Cyfoeth Naturiol Cymru
Natural Resources Wales

Ecological Surveys of Welsh Lakes 2017

Shilland EM[1], Goldsmith B[1], Hatton-Ellis TW[2].

[1] ENSIS Ltd. London [2] NRW

NRW Evidence Report No. 257

About Natural Resources Wales

Natural Resources Wales's purpose is to pursue sustainable management of natural resources. This means looking after air, land, water, wildlife, plants and soil to improve Wales's well-being, and provide a better future for everyone.

Evidence at Natural Resources Wales

Natural Resources Wales is an evidence based organisation. We seek to ensure that our strategy, decisions, operations and advice to Welsh Government and others are underpinned by sound and quality-assured evidence. We recognise that it is critically important to have a good understanding of our changing environment.

We will realise this vision by:

- Maintaining and developing the technical specialist skills of our staff;
- Securing our data and information;
- Having a well-resourced proactive programme of evidence work;
- Continuing to review and add to our evidence to ensure it is fit for the challenges facing us; and
- Communicating our evidence in an open and transparent way.

This Evidence Report series serves as a record of work carried out or commissioned by Natural Resources Wales. It also helps us to share and promote use of our evidence by others and develop future collaborations. However, the views and recommendations presented in this report are not necessarily those of NRW and should, therefore, not be attributed to NRW.

Report series: NRW Evidence Report
Report number: 257
Publication date: February 2018
Contract number: NRWFW16-01
Contractor: ENSIS Ltd. Environmental Change Research Centre, UCL, London.
Contract Manager: T. Hatton-Ellis
Title: **Macrophyte Surveys of Welsh Lakes 2017**
Author(s): **Shilland EM, Goldsmith B, Hatton-Ellis TW.**
Restrictions: None

Distribution List (core)

NRW Library, Bangor	2
National Library of Wales	1
British Library	1
Welsh Government Library	1
Scottish Natural Heritage Library	1
Natural England Library (Electronic Only)	1

Distribution List (others)

Nicola Broadbridge, NRW
Bob Edwards, NRW
Sally Ellis, NRW
Tom Harrison, NRW
Jon Turner, NRW
Julian Woodman, NRW
Huw P. Jones, NRW
Dave Johnston, NRW
Melissa Lacan, NRW
Claire Liversage, NRW
John Ratcliffe, NRW
Graham Rutt, NRW
Heather Garrett, NRW
Rob Blacklidge, NRW
Dafydd Roberts, Eryri / Snowdonia National Park
Hannah Shaw, Freshwater Habitats Trust
Ian Hawkins, RSPB
Lizzie Wilberforce, WTSWW
Jo-Anne Pitt, Environment Agency
Adrian Lloyd Jones, North Wales Wildlife Trust
Sean McHugh, Wales Biodiversity Partnership
Dusi Thomas, Dwr Cymru / Welsh Water
Ruth Hall, Natural England
Stewart Clarke, National Trust

Recommended citation for this volume:

Shilland EM, Goldsmith B, Hatton-Ellis TW. 2019. *Ecological Surveys of Welsh Lakes 2017*. NRW Evidence Report No 257. 103pp, Natural Resources Wales, Bangor

Contents

List of Figures

List of Tables

1. Crynodeb Gweithredol

Aeth y prosiect hwn ati i gasglu, prosesu a chyflenwi data ecolegol ac amgylcheddol i CNC o rwydwaith o 16 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 eraill o ran deddfwriaeth a pholisi. Mae'r arolygon wedi'u hanelu'n benodol at lywio'r gwaith o reoli ac adfer safleoedd gwarchodedig a hwyluso'r broses o gyflawni Cynlluniau Rheoli Basn Afon.

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.

- 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).

Dim ond dau o'r 16 o lynnoedd yma a ystyriwyd yn ffafriol, gyda'r mwyafrif yn anffafriol. Yn gyffredinol, roedd cyfatebiaeth dda rhwng canlyniadau dosbarthu LEAFPACS a chanlyniadau asesu cyflwr SoDdGA, er bod gwahaniaethau pwysig mewn safleoedd unigol o ganlyniad i'r gofyniad ar SoDdGA / ACA i warchod nodweddion penodol, yn hytrach na chysyniad cyffredinol o ansawdd da fel y ceir yn unol â'r Gyfarwyddeb Fframwaith Dŵr.

Trafodir rhai gwelliannau posibl i offeryn LEAFPACS o ran y ffordd y defnyddir dyfnder i ragfynegi cymuned o blanhigion, a'r posibilrwydd o ddefnyddio gorchudd planhigion yn hytrach na phresenoldeb / absenoldeb yn yr offeryn. Mae diffyg metrig rhywogaethau estron goresgynnol yn LEAFPACS hefyd yn wendid sylweddol o ystyried pwysigrwydd y pwysau hwn yn llynnoedd Cymru.

2. Executive Summary

This project set out to collect, process and supply to NRW ecological and environmental data from a network of 16 lake sites across Wales, in support of NRW's integrated monitoring programme for protected sites (SACs and SSSIs), the Water Framework Directive, Nitrates Directive, Biodiversity Action Plans and other legislative and policy drivers. In particular the surveys are aimed at informing management and restoration of protected sites and facilitating delivery of River Basin Management Plans.

Using standard methods, lakes were surveyed to assess the species and abundance of aquatic plants growing within and directly around the lake and to measure water clarity, dissolved oxygen and temperature within the lakes.

- 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).

Only two of the sixteen lakes here were considered favourable, with most being unfavourable. In general, there was a good correspondence between LEAFPACS classification results and SSSI Condition assessment outcomes, though there were important differences at individual sites resulting from the requirement of SSSIs / SACs to protect specific features, rather than a generalised concept of good quality as per the Water Framework Directive.

Some potential improvements to the LEAFPACS tool are discussed relating to the way in which depth is used to predict plant community, and the potential for using plant cover rather than presence / absence in the tool. The lack of an invasive non-native species metric in LEAFPACS is also a significant weakness given the importance of this as a pressure in Welsh lakes.

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 sampling 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 are assessed against their type and location to derive site condition status and also to calculate metrics which allow WFD classification.

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 16 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 16 lakes surveyed for this report, all but two 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 Llynnau Mymbyr and Llyn Fach where 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 16 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 Types: HC = Hard oligo-mesotrophic waters, OML = Oligo-mesotrophic waters, OML_M = Oligo-mesotrophic waters, mesotrophic subtype; NE = Natural Eutrophic Waters. See also JNCC (2015) and Hatton-Ellis (2014).

Lake Name	WBID	Grid ref.	Survey date	Lake Type**
Hanmer Mere	34780	SJ452392	15/08/2017	NE
Llynnau Mymbyr	33932	SH705572	17/08/2017	OML
Llyn Fach	41210	SN905038	17/08/2017	OML
Llyn Maelog	33160	SH326730	18/08/2017	NE
Llanbwchllyn Reservoir	39267	SO119463	18/08/2017	OML_M
Llyn Llygeirian	32435	SH346898	19/08/2017	NE
Bosherston Lily Ponds – Eastern Arm	47013	SR976954	19/08/2017	HC
Bosherston Lily Ponds – Central Arm	47014	SR972949	20/08/2017	HC
Bosherston Lily Ponds – Western Arm & Central Lake	47015	SR971946	20/08/2017	HC
Llyn Penrhyn	32968	SH313768	20/08/2017	NE
Llyn Llywenan	32746	SH347816	21/08/2017	NE
Llangorse Lake	40067	SO132264	21/08/2017	NE
Llyn Tegid / Bala Lake	34987	SH909335	22/08/2017	OML
Llwyn-On Reservoir	40648	SO007120	22/08/2017	-
Llyn Mwyngill (Tal-y-Llyn Lake)	36405	SH717099	24/08/2017	OML
Llyn Gwynant	34153	SH644519	22/09/2017	OML

Table 1. Details of the lakes included in this report.

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 colonization. These were carried out at each site on up to four discrete 100 m sections of shoreline which were considered representative of the lake and gave good geographical coverage. In order to reduce

disturbance, a maximum of 25% of the shoreline was surveyed, resulting in fewer than four sections being surveyed at smaller lakes.

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. 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 8.2.

Figure 1. Map of Wales showing the location of the 2017 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 aim to produce a complete species list for a lake, comparison with a more thorough mapping approach generally show that the transect method consistently detects more than 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 other species which did not occur in any of the survey sections.

The CSM aquatic macrophyte surveys, upon which the data assessments in this report are based, were carried out between August and September 2017. *In-situ* macrophyte identifications were made by Ben Goldsmith or Ewan Shilland. Specimens of *Luronium natans* were collected under Protected Species Licence 59401:OTH:SP:2014 (B. Goldsmith with E. Shilland as accredited agent). Voucher specimens were collected for all taxonomically ambiguous species 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 sent to 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:

- 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 550 meter. These data were used to assess oxygen availability within the water.

Secchi disc depths were recorded at the time of the macrophyte surveys from the deepest point of all lakes and further measurements taken at each survey section at sites where variability in water clarity was observed. A standard 20 cm diameter Secchi plate was used and the Secchi depth (Z_S) expressed in metres.

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 2018) and Aerial photographs from either Bing Maps (© Microsoft 2018).or Google Maps (© Google 2018).

4.4. 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 on the LEAFPACS tool only they therefore do not represent final NRW water body classifications, which will be carried out separately according to our 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 pressure. 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 list of species for each site is given in Appendix 8.1.

Site	LMNI	NTAXA	NFG	COV	ALG	INV	MAXD	NTYP	Secchi
Hanmer Mere	7.16	14	9	7.18	0.07	1	3.4	1	4.05
Llynnau Mymbyr	3.92	18	10	5.85	0.31	0	3.0	4	3.20
Llyn Fach	3.45	12	6	6.62	0.15	0	3.9	4	3.60
Llyn Maelog	7.16	11	8	2.30	0.18	1	1.9	3	0.55
Llanbwchllyn	6.23	18	11	4.03	0.00	0	3.9	3	0.90
Llyn Llygeirian	6.51	15	10	4.38	0.03	1	1.3	3	0.55
Bosherston E. Arm	7.42	14	10	6.20	0.27	2	1.5	0	>1.50
Bosherston C. Arm	6.39	7	5	12.95	0.04	0	1.3	1	>1.30
Bosherston W. Arm	6.41	17	11	5.88	0.20	1	1.6	1	>1.60
Llyn Penrhyn	7.09	20	11	4.52	0.21	2	2.5	4	0.56
Llyn Llywenan	7.24	13	10	6.32	0.10	1	1.5	0	1.03
Llangorse Lake	7.04	25	11	4.09	0.06	3	2.9	6	1.40
Llyn Tegid	5.36	16	10	2.74	0.40	1	1.8	5	2.30
Llwyn-On Resr.	4.91	5	5	7.66	0.00	0	1.8	1	1.85
Llyn Mwyngill	5.29	14	9	7.05	0.25	2	3.45	4	>3.45
Llyn Gwynant	3.82	16	10	5.47	0.02	1	5.3	6	6.8

Table 2. Summary of the LEAFPACS lake metrics, typical taxa, non-native species and maximum depth of macrophyte colonisation for the 16 lakes.

5.2. Sites

5.2.1. Hanmer Mere

Contains OS data © Crown copyright (2017) *© Bing Maps (2017)*

Figure 2. Site map and aerial photograph of Hanmer Mere.

Figure 3. Hanmer Mere site photo; from the south end looking north.

Hanmer Mere is a small (18 ha), shallow, high alkalinity lowland lake located in Wrexham, North Wales. Along with some of the adjoining catchment it forms the Hanmer Mere SSSI and is a component of the Midland Meres & Mosses Phase 2 Ramsar Site. The catchment is predominantly improved grassland but the lake itself is surrounded on most sides by *Alnus* and *Salix* woodland. The northern edges are fringed with reeds, in an assemblage dominated by *Typha angustifolia, Phalaris arundinacea* and *Iris pseudacorus*.

A band of *Nuphar lutea,* with occasional *Nymphaea alba* and *Lemna minor*, encircles the southern and western shores of the lake, underneath which the benthic species are largely comprised of *Elodea canadensis*, *Ceratophyllum demersum* and *Lemna trisulca*, interspersed between the submerged leaves of the *N. lutea* (Table 3). The open water, especially in the southern end of the lake, is dominated by extensive beds of *C. demersum* in amongst which *E. canadensis*, *Potamogeton berchtoldii*, *Potamogeton crispus* and small amounts of *Potamogeton trichoides* and *Nitella flexilis* agg. also occur. An area of the shore in the southeast, around section two, is

open to cattle grazing, and the poaching activities in the shallows have created more open, sandy conditions in which *Zannichellia palustris* and *Elatine hydropiper* can be found (Figure 4). The maximum depth of colonisation found during the survey was for *P. berchtoldii* and *P. crispus* at 3.4 m on transect three. This is somewhat deeper than that from the surveys of 2003, 2008 and 2011, with 1.8 m, 2.7 m and 2.55 m maxima respectively.

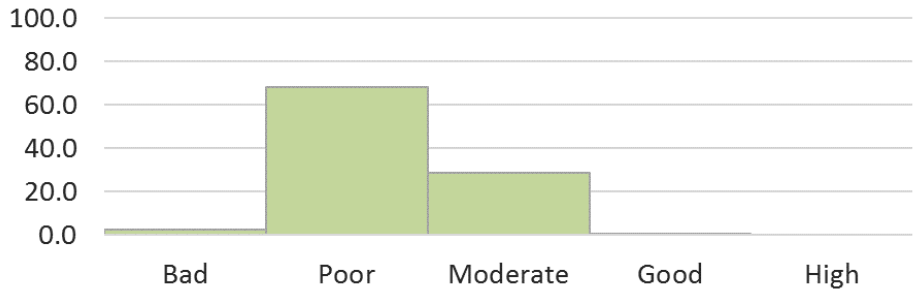
Figure 4 Cattle-poached sandy area with *Elatine hydropiper* (S2 @ 50 cm)

The current aquatic macrophyte assemblage at Hanmer Mere has only one out of the required six characteristic species and this 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. The alien invasive aquatic macrophyte species *E. canadensis* is present throughout the site but levels of filamentous algae are low to moderate.

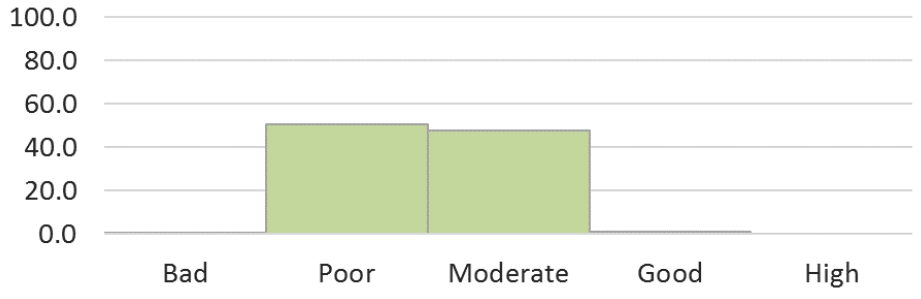
Whilst the Leafpacs tool suggests a deterioration in class since the 2014 survey from Moderate to Poor, this is mainly driven by turnover in relatively rare species in the surveys, especially the occurrence of a small amount of the highly nutrient-tolerant *Zannichellia palustris* in 2017. On the other hand, the COV metric for 2017 is much higher than 2014 (7.18 compared to 2.96) and the maximum depth of colonisation also increased, indicating that Hanmer Mere is more macrophyte dominated than in 2014. This may indicate that the lake is starting to recover, but further data are required to confirm this.

Submerged and floating vegetation	% cover	Submerged and floating vegetation	% cover
Ceratophyllum demersum	31.7	*Nuphar lutea*	7.9
Elatine hydropiper	1.7	*Nymphaea alba*	2.4
Elodea canadensis	14.0	*Persicaria amphibia*	0.1
Filamentous algae	7.2	*Potamogeton berchtoldii*	6.9
Lemna minor	13.6	***Potamogeton crispus***	**6.6**
Lemna trisulca	1.7	*Potamogeton trichoides*	2.3
Nitella flexilis agg.	0.7	*Zannichellia palustris*	3.7
Species richness			**14**
WFD LEAFPACS Classification			**Poor**
EQR_{LMNI}	0.501	EQR_{NFG}	1.434
EQR_{NTAXA}	1.388	EQR_{COV}	0.935
EQR_{ALG}	0.977	$EQR_{LEAFPACS}$	0.389
Confidence in Class			54.7%
Confidence < Good			99%
Invasive Plant Species Cover			**15.0%**
CSM Result		**Target**	**Measured**
Typical Species % Cover (Eutrophic)			19.3
No. of Characteristic Species		6	1
Loss of Characteristic Species		0	0
% Samples with High Algal Cover		≤20%	2.2%
Invasive Alien Species		0	1
Condition (Macrophytes Only)			**Unfavourable**

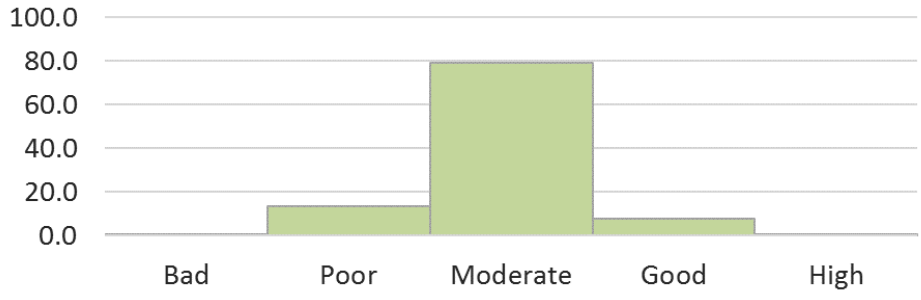
Table 3. CSM Survey results from Hanmer Mere 2017.



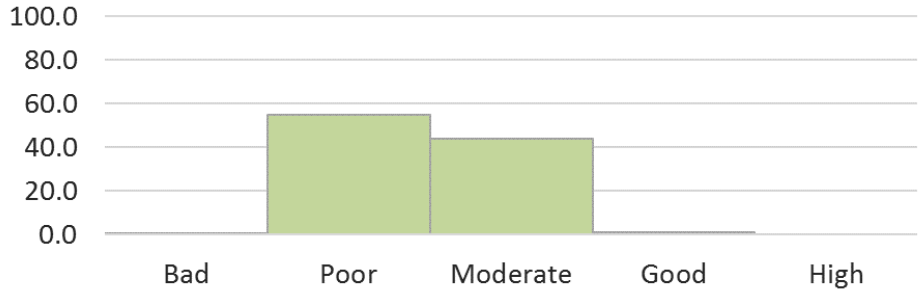
(a) 2003



(b) 2011



(c) 2014



(d) 2017

Figure 5. Leafpacs2 Confidence in Class values for Hanmer Mere, 2003-2017.

Dissolved oxygen and temperature profiles showed Hanmer Mere to be mixed at the time of sampling and with no thermocline evident. Dissolved oxygen declined slightly with increasing depth until the water/sediment interface at 5 m, where levels reduced to 0.39 mg/l (Figure 6) This is a very similar result to the profiles performed on 11/07/08 and 10/08/11 during previous surveys. Water clarity on 15/08/17 was good, with a Secchi depth of 4.05 m.

Dissolved Oxygen Profile

GPS Location	SJ4539539511
Maximum Depth (m)	5.2 m
Secchi Depth (cm)	4.05 cm

Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	6.25	18.5
0.5	5.96	18.5
1	5.84	18.4
1.5	5.7	18.4
2	5.79	18.4
3	5.39	18.3
4	5.39	18.2
5	0.39	17.5

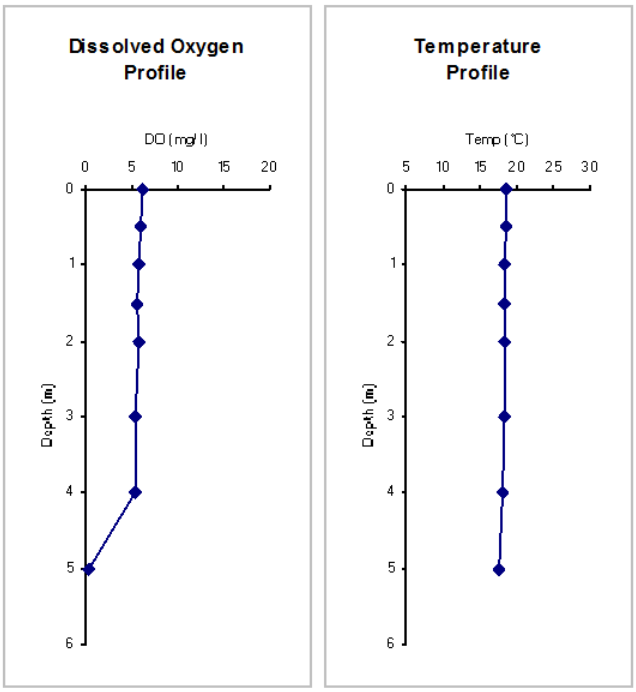
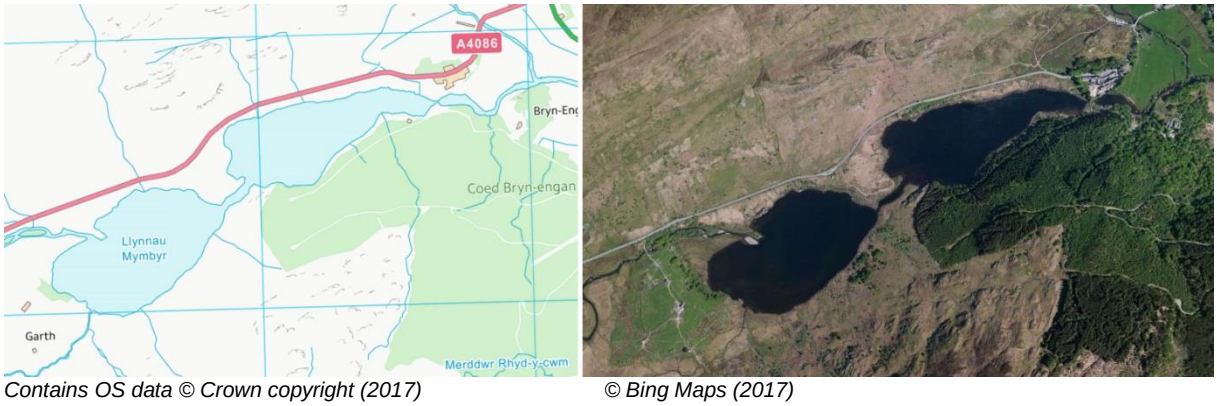


Figure 6. Dissolved oxygen and temperature profiles at Hanmer Mere (15/08/2017).

Recent nutrients data from Hanmer Mere found extremely high levels of phosphorus, with an annual mean of 886 µg l^{-1} as well as elevated N (Hatton-Ellis 2016). The high P levels are primarily due to a leaky sewer, a problem that has now been addressed. The catchment of the lake is also designated as a Nitrate Vulnerable Zone (NVZ).

It is recommended that efforts to reduce the nutrient inputs to Hanmer Mere are continued and that the actions required for the local Nitrate Vulnerable Zone are carried out assiduously.

