessments in this report are based, were carried out during September and early October 2019 (see Table 1; Figure 1). *In-situ* macrophyte identifications were made by Ben Goldsmith or Nick Stewart. Sites where Floating water Plantain (*Luronium natans*) occurs were surveyed under NRW Protected Species Licence 76427:OTH:SP:2017 (B. Goldsmith). Voucher specimens were collected for any taxonomically ambiguous species and identifications confirmed either from fresh materials (usually in the evening of the survey) or at a later date from pressed specimens. Vouchers of charophytes and *Utricularia* were preserved in alcohol and examined by Nick Stewart (BSBI Charophyte Referee and expert on aquatic botany) for confirmation. Quality control was performed in-house with reference to previously collected herbaria specimens. Botanical nomenclature follows Stace (1997) for higher plants, Moore (1986) for Stoneworts (updated by N. Stewart, pers. comm.) and Atherton *et al.* (2010) for bryophytes.

All field data were recorded onto standard forms printed onto waterproof paper and transcribed into standard MS Excel spreadsheets designed to calculate values for the following metrics (see Willby *et al.* 2010 and WFD-UKTAG 2014):

- Lake Macrophyte Nutrient Index (LMNI)
- Number of Functional Groups (NFG)
- Number of Macrophyte Taxa (NTAXA)
- Mean per cent cover of hydrophytes (COV)
- Relative per cent cover of filamentous algae (ALG)

In addition the following observations and metrics were recorded (JNCC, 2015):

- Maximum depth of macrophyte colonisation (MAXD)
- Number of typical taxa for habitat type (NTYP) based on JNCC CSM guidance (2015)
- Relative per cent cover of non-native species (INV)

The relative per cent cover of invasive alien macrophyte species (INV, Willby *et al.* 2010) is expressed relative to the overall COV score. The full list of these species in given in Willby *et al.* (2010).

4.3. 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 Pro20 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 centimetres.

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 new UK Lakes administered by CEH (CEH 2018). Ordnance Survey maps are taken from OS OpenData™ (© Crown copyright 2019) and Aerial photographs from either Bing Maps (© Microsoft 2019) or Google Maps (© Google 2019).

The summer of 2018 was unusually hot and dry in Wales, especially during June and July (Met Office 2018), with many areas experiencing less than 20% of the normal average during June. This resulted in reservoir sites having much more drawdown than usual, and potentially could also have affected the plant community. This is discussed further in the results and the Discussion.

4.4. Water Chemistry

Water chemistry data for CSM Assessments was extracted from NRW's WIMS database and analysed against relevant CSM Targets for the relevant lake type (JNCC 2015). Only nutrients (phosphorus and where available, nitrogen) and acidity (ANC and / or pH) were examined in detail; acidity was only assessed in lakes considered likely to be acid sensitive (i.e. with an alkalinity <100 µeq l^{-1}). Note that water chemistry targets reflect the latest JNCC guidance, which may not always correspond with the published targets in NRW's SAC Core Management Plans, as these have not yet been updated.

The water chemistry assessments here are generally based on WFD standards and should therefore reflect these, though as with the macrophyte data, these are not formal classification results and should be read in this context. They will however help to provide greater insight into the results of past and future WFD classifications for relevant water bodies.

4.5. Element Level WFD Classification Results

For interpretation purposes we have reported element level WFD classification results together with a short commentary on each classification. These are published for comparative purposes, in particular so that LEAFPACS results can be compared with the accounts of the data. LEAFPACS results have been published both for WFD water bodies and lakes that are not WFD water bodies, though in the latter case this result is illustrative only. Nevertheless, LEAFPACS results can be useful in these situations to help identify nutrient pollution issues.

It should be emphasised that since these are based herein on the LEAFPACS tool, they do not represent final NRW water body classifications, which will be carried out separately according to the formal classification processes. It is also possible that the final macrophyte classification may change, for example as a result of additional survey data or changes to the method.

LEAFPACS is only designed to measure nutrient pressures (eutrophication). The tool mainly does this using the Lake Macrophytes Nutrient Index (LMNI) a trophic ranking approach that assigns a nutrient score to each aquatic plant species found in the UK. Scores for each species found in the lake are averaged to give an LMNI score and this is then compared to a predicted score for the lake based on reference conditions. Four other metrics, NTaxa, Number of Functional Groups (N_FG), Cover (COV) and filamentous algal cover (ALG) are also used but these play a subsidiary role.

Of the other key pressures on lakes, the tool is uninformative for assessing acidification. Macrophyte invasive species have been detected using the tool and text on these has been included in the individual lake accounts to help guide management. Hydrological pressures (i.e. water level fluctuation associated with abstraction) can cause large changes to aquatic plant communities resulting in failures of LEAFPACS. In general these can be detected because (i) very few species are present and / or (ii) metrics other than LMNI are causing LEAFPACS failures. Where water bodies are Heavily Modified, likely reasons for any failures are discussed in the text.

5. Survey Results and Metrics.

5.1. Lake metrics

The following table summarises the results of the aquatic macrophyte-derived metrics and limnological data. A full species list for each site is given in Appendix 7.1.

Site	LMNI	NTAXA	NFG	COV	ALG	INV	MAXD	NTYP	Secchi
Llyn Cadarn	6.69	7	4	7.12	0.00	0.00	3.5	0	2.20
Llyn yr Wyth Eidion	6.03	8	6	10.78	0.12	0.00	3.6	0	3.80
Llyn Dinam	6.76	27	14	3.72	0.19	1.16	1.4	8	0.65
Llyn Traffwll	6.84	17	11	1.84	0.06	0.42	1.9	4	1.00
Llyn Maelog	7.21	11	8	5.53	0.15	3.85	2.4	4	0.85
Llyn Cwellyn	3.61	14	7	5.15	0.04	0.00	5.2	6	5.90
Llyn Padarn	4.56	13	10	3.77	0.07	2.42	6.2	3	3.75
Llyn Cwmorthin	3.56	14	8	6.39	0.30	0.00	4.3	N/A	4.60
Llyn Glasfryn	5.92	12	8	8.05	0.02	0.00	1.15	1	0.65
Llyn Hîr	3.57	13	8	6.18	0.49	0.00	3.1	5	3.10
Llangorse Lake	7.05	23	10	4.75	0.15	7.84	3.1	4	1.80
Llyn Pencarreg	3.46	4	3	9.32	0.00	0.00	1.7	3	1.80
Kenfig Pool	5.85	23	10	4.38	0.22	3.01	2.8	3	1.40
Llyn Blaenmelindwr	3.66	15	10	4.19	0.09	0.00	3.0	N/A	2.40
Llyn Rhosgoch	3.40	13	8	6.87	0.37	0.00	1.2	N/A	>1.20
Llyn Syfydrin	3.57	6	4	1.65	0.01	0.00	1.6	N/A	0.80
Caban-Coch Reservoir	2.42	1	1	0.00	0.00	0.00	0	N/A	1.50
Claerwen Reservoir	3.25	2	2	1.00	0.00	0.00	0	N/A	1.45
Llandegfedd Reservoir	5.79	5	5	1.07	0.00	0.63	0	N/A	2.45

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

5.2. Sites

5.2.1. Llyn Cadarn

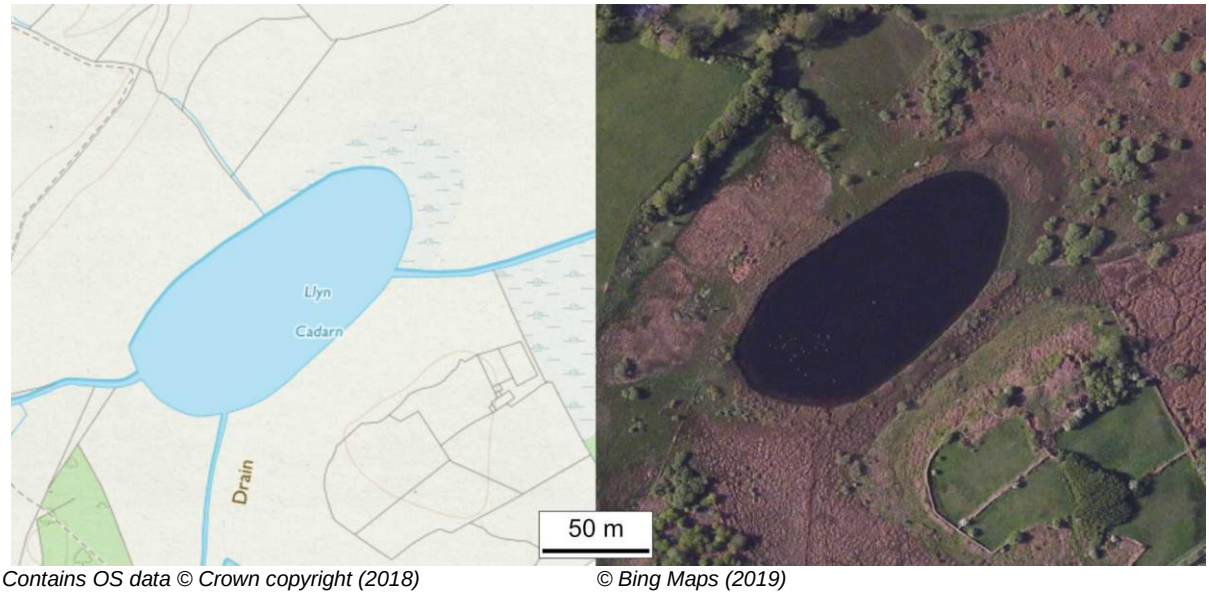

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Figure 2. Site map and aerial photograph of Llyn Cadarn.

Figure 3. Llyn Cadarn site photo; from the south side looking northwest.

Llyn Cadarn is a very small (1 ha), shallow (mean depth 4.6 m) high alkalinity lowland lake located on the Isle of Anglesey, North Wales. It lies within the Cors Goch SSSI and NNR and Corsydd Môn/ Anglesey Fens SAC. The catchment is predominantly improved grassland but the lake itself lies within an area of alkaline fen and is surrounded on all sides by reeds, in an assemblage dominated by *Typha angustifolia, Phragmites australis* and *Cladium mariscus*. The lake was cored in 2007 by Davidson *et al.* (2009) in order to explore the aquatic vegetation history of the site.

The aquatic flora (Table 3) is characterised by a floating layer of *Nuphar lutea* (Figure 4a) extending to a maximum recorded depth of 3.5 m, with occasional *Nymphaea alba* (1-2 m), underneath which there is a relatively spare cover of *Lemna trisulca* with the moss *Fontinalis antipyretica* occurring mainly within the reed beds. No plants were recorded growing deeper than 3.5 m, which is a reduced depth to that recorded in 2016 (4.9. m, Shilland *et al.* 2017).

The previous two CSM surveys have recorded a single locality for *Chara rudis* within the site (Goldsmith *et al.* 2014a and Shilland *et al.* 2017). The same location was searched extensively in 2018, but no *Chara* species were found. There are no alien invasive aquatic macrophyte species present and levels of filamentous algae are low.

Submerged and floating vegetation	% cover 2016	%Cover 2018
Chara rudis	**1.0**	**0**
Chara vulgaris	1.0	0
Fontinalis antipyretica	3.8	6.2
Lemna minor	1.0	2.9
Lemna trisulca	18.2	13.7
Nymphaea alba	4.0	1.1
Nuphar lutea.	16.9	23.9
Menyanthes trifoliata	2.1	1.9
Utricularia minor.	1.0	0
Species richness	**9**	**6**

Table 3. CSM Survey LEAFPACS cover results from Llyn Cadarn 2016 and 2018.

Llyn Cadarn had none of the JNCC (2015) characteristic species for “hard oligo-mesotrophic waters with benthic vegetation of Chara spp” in 2018. The lake therefore continues to fail the target for this lake type. No fine or broad leaved *Potamogeton* sp. were found in the current survey, nor any of the other historically present *Chara* species, thus there is no evidence that the site is making progress towards the reference conditions established by Davidson *et al.* (2009). It is recommended that efforts to reduce the nutrient inputs to Llyn Cadarn are continued (Hatton Ellis 2014).

The site has been subject to cattle grazing in 2018, resulting in quite extensive loss of marginal reeds around the south and western shore of the lake (Figure 4a). The resulting reduction in shading may help to facilitate the growth of submerged plants in the littoral zone, including charophytes.

a.) b.)

Figure 4 a.) Sparse band of *Nuphar lutea* and b.) area of heavily grazed reed at Llyn Cadarn

Dissolved oxygen and temperature profiles showed Llyn Cadarn to be mixed at the time of sampling and with no thermocline evident. Dissolved oxygen remained high throughout the water column (Figure 5) This is a very similar result to the profiles

performed on 11/07/08 and 10/08/11 during previous surveys. The Secchi depth was 2.2 m on 18/09/2018, possibly compromised slightly by windy conditions.

Dissolved Oxygen Profile

GPS Location	SH4920581114
Maximum Depth (m)	6.2 m
Secchi Depth (cm)	220 cm
Notes:	

Depth (m)	DO (mg/l)	Temp (°C)
0	8.75	15.9
0.5	8.76	15.9
1	8.79	15.9
1.5	8.74	15.9
2	8.7	15.9
2.5	8.71	15.9
3	8.65	15.9
3.5	8.62	15.9
4	8.56	15.9
4.5	8.54	15.9
5	8.52	15.9
5.5	8.51	15.9
6	8.49	15.9

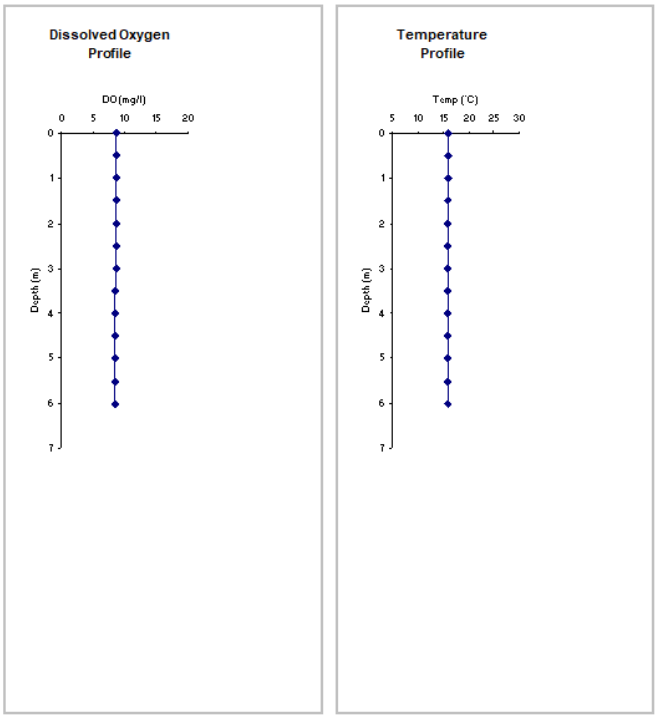

Figure 5. Dissolved oxygen and temperature profiles at Llyn Cadarn (18/09/2018).

Water Quality

Limited recent NRW monthly water quality data for the lake are available, from between January and May 2016. Over this period the lake had a weakly alkaline mean pH of 8.0, and a mean alkalinity of 3492 µg l^{-1}. The water was relatively coloured (Mean colour = 21.5 Pt Units), reflecting the presence of peat in the catchment. However, this level of colour is not consistent with the previous status of this lake as a marl depositing lake.

Total oxidised nitrogen concentrations varied widely with a peak of 2.1 mg l^{-1} in January, compared with 0.76 mg l^{-1} in May. These values are a likely contributor to the very poor status of the plant community. Phosphorus mean concentrations of 20.6 µg l^{-1} were also somewhat above the recommended concentration for this lake type. Chlorophyll levels were relatively high, with a mean of 9.9 across the five samples including a peak of 25.6 µg l^{-1} on 8 March.

Although the available water quality data are insufficient to draw firm conclusions, they provide important context for the plant survey data and reinforce previous impressions that peat erosion from surface water input and nutrients are damaging Llyn Cadarn. Further data collection has commenced and possibilities for ending or diverting the surface water inflow should be investigated.

Overall Condition

Macrophyte data indicates that Llyn Cadarn is in **Unfavourable - Bad Condition** with **High** confidence, though more water quality data is required to give a better understanding of the drivers for this. Further investigation of the impact of the surface water inputs draining to the lake is required.

5.2.2. Llyn yr Wyth Eidion

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Figure 6. Site map and aerial photograph of Llyn yr Wyth Eidion.

Figure 7. Llyn yr Wyth Eidion site photo; from the west side, looking north.

Llyn yr Wyth Eidion a very small (1 ha), moderately shallow (mean depth 6 m) but steeply shelving, lowland glacial kettle-hole lake located on the Isle of Anglesey, North Wales. It forms part of the Cors Erddreiniog NNR and SSSI and Corsydd Môn/ Anglesey Fens SAC. Similar to the nearby Llyn Cadarn, the catchment is predominantly improved grassland but the lake itself sits within an alkaline fen.

The aquatic macrophyte flora (Table 4) is dominated by beds of *Nuphar lutea,* interspersed with *Nymphaea alba,* above an abundant carpet of the aquatic moss *Fontinalis antipyretica.* The *N. lutea* and *F. antipyretica* both extend to a maximum depth of 3.6 m, whereas *N. alba* only to 2.1 m. *Potamogeton berchtoldii* was present within the littoral zone and there are also patches of *Hippuris vulgaris*. A floating-leaved aquatic *Sparganium* sp. is also present, recorded mainly at depths of 1-2 m at the point where the lake shelves steeply. This is most likely to be *S. emersum*, but no inflorescences were found during the survey to enable identification to species level.

Lemna minor and *Lemna trisulca* were both recorded in the previous survey (Shilland *et al.* 2017), but not in 2018. The lack of *L. minor* can be explained by the high winds during and preceding the survey, but the absence of *L. trisulca* is more surprising. No alien invasive aquatic macrophyte species are present and levels of filamentous algae remain relatively low.

Submerged and floating vegetation	% cover 2016	% cover 2018
Callitriche sp.	1.8	0
Fontinalis antipyretica	19.7	29.8
Hippuris vulgaris	4.7	6.0
Lemna minor	3.0	0
Lemna trisulca	6.4	0
Menyanthes trifoliata	1.4	1.4
Nuphar lutea	20.2	19.3
Nymphaea alba	12.1	12.6
Potamogeton berchtoldii	4.9	2.8
Sparganium (aquatic indet.)	2.1	3.9
Species richness	**10**	**7**

Table 4. CSM Survey LEAFPACS cover results Llyn yr Wyth Eidion 2016 and 2018.

The maximum depth of colonisation, at 3.6 m for *Nuphar lutea* and *Fontinalis antipyretica* in Section 1, is considerably shallower than that of other recent surveys of the site, with plant previously recorded at a maximum depth of 5.7 m in 2008 (Burgess *et al.* 2013), 5.5 m in 2013 (Goldsmith *et al.* 2014a) and 4.8 in 2016 (Shilland *et al.* 2017).

The current species assemblage, with all qualifying characteristic species being absent, would place the site in unfavourable condition with respect to its flora under JNCC CSM Guidelines (JNCC 2015) for Hard oligo-mesotrophic waters with benthic stoneworts (*Chara* spp.). No *Chara* species or broad-leaved *Potamogeton* species were recorded in the 2018 survey, with *Chara virgata*, *Chara vulgaris*, *Potamogeton perfoliatus* and *Potamogeton crispus* last found in the survey of 2003 (Goldsmith *et al.*, 2006) and absent from subsequent surveys in 2008 (Burgess *et al.* 2013) and 2013 (Goldsmith *et al.* 2014a) and 2016 (Shilland *et al.* 2017). The successive reduction in the maximum depth of macrophyte colonisation should also give cause for concern. It is recommended that efforts to reduce the nutrient inputs to Llyn yr Wyth Eidion are continued (Hatton-Ellis 2014 and 2016).

No alien invasive aquatic macrophyte species are present but levels of filamentous algae are relatively high.

The dissolved oxygen and temperature profile at Llyn yr Wyth Eidion showed the lake to be mixed in late-September, with only a slight decline in dissolved oxygen concentrations and temperature observed with increasing depth (Figure 8). Under calmer summer conditions the site has shown thermal stratification between 6-7 m, below which DO drops to almost zero (Shilland *et al.* 2017, Monteith, (ed.) 1997).

Dissolved Oxygen Profile

GPS Location	SH4741681883
Maximum Depth (m)	9.2 m
Secchi Depth (cm)	380 cm

Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	9.56	15.9
0.5	9.55	15.9
1	9.25	15.9
1.5	8.87	15.8
2	8.29	15.8
2.5	8.21	15.7
3	7.96	15.5
4	7.88	15.3
5	7.78	15.2
6	7.6	14.9
7	6.89	14.7
8	6.28	14.6
8.5	6.26	14.5

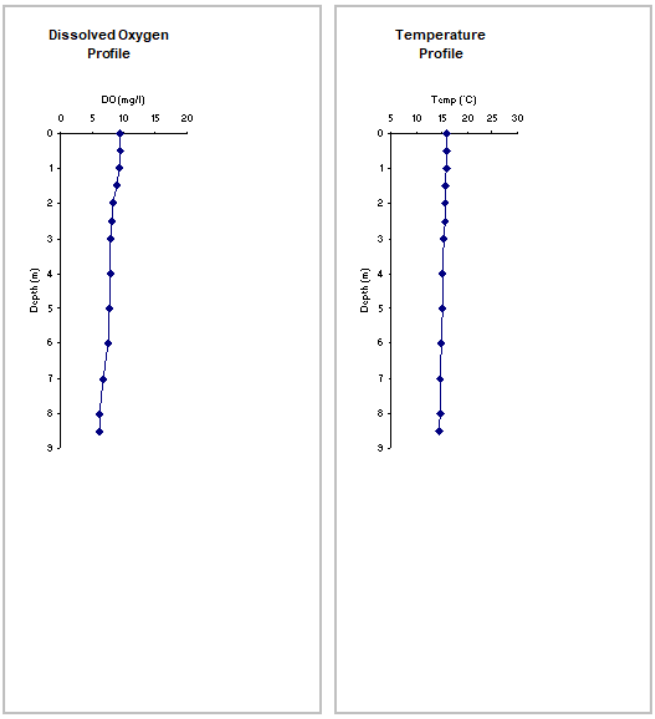

Figure 8. Dissolved oxygen and temperature profiles at Llyn yr Wyth Eidion (18/09/2018).

Water Quality

Limited recent NRW monthly water quality data for the lake are available, from between January and June 2016. Llyn yr Wyth Eidion had a weakly alkaline mean pH of 7.9, and a mean alkalinity of 4224 µg l^{-1}.

Total oxidised nitrogen concentrations varied widely with a peak of 2.24 mg l^{-1} in January, compared with 0.43 mg l^{-1} in May. These values are a likely contributor to the very poor status of the plant community. Phosphorus mean concentrations of 14.3 µg l^{-1} were also within target levels, though it should be stressed that this is a very small dataset. Chlorophyll levels were low, but do not cover the period when algal blooms are most likely (late summer).

Although the available water quality data are insufficient to draw firm conclusions, they provide useful context for the plant survey. Further data collection has commenced and possibilities for ending or diverting the surface water inflow should be investigated.

Overall Condition

Macrophyte data indicates that Llyn yr Wyth Eidion is in **Unfavourable-Bad Condition** with **High** confidence, though more water quality data is required to give a better understanding of the drivers for this. Previous recommendations to divert the artificial surface water inflow should be implemented.

5.2.3. Llyn Dinam

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Figure 9. Site map and aerial photograph of Llyn Dinam.

Figure 10. Llyn Dinam site photo; from the north shore looking south.

Llyn Dinam is a very shallow (max. 1.9 m), naturally eutrophic lake lying 1.5 km from the coast of western Anglesey within the Llynnau 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 5). 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,* two small patches of *Littorella uniflora* in S3 & S4 (Figure 11a), and the occurrence of *Potamogeton lucens* in the standline material of S3 (Figure 11b). The latter species was recorded from Llyn Dinam by Seddon (1972) in the 1960's, and was more

recently seen nearby in Llyn Penrhyn (Lansdowne 2013), but there are no other recent records from the site.

Submerged and floating vegetation	% Cover 2015	% Cover 2018
Azolla filiculoides	0.00	0.74
Callitriche hermaphroditica	**6.32**	**3.18**
***Callitriche* sp.**	**0.32**	**0.10**
Callitriche truncata	**1.76**	**1.58**
Ceratophyllum demersum	10.06	15.23
Chara globularis	**1.64**	**5.00**
Elatine hydropiper	3.26	2.09
Eleocharis acicularis	0.49	0.98
Elodea canadensis	2.42	1.00
Filamentous algae	0.14	19.45
Fontinalis antipyretica	0.99	5.03
Lemna minor	1.45	0.09
Lemna minuta	0.62	2.56
Lemna trisulca	4.74	10.45
Littorella uniflora	**0.12**	**0.89**
Menyanthes trifoliata	3.81	2.93
Myriophyllum spicatum	1.47	12.01
Nitella flexilis agg.	6.40	6.79
Nitella opaca	1.67	0.00
Nuphar lutea	0.39	0.00
Nymphaea alba	2.01	6.55
Persicaria amphibia	2.60	0.41
Potamogeton berchtoldii	3.88	0.05
Potamogeton crispus	**0.86**	**0.00**
Potamogeton lucens	**0.00**	**0.71**
Potamogeton natans	0.11	0.00
Potamogeton obtusifolius	**0.71**	**0.09**
Potamogeton pectinatus	1.11	0.12
Potamogeton perfoliatus	**0.37**	**0.77**
Potamogeton trichoides	0.02	0.00
Ranunculus aquatilis agg.	0.74	0.14
Ranunculus lingua	0.18	1.45
Species richness	**29**	**26**

Table 5 CSM Survey LEAFPACS cover results from Llyn Dinam 2015 and 2018

While Llyn Dinam maintains a relatively species rich flora, it is dominated by *Ceratophyllum demersum* and lacks the abundance of broad-leaf *Potamogeton* species and other characteristic species one expects to see in natural eutrophic sites in favourable condition. In addition to *Potamogeton lucens,* a few plants of *P. perfoliatus* were recorded in 2018, but the *P. crispus* seen in 2015 (Goldsmith *et al.* 2016) was absent. The 2018 survey was conducted in September, after many of the fine-leaved macrophytes and stoneworts had begun to senesce, making identification of some species problematic.

The presence of non-native invasive species *Azolla filiculoides* and *Lemna minuta,* is unfavourable under CSM guidelines. These species are unlikely to become

established in open water due to wind-stress, but they do pose a threat to small, sheltered pools within the extensive reed swamp to the south and east of the lake. *Elodea canadensis* is present, but remains at low cover values.

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 Burgess *et al.* 2006) and the presence on non-native species is unfavourable. Water clarity was also very poor in 2015 and 2018 (Secchi depths of 0.75 m and 0.65 m).

b)

Figure 11. a) *Littorella uniflora* (S3 at lake edge and b) strandline material from S3, including *Potamogeton lucens.*

The site is very shallow and exposed and at the time of survey the water was well oxygenated (Figure 12).

Dissolved Oxygen Profile

GPS Location	SH3097877444
Maximum Depth (m)	1.7 m
Secchi Depth (cm)	65 cm

Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	8.65	16
0.5	8.69	16
1	8.64	15.9
1.5	8.62	15.9

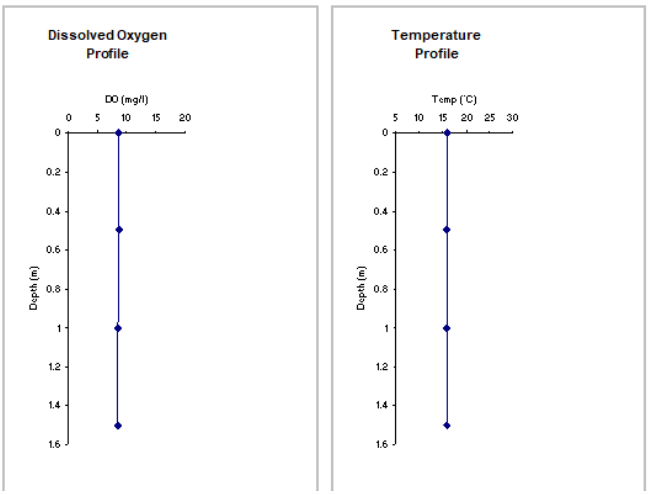

Figure 12. Dissolved oxygen and temperature profiles at Llyn Dinam (19/09/2018).

Water Quality

Fifty-three water samples have been collected from Llyn Dinam at Sample point 29161 between January 2015 and March 2019. These had a mean pH of 7.92 and

mean alkalinity of 1536 µg l^{-1}. The focus of this analysis is on nutrients, as the lake is not acid sensitive.

Total Phosphorus

Two samples with anomalous high TP readings were removed from the dataset. Total Phosphorus values in Llyn Dinam were high and well above the target value of 50 µg l^{-1} (CCW, 2008), generally fluctuating around 80-100 µg l^{-1}. Geometric Annual Mean TP Values were: 2015: 89 µg l^{-1}; 2016: 87 µg l^{-1}; 2017: 80 µg l^{-1} and 2018: 99 µg l^{-1}. No clear trend in TP is evident over this timescale, though there does appear to have been a gradual increase in TP at this site over the longer term.

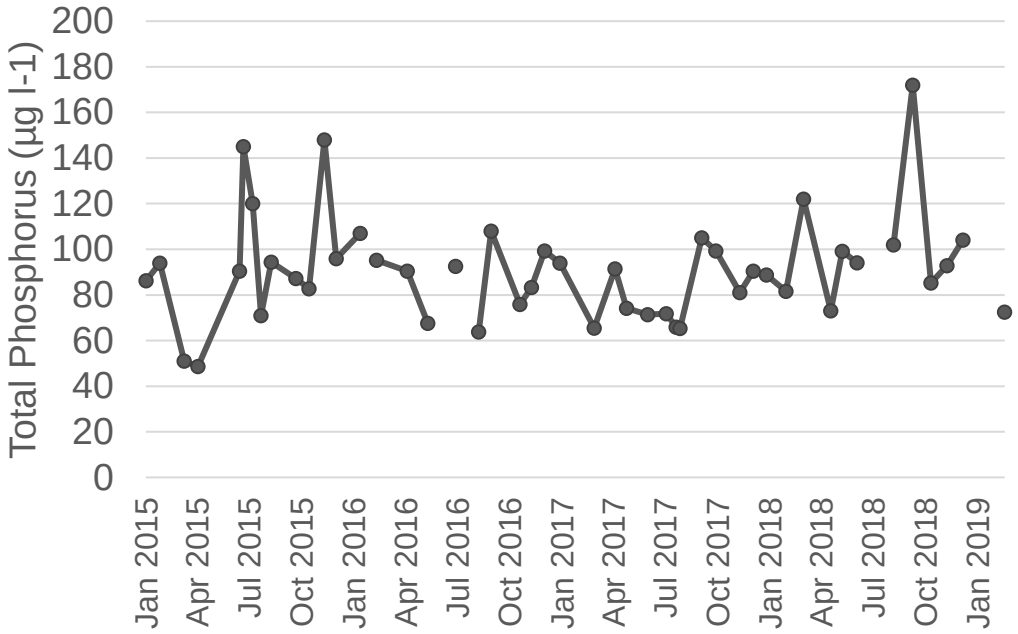

Figure 13. Total phosphorus concentrations in Llyn Dinam, 2015-2019.

Total Oxidised Nitrogen

Forty TON samples were available between January 2016 and March 2019. Nitrogen concentrations in Llyn Dinam were consistently low to very low for a lowland lake, reflecting the small catchment with limited agricultural inputs. A single high reading of 4.38 from February 2016 was considered anomalous and not used. Winter nitrogen concentrations rarely exceeded 1 mg l-1, whilst summer N concentrations were generally below the limit of detection, suggesting that the lake is nitrogen limited during the growing season.