5.2.2. Llynnau Mymbyr



Contains OS data © Crown copyright (2017) *© Bing Maps (2017)*

Figure 7. Site map and aerial photograph of Llynnau Mymbyr.

Figure 8. Llynnau Mymbyr site photo; from the north end of the neck, looking north-east.

Llynnau Mymbyr are a pair of fairly small, shallow, low-alkalinity lakes near Capel Curig in Snowdonia, North Wales. There are two basins, connected by a narrow bouldery channel. The catchment is medium-sized and composed largely of moorland and acid grassland which is grazed by sheep. An area of coniferous plantation forestry is present on the south-east shore and the A4086 road passes along the northern side of the lake. Llyn Cwmffynnon and the smaller Llyn Pen-y-Gwryd lie upstream from the site and are hydrologically connected via the Nant Gwryd. The lake and much of the catchment lie within the Eryri SSSI and most of the northern catchment within the Eryri / Snowdonia SAC.

The aquatic macrophyte flora (Table 4) is typical for an upland oligotrophic lake and consists of *Littorella uniflora* and *Lobelia dortmanna* in the shallower water, transitioning to *Juncus bulbosus*, *Isoetes lacustris*, *Myriophyllum alterniflorum*, *Potamogeton berchtoldii* and *Nitella flexilis* agg. as depths increase. Monteith (Ed, 1997) recorded the *Potamogeton* sp. as *P. obtusifolius* but the current authors consider it consistent with the light green blunt-leaved form of *P. berchtoldii* described on p.198 of Preston (1995). Of particular note is the continued presence of the rare stonewort *Nitella gracilis*, first found by Monteith in 1996 (Monteith, Ed 1997) and not re-found for some years (N. Stewart, pers comm). This species led to Llynnau Mymbyr being classified as an Important Stonewort Area by Plantlife (Stewart, 2004).

Emergent vegetation around the shoreline predominantly consists of *Ranunculus flammula* and *Juncus articulatus,* but in the sheltered western ends of both basins *Phragmites australis, Carex rostrata* and *Equisetum fluviatile* are also present. Section four, at the westernmost end of the site, has the richest marginal flora and was the only location where *Potentilla palustris*, *Menyanthes trifoliata* and the floating-leaved *Nuphar lutea* and *Potamogeton natans* were recorded.

The maximum depth of colonisation found was for *Isoetes lacustris* and *Utricularia vulgaris* at 3.0 m in Section one in the eastern basin. This is shallower than that observed by Monteith (Ed, 1997) who noted *Potamogeton berchtoldii* growing at 3.8 m.

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

Llynnau Mymbyr hosts four characteristic macrophyte taxa that fulfil the JNCC (2015) target levels for "Oligo-mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea"* and a population of the priority BAP charophyte species *Nitella gracilis.*

Submerged and floating vegetation	**% cover**	**Submerged and floating vegetation**	**% cover**
Batrachospermum sp.	0.6	*Myriophyllum alterniflorum*	10.0
Callitriche brutia var. *hamulata*	0.0	*Nitella flexilis* agg.	2.5
Eleocharis multicaulis	0.7	*Nitella gracilis*	0.8
Filamentous algae	32.4	*Nuphar lutea*	3.3
Isoetes lacustris	**22.1**	*Potamogeton berchtoldii*	1.7
Juncus bulbosus	9.1	*Potamogeton natans*	1.3
Littorella uniflora	**9.9**	*Potamogeton polygonifolius*	0.0
Lobelia dortmanna	**6.6**	*Sphagnum* (aquatic indet.)	1.5
Menyanthes trifoliata	0.7	***Utricularia vulgaris***	**1.9**
Species richness			**18**
WFD LEAFPACS Classification			**Good**
EQR_{LMNI}	0.752	EQR_{NFG}	1.649
EQR_{NTAXA}	1.742	EQR_{COV}	0.845
EQR_{ALG}	0.729	$EQR_{LEAFPACS}$	0.725
Confidence in Class			93.7%
Confidence < Good			1.3%
Invasive Plant Species Cover			**0%**
CSM Result		**Target**	**Measured**
Typical Species % Cover (Oligotrophic)			82.4%
No. of Characteristic Species		≥3	4
Loss of Characteristic Species		0	0
% Samples with High Algal Cover		≤20%	21.1
Invasive Alien Species		0	0
Condition (Macrophytes Only)			**Favourable**

Table 4. CSM Survey results from Llynnau Mymbyr 2017.

Dissolved oxygen and temperature profiles showed the lake to be mixed at the time of the 2017 Llynnau Mymbyr survey with no thermocline evident and only a slight

decline in dissolved oxygen towards the bottom of the profile (Figure 9). This is in contrast to Monteith (Ed,1997) who observed thermal stratification at the site on 17/7/1996.

There are no significant issues with Llynnau Mymbyr and the classification of Good Status is considered, if anything, slightly pessimistic.

Dissolved Oxygen Profile

GPS Location	SH7050857146
Maximum Depth (m)	6 m
Secchi Depth (cm)	3.2 cm

Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	9.79	15
0.5	9.7	15
1	9.71	15
1.5	9.71	15
2	9.71	14.9
3	9.71	14.8
4	9.69	14.7
5	9.66	14.5
6	9.59	14.2

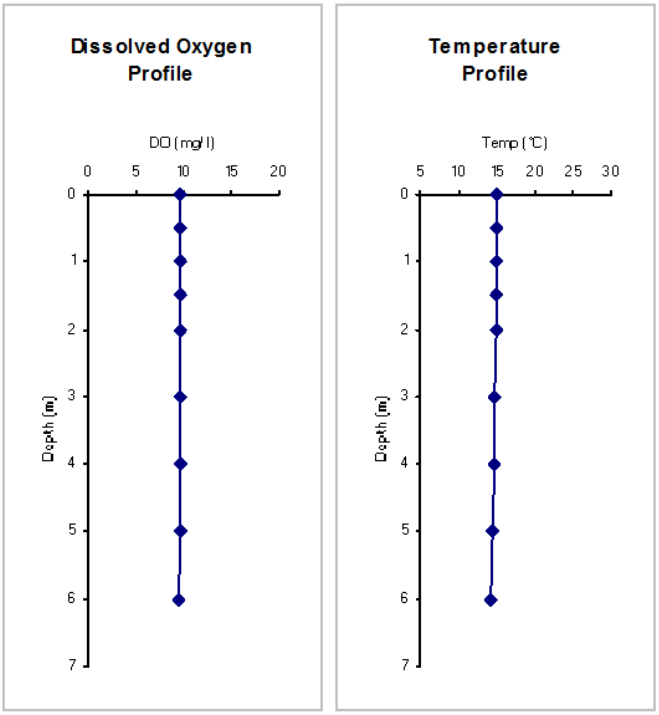
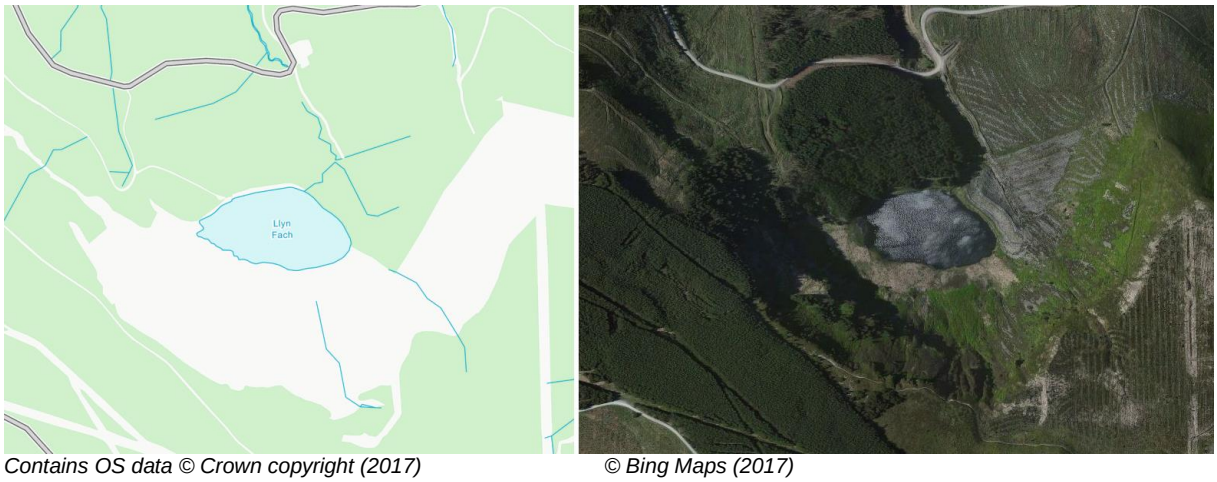


Figure 9. Dissolved oxygen and temperature profiles at Llynnau Mymbyr (17/08/2017).

5.2.3. Llyn Fach



Contains OS data © Crown copyright (2017) *© Bing Maps (2017)*

Figure 10. Site map and aerial photograph of Llyn Fach.

Figure 11. Llyn Fach site photo; from the ridge above the east shore looking west.

Llyn Fach is a small (3.1 ha), shallow (max. recorded depth 5.9 m) lake, lying at 449 m (A.O.D). The lake lies within a glacial valley, with steep crags rising up to the Pennant Sandstone Plateau to the south and east of the lake. The lake is within the Craig-y-llyn SSSI, with the designated area including areas of rock, scree, dry heath, marshy grassland, acid grassland, running water features, and the oligotrophic standing water features of Llyn Fach and Llyn Fawr Reservoir. The catchment is relatively small (46 ha) and lies mainly to the south of the lake, with the upper reaches afforested in the 1960s and 1970s with mature coniferous plantations. Forrest to the south east of the lake was clear-felled by 2001, and not replanted.

The lake, and much of the non-afforested catchment to the south is managed as a nature reserve by the Wildlife Trust of South and West Wales. Management objectives include the clearance of regenerating conifers on previously afforested areas and enhancing wetland habitats to protect Llyn Fach in recognition of species such as *Lobelia dortmanna* (for which Llyn Fach is the southernmost UK locality) and water vole (*Arvicola amphibius*).

There are several seeps and small inflows entering the lake around the west and south margin of the lake. The west end has extensive areas of *Sphagnum* sp. / *Carex rostrata* bog replaced in deeper water (to approx. 1.0 m) by a large bed of *Equisetum fluviatile.* The *C. rostrata* extends in a thinner band around much of the southern shore. The north shore has mature conifers to within 5 m of shore and has only sparse emergent vegetation. *Lobelia dortmanna* and *Isoetes echinospora are* common where the boulders and cobbles give way to compacted fine sediments. There is a single outflow leaving the lake to the north.

Submerged and floating vegetation	% cover	Submerged and floating vegetation	% cover
Eleogiton fluitans	**12.8**	***Lobelia dortmanna***	**17.9**
Filamentous algae	11.7	*Menyanthes trifoliata*	1.4
Fontinalis antipyretica	0.2	*Myriophyllum alterniflorum*	6.1
Isoetes echinospora	**21.1**	*Potamogeton natans*	4.0
Juncus bulbosus	10.6	*Potamogeton polygonifolius*	3.1
Littorella uniflora	**0.8**	*Sphagnum* (aquatic indet.)	3.3
Species richness			**12**
WFD LEAFPACS Classification			**High**
EQR_{LMNI}	0.963	EQR_{NFG}	1.054
EQR_{NTAXA}	1.373	EQR_{COV}	0.973
EQR_{ALG}	0.920	$EQR_{LEAFPACS}$	0.924
Confidence in Class			**100%**
Certainty < Good			**0%**
Invasive Plant Species Cover			**0%**
CSM Result		**Target**	**Measured**
Typical Species % Cover (Oligotrophic)		≥60%	81.5%
No. of Characteristic Species		≥3	4
Loss of Characteristic Species		0	0
% Samples with High Algal Cover		≤20%	0
Invasive Alien Species		0	0
Condition (Macrophytes Only)			**Favourable**

Table 5. CSM Survey results from Llyn Fach 2017.

Although reaching a maximum depth of 5.9 m, the deepest water is restricted to a relatively small area located towards the east shore (see Monteith 1996). The majority of the lake is therefore less than 4 m in depth and colonised throughout by plants and algae. The aquatic macrophyte flora is relatively rich for an upland oligotrophic lake with eleven aquatic species recorded (Table 5).

a) b)

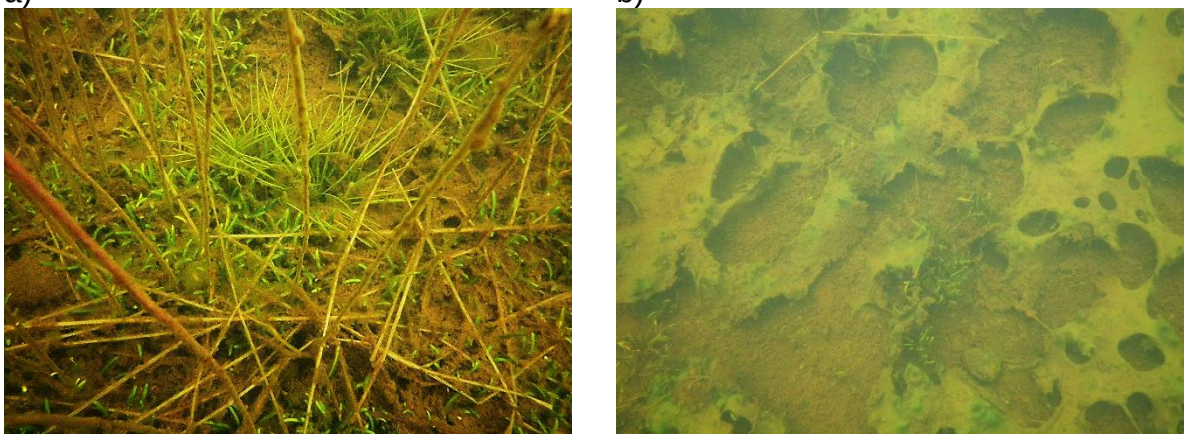


Figure 12. a) *Lobelia dortmanna* and *Isoetes echinospora* (S2 at 75 cm) and b) growths of mat-forming cyanobacteria (*Plectonema* sp.) seen at 1.0 – 1.5 m.

The most abundant taxon within the two survey sections was *Isoetes echinospora*[1] which was recorded growing from as shallow as 25 cm on exposed littoral substrates, but was more common in deeper water (max. of 3.6 m), particularly where other species were sparse. *Lobelia dortmanna* was also common, and often co-occurring with *I. echinospora* up to a maximum depth of 1.6 m (Figure 12a).

Juncus bulbosus and *Eleogiton* (*Isolepis*) *fluitans* were both common within the lake, but had a patchy distribution. *Juncus bulbosus* was most abundant in deeper water (2.5 – 3.9 m) in Section one (southeast end), but also occurred in the shallower littoral zone throughout the lake. It was not recorded in the open water on the north side. *Eleogiton fluitans* was common around the margin, often growing within the shallow waters with *C. rostrata.* There was also a relatively large bed of *E. fluitans,* extending west from the centre of the lake and forming dense growths in depths of approximately 1.5 m, often with *I. echinospora* below and interspersed with *Myriophyllum alterniflorum*; the latter being only occasional within the survey sections.

Littorella uniflora was recorded from both the north and south shore, but was rare within the site. There was a bed of *Potamogeton natans* towards the western end of the north shore and *P. polygonifolius* occurred mainly within the boggy margins associated with *C. rostrata.*

Filamentous green algae was recorded only at low abundance, but there was an area of the mat forming cyanobacteria *Plectonema* sp. located towards the north shore at 1.3-1.5 m depth (Figure 12b). This species was relatively rare in the site, but is noteworthy in that it can smother other aquatic plants when abundant, as seen as Llyn Cwm Mynach (Kernan *et al.* 2010), and has been associated with sites where heavy metals are present, particularly manganese (John *et al.* 2002). The maximum depth of colonisation (*Juncus bulbosus)* in the lake was 3.9 m.

[1] All megaspores examined confirmed as *I. echinospora*

The aquatic macrophyte assemblage appears to have remained relatively stable compared to previous surveys. Seddon (1972) and Monteith *et al.* (1996) report a similar assemblage, with the noticeable exception of *Sparganium angustifolium* having been present in past studies (see also Trow 1911). This species is usually very visible where it does occur (often seen in the strandline), and therefore unlikely to have been overlooked in the recent survey. The possible disappearance or major decline, of *S. angustifolium* is of concern; particularly for a species uncommon in South Wales. Monteith *et al.* (1996) noted the absence of *Littorella uniflora,* but this is confirmed still to be present, also recorded by Seddon (1972) and Trow (1911), the latter remarking on being extinct after 1895, which suggests it has always been rare there. Seddon (1972) reports *I. lacustris* and *I. echinospora* present in Llyn Fach, Trow (1911), mentions only *I. lacustris,* but notes both species from nearby Llyn Fawr (SN917035). Confusion between these species is common, and while microscopic examination confirms *I. echinospora* as present in 2017, it was restricted to only a few plants and thus presence of *I. lacustris* should not be ruled out completely.

The Leafpacs tool classified the lake as High status with 100% confidence. There is no evidence of any nutrient impact in Llyn Fach and this is therefore considered to be an accurate assessment.

Dissolved oxygen and temperature profiles showed the lake to be mixed during summer with no thermocline evident and no decline in dissolved oxygen with increasing depth (Figure 13). The Secchi depth was measured at 3.6 m on 17/08/2017.

Dissolved Oxygen Profile

GPS Location	SN9057903843
Maximum Depth (m)	5.9 m
Secchi Depth (cm)	3.6 cm
Notes:	

Depth (m)	DO (mg/l)	Temp (°C)
0	9.85	17.2
0.5	10.1	16.9
1	10.02	16.6
1.5	9.96	16.4
2	9.89	16.1
3	9.81	16
4	9.83	16
5	9.82	15.9
5.5	9.75	15.8

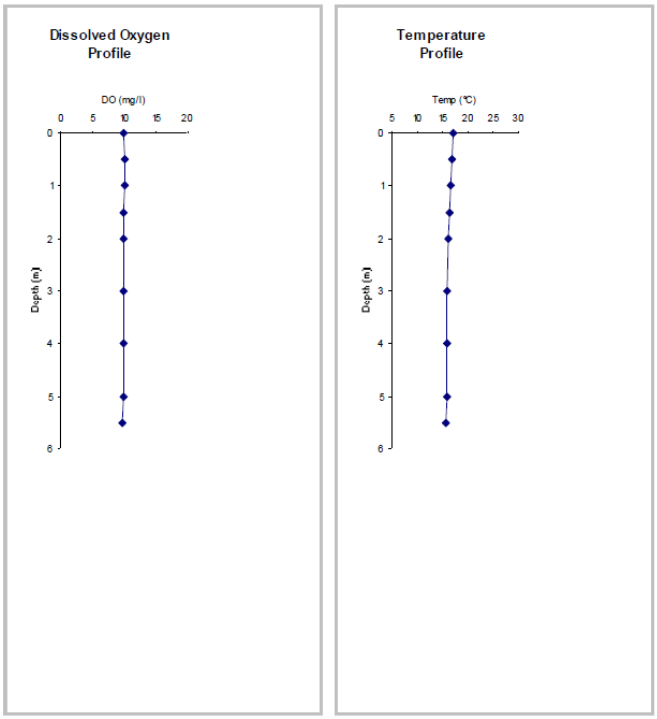
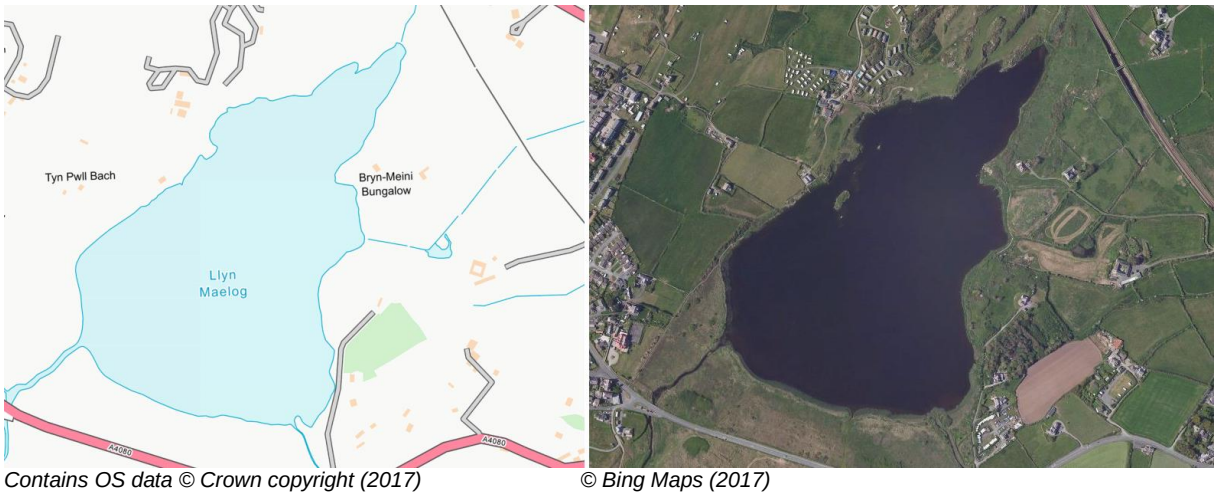


Figure 13. Dissolved oxygen and temperature profiles at Llyn Fach (17/08/2017).

5.2.4. Llyn Maelog



Contains OS data © Crown copyright (2017) *© Bing Maps (2017)*

Figure 14. Site map and aerial photograph of Llyn Maelog .

Figure 15. Llyn Maelog site photo; from the eastern shore looking south west.

Llyn Maelog is a medium-sized (24 ha), very shallow, high alkalinity lake located near Rhosneigr on the southwest coast of Anglesey. The lake and the area just to the south form Llyn Maelog SSSI. The large catchment is mostly improved and calcareous grassland, with lesser amounts of arable, woodland and rural development. A public footpath runs around the site and it is used for angling and recreational water sports.

Much of the lake, particularly to the south, is fringed with reeds, especially *Phragmites australis*, *Iris pseudacorus*, *Phalaris arundinacea* and *Eleocharis palustris*. The aquatic macrophyte cover in the 2017 survey was low overall. As it was performed slightly late in the season some of the *Potamogeton* sp. had already senesced and the senescing material/turions was ascribed to *Potamogeton pusillus* in the LEAFPACS tool and database. *Potamogeton perfoliatus* was still readily identifiable however. The sparse submerged flora (Table 6). is characterised by *Elodea canadensis* and *P. pusillus*. Small amounts of *P. perfoliatus*, *Callitriche hermaphroditica* and *Chara globularis* were also encountered. In section four on the

east of the site small populations of *Eleocharis acicularis* and *Elatine hexandra* were found. A directly comparable survey, using identical standard CSM methodologies, was performed in 2007 (Burgess *et al,* 2009). *Zannichellia palustris, Potamogeton crispus* and *Nymphaea alba* were all recorded in 2007 but could not be re-found in 2017. The maximum depth of colonisation of 1.9 m was identical for both surveys.

Possessing only three out of the required six characteristic species, the current aquatic macrophyte assemblage 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 at low amounts around some of the edges of the lake but very little is found in the main body of water. One alien invasive macrophyte species, *E canadensis*, was present during the current survey.