Chlorophyll

Chlorophyll concentrations in Llyn Dinam are comparatively high, with an overall mean of 14.8 µg l^{-1} and peaks of up to 60 µg l^{-1}. Peaks generally occur in spring, coinciding with the steep springtime decline in nitrogen concentrations. There is no evidence of increased phytoplankton in the hot summer of 2018.

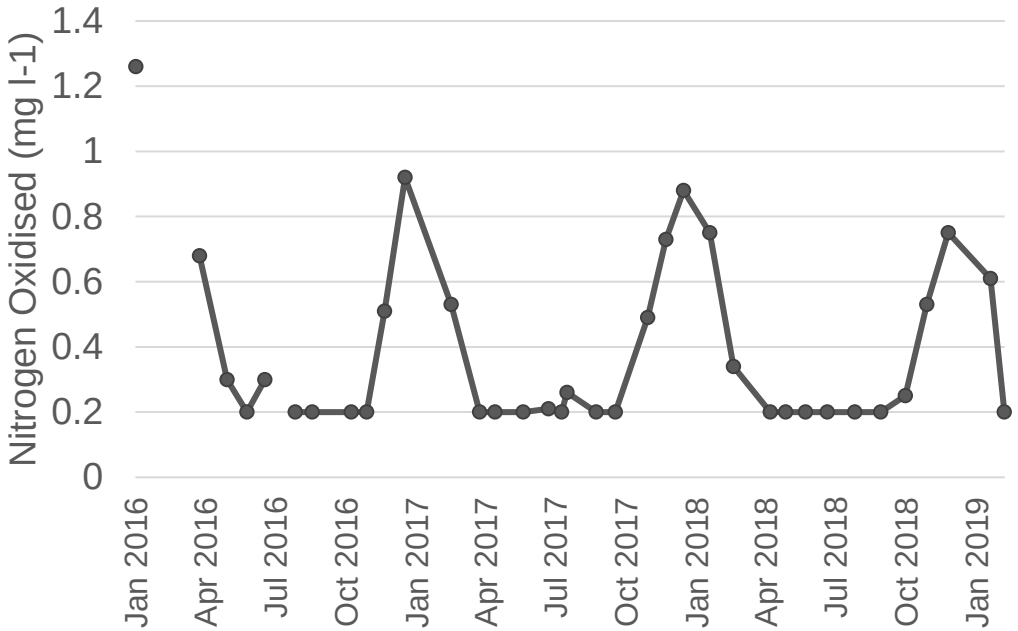

Figure 14. Total oxidised nitrogen concentrations in Llyn Dinam, 2016-2019.

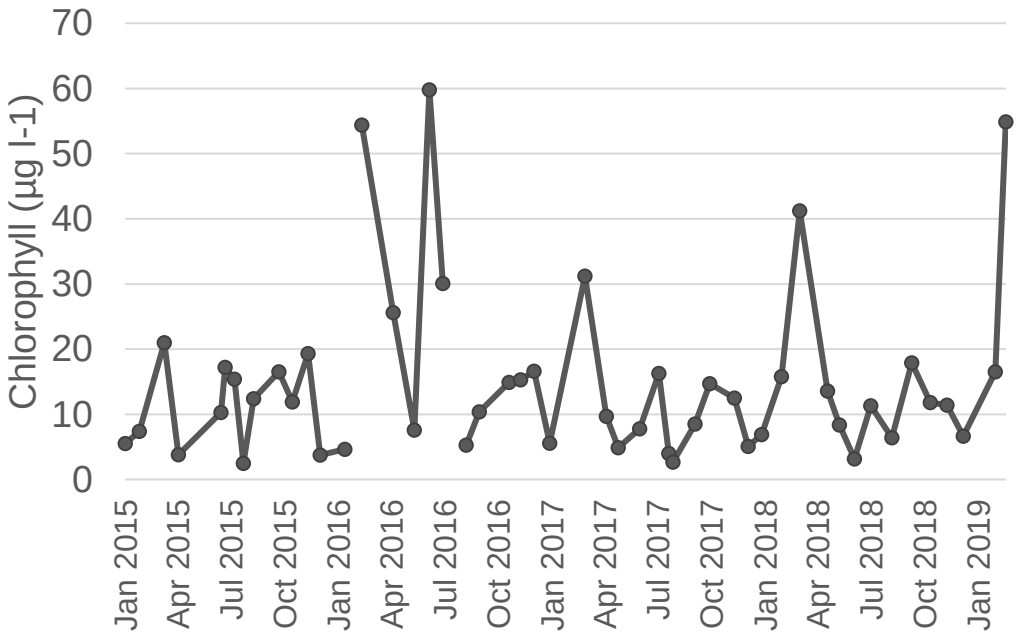

Figure 15. Chlorophyll concentrations in Llyn Dinam, 2016-2019.

Overall Condition

Macrophyte, nutrient and chlorophyll data all indicate that Llyn Dinam is in **Unfavourable - Inadequate Condition** with **High** confidence. However, a diverse plant community remains in the lake and so there are good reasons to expect an improvement in condition if nutrient levels can be reduced.

5.2.4. Llyn Traffwll

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Figure 16. Site map and aerial photograph of Llyn Traffwll.

Figure. 17 Llyn Traffwll site photo; from above the east shore, looking west.

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 umbellatus*) being of particular interest, the latter not recorded in this survey. 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).

At the time of survey (20/09/2018), following a long, dry summer, the water levels were approximately 50 cm below normal, and hence areas of the shallow littoral zone

were exposed. The aquatic macrophyte flora is relatively rich, with 17 species recorded, most of which are typical of eutrophic waters (Table 6). *Elatine hydropiper* remains common, growing on sandy substrates in the littoral zone (Figure 18a & b) and although rare in the site, *Littorella uniflora* was recorded growing in section 3 (Figure 18c) and seen at two other location on the north shore. *Callitriche truncata* remains present, but less common than in 2015, whereas *Eleocharis acicularis* and *Potamogeton perfoliatus* have increased slightly.

While the flora remains similar to 2015, it was less well distributed through the site, with the maximum depth of colonisation being mostly less than 1.2 m (1.7 m under normal water level conditions). This compares to 2.3 - 2.7 m in 2015 (Goldsmith *et al.* 2016). The current species assemblage has only four qualifying characteristic species and would be considered to be in unfavourable condition with respect to its flora under JNCC CSM Guidelines (JNCC 2015) for natural eutrophic lakes. The WFD LEAFPACS tool classifies the site as moderate with respect to its flora.

Submerged and floating vegetation	% Cover 2015	% Cover 2018
Callitriche stagnalis	**1.3**	**0.0**
Callitriche truncata	**4.8**	**2.4**
Ceratophyllum demersum	2.5	2.0
Chara globularis	**1.0**	**0.2**
Elatine hydropiper	5.6	6.0
Eleocharis acicularis	0.7	5.5
Elodea canadensis	2.5	0.8
Filamentous algae	48.0	1.7
Hydrodictyon reticulatum	0.5	0.1
Lemna minor	0.0	2.1
Lemna trisulca	0.3	0.1
Littorella uniflora	**0.0**	**1.0**
Myriophyllum spicatum	0.1	0.0
Nitella flexilis agg.	0.7	0.0
Nymphaea alba	0.0	0.7
Persicaria amphibia	1.4	0.0
Potamogeton berchtoldii	7.0	0.5
Potamogeton crispus	**0.1**	**0.0**
Potamogeton pectinatus	4.4	1.0
Potamogeton perfoliatus	**2.1**	**5.6**
Ranunculus aquatilis var. *aquatilis.*	0.0	0.7
Ranunculus omiophyllus	0.0	0.7
Ulva flexuosa	1.9	0.0
Zannichellia palustris	3.0	0.0
Species richness	**18**	**17**

Table 6 CSM Survey LEAFPACS cover results from Llyn Traffwll 2015 & 2018

a). b). c).

Figure 18 a) *Elatine hydropiper* growing with *Eleocharis acicularis* at S2; b) *E. hydropiper* seed; c) *Littorella uniflora* growing just above the waterline at S3.

Llyn Traffwll is very shallow throughout the majority of its basin, reaching a maximum of 4.1 m under normal water level conditions. Dissolved oxygen and temperature profiles show oxygen concentrations to fall dramatically below 2.0 m, with almost no DO below 5 m. This is typical of lakes with high algal biomass, whereby the turbidity prevents light penetration through the water column, thus limiting photosynthesis and resulting in anoxia within the deeper water (Figure 19).

Dissolved Oxygen Profile

GPS Location	SH3261476752
Maximum Depth (m)	3.5 m
Secchi Depth (cm)	100 cm

Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	9.23	14.6
0.5	9.19	14.7
1	9.1	14.7
1.5	9.1	14.6
2.5	9.08	14.6
3	9.08	14.6
2	9.09	14.6

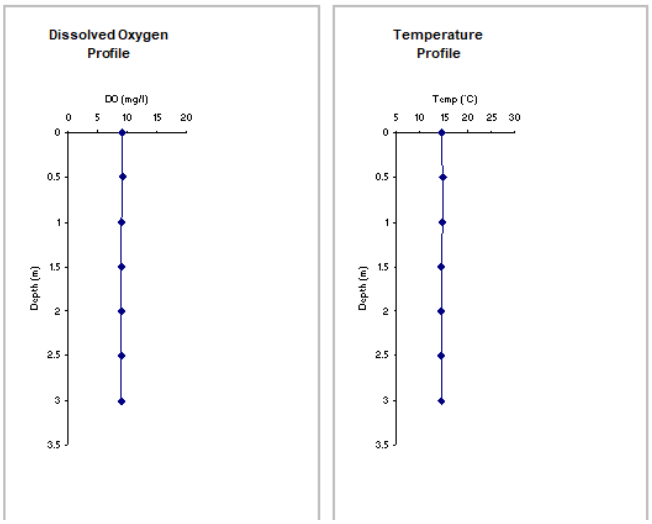

Figure 19. Dissolved oxygen and temperature profiles at Llyn Traffwll (20/09/2019).

Water Quality

There are 39 NRW water samples from Llyn Traffwll between January 2016 and March 2019. The focus of this analysis is on nutrients, as the lake is not acid sensitive.

Total Phosphorus

Total Phosphorus concentrations in Llyn Traffwll are variable but very high. Geometric Annual means were: 2016: 202 µg l^{-1}; 2017; 198 µg l^{-1}; 2018; 229 µg l^{-1}. This substantially exceeds the recommended value for this lake type of 50 µg l^{-1} (JNCC 2015).

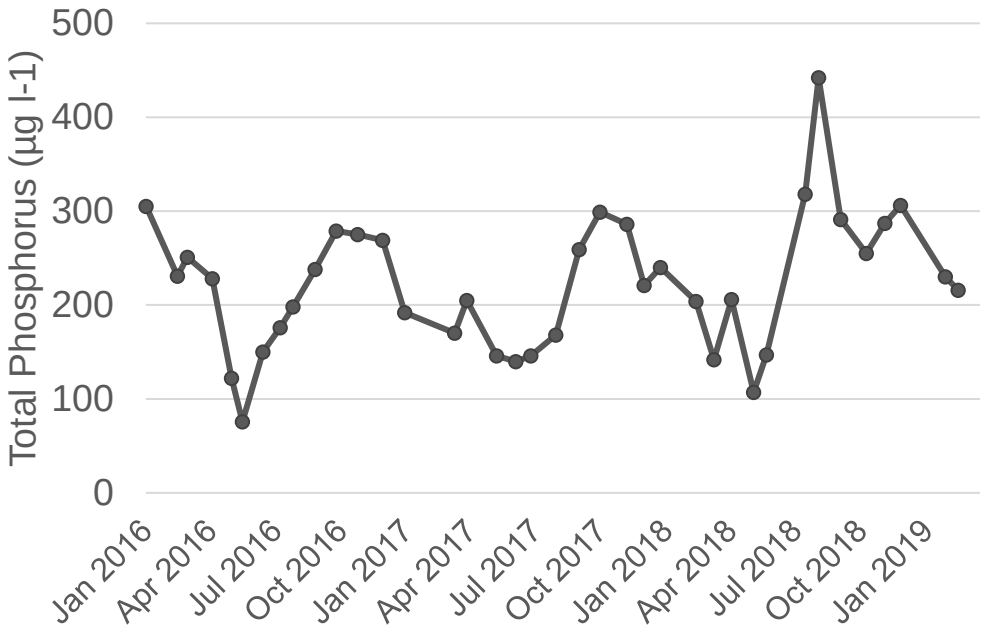

Figure 20. Total phosphorus concentrations in Llyn Traffwll, 2016-2019.

Total Oxidised Nitrogen

Total Oxidised Nitrogen levels were generally low, and frequently below detection limits in summer, suggesting that the lake is nitrogen limited for at least part of the time. Winter N peaks are slightly higher than in Llyn Dinam at around 1.2 mg l-1.

Chlorophyll

Chlorophyll concentrations in Llyn Traffwll were high, indicating regular algal blooms, despite low N levels. High P levels combined with low N make the lake vulnerable to blue-green algal blooms, and aerial imagery suggests that these occur regularly.

Overall Condition

Macrophyte, nutrient and chlorophyll data all indicate that Llyn Traffwll is in **Unfavourable - Bad Condition** with **High** confidence. Although a diverse plant community remains in the lake and in the adjoining Valley Lakes, high nutrient levels are causing algal blooms. Sources of phosphorus in the catchment need to be identified and reduced. Nitrogen is of lesser concern for this lake.

Given the very high P levels in the lake and the low flushing lake, use of a flocculant such as Phoslock could be considered to aid recovery.

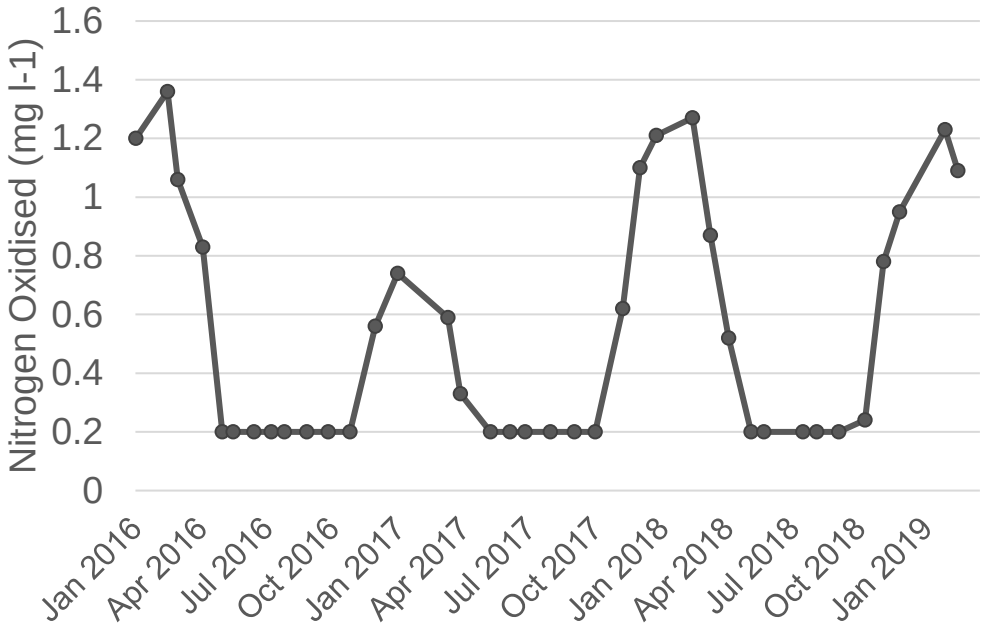

Figure 21. Oxidised nitrogen concentrations in Llyn Traffwll, 2016-2019.

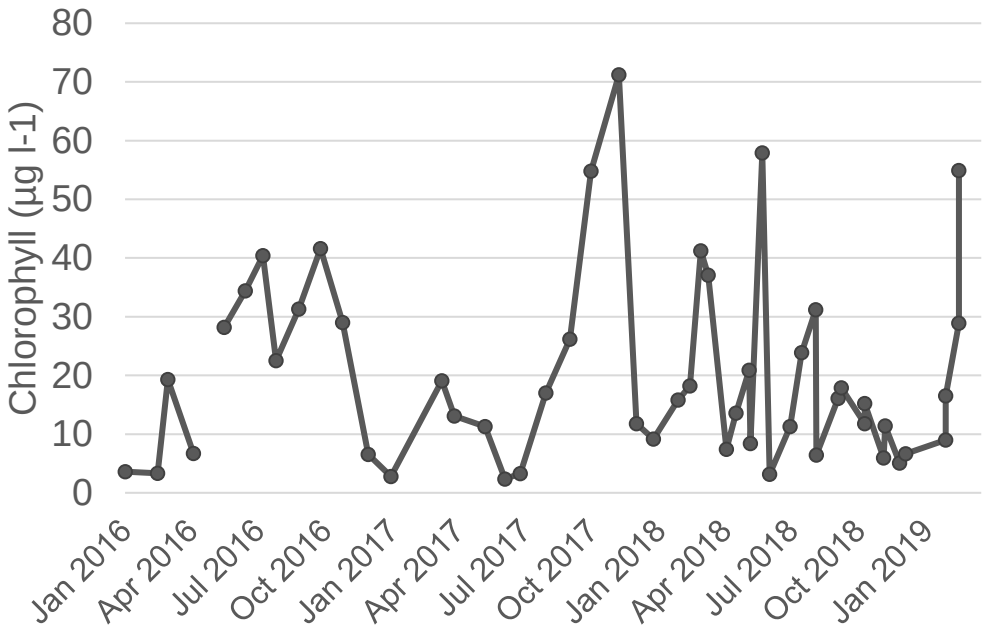

Figure 22. Chlorophyll concentrations in Llyn Traffwll, 2016-2019.

5.2.5. Llyn Maelog

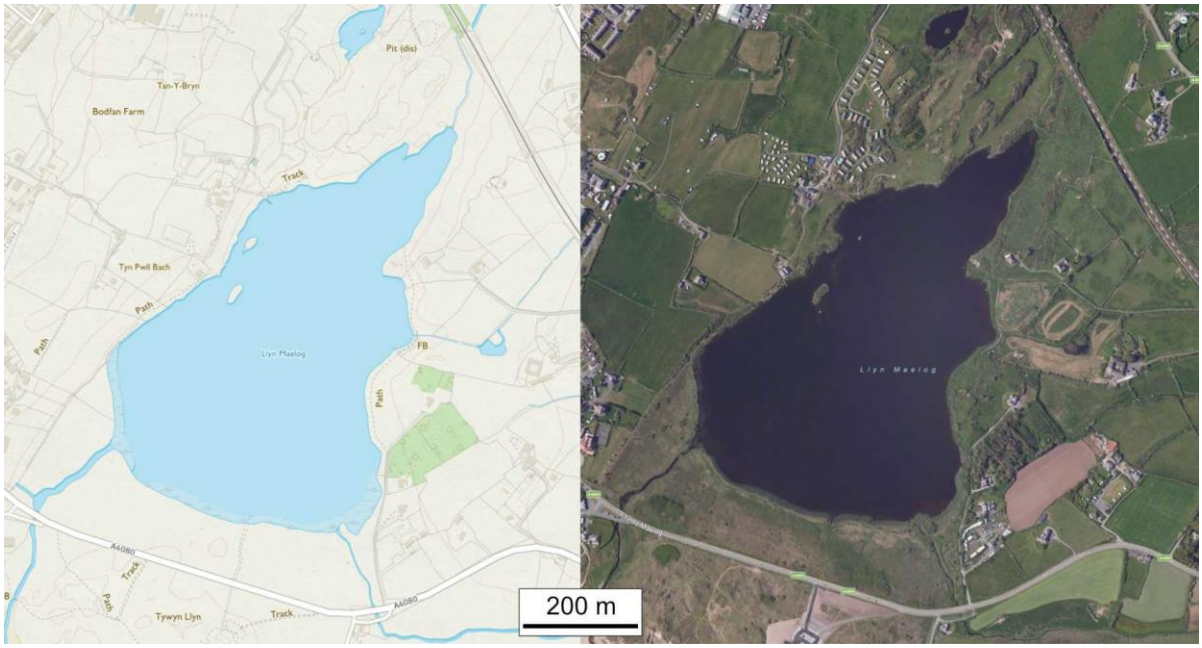

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Figure 23. Site map and aerial photograph of Llyn Maelog .

Figure 24. Llyn Maelog site photo; from the north shore looking south west.

Llyn Maelog is a small (24 ha), very shallow (Max. 2.4 m), high alkalinity lake located near the coast of the Isle of Anglesey, Wales. The lake and the area just to the south form Llyn Maelog SSSI. The large lowland catchment is mostly improved and calcareous grassland, with lesser amounts of arable, woodland and rural development (CEH 2018). A public footpath runs around the site and it is used for angling and recreational water sports. The lake has recently been subject to efforts to maintain the water levels by improvements to the sluice at the north end of the lake. Much of the lake, particularly to the south, is fringed with reeds, especially *Phragmites australis*, *Iris pseudacorus*, *Phalaris arundinacea* and *Eleocharis palustris*.

Llyn Maelog was last subject to a CSM survey in 2017 (Shilland *et al.* 2018) and the results of this and the 2018 survey are presented in table (Table 7). Like the 2017 survey, the 2018 survey was carried out late in the summer, and many of the aquatic macrophytes were senescing, making accurate identification difficult. In particular, fine leaf *Potamogeton* species were mostly reduced to rotting brown stems (a) with

identification of *P. pusillus* and *P. pectinatus* being made from turions (b). Within the open water, the majority of degraded fine-leaf *Potamogeton* was accompanied by *P. pectinatus* turions and thus ascribed as such in the LEAFPACS tool and database. *Potamogeton pusillus* turions were less common. *Potamogeton perfoliatus* was still readily identifiable and the *Chara globularis*, where present, intact. *Elodea canadensis* and *P. pectinatus were dominant, Callitriche hermaphroditica* was present mainly in the strandline, and *Potamogeton crispus* recorded only as turions. *Eleocharis acicularis* and *Elatine hexandra* were recorded as rare in 2017, but not seen in 2018. The water was extremely turbid in the margins due to wave action, hampering efforts for visual surveys, which may account for these small species being overlooked.

Submerged and floating vegetation	% Cover 2017	% Cover 2018
Callitriche hermaphroditica	**1.6**	**1.7**
Chara globularis	**0.8**	**1.6**
Elatine hexandra	0.8	0.0
Eleocharis acicularis	0.9	0.0
Elodea canadensis	7.7	21.3
Filamentous algae	4.0	9.0
Hydrodictyon reticulatum	0.5	0.0
Lemna minor	1.4	2.1
Nymphaea alba	0.0	0.1
Persicaria amphibia	3.0	2.9
Potamogeton crispus	**0.0**	**0.1**
Potamogeton pectinatus	0.0	15.1
Potamogeton perfoliatus	**1.9**	**3.7**
Potamogeton pusillus	2.7	3.3
Species richness	**10**	**10**

Table 7. CSM Survey LEAFPACS cover results from Llyn Maelog 2017 and 2018.

b)

Figure 25. a) senescing fine-leaf *Potamogeton* spp. sampled from open water in S4 and b) turions from *P. pusillus* (top) and *P. pectinatus* (below).

The results are similar to those reported in 2007 by Burgess *et al.* (2009) with the notable introduction and increase of the non-native *E. canadensis* in 2017 and 2018.

Aquatic plants were recorded to a maximum depth of 2.4 m, 0.5 m greater than in 2017.

Having only three out of the required six characteristic species present, the current aquatic macrophyte assemblage from Llyn Maelog would place the site in unfavourable condition with respect to its flora under the JNCC CSM Guidelines (JNCC 2015) for natural eutrophic lakes with *Magnapotamion* or *Hydrochariton*-type vegetation. Filamentous algae is present, but mainly restricted to the littoral zone.

The low number of characteristic eutrophic species and low species richness are likely to be due to the nutrient pressures identified at the site by Hatton-Ellis (2016). It is recommended that efforts to reduce nutrient inputs to Llyn Maelog continue and the results of the current survey would support the designation of the catchment as a Nitrate Vulnerable Zone.

Dissolved oxygen and temperature profiles showed the lake to be mixed at the time of sampling, with no thermocline evident and only a slight decline in dissolved oxygen with increasing depth. The lake is shallow and exposed, and breezy conditions during the survey resulted in relatively low Secchi depth (0.85 m), which was further reduced in the margins due to wave action and re-suspension of sediments.

Dissolved Oxygen Profile

GPS Location	SH3278673249
Maximum Depth (m)	2.5 m
Secchi Depth (cm)	85 cm

Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	10.46	15.6
0.5	10.49	15.6
1	10.49	15.6
1.5	10.5	15.6
2	10.5	15.6

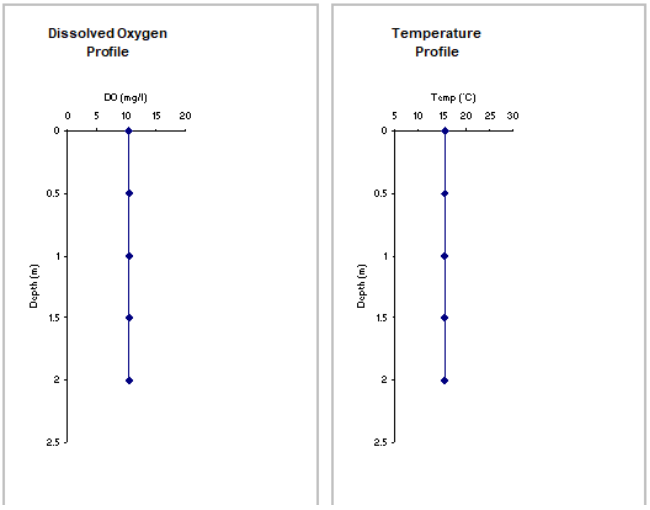

Figure 26. Dissolved oxygen and temperature profiles at Llyn Maelog (17/09/2018).

Water Quality

There are 39 NRW water samples from Llyn Maelog (sample point 27875) between January 2016 and March 2019. The lake is alkaline, with a mean pH of 8.09 and a mean alkalinity of 1366 µg $l^{-}1$. The focus of this assessment is on nutrients, as the lake is not acid sensitive.

Total Phosphorus

Total Phosphorus concentrations in Llyn Maelog are variable but high. Geometric Annual means were: 2016: 99 µg l^{-1}; 2017; 95 µg l^{-1}; 2018; 102 µg l^{-1}. This

substantially exceeds the recommended value for this lake type of 50 µg l^{-1} (JNCC 2015) and reflects the poor state of the aquatic plant community.

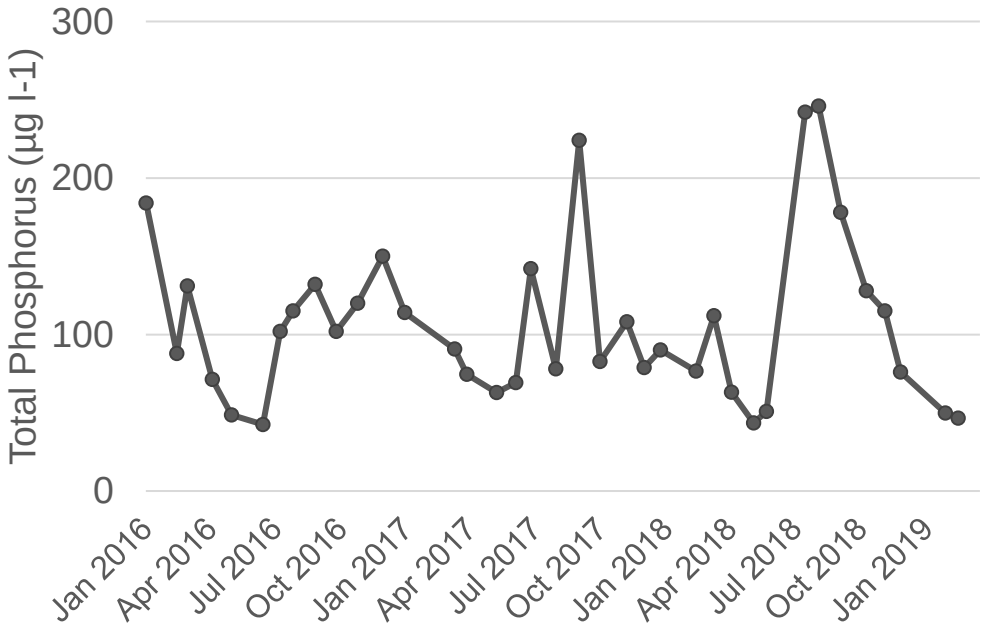

Figure 27. Total phosphorus concentrations in Llyn Maelog, 2016-2019.

Total Oxidised Nitrogen

Total Oxidised Nitrogen levels fluctuated greatly. Winter N peaks are high, at just under 5 mg l-1. In contrast, summer concentrations were generally low, and frequently below detection limits, suggesting that the lake is nitrogen limited for at least part of the time.

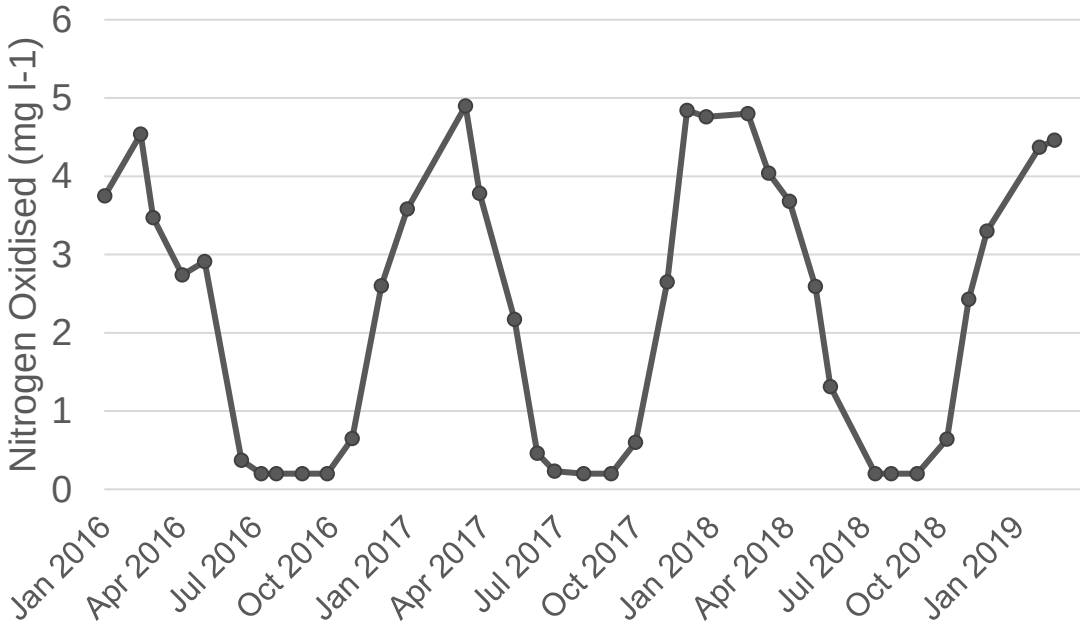

Figure 28. Oxidised nitrogen concentrations in Llyn Maelog, 2016-2019.

Chlorophyll

Chlorophyll concentrations in Llyn Maelog were high, indicating regular algal blooms, driven by high nutrient levels. Blooms predominantly occurred in spring and autumn, with macrophytes still being able to suppress phytoplankton growth in this very shallow lake during summer. There was some evidence of increased chlorophyll concentrations during the hot summer of 2018.