Submerged and floating vegetation	**% cover**	**Submerged and floating vegetation**	**% cover**
Callitriche hermaphroditica	**1.6**	*Hydrodictyon reticulatum*	0.5
Chara globularis	**0.8**	*Lemna minor*	1.4
Elatine hexandra	0.8	*Persicaria amphibia*	3.0
Eleocharis acicularis	0.9	***Potamogeton perfoliatus***	**1.9**
Elodea canadensis	7.7	*Potamogeton pusillus*	2.7
Filamentous algae	4.0		
Species richness			**11**
WFD LEAFPACS Classification			**Moderate**
EQR_{LMNI}	0.541	EQR_{NFG}	1.221
EQR_{NTAXA}	0.970	EQR_{COV}	0.529
EQR_{ALG}	0.866	$EQR_{LEAFPACS}$	0.439
Confidence in Class			**65.3%**
Certainty < Good			**97.3%**
Invasive Plant Species Cover			**37.19%**
CSM Result		**Target**	**Measured**
Typical Species % Cover (Eutrophic)		≥60%	5.9%
No. of Characteristic Species		6	3
Loss of Characteristic Species		0	0
% Samples with High Algal Cover		≤20%	5.6%
Invasive Alien Species		0	1
Condition (Macrophytes Only)			**Unfavourable**

Table 6. CSM Survey results from Llyn Maelog 2017.

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 the somewhat chilly and breezy conditions during the survey resulted in the surface water being slightly colder than the water below. (Figure 16). Water clarity was poor, with a Secchi depth of only 0.55 m on 18/08/17.

Low taxon richness and abundances at this site are likely to be due to the nutrient pressures identified by Hatton-Ellis (2016). The face value Leafpacs classification improved from Poor to Moderate status, but still with very high confidence that the

lake is worse than Good, and macrophyte cover was worryingly low. Confidence in class data show that there has been little change between 2014 and 2017, with both classifications producing results very close to the Moderate-Poor boundary.

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 Profile

GPS Location	SH3262673011
Maximum Depth (m)	1.9 m
Secchi Depth (cm)	0.55 cm

Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	9.56	16.9
0.5	9.5	16.9
1	9.41	17
1.5	9.41	17
1.8	9.39	17

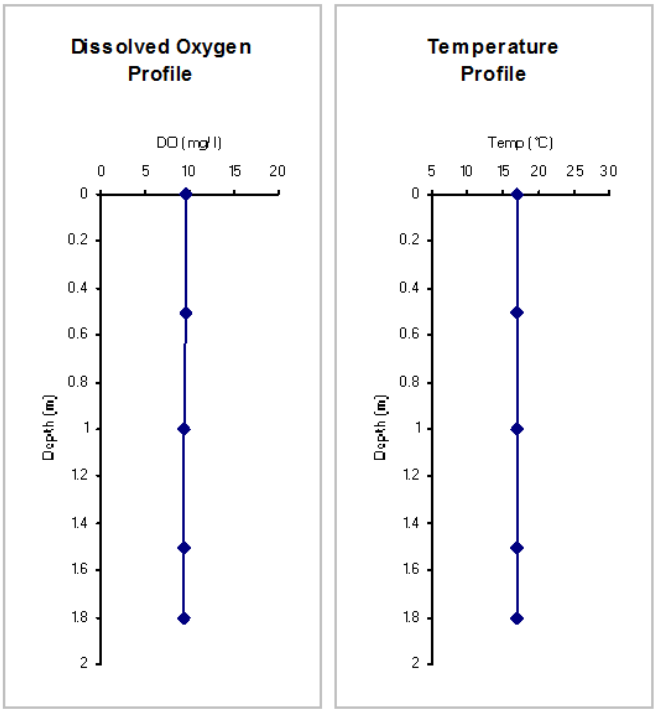


Figure 16. Dissolved oxygen and temperature profiles at Llyn Maelog (18/08/2017).

5.2.5. Llanbwchllyn Lake

Contains OS data © Crown copyright (2017) *© Bing Maps (2017)*

Figure 17. Site map and aerial photograph of Llanbwchllyn Lake.

Figure. 18 Llanbwchllyn Lake site photo; from the bird hide at the west end, looking east.

Llanbwchllyn Lake is a small (9.7 ha), shallow (max. recorded depth 7.5 m) lake, lying at 298 m A.O.D. in Powys, Wales, 10 km south east of Builth Wells. The catchment, which extends to an area north of the lake, covers an area of approximately 296 ha on Silurian sedimentary rocks, with Manod series soils in the upper catchment and well drained fine loams from the Denbigh series surrounding the lake (Monteith *et al.* 1996). Catchment land use ranges from heath dominated rough grazing, through a range of acid, and neutral grasslands, down to improved pasture around the lake. The land sloping down to the lake shore along the north shore is broadleaf woodland and a narrow band of trees, including some introduced conifers, extends around the rest of the lake.

Llanbwchllyn was designated as a SSSI in 1954, being heralded at the time as a good example of a mesotrophic lake with good marginal habitats and ornithological and entomological interest. The use of the site for increased water storage and supply was facilitated in 1964 by the Hay and Painscastle Water Order, and in 1975 a low earth dam was constructed to raise the water level by 1.0 m and in so doing increase the available capacity by 50%. See Burgess *et al*. 2008, for a broader review of the literature for the site.

The lake is fed by a number of small streams from the north and west, with additional inputs from a number of sprigs that rise along the slopes above the north shore. It is understood the lake is no longer used for water supply, but the low dam remains in place across the original outflow towards the south-west side of the lake. The extent to which this dam remains effective is unclear, as water levels were estimated to be 50 cm below their recent maximum, resulting in exposure of littoral sediments within the marginal wetlands.

At the time of sampling, the water was turbid and green/brown in colour due to high algal biomass (Secchi depth 90 cm) and with a visible cyanobacterial bloom, with *Aphanizomenon* sp. visible on the surface and within the water column. This resulted in a Secchi depth of only 90cm. Conditions were poor for underwater photography.

The marginal and emergent flora is relatively rich and varied around the lake. *Salix* spp. and alder are common around the shore and in places, encroach over the water, shading the littoral zone. *Phragmites australis, Typha latifolia* and *Carex acutiformis* form extensive stands of emergent reed bed and fen, within which there is a rich wetland herb community, including *Ranunculus lingua,* a localised plant in Wales.

Llanbwchllyn Lake is classified as a medium alkalinity, mesotrophic lake. The submerged and floating leaved aquatic macrophyte assemblage is relatively rich with 18 species recorded on the three survey sections (Table 7).

Submerged and floating vegetation	% cover	Submerged and floating vegetation	% cover
Callitriche brutia var. *brutia*	1.0	*Nymphaea alba*	3.9
Ceratophyllum demersum	0.5	*Persicaria amphibia*	2.4
Chara globularis	4.4	*Potamogeton crispus*	1.0
Lemna trisulca	10.9	*Potamogeton natans*	1.7
Menyanthes trifoliata	2.9	*Potamogeton obtusifolius*	11.3
Myriophyllum alterniflorum	2.3	*Potamogeton pectinatus*	1.0
Myriophyllum spicatum	11.4	***Potamogeton praelongus***	**5.6**
***Nitella flexilis* agg.**	**6.6**	*Ranunculus circinatus*	1.0
Nuphar lutea	3.8	*Ranunculus lingua*	1.0
Species richness			**18**
WFD LEAFPACS Classification			**Moderate**
EQR_{LMNI}	0.528	EQR_{NFG}	1.382
EQR_{NTAXA}	1.547	EQR_{COV}	0.701
EQR_{ALG}	1.000	$EQR_{LEAFPACS}$	0.425
Confidence in Class			59.5
Certainty < Good			98%
Invasive Plant Species Cover			**0%**

CSM Result	Target	Measured
Typical Species % Cover (Mesotrophic)	≥60%	21.5%
No. of Characteristic Species	8	2
Loss of Characteristic Species	0	1
% Samples with High Algal Cover	≤20%	0
Invasive Alien Species	0	0
Condition (Macrophytes Only)		**Unfavourable**

Table 7. Leafpacs and CSM Survey results from Llanbwchllyn Lake 2017.

Common species recorded in Llanbwchllyn Lake were *Potamogeton obtusifolius, Lemna trisulca* and *Myriophyllum spicatum.* It is worthy of note that *M. alterniflorum* was also present, albeit less frequent, than *M. spicatum,* two species that are only rarely found growing within the same site (Figure 19a). Throughout the majority of the shoreline, the littoral zone is either dominated by emergent vegetation or over shadowed by *Salix* and *Alnus,* the result being rather sparse submerged flora in shallow water. *Lemna trisulca* was locally abundant within the emergent reeds and present at low density out into open water to a depth of 3.5 m. There are extensive beds of *Nuphar lutea and Nymphaea alba* (often mixed, see Figure. 18) around the south and south-west margin to depths of 1.2 m and 1.5 m respectively.

a)

b)

Figure 19. a) Leaf details of *Myriophyllum spicatum* (bottom) and *M. alterniflorum* (top) from Llanbwchllyn and b) *Potamogeton praelongus*

Moving into open water, the most typical vegetation, was a mosaic of mixed beds of *Potamogeton obtusifolius*, *M. spicatum* and *Chara globularis* to depths of approximately 2.5 m. Within this mosaic, *Lemna trisulca* was almost constant, but at low abundance, and *M. alterniflorum* occasional. *Nitella flexilis* agg. was also common within the mosaic, but generally occurred in deeper water with recorded ranging from 1.7 m to the maximum depth of colonisation of 3.9 m.

Potamogeton praelongus (Figure 19b) was recorded at two separate locations within the site; at the east end (S2) and beyond the water lilies along the south shore (S2). These beds were relatively dense and in excess of 100 m wide at depths of 50 – 140 cm, with occasional records to 2.9 m. Water levels quoted here are approximately 50 cm below the site maximum. Other submerged species were rare within the survey sections, and it is encouraging to note that no non-native species were recorded.

a) b) c)

Figure 20. Rake trawls: a) *Potamogeton praelongus* / *M. spicatum* / *C. demersum* (S1 @ 1.4 m); b) *N. flexilis* agg./ *C. globularis* / *M. spicatum* (S1 @ 1.6 m); c) *P. obtusifolius* / *M. spicatum* (S3 @1.4 m).

The current flora bears some similarity to past surveys, but there has undoubtedly been changes over the past few decades, including the loss (or at least significant reduction) of the typical mesotrophic species *Littorella uniflora*, recorded by Monteith (1996), Seddon (1972) and in the SSSI citation, but not seen (despite additional searches) in this survey or in 2007 (Burgess *et al.* 2009). Other changes include the appearance of *M. spicatum* and *P. praelongus*, not seen by Seddon, but recorded in 1995 by Monteith and seemingly increased significantly in subsequent surveys. Burgess *et al* (2009) recorded *P. pectinatus* as “Frequent”, and *C. demersum* as “Abundant”; two species indicative of eutrophication. The latter is now rare in the site and *P. pectinatus* was not recorded in 2017. Compared with the most recent survey data in 2014 (Baxter & Stewart 2015), there has been a further reduction in nutrient-tolerant species and a general increase plant diversity and cover.

The long-term changes are indicative of eutrophication at the site, but the current survey results suggest an improvement since 2007, with an increase in the abundance of typical mesotrophic species (e.g. *N. flexilis* agg and *P. praelongus*) and reduction of eutrophic species.

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 22).

Figure 21. Leafpacs confidence in class results for Llanbwchllyn Lake, 2014 and 2017.

Leafpacs classification data indicated an improvement since 2014 of about 1 class, from Poor-Bad to Moderate-Poor status. This is driven by an improvement in the LMNI metric, with an improvement in EQR from 0.40 to 0.52. The COV (plant cover) metric also improved from 0.58 to 0.70. These are potentially significant improvements and may reflect actions within the catchment to reduce nutrient inputs. It is likely that more time will be needed for further recovery, and possibly further catchment-based actions to ensure that this recovery is sustained.

Although the lake has not been stocked for a number of years, there is a resident coarse fish population consisting of roach, perch, pike and a small number of bream (Hänfling et al. in press). Roach and bream are likely to promote algal blooms by feeding on zooplankton, and their numbers may need management in order for favourable condition to be reached.

Dissolved Oxygen Profile

GPS Location	SO1192746303
Maximum Depth (m)	7.2 m
Secchi Depth (cm)	90 cm

Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	11.76	17.2
0.5	11.72	17.2
1	11.65	17.2
1.5	11.52	17.2
2	11.19	17.1
2.5	9.02	16.7
3	6.04	16.3
3.5	5.57	16.3
4	4.08	16
4.5	3.17	15.8
5	0.27	15.5
5.5	0.28	15.4
6	0.28	15
6.5	0.3	14.8
7	0.3	14.6

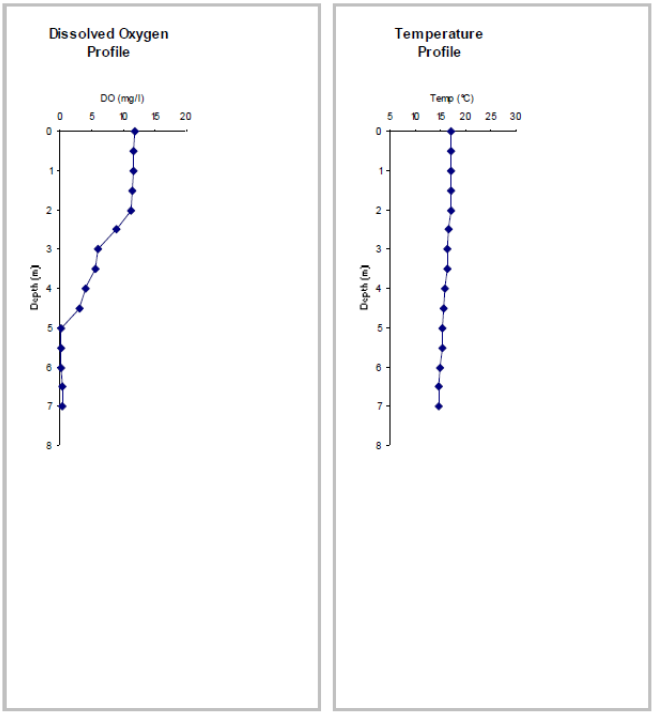
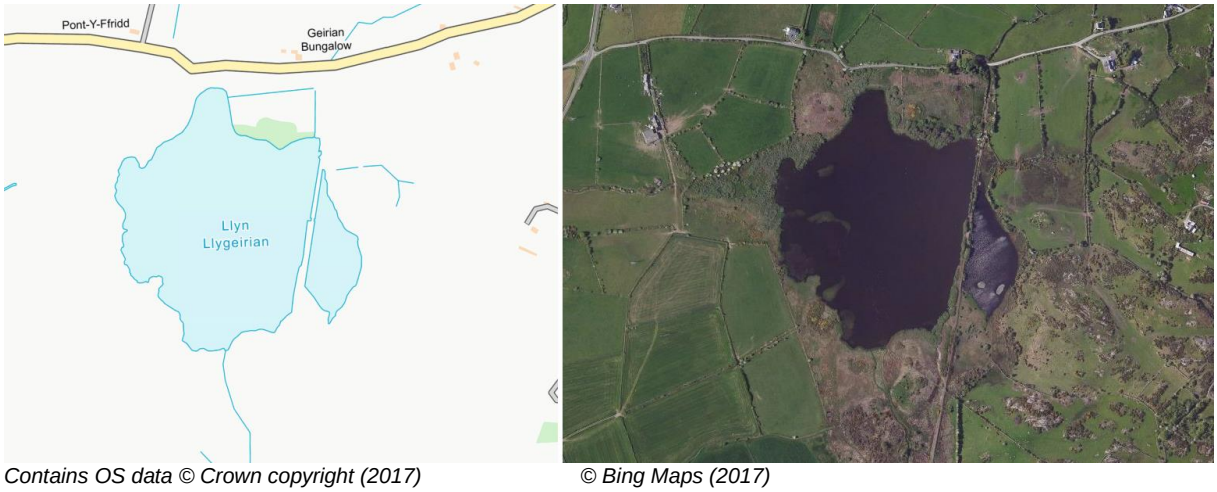


Figure 22. Dissolved oxygen and temperature profiles at Llanbwchllyn Reservoir (18/08/2017).

5.2.6. Llyn Llygeirian



Contains OS data © Crown copyright (2017) *© Bing Maps (2017)*

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

Figure 24. Llyn Llygeirian site photo; from the north-east shore looking south-west.

Llyn Llygeirian is a small (11 ha), very shallow (about 1m deep), high alkalinity, low altitude lake near Cemaes Bay on Anglesey, and the lake plus surrounding wetland form the Llyn Llygeirian SSSI. The catchment is largely agricultural and land-use consists of improved and calcareous grassland as well as arable. A fishing club stock the site with brown trout and there is both shore and boat angling.

Wetland and reeds fringe most of the edge of the lake and the area at the southern end of the site is particularly species-rich. *Typha latifolia*, *Schoenoplectus lacustris*, *Equisetum fluviatile*, *Iris pseudacorus*, *Phalaris arundinacea, Menyanthes trifoliata* and *Sparganium erectum* characterise the shoreline and unusually for a lowland site there are also beds of *Carex rostrata.*

At the time of the 2017 survey aquatic plants were present over the entire lake bed, demonstrating that the light climate of this shallow lake (max depth 1.2 m) had been suitable for plant growth in the preceding months. The submerged aquatic flora was dominated by *Elodea canadensis* and *Myriophyllum alterniflorum* (Table 8), but there were also abundant *Potamogeton* turions, suggesting that macrophyte abundances would have been greater earlier in the season before the fine-leaved *Potamogeton* sp. died-back. Turions were ascribed to *Potamogeton pusillus* based on the data from previous surveys (Burgess *et al,* 2006). Other species characteristic of the open

water were *Nitella flexilis* agg and *Lemna trisulca,* and there are beds of the floating-leaved taxa *Nymphaea alba* and *Persicaria amphibia* on the western side of the lake. Section one at the southern edge of the site was especially rich and here we located *Hydrocharis morsus-ranae*, a species not found in the 2003 or 2007 surveys of the site, regionally rare in North Wales and present on the SSSI notification for Llyn Llygeirian. This is a new location for this species on the site, which has previously only been recorded from the northern tip of the smaller cut-off section of the lake to the east of the causeway (R.A. Jones pers. comm). It is also the only known lake site for this species in Wales.

A few individuals of readily-identifiable *Potamogeton perfoliatus* were also present in Section one. *Littorella uniflora* was discovered growing in small amounts in Section two and a single sample of *Eleocharis acicularis* was surveyed in Section three. The latter species has seen its abundance drop significantly at the site since the 2003 and 2007 surveys. Similarly, no *Elatine hydropiper* nor *Chara* sp. were located in 2017, having been common in the previous surveys. An addition to the taxa list compared to historic surveys was a single plant of *Ceratophyllum demersum* found in Section one.

Figure 25. *Hydrocharis morsus-ranae* at Llyn Llygeirian (S1 @ 50cm).

With just three characteristic taxa, the 2017 aquatic macrophyte assemblage 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. One alien species, *E. canadensis*, was recorded and very little filamentous algae was present during the current survey. Concerns might be raised at the increased abundances of *E. canadensis*, the major reductions of *E. acicularis* and the apparent absence altogether of *E. hydropiper* and *Chara* sp.

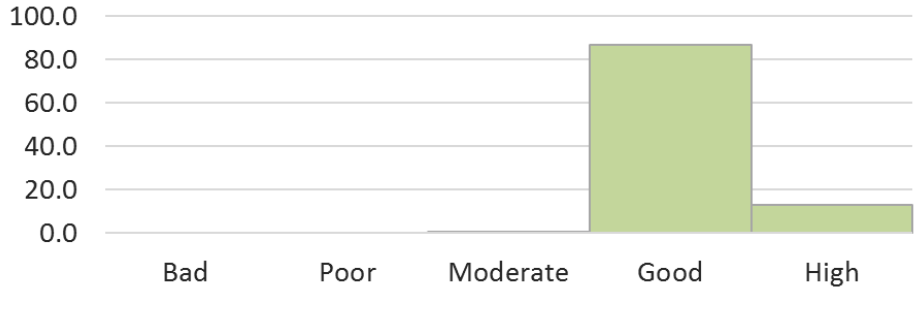
Submerged and floating vegetation	% cover	Submerged and floating vegetation	% cover
Ceratophyllum demersum	0.1	*Menyanthes trifoliata*	4.5
Eleocharis acicularis	0.1	*Myriophyllum alterniflorum*	11.6
Elodea canadensis	17.9	*Nitella flexilis* agg.	4.8
Filamentous algae	2.3	*Nymphaea alba*	0.9
Hydrocharis morsus-ranae	**2.1**	*Persicaria amphibia*	3.3
Lemna minor	2.8	***Potamogeton perfoliatus***	**0.8**
Lemna trisulca	8.6	*Potamogeton pusillus*	4.6
Littorella uniflora	**1.2**		
Species richness			**17**
WFD LEAFPACS Classification			**Good**
EQR_{LMNI}	0.695	EQR_{NFG}	1.725
EQR_{NTAXA}	1.577	EQR_{COV}	0.730
EQR_{ALG}	1.000	$EQR_{LEAFPACS}$	0.650
Confidence in Class			**78.8**
Confidence < Good			**21.0**
Invasive Plant Species Cover			17.9%

CSM Result	Target	Measured
Typical Species % Cover (Mesotrophic)	≥ 60%	8.1
No. of Characteristic Species	≥ 8	3
Loss of Characteristic Species	0	2
% Samples with High Algal Cover	≤ 20%	0
Invasive Alien Species	0	1
Condition (Macrophytes Only)		**Unfavourable Declining**

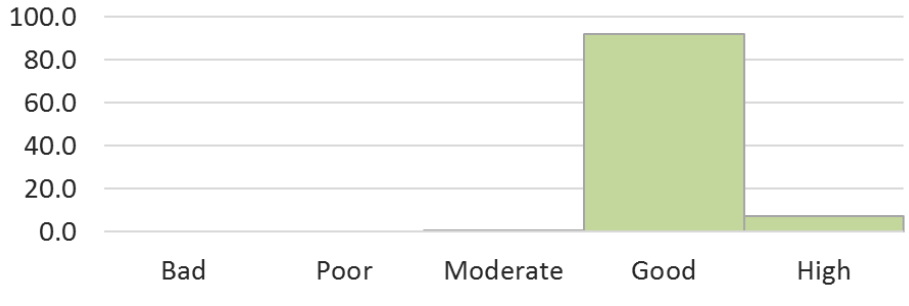
Table 8. CSM Survey results from Llyn Llygeirian 2017.

Dissolved oxygen and temperature profiles showed the lake to be mixed at the time of survey with no thermocline evident and only a slight decline in dissolved oxygen with increasing depth (Figure 27). This is not unexpected for a site that is shallow and exposed. Water clarity was poor however, with Secchi depth only 0.55 m on 19/08/17.