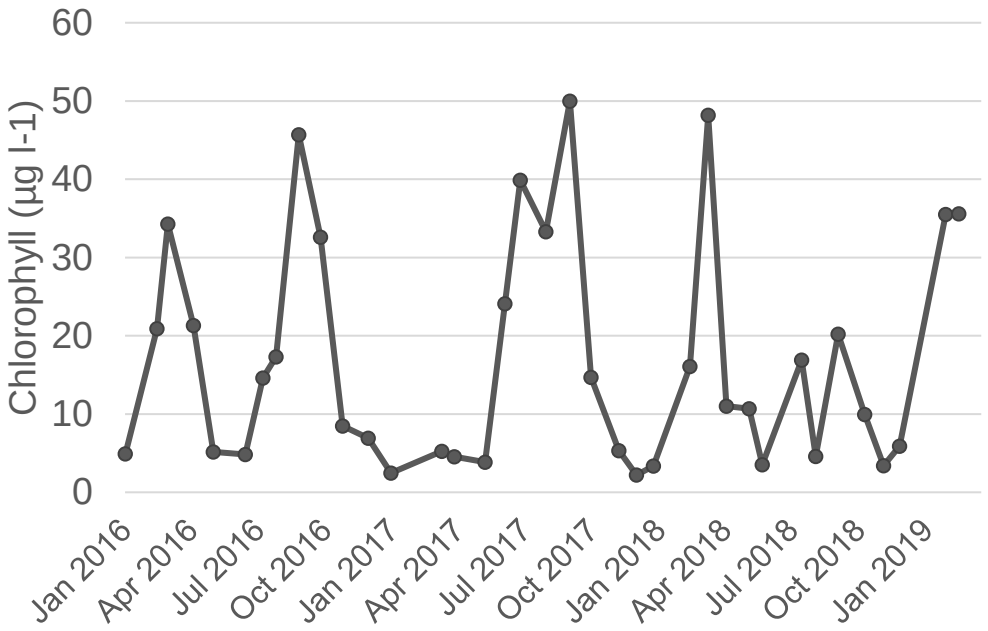

Figure 29. Chlorophyll concentrations in Llyn Maelog, 2016-2019.

Overall Condition

Macrophyte, nutrient and chlorophyll data all indicate that Llyn Maelog is in **Unfavourable – Bad** Condition with **High** confidence. Although a fairly diverse plant community remains in the lake, high nutrient levels are causing algal blooms. Sources of phosphorus in the catchment need to be identified and reduced. Nitrogen is also a significant concern for this lake, which has previously been proposed as a Nitrate Vulnerable Zone (Hatton-Ellis 2016).

5.2.6. Llyn Cwellyn

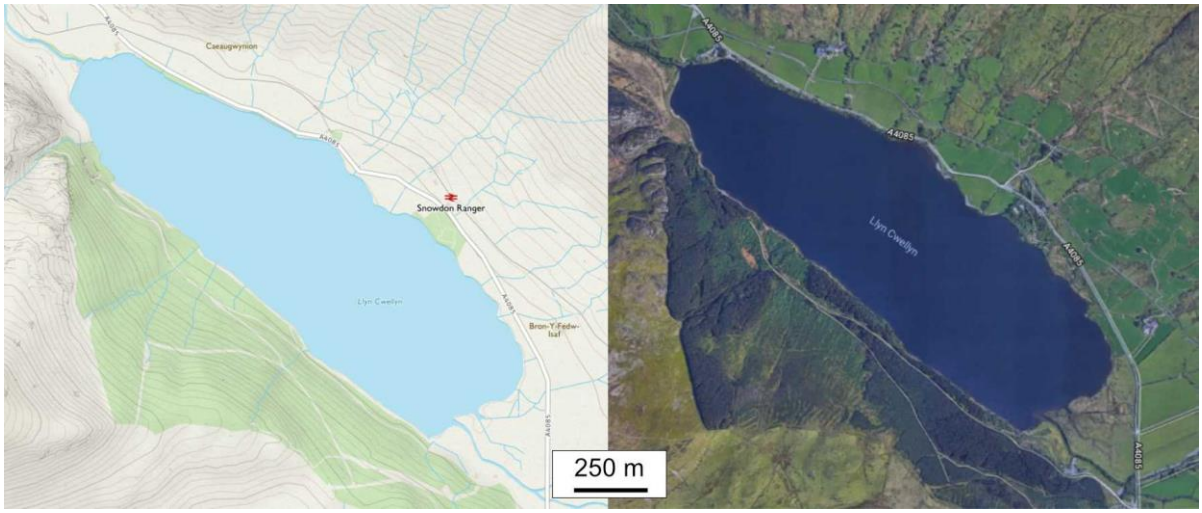

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Figure 30. Site map and aerial photograph of Llyn Cwellyn.

Figure 31. Llyn Cwellyn site photo; from the north-west shore looking east towards Snowdon

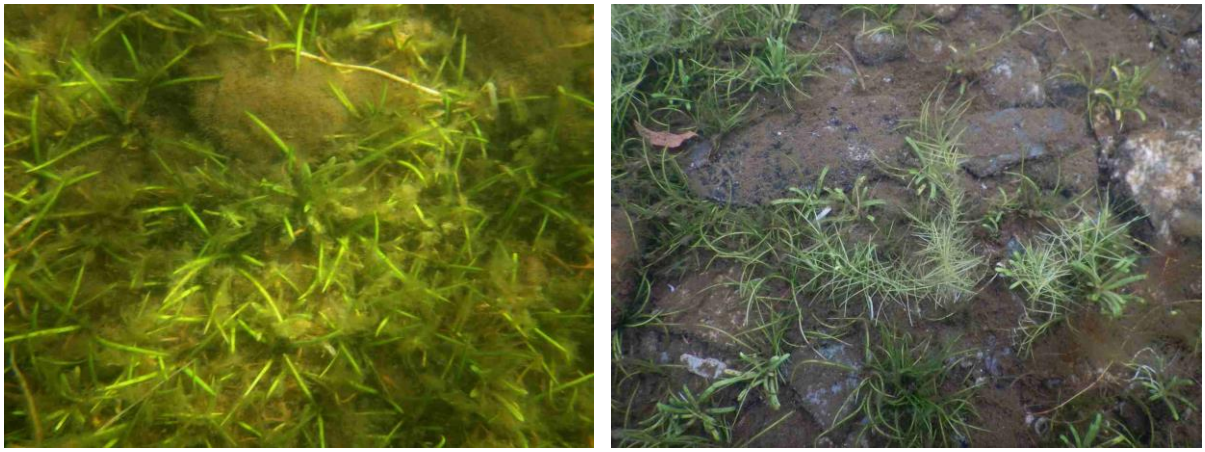
Llyn Cwellyn is a deep (36 m) oligotrophic lake of glacial origin situated at an altitude of 142 m in the Nant y Betws valley in Gwynedd. The site forms part of the Afon Gwyrfai a Llyn Cwellyn SAC and lies within the Snowdonia National Park. Llyn Cwellyn has a history of acidification (Duigan *et al.* 1998) and is a WFD surveillance site. The site supports one of the few natural Welsh populations of Arctic charr (*Salvelinus alpinus*).

The current lake level is maintained by a low concrete weir on the outflow at the north-west end 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.

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 5.2 m (Figure 32). In addition and 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 snorkel surveys conducted in 2014 (Goldsmith *et al.* 2014b) that it occurs in at least three separate populations within the site (Figure 33). These areas were visually checked in 2018 and the populations appear stable and healthy. The rest of the aquatic flora also remains very stable relative to the 2015 survey (Table 8). The current species assemblage would place Llyn Cwellyn in favourable condition with respect to its flora under JNCC CSM Guidelines (JNCC 2015), and the LEAFPACS scores classify the WFD status as "good".

Submerged and floating vegetation	% Cover 2015	% Cover 2018
Callitriche brutia var. *hamulata*	3.6	3.1
Elatine hexandra	**0.1**	**0.0**
Filamentous algae	28.1	2.7
Fontinalis antipyretica	1.0	2.1
Isoetes lacustris	**21.6**	**21.0**
Juncus bulbosus	6.2	3.4
Littorella uniflora	**8.7**	**10.1**
Lobelia dortmanna	**15.3**	**9.8**
Luronium natans	**1.3**	**1.3**
Myriophyllum alterniflorum	5.7	5.4
Nitella flexilis agg.	4.3	4.5
Potamogeton berchtoldii	0.0	2.1
Potamogeton polygonifolius	0.8	0.0
Sparganium angustifolium	**0.0**	**0.1**
Sphagnum (aquatic indet.)	2.5	5.9
Subularia aquatica	**0.3**	**0.8**
Species richness	**13**	**13**

Table 8. CSM Survey LEAFPACS cover results from Llyn Cwellyn 2015 and 2018.



a) b)

Figure 32. a) *Littorella uniflora* and *Lobelia dortmanna* at 75 cm (S3) and b) *Isoetes lacustris, Callitriche brutia* var. *hamulata* and *Lobelia dortmanna* at 1.5 m in S1.

Dissolved oxygen and temperature profiles show the lake to be stratified a thermocline at approximately 16 m, below which temperatures fall to 7.4 ºC. Dissolved oxygen concentrations remain relatively stable throughout the profile (Figure 34).

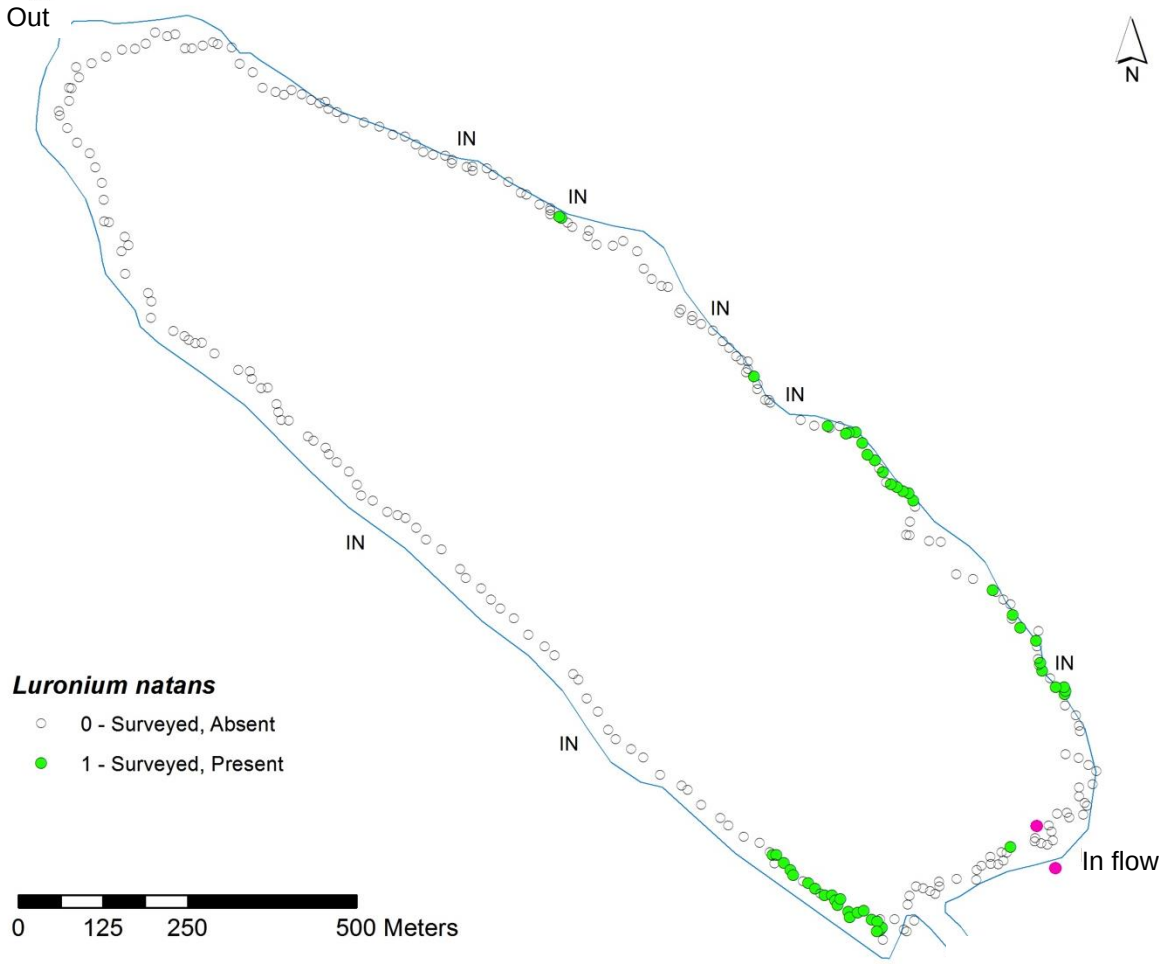


Figure 33. Distribution of *Luronium natans* in Llyn Cwellyn in 2014 (From: Goldsmith *et al.* 2014b)

Dissolved Oxygen Profile

GPS Location	SH5554455222
Maximum Depth (m)	36 m
Secchi Depth (cm)	590 cm
Notes:	

Depth (m)	DO (mg/l)	Temp (°C)
0	10.19	13
1	10.17	13
2	10.18	13
5	10.13	13
6	10.04	12.9
7	10.06	12.7
8	10.06	12.6
10	9.97	12.5
12	9.97	12.5
15	9.93	12.4
16	9.76	12.4
17	9.43	11.2
17.5	9.16	9.7
18	8.9	9.1
19	8.76	8.4
20	8.62	8.3
22	8.42	7.9
24	8.13	7.8
26	7.83	7.6
28	7.22	7.5
30	6.66	7.4

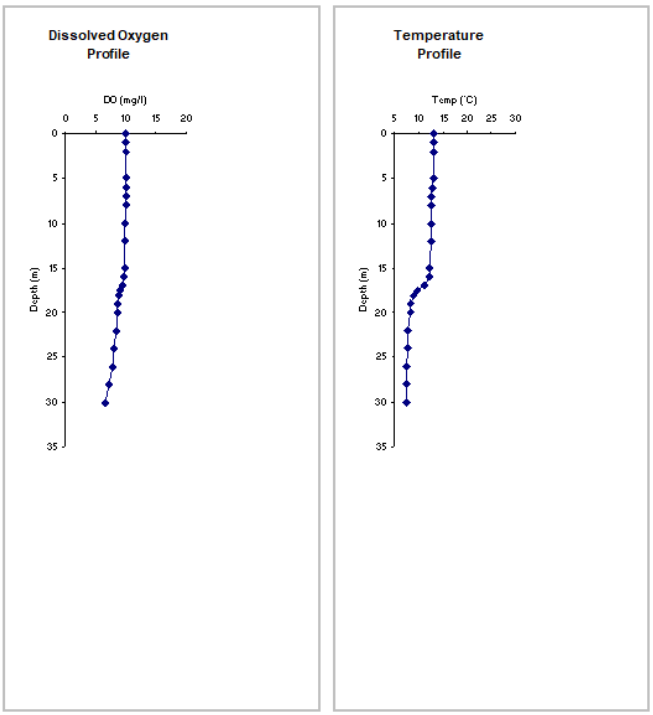


Figure 34. Dissolved oxygen and temperature profiles at Llyn Cwellyn (28/09/2018).

Water Quality

There are 36 NRW water samples from Llyn Cwellyn (sample point 29162) between January 2016 and March 2019: older data is available from a different sample point near the outflow but this has not been used for this assessment. The lake is weakly acidic, with a mean pH of 6.59[1]. Both nutrients and acid sensitivity have been assessed here.

Acid Neutralising Capacity (ANC)

Mean Cantrell ANC was relatively stable, varying between 40 and 70 µeq l^{-1}, except for two instances late in 2018-19 when higher values were recorded. These high values do not affect the overall conclusions.

Annual mean ANC values were 53 µeq l^{-1} for 2016; 52 µeq l^{-1} for 2017 and 56 µeq l^{-1} for 2018. These are well above the target minimum value of 40 µeq l^{-1} and therefore indicate the lake passes its acidity target.

[1] An anomalous low measurement of 4.1 from May 2018 was removed from the dataset as it was considered most likely to be due to instrument error.

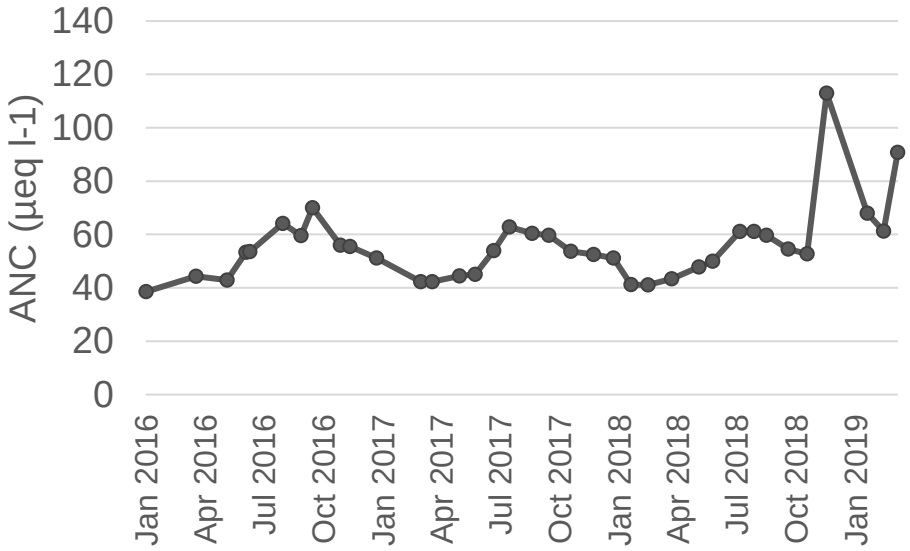


Figure 35. ANC concentrations in Llyn Cwellyn, 2016-2019.

Total Phosphorus

Total Phosphorus concentrations in Llyn Cwellyn are low and within the target values for an oligotrophic lake, though there are some winter peaks that give cause for concern. Geometric Annual means were: 2016: 7.0 µg l^{-1}; 2017; 8.1 µg l^{-1}; 2018; 6.2 µg l^{-1}. These values pass the target at present but are higher than is desirable for a deep lake.

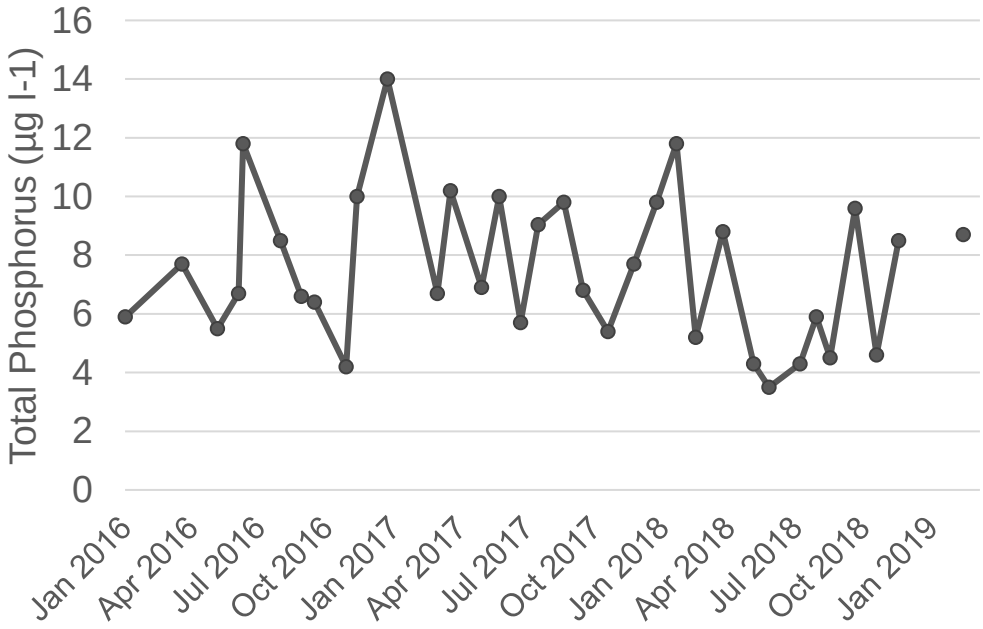


Figure 36. Total Phosphorus concentrations in Llyn Cwellyn, 2016-2019.

Nitrogen

Oxidised nitrogen concentrations were low, showing weak seasonal fluctuations in concentration, with peaks occurring in winter. A markedly higher peak occurred in winter 2018-19. The reason for this is unknown but could perhaps be due to accumulation of N in the catchment during the unusually dry summer.

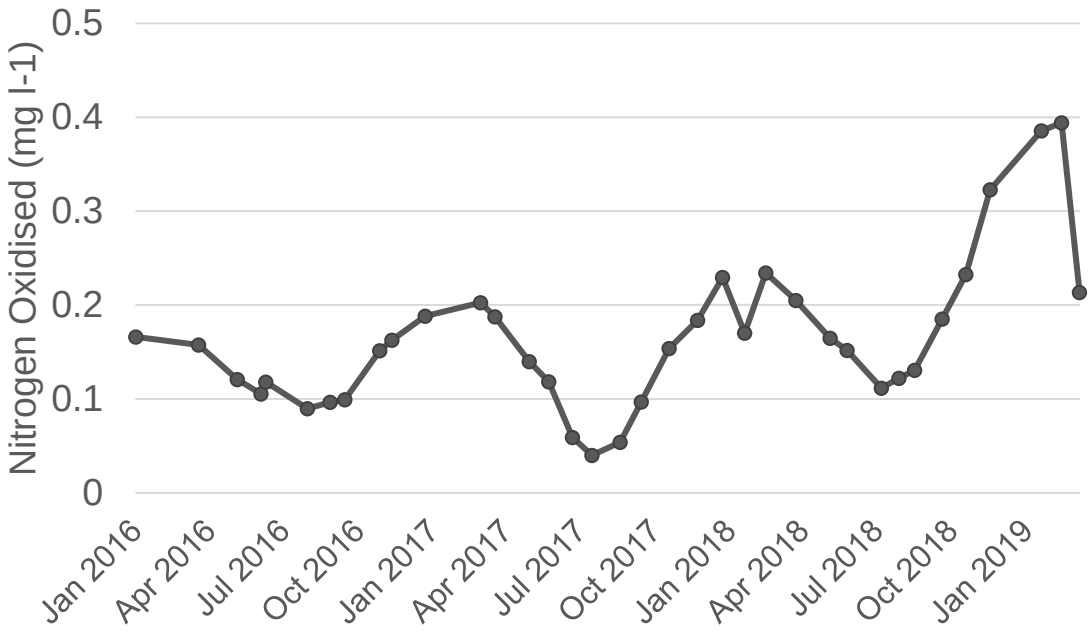


Figure 37. Oxidised Nitrogen concentrations in Llyn Cwellyn, 2016-2019.

The recorded nitrogen values do not suggest that nitrogen concentrations are having a significant negative effect on Llyn Cwellyn at present.

Overall Condition

Macrophyte, nutrient and chlorophyll data all indicate that Llyn Cwellyn is in **Favourable Condition** with **High** confidence. The plant community includes all of the expected species including Luronium natans, the hypolimnion is well oxygenated and there is no evidence of significant eutrophication or acidification.

5.2.7. Llyn Padarn

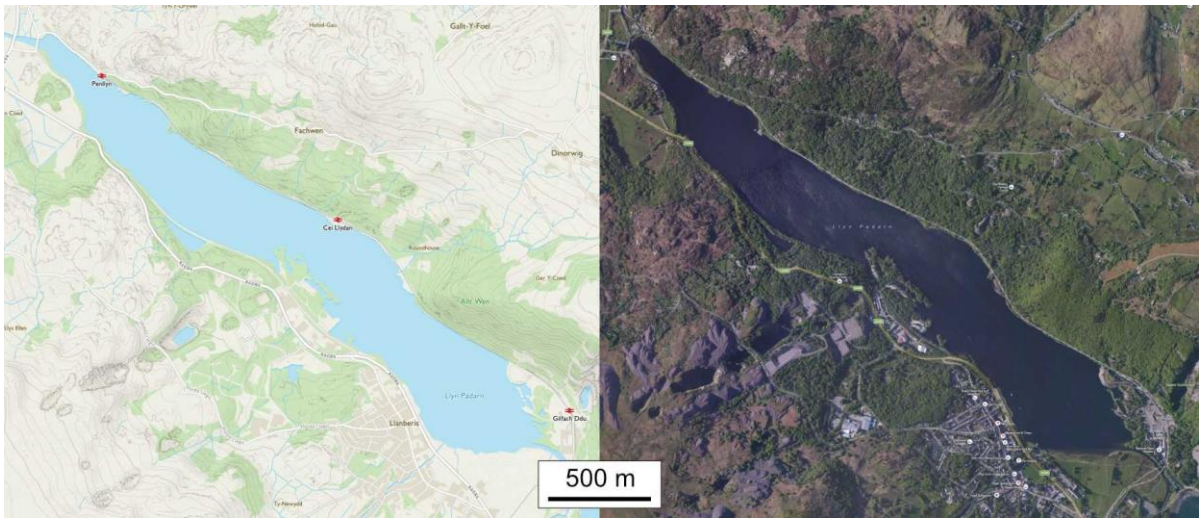


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Figure 38. Site map and aerial photograph of Llyn Padarn.

Figure 39. Llyn Padarn site photo; from the north-west looking south-east towards the Llanberis pass and Snowdon.

Llyn Padarn is a large (98 ha), deep (max. depth 28.0 m) lowland lake located in Gwynedd, North Wales. It is designated as the Llyn Padarn SSSI, but falls just outside the Snowdonia National Park boundary. The large catchment includes much upland moorland and acid grassland, but also woodland, several lakes and the town of Llanberis (CEH 2018). The lake is used extensively for water sports and recreation, and is a designated inland bathing water. There have been historic issues at the site with respect to nutrient levels, deoxygenation of the hypolimnion and algal blooms (Hatton-Ellis, 2016). Llyn Padarn is a WFD surveillance and site and hosts notable populations of Arctic charr (*Salvelinus alpinus*) and floating water-plantain (*Luronium natans*).

A snorkelling survey conducted in 2014 (Goldsmith *et al.* 2014b) demonstrated that whilst only one out of the four original fixed CSM sections established at Llyn Padarn for WFD surveillance purposes overlapped with the distribution of *Luronium natans* in

the lake, the population is distributed sporadically along approximately half of the southern shore. A fifth section was therefore added for the 2016 survey (Shilland *et al.* 2017) in an area known to have an extensive population of the plant. This section was repeated in 2018.

The submerged aquatic macrophyte flora is typical for a low alkalinity, clear water lake, and where suitable littoral habitats occur, *Littorella uniflora, Lobelia dortmanna* and *Isoetes lacustris* are found, but mostly restricted to less than 1.6 m depth (Figure 40). In deeper water, *Myriophyllum alterniflorum* and *Nitella flexills* agg. were most abundant, and co-occurred with the non-native invasive species *Elodea nuttallii. Nitella flexills* agg. was recorded at a maximum depth of 6.2 m. The benthic habitats vary considerably through the site and much of the north side and the middle section of the south side comprise mostly of boulders and shelve steeply to over 6 m depth. In these areas the flora is very limited. The flora remains similar to the 2016 survey, and although having five characteristic species, the cover of these is low.

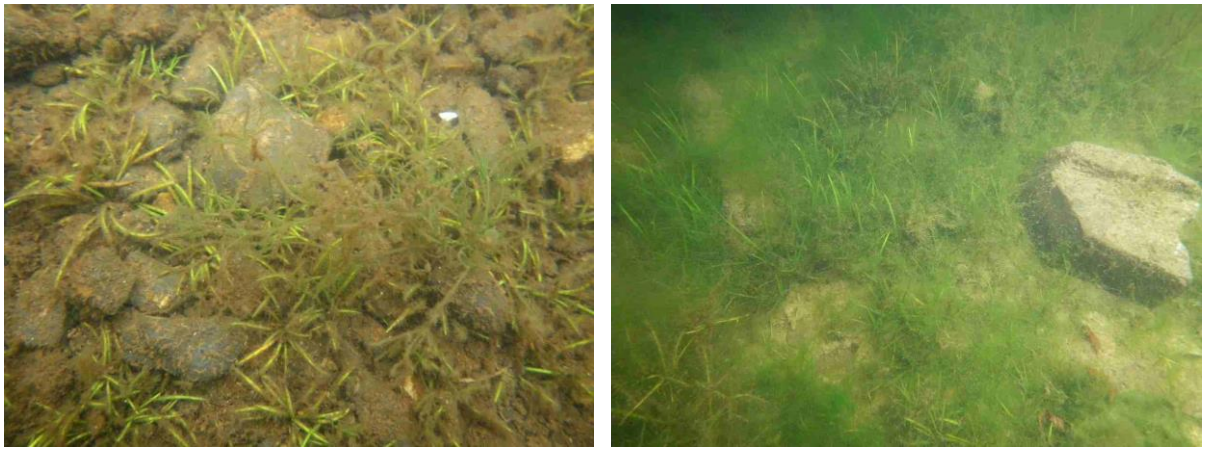
Submerged and floating vegetation	% Cover 2015	% Cover 2018
Callitriche brutia var. *hamulata*	1.7	0.1
Elatine hexandra	**1.8**	**0.0**
Elodea nuttallii	10.5	9.1
Filamentous algae	22.4	3.5
Fontinalis antipyretica	2.5	0.7
Isoetes lacustris	8.0	6.6
Juncus bulbosus	0.3	0.0
Lagarosiphon major	0.7	0.0
Littorella uniflora	**7.6**	**6.7**
Luronium natans	**6.7**	**3.2**
Lythrum portula	0.7	0.0
Menyanthes trifoliata	0.0	1.1
Myriophyllum alterniflorum	5.0	3.4
Nitella flexilis agg.	4.6	11.4
Nitella translucens	2.4	0.1
Potamogeton berchtoldii	2.7	2.6
Ranunculus aquatilis agg.	1.6	0.5
Subularia aquatica	**0.2**	**0.0**
Species richness	**13**	**13**

Table 9. CSM Survey LEAFPACS cover results from Llyn Padarn 2016 and 2018.

Where it occurred, *Luronium natans* appeared to be healthy and the populations stable. In section five, the area remained similar to that recorded in 2014 (point 3 in Figure 41) and in 2016 (Shilland *et al.* 2017). In 2016, more sample points were taken within the *L. natans* beds on the boat transect in section 5, giving a higher number of points than in 2018, but the actual location of the bed and depth distribution has remained the same. The non-native invasive species *Lagarosiphon major* recorded in 2016, was not recorded in 2018.

The current species assemblage would place Llyn Padarn in unfavourable condition with respect to its flora under JNCC CSM Guidelines (JNCC 2015), due to a lower

than expected frequency of characteristic species (<60%) and the presence of Elodea nuttallii a high abundance. The LEAFPACS scores classify the WFD status as “moderate”.



a) b)

Figure 40. a) *Littorella uniflora, Isoetes lacustris* and *Nitella flexilis* agg. growing at 75 cm at S4 and b) *Luronium natans* with a moderate cover of filamentous algae at S5..