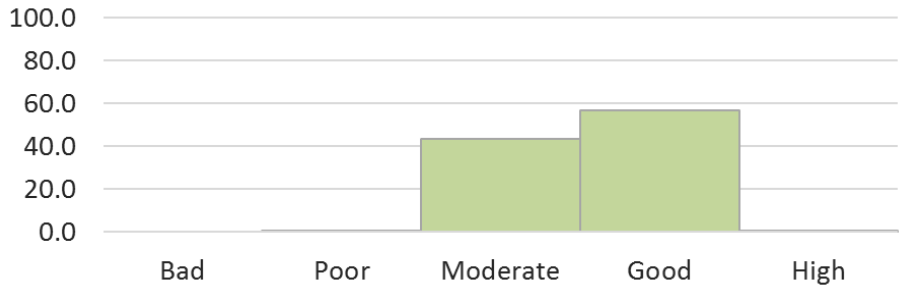
Although the Leafpacs classification shows the lake to be in Good status, there is a declining trend with the overall EQR having declined steadily from 0.75 to 0.65 between 2003 and 2017. In combination with the poor water clarity, this constitutes evidence of an ongoing nutrient pressure at this lake. Investigations of potential catchment nutrient sources are required to establish and manage the causes of this.



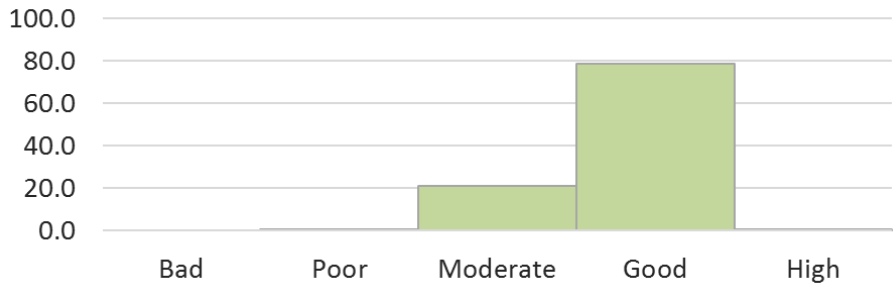
(a) 2003



(b) 2007



(c) 2014



(d) 2017

Figure 26. Leafpacs confidence in class for Llyn Llygeirian, 2003-17.

Dissolved Oxygen Profile

GPS Location	SH3473389193
Maximum Depth (m)	1.3 m
Secchi Depth (cm)	0.55 cm

Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	9.76	15.5
0.5	9.55	15.5
1	9.54	15.5
1.2	8.98	15.5

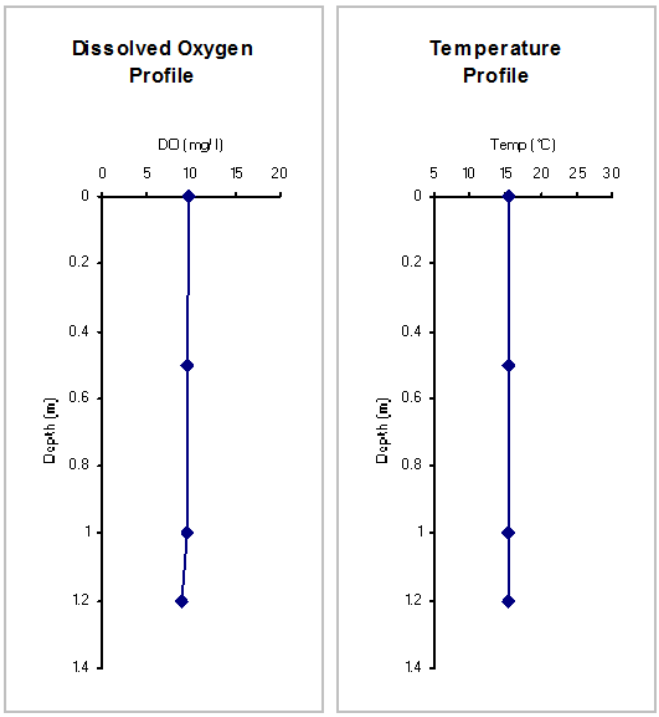
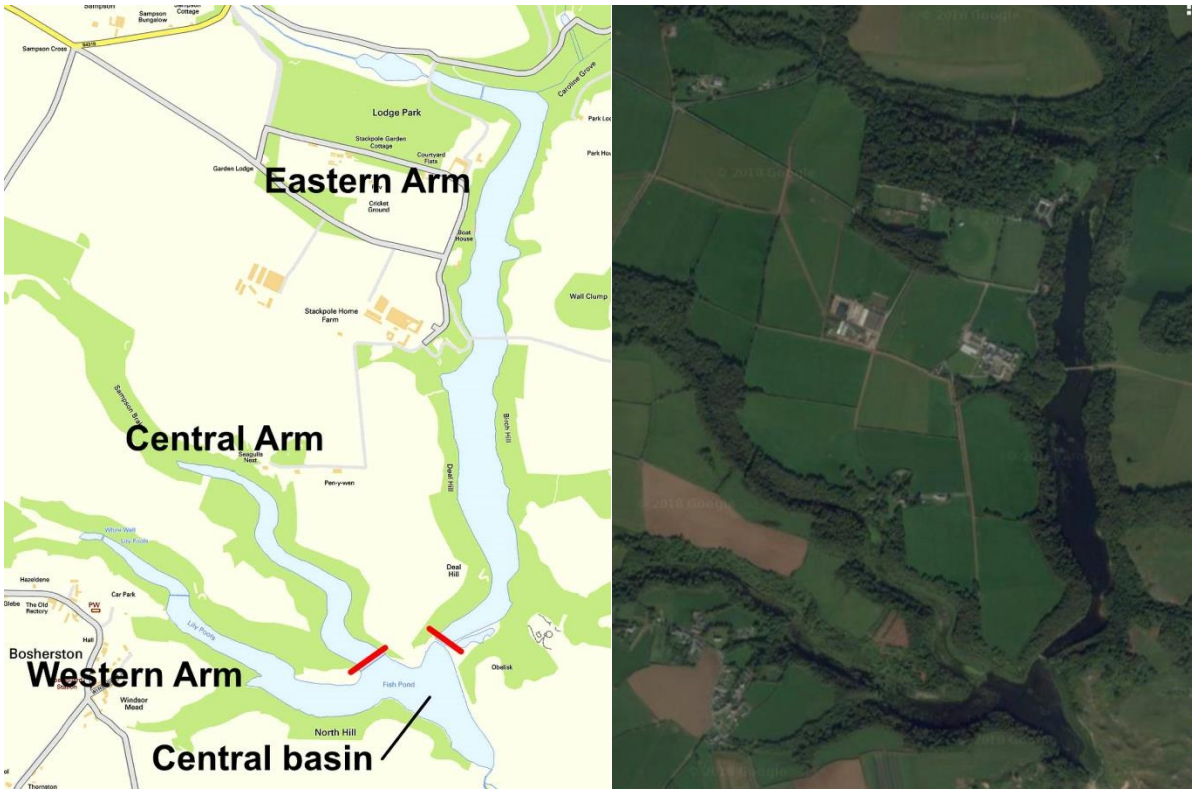


Figure 27. Dissolved oxygen and temperature profiles at Llyn Llygeirian (19/08/2017).

5.2.7. Bosherston Lily Ponds – Eastern Arm



Contains OS data © Crown copyright (2017) *© Google Maps (2017)*

Figure 28. Site map and aerial photograph of Bosherston Lily Ponds – Eastern Arm.

Figure 29. Bosherston Lily Ponds – Eastern Arm; from Eight Arch Bridge, looking north.

Bosherston Lily Ponds consist of three distinct arms, running down separate steep-sided valleys, which cut through carboniferous limestone and meet at a central basin, before outflowing towards Broadhaven beach to the southwest of Stackpole Head. The lakes, are artificial, having been formed in the 18th and early 19th Centuries by the construction of a series of barriers across the valleys that in effect, step the water level down towards the outlet. All three basins are very shallow (1.0 – 2.0 m). The Eastern Arm is fed by small streams at its upper end, and there are additional inputs of calcium-rich groundwater, particularly to the Central and Western arms. Due to the physical separation of the arms and their differing water supply (and water quality) the three arms are distinct in their flora and considered separately here.

The lakes are recognised to be of significant conservation value and are designated as a Special Area of Conservation (SAC) under the Habitats Directive as the Annex I habitat “Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp.”.

The Eastern Arm stretches approximately 2.1 km, mainly in a northerly direction, but turning sharply to the west at the northern end (Figure 28). Covering a total area of approximately 18 ha (measured from OS mapping), the arm is divided by a low weir under Eight Arch Bridge, and again towards the top end. The pool shown on the map at the uppermost end of the arm (Figure 28), is no longer open water, but has succumbed to encroachment of willow and *Phragmites australis.* It is used as a sediment trap for the lake and is periodically desilted.

With steep wooded valleys rising from the shore, there is only a very narrow band of marginal and emergent flora around much the Eastern Arm. In addition to overhanging *Salix* spp. and *Alnus glutinosa, Sparganium erectum* is abundant as an emergent, often with sparse *Iris pseudacorus, Phalaris arundinacea, Solanum dulcamara* and *Oenanthe crocata* at the water’s edge. *Butomus umbellatus* was recorded along the north-east shore.

The submerged aquatic macrophyte flora of Bosherston Lily Ponds – Eastern Arm is dominated by only two plant species: *Potamogeton crispus* and *Elodea canadensis* (Table 9). These form dense beds throughout the open water, often with thick growths of filamentous green algae covering them (Figure 30). In the northern half of the site, there was only occasional plants of *Myriophyllum spicatum, Potamogeton pectinatus* and *Chara globularis* seen; these species becoming more common at the southern end, particularly *M. spicatum. Chara hispida,* which is common in the Central and Western Arm, was not recorded from the Eastern Arm.

The presence of the non-native (naturalised), *Elodea canadensis* clearly impacts on the function of the submerged habitat. In many areas, it grows at very high density and with no other plant species beneath. The non-native least duckweed *Lemna minuta* was also recorded from a single location in the margins. This species is widespread within the UK, and a potential nuisance species where it occurs at high density.

Submerged and floating vegetation	% cover	Submerged and floating vegetation	% cover
Butomus umbellatus	0.7	*Myriophyllum spicatum*	8.9
Chara globularis	3.8	*Nymphaea alba*	0.5
Elodea canadensis	18.6	*Persicaria amphibia*	3.4
Filamentous algae	23.6	*Potamogeton berchtoldii*	0.1
Lemna minor	4.0	*Potamogeton crispus*	18.9
Lemna minuta	0.1	*Potamogeton pectinatus*	2.7
Species richness			**12**
WFD LEAFPACS Result			**Poor**
EQR_{LMNI}	0.486	EQR_{NFG}	0.942
EQR_{NTAXA}	0.838	EQR_{COV}	0.871
EQR_{ALG}	0.768	$EQR_{LEAFPACS}$	0.486
Confidence in Class			**62**
Certainty < Good			**99.3%**
Invasive Plant Species Cover			18.7%

CSM Result	Target	Measured
Typical Species % Cover (Hard with Chara)	60%	0
No. of Characteristic Species	1	0
Loss of Characteristic Species	0	0
% Samples with High Algal Cover	≤20%	36.7
Invasive Alien Species	0	2
Condition (Macrophytes Only)		**Unfavourable**

Table 9. CSM Survey results from Bosherston Lily Ponds – Eastern Arm 2017

In addition to the flora, a high density of freshwater mussels (*Anodonta* sp.) was noted, particularly in the soft sediments along the northeast shore (Figure 31a), and a colony of the bryozoan *Cristatella mucedo* recorded growing on submerged dead-wood close to the end of Section one at SR9774095713 (Figure 31b).

The current flora has remained relatively stable in terms of species in recent years, with a survey conducted in 2011 producing a similar list (Goldsmith *et al.* 2011), with *E. canadensis* dominant and *Chara globularis* and *L. trisulca* more common than *P. crispus* and *M. spicatum.* Since 1977, Natural Resources Wales and its predecessors, undertook regular aquatic plant surveys along fixed transects, led in latter years by Bob Haycock and George Hinton (see Holman *et al.* 2009 for summary). These surveys show *M. spicatum* and *P. pectinatus* to have been dominant in the Eastern Arm until the mid-1980s, after which *E. canadensis* increased dramatically to become dominant, replacing *P. pectinatus.* Charophytes have not been common, and *C. hispida* only occasionally recorded at the southern end (Haycock and Hinton 2010). In the absence of earlier survey records, the Eastern Arm would benefit from palaeoecological evidence, particularly plant sub-fossil analysis (e.g. Davidson *et al.* 2005), to elucidate the past vegetation history of the site.

a)

b)

c)

Figure 30. a) *Elodea canadensis* and *P. crispus* in turbid water (S2 @ 1.5 m); b) rake trawl with *E. canadensis* and *M. spicatum* showing dense cover of filamentous green algae (S3 @ 1.0 m); c) *E. canadensis* and filamentous green algae (S3 @ 85 cm).

a)

b)

Figure 31. a) Freshwater mussel (*Anodonta* sp.) filter feeding; b) colony of the freshwater bryozoan *Cristatella mucedo*.

The site is very shallow (maximum during low summer level, 1.5 m) and the water was well oxygenated throughout the water column (Figure 32). Water clarity was generally good, with Secchi depth in excess of 1.5 m where plants were abundant. There was increased algal turbidity noted where plant growth was less dense.

Dissolved Oxygen Profile

GPS Location	SR9770695759
Maximum Depth (m)	1.5 m
Secchi Depth (cm)	-

Notes: Secchi depth > water depth

Depth (m)	DO (mg/l)	Temp (°C)
0	12.52	18.7
0.5	12.65	18.6
1	13.19	18.1
1.25	13.09	18

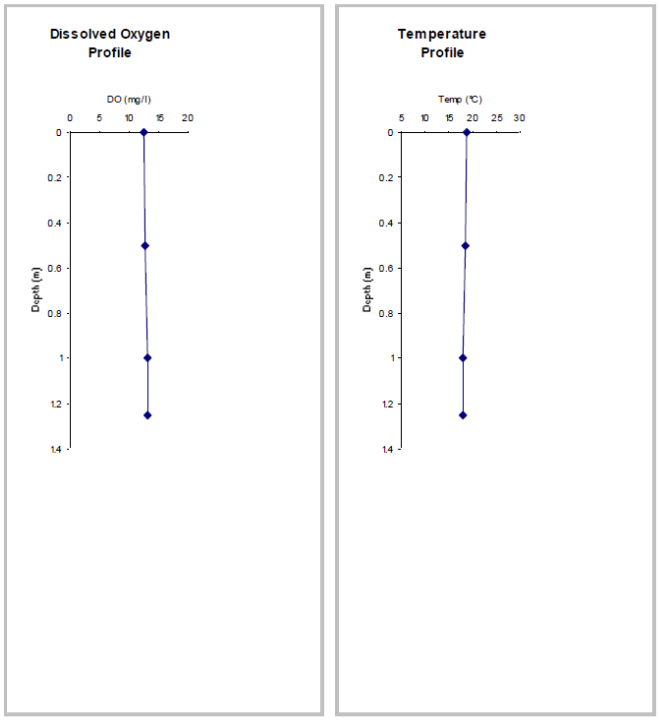


Figure 32. Dissolved oxygen and temperature profiles at Bosherston Lily Ponds – Eastern Arm (19/08/2017).

5.2.8. Bosherston Lily Ponds – Central Arm

See Figure 28 above for site map and aerial photo.

Figure 33. Bosherston Lily Ponds – Central Arm site and catchment photo; from the southeast shore, looking northwest.

Bosherston Lily Ponds – Central Arm is the smallest of the three arms, formed by the damming of a narrow valley that cuts through the Carboniferous limestone. The Central Arm is approximately 800 m long, and 4,3 ha in area, with the water retained by a low stone dam, over which lies a wooden walkway.

The margins are steep-sided and wooded throughout, with many areas having dense overhanging trees including dense canopied sycamore *Acer pseudoplatanus* (e.g. Figure 33). Where shading is less, there exist narrow areas of marginal and emergent plants including; *Sparganium erectum, Phragmites australis, Bolboschoenus maritimus, Lythrum salicaria* and *Epilobium hirsutum* all common.

Submerged and floating vegetation	% cover	Submerged and floating vegetation	% cover
Chara hispida	49.3	*Persicaria amphibia*	2.9
Nymphaea alba	29.4	*Fontinalis antipyretica*	1.4
Filamentous algae	3.7	*Chara virgata*	0.7
Lemna trisulca	2.9		
Species richness			**7**
WFD LEAFPACS Result			**Good**
EQR_{LMNI}	0.728	EQR_{NFG}	1.000
EQR_{NTAXA}	1.000	EQR_{COV}	1.257
EQR_{ALG}	1.000	$EQR_{LEAFPACS}$	0.703
Confidence in Class			**94.2%**
Certainty < Good			**3.8%**
Invasive Plant Species Cover			0%
CSM Result		**Target**	**Measured**
Typical Species % Cover (Hard with Chara)		≥ 60%	67%
No. of Characteristic Species		1	1
Loss of Characteristic Species		0	0
% Samples with High Algal Cover		≤ 20%	0
Invasive Alien Species		0	0
Condition (Macrophytes Only)			**Favourable Maintained**

Table 10. CSM Survey results from Bosherston Lily Ponds – Central Arm 2017.

The aquatic macrophyte flora of Bosherston Lily Ponds – Central Arm is characterised by a marginal ring (mostly 5 – 20 m wide) of *Nymphaea alba,* with the open water dominated in its entirety by very dense growths of *Chara hispida* (Figure 34a). So dense is the *C. hispida,* that it has built up over the years to forms a deep layer of decaying and calcified stems, over which new growth perpetuates. There are no other plants within the open water and water depths can only be estimated by measuring at the outer edge of the *N. alba* zone. Where the *N. alba* forms a dense canopy layer, there are a few plants below. Within the littoral zone however, and where gaps occur in the lilies, several other species do occur (Table 10), including more open beds of *C. hispida* (Figure 34b), and *Chara virgata* recorded in shallow water (25-75 cm) in Section one. Filamentous algal growth was only very slight, with a light covering over the top of the *C. hispida* beds in Section two.

a)

b)

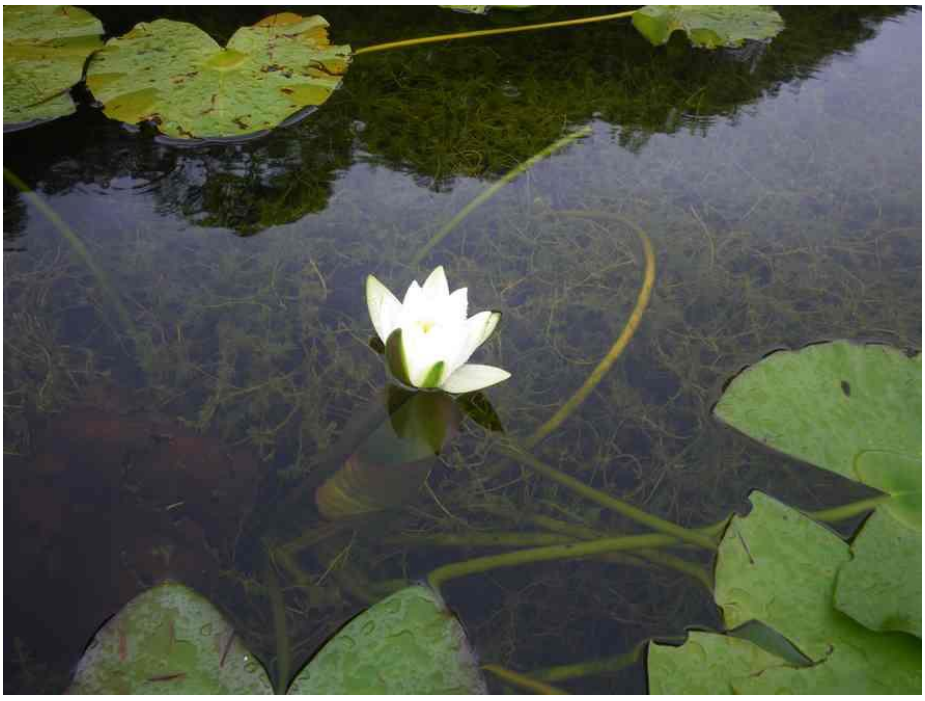


Figure 34. a) mono-specific bed of *Chara hispida* in open water (S2 @ 85 cm); b) *C. hispida* growing within open canopy area of *N. alba* (S1 @ 85 cm).

Monitoring of the aquatic flora since 1977, (Bob Haycock and George Hinton, cited in Holman *et al.* 2009), suggests the Central Arm to have remained very stable over the past 40 years, with *C. hispida* dominant in open water and *N. alba* fringing the site.

The Central Arm is very shallow (maximum during low summer level, 1.3 m) and the water very clear (Secchi depth well in excess of site depth. Being so shallow and having dense *Chara hispida* beds throughout the open water, no dissolved oxygen profile was undertaken. Surface water temperature was 18.3 °C, and DO was 13.78 mg/l.

The Leafpacs tool classified the Central Arm as being at Good Status, with confidence in class of 94.2%. This is probably a rather pessimistic view given the very clear water, high *Chara* cover and low cover of nutrient-tolerant species. Leafpacs seems to perform less accurately in marl lakes, perhaps because the LMNI metric does not take species specific cover scores into account. The Central Arm is in Favourable Condition and a classification of High seems more appropriate.

5.2.9. Bosherston Lily Ponds – Western Arm & Central Lake

See Figure 28 above for site map and aerial photo.

Figure 35. Bosherston Lily Ponds – Western Arm & Central Lake site and catchment photo; from the north looking south.

The Western Arm stretches approximately 1.35 km, mainly in a north-westerly direction from the outflow. The westerly end, characterised by steep sloping sides and within a narrow valley, differs somewhat to the more open basin at the eastern end, which receives water directly from the Central and Eastern Arms (Figure 28). In total the Western Arm is approximately 11.3 ha (measured from OS mapping), and although there is a causeway towards the western end, there is free flow beneath it, ensuring water levels remain equal on both sides (Holman *et al.* 2009).

Like the other Arms, the Western Arm lies mainly within a steep wooded valley. The exception is along the eastern shore, which is bounded by the dune formations behind Broadhaven Bay. In this region, the littoral substrates comprise of compacted sands and there is an extensive stand of emergent reeds (dominated by *Phragmites australis* and *Sparganium erectum*), backed by *Salix* spp. scrub. Around the rest of the Western arm, there is little space for marginal wetland vegetation to develop. Beds of emergent *S. erectum* are common, but mainly restricted close to shore. *Fontinalis antipyretica* was common on the exposed rocks above the waterline, and *Hydrocotyle vulgaris, Solanum dulcamara, Persicaria amphibia, Mentha aquatica, Lycopus europaeus* and *Eupatorium cannabinum* were present around much of the shore.