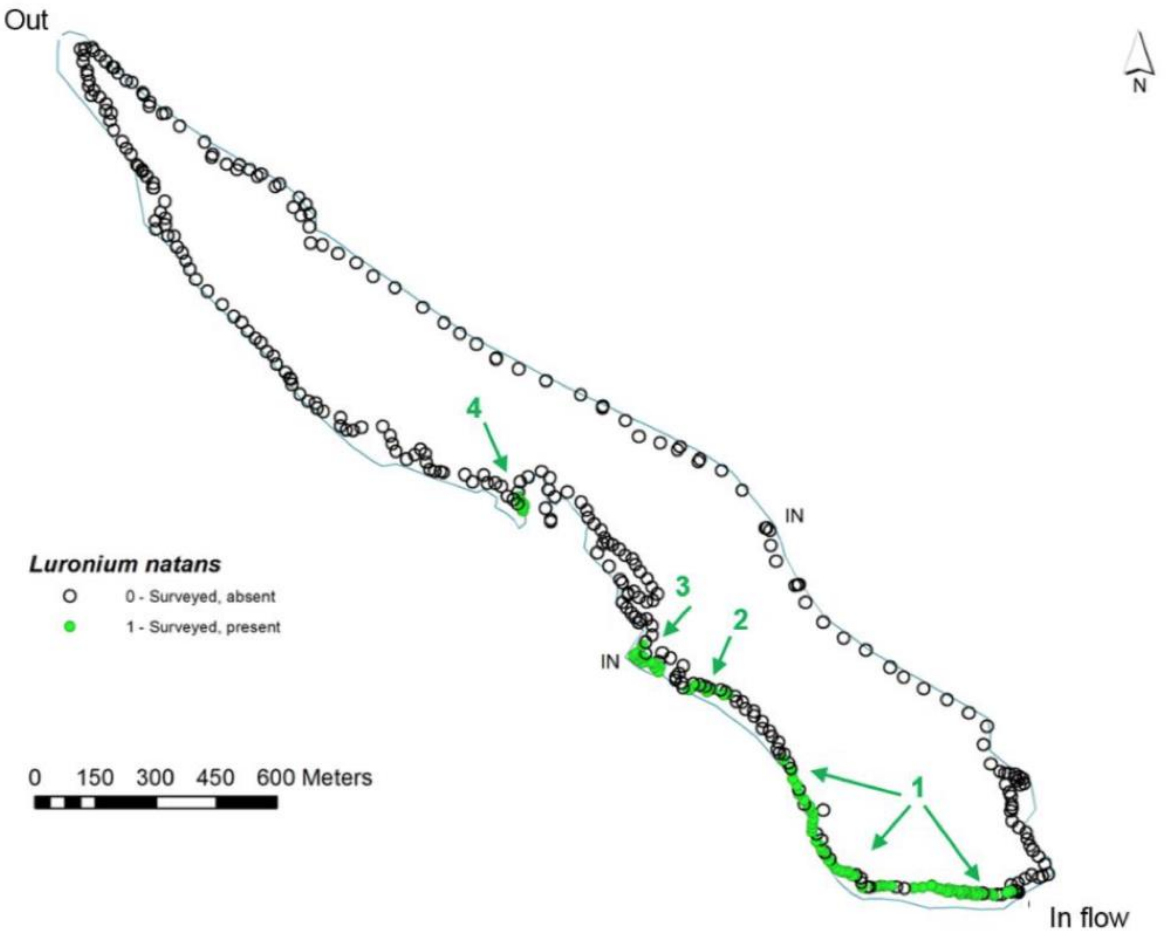


Figure 41. Distribution of *Luronium natans* in Llyn Padarn in 2014 (From: Goldsmith *et al.* 2014b).

Dissolved oxygen and temperature profiles show the lake to be stratified with a gradual thermocline at approximately 16 m, below which temperatures fall to 9.8 ºC. Dissolved oxygen concentrations drop rapidly below 16 m with the profundal waters being anoxic. (Figure 34).

Dissolved Oxygen Profile

GPS Location	SH5811060536
Maximum Depth (m)	28 m
Secchi Depth (cm)	375 cm

Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	9.93	13
1	9.87	13.1
2	9.84	13.1
3	9.8	13.1
4	9.79	13.1
5	9.77	13.1
6	9.77	13.1
7	9.76	13.1
8	9.54	13
9	9.45	12.9
10	9.36	12.8
12	9.34	12.7
14	9.27	12.5
16	9.04	12.2
18	7.81	11.9
20	4.88	11.3
22	2.46	10.6
24	0.55	10.1
26	0.42	9.9
27	0.38	9.8

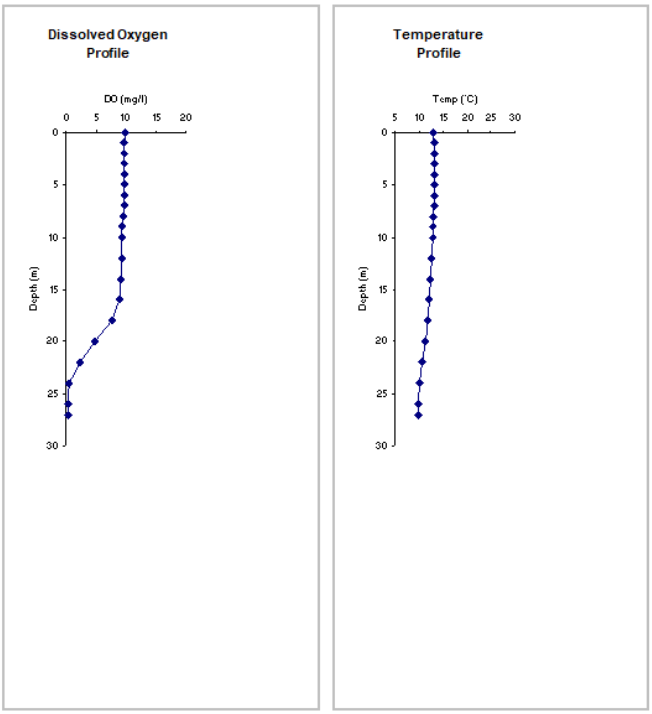


Figure 42. Dissolved oxygen and temperature profiles at Llyn Padarn (30/09/2018).

Water Quality

There are 69 NRW water samples from Llyn Padarn (sample point 22509, situated at the outflow to the northwest) between January 2014 and March 2019. This sample point is not ideally located to measure water quality in the lake, since the most sensitive part of the lake to eutrophication is the deeper southeastern end. The lake is circumneutral, with a mean pH of 6.81 and a mean alkalinity of 129 µeq l^{-1}, meaning that the lake is not acid sensitive. Therefore, only nutrients have been assessed.

Total Phosphorus

Total Phosphorus concentrations in Llyn Padarn are low and within the target values for an oligotrophic lake. Geometric Annual means were: 2014: 6.3 µg l^{-1}; 2015: 6.3 µg l^{-1}; 2016: 5.9 µg l^{-1}; 2017; 6.5 µg l^{-1}; 2018; 6.6 µg l^{-1}. These values pass the target, but do not correspond with the deoxygenation seen in the hypolimnion in this and other years (Fig. 42), most likely reflecting the discrepancy between the sampling location and the part of the lake at greatest risk.

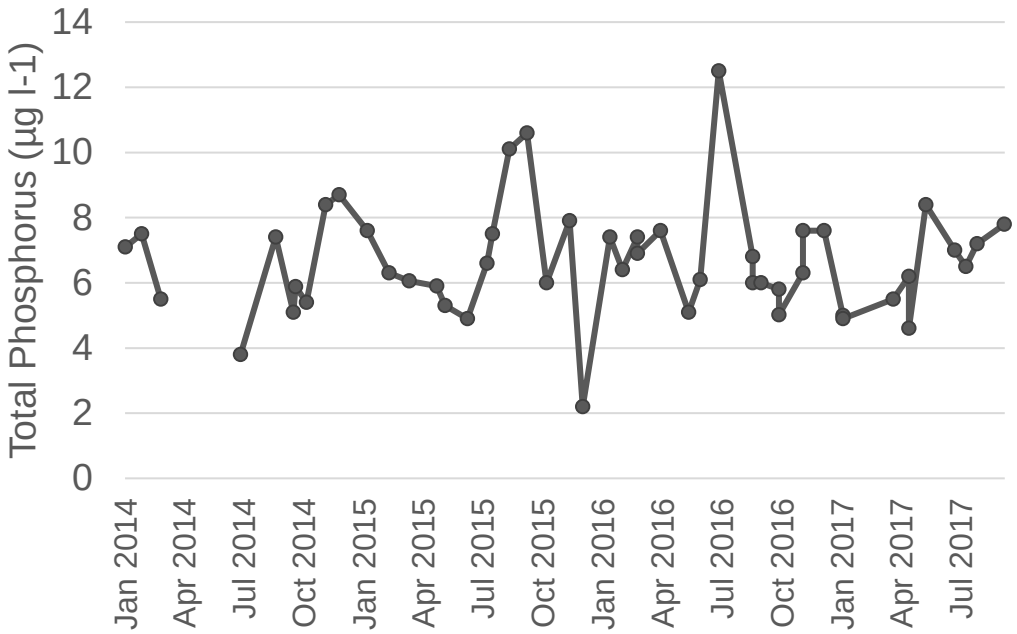


Figure 43. Total Phosphorus concentrations in Llyn Padarn, 2014-2019.

Nitrogen

Only limited data for nitrogen was available, with monitoring for this determinand having been discontinued in December 2015. These data showed TON concentrations to be low, generally being at or below the detection limit of 0.2 mg l^{-1}.

The recorded nitrogen values do not suggest that nitrogen concentrations are having a significant negative effect on Llyn Padarn at present.

Overall Condition

Macrophyte, nutrient and chlorophyll data all indicate that Llyn Padarn is in **Unfavourable - Inadequate Condition** with **High** confidence. The plant community includes all of the expected species including *Luronium natans*, but the cover of characteristic species is low and the invasive non-native *Elodea nuttallii* is the most abundant vascular plant. Another invasive species, *Lagarosiphon major*, was not refound during this survey and may have failed to establish, but further monitoring is recommended as this species can be very invasive, as for example at Tal-y-Llyn Lake.

Water chemistry appears to be sufficient with low levels of phosphorus and nitrogen. However, additional monitoring of oxygenation in the hypolimnion is required as this is important summer habitat for the threatened Arctic charr population of the lake, an SSSI feature.

5.2.8. Llyn Cwmorthin

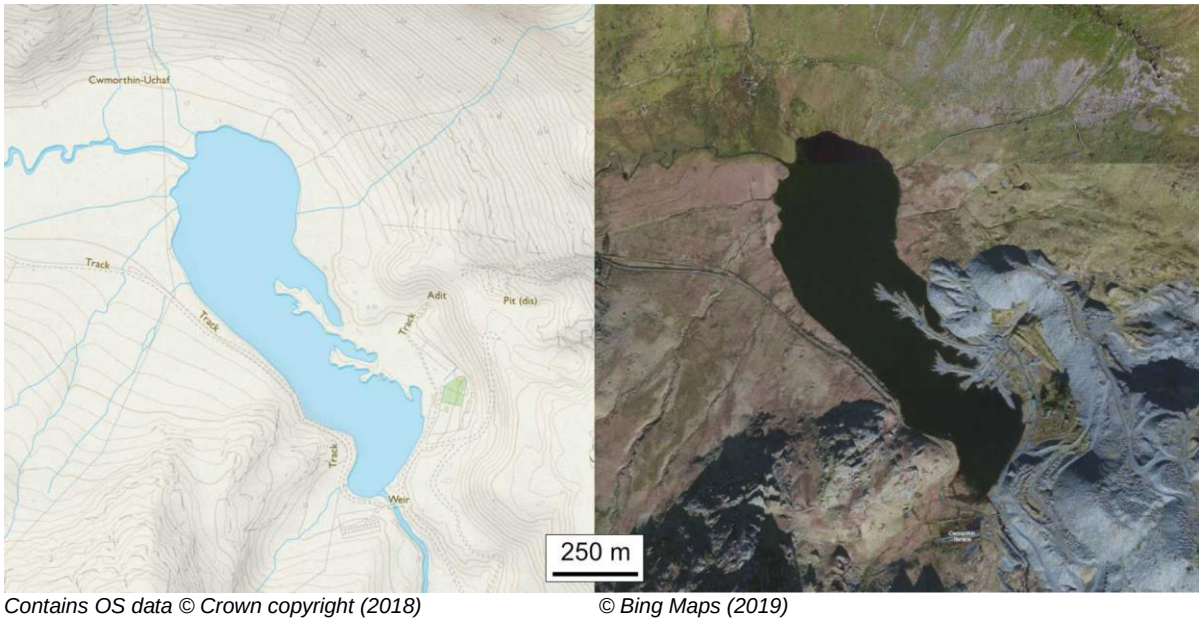


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Figure 44. Site map and aerial photograph of Llyn Cwmorthin.

Figure 45. Llyn Cwmorthin site photo; from the south-east shore looking north-west.

Llyn Cwmorthin is a small (5.6 ha), shallow (max. 8.9 m) lake lying at 325 m AOD, and 2 km to the west of Blaenau Ffestiniog. The lake lies on the western edge of the vast slate quarries to which it owes its origins, having been dammed in the 19th century to provide a head of water for the slate dressing mills.

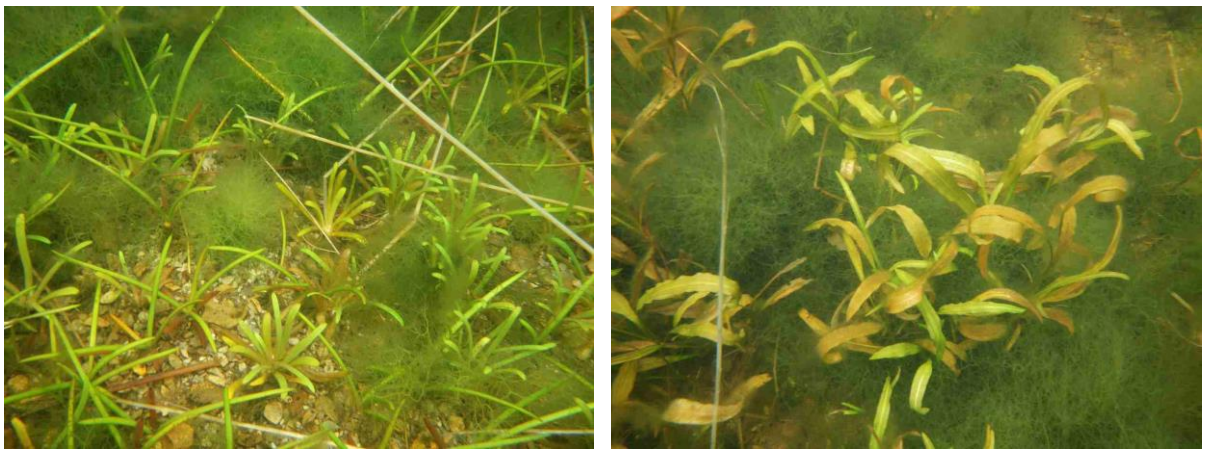
The site lies outside of any statutory designations, and has not been subject to any previous CSM surveys by NRW. The site is however documented as supporting a population of *Luronium natans* (Benoit and Richards, 1963; Kay *et al.* 1999), a European protected species for which Wales is internationally important. Given the historic presence of this species and shortage of recent knowledge for the site, it was chosen for survey for its potential biodiversity interest.

The aquatic macrophyte flora is typical of low alkalinity, clear water lakes (Table 10), with *Littorella uniflora, Lobelia dortmanna* and *Isoetes lacustris* all common in the

littoral zone and to depths of up to 1.9 m (*I. lacustris*), often growing with abundant growths of the red algae (Rhodophyta) *Batrachospermum* sp. (Figure 46). The aquatic form of *Juncus bulbosus* was common in the site, extending from the shallows to a maximum depth of 4.5 m, often with *Myriophyllum alterniflorum* and *Sphagnum* sp. *Potamogeton polygonifolius* was present in marginal flushes, and also occurred in deeper water in its submerged form in S2 (Figure 46). *Luronium natans* was common in the lake between 0.75 – 1.5 m, forming extensive beds of often large plants (up to 25 cm, see Figure 47a) in the north-east of the lake. No flowering material was seen, but floating leaves of *L. natans* were observed growing up between, and in the shelter of large boulders on the southwest shore (Figure 47b).

Submerged and floating vegetation	% Cover 2018
Batrachospermum sp.	5.8
Callitriche brutia var. *hamulata*	2.2
Filamentous algae	27.0
Isoetes lacustris	**2.9**
Juncus bulbosus	15.8
Littorella uniflora	**3.6**
Lobelia dortmanna	**2.7**
Luronium natans	**5.1**
Myriophyllum alterniflorum	7.9
Nitella gracilis	0.2
Nuphar lutea	0.9
Potamogeton polygonifolius	0.5
Sparganium angustifolium	**2.3**
Sphagnum (aquatic indet.)	12.4
Species richness	**13**

Table 10. CSM Survey LEAFPACS cover results from Llyn Cwmorthin 2018.



a) b)

Figure 46. a) *Littorella uniflora* and *Lobelia dortmanna* growing within tufts of the red algae *Batrachospermum* sp. at S2 and b) strappy underwater leaves of *Potamogeton polygonifolius* in S2 at 0.9 m.

Other notable species included *Sparganium angustifolium* growing in section 3 near the southwest shore and a single occurrence of *Nitella gracilis,* a species of small stonewort that is rare in the UK. The current species assemblage is of high

conservation interest due to the population of *Luronium natans* and *Nitella gracilis.* The lake has five CSM characteristic oligotrophic species, but these occur at less than 60% frequency and therefore Llyn Cwmorthin would be classified as being in unfavourable condition with respect to its flora under JNCC CSM Guidelines (JNCC 2015). The LEAFPACS scores classify the WFD status as “high”.

a)

b)

Figure 47. a) Long underwater leaves of *Luronium natans* growing in S2 at 1.5 m b) Floating leaves of *L. natans*, sheltered between boulders on the south-west shore.

The water was very clear at the time of survey (Secchi depth of 4.6 m) and the Dissolved oxygen and temperature profiles show the lake to be well mixed at its deepest point of 8.9 m (Figure 48)

Dissolved Oxygen Profile

GPS Location	SH6770246320
Maximum Depth (m)	8.9 m
Secchi Depth (cm)	460 cm
Notes:	

Depth (m)	DO (mg/l)	Temp (°C)
0	10.26	11.1
1	10.17	11.1
2	10.18	11.1
3	10.13	11
4	9.86	10.8
5	9.9	10.7
6	9.73	10.6
7	9.04	10.3
8	8.42	10.1

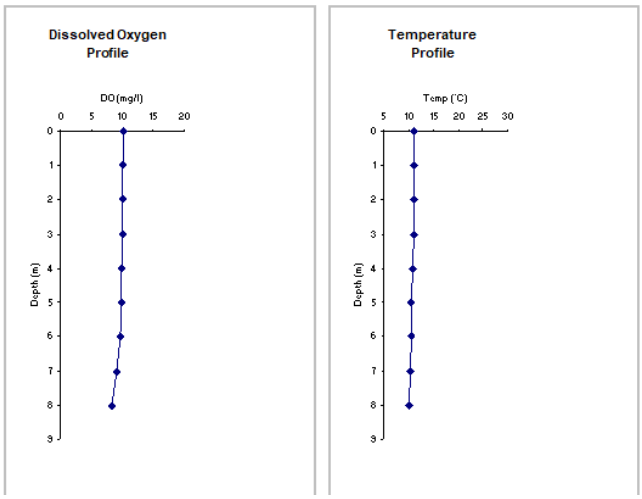


Figure 48. Dissolved oxygen and temperature profiles at Llyn Cwmorthin (29/09/2018).

Water Quality

There are no recent water chemistry samples from Llyn Cwmorthin (sample point 28574), which was last sampled in April 1996. Data from 1995-96 showed the lake to be acidified, with an ANC of 17 and a mean pH of 5.56. Based on data from other lakes, it is likely that this pressure has reduced and that consequently ANC and pH

are now higher. No relevant phosphorus data are available, and N concentrations were very low at around 0.1 mg l^{-1}. Monitoring has taken place of minewater outflows in the catchment in the past, but these did not suggest a serious contamination problem.

Overall Condition

Llyn Cwmorthin is an artificial lake and is not designated as a Protected Site. Nevertheless, it has a diverse macrophyte community including *Luronium natans* and *Nitella gracilis*. The water column is well oxygenated throughout. However, further monitoring is required to assess the current impact of potential acid and minewater pressures.

Macrophyte and dissolved oxygen data indicate that Llyn Cwmorthin is in Favourable Condition with Low confidence.

5.2.9. Llyn Glasfryn

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Figure 49. Site map and aerial photograph of Llyn Glasfryn.

Figure 50. Llyn Glasfryn site photo; from the west shore looking east.

Llyn Glasfryn is a small, very shallow lake (max. recorded depth 1.15m) situated on acid soils (Arfon series) within the gently undulating countryside of the Lleyn peninsula. The immediate catchment is small and dominated by improved grassland and broadleaf woodland, and the site is used to feed and raise ducks for shooting. 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 Lleyn 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).

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 structure of the aquatic flora has changed significantly over the past decade. In 2012 *Callitriche brutia* var. *hamulata* was dominant (Goldsmith *et al.* 2014b), whereas in 2015 (Goldsmith et al 2016) and in this survey, *Ceratophyllum demersum* was dominant. *Nitella flexilis* agg. also occurred at relatively high abundance in 2015, but was rare in 2018 (Table 11); *C. demersum* now dominating where *Nitella* had been present. Species more typical of mesotrophic conditions such as *Myriophyllum alterniflorum* and *Callitriche brutia* var. *hamulata* remain present, but at low abundance. Both *Elatine hexandra* and *E. hydropiper* were confirmed from the site in 2015, but only the latter was recorded in 2018, with dense growths of *C. demersum* occurring where *Elatine* sp. were previously recorded..

Submerged and floating vegetation	% Cover 2015	% Cover 2018
Callitriche brutia var. *hamulata*	1.4	0.7
Callitriche sp.	0.7	1.4
Ceratophyllum demersum	28.5	63.7
Elatine hexandra	**1.0**	**0.0**
Elatine hydropiper	3.5	2.5
Filamentous algae	43.2	1.9
Fontinalis antipyretica	1.1	0.3
Lemna minor	0.7	0.0
Menyanthes trifoliata	7.9	8.0
Myriophyllum alterniflorum	16.2	7.1
***Nitella flexilis* agg.**	**19.4**	**1.8**
Nuphar lutea	2.4	4.0
Nymphaea alba	1.1	1.8
Persicaria amphibia	3.4	3.4
Potamogeton perfoliatus	**0.04**	**0.0**
Species richness	**14**	**12**

Table 11. CSM Survey LEAFPACS cover results from Llyn Glasfryn 2018.

The previous site condition reports (Burgess *et al.* 2006, Goldsmith *et al.* 2014b) and CSM survey (Goldsmith *et al.* 2016), 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 water quality.

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 LEAFPACS scores classify the WFD status as “moderate”.

The site is very shallow and at the time of survey the water extremely turbid (Secchi 0.65 m). The water was well oxygenated.

Dissolved Oxygen Profile

GPS Location	SH4022642144
Maximum Depth (m)	1.1 m
Secchi Depth (cm)	65 cm

Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	10.23	14.7
0.5	10.21	14.8
0.75	10.09	14.7

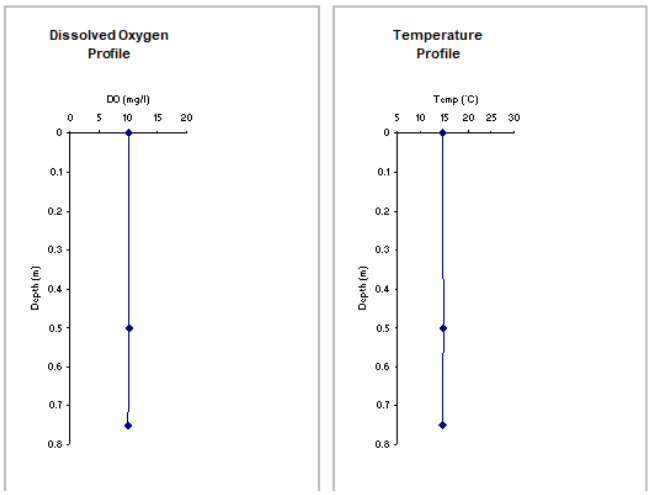

Figure 51. Dissolved oxygen and temperature profiles at Llyn Glasfryn (21/09/2018).

Water Quality

There are 39 NRW water samples from Llyn Glasfryn (sample point 26366) between January 2016 and March 2019. The lake is not acid sensitive.

Total Phosphorus

Total Phosphorus concentrations in Llyn Glasfryn are high and increasing. In 2004 the geometric mean TP was 45 µg l^{-1} and in 2005 79 µg l^{-1}. Recent geometric annual means were: 2016: 61 µg l^{-1}; 2017; 74 µg l^{-1}; 2018; 110 µg l^{-1}. These values greatly exceed the upper limit for this lake type.

High peaks in 2018 may reflect increased concentration resulting from low water levels in this very shallow lake. Nevertheless, subsequent nutrient levels suggest the lake has not stabilised following the hot summer.

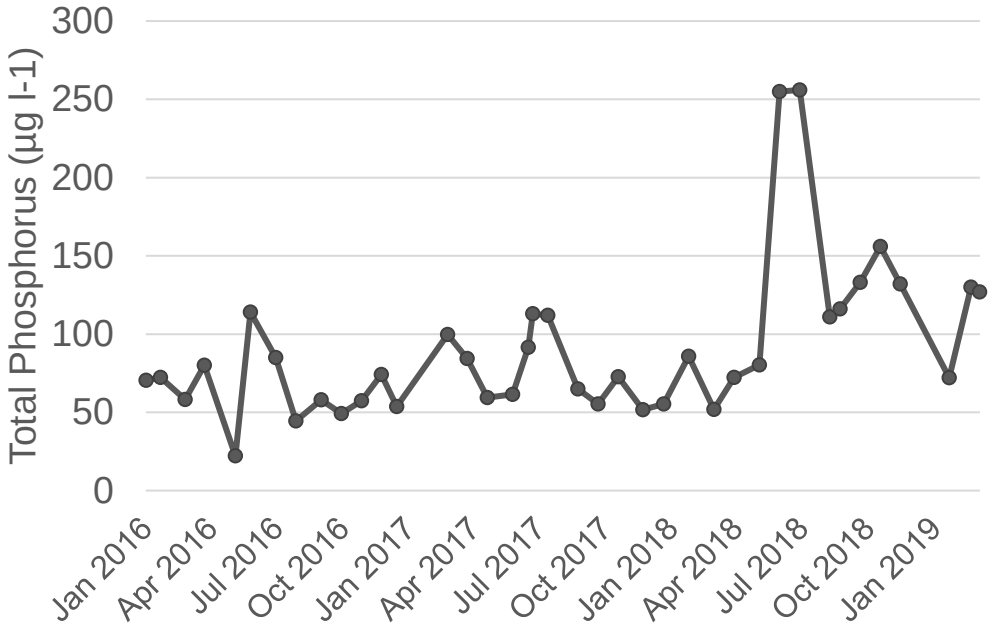

Figure 52. Total Phosphorus concentrations in Llyn Glasfryn, 2016-2019.

Nitrogen

Oxidised nitrogen concentrations were low and usually below the 0.2 mg l^{-1} limit of detection, suggesting that Llyn Glasfryn is usually nitrogen limited. Winter spikes sometimes occur, notably in 2017-18.

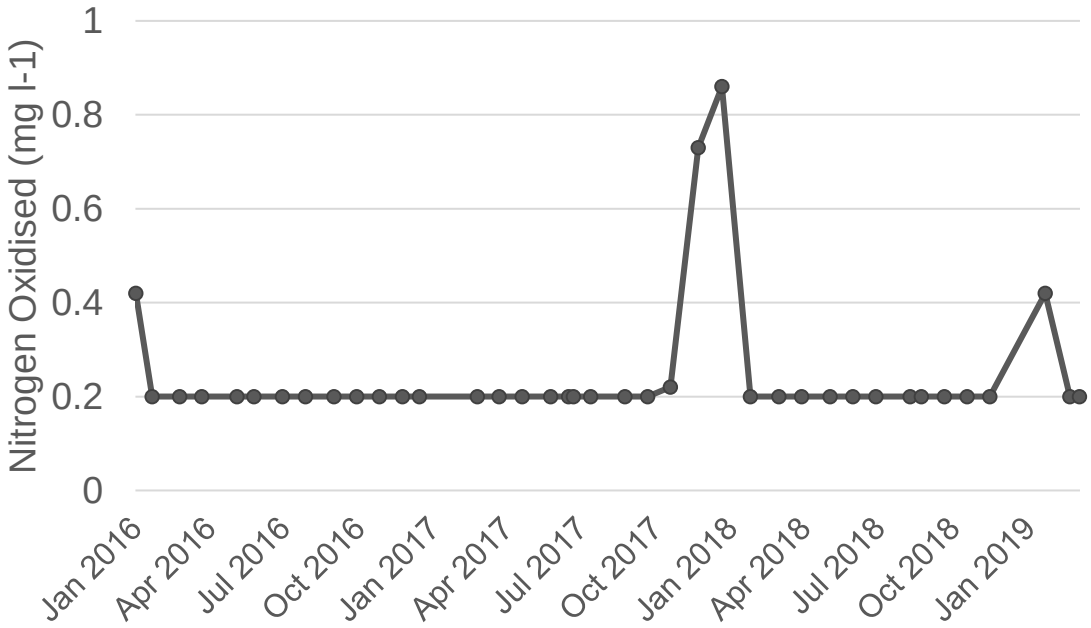

Figure 53. Oxidised Nitrogen concentrations in Llyn Glasfryn, 2016-2019.

The recorded nitrogen values do not suggest that nitrogen concentrations are having a significant negative effect on Llyn Glasfryn at present.

Overall Condition

Macrophyte, nutrient and chlorophyll data all indicate that Llyn Glasfryn is in **Unfavourable - Bad Condition** with **High** confidence. The plant community contains very few of the typical species that would be expected and instead is dominated by species that favour high nutrient levels. The lake has very high phosphate concentrations, well above the target values. Efforts should be made to reduce nutrient inputs, especially phosphorus, in the catchment and on the lake.

5.2.10. Llyn Hîr

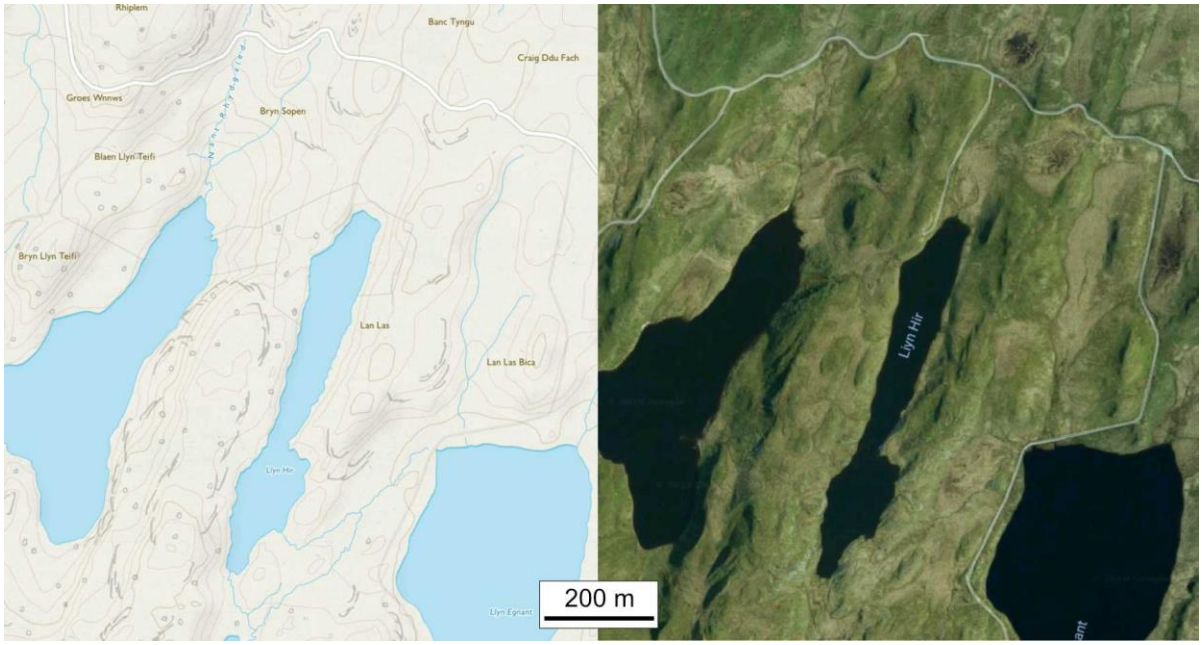

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Figure 54. Site map and aerial photograph of Llyn Hîr.

Figure 55. Llyn Hîr site photo; from the south-east shore looking north.

Llyn Hîr is a relatively shallow (max. recorded depth 7.9 m) oligotrophic lake situated within the Tiefi 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 (Goldsmith *et al.* 2006).

Llyn Hîr has an aquatic macrophyte flora typical of low alkalinity, oligotrophic lakes. *Littorella uniflora* and *Lobelia dortmanna* are both abundant, and the lake supports a number of other characteristic species for this lake type including *Subularia aquatica, Isoetes echinospora* and *Luronium natans* (Table 12). In previous surveys both *Isoetes echinospora* and *I. lacustris* have been confirmed from the site (Figure 56), but in 2018, only *I. echinospora* was verified. This was in part due to a lack of fertile material being found, but also due to high cover of very fine filamentous algae that not only obscured the plants, but was also very easily disturbed into the water column, further hampering visual survey of low growing plants.

Submerged and floating vegetation	% Cover 2015	% Cover 2018
Batrachospermum sp.	0.1	0.0
Filamentous algae	57.8	39.5
Fontinalis squamosa	0.7	0.0
Isoetes echinospora	**4.1**	**0.4**
Isoetes lacustris	**0.3**	**0.0**
Juncus bulbosus	1.7	1.4
Littorella uniflora	**8.1**	**7.0**
Lobelia dortmanna	**7.3**	**7.2**
Luronium natans	**3.7**	**1.9**
Menyanthes trifoliata	0.7	1.0
Myriophyllum alterniflorum	7.5	4.7
Nitella flexilis agg.	15.9	12.5
Potamogeton polygonifolius	3.4	3.2
Ranunculus omiophyllus	0.7	1.0
Sparganium angustifolium	**0.1**	**0.0**
Sphagnum (aquatic indet.)	1.7	0.6
Subularia aquatica	**1.6**	**0.05**
Species richness	**16**	**12**

Table 12. CSM Survey LEAFPACS cover results from Llyn Hîr 2018.

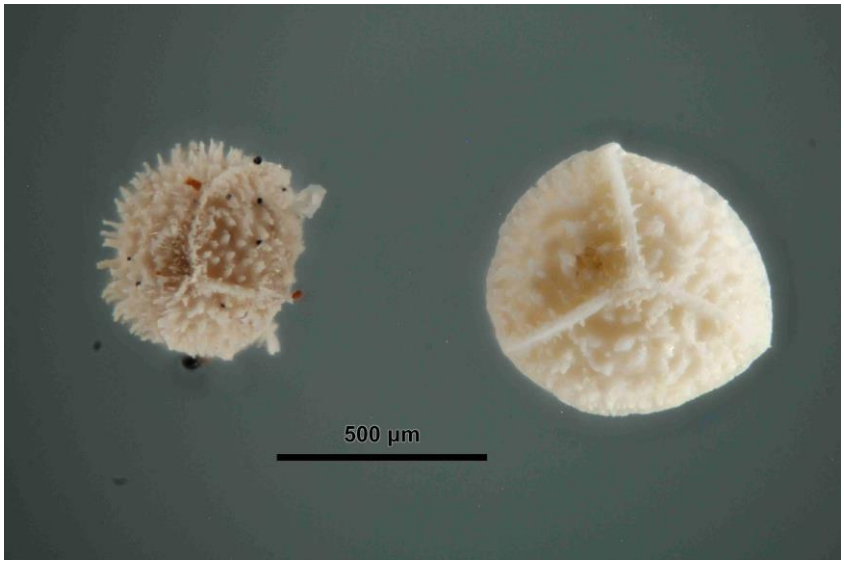

Figure 56. *Isoetes* megaspores collected from Llyn Hîr in 2015, confirming the presence of both *I. echinospora* (left) and *I. lacustris* (right).

The current levels of filamentous algae are high and suggest elevated nutrient availability in the site, which warrants further investigation. The current species assemblage is relatively good and would place the site in favourable condition with respect to its flora under JNCC CSM Guidelines (JNCC 2015). However, the data suggest the loss of two characteristic species from the site since 2015 (*I. lacustris* and *Sparganium angustifolium*). Further investigation is required to determine if *I. lacustris* remains present at the site, with snorkel survey recommended where conditions limit effective boat and wader-based surveying. The apparent loss of *S. angustifolium* is most likely incorrect; the 2015 survey having included an additional section in the south-west of the lake where this species was recorded. The LEAFPACS scores classify the WFD status as “good”.

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 57).

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

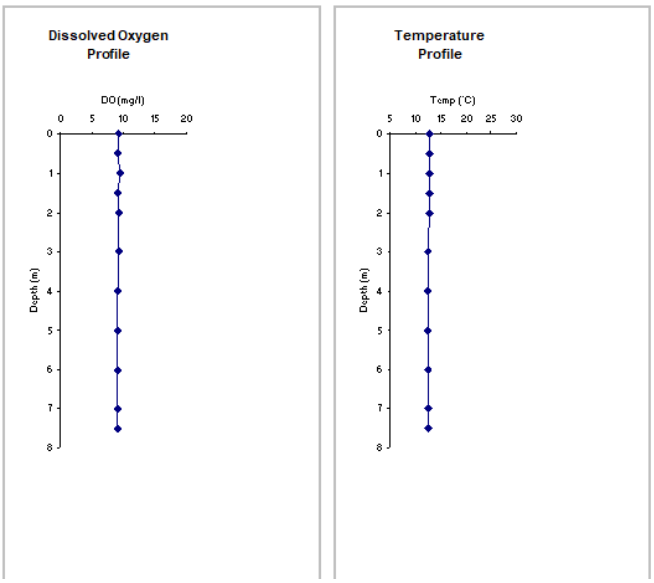

Figure 57. Dissolved oxygen and temperature profiles at Llyn Hîr (01/10/2018).

Water Quality

There are 51 NRW water samples from Llyn Hîr (sample point 89176) between January 2015 and March 2019: a much longer time series is available but this has not generally been used for this assessment. Although acid sensitive, the lake is now circumneutral, with a mean pH of 6.96. Both nutrients and acid sensitivity have been assessed here.

Acid Neutralising Capacity (ANC)

Mean Cantrell ANC ranged between 30 and 90 µeq l^{-1}, with the lowest values typically occurring in winter and early spring. Alkalinity has increased significantly since the first decade of the century, resulting in increased ANC.

Annual mean ANC values were 52 µeq l^{-1} for 2015; 64 µeq l^{-1} for 2016, 61 µeq l^{-1} for 2017 and 53 µeq l^{-1} for 2018. These are well above the target minimum value of 40 µeq l^{-1} and therefore indicate the lake passes its acidity target.

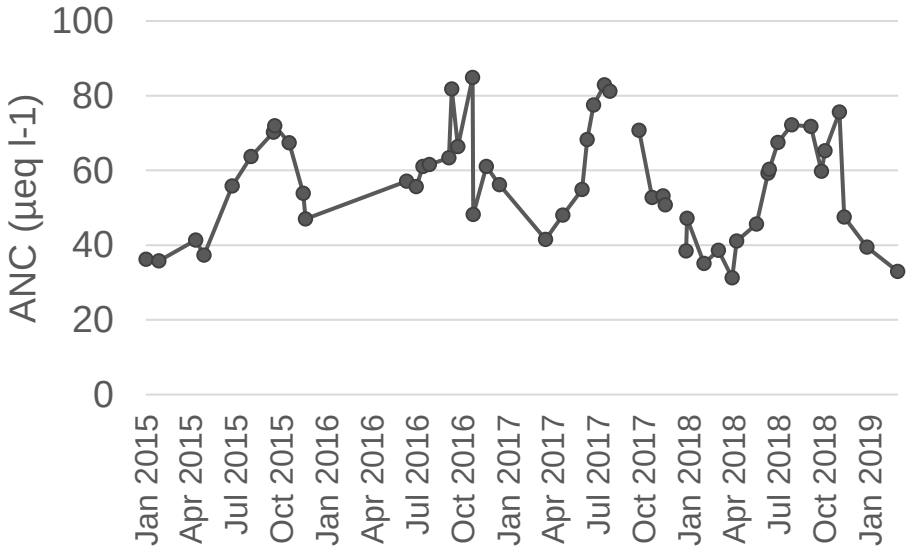

Figure 58. ANC concentrations in Llyn Hîr, 2015-2019.

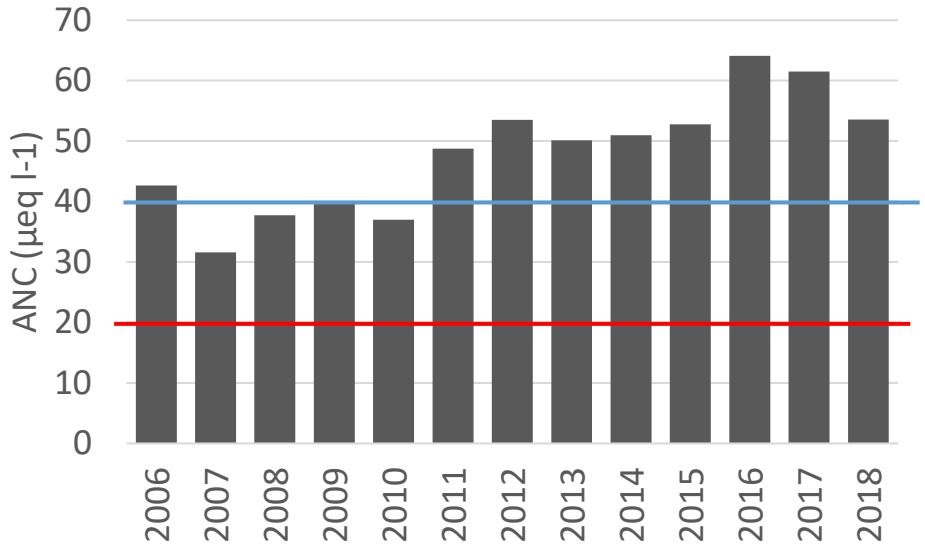

Figure 59. Long-term ANC concentrations in Llyn Hîr. The blue line indicates the High / Good Boundary and the Red line the Good / Moderate boundary.

Inspection of longer-term data clearly indicates that in chemical terms, Llyn Hîr is no longer affected by acidification.

Total Phosphorus

Total Phosphorus concentrations in Llyn Hîr are low and within the target values for an oligotrophic lake, though there are some winter peaks that give cause for concern. Geometric Annual means were: 2015: 7.3 µg l-1; 2016: 8.2 µg l^{-1}; 2017; 8.0 µg l^{-1}; 2018; 10.0 µg l^{-1}. These values pass the target. The small apparent increase in mean TP is a statistical artefact and not reflected in long-term data.

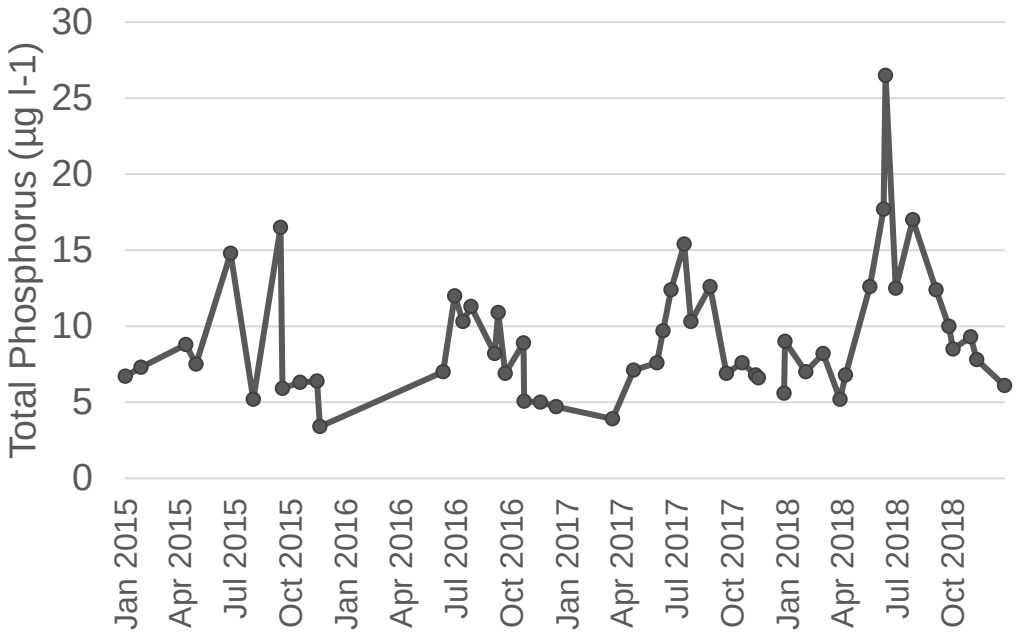

Figure 60. Total Phosphorus concentrations in Llyn Hîr, 2015-2019.

Nitrogen

Total nitrogen concentrations were low, showing weak fluctuations in concentration. There is some evidence of a long-term increase in total nitrogen concentrations in Llyn Hîr.

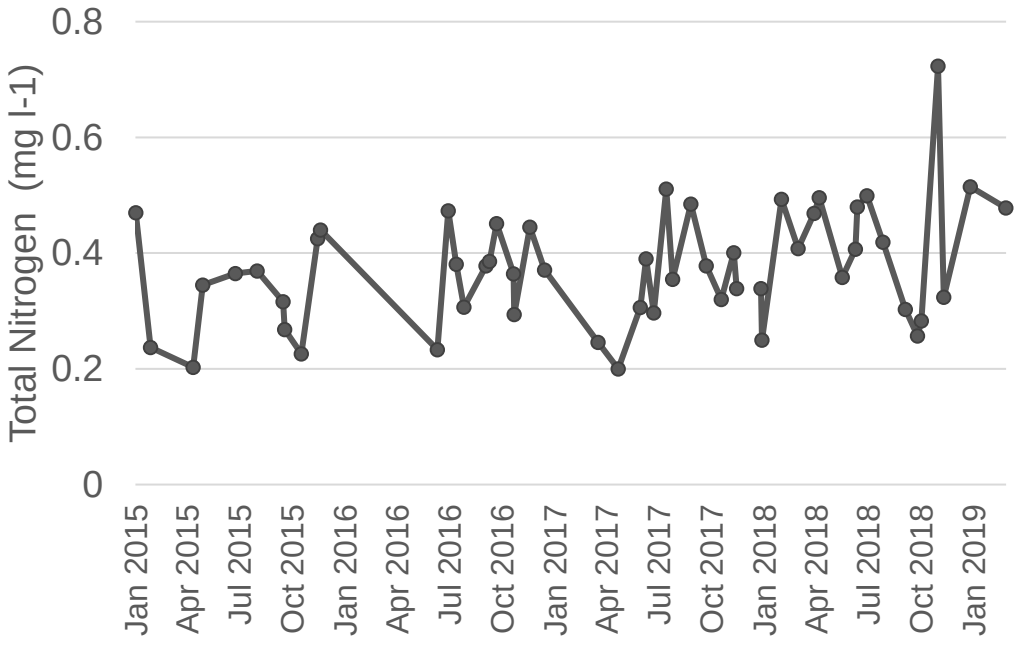

Figure 61. Oxidised Nitrogen concentrations in Llyn Hîr, 2015-2019.

The recorded nitrogen values do not suggest that nitrogen concentrations are having a significant negative effect on Llyn Hîr at present.

Overall Condition

Macrophyte, nutrient and chlorophyll data all indicate that Llyn Hîr is in **Favourable Condition** with **Moderate** confidence. The general plant community is favourable though apparently prone to high levels of filamentous algae. Future surveys should attempt to establish whether *Isoetes lacustris* has been lost from the site, or whether a population crash has occurred. This species and *I. echinospora* do appear to show cyclical changes in abundance in several of the lakes in which they co-occur in Wales. Water quality is generally favourable at present but there is some evidence of increases in nutrient levels, possibly from peat erosion.

5.2.11. Llangorse Lake

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Figure 62. Site map and aerial photograph of Llangorse Lake

Figure 63. Llangorse Lake site photo; from the south-west shore, looking north-east.

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 lake is recognised to be of significant conservation value and was designated as a SSSI in 1954 and a Special Area of Conservation (SAC) under the Habitats Directive as the Annex I habitat "Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation". 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 lake margins have a diverse array of wetland habitats including areas of wet woodland and seasonally flooded *Salix* spp. swamp, wet grassland and *Carex* spp. fen, as well as extensive areas of emergent reedbeds dominated by *Phragmites australis, Typha angustifolia, T. latifolia, Sparganium erectum* and *Schoenoplectus tabernaemontani*. The outer face of the reedbeds extends out to 1.0 m water depth (summer level), often with very little aquatic vegetation below (*Lemna minor, L. trisulca* and *Spirodela polyrhiza* common).

The aquatic vegetation is species rich, with 22 species recorded in 2018 (Table 13), and typical of eutrophic waters. Beyond the wetland fringe, there were extensive beds of water lilies in many areas of the lake, with *N. lutea* the most frequent, *N. alba* relatively rare and the introduced (locally absent) species *Nymphoides peltata* also frequent. The broad-leaf Shining pondweed *Potamogeton lucens* was locally common within the site, often occurring in the more sheltered areas within sparse reed beds or lily beds. *Potamogeton lucens* was recorded in four of the six survey sections. Other species confined to the littoral zone included *Eleocharis acicularis, Butomus umbellatus, Sparganium emersum, Ranunculus lingua* and *Persicaria amphibia.* In contrast with the two most recent previous surveys, *Chara* sp. were absent in 2018, otherwise the species composition and cover values remained similar.

Submerged and floating vegetation	% Cover 2015	% Cover 2017	% Cover 2018
Butomus umbellatus	2.1	2.1	2.0
Ceratophyllum demersum	4.4	7.7	10.7
Chara contraria* var. *contraria	**1.5**	**0.0**	**0.0**
Chara globularis	**2.5**	**6.2**	**0.0**
Eleocharis acicularis	0.5	0.3	0.2
Elodea canadensis	2.8	8.6	7.8
Elodea nuttallii	18.9	20.8	25.0
Filamentous algae	18.8	5.4	16.4
Lemna minor	3.0	4.0	4.1
Lemna trisulca	6.8	8.7	7.1
Menyanthes trifoliata	1.8	1.9	1.9
Myriophyllum alterniflorum	0.1	0.0	0.0
Myriophyllum spicatum	5.8	6.6	8.9
Nitellopsis obtusa	1.0	2.8	2.7
Nuphar lutea	4.3	5.1	4.0
Nymphaea alba	1.6	0.9	0.3
Nymphoides peltata	2.4	4.1	4.5
Persicaria amphibia	1.5	2.7	2.9
Potamogeton crispus	**0.0**	**0.0**	**0.3**
Potamogeton lucens	**1.9**	**3.1**	**2.4**
Potamogeton pectinatus	2.1	0.2	0.1
Potamogeton perfoliatus	**0.8**	**0.1**	**0.1**
Potamogeton pusillus	0.3	0.1	0.0
Ranunculus circinatus	**0.2**	**0.1**	**0.0**
Ranunculus lingua	1.4	2.0	2.7
Sparganium emersum	0.2	0.5	1.2
Spirodela polyrhiza	**3.1**	**4.2**	**3.3**
Zannichellia palustris	0.0	0.0	0.9
Species richness	**25**	**23**	**22**

Table 13. CSM Survey LEAFPACS cover results from Llangorse Lake 2015, 2017 & 2018

The open water was dominated throughout most of the lake by dense growths of *Elodea nuttallii,* which reached a maximum depth of 3.1 m. With the *E. nuttallii, Myriophyllum spicatum and Ceratophyllum demersum* are common and *Elodea canadensis* also present. *Nitellopsis obtusa* was recorded from three of the six

sections at depths ranging from 1.4 m to 2.7 m. This stonewort species was first detected in Llangorse Lake in 2014 (N. Stewart, pers. comm.) and recorded from one section in 2015 (Goldsmith *et al.* 2016) and four in 2017 (Shilland *et al.* 2018). 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.

Compared with other recent surveys, Llangorse lake has remained relatively stable, albeit with the notable addition of *Nitellopsis obtusa. Elodea nuttallii* has been recorded as dominant in WFD and condition surveys conducted since 2003 (Goldsmith *et al.* 2004), and although there have been changes in the frequency of the common taxa (e.g. *C. demersum, M. spicatum* and *L. trisulca*), the overall assemblage has remained similar. Earlier surveys, show more significant shifts. Monteith *et al.* (1995), records only *Elodea canadensis,* and no *E. nuttallii,* which is consistent with the westward and northerly spread of the latter species since the 1970s (NBN Atlas, 2018), and Wade (1999) documents a poor species assemblage in 1974. No *Chara* species were recorded in 2018.

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

The current species assemblage has only four qualifying characteristic species and would be considered to be in unfavourable condition with respect to its flora under JNCC CSM Guidelines (JNCC 2015) for natural eutrophic lakes. Furthermore, there are characteristic species recorded in 2015 which were not seen in 2018, suggesting potential loss of typical species from the site (e.g *Chara species*). The WFD LEAFPACS tool classifies the site as “good” with respect to its flora.

Dissolved oxygen and temperature profiles showed the site to be mixed with no thermocline evident and only a slight decline in dissolved oxygen and temperature with increasing depth (Figure 64).

Dissolved Oxygen Profile

GPS Location	SO1341826623
Maximum Depth (m)	6.9 m
Secchi Depth (cm)	180 cm

Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	10.27	14
1	10.19	14
2	10.14	14
3	9.89	13.7
3.5	9.63	13.7
4	9.49	13.7
4.5	9.36	13.6
5	9.22	13.6
5.5	8.79	13.6
6	8.7	13.6

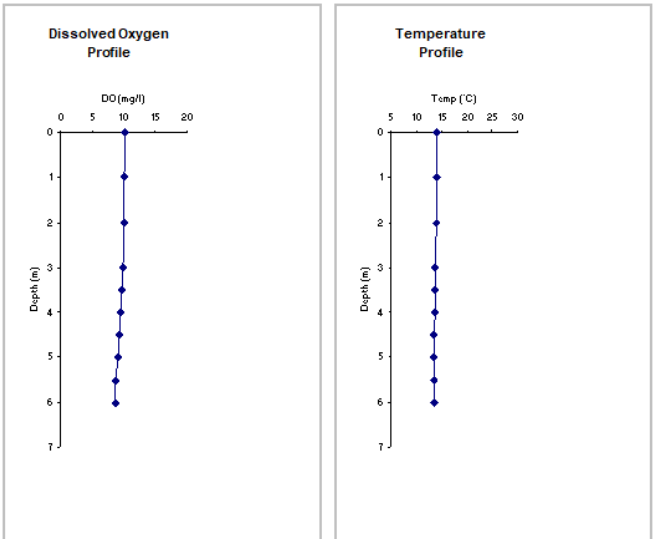

Figure 64. Dissolved oxygen and temperature profiles at Llangorse Lake (03/10/2018).

Water Quality

There are 64 NRW water samples from Llangorse Lake (sample point 51285) between January 2014 and March 2019. The lake is alkaline, with a mean pH of 8.26 and a mean alkalinity of 2483 µeq l^{-1}.

Total Phosphorus

Total Phosphorus concentrations in Llangorse Lake are high, with summer peaks reflecting nitrogen limitation during the growing season. Geometric Annual means were: 2014: 117 µg l^{-1}; 2015: 107 µg l^{-1}; 2016: 121 µg l^{-1}; 2017; 137 µg l^{-1}; 2018; 174 µg l^{-1}. These values are well above the target for the lake.

Nitrogen

Oxidised nitrogen concentrations were variable, showing very strong seasonal fluctuations in concentration, with peaks occurring in winter and very low levels in summer, though a change to the detection limit from summer 2016 onwards meant these could not be measured accurately. A higher and longer peak occurred in winter 2018-19. The reason for this is unknown but could perhaps be due to accumulation of N in the catchment during the unusually dry summer.

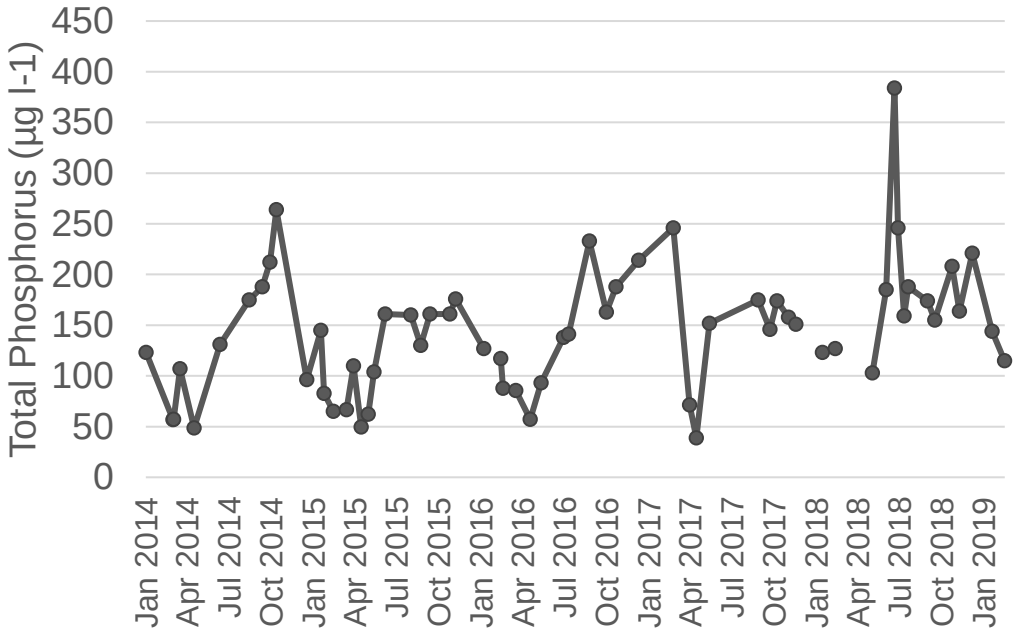

Figure 65. Total Phosphorus concentrations in Llangorse Lake, 2014-2019.

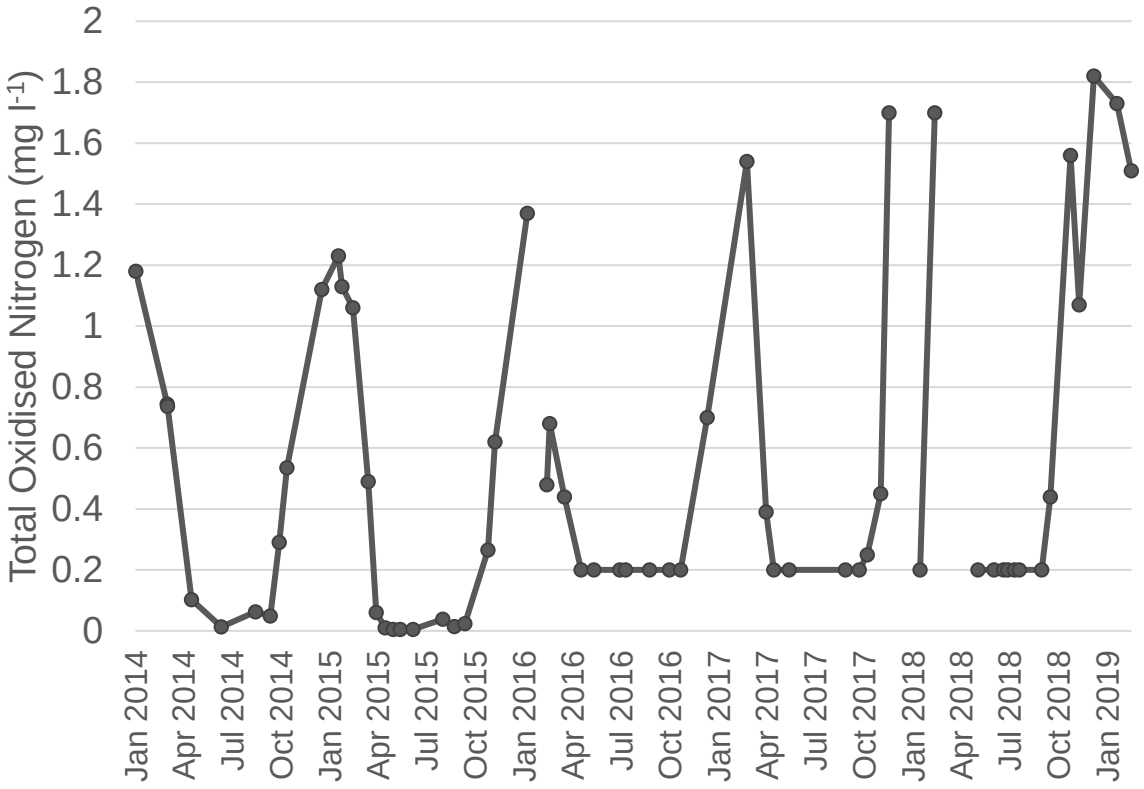

Figure 66. Oxidised Nitrogen concentrations in Llangorse Lake, 2014-2019.

The recorded nitrogen values are thought to be the controlling nutrient at Llangorse Lake and it is therefore very important that levels in both summer and winter are kept low.

Chlorophyll

Chlorophyll concentrations in Llangorse Lake indicate that the algal community tends to respond mainly to nitrogen availability, with any peaks occurring in autumn and winter. These did not occur predictably however, perhaps due to low temperatures in some years restricting algal growth.

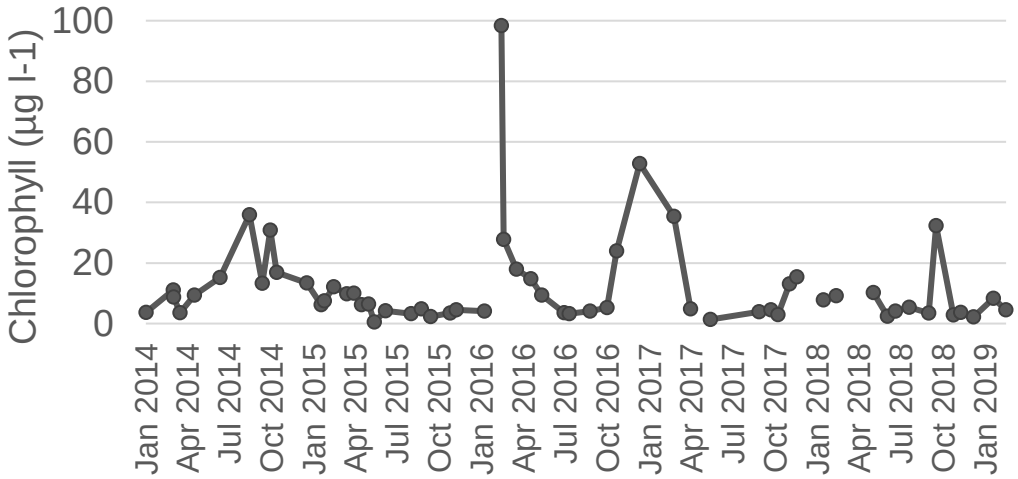

Figure 67. Chlorophyll concentrations in Llangorse Lake, 2014-2019.

Overall Condition

Macrophyte, nutrient and chlorophyll data all indicate that Llangorse Lake is in **Unfavourable – Bad Condition** with **High** confidence. The plant community includes a wide range of characteristic species, chlorophyll levels are generally fairly low and the water column is well oxygenated. However, the plant community is dominated by the invasive non-native *Elodea nuttallii*, and nutrient levels are very high.

It is recommended that a package of catchment based measures be introduced to trap silt and nutrients in the main inflow streams, in order to reduce nutrient transport to the lake especially during high flow events. This should include re-meandering of the Llynfi, the main inflow stream.