The aquatic flora is relatively rich, with 15 species recorded (Table 11). There is substantial differences within the site, with a more typically calcareous, *Chara hispida* dominated assemblage, co-occurring with *N. alba* towards the west end and an elodeid assemblage towards the east end. Section one is located on the north side, approximately half way along the arm. Here the littoral zone was species rich, including *Apium inundatum* (Figure 36a), *Nitella flexillis* agg., *Chara hispida* (Figure 36b), *C. virgata, N. alba, Persicaria amphibia, Elodea canadensis, Potamogeton berchtoldii,* P. crispus, *P. pectinatus, Fontinalis antipyretica,* and *Lemna trisulca*. The open water in this region was a mosaic of *C. hispida* and *N. alba* (Figure 35) dominating, with most of the above-named species occurring occasionally within. In

places, there were dense growths of gelatinous 'algal' balls (probably *Nostoc* sp., a cyanobacteria), forming around the stems of *Chara hispida* (Figure 36c).

Submerged and floating vegetation	% cover	Submerged and floating vegetation	% cover
Apium inundatum	1.0	*Nitella flexilis* agg.	2.0
Chara hispida	5.9	*Nymphaea alba*	10.3
Chara virgata	6.3	*Persicaria amphibia*	2.3
Elodea canadensis	6.0	*Potamogeton berchtoldii*	0.5
Filamentous algae	20.0	*Potamogeton crispus*	20.3
Fontinalis antipyretica	2.5	*Potamogeton pectinatus*	3.1
Lemna trisulca	2.1	*Sparganium emersum*	2.0
Myriophyllum spicatum	15.6	*Zannichellia palustris*	0.04
Species richness			**16**
WFD LEAFPACS Result			**Good**
EQR_{LMNI}	0.728	EQR_{NFG}	1.000
EQR_{NTAXA}	1.000	EQR_{COV}	0.847
EQR_{ALG}	0.842	$EQR_{LEAFPACS}$	0.728
Confidence in Class			**93.7%**
Certainty < Good			**5.3%**
Invasive Plant Species Cover			6.0%

CSM Result	Target	Measured
Typical Species % Cover	≥ 60%	19.4
No. of Characteristic Species	1	1
Loss of Characteristic Species	0	0
% Samples with High Algal Cover	≤ 20%	6%
Invasive Alien Species	0	1
Condition (Macrophytes Only)		**Unfavourable Maintained**

Table 11. CSM Survey results from Bosherston Lily Ponds – Western Arm & Central Lake 2017

a) b) c)

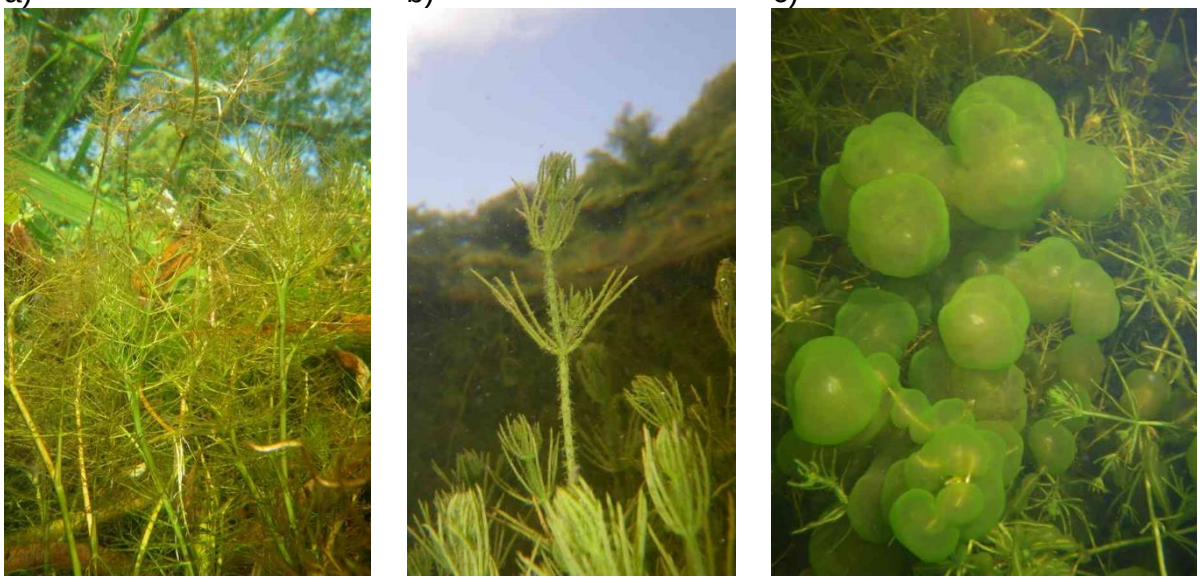


Figure 36. a) *Apium inundatum* (S1 @ 50 cm); b) *C. hispida* growing within open canopy area of *N. alba* (S1 @ 120 cm); c) 'algal' balls (*Nostoc* sp.) on *Chara* stems (S1 @ 120 cm).

Section two, located on the south shore, towards the central basin, had very little marginal vegetation; the littoral zone sloping steeply into the lake. This area is transitional in terms of the aquatic vegetation. Patches of *N. alba* remain and *C. hispida* occurred, but was no longer constant, and instead was replaced by *Potamogeton crispus* as dominant, with *M. spicatum, Nitella flexilis* agg. and *Sparganium emersum* (Figure 37a) also recorded out into open water. The growths of *P. crispus,* consisted almost entirely of young plants, rarely more than 20 cm high (Figure 37b).

Sections three and four are located within the central basin. Here the marginal zone is dominated by emergent vegetation, *Sparganium erectum* in S3 and *Phragmites australis* with *S. erectum* in S4 along the dune shore. Except for occasional plants within the reed beds, *Nymphaea alba* was absent from the central basin. Generally, the water here was more turbid, and the submerged flora heavily encrusted with algae and carbonate or carbonate rich silt (Figure 37c). *Elodea canadensis* was locally abundant, particularly at the reed face in Section three, with the open water was dominated by *P. crispus, Chara virgata* and *M. spicatum.* The sandy substrates. *Chara hispida*, was rare within the central basin.

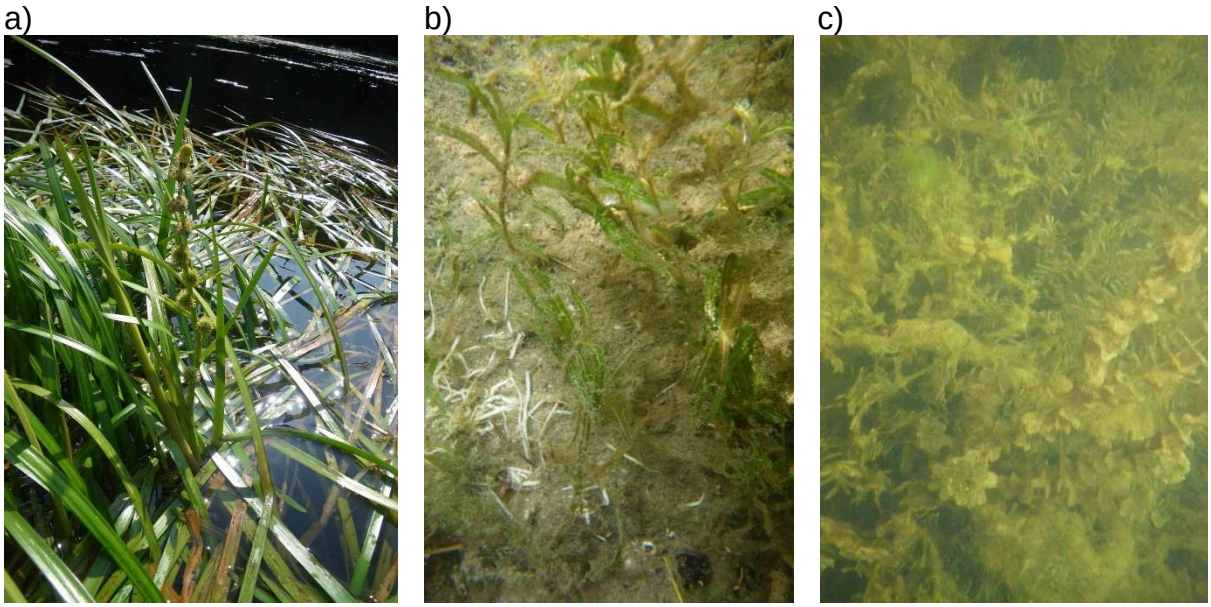


Figure 37. a) *Sparganium emersum* (S2 @ 140 cm); b) *Potamogeton crispus* (S2 @ 130 cm); c) *P. crispus* and *M. spicatum* showing silty encrustations (S4 @ 115 cm).

The aquatic macrophyte flora of Western Arm & Central Lake has undergone significant change over the past decades, with major declines in the abundance of *Chara* species, and particularly *C, hispida,* in the mid 1980s (see Holman *et al.* 2009). Recovery has been quicker in the upper areas of the Western Arm, where *C. hispida* is once again abundant, but the central basin remains relatively poor, and mostly without *C. hispida.* The decline in *Chara* spp. is further evidenced from the palaeoecological record, which showed a decline in *Chara* spp. oospores from very high concentration prior to 1930s (indicative of *Chara* lawns), to low abundance at the sediment surface (Davidson *et al*. 2002).

The Leafpacs result for the Western Arm and Central Lake produces a classification of Good Status with confidence in class of 93.7%. This does not reflect the overall status of the lake which is probably better classed as just below the Good/Moderate boundary, reflecting the low *Chara* cover and relatively high abundance of more nutrient-tolerant species such as filamentous algae and fine-leaved pondweeds.

The site is very shallow throughout and relatively exposed at the eastern end. The water was well oxygenated throughout the water column (Figure 38). Water clarity was very high where *Chara hispida* and *N. alba* were abundant in the upper reached of the Western Arm, but less so in the central basin.

Dissolved Oxygen Profile

GPS Location	SR9756794548
Maximum Depth (m)	1.6 m
Secchi Depth (cm)	-

Notes: Secchi greater than site, but water slightly turbid.

Depth (m)	DO (mg/l)	Temp (°C)
0	8.94	17.1
0.5	8.75	17.1
1	8.58	17.1
1.5	8.52	17.1

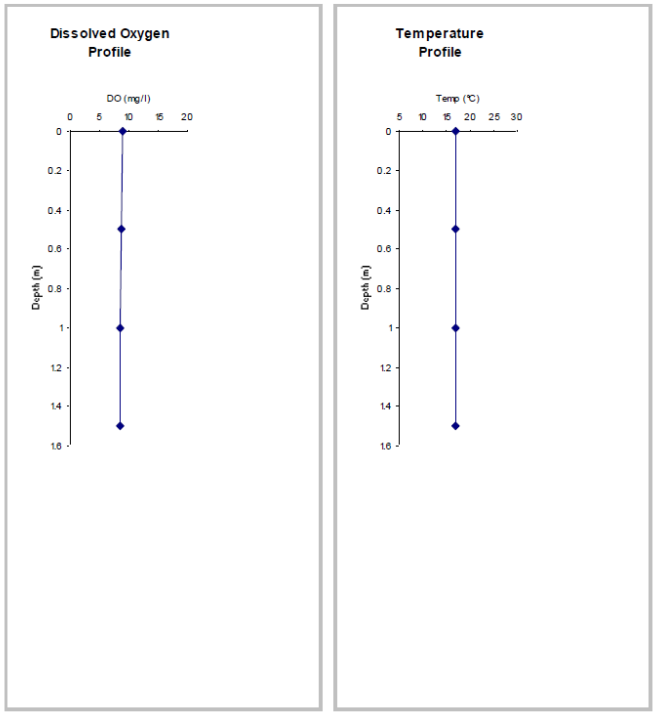


Figure 38. Dissolved oxygen and temperature profiles at Bosherston Lily Ponds – Western Arm (taken in central basin) (20/08/2017).

5.2.10. Llyn Penrhyn

Contains OS data © Crown copyright (2017) *© Bing Maps (2017)*

Figure 39. Site map and aerial photograph of Llyn Penrhyn.

Figure 40. Llyn Penrhyn site photo; from the south looking north-west.

Llyn Penrhyn is a moderate sized (22 ha), shallow (max. depth 2.7 m), high alkalinity, low altitude lake located in the isle of Anglesey, Wales. It forms part of the designated Llynnau y Fali -Valley Lakes SSSI and the Valley Wetlands RSPB reserve. The catchment is largely a mixture of acid, neutral and improved grassland with some areas of development, specifically the RAF Valley airbase. The airbase sewage treatment works discharge into the lake and high phosphorus levels have been a problem at the site for a considerable period (Bennion, 1995; Hatton-Ellis, 2016).

The margins of Llyn Penrhyn are fringed by extensive areas of *Phragmites australis* reed beds, with *Scheonoplectus lacustris* and *Typha latifolia* also frequent. All the margins are relatively species-rich but there is a particularly diverse area at the south of the site where scrapes have been made in the reed-beds for the benefit of birdlife. Survey Section three covers this area and was the only section containing *Ranunculus lingua*, *Rumex hydrolapathum, Equisetum fluviatile, Caltha palustris, Hydrocotyle vulgaris, Alisma plantago-aquatica, Veronica beccabunga, Potentilla palustris and Ranunculus flammula,* some of which have been recorded very

infrequently, or not at all, in previous surveys (Lansdown 2013). There are also beds of water lilies, particularly *Nymphaea alba*, in more sheltered areas at the west of the lake.

The submerged aquatic flora (Table 12) extends from the reedbeds to a maximum depth of 2.5 m, but is not continuous across the available lake bed habitat. The open water is dominated by *Ceratophyllum demersum* in conjunction with smaller amounts of *Elodea canadensis* and *Lemna trisulca*. Interspersed amongst these are *Callitriche truncata*, *Chara virgata*, *C. globularis, Potamogeton pectinatus*, *P. perfoliatus, P. pusillus* and *Myriophyllum spicatum*. *Elatine hydropiper* is not uncommon in the slightly shallower areas between 1.0 m and 1.7 m in the main body of the lake.

Lansdown (2013) collated the results from several recent and historic macrophyte surveys at Llyn Penryn, charting the progress of eutrophication at the site and the subsequent losses of species and changes in the assemblage. The species list in the 2017 survey is similar to that in both Lansdown's of 2012 and the two most recent Common Standards Monitoring surveys from 2013 and 2015*. Myriophyllum spicatum* was, however, unusual in its occurrence and notably *Zannichellia palustris* was not located in the most recent site visit*. Potamogeton lucens*, found in a western bay by Lansdowne in 2012 was searched for but not re-found on the current survey. Similarly, *Eleocharis acicularis* was not located in 2017.

The current aquatic macrophyte assemblage 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. This is due to only four out of the required six characteristic species being present: *Callitriche truncata*, *Chara globularis*, *C. virgata* and *Potamogeton perfoliatus*. Filamentous algae is present at moderate levels. Two alien invasive macrophyte species, *Elodea canadensis and Lemna minuta*, were recorded during the 2017 survey.

Submerged and floating vegetation	% cover	Submerged and floating vegetation	% cover
Callitriche truncata	**2.5**	*Lemna trisulca*	9.5
Ceratophyllum demersum	14.1	*Menyanthes trifoliata*	1.7
Chara globularis	**1.2**	*Myriophyllum spicatum*	3.0
Chara virgata	**3.0**	*Nuphar lutea*	0.9
Elatine hydropiper	3.4	*Nymphaea alba*	4.0
Elodea canadensis	8.5	*Persicaria amphibia*	1.7
Filamentous algae	18.5	*Potamogeton pectinatus*	3.6
Hydrodictyon reticulatum	0.02	***Potamogeton perfoliatus***	**3.8**
Lemna minor	4.0	*Potamogeton pusillus*	5.3
Lemna minuta	0.8	*Ranunculus lingua*	0.7
Species richness			**20**
WFD LEAFPACS Result			**Moderate**
EQR_{LMNI}	0.566	EQR_{NFG}	1.616
EQR_{NTAXA}	1.746	EQR_{COV}	0.742
EQR_{ALG}	0.837	$EQR_{LEAFPACS}$	0.566
Confidence in Class			**77%**
Certainty < Good			**94.1%**
Invasive Plant Species Cover			9.3%
CSM Result		**Target**	**Measured**
Typical Species % Cover (Magnopotamion)		≥ 60%	28.2
No. of Characteristic Species		6 (inc 1 Magno.)	4 (inc. 1)
Loss of Characteristic Species		0	1
% Samples with High Algal Cover		≤ 20%	20.2
Invasive Alien Species		0	2
Condition (Macrophytes Only)			**Unfavourable Maintained**

Table 12. CSM Survey results from Llyn Penrhyn 2017.

The Leafpacs classification tool gave a classification of Moderate status, with confidence in class of 77% and a certainty that the lake is worse than Good of 94.1%. This is primarily driven by the LMNI metric and is considered to be an accurate assessment of the current status of Llyn Penrhyn based on the plant community, since there is a good diversity of aquatic plants but the majority of these are nutrient-tolerant species. The classification result is similar to surveys from 2015 and 2013.

Dissolved oxygen and temperature profiles showed the lake to be isothermal at the time of the 2017 survey with no thermocline evident and only a slight decline in dissolved oxygen and temperature towards the bottom of the profile (Figure 41). The Secchi depth was 0.56 m on 20/08/17.

Dissolved Oxygen Profile

GPS Location	SH3136276774
Maximum Depth (m)	2.6 m
Secchi Depth (cm)	0.56 cm

Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	9.53	17
0.5	9.55	16.9
1	9.32	16.8
1.5	9.37	16.7
2	8.87	16.6
2.3	8.35	16.5

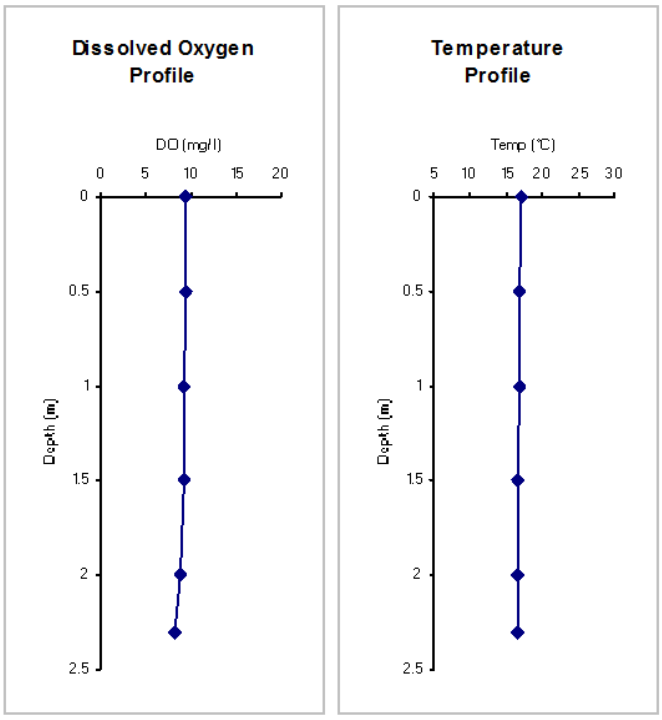
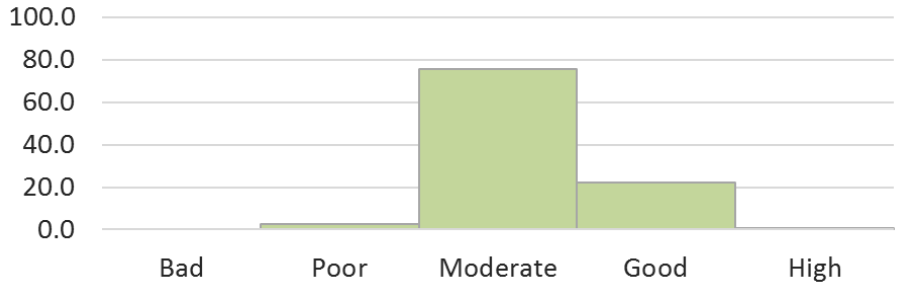
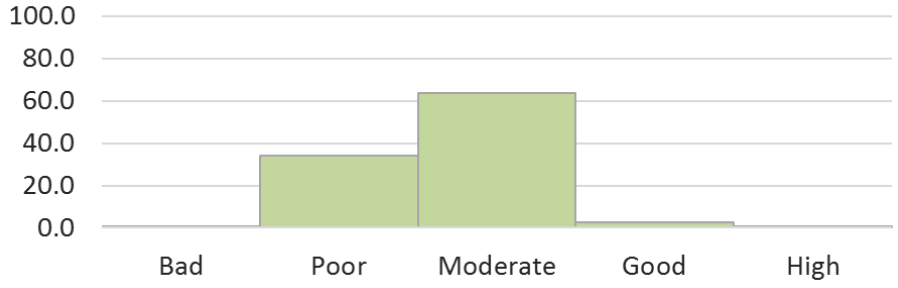


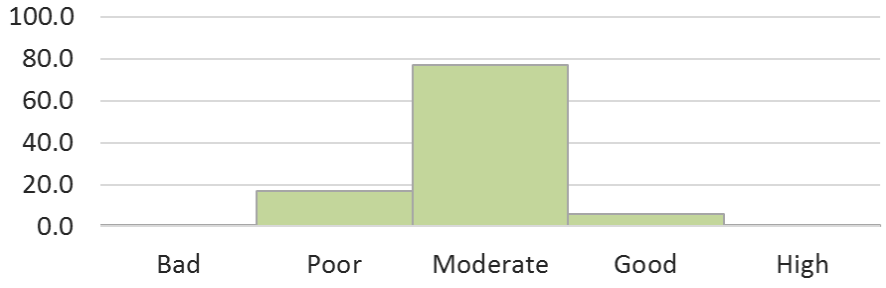
Figure 41. Dissolved oxygen and temperature profiles at Llyn Penrhyn (20/08/2017).



(a) 2013



(b) 2015



(c) 2017

Figure 42. Leafpacs confidence in class for Llyn Penrhyn, 2013-2017.

5.2.11. Llyn Llywenan

Contains OS data © Crown copyright (2017) *© Bing Maps (2017)*

Figure 43. Site map and aerial photograph of Llyn Llywenan.

Figure 44. Llyn Llywenan site photo; from the west shore looking north-east.

Llyn Llywenan is a small (39 ha), very shallow (max. depth 1.5 m) medium alkalinity, low altitude lake located in the Isle of Anglesey, Wales. It forms the Llyn Llywenan SSSI. The relatively small catchment is dominated by agriculture, consisting largely of improved and calcareous grassland with some arable and patches of woodland.

There are extensive areas of reed-swamp in the west and south east of the lake. An especially rich emergent flora was found in the reed-swamp corner at the start of Section three, but these areas were not covered in detail by the current survey which concentrated on the submerged flora. A fourth fixed survey section at the north east of the site was added to the three historic sections.

The aquatic macrophyte flora is rather species-poor and dominated by the alien invasive taxon *Elodea canadensis* (Table 13). It is abundant throughout the lake in all survey sections and grows down to the maximum recorded site depth of 1.5 m. *Potamogeton pusillus* grows in association with the *Elodea* in many areas, though in lower abundances. *Elatine hydropiper* occurs in shallower water and was found in the strandline of all four survey sections. *Eleocharis acicularis* was present at small amounts in the strandline of three sections, but was only found rooted at one sampling point on Section one and one point on Section three. Single specimens each of *Callitriche stagnalis* and *Ranunculus aquatilis* agg. were recorded.