5.2.12. Llyn Pencarreg

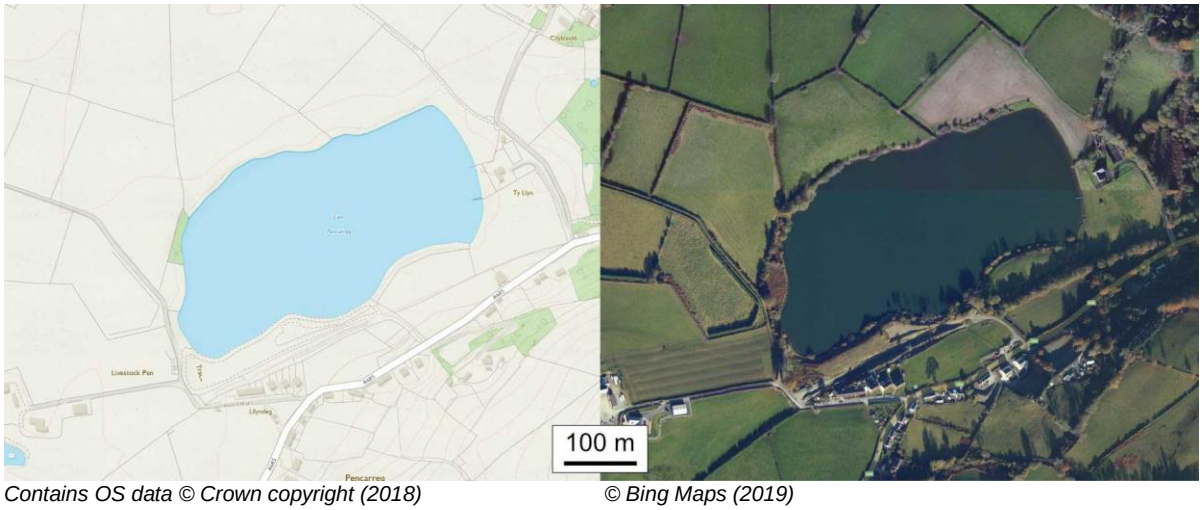

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Figure 68. Site map and aerial photograph of Llyn Pencarreg.

Figure 69. Llyn Pencarreg site photo; from the south-west looking north-east (taken 2012).

Llyn Pencarreg is a kettle-hole lake lying within the Teifi Valley to the south-west of Lampeter. The lake was designated as a SSSI in 1973, the primary feature being its oligotrophic waters, which are rare in this region of lowland Wales, and its populations of overwintering waterfowl and breeding pochard. With respect to the flora, the SSSI citation notes *Littorella uniflora* as the only aquatic species present, but we from the previous CSM survey that the lake also supports *Isoetes lacustris* and *Elatine hexandra* (Goldsmith *et al.* 2014c).

Llyn Pencarreg has no significant inflows and no surface outflows and is assumed therefore to groundwater fed. The lake is surrounded by improved pasture which slopes down steeply to the shore around much of the lake, buffered to some degree to the west and north by a narrow strip of in trees and hawthorn scrub. An old disused railway cutting runs close (20 m) to the south shore.

The 2018 CSM results show the aquatic macrophyte flora of Llyn Pencarreg to have remained similar to the 2012 survey, with *Littorella uniflora*, *Isoetes lacustris* and *Elatine hexandra* the only species recorded growing, and a single occurrence of *Callitriche brutia* var *hamulata* found in the strandline at section 1 (Table 14)

Submerged and floating vegetation	% Cover 2012	% Cover 2018
Littorella uniflora	**14.7**	**26.9**
Elatine hexandra	**13.1**	**7.4**
Isoetes lacustris	**1.13**	**2.3**
Callitriche brutia var. hamulata	0.0	0.7
Species richness	**3**	**4**

Table 14. CSM Survey LEAFPACS cover results from Llyn Pencarreg 2012 & 2018

The lake therefore remains species-poor, but nonetheless supports three JNCC (2015) characteristic species for “oligo-mesotrophic standing waters” in 2018. The distribution of these species within the site is however rather poor. *Littorella uniflora* was the most common species, and reached a maximum depth of 1.7 m in Section 1, but mostly only occurred at less than 1.2 m depth. *Isoetes lacustris* was rare in the site and only recorded at three points in section 1, the deepest at 1.1 m. *Elatine hexandra* was restricted to depths of less than 1.0 m. The south side of the lake, including section 4 was mostly devoid of any aquatic vegetation.

Three was no filamentous algae recorded, but large areas of the littoral zone, as well as submerged plants were covered with a decaying crust of what appeared to be cyanobacteria biomass. There was also a noticeable blue-green algal bloom in the water.

In terms of CSM classification, the site appears favourable with respect to its aquatic flora, having three characteristic species, achieving 100% presence in vegetated sample points. This however belies the fact that the aquatic flora is mainly restricted to shallow water and that large areas of the littoral zone have no plant present. The water quality was very poor in 2012 (TP ranging from 125 – 448 μgl^{-1}, Goldsmith *et al.* 2014c) and the presence of cyanobacterial blooms (reported by NRW staff as having been in excess of 500,000 cells per ml of *Aphanizomenon flos aquae* in the summer of 2018) is indicative of high nutrient levels at the site. Palaeoecological evidence of nutrient enrichment at the site is presented in Goldsmith *et al.* (2014c).

With respect to site management, Llyn Pencarreg appears to be clinging on to the remnants of its characteristic oligotrophic flora despite high nutrients. A better understanding of the nutrient sources (e.g. agricultural and residential) and how they are reaching the site (e.g. surface flow and groundwater) is necessary in order to tackle further enrichment. The site would also benefit greatly from fenced buffer strips to the north, east and south of the lake to limit bank erosion by livestock and help to reduce sediment and nutrient inputs from the surrounding farmland.

Dissolved oxygen and temperature profiles showed the site to be stratified in early October, with a sharp decline in both dissolved oxygen and temperature below 8 m. The profundal waters were anoxic (Figure 64).

Dissolved Oxygen Profile

GPS Location	SN5376745676
Maximum Depth (m)	12.1 m
Secchi Depth (cm)	108 cm

Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	8.43	14.5
0.5	8.38	14.5
1	8.3	14.4
1.5	8.18	14.4
2	8.14	14.4
3	8.02	14.4
4	7.93	14.4
5	7.73	14.4
6	7.76	14.4
7	7.74	14.4
8	7.44	14.3
9	0.6	11.2
10	0.58	10.2
11	0.5	10
12	0.45	9.8

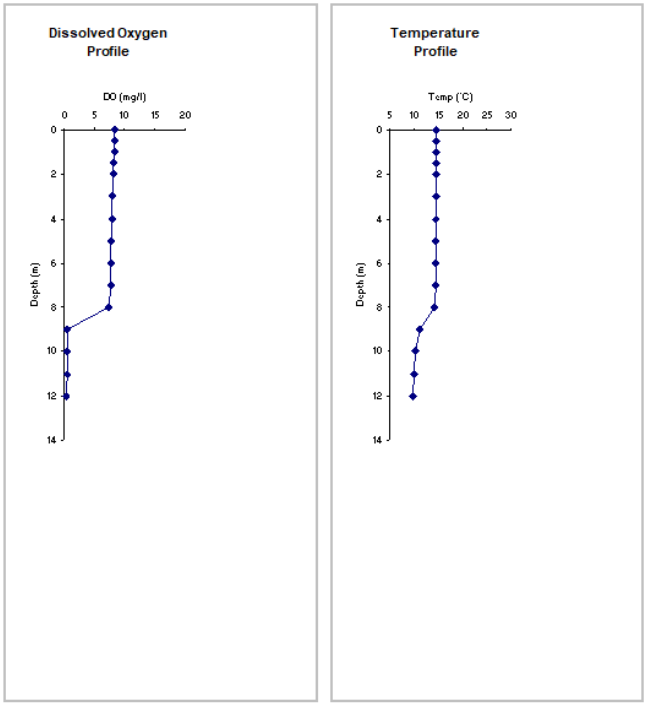

Figure 70. Dissolved oxygen and temperature profiles at Llyn Pencarreg (02/10/2018).

Water Quality

There are 36 NRW water samples from Llyn Pencarreg (sample point 28561) between January 2016 and March 2019. The lake is weakly alkaline, with a mean pH of 7.78 but a low mean alkalinity of 55 µeq l^{-1}. Only nutrients have been assessed here as although the lake is potentially acid sensitive, neither the pH or the alkalinity data indicate an impact of acidification.

Total Phosphorus

Total Phosphorus concentrations in Llyn Pencarreg are high and above the target values for an oligotrophic lake, with peak values tending to occur in autumn, possibly reflecting fertilizer application or slurry spreading on adjacent land. Geometric Annual means were: 2016: 121 µg l^{-1}; 2017; 106 µg l^{-1}; 2018; 85 µg l^{-1}. Further data is required to determine whether phosphorus levels continue to reduce.

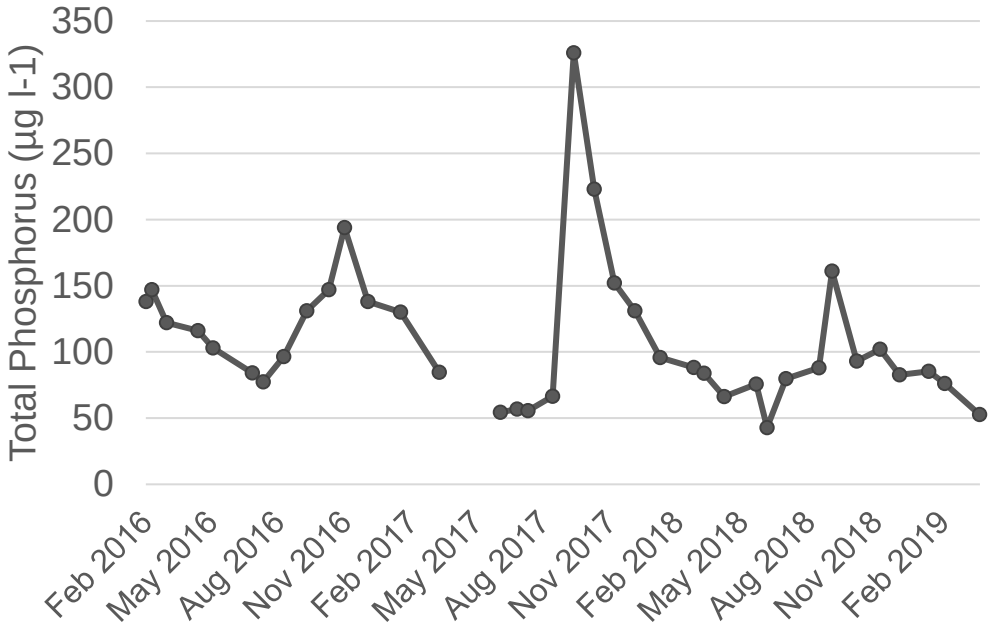

Figure 71. Total Phosphorus concentrations in Llyn Pencarreg, 2016-2019.

Nitrogen

Total nitrogen concentrations were moderate to high, showing weak seasonal fluctuations in concentration, with peaks occurring in winter. Higher peaks occurred in winter 2017-18 and 2018-19. In combination with the elevated phosphorus concentrations at the site, these N concentrations are a significant cause for concern.

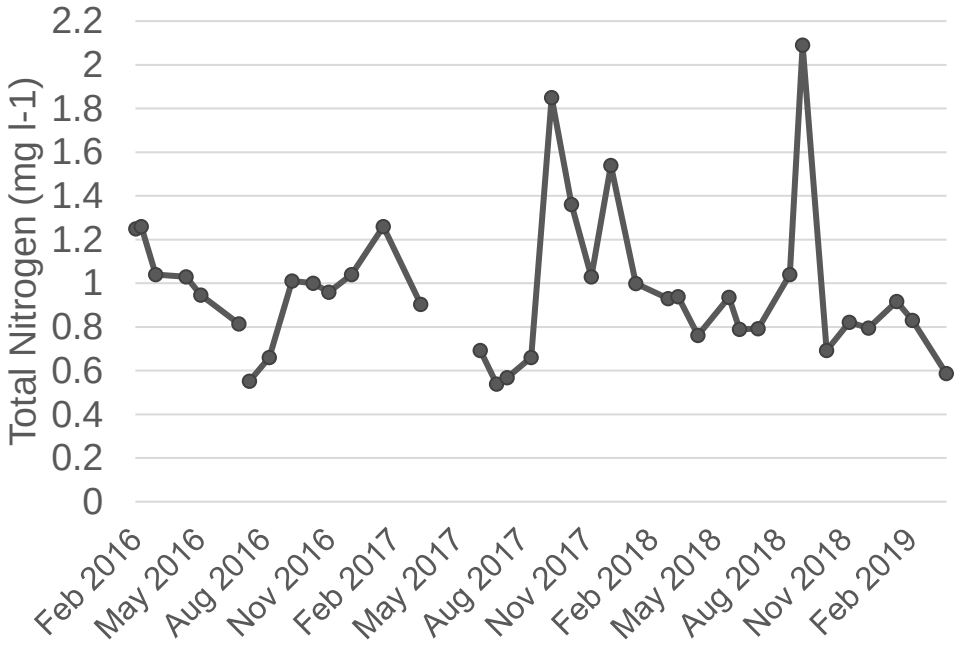

Figure 72. Total Nitrogen concentrations in Llyn Pencarreg, 2016-2019.

Chlorophyll

Chlorophyll concentrations in Llyn Pencarreg showed clear seasonality, peaking in September. These peaks have increased in magnitude over the past three years.

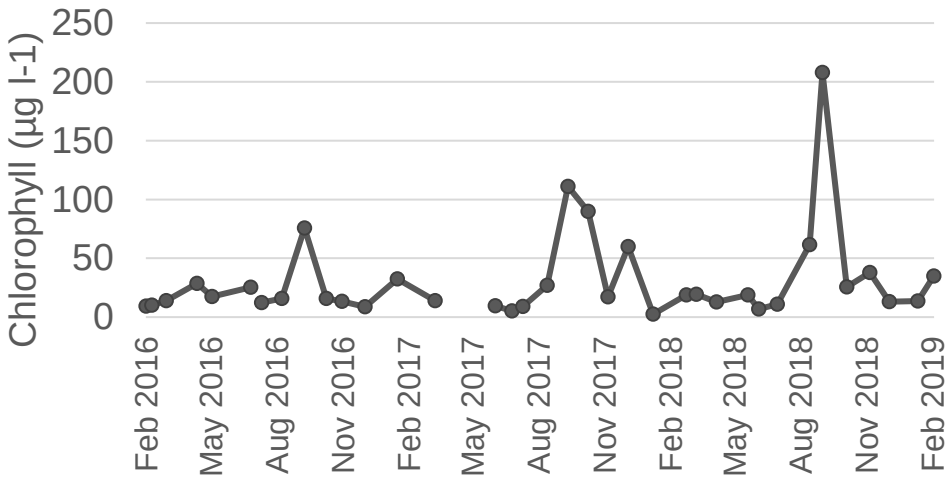

Figure 73. Chlorophyll concentrations in Llyn Pencarreg, 2016-2019.

Overall Condition

Macrophyte, nutrient and chlorophyll data all indicate that Llyn Pencarreg is in **Unfavourable - Bad Condition** with **High** confidence. The plant community is very species-poor, there is evidence of algal blooms, the hypolimnion is deoxygenated and there are high nutrient levels. Although there is some evidence of a slight improvement since the last assessment, with lower phosphorus concentrations and the colonization of *Callitriche hamulata*, overall condition remains very poor.

5.2.13. Kenfig Pool

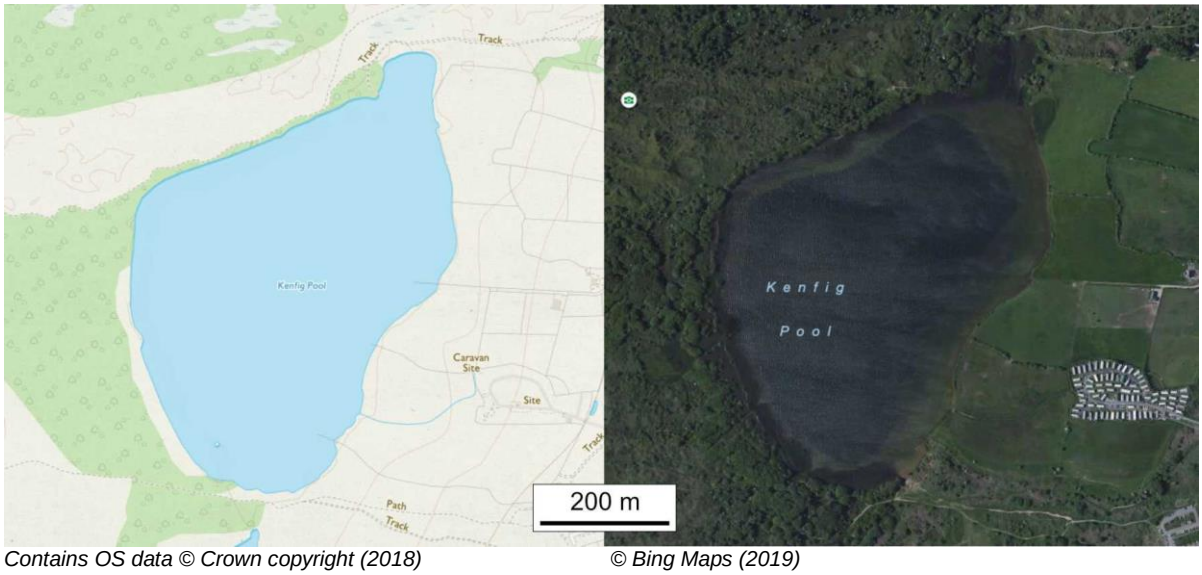

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Figure 74. Site map and aerial photograph of Kenfig Pool

Figure 75. Kenfig Pool site photo; from the south-east shore looking north (taken 2015)

Kenfig Pool is a very shallow (2.8 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.", for which it is of great importance in Wales (Hatton-Ellis 2018). 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.

The aquatic macrophytes flora of Kenfig Pool is relatively species rich (Table 15) with a mosaic of different plant species extending throughout the lake to the deepest point at 2.8 m. Specific to the SAC feature, three species of *Chara* were recorded in 2018, with at least one species recorded at 45% of the sample points. The dense *Chara* spp. beds were mainly restricted to the sandy substrates just beyond the reed face to the west and north shore, and on the exposed littoral shore to the east, extending out into open water to 1.6 m. *Chara* species only rarely extend beyond 1.6 m depth with *C. virgata and C. contraria var. contraria* recorded at low abundance within the mosaic of higher plants between 1.6 – 2.5. The overall cover of *Chara* species was slightly higher than in 2015, and one additional species was recorded in 2018; *C.*

contraria var. *contraria.* It is possible that *C. globularis* is also present, but material was difficult to determine (by Nick Stewart) and placed in *C. virgata. Chara globularis* is rare in south Wales and not previously recorded from Kenfig Pool.

Of the remaining flora, *Ceratophyllum demersum* was dominant in 2015 and in 2018, with *Myriophyllum spicatum* frequent and *Elodea canadensis* locally abundant. Other notable species included *Nitellopsis obtusa, Littorella uniflora* and *Nitella mucronata*. *Elodea nuttallii* was recorded at low abundance, a non-native species which can become aggressively competitive and threaten low-growing species such as charophytes. Filamentous algae was present throughout much of the lake, but mainly at low cover scores.

Submerged and floating vegetation	% Cover 2015	% Cover 2018
Ceratophyllum demersum	14.6	19.7
Chara aspera	**7.4**	**11.4**
Chara contraria* var. *contraria	**0.0**	**3.1**
Chara virgata	**3.9**	**3.9**
Elodea canadensis	14.2	13.6
Elodea nuttallii	0.0	0.1
Filamentous algae	0.0	22.6
Fontinalis antipyretica	2.3	3.0
Lemna trisulca	5.9	2.4
Littorella uniflora	3.2	4.0
Menyanthes trifoliata	2.8	3.4
Myriophyllum alterniflorum	3.1	0.0
Myriophyllum spicatum	9.9	4.8
Nitella confervacea	0.1	0.0
Nitella flexilis agg.	0.0	0.2
Nitella mucronata	0.0	0.8
Nitellopsis obtusa	0.0	0.4
Persicaria amphibia	3.6	2.4
Potamogeton berchtoldii	0.2	0.0
Potamogeton gramineus	0.03	0.0
Potamogeton natans	0.1	0.8
Potamogeton pectinatus	0.8	0.0
Potamogeton perfoliatus	0.7	0.7
Potamogeton pusillus	0.0	0.1
Potamogeton trichoides	7.9	0.4
Potamogeton x *angustifolius (*x *zizii)*	0.7	0.7
Ranunculus circinatus	0.4	0.0
Ranunculus lingua	2.1	2.1
Zannichellia palustris	0.1	0.0
Species richness	**21**	**21**

Table 15. CSM Survey LEAFPACS cover results from Kenfig Pool 2015 & 2018

The site is notable for supporting at least five *Potamogeton* species and one hybrid (Table 15). *Potamogeton gramineus* was rare in 2015 and not recorded in 2018, but its *P. lucens* hybrid (*P. x angustifolius*) remains present in the sheltered areas at the back of the reed fringed north shore. The small bay at the northern extent of the lake is particularly species rich, but poorly covered by the CSM survey due to it being a

uniform depth of 40 cm. *Myriophyllum spicatum* was common, but *M. alterniflorum* was not recorded in 2018. The ecological ranges of these species only rarely overlap, but both were confirmed at the site in 2015.

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 relatively low cover of *Chara* spp. coupled with high cover of *Elodea canadensis* (and arrival of *E. nuttallii*) are the main reason for failure. The dominance of *C. demersum* in 2015 and 2018 is of concern and we would recommend regular monitoring of the flora and water quality to help inform site management.

Kenfig Pool is very shallow and exposed site and the dissolved oxygen and temperature profiles show the lake to be well mixed with good oxygen concentration throughout the water column (Figure 76).

Dissolved Oxygen Profile

GPS Location	SS7965581482
Maximum Depth (m)	2.3 m
Secchi Depth (cm)	140 cm

Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	10.06	14.4
0.5	9.98	14.3
1	9.96	14.3
1.5	9.94	14.3
2	9.89	14.2

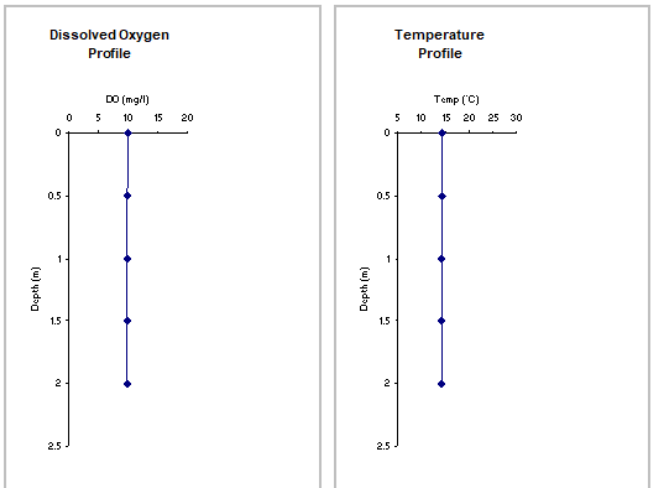

Figure 76. Dissolved oxygen and temperature profiles at Kenfig Pool (03/10/2018).

Water Quality

There are 36 NRW water samples from Kenfig Pool (sample point 19024) between January 2014 and February 2019. The lake has an alkalinity of 1419 µeq l^{-1} and an alkaline mean pH of 8.36. The lake is not acid sensitive and so only nutrient pressures are assessed here.

Total Phosphorus

Total Phosphorus concentrations in Kenfig Pool exceed the target values for this lake type, with summer peaks that give cause for concern. Geometric Annual means were: 2014: 24.0; 2015: 21.9; 2016: 26.3 µg l^{-1}; 2017; 34.2 µg l^{-1}; 2018; 31.0 µg l^{-1}. These values consistently fail the target and have increased over the course of the assessment period. Higher phosphorus concentrations may be linked to sightings of

carp spawning in the lake and more successful recruitment following warmer spring temperatures.

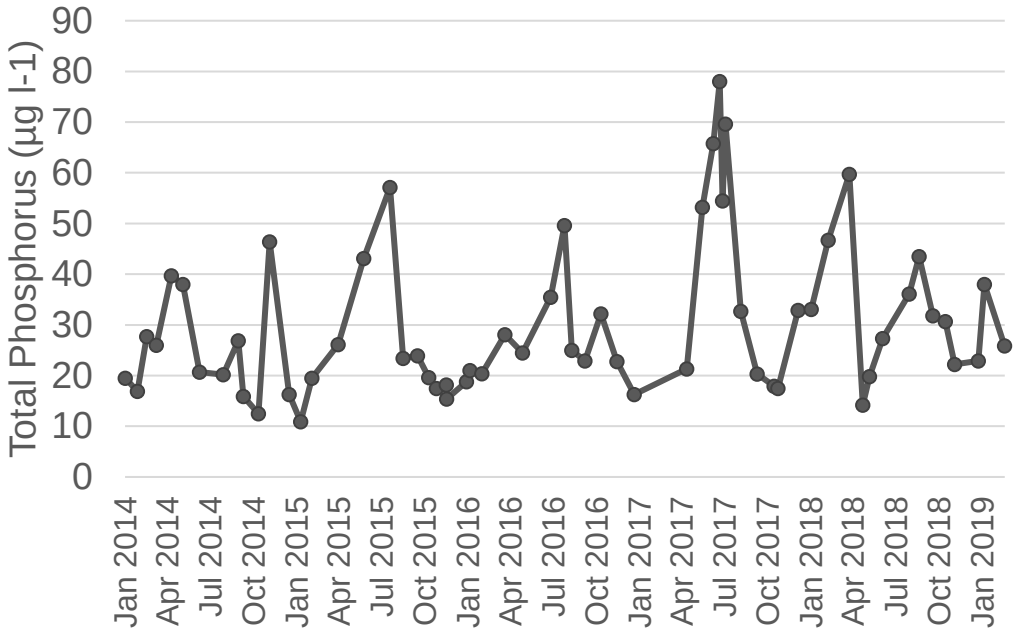

Figure 77. Total Phosphorus concentrations in Kenfig Pool, 2014-2019.

Nitrogen

Total nitrogen concentrations show an increasing trend over the course of the assessment period, with some high peaks in late summer (July – August). The cause of this is uncertain but may be due to increasing numbers of Canada Geese using the lake for moulting.

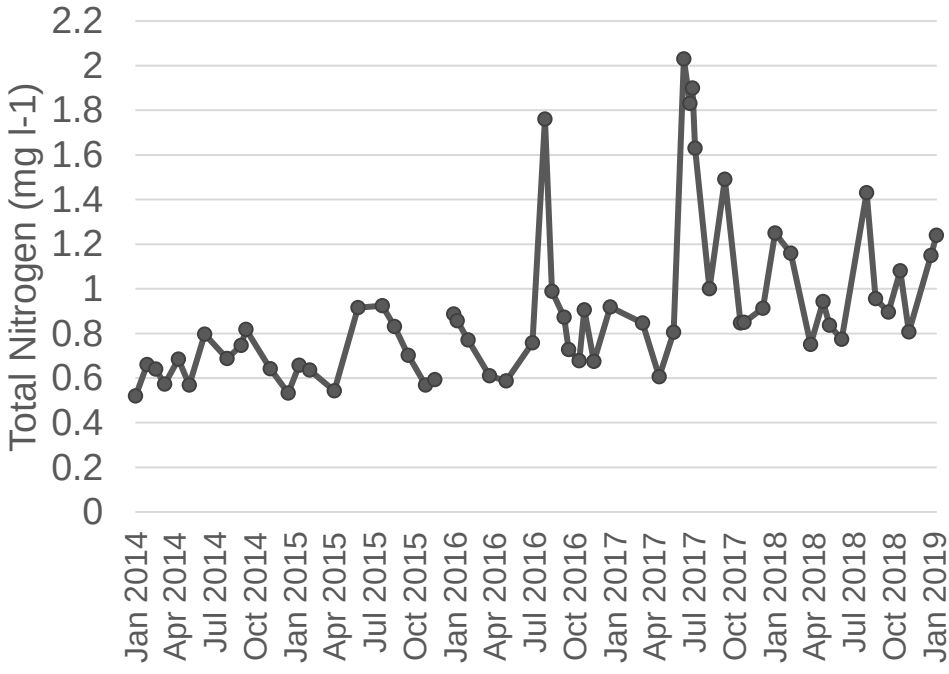

Figure 78. Oxidised Nitrogen concentrations in Kenfig Pool, 2014-2019.

Chlorophyll

Chlorophyll concentrations have increased markedly in Kenfig Pool in response to increased nutrient loading, with blooms occurring in 2017 and 2018. Whereas the 2017 bloom occurred only in summer, in 2018 late winter / spring and autumn blooms occurred. This pattern looks likely to be repeated in 2019. These patterns have not previously been observed, as Kenfig Pool has no history of algal blooms.

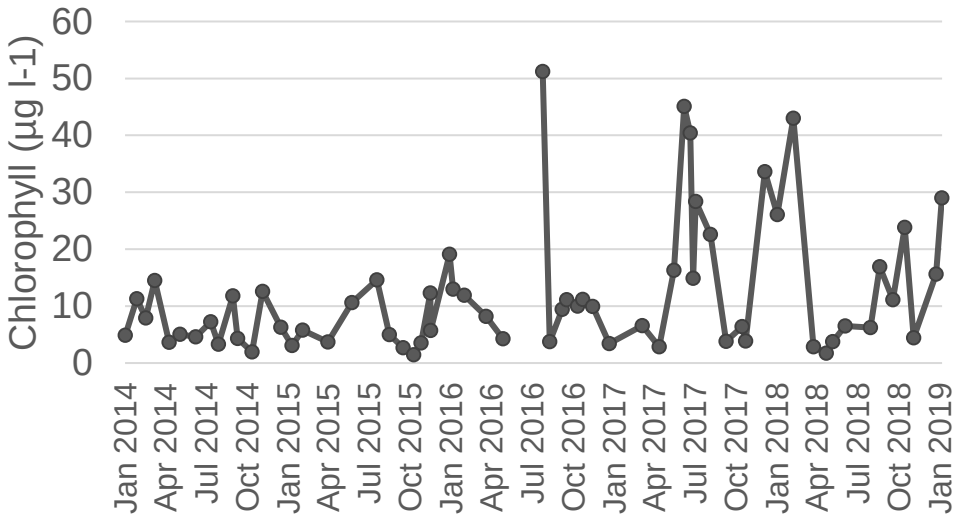

Figure 79. Chlorophyll concentrations in Kenfig Pool, 2014-2019.

Overall Condition

Macrophyte, nutrient and chlorophyll data all indicate that Kenfig Pool is in **Unfavourable – Inadequate and Declining Condition** with **Moderate** confidence. The plant community is relatively stable and the water column is well oxygenated, but increasing concentrations of nitrogen and phosphorus are a serious cause for concern and require further investigation and action.

5.2.14. Llyn Blaenmelindwr

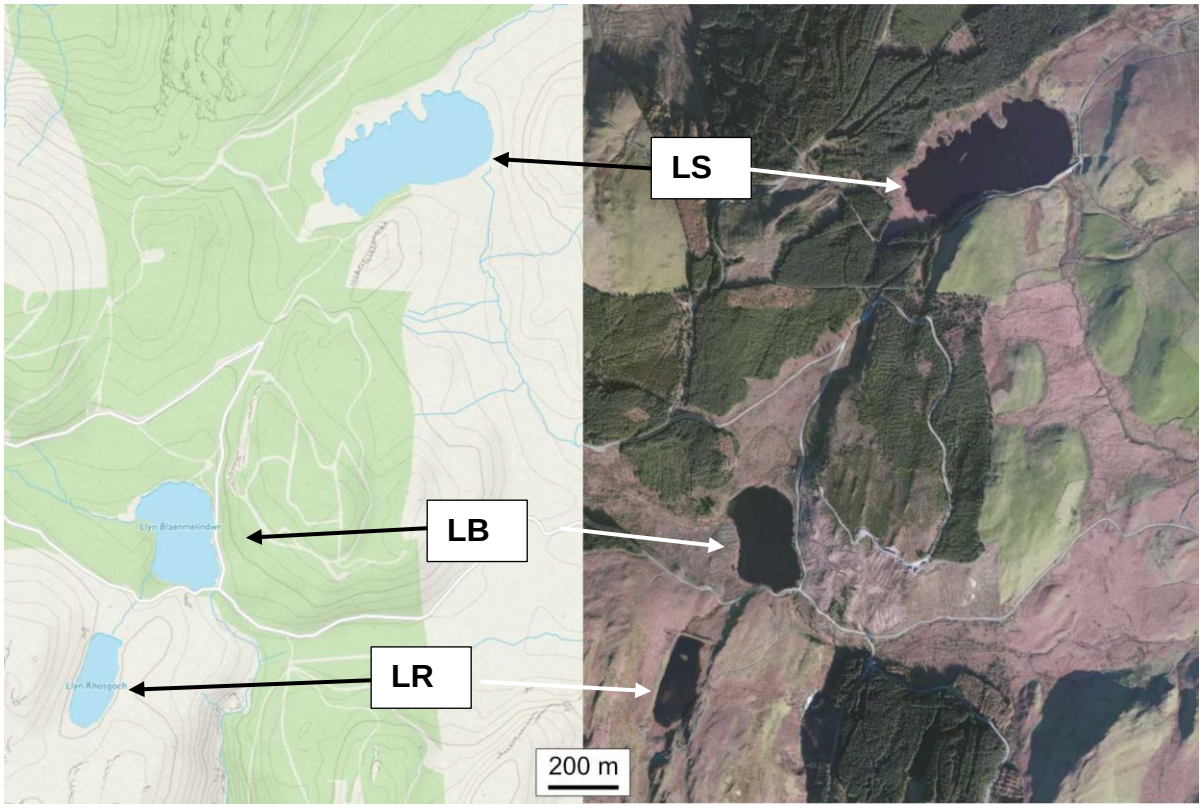

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Figure 80. Site map and aerial photograph of Llyn Blaenmelindwr (LB), L. Rhosgoch (LR) and L. Syfydrin (LS).