The authors performed a survey at the site in 2007 (Burgess *et al*, 2009). Whilst the results from the 2017 survey are broadly similar, *Littorella uniflora* and *Nitella flexilis* agg. were not located and abundances of *Eleocharis acicularis* have declined. Effort was made outside the survey sections to locate *Isoetes echinospora*, one of the species listed on the SSSI citation, but none was recovered.

Hosting none of the required species considered characteristic of this lake type, the current species assemblage at Llyn Llywenan would place the site in unfavourable condition with respect to its flora under JNCC CSM Guidelines for mesotrophic lakes (JNCC 2015). There were low amounts of filamentous algae in most survey sections but very large amounts of the invasive species *Elodea canadensis*.

Submerged and floating vegetation	% cover	Submerged and floating vegetation	% cover
Butomus umbellatus	0.8	*Lemna minor*	5.7
Callitriche stagnalis	0.9	*Menyanthes trifoliata*	1.6
Elatine hydropiper	4.0	*Nuphar lutea*	0.7
Eleocharis acicularis	2.3	*Persicaria amphibia*	2.5
Elodea canadensis	41.3	*Potamogeton pusillus*	13.7
Filamentous algae	8.0	*Ranunculus aquatilis* agg.	0.1
Hydrodictyon reticulatum	0.5		
Species richness			**13**
WFD LEAFPACS Result			**Moderate**
EQR_{LMNI}	0.511	EQR_{NFG}	1.687
EQR_{NTAXA}	1.270	EQR_{COV}	0.878
EQR_{ALG}	0.944	$EQR_{LEAFPACS}$	0.511
Confidence in Class			**49.5%**
Certainty < Good			**98.7%**
Invasive Plant Species Cover			**41.3%**
Invasive Plant Species Cover			41.3%
CSM Result		**Target**	**Measured**
Typical Species % Cover (High Alkalinity)		≥ 60%	0
No. of Characteristic Species		6	0
Loss of Characteristic Species		0	2
% Samples with High Algal Cover		≤ 20%	11.8
Invasive Alien Species		0	1
Condition (Macrophytes Only)			**Unfavourable Declining**

Table 13. CSM Survey results from Llyn Llywenan 2017.

Leafpacs data classified Llyn Llywenan as Moderate, though the confidence in class data indicate that it is very close to the Moderate/Poor boundary. This conclusion is in line with the observed survey results and indicates a significant nutrient pressure.

Dissolved oxygen and temperature profiles showed the lake to be mixed during the survey period with stable temperature and DO values down through the water column (Figure 45). Oxygen levels were very low at the lake water/sediment boundary. The Secchi depth was recorded as being 1.03 m on 21/08/17.

Dissolved Oxygen Profile

GPS Location	SH3480781608
Maximum Depth (m)	1.5 m
Secchi Depth (cm)	1.03 cm

Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	8.53	16.2
0.5	8.96	16.2
1	8.7	16.1
1.5	0.34	16

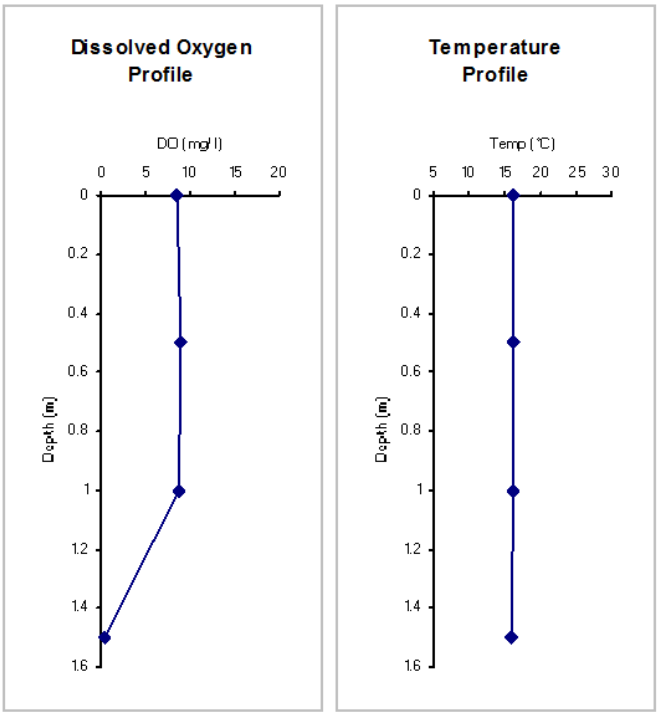


Figure 45. Dissolved oxygen and temperature profiles at Llyn Llywenan (21/08/2017).

5.2.12. Llangorse Lake

Contains OS data © Crown copyright (2017) *© Bing Maps (2017)*

Figure 46. Site map and aerial photograph of Llangorse Lake.

Figure 47. Llangorse Lake site photo; from the south-west shore, looking north-east towards Mynydd Troed.

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 was turbid at the time of the survey and conditions were poor for underwater photography.

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).

Submerged and floating vegetation	% cover	Submerged and floating vegetation	% cover
Butomus umbellatus	2.1	*Nuphar lutea*	5.1
Ceratophyllum demersum	7.7	*Nymphaea alba*	0.9
Chara globularis	**6.2**	*Nymphoides peltata*	4.1
Eleocharis acicularis	0.3	*Persicaria amphibia*	2.7
Elodea canadensis	8.6	***Potamogeton lucens***	**3.1**
Elodea nuttallii	20.8	*Potamogeton pectinatus*	0.2
Filamentous algae	5.4	***Potamogeton perfoliatus***	**0.1**
Lemna minor	4.0	*Potamogeton pusillus*	0.1
Lemna trisulca	8.7	***Ranunculus circinatus***	**0.05**
Menyanthes trifoliata	1.9	*Ranunculus lingua*	2.0
Myriophyllum spicatum	6.6	*Sparganium emersum*	0.5
Nitellopsis obtusa	2.8	***Spirodela polyrhiza***	**4.2**
Species richness			**24**
WFD LEAFPACS Result			**Moderate**
EQR_{LMNI}	0.611	EQR_{NFG}	1.487
EQR_{NTAXA}	1.996	EQR_{COV}	0.706
EQR_{ALG}	0.994	$EQR_{LEAFPACS}$	0.611
Confidence in Class			**77.8%**
Certainty < Good			**81.4%**
Invasive Plant Species Cover			29.4
CSM Result		**Target**	**Measured**
Typical Species % Cover (Magnopotamion)		≥ 60%	51.4%
No. of Characteristic Species		6	5
Loss of Characteristic Species		0	0
% Samples with High Algal Cover		≤20%	4.2
Invasive Alien Species		0	2
Condition (Macrophytes Only)			**Unfavourable Recovering**

Table 14. CSM Survey results from Llangorse Lake in 2017.

The aquatic vegetation was species rich (24 species, Table 14) 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. Shining pondweed *Potamogeton lucens* was locally common within the site, often occurring in the more sheltered areas within sparse reed beds or lily beds (Figure 48a). *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.*

The open water was dominated throughout most of the lake by dense growths of *Elodea nuttallii* (Figure 48b), which reached a maximum depth of 2.9 m. Within the *E. nuttallii, Chara globularis* was often present at low abundance (also to a max. depth of 2.9 m) and *Myriophyllum spicatum and Ceratophyllum demersum* also common. *Elodea canadensis* co-occurred with *E. nuttallii,* but was rarely as abundant and seldom found deeper than 2.0 m. *Nitellopsis obtusa* (Figure 48c) was recorded from four of the six sections at depths ranging from 1.0 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). 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.

a) b) c)

Figure 48. a) *Potamogeton lucens* growing under lilies (S1 @ >75 cm); b) Dense growths of *E. nuttallii* in open water with *M. spicatum* (S3 @ 160 cm); c) *Nitellopsis obtusa* (S6 @ 190 cm).

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 the 1970s, the result of sewage pollution.

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

While the species assemblage remains broadly similar to recent surveys, the current data suggest there to be an ongoing decline of the characteristic eutrophic species, *Potamogeton perfoliatus.* This species was recorded in only three sample points (<2% frequency) in 2017, compared to seven (5.5%) in 2015 (Goldsmith *et al*. 2016) and fifteen sample points (12.5%) in 2003 (Goldsmith *et al.* 2004). Monteith *et al.* (1996) recorded it as “frequent” and previous surveys having described it as having intermediate abundance (ICLE, 1993).

The Leafpacs classification placed Llangorse Lake as Moderate status with high confidence, and with the lowest EQR for macrophytes since 2007 (Figure 45). It is not clear if this represents a genuine decline or a short-term fluctuation.

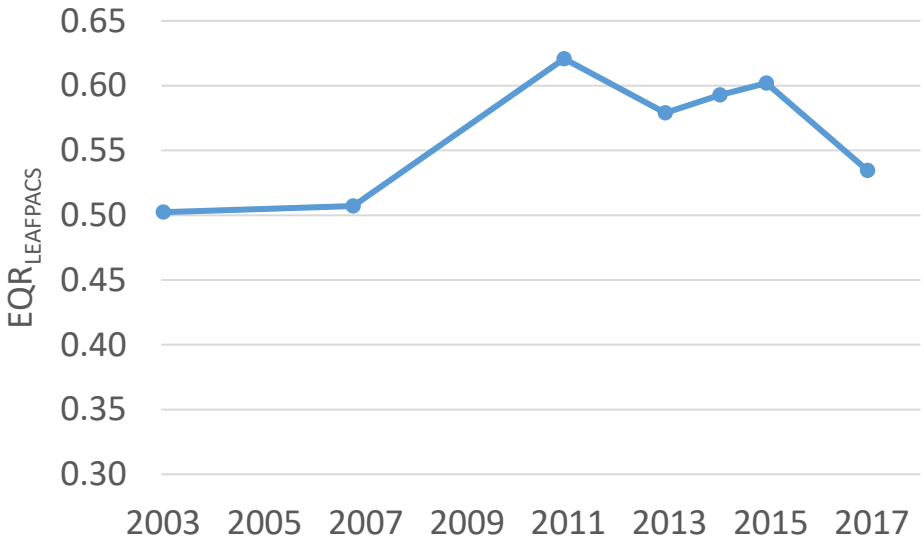
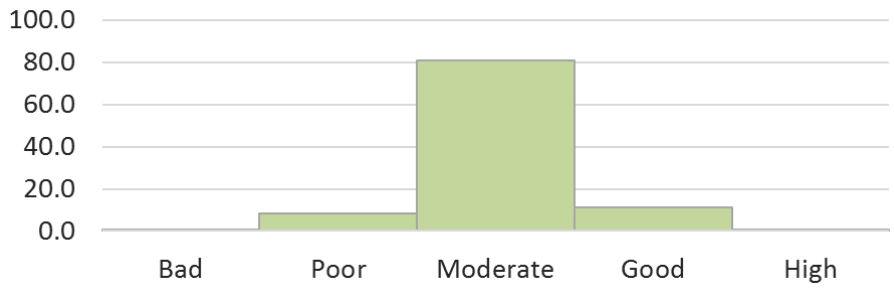
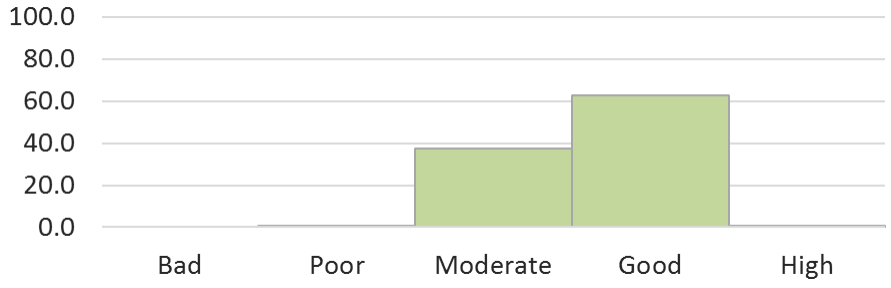


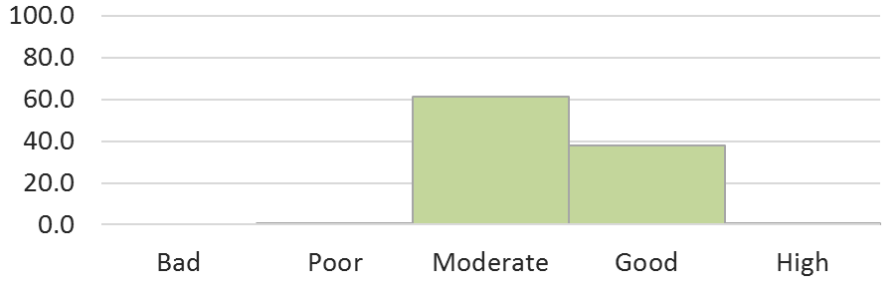
Figure 49. Change in Leafpacs EQR in Llangorse Lake, 2003-2017. Higher EQRs indicate better quality.



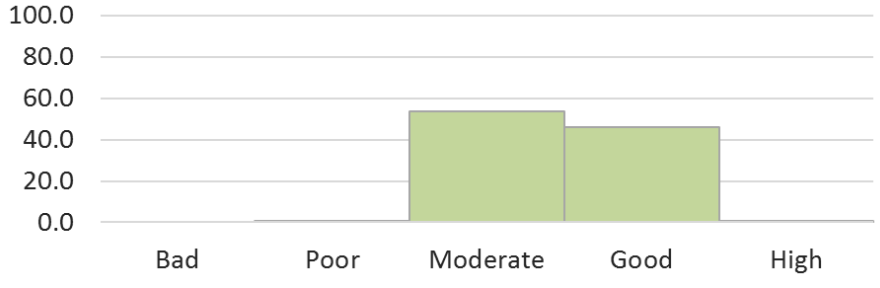
(a) 2007



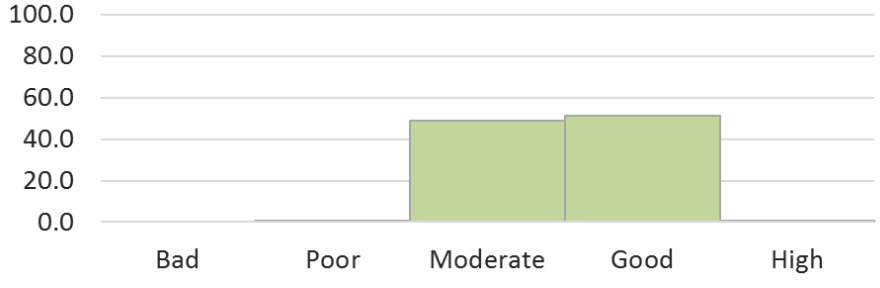
(b) 2011



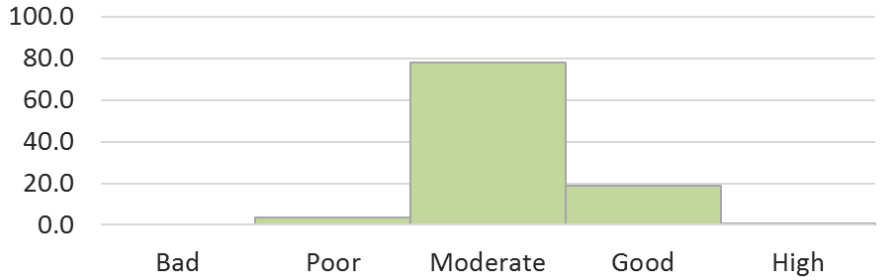
(c) 2013



(d) 2014



(e) 2015



(f) 2017

Figure 50. Leafpacs confidence in class results for Llangorse Lake, 2007-2017.

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 51).

Dissolved Oxygen Profile

GPS Location	SO1330426659
Maximum Depth (m)	7.5 m
Secchi Depth (cm)	140 cm
Notes:	

Depth (m)	DO (mg/l)	Temp (°C)
0	10.24	17.9
0.5	10.24	17.9
1	10.09	17.8
1.5	10.03	17.8
2	9.71	17.7
2.5	8.84	17
3	8.46	17
3.5	8.4	17
4	8.33	16.9
4.5	8.18	16.9
5	8.1	16.9
5.5	6.69	16.8
6	6.08	16.8
7	6.42	16.8

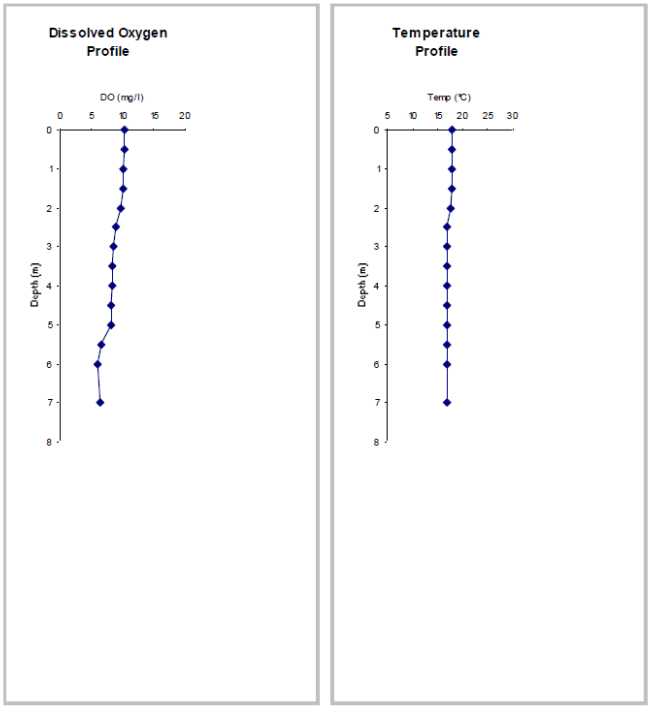
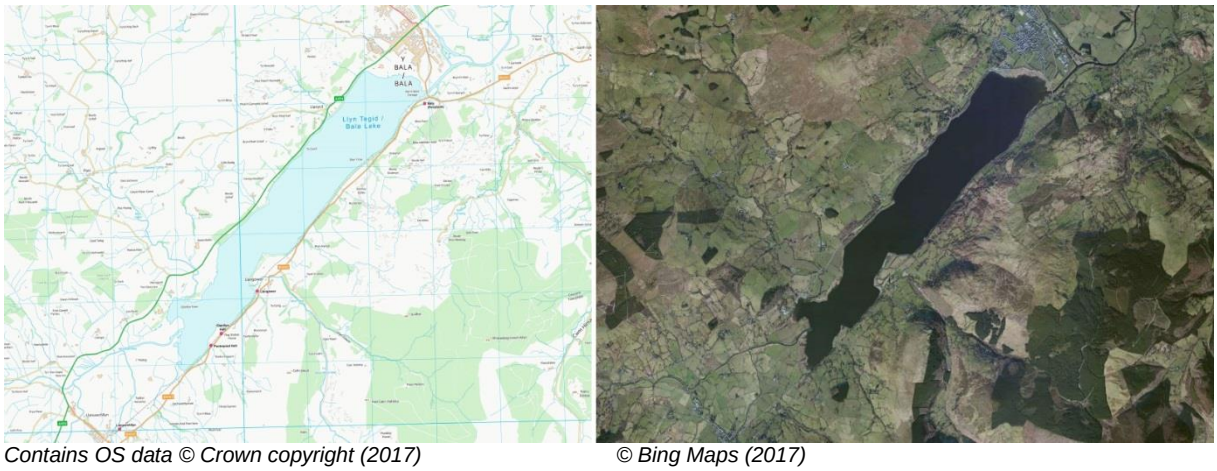


Figure 51. Dissolved oxygen and temperature profiles at Llangorse Lake (21/08/2017).

5.2.13. Llyn Tegid / Bala Lake



Contains OS data © Crown copyright (2017) *© Bing Maps (2017)*

Figure 52. Site map and aerial photograph of Llyn Tegid.

Figure 53. Llyn Tegid site photo; from the south-east looking north-west.

At 415 ha in area, Llyn Tegid is the largest lake in Wales It is a deep (max. depth 43.0 m), low alkalinity, lowland lake located in Gwynedd, North Wales. It is designated as the Llyn Tegid SSSI and Ramsar site, and the River Dee and Bala Lake / Afon Dyfrdwy a Llyn Tegid SAC.

The large catchment includes much upland moorland but also notable amounts of coniferous plantation woodland and agricultural grassland The A494 runs along the northern side of the site, the B4403 along the southern side and the town of Bala is at the north eastern (outflow) end. Water levels can fluctuate when the lake is used as part of the River Dee regulation scheme and it is used extensively for water sports and recreation. There have been historic concerns at the site with respect to eutrophication, potential deoxygenation of the hypolimnion and algal blooms (Hatton-Ellis, 2016). Llyn Tegid is a WFD surveillance site and hosts populations of the unique gwyniad fish (*Coregonus lavaretus*), the only known UK population of glutinous snail (*Myxas glutinosa*) and the rare floating water-plantain (*Luronium natans*).

Much of the shoreline in the central part of the lake is poor in aquatic plants and the majority of the macrophyte diversity and abundance is concentrated in the more gently shelving, more sheltred areas at the north east and south west ends of the site (Table 15). Sections three, six, seven and eight are in the exposed central area and are characterised by *Phalaris arundinacea* and *Oenanthe crocata* at the water's edge. A substrate of cobbles and boulders hosts few aquatic plants (Figure 54a), with the exception of some *Fontinalis antipyretica* and very sporadic *Isoetes lacustris* in deeper water.

a) b)

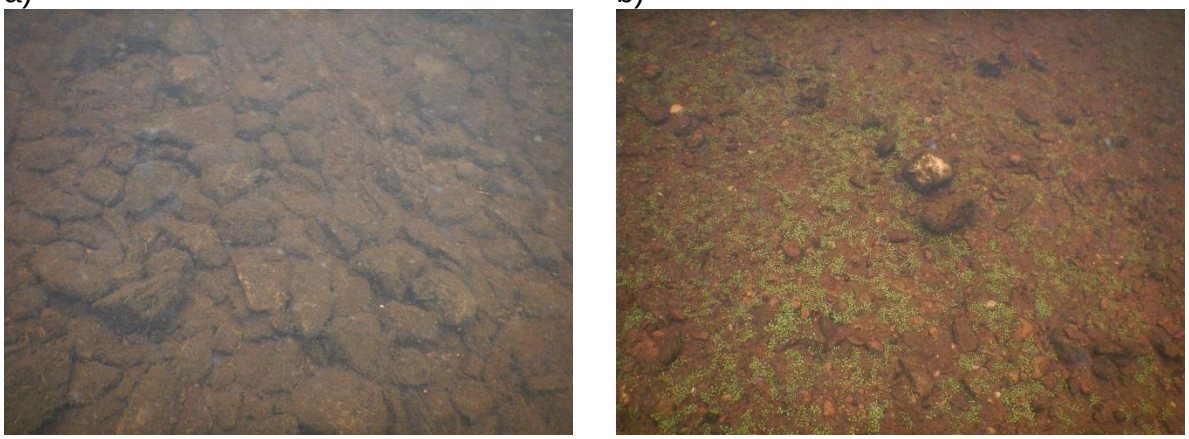


Figure 54. a) Macrophyte-poor substrates characteristic of lake edges, and b) shallow area in south west of lake (S1 @ 50 cm).