Figure 81. Llyn Blaenmelindwr site photo; from the south looking north-west.

Llyn Blaenmelindwr is an artificial water body retained by a stone and earth dam to the south-eastern end, over which the road now passes. Much of the immediate catchment to the north, east and west is planted with conifers, including both young

stands and recently felled mature plantation. The unforested areas are predominantly upland acid / rough grassland with little evidence of grazing. The lake is shallow with a maximum recorded depth of 3.6 m.

Submerged and floating vegetation	% Cover 2018
Batrachospermum sp.	0.6
Eleogiton fluitans	**0.9**
Filamentous algae	5.9
Isoetes echinospora	**2.0**
Juncus bulbosus	14.7
Littorella uniflora	**0.3**
Menyanthes trifoliata	2.2
Myriophyllum alterniflorum	8.3
Nymphaea alba	0.7
Potamogeton berchtoldii	0.4
Potamogeton natans	4.2
Potamogeton polygonifolius	1.8
Sparganium angustifolium	**2.4**
Sphagnum (aquatic indet.)	6.8
Utricularia minor	**11.7**
Species richness	**14**

Table 16. CSM Survey LEAFPACS cover results from Llyn Blaenmelindwr 2018

The aquatic macrophytes flora of Llyn Blaenmelindwr is typical for an upland acid water body, with species such as *Juncus bulbosus, Utricularia minor, Sphagnum* spp. and *Myriophyllum alterniflorum* most frequent and extending to a maximum depth of 3.0 m (*M. alterniflorum* in Section 4). Five typical oligotrophic species were recorded, but all are relatively low abundance (Table 16). BSBI records show both *Isoetes lacustris* and *I. echinospora* to be present in the past, but where megaspores were present, only *I. echinospora* was confirmed and all vegetative material was similar in general appearance. *Littorella uniflora* was recorded only in the littoral zone in Section 3 on the south-east side and *Sparganium angustifolium* mainly in Section 2 to the south-west side. *Utricularia minor* was the most commonly recorded characteristic species and overall, 58% of the vegetated sample points had one or more of the five characteristic species present, suggesting the flora to be in favourable condition. Filamentous algae was present, but mainly restricted to the margins and did not occur at high cover scores.

Llyn Blaenmelindwr is shallow and exposed resulting in the lake being well mixed with dissolved oxygen and temperature profiles showing little change between the surface and the deeper water (Figure 82). The water is slightly brown, but was otherwise clear with a Secchi depth was 204 m.

Dissolved Oxygen Profile

GPS Location	SN7156283559
Maximum Depth (m)	2.6 m
Secchi Depth (cm)	240 cm

Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	8.87	12.1
0.5	8.83	12.1
1	8.9	12.2
1.5	8.88	12.2
2	8.88	12.2
2.5	8.63	12.1

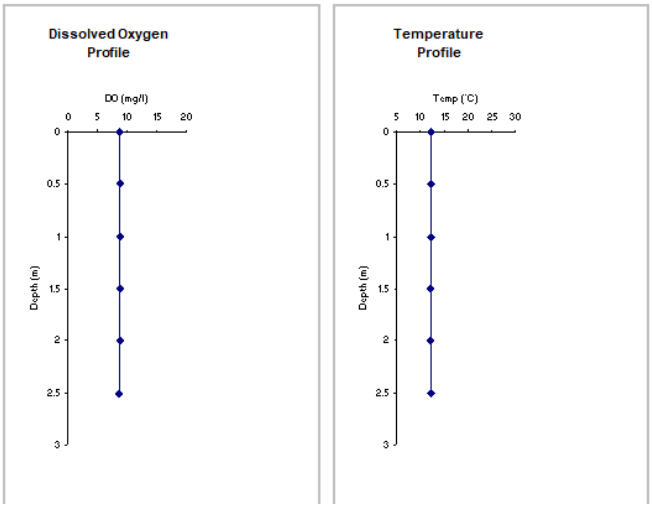

Figure 82. Dissolved oxygen and temperature profiles at Llyn Blaenmelindwr (30/09/2018).

Water Quality

No recent water quality data are available from Llyn Blaenmelindwr. The lake was sampled during the 1980s and 1990s, when data suggest that it was acidified, with a mean pH of 5.35 in 1993-4. Alkalinity data suggest the lake was probably limed at this time, as large fluctuations in this parameter are evident. No reliable nutrient data are available.

Overall Condition

Macrophyte, nutrient and chlorophyll data all indicate that Llyn Blaenmelindwr is in **Favourable Condition** with **Low confidence**. The plant community includes all of the expected species, and the water column well oxygenated. However, lack of water quality data means that the potential impact of acidification cannot be assessed.

5.2.15. Llyn Rhosgoch.

Figure 83. Llyn Rhosgoch site photo; from the north-west shore, looking south.

Llyn Rhosgoch lies up-stream and approximately 250 m to the south-west of Llyn Blaenmelindwr (see Figure 80 for the site map). The lake is small (3 ha) and very shallow, with a maximum recorded depth of only 1.2 m. The water was clear, but with a slight peaty-brown tinge. Although there lake is probably natural in origin, there is a low dam to the south end, but this has long been breached. The current outflow now passes out of the lake via the former sluice, apparently returning the lake to somewhere close to its natural level. The small cathment consits of upland acid grassland wirth evidence of only light grazing by sheep. A sign reading “Private fishing” suggests the site to be used by anglers.

Submerged and floating vegetation	% Cover 2018
Batrachospermum sp.	1.1
Elatine hexandra	**11.0**
Filamentous algae	33.2
Isoetes echinospora	**12.3**
Juncus bulbosus	0.3
Littorella uniflora	**5.4**
Menyanthes trifoliata	1.0
Nitella gracilis	1.0
Potamogeton natans	2.0
Potamogeton polygonifolius	1.0
Sparganium angustifolium	**12.0**
*Sphagnum (*aquatic indet.)	5.8
Utricularia minor	**3.1**
Species richness	**12**

Table 17. CSM Survey LEAFPACS cover results from Llyn Rhosgoch 2018

The aquatic macrophytes flora of Llyn Rhosgoch is typical for an upland acid water body, and included five characteristic oligotrophic HD species (at 98 % of the sample points) as well as *Nitella gracilis*, a species of small stonewort that is rare in the UK.

Littorella uniflora was common, but occurred only in the margins below 75 cm depth, giving way to quite extensive cover of *Isoetes echinospora* and *Elatine hexandra* in the open water areas and to a maximum depth of 1.2 m. Like Llyn Blaenmelindwr, the *Isoetes*, where fertile, were all confirmed to be *I. echinospora*. In addition to mature plants, there were relatively high numbers of seedling *Isoetes* present which were assumed from their general form to also be *I. echinospora*. *Sparganium angustifolium* formed extensive beds in open water, particularly in the southern half of the lake and *Utricularia minor* was common throughout the open water area.

With at least one of the five characteristic species present at 98% of the vegetated sample points, the aquatic flora is considered to be favourable condition. Filamentous algae was present through most of the lake, often forming in loose ‘clouds’ within plant stems, particularly those of the *Sparganium angustifolium.* Although occurring at high frequency, the abundance scores were mostly low.

The site is very shallow and exposed, and consequently the water was well oxygenated (Figure 84).

Dissolved Oxygen Profile

GPS Location	SN7124983206
Maximum Depth (m)	1.2 m
Secchi Depth (cm)	-

Notes: Secchi >1.2

Depth (m)	DO (mg/l)	Temp (°C)
0	9.33	12.7
0.5	9.34	12.7
1	9.15	12.7

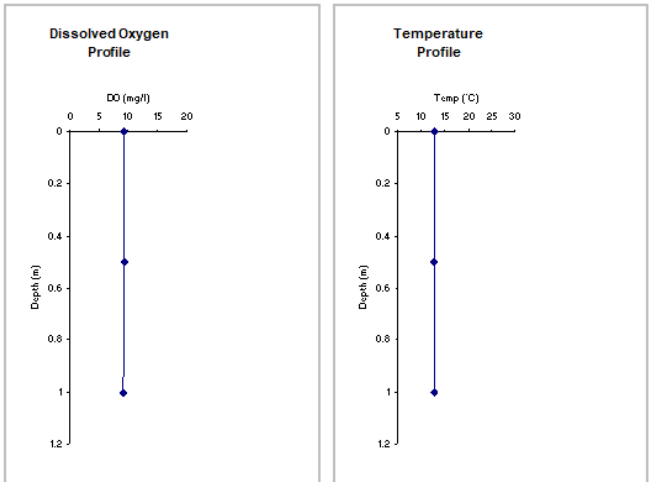

Figure 84. Dissolved oxygen and temperature profiles at Llyn Rhosgoch (28/09/2018).

Water Quality

There are no recent water quality data from Llyn Rhosgoch, with the most recent data being from 1993 when mean pH was 5.88. Alkalinity was surprisingly high (Mean = 79 µeq l^{-1}) and very variable (Min = 28.8, Max = 235.8 µeq l^{-1}), suggesting the lake was limed at this time.

Overall Condition

Macrophyte, nutrient and chlorophyll data all indicate that Llyn Rhosgoch is in Favourable Condition with Low confidence. The plant community includes most of the expected species including the rare *Nitella gracilis*. However, water quality data are needed for a full assessment.

5.2.16. Llyn Syfydrin

Figure 85. Llyn Syfydrin site photo; from the south-west shore, looking north.

Llyn Syfydrin is a very shallow (maximum recorded depth 1.8 m), small (11 ha) artificial water body located just over 1 km to the northwest of Llyn Blaenmelindwr (see Figure 80 for the site map). The immediate catchment consists of mature conifer plantation to the north and west (including recent felling) and upland acid grassland to the east. The pasture to the south of the lake is semi-improved with sheep grazing. Unlike Llyn Blaenmelindwr, which has relatively clear water, Llyn Syfyrin is a rich, peaty-brown, and the Secchi disc depth was only 80 cm. In terms of its lake type the peaty water and lack of deep-water flora points to Llyn Syfydrin being a dystrophic lake.

Submerged and floating vegetation	% Cover 2018
Callitriche brutia var. *hamulata*	1.4
Filamentous algae	0.1
Fontinalis squamosa	1.5
Juncus bulbosus	0.3
Orontium aquaticum	+
Pontederia cordata	+
Sphagnum (aquatic indet.)	5.9
Utricularia minor	**0.7**
Species richness	**7**

Table 18. CSM Survey LEAFPACS cover results from Llyn Syfydrin 2018

With poor light penetration, the aquatic flora was mostly limited to emergent, marginal species (*Carex rostrata* and *Juncus effusus*) and bryophytes. Only *Sphagnum* spp. and *Fontinalis squamosa* were recorded in the open water areas, and these plants were unrooted and therefore prone to drifting. *Utricularia minor* and *Callitriche brutia* var. *hamulata* were recorded only in the strandline areas and the aquatic form of *Juncus bulbosus* growing no deeper than 50 cm.

Two species of non-native aquatic macrophyte were seen in the site; *Orontium aquaticum* (Golden rod) and *Pontederia cordata* (Pickerel weed). Presumably these

plants were introduced to the site deliberately and although undesirable in a wild setting, do not appear to be spreading within the lake at present.

The site is used by anglers and the track to the south of the lake was being used by recreational 4x4 vehicles and mountain bikers on the day it was surveyed. Litter and discarded fishing tackle were noted, particularly along the south shore.

The lake is very shallow and exposed, and the water was well oxygenated (Figure 86).

Dissolved Oxygen Profile

GPS Location	SN7213384650
Maximum Depth (m)	1.8 m
Secchi Depth (cm)	80 cm

Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	8.31	12.3
0.5	8.35	12.3
1	8.39	11.9
1.5	8.29	11.6
1.7	8.19	11.6

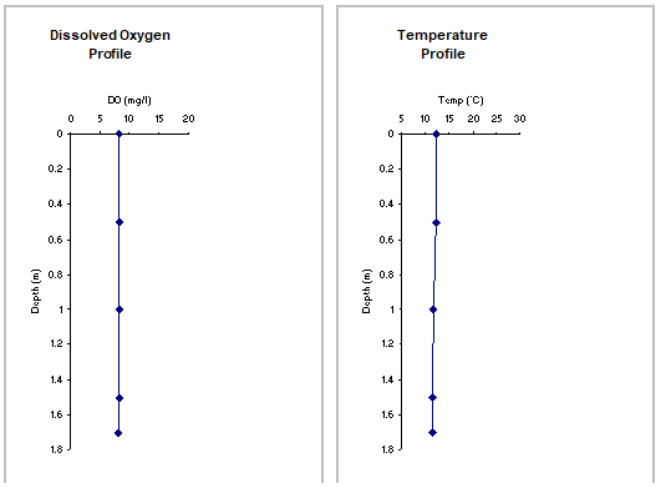

Figure 86. Dissolved oxygen and temperature profiles at Llyn Syfydrin (01/10/2018).

Water Quality

As with Llyn Blaenmelindwr and Rhosgoch, the most recent water quality data are from the early 1990s, when Llyn Syfydrin was very acid, with a mean pH of 4.94. In spite of this, the lake was relatively well-buffered with an ANC of around 20-40. Liming appears to have taken place in the early 1990s, resulting in a dramatic increase in alkalinity and ANC. The dark brown peaty water suggests Llyn Syfydrin to be a dystrophic lake.

Overall Condition

Macrophyte, nutrient and chlorophyll data all indicate that Llyn Syfydrin is in **Unfavourable Condition** with **Low** confidence. The plant community includes only one predicted species (*Utricularia minor*), but it is possible that this is a dystrophic lake. Water chemistry information is required to assess this, including data on Colour.

5.2.17. Caban Coch Reservoir

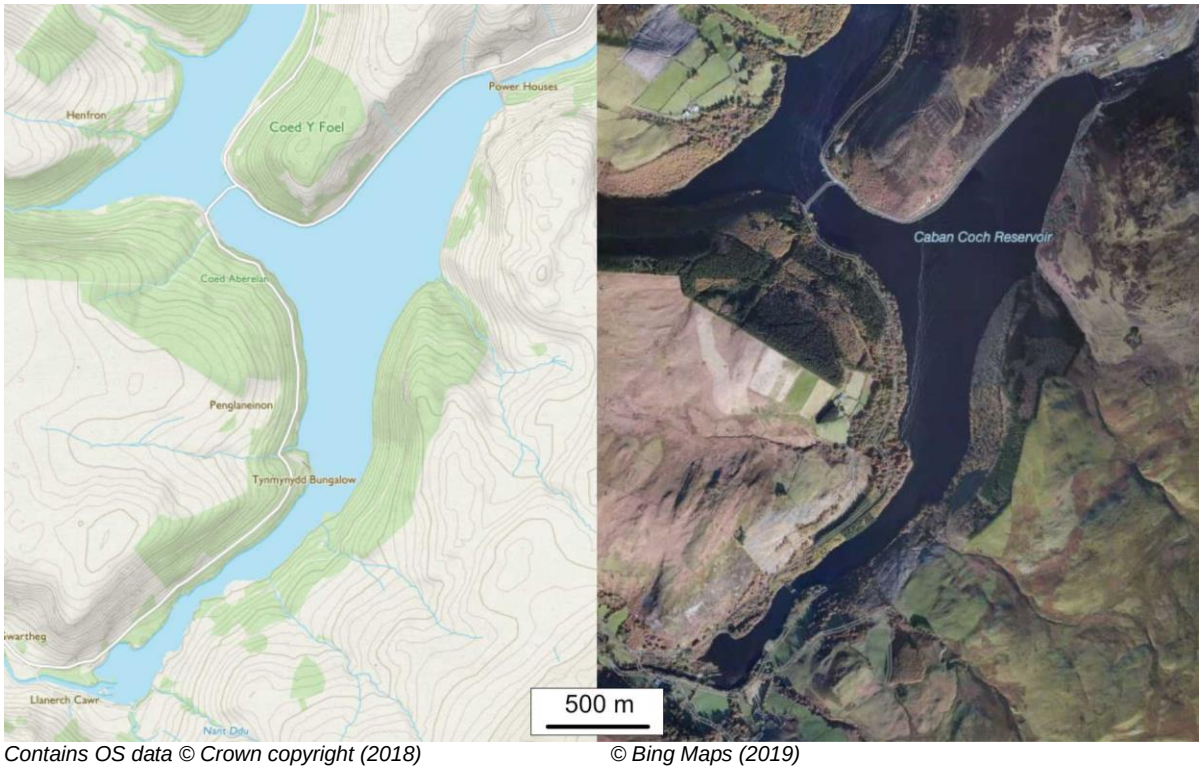

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Figure 87 Site map and aerial photograph of Caban Coch Reservoir

Figure 88 Caban Coch Reservoir site photo; from the north-west shore at Garreg Ddu dam, looking south-east.

Caban Coch Reservoir is the lowest of the four large Elan Valley reservoirs in Powys. The 37 m high dam at the north-west end, retains an area of just over 200 ha of open water with a top water level at 250.5 m AMSL. The Elan Valley reservoirs were constructed in the late 19th century to provide water to Birmingham.

Due to extensive drawdown (approximately 12 m below TWL), it was considered unsafe to launch and use a boat on the reservoir and therefore all survey work was conducted on foot. No dissolved oxygen / temperature profile was taken. A surface reading was taken close to the dam; DO = 9.58 mgl^{-1} and water temperature = 13.3 °C.

There was no evidence of any aquatic plants growing within the reservoir and none were found on the strandline. Much of the draw-down zone was steeply sloping and consisted of loose rocky material (e.g. Figure 89a S1 on the east shore). Where fine sediments have accumulated, the sustained period of exposure had allowed seedlings to establish, including *Juncus* spp. (mainly *J. articulatus* & *J. effusus*), *Lythrum portula and Carex ovalis* (Figure 89b).

a) b)

Figure 89. a) East shore of Caban Coch Reservoir showing the draw-down zone b) *Lythrum portula* and *Juncus* spp. seedlings at S3.

No water quality assessment has been carried out, as this site is not protected and a separate water quality assessment will be carried out for the Water Framework Directive.

5.2.18. Claerwen Reservoir

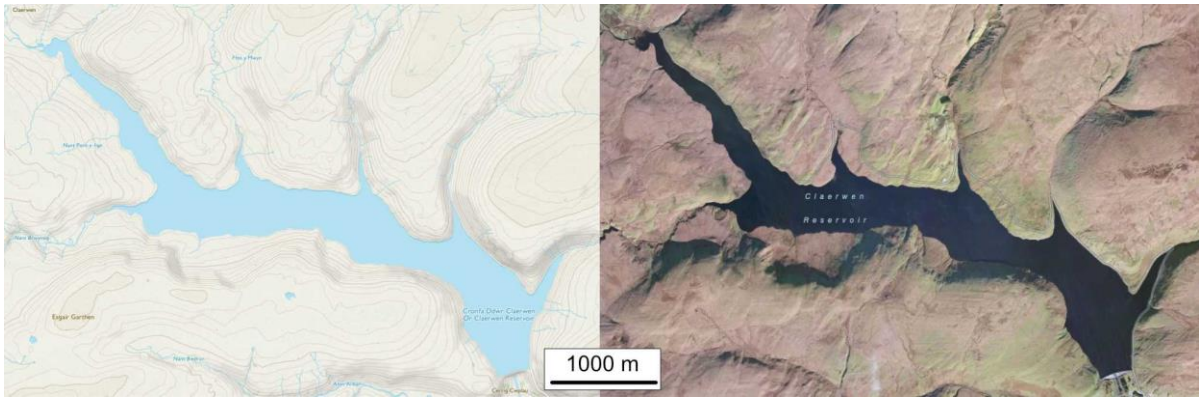

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Figure 90 Site map and aerial photograph of Claerwen Reservoir

Figure 91. Claerwen Reservoir site photo; from the east shore looking west.

Claerwen Reservoir is the highest in the chain of the four large Elan Valley reservoirs in Powys, and is situated within an extensive upland catchment of acid grassland. The 56 m high dam at the south-east end, retains an area of 263 ha of open water with a top water level at 268.8 m AMSL. The reservoirs were constructed in the late 19th century to provide water to Birmingham, Claerwen releasing water to the Afon Claerwen, which flows into Caban-Coch.

Due to the extensive drawdown (Stage reading at the dam read 10 m below TWL), it was considered unsafe to launch and use a boat on the reservoir and therefore all survey work was conducted on foot. No dissolved oxygen / temperature profile was taken. A surface reading was taken close to the dam; DO = 9.42 mgl^{-1} and water temperature = 13.4 °C.

There was no evidence of any aquatic plants growing within the reservoir and none were found on the strandline. Much of the draw-down zone along the north shore was steeply sloping and consisted of course rocky boulders towards the top and finer material towards the water's edge The north shore was largely unvegetated. The western end and southern shore was more gently sloping with finer sediments and eroded peat (e.g. Figure 92b), on which plants had established.

a)

b)

Figure 92. a) North shore of Claerwen Reservoir showing the draw-down zone b) Gently sloping Southwest shore at S1.

While much of the vegetation recorded within the draw-down zone was *Juncus* spp. seedlings and terrestrial bryophytes (mainly *Polytrichum commune*), in places towards the top water level zone, *Littorella uniflora* was present, and where the sediment remained moist, *Callitriche brutia* var. *hamulata* was found (Figure 93a). The inflow stream at the far western end, below Claerwen Farm, had *Myriophullum alterniflorum* and *Callitriche brutia* var *hamulata* present (Figure 93b). The paucity of plants and extensive draw-down means no reliable classification can be made using the aquatic macrophytes.

a)

b)

Figure 93. a) *Littorella uniflora* and b) *Callitriche brutia* var. *hamulata* growing near the top of the draw-down zone at the west end of Claerwen Reservoir.

No water quality assessment has been carried out, as this site is not protected and a separate water quality assessment will be carried out for the Water Framework Directive.

5.2.19. Llandegfedd Reservoir

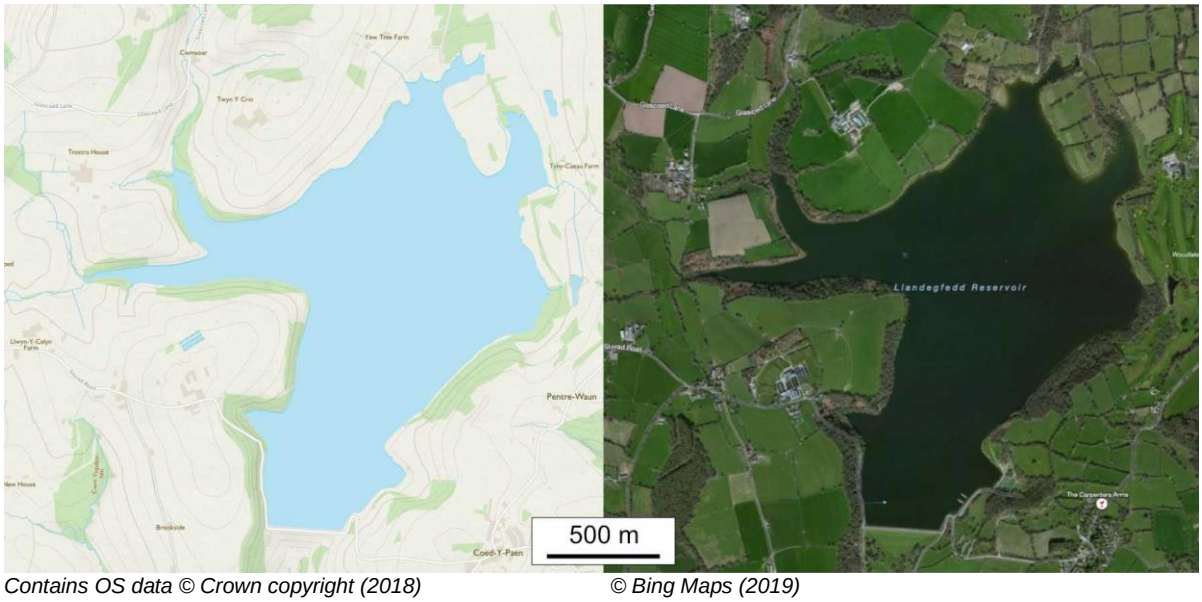

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Figure 94 Site map and aerial photograph of Llandegfedd Reservoir

Figure 95. Llandegfedd Reservoir site photo; from the south-west shore, looking east.

The reservoir was drawn down to approximately 10 m below top water level and still falling at time of survey, with large areas of foreshore exposed. No aquatic plants were recorded growing in the water and only a few aquatic plants recorded growing on the exposed shore (Table 19). With the reservoir having been low for much of the summer, a number of generalist species were present, the most abundant being the fast growing annual *Chenopodium album,* often with *Potentilla anserina* towards the top water level. A small area of *Littorella uniflora* (Figure 96a) was recorded close to the line of top water level in section 5 where *Lythrum portula* (Figure 96b) and *Callitriche* sp. were also found.

The non-native invasive species *Crassula helmsii* was recorded growing on damp sediments above the water line in S2 (Figure 97a), but not seen elsewhere in the

site. Zebra mussels were abundant, both in the water, and many more being stranded and desiccated as the water levels dropped (Figure 97b)

Submerged and floating vegetation	% Cover 2018
Callitriche sp.	0.7
Crassula helmsii	0.7
Littorella uniflora	0.7
Lythrum portula	0.7
Persicaria amphibia	2.7
Species richness	**5**

Table 19. CSM Survey LEAFPACS cover results from Llandegfedd Reservoir 2018

a) b)

Figure 96 a) *Littorella uniflora* and b) *Lythrum portula* growing on exposed sediments in section 5.

a) b)

Figure 97 a) *Crassula helmsii* growing near the TWL at S2 and b) desiccated Zebra mussel shells at S1.

Section 2 spans an inflow stream resulting in the silts staying wet in the gully area. Here *Crassula* was abundant, but this area also supported a stand of the grass

Orange foxtail (*Alopecurus aequalis*), a species that is rare in Wales and has declined nationally.

We are uncertain if the reservoir is aerated, none were visible. The site was however well mixed at the deepest point with only a slight decline in both dissolved oxygen and temperature with increasing depth (Figure 99).

Figure 98. Orange foxtail (*Alopecurus aequalis*), recorded in section 2 at Llandegfedd Reservoir.

Dissolved Oxygen Profile

GPS Location	ST3257698756
Maximum Depth (m)	20 m
Secchi Depth (cm)	345 cm

Notes: water level 10 m below TWL

Depth (m)	DO (mg/l)	Temp (°C)
0	9.13	14.9
2	8.81	14.9
4	8.71	14.8
5	8.52	14.8
6	8.46	14.8
8	8.44	14.7
10	8.24	14.7
12	8.15	14.7
14	8.13	14.5
16	8.06	14.4
18	8.01	14.3
20	7.9	14.3

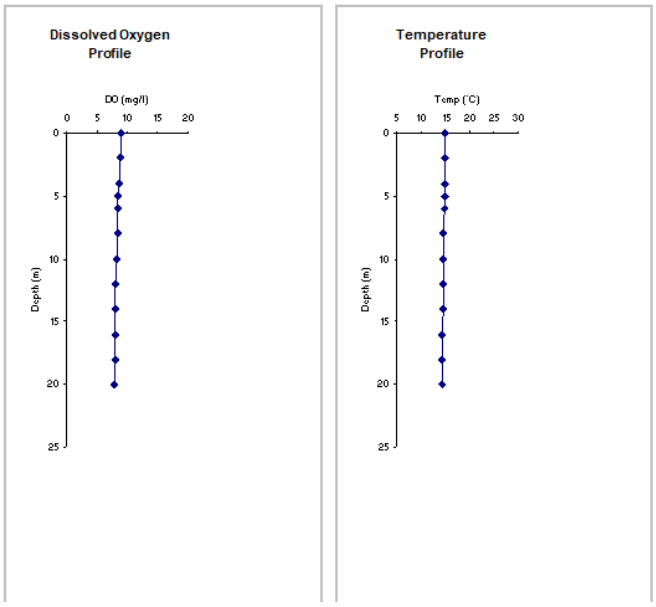

Figure 99. Dissolved oxygen and temperature profiles at Llandegfedd Reservoir (04/10/2018).

No water quality assessment has been carried out, as this site is not protected and a separate water quality assessment will be carried out for the Water Framework Directive.

6. Conclusions

The nineteen lakes surveyed cover a wide area of Wales and are broadly representative of the main water body types in the country, ranging from small, lowland high alkalinity sites, to low alkalinity upland lakes, and including three large artificial water bodies.

The results of this survey work will be used by NRW to generate formal WFD classifications and Condition Assessments for the Habitats Directive. It is not the aim of this report to replicate this process and so this is not taken further: key metrics for this purpose are listed in Table 2 and outline classifications in the site accounts. However, the following remarks are relevant to the management and understanding of the lakes surveyed and are therefore included for

6.1. Threatened Native Plant Biodiversity

A range of uncommon and threatened plant species were found or confirmed as still present during this work. These include:

Floating water-plantain *Luronium natans* is listed on Annexe II of the Habitats Directive and is protected under the Wildlife and Countryside Act. Wales has special responsibility for this species and good populations were found in four lakes: Llyn Cwellyn, L. Padarn, Llyn Hîr and L. Cwmorthin. These are all known sites for this species although this is the first time a CSM survey has been conducted at Llyn Cwmorthin, and shows there to be a significant population within the site. We also know from previous snorkel surveys of L. Cwellyn and Padarn (see Goldsmith 2014b) that the population of *L. natans* extends well beyond the CSM survey sections and is underrepresented in these lakes.

Slender stonewort *Nitella gracilis* is a Biodiversity Action Plan priority species found predominantly in nutrient-poor, often slightly peaty lakes. It was found in two lakes: Llyn Rhosgoch and L. Cwmorthin, neither of which have any previous records for this species.

Starry Stonewort *Nitellopsis obtusa* is nationally scarce species and was recorded from two lakes: Kenfig Pool and Llangorse. Previous records occur for both sites, and thus the current surveys show this rare species to be persisting.

Eight-stamened waterwort *Elatine hydropiper* is a national rare species in Wales and was recorded from three lakes: Llyn Dinam, L. Traffwll and L. Glasfryn. It has previously been recorded from all three lakes, with Anglesey being a stronghold for the species. The population at Llyn Glasfryn has shown a dramatic reduction however, the site being dominated by dense grows of *Ceratophyllum demersum* in recent years and with turbid water.

Spring quillwort *Isoetes echinospora* is considered Nationally Scarce, though it is probably under-recorded due to its similarity to the commoner *I. lacustris*. Spring quillwort was found in three lakes: Llyn Hîr, L. Blaenmelindwr, L.Rhosgoch. Previous records exist from all three sites, but this is the first structured survey of the latter two.

6.2. Invasive Non-native Species

Invasive non-native species (INNS) are an increasing threat to native biodiversity, especially in aquatic systems where they can spread very rapidly and outcompete native vegetation. In general, invasive species are correlated with human activity and so tend to be found disproportionately close to settlements and / or in lakes where intensive recreational activity occurs. The following INNS were found during the survey:

Australian swamp stonecrop *Crassula helmsii* was found at one location in Llandegfedd Reservoir, where it was growing on the exposed muds oin the draw-down zone in section 2 (SO3357200420). Reservoirs can be highly suitable environments for this plant as it is tolerant of fluctuating water levels. However, it is possible that this population is still fairly small and controllable, so further survey followed by control measures if possible is recommended.

Canadian waterweed *Elodea canadensis* was found at five lakes, with low to moderate cover at Llyn Dinam, Traffwll and Llangorse and at high cover in Kenfig Pool and Llyn Maelog. **Nuttall's waterweed *E. nuttallii*** was recorded in three lakes; being abundant in Llyn Padarn and Llangorse, and occurring as a single record in Kenfig Pool. Where these species are already present control methods are usually impractical and the focus should therefore be on ensuring suitable biosecurity measures are effectively communicated and put in place.

Curly water-thyme *Lagarosiphon major* was recorded in for the first time in Llyn Padarn in 2017 (Shilland *et al.* 2018). It is encouraging to report that it was not recorded in 2018 and does not therefore appear to have established in the lake. Further surveys are recommended and if found, efforts should be made to remove the plants to prevent it spreading.

Water fern *Azolla filiculoides* was recorded in Llyn Dinam where it was restricted to a small area within the shelter of the reeds in section 4 (SH3129277637). This species performs best in smaller, more sheltered sites and is therefore unlikely to establish further within the lake; it has been recorded in the lake previously in the mid 1990s. The main threat is poses here is to the smaller pool within the surrounding fen, which although not surveyed here, are known to include a number of species not recorded in the lake (I. Sims, *Pers. comm.*). This species is easily transported between sites on footwear and clothing, and stringent biosecurity should be applied at the site.

Golden rod *Orontium aquaticum* and Pickerel weed *Pontederia cordata* were recorded at Llyn Syfydrin. Both species have previously been recorded from the site in 2010 (Ellis 2011), and although they do not appear to have spread greatly, their persistence in the site is of concern. It is recommended that efforts are made to remove these populations from the site.

6.3. General Observations on the Plant Communities

Species Richness varied widely within this set of lakes (Figure 100). Not surprisingly, the large artificial water bodies, where water levels fluctuate significantly, had very few aquatic plant species present. At these sites WFD classification using

these data is not recommended. Conversely, the majority of more natural sites had relatively high species richness, mostly in excess of 10 aquatic species and in the case of Llyn Dinam, Llangorse Lake and Kenfig Pool, over 20 species were recorded.

Llyn Cadarn and Llyn yr Wyth Eidion both had low species richness; in part due to their physical structure, where the densely-shaded reed fringe gives way to a very steeply sloping littoral zone. But these sites also lack the typical hard-water flora expected of them, which is indicative of degradation. Similarly, Llyn Pencarreg had low species richness for a SSSI lake originally classified as being oligotrophic. Here there were signs of nutrient enrichment and cyanobacterial blooms have had a deleterious impact on water clarity in the site.

The other site with low species richness is Llyn Syfydrin and this is in contrast with the nearby sites, L. Rhosgoch and L. Blaenmelindwr. Unlike the neighbouring sites however, Syfydrin has very brown, peat-stained water which limits light penetration within the lake and therefore limits plant growth to the margins. This lake is more akin to the dystrophic lake type and as such would not be expected to have high plant diversity.

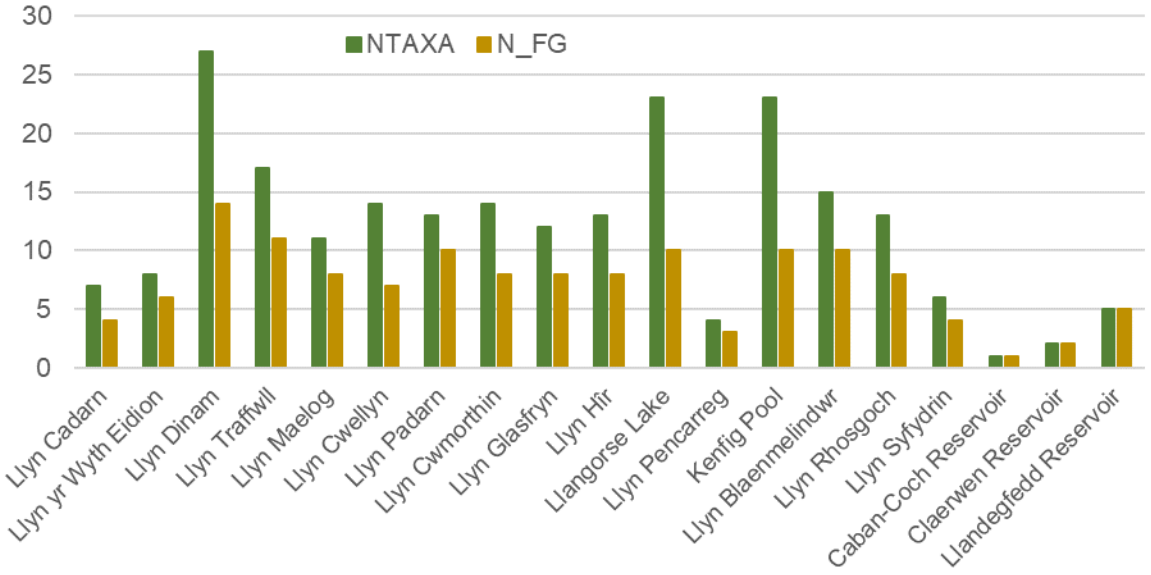

Figure 100 Number of taxa (NTaxa) and N_FG for the 19 lakes surveyed in 2018

The **number of functional groups (N_FG)** showed a strong positive correlation with species richness, with N_FG being around 40% of NTaxa (Figure 101).

The WFD **algal metric ALG** showed no relationship with the LMNI nutrient metric (Figure 102). In fact, the three sites with the highest algal cover (Llyn Hîr, L. Cwmorthin and L. Rhosgoch) are all upland lakes with no identifiable nutrient pressures and where previous water chemistry data has indicated low nutrient concentrations. This may perhaps be explained by the tendency of upland lakes with a high proportion of rocky substrates to support higher filamentous algal cover, but nonetheless supports the low weighting given to the ALG metric in the LEAFPACS tool.

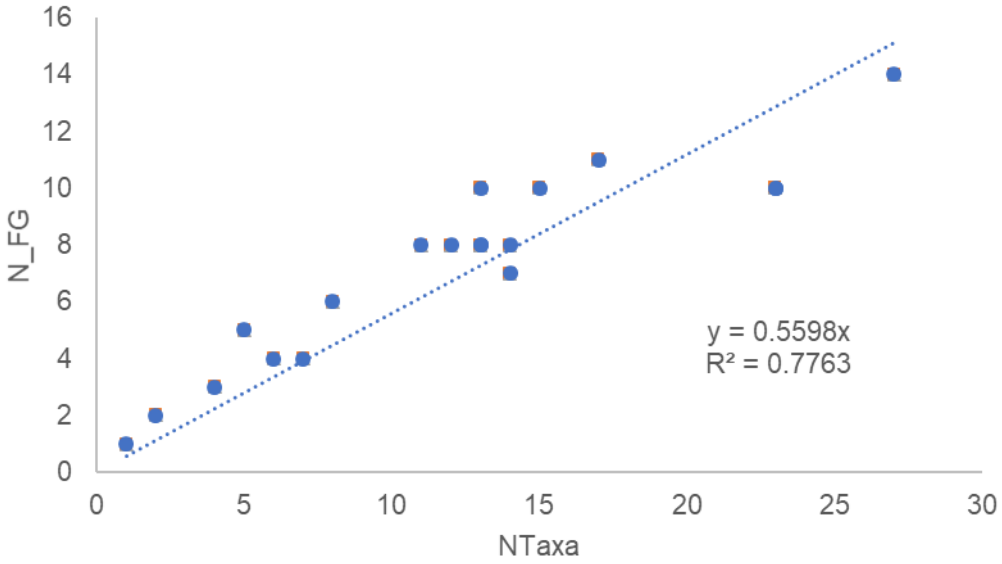

Figure 101 Relationship between NTaxa and N_FG for the 19 lakes surveyed

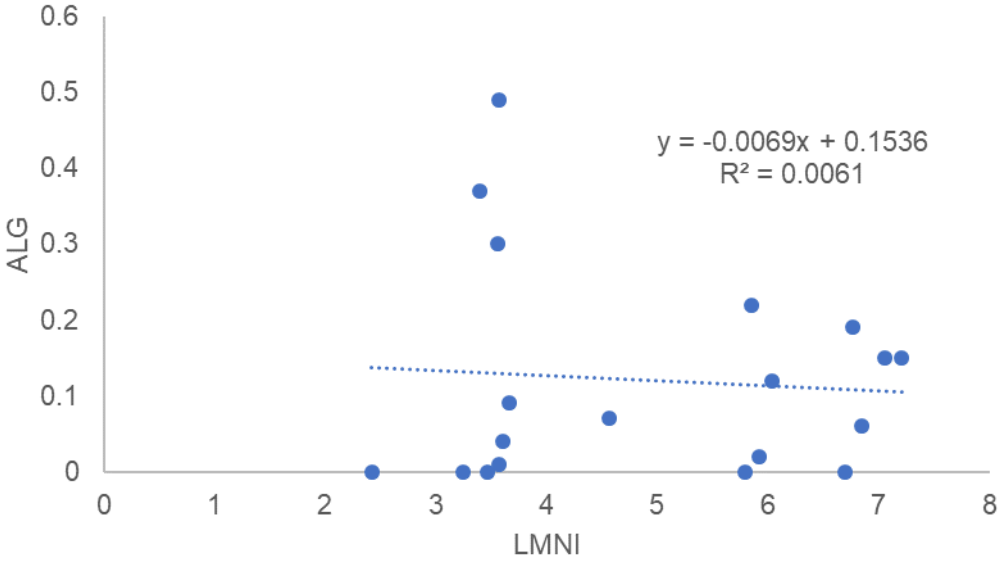

Figure 102 Relationship between LMNI and ALG for the 16 lakes surveyed.

Maximum depth of colonisation is a well-established lake metric used in site condition monitoring but not for WFD. It is particularly useful as a measure of ecosystem structure. The majority of lakes surveyed had a good maximum colonization depth of between 3 and 6 m, consistent with clear water conditions and reasonably low algal loadings. Llyn Dinam and Llyn Traffwll were lower than previous records for these lakes, but the surveys were late in the year and plants heavily degraded in open water, and thus this may not be a true representation for the sites. As discussed above, Llyn Pencarreg has suffered from significant cyanobacterial blooms which limit light penetration during the growing season and therefore restrict plant growth in deeper water. And Llyn Syfydrin should be considered as a dystrophic lake with naturally peat-stained water, which will also limit plant growth.

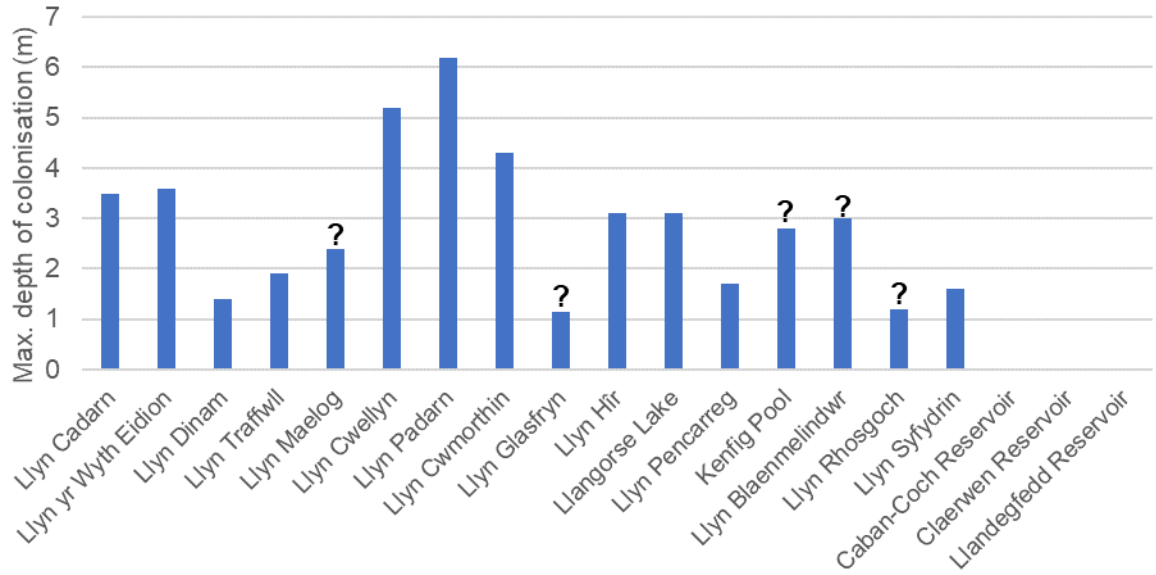

Figure 103 Maximum depth of plant colonisation at the 19 lakes. A "?" denotes shallow sites where plants are recorded to the maximum depth of the site.

For SSSIs and SACs, the **number of typical species** is an important consideration. This varies depending on lake type (see JNCC 2015), but of the ten SSSI lakes included here, six contained the requisite number of typical species and four did not. Of the six, only Llyn Cwellyn, L. Hîr and Kenfig Pool also had high abundance of typical species, Whereas, Llyn Padarn was dominated by the NNIS *Elodea nuttallii,* Llyn Pencarreg had very few plants at all, and although Llyn Dinam had eight typical species present, most were at very low abundance and the site was dominated by more generalist species.

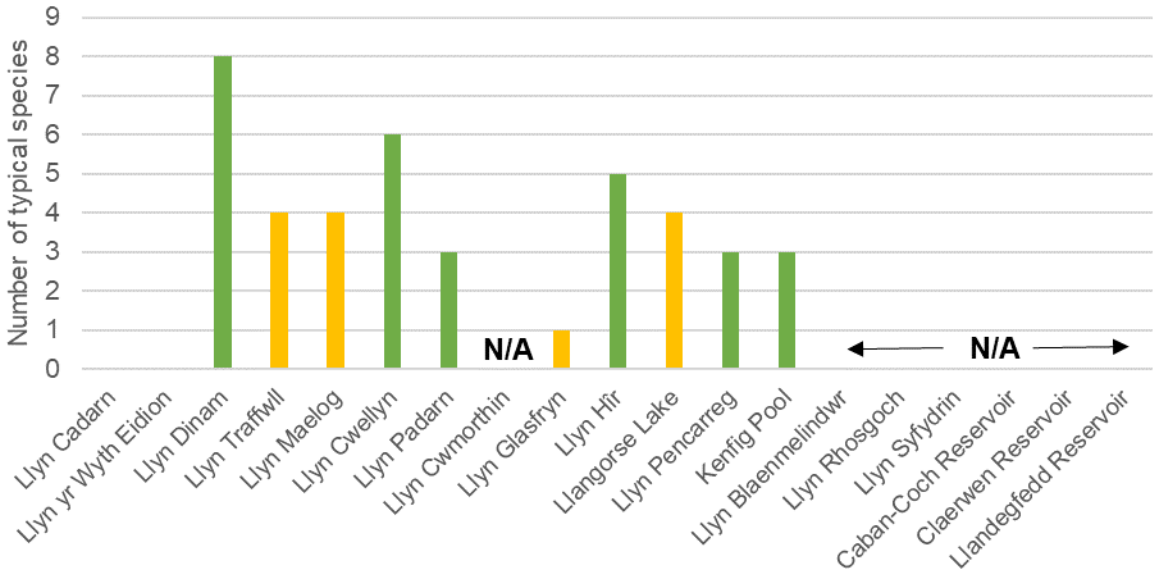

Figure 104 Number of "typical" species recorded at the 10 SSSI lakes. Those in green meet the JNCC target for their lake type.

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7. Appendices

7.1. Appendix I: Aquatic species data for all sites

	Llyn Cadarn	Llyn yr Wyth Eidion	Llyn Dinam	Llyn Traffwll	Llyn Maelog	Llyn Cwellyn	Llyn Padarn	Llyn Cwmorthin	Llyn Glasfryn	Llyn Hîr	Llangorse Lake	Llyn Pencarreg	Kenfig Pool	Llyn Blaenmelindwr	Llyn Rhosgoch	Llyn Syfydrin	Caban-Coch Reservoir	Claerwen Reservoir	Llandegfedd Reservoir
Azolla filiculoides			0.7																
Batrachospermum sp.								5.8						0.6	1.1				
Butomus umbellatus											2.0								
Callitriche brutia var. *hamulata*						3.1	0.1	2.2	0.7			0.7				1.4		2.0	
Callitriche hermaphroditica			3.2		1.7														
Callitriche sp.			0.1						1.4										0.7
Callitriche truncata			1.6	2.4															
Ceratophyllum demersum			15.2	2.0					63.7		10.7		19.7						
Chara aspera													11.4						
Chara contraria var. *contraria*													3.1						
Chara globularis			5.0	0.2	1.6														
Chara virgata													3.9						
Crassula helmsii																			0.7
Elatine hexandra												7.4			11.0				
Elatine hydropiper			2.1	6.0					2.5										
Eleocharis acicularis			1.0	5.5							0.2								
Eleogiton fluitans														0.9					
Elodea canadensis			1.0	0.8	21.3						7.8		13.6						
Elodea nuttallii							9.1				25.0		0.1						
Filamentous algae	0.1	10.4	19.4	1.7	9.0	2.7	3.5	27.0	1.9	39.5	16.4		22.6	5.9	33.2	0.1			
Fontinalis antipyretica	6.2	29.8	5.0			2.1	0.7		0.3				3.0						

	Llyn Cadarn	Llyn yr Wyth Eidion	Llyn Dinam	Llyn Traffwll	Llyn Maelog	Llyn Cwellyn	Llyn Padarn	Llyn Cwmorthin	Llyn Glasfryn	Llyn Hîr	Llangorse Lake	Llyn Pencarreg	Kenfig Pool	Llyn Blaenmelindwr	Llyn Rhosgoch	Llyn Syfydrin	Caban-Coch Reservoir	Claerwen Reservoir	Llandegfedd Reservoir
Fontinalis squamosa																1.4			
Hippuris vulgaris		6.0																	
Hydrodictyon reticulatum				0.1															
Isoetes echinospora										0.4				2.0	12.3				
Isoetes lacustris						21.0	6.6	2.9				2.3							
Juncus bulbosus						3.4		15.8		1.4				14.7	0.3	0.3			
Lemna minor	2.9		0.1	2.1	2.1						4.1								
Lemna minuta			2.6																
Lemna trisulca	13.7		10.5	0.1							7.1		2.4						
Littorella uniflora			0.9	1.0		10.1	6.7	3.6		7.0		26.9	4.0	0.3	5.4				0.7
Lobelia dortmanna						9.8		2.7		7.2									
Luronium natans						1.3	3.2	5.1		1.9									
Lythrum portula																			0.7
Menyanthes trifoliata	1.9	1.4	2.9				1.1		8.0	1.0	1.9		3.4	2.2	1.0				
Myriophyllum alterniflorum						5.4	3.4	7.9	7.1	4.7				8.3					
Myriophyllum spicatum			12.0								8.9		4.8						
Nitella flexilis agg.			6.8			4.5	11.4		1.8	12.5			0.2						
Nitella gracilis								0.2							1.0				
Nitella translucens							0.1												
Nitellopsis obtusa											2.7		0.4						
Nuphar lutea	23.9	19.3						0.9	4.0		4.0								
Nymphaea alba	1.1	12.6	6.5	0.7	0.1				1.8		0.3			0.7					
Nymphoides peltata											4.5								
Persicaria amphibia			0.4		2.9				3.4		2.9		2.4						2.7
Potamogeton berchtoldii		2.8	0.1	0.5		2.1	2.6							0.4					
Potamogeton crispus					0.1						0.3								
Potamogeton lucens			0.7								2.4								

	Llyn Cadarn	Llyn yr Wyth Eidion	Llyn Dinam	Llyn Traffwll	Llyn Maelog	Llyn Cwellyn	Llyn Padarn	Llyn Cwmorthin	Llyn Glasfryn	Llyn Hîr	Llangorse Lake	Llyn Pencarreg	Kenfig Pool	Llyn Blaenmelindwr	Llyn Rhosgoch	Llyn Syfydrin	Caban-Coch Reservoir	Claerwen Reservoir	Llandegfedd Reservoir
Potamogeton natans													0.8	4.2	2.0				
Potamogeton obtusifolius			0.1																
Potamogeton pectinatus			0.1	1.0	15.1						0.1								
Potamogeton perfoliatus			0.8	5.6	3.7								0.7						
Potamogeton polygonifolius								0.5		3.2				1.8	1.0				
Potamogeton pusillus					3.3								0.1						
Potamogeton trichoides													0.4						
Potamogeton x zizii													0.7						
Ranunculus aquatilis agg.			0.1				0.5												
Ranunculus aquatilis				0.7															
Ranunculus lingua			1.5								2.7		2.1						
Ranunculus omiophyllus				0.7						1.0									
Sparganium angustifolium						0.1		2.3						2.4	12.0				
Sparganium emersum		3.8									1.2								
Sphagnum (aquatic indet.)						5.9		12.4		0.6				6.8	5.8	5.9			
Spirodela polyrhiza											3.3								
Subularia aquatica						0.8													
Utricularia minor														11.7	3.2	0.7			
Zannichellia palustris											0.9								

Table 20. Summary of all aquatic and macrophyte species for the 19 lakes. Figures represent per cent cover at a site based on the LEAFPACS method; invasive alien species (INV) are shaded in orange.

7.2. Appendix II: Macrophyte Survey Section Locations

Common Standards Monitoring methods require that all transects (sections) are recorded with GPS, backed up by digital photographs. Table 21 details the wader survey start and end point, and the shore end and outer end of the boat sections. Photo numbers refer to the last 3 or 4 digits of the photo file name stored in folder “NWR_2018_Section_Photos” the NRW data archive (see Appendix 7.3). All photo filenames have a suffix of the site WBID.

Table 21. Survey section OS Landranger grid references and photo numbers for the 19 lakes.

Site	WBID	Survey date	Section	Wader start GPS	Wader end GPS	Boat Shore GPS	Boat Lake GPS	Start Photo	Section Photo	End Photo	Submerged Photo
Llyn Cadarn	32792	18/09/18	1	SH4925981114	SH4918981073	SH4922681087	SH4921780817	256	254	253	N/A
			2	SH4928581188	SH4920781163	SH4924281181	SH4923881174	252	251	250	N/A
Llyn yr Wyth Eidion	32761	18/09/18	1	SH4747181838	SH4741481808	SH4745681806	SH4744581814	258	257	259	3251
			2	SH4739181921	SH4745581937	SH4741381955	SH4741981939	262	263	264	N/A
Llyn Dinam	32948	19/09/18	1	SH3099677357	SH3090577379	SH3095377351	SH3097877438	268	269	270	N/A
			2	SH3085377588	SH3085077503	SH3084477548	SH3083677544	272	273	277	283
			3	SH3107377775	SH3114477726	SH3112677766	SH3102377497	278	279	280	281
			4	SH3136277666	SH3131877630	SH3129077668	SH3134577703	284	285	286	265
Llyn Traffwll	32964	20/09/18	1	SH3217477130	SH3220877194	SH3216377165	SH3225377119	298	299	301	300
			2	SH3272276759	SH3274476683	SH3273576729	SH3269476709	288	289	296	295
			3	SH3295477378	SH3299577327	SH3295977352	SH3292377248	303	304	305	302
			4	SH3300977112	SH3296877021	SH3298377073	SH3294277128	309	310	311	N/A
Llyn Maelog	33160	17/09/18	1	SH3233673029	SH3241373091	SH3236673062	SH3257972986	206	207	208	211
			2	SH3292973396	SH3284473371	SH3288673362	SH3259972993	227	228	229	222
			3	SH3248072769	SH3256072721	SH3252272751	SH3270973069	230	231	234	233
			4	SH3285573053	SH3278272978	SH3282173017	SH3265273017	247	248	249	243
Llyn Cwellyn	34002	28/09/18	1	SH5567555472	SH5577655426	SH5572755452	SH5572455432	016	017	018	754

Site	WBID	Survey date	Section	Wader start GPS	Wader end GPS	Boat Shore GPS	Boat Lake GPS	Start Photo	Section Photo	End Photo	Submerged Photo
			2	SH5564454906	SH5559654968	SH5562054925	SH5564854935	011	012	013	N/A
			3	SH5670954387	SH5662454358	SH5667254359	SH5663054415	007	008	009	010
			5	SH5633154304	SH5625454358	SH5629354339	SH5630054356	001	002	003	004
Llyn Padarn	33730	30/09/18	1	SH5825260235	SH5815560238	SH5820060246	SH5819460272	073	072	071	N/A
			2	SH5811560777	SH5802660825	SH5807060796	No plants	070	069	068	N/A
			3	SH5644661604	SH5651661478	SH5650161556	SH5650661589	060	061	062	N/A
			4	SH5599762301	SH5603162213	SH5602062258	SH5605762266	053	054	055	058
			5	SH5737060853	SH5745560799	SH5741460829	SH5744560877	063	064	067	065/6
Llyn Cwmorthin	34397	29/09/18	1	SH6781746334	SH6775646415	SH6779846379	SH6779146367	022	023	033	031
			2	SH6760846603	SH6770846598	SH6765746551	SH6773646416	035	035	043	029
			3	SH6781246138	SH6774546209	SH6776846158	SH6779646176	044	045	047	3442
			4	SH6795446162	SH6792046067	SH6794646112	SH6787446136	048	049	051	N/A
Llyn Glasfryn	34622	21/08/18	1	SH4041442213	SH4040542163	SH4042142182	SH4029942205	324	321	320	N/A
			2	SH4022642276	SH4032442294	SH4023242269	SH4029242189	325	327	328	N/A
			3	SH4023742062	SH4017142065	SH4018642070	SH4021542140	316	315	314	312
			4	SH4011642211	SH4017842290	SH4015642248	SH4017642213	334	330	329	331
Llyn Hîr	38394	01/10/18	1	SN7896967849	SN7893467787	SN7893967829	SN7896667810	043	044	045	N/A
			3	SN7885967332	SN7891567410	SN7890467374	SN7887967383	039	040	041	N/A
			4	SN7897867674	SN7901967754	SN7899867705	SN7898767705	036	037	038	N/A
Llangorse Lake	40067	03/10/18	1	SO1292426240	SO1302926242	SO1297626241	SO1307626468	162	163	161	164
			2	SO1373625954	SO1376025861	SO1374225914	SO1377625900	127	128	129	130
			3	SO1378126718	SO1387226695	SO1382026712	SO1379126617	152	153	154	156
			4	SO1242226703	SO1244026815	SO1242626763	SO1299426622	165	166	169	168
			5	SO1408525944	SO1409826043	SO1406725991	SO1405525986	132	133	135	134
			6	SO1359126880	SO1353526960	SO1357426927	SO1345426814	157	158	159	160

Site	WBID	Survey date	Section	Wader start GPS	Wader end GPS	Boat Shore GPS	Boat Lake GPS	Start Photo	Section Photo	End Photo	Submerged Photo
Llyn Pencarreg	39303	02/10/18	1	SN5388445776	SN5378645753	SN5383445766	SN5382745765	046	047	048	N/A
			2	SN5387345599	SN5379045542	SN5381645582	SN5381445585	049	050	051	N/A
			3	SN5353245640	SN5352445533	SN5352645582	SN535284558	058	057	056	N/A
			4	SN5370845499	SN5360945474	SN5365545503	SN5365245506	052	054	055	N/A
Kenfig Pool	42170	03/10/18	1	SS7947881368	SS7944081464	SS7946481423	SS7965581482	059	060	061	N/A
			2	SS7966981748	SS7975581770	SS7973481733	SS7966981521	062	063	064	N/A
			3	SS7987281814	SS7990581817	SS7990481863	SS7968181522	067	068	069	N/A
			4	SS7992581494	SS7984481429	SS7987881462	SS7968481489	070	071	072	N/A
Llyn Blaenmelindwr	37777	30/09/18	1	SN7147683470	SN7145283564	SN7144383513	SN7154883491	024	025	026	N/A
			2	SN7143183661	SN7144783738	SN7141683693	SN7152383640	028	027	029	N/A
			3	SN7160983723	SN7162583626	SN7162583679	SN7153483650	030	031	032	N/A
			4	SN7163683526	SN7160583451	SN7156283559	SN7163483478	033	034	035	N/A
Llyn Rhosgoch	37793	28/09/18	1	SN7130983307	SN7132683245	SN7134283281	SN7128683258	002	003	004	N/A
			2	SN7123983050	SN7117783085	SN7119783047	SN7125283158	005	006	007	N/A
			3	SN7122483221	SN7118983127	SN7120383175	SN7126183179	009	010	011	N/A
Llyn Syfydrin	37743	29/09/18	1	SN7207784575	SN7200384625	SN7203784591	SN7209184652	012	013	014	N/A
			2	SN7211084798	SN7218484828	SN7214684807	SN7229484735	015	016	017	N/A
			3	SN7231884909	SN7241284913	SN7237284912	SN7243484761	018	019	020	N/A
			4	SN7244584682	SN7250584759	SN7249084712	SN7246884781	021	022	023	N/A
Caban-Coch Reservoir	38419	02/10/18	1	SN9188163240	SN9182163113	SN9184463163	N/A	116	118	117	N/A
			2	SN9139763450	SN9132863539	SN9135663479	N/A	115	114	113	N/A
			3	SN9144462688	SN9142262794	SN9142462719	N/A	108	109	112	110
			4	SN9212764399	SN9219064457	SN9215864419	N/A	125	124	122	N/A
Claerwen Reservoir	38427	01/10/18	1	SN8402565054	SN8393265046	SN8398465046	N/A	091	092	093	095
			2	SN8325765146	SN8325065220	SN8524065195	N/A	089	088	087	098

Site	WBID	Survey date	Section	Wader start GPS	Wader end GPS	Boat Shore GPS	Boat Lake GPS	Start Photo	Section Photo	End Photo	Submerged Photo
			3	SN8337066048	SN8341365961	SN8340566007	N/A	079	080	081	084
			4	SN8632865249	SN8634565258	SN8632465299	N/A	076	077	078	N/A
			5	SN8705164046	SN8706863978	SN8707664016	N/A	103	102	101	N/A
			6	SN8657963843	SN8653963934	SN8656063891	N/A	104	105	106	N/A
Llandegfedd Reservoir	41363	04/10/18	**1**	ST3205599941	SO3201900019	ST3203299966	N/A	181	182	184	183
			2	SO3363500398	SO3367300310	SO3366400343	N/A	3564	3566	3568	3572
			3	ST3334199347	ST3327999295	ST3330799323	N/A	170	171	173	174
			4	ST3236099020	ST3232699080	ST3235799054	N/A	189	192	191	190
			5	SO3289300327	SO3295000410	SO3292500365	N/A	176	177	178	179
			6	ST3234299736	ST3244199725	ST3239299734	N/A	185	186	187	N/A

7.3. Appendix III: Data Archiving

Data outputs associated with this project are archived on server–based storage at Natural Resources Wales.

The data archive contains:

[A] The final report [NRW_Ecological_Surveys_of_Welsh_Lakes_2018_Final.docx] in Microsoft Word and Adobe PDF formats.

[B] Leafpacs calculator files within folder [NRW_2018_Leafpacs_Data] in Microsoft Excel format [Lake_name_LEAFPACS 2 0_metriccalculator_Month_Year] and summary information in MS Excel format [Site_metrics_Summary_2018.xls]

[C] A full set of digital photographs from the surveys in [jpg] format in folder [NRW_2018_Section_Photos] and sub-folders [<site_name_WBID>].

[D] A species list for all sites in MS Excel format suitable for upload to Recorder [NRW_2018_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 123035

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