The submerged aquatic macrophyte flora at the southern end of the lake, in Section one, shows a distinctive depth pattern, which may reflect changes in water level at the site. *Littorella uniflora*, *Callitriche brutia* var. *hamulata* and *Elatine hexandra* dominate the shallows (Figure 54b). In slightly deeper water they are joined by *Eleocharis acicularis* and *Nitella flexilis* agg. At around 75 cm depth *Isoetes lacustris* appears and at approximately 1.0 m depth *Elodea nuttallii* and *Luronium natans* occur, with macrophytes continuing to a maximum depth of 1.8 m. The assemblage in the bay containing Section two exhibited a very similar composition and zonation, although *Eleocharis acicularis* was absent. Sections one and two at the south of the lake were the only sections containing *Luronium natans* in the 2017 survey.

At the north end of Llyn Tegid the littoral zone is very gently shelving and thus relatively extensive. Macrophyte colonisation is patchy in shallower areas however, perhaps due to exposure. In the deeper areas *Isoetes lacustris* is abundant, completely dominating between 1.1 m and a maximum depth of 1.8 m. Sporadic *Elatine hexandra* grows from 1.1 m to around 50 cm and *Littorella uniflora* between 75 cm and 50 cm. The shoreline shallows are a complex pattern of *Phalaris arundinacea* and small submerged specimens of *Callitriche brutia* var. *hamulata.* In areas sheltered by the *Phalaris* some species not found elsewhere in the survey occur at low abundances*: Potamogeton berchtoldii, Potamogeton natans, Juncus bulbosus* and *Ranunculus aquatilis* agg.

The species recorded on this survey and their relative abundances are very similar to Common Standards Monitoring surveys performed at the site by the authors in 2011 and 2008. In particular there appears to be little change in the abundance and

distribution of *Luronium natans* at the southern end of the lake, though *L. natans* was also found in Section five in 2011. *Limosella aquatic*a was not located in 2017 but this may have been due to water levels being higher than those during the 2011 and 2008 surveys. Also absent were *Nitella translucens* and *Sparganium emersum*, located in the site by Monteith (1997).

Isoetes specimens were confirmed as *I. lacustris* by microscopic examination of megaspores.

The current species assemblage, including five out of a required eight target species for mesotrophic lakes, would place the site in unfavourable condition with respect to its flora under JNCC CSM Guidelines (JNCC 2015). This result is important, as Llyn Tegid constitutes 70% of the area of the mesotrophic lake type in Wales (Hatton-Ellis, 2014). Filamentous algae was ubiquitous during the 2017 survey although levels were slightly lower in Sections one and two at the south western end of the site. One alien invasive species, *Elodea nuttallii*, was recorded.

Submerged and floating vegetation	**% cover**	**Submerged and floating vegetation**	**% cover**
Callitriche brutia var. *hamulata*	4.3	*Juncus bulbosus*	0.01
Elatine hexandra	**3.3**	***Littorella uniflora***	**3.0**
Eleocharis acicularis	0.7	***Luronium natans***	**1.0**
Elodea nuttallii	1.1	***Nitella flexilis* agg.**	**1.8**
Filamentous algae	12.4	*Potamogeton berchtoldii*	0.4
Fontinalis antipyretica	2.7	*Potamogeton natans*	0.05
Isoetes lacustris	**6.4**	*Ranunculus aquatilis* agg.	0.4
Species richness			**14**
WFD LEAFPACS Classification			**Moderate**
EQR_{LMNI}	0.432	EQR_{NFG}	1.306
EQR_{NTAXA}	1.187	EQR_{COV}	0.578
EQR_{ALG}	0.633	$EQR_{LEAFPACS}$	0.303
Confidence in Class			**74.3%**
Certainty < Good			**99.8%**
Invasive Plant Species Cover			1.1
CSM Result		**Target**	**Measured**
Typical Species % Cover (Oligotrophic)		≥60%	82.7
No. of Characteristic Species		≥4 (inc 3 Littorelletea)	4 (2 Littorelletea)
Loss of Characteristic Species		0	0
% Samples with High Algal Cover		≤20%	0
Invasive Alien Species		0	1
			Unfavourable Maintained

Table 15. CSM Survey results from Llyn Tegid 2017.

Dissolved oxygen and temperature profiles show the lake to be weakly stratified at the time of sampling with the main recorded boundary in temperature and oxygen occurring between 15 m and 17.5 m, below which temperatures fall to 10.4 ºC and oxygen to 4.94 mg/l by 30 m (Figure 55). This is in line with previous monitoring results for the lake. Unfortunately the available probe had a 30 m cable and it was

not possible to measure the bottom 10 m of the profile. The Secchi depth was 2.3 m on 22/08/17.

Dissolved Oxygen Profile

GPS Location	SH9051833213
Maximum Depth (m)	40.8 m
Secchi Depth (cm)	2.3 cm

Notes: Meter cable only 30m long

Depth (m)	DO (mg/l)	Temp (°C)
0	9.56	16.6
0.5	9.59	16.4
1	9.6	16.3
1.5	9.57	16.2
2	9.53	16.1
3	9.49	16
4	9.38	15.8
5	9.3	15.7
6	9.22	15.6
7	9.17	15.6
8	8.87	15.5
9	8.86	15.4
10	8.61	15.2
12.5	8.68	14.9
15	8.01	14.1
17.5	6.78	13
20	5.99	11.7
22.5	5.65	11.1
25	5.32	10.7
27.5	5.05	10.5
30	4.94	10.4

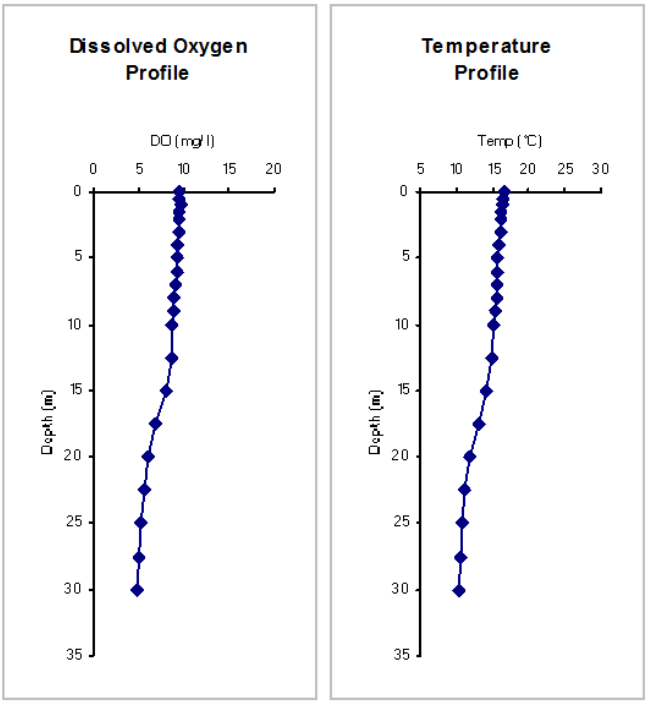
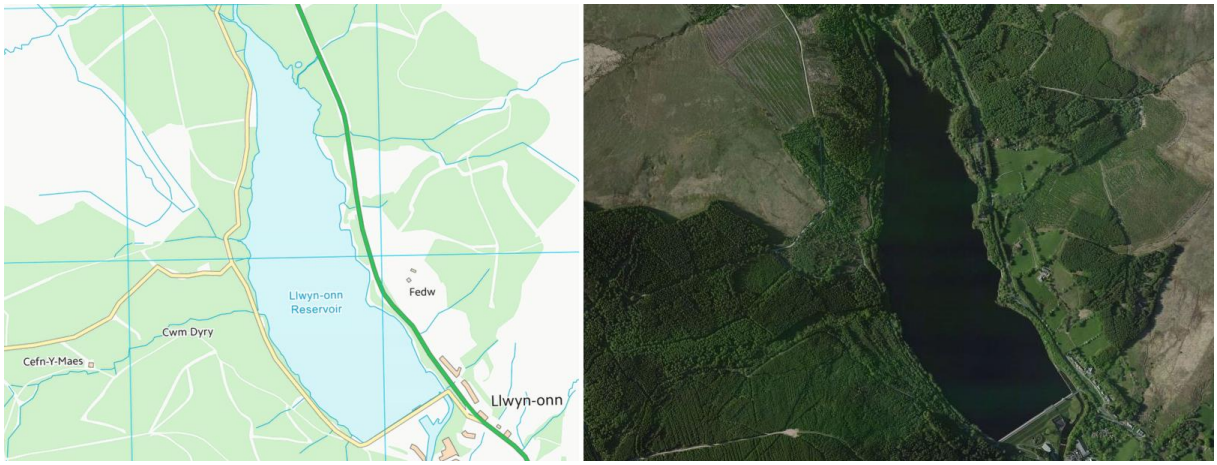


Figure 55. Dissolved oxygen and temperature profiles at Llyn Tegid/Lake Bala (22/08/2017).

5.2.14. Llwyn-On Reservoir



Contains OS data © Crown copyright (2017) *© Bing Maps (2017)*

Figure 56. Site map and aerial photograph of Llwyn-On Reservoir.

Figure 57. Llwyn-On Reservoir site photo; from the south-east shore looking north-west.

Llwyn-On Reservoir is an artificial waterbody, situated above Merthyr Tydfil at an altitude of 260 m A.O.D. The reservoir is 54 ha in area, with a maximum recorded depth of 22 m and mean depth of 9.4 m (CEH 2018). The reservoir lies within the Taff Fawr valley in South Wales, is owned and managed by Welsh Water and located within the Brecon Beacons National Park. The catchment (4388 ha) is predominantly unimproved upland acid and wet grassland, with 16% of the catchment area currently under coniferous plantation (Hatton-Ellis 2016). As a result, the water is of moderate alkalinity, and visibly brown in colour, due to elevated humic content. Mean total phosphorus and total nitrogen is relatively low (2009-2014, 16.3 μgl^{-1} and 0.5 mgl^{-1} respectively, Hatton-Ellis, 2016). Llwyn-on is and active water supply reservoir, and as such is subject to periods of significant draw-down.

Submerged and floating vegetation			% cover
Littorella uniflora			**18.8**
Persicaria amphibia			5.3
Fontinalis antipyretica			5.1
Callitriche brutia var. *hamulata*			4.6
Lythrum portula			4.5
Species richness			5
WFD LEAFPACS Classification			**Moderate**
EQR_{LMNI}	0.641	EQR_{NFG}	0.624
EQR_{NTAXA}	0.397	EQR_{COV}	0.966
EQR_{ALG}	1.000	$EQR_{LEAFPACS}$	0.466
Confidence in Class			74.7%
Certainty < Good			95.1%
Invasive Plant Species Cover			**0%**
CSM Result			**Not Applicable**

Table 16. CSM Survey results from Llwyn-On Reservoir 2017.

The marginal wetland habitats around the lake are rather limited due to the artificial nature of the reservoir. Where the upper water limit coincides with more gentle relief, particularly around the north end, there are areas of *Carex rostrata* fen and *Salix* spp. woodland, but generally the margins are without a transitional wetland zone and grade quickly to rough grassland, coniferous plantation and regenerating broadleaf woodland. Greater tussock sedge *Carex paniculata,* is a slightly unusual species to find growing along the north-west shore.

a) b)

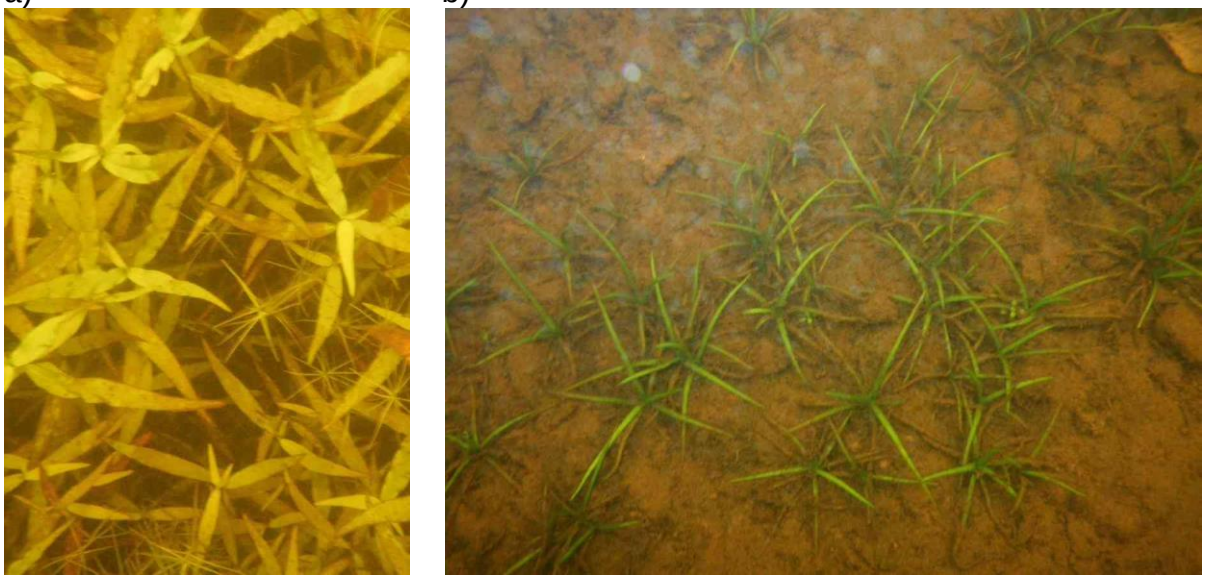


Figure 58. a) *Persicaria hydropiper* growing submerged with *Callitriche brutia* var. *hamulata* (S1 @ 110 cm); b) *Littorella uniflora* (S4 @ 50 cm).

At the time of survey, the reservoir was at its upper level, having recently risen after heavy rain. Such fluctuations in water level are typical for supply reservoirs and pose significant challenges for aquatic plants, thus favouring only species able to tolerate

exposure and inundation. The recent water level rise was further evidenced by an abundance of *Persicaria hydropiper* growing submerged to depths of 1.8 m around the north end of the reservoir. While tolerant of inundation, this species only normally develops at this density when above the waterline. *Callitriche brutia* var. *hamulata,* was recorded in the same location, apparently having tolerated exposure to air, but since benefiting from inundation (Figure 58).

The aquatic macrophyte flora was poor, with only five species recorded (Table 16). *Littorella uniflora* was locally frequent, but rarely occurred at depths greater than 1.0 m. A bed of *Persicaria amphibia* was recorded in section one at the north-east end, where *C. brutia* var. *hamulata* and *Lythrum portula* also occurred alongside inundated *Persicaria hydropiper. Fontinalis antipyretica* was frequent along and just below the waterline, growing mainly on large boulders.

When surveyed in 2011 (Goldsmith *et al.* 2012), water levels were approximately 1.5 m lower, but the aquatic flora was very similar, albeit with slightly higher frequency of *L. uniflora*.

The non-native invasive signal crayfish *Pacifastacus leniusculus* were noted during the survey; adults and juveniles being particularly prevalent in areas with large boulders, beneath which they would retreat when disturbed. A small bed of Japanese knotweed was noted growing above section two at SO0079712431.

The water was peaty brown in colour and although relatively clear, a low concentration of cyanobacterial bloom was noted, particularly in sheltered marginal areas. Dissolved oxygen and temperature profiles show the lake to be mixed, with only a gradual decline of DO and temperature with depth (Figure 59).

The Leafpacs classification tool gave a conclusion of Moderate status for Llwyn-on Reservoir, with a confidence in class of 74.7% and certainty < Good of over 95%. This is driven by the LMNI metric (Unadjusted EQR=0.641), although EQRs for NTAXA (0.397) and NFG (0.624) were also low. The COV and ALG metrics were normal, however (0.966 and 1 respectively). This is unlikely to reflect nutrient pressures (the primary focus of the Leafpacs tool) but rather the artificial nature of the habitat and its operational regime which restricts the diversity and composition of macrophyte species. Selective grazing by signal crayfish may also affect macrophyte composition. There has been little change in the tool outputs between 2011 and 2017.

Dissolved Oxygen Profile

GPS Location	SO0095111507
Maximum Depth (m)	17 m
Secchi Depth (cm)	185 cm

Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	8.99	16.9
0.5	8.88	16.8
1	8.81	16.5
1.5	8.59	15.8
2	8.61	15.7
3	8.53	15.5
4	8.22	15.2
5	7.51	15
6	7.52	14.9
7	7.61	14.9
8	7.55	14.8
9	7.48	14.7
10	7.52	14.7
11	7.51	14.6
12	7.77	14.6
13	7.64	14.5
14	7.54	14.5
15	7.75	14.5
16	7.64	14.4

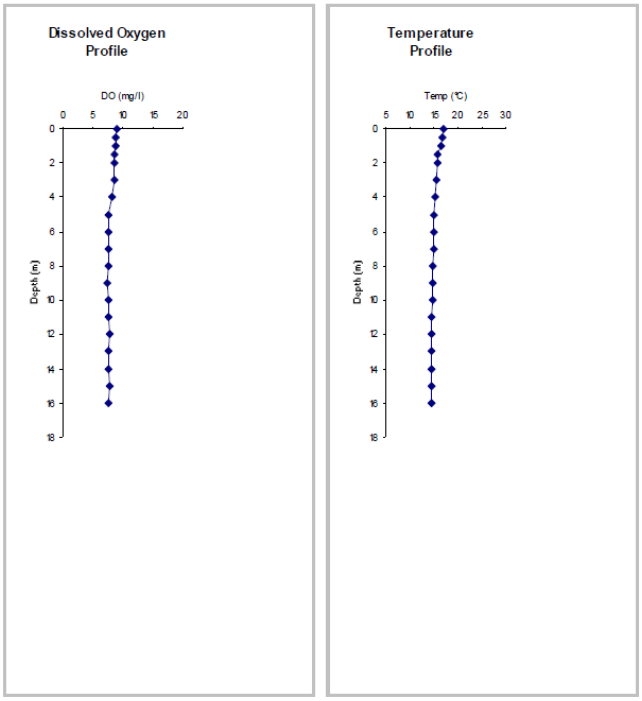


Figure 59. Dissolved oxygen and temperature profiles at Llwyn-On Reservoir (22/08/2017).

5.2.15. Llyn Mwyngill (Tal-y-Llyn Lake)

Contains OS data © Crown copyright (2017) *© Google Maps (2017)*

Figure 60. Site map and aerial photograph of Llyn Mwyngill (Tal-y-Llyn Lake).

Figure 61. Llyn Mwyngill site photo; from the south looking north-east.

Llyn Mwyngill (Tal-y-Llyn Lake) is a large (52 ha), shallow (max. depth 3.9 m), low alkalinity, low altitude lake located in Gwynedd, North Wales. It lies within the Cadair Idris SSSI, and the catchment falls within the Cadair Idris SAC, the Cader Idris NNR and the Dyfi Biosphere Reserve. Land-use in the catchment consists largely of acid grassland, with some areas of heath, improved grassland, coniferous plantation and broad leaved woodland, and the B4405 runs along the southern shore of the lake. The corrie lake Llyn Cau drains into the site via the Nant Cadair and Afon Faw streams. Both shore and boat angling are permitted.

Little of the site is reed-fringed, but Section one at the eastern end of the lake possesses a reasonably diverse mixture of emergent and floating-leaved species

including *Eleocharis palustris*, *Carex rostrat*a, *Menyanthes trifoliata*, *Phalaris arundinacea*, *Sparganium erectum*, *Equisetum fluviatile*, *Ranunculus flammula* and *Nymphaea alba*.

The deep water aquatic flora is dominated by an almost continuous bed of the invasive alien *Lagarosiphon major* (Table 17) growing up through most of the water-column and representing a considerable amount of biomass. *Nitella flexilis* agg. is also present in this zone alongside small amounts of *Elodea nuttallii* and *Callitriche brutia* var. *hamulata.* Ringing the deeper-water *Lagarosiphon,* around the edges of the lake, is a more diverse assemblage typified by *Isoetes lacustris*, *Elatine hexandra*, *Littorella uniflora* and occasional *Eleocharis acicularis* and *Potamogeton berchtoldii*. *Isoetes* specimens were confirmed as *I. lacustris* by microscopic examination of megaspores.

Llyn Mwyngill has been surveyed previously using the Common Standards Methodology, in 2004 (Burgess *et al*, 2006), 2008 (Goldsmith & Shilland 2010) and 2010 (Burgess *et al*, 2013). The major change in that time has been the invasion of *Lagarosiphon*, which happened between 2004 and 2008 and which by 2017 has almost completely displaced another invasive species, the formerly abundant *Elodea nuttallii*. The other components of the assemblage have remained largely unchanged, although for the first time *Myriophyllum alterniflorum* was not recorded in 2017*. Potamogeton perfoliatus* and *Sparganium angustifolium*, present at very low abundances in 2008 were not re-found in 2017.

Supporting only four of the required eight characteristic species for mesotrophic lakes (*Elatine hexandra*, *Isoetes lacustris*, *Littorella uniflora and Nitella flexilis* agg.) Llyn Mwyngill does not fulfil the JNCC (2015) macrophyte target criteria for this lake type. Moderately high levels of filamentous algae and two alien invasive macrophyte species were found during the current survey.

The Leafpacs tool at Llyn Mwyngill gave a classification of moderate, with just over 85% confidence that the lake is worse than Good status. This is driven by the LMNI metric, for which the EQR has deteriorated from 0.788 in 2014 to 0.602 in 2017. This is due to the loss of three nutrient-sensitive species (*Myriophyllum alternifolium*, *Sparganium angustifolium* and *Potamogeton perfoliatus*), but most likely reflects the impact of the invasive *Lagarosiphon major* reducing their ecological space rather than a nutrient problem.

Dissolved oxygen and temperature profiles showed the lake to be mixed at the time of sampling with no thermocline evident and only slight declines in temperature with increasing depth (Figure 62). Oxygen levels are consistent down the profile, then increase slightly in the macrophyte beds at 2.5 m depth before decreasing at the sediment boundary. The Secchi depth was >3.45 m, or greater than the site depth, on 15/08/17.

Submerged and floating vegetation	% cover	Submerged and floating vegetation	% cover
Callitriche brutia var. *hamulata*	8.1	***Isoetes lacustris***	**12.9**
Callitriche sp.	0.7	*Lagarosiphon major*	26.7
Elatine hexandra	**1.8**	***Littorella uniflora***	**11.0**
Eleocharis acicularis	0.1	*Menyanthes trifoliata*	2.7
Elodea nuttallii	0.6	***Nitella flexilis* agg.**	**6.2**
Filamentous algae	25.1	*Nymphaea alba*	2.0
Fontinalis antipyretica	0.7	*Potamogeton berchtoldii*	0.1
Species richness			**14**
WFD LEAFPACS Classification			**Moderate**
EQR_{LMNI}	0.602	EQR_{NFG}	1.314
EQR_{NTAXA}	1.200	EQR_{COV}	0.927
EQR_{ALG}	0.785	$EQR_{LEAFPACS}$	0.522
Confidence in Class			79.9%
Confidence < Good			85.1%
Invasive Plant Species Cover			27.7%
CSM Result		**Target**	**Measured**
Typical Species % Cover (Mesotrophic)		≥60%	54.9%
No. of Characteristic Species		≥8	4
Loss of Characteristic Species		0	3
% Samples with High Algal Cover		≤20%	13.2
Invasive Alien Species		0	2
Condition (Macrophytes Only)			**Unfavourable Declining**

Table 17. CSM Survey results from Llyn Mwyngill 2017.

Dissolved Oxygen Profile

GPS Location	SH7212410235
Maximum Depth (m)	3.45 m
Secchi Depth (cm)	3.45 cm

Notes: Secchi greater than site depth

Depth (m)	DO (mg/l)	Temp (°C)
0	10.07	15
0.5	10.08	14.9
1	10	14.9
1.5	10.03	14.9
2	10.04	14.9
2.5	10.42	13.1
3	8.64	12.1

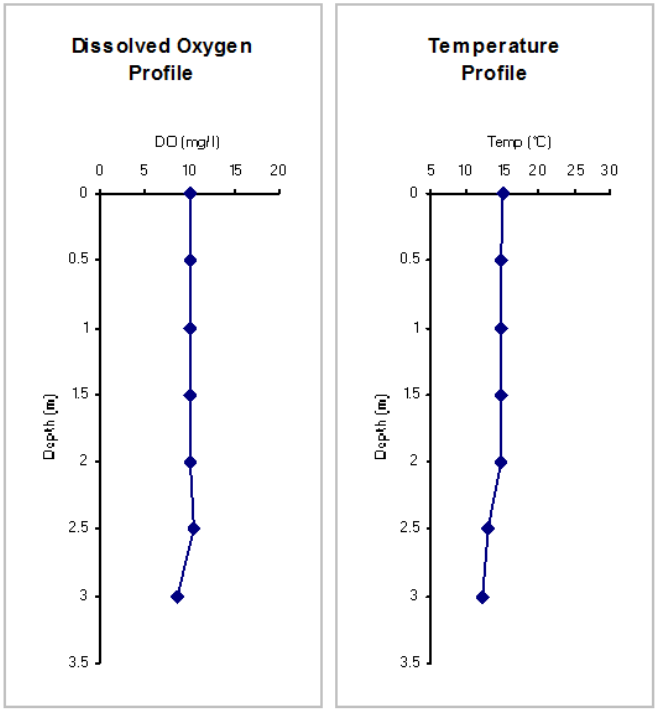


Figure 62. Dissolved oxygen and temperature profiles at Llyn Mwyngill (Tal y Llyn) (24/08/2017).

5.2.16. Llyn Gwynant

Contains OS data © Crown copyright (2017) *© Bing Maps (2017)*

Figure 63. Site map and aerial photograph of Llyn Gwynant.

Figure 64. Llyn Gwynant site photo; from the western end, looking north-east.

Llyn Gwynant is an oligotrophic lowland (65 m A.O.D) lake located within the Snowdonia National Park in Gwynedd, North Wales, between Beddgelert and Capel Curig on the A498 road. The lake is of glacial origin, lying on the River Glaslyn in the Nant Gwynant, a steep-sided valley below the southern slopes of Snowdon. The lake is of moderate size (45ha) and with a maximum recorded depth of 16.7 m. For a bathymetric map, see Goldsmith *et al*. (2010).

The lake catchment rises on to the eastern slopes of the Snowdon massif and western slopes of Cerrig Cochion. The hydrology of the catchment is complicated by the periodic release of water via the pipeline from Llyn Llydaw, used to generate hydroelectric power in the Cwm Dyli hydroelectric power station. Catchment land use comprises over 50% acid upland grassland and heath, with deciduous woodland and improved grasslands lower down the valley. The Llyn Gwynant Campsite is located at the northeast end of the lake, providing >400 pitches for tents and caravans. The

lake and its environs are utilized for a variety of water sports, adventure activities and hiking and have provided the backdrop for a number of films (www.gwynant.com).

The lake margins are mainly broad-leaf woodland, interspersed with areas of rough, and semi-improved pasture. Emergent and wetland plants are limited to around the inflow and outflow areas, where there is *Juncus* spp. dominated bog and areas of *Phragmites australis* and *Schoenoplectus lacustris* present. Although oligotrophic, previous monitoring indicates that the lake supports significant mesotrophic elements to the flora. However, the oligotrophic targets have been used as the lake is not species-rich enough to meet the mesotrophic targets, and there is no evidence of loss of species.

Submerged and floating vegetation	**% cover**	**Submerged and floating vegetation**	**% cover**
Callitriche brutia var. *hamulata*	1.4	***Littorella uniflora***	**11.4**
Chara virgata	4.8	***Lobelia dortmanna***	**8.4**
Crassula helmsii	0.2	*Myriophyllum alterniflorum*	23.6
Elatine hexandra	0.7	*Nitella flexilis* agg.	5.7
Filamentous algae	1.7	*Potamogeton berchtoldii*	1.5
Fontinalis antipyretica	2.7	*Potamogeton polygonifolius*	1.4
Isoetes lacustris	**23.3**	***Subularia aquatica***	**0.3**
Juncus bulbosus	0.1	*Utricularia* sp.	0.2
Species richness			**16**
WFD LEAFPACS Result			**Good**
EQR_{LMNI}	0.777	EQR_{NFG}	1.513
EQR_{NTAXA}	1.400	EQR_{COV}	0.816
EQR_{ALG}	1.000	$EQR_{LEAFPACS}$	0.768
Confidence in Class			77.9%
Certainty < Good			0.1%
Invasive Plant Species Cover			0.25%
CSM Result		**Target**	**Measured**
Typical Species % Cover (Oligotrophic)		≥60%	86.1%
No. of Characteristic Species		≥6	7
Loss of Characteristic Species		0	0
% Samples with High Algal Cover		≤20%	0
Invasive Alien Species		0	1
			Unfavourable

Table 18. CSM Survey results from Llyn Gwynant 2017.

Figure 65. *Littorella uniflora* and *Myriophyllum alterniflorum* growing on soft sediments (S3 @ 50 cm)

The submerged aquatic flora was typical for an oligotrophic lake (Table 18). *Littorella uniflora* was abundant in the littoral zone (Figure 65), overlapping with *Lobelia dortmanna* and *Isoetes lacustris* in slightly deeper water. *Isoetes lacustris* was abundant in all four sections between depths of 1.0 m to 3.5 m. *Myriophyllum alterniflorum* was also frequent throughout the site (locally abundant), recorded from shallow water, to 4.8 m. The maximum depth of colonisation was 5.3 m, for *Chara virgata* in Section three, where it was abundant in deep water (4.0 – 5.3 m). *Subularia aquatica* was rare in the site, recorded at only 2 locations.

The non-native, invasive species *Crassula helmsii* was recorded in Section one, on the north shore, close to the outflow (SH6381851506). This species is currently rare in Snowdonia, but can proliferate in oligotrophic waters and should therefore be monitored in Llyn Gwynant, and efforts made to contain its spread, both within this site and onwards to other lakes.

Previous surveys show the macrophyte assemblage in Llyn Gwynant to be relatively stable. Seddon (1964) and Wade (1980), detail a very similar list of species to the current survey, although *Sparganium angustifolium* and *S. emersum* are additional. The current survey differs little from the CSM survey conducted in 2007 by Goldsmith *et al.* (2009), with *Nitella translucens* the only additional species (recorded are rare). *Crassula helmsii* was not recorded in 2007 and must be assumed to be a recent arrival at the site.

There was a strong breeze during the survey and as a consequence the water column was well mixed to maximum depth and with no appreciable decline in dissolved oxygen concentration or temperature (Figure 66).

Dissolved Oxygen Profile

GPS Location	SH6441352061
Maximum Depth (m)	16.5 m
Secchi Depth (cm)	-

Notes:

Depth (m)	DO (mg/l)	Temp (°C)
0	9.91	13
1	9.9	13
2	9.88	12.9
3	9.86	12.9
4	9.85	12.9
5	9.82	12.9
6	9.81	12.9
7	9.81	12.9
8	9.79	12.9
9	9.74	12.9
10	9.71	12.9
12	9.61	12.8
14	9.48	12.6
16	9.35	12.5

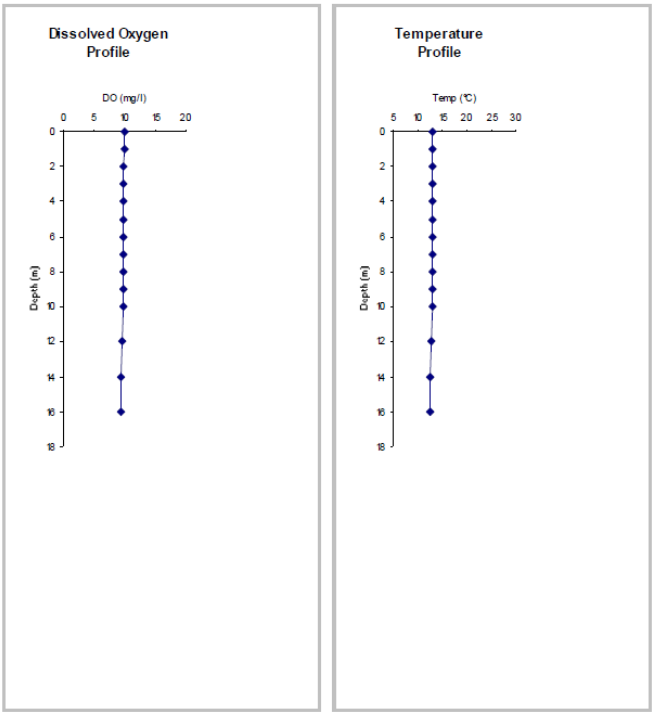


Figure 66. Dissolved oxygen and temperature profiles at Llyn Gwynant (22/09/2017).

6. Discussion and Recommendations

6.1. Pressures and Management

The survey results here provide updated data for a series of lakes in Wales covering a broad spectrum of ecological types. In general, the main ecological issues are (i) various symptoms relating to nutrient enrichment, notably shifts in plant communities towards more nutrient-tolerant species, reductions in aquatic plant cover, turbid water and deoxygenation of deeper water areas and (ii) the spread and ecological impact of invasive non-native plant species (Table 19).

Lake Name	Nutrients	INNS	Recommended Measures
Hanmer Mere	Yes	Yes	Sediment Nutrient Management.
Llynnau Mymbyr	No	No	None.
Llyn Fach	No	No	Maintain favourable forestry management.
Llyn Maelog	Yes	Yes	Reduce catchment nutrient loading.
Llanbwchllyn Reservoir	Yes	No	Reduce catchment nutrient loading; consider reinstatement of original water level and / or sediment nutrient management.
Llyn Llygeirian	Yes	No	Investigate and tackle catchment and in-lake nutrient sources.
Bosherston Lily Ponds – Eastern Arm	Yes	Yes	Sediment nutrient management and reduction of catchment nutrient loading.
Bosherston Lily Ponds – Central Arm	No	No	None.
Bosherston Lily Ponds – Western Arm & Central Lake	Yes	Yes	Reduce catchment and in-lake nutrient loading.
Llyn Penrhyn	Yes	Yes	Sediment nutrient management and reduction of catchment nutrient loading.
Llyn Llywenan	Yes	Yes	Reduction of catchment nutrient loading.
Llangorse Lake	Yes	Yes	Reduction of catchment nutrient loading, including restoration of inflow streams.
Llyn Tegid / Bala Lake	Yes	No	Reduction of catchment nutrient loading.
Llwyn-On Reservoir	No	Yes*	Biosecurity, examine feasibility of signal crayfish control.
Llyn Mwyngill (Tal-y-Llyn Lake)	No	Yes	Biosecurity measures.
Llyn Gwynant	No	Yes	Urgently attempt *Crassula* removal.

Table 19. Summary of pressures and recommended measures required for the different lakes monitored.

Nutrient impacts are generally well-known and often long-standing (e.g. Burgess et al. 2006, 2009; Holman et al. 2009; May *et al*. 2009, Hatton-Ellis 2012a, b, 2015). In general their management is not simple, because it requires the identification and management of multiple catchment sources, many of which are unconsented, seasonal and / or otherwise difficult to trace and tackle. Some lakes also suffer from the long-term accumulation and subsequent internal recycling of a pool of nutrient-rich sediment that can continue to affect the ecosystem for decades after the original source has been tackled (e.g. Bosherston Eastern Arm). In-lake measures such as sludge pumping or the use of a product such as Phoslock could then be considered to remove this impact, though such measures are very expensive and would require capital funding.

Invasive non-native species are a particularly difficult problem in freshwaters. Biosecurity measures can slow or even prevent spread, but they are relatively onerous and difficult to enforce. Once established, invasive non-native species are virtually impossible to control and are then liable to be a more or less permanent feature. At the early stage of establishment they could potentially be controlled by manual removal and therefore it is important that a removal attempt of the *Crassula* be carried out at Llyn Gwynant before the species becomes more widespread.

6.2. Leafpacs Tool Development Considerations

In general terms the Leafpacs lake macrophyte tool is an effective means for monitoring nutrient pressures on lakes that delivers broadly accurate results. The results of this and other work are however starting to show some general patterns indicating where further development could be targeted to enhance its effectiveness. These are summarised as follows:

- Use of lake depth in the reference model:

Leafpacs has a tendency to be too lax in its classification of very shallow lakes (e.g. Llyn Llywenan, Bosherston Western Arm) and too stringent in its classification of deep lakes (e.g. Llyn Tegid). Some minor modifications to the way in which depth is used in the reference model could help address this issue.

- Species-specific cover values should be used to calculate LMNI.

LMNI is the most important metric in Leafpacs and is the only metric used in 43% of Welsh lakes classifications. However, LMNI responds only to changes in species composition and not to changes in cover of the existing species pool. This is a weakness, because response to nutrient levels is more likely to be manifested in changes in cover within the existing species pool, rather than colonisation of new species, and because two lakes with the same species pool but very different cover values can be indicative of quite different levels of nutrient pressure (e.g. dominance of *Chara* at low nutrient levels in alkaline lakes).

Use of cover-weighted LMNI values would address this problem and make Leafpacs a more effective tool for tracking environmental change in individual lakes. In

addition, this approach would also allow better alignment between Leafpacs and Habitats Directive monitoring, and allow the tool to be more effective in marl lakes where it is generally relatively ineffective. At Bosherston, the tool as currently set up does not differentiate between the *Chara*-dominated Central Arm where TP is <20µg l^{-1}, and the elodeid dominated Western Arm & Central Lake where TP is approximately 40µg l^{-1}, classifying both as Good with LMNI scores of 6.39 and 6.41 respectively. However, when cover-weighted LMNI values were used, the Western Arm was classified as Good with a 26% chance of being worse than Good (LMNI of 6.61), and the Central Arm as High with 100% confidence (LMNI of 5.30).

Cover-weighted LMNI was originally considered by the Leafpacs project (Willby *et al*. 2010) but was discounted because it did not improve the overall global relationship between lake plants and phosphorus. It is possible that this reflects a mismatch with the space for time substitution used in WFD.

6.3. Alignment between the Leafpacs Tool Classification and CSM Favourable Condition Attributes

In general, the relationship between the Leafpacs results and CSM Favourable Condition attributes is good. This is not surprising as both methods seek to measure pressures on lakes by assessing the ecological quality of their aquatic plants. In general terms, Leafpacs is more quantitative and objective but narrower in focus, whereas the CSM approach is more qualitative but takes a wider range of pressures and habitat structure into account. Differences tend to arise mainly because of (i) different pressures being assessed, and in particular the lack of an invasive species metric in Leafpacs (ii) the requirement of CSM to identify specific plant communities and (iii) technical differences in the way habitats are assessed.

Conceivably these differences could be absorbed into a single common tool, but this would require significant additional development and potentially some recalibration of boundaries. It is doubtful that the technical work required to achieve this would be cost-effective and therefore at present it is preferable to retain separate tools, but with an acknowledgement that each can complement the other.

7. References

Atherton I, Bosanquet S, Lawley M. 2010. *Mosses and Liverworts of Brian and Ireland: A Field Guide*. British Bryological Society, Plymouth, 848 pp.

Bennion H 1995. *Quantitative reconstructions of the nutrient histories of three Anglesey lakes.* Report to CCW, CCW Contract Science Report No. 87. ECRC Research Report 16. Environmental Change Research Centre, University College London, London

Bennion H, Kelly MG, Juggins S, Yallop ML, Burgess A, Jamieson J, Krokowski J. 2014. Assessment of ecological status in UK lakes using benthic diatoms. *Freshwater Science*, 33**,** 639-654. doi:10.1086/675447

Burgess A, Goldsmith B, Hatton-Ellis T. 2006. *Site condition assessments of Welsh SAC and SSSI standing water features.* CCW Contract Science Report No. 705. Countryside Council for Wales, Bangor.

Burgess A, Goldsmith B, Hatton-Ellis T, Hughes M, Shilland E. 2009. *CCW Standing Waters SSSI Monitoring 2007-08*. CCW Contract Science Report 855. Bangor: Countryside Council for Wales.

Burgess A, Goldsmith B, Hatton-Ellis TW. 2013. *Site Condition Assessments of Welsh SAC and SSSI Standing Water features, 2007-2012*. CCW Contract Science Report 983, Bangor: Countryside Council for Wales

Centre for Hydrology and Ecology (CEH). 2018. *A GIS-based inventory of lakes for Great Britain (Beta).* Online lakes resource based on Hughes *et al.* 2004. Accessed January 2018 https://eip.ceh.ac.uk/apps/lakes/index.html

Davidson TA, Bennion H, Yang H, Appleby P, Luckes S. 2002. *Investigation of environmental change at the Bosherston Lakes, Pembrokeshire.* Countryside Council for Wales. CCW Contract Science Report 496, Bangor.

Davidson TA, Sayer CD, Bennion H, David C, Rose N, Wade MP. 2005. A 250 year comparison of historical, macrofossil and pollen records of aquatic plants in shallow lakes. *Freshwater Biology*, **50**, 1671-1686.

Duigan C, Kovach W, Palmer M. 2006. *Vegetation Communities of British Lakes: a revised classification*. Peterborough: Joint Nature Conservation Committee (JNCC).

European Communitiy.1992. *Council Directive 92/43//EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.* Official Journal of the European Communities. L206, pp. 7-50.

Goldsmith B, Bennion H, Hughes M, Jones V, Rose C, Simpson GL. 2006. *Integrating Habitats Directive and Water Framework Directive monitoring: Baseline survey of Natura 2000 standing water habitats in Wales*. CCW Contract Science Report No. 704. Countryside Council for Wales, Bangor

Goldsmith B, Burgess A, Bennion H, Turner SD, Appleby PG. Piliposian GT. 2010. *Palaeoecological and surface sediment analysis of Welsh SSSI / SAC lakes incorporating chemical and bathymetric surveys*. Report to CCW as part of: Lake Macrophyte and Habitat Surveys for the Water Framework Directive, 2007-10. Contract No.20457 The Environment Agency. ENSIS Ltd. London.

Goldsmith B, Shilland E. 2010. *Common Standards Macrophyte Surveys: Welsh Standing Waters 2007 – 2009*, Data Summary. Report to CCW as part of: *Lake Macrophyte & Habitat Surveys for the Water Framework Directive, 2007-10*. Contract No: 20457. The Environment Agency. 129 pp.

Goldsmith, B., Shilland, E.M., Bennion, H., Sayer, C. D., Salgado, J., Burgess, A. & Darwell, A. (2011). *Lake Macrophyte and Habitat Surveys for Water Framework Directive Status Classification and Site Condition Assessment*: Data Report. Contract No: 20457. Environment Agency, Bristol.

Goldsmith B, Shilland E. Sayer CD, Salgado J, Burgess, A. Darwell A. 2012. *Lake Macrophyte Surveys for the Water Framework Directive 2011*. EA Ecological Services Contract 22383. Data report, ENSIS, London.

Goldsmith B, Shilland EM, Shilland JD, Bennion HB, 2004. *Pilot lake monitoring for the WFD - Phase 1 Data report to EA*. ENSIS Ltd. University College London.

Goldsmith B, Salgado, Bennion, H. & Goodrich. 2014. *Lake Ecological Surveys (Wales) 2013*. NRW Evidence Report No 28. 19 pp, Natural Resources Wales, Bangor

Goldsmith BJ, Turner SD, Shilland EM, Goodrich S. 2016. *Ecological Surveys of Welsh Lakes 2015*. NRW Evidence Report No 145. Bangor.

Hatton-Ellis TW. 2014. *Lake BAP Priority Areas in Wales: A Strategic Review*. Cardiff: Wales Biodiversity Partnership. Available online at http://www.biodiversitywales.org.uk/Freshwater

Hatton-Ellis, T.W. 2016. *Evidence Review of Lake Nitrate Vulnerable Zones in Wales*..NRW Evidence Report No: 135, 163pp, Natural Resources Wales, Bangor.

Haycock B, Hinton G. 2010. Monitoring Stoneworts *Chara* spp. at Bosherston Lakes. In: Hurford C., Schneider M., Cowx I. (eds) *Conservation Monitoring in Freshwater Habitats*. Springer, Dordrecht. pp 277-290.

Holman, IP, Davidson T, Burgess A, Kelly A, Eaton J, Hatton-Ellis TW. 2009. *Understanding the effects of coming environmental change on Bosherston Lakes as a basis for a sustainable conservation management strategy.* CCW Contract Science Report No. 858 Countryside Council for Wales, Bangor

Hughes M, Bennion H, Kernan M, Hornby DD, Hilton J, Phillips G, Thomas R. 2004. The development of a GIS-based inventory of standing waters in Great Britain together with a risk-based prioritisation protocol. *Water, Air and Soil Pollution* 4, 73-84.

International Centre of Landscape Ecology. 1993. *Review and assessment of reports and literature relevant to ecology and recreational use of Llangorse Lake SSSI*, Brecknock, South Wales.

Jeppesen E, Søndergaard M, Søndergaard M, Christoffersen K (Eds.) 1998. *The Structuring Role of Submerged Macrophytes in Lakes*. Ecological Studies, Vol. 131. Springer. 423 pp.

Joint Nature Conservation Committee (JNCC). 2015. *Common Standards Monitoring Guidance for Freshwater Lakes (Version March 2015)*. Interagency Freshwater Group Report, JNCC, Peterborough. An electronic version of this report is available at: http://jncc.defra.gov.uk/pdf/0315_CSM_Freshwater_lakes.pdf

Joint Nature Conservation Committee (JNCC) 2005. *Common Standards Monitoring Guidance for Freshwater Habitats and Species (Standing Water), 1st version.* ISSN 1743-8160 (Online). Available online at http://jncc.defra.gov.uk/page-2232

John DM, Whitton BA & Brook AJ. 2002. *The Freshwater Algal Flora of the British Isles*, Cambridge University Press, Cambridge

Kernan M, Battarbee RW, Curtis CJ, Monteith DT, Shilland EM. 2010. *UK Acid Waters Monitoring Network 20 Year Interpretative Report*, 1-477, ENSIS Ltd, Environmental Change Research Centre, University College London, London.

May L, Dudley B, Spears BM, Hatton-Ellis TW. 2008. *Nutrient modelling and a nutrient budget for Llangorse Lake*. CCW Contract Science Report No: 831, 75 pp, Countryside Council for Wales, Bangor.

Monteith DT. (Ed.). 1997. *Integrated classification and assessment of lakes in Wales: Phase IV*. CCW Contract Science Report No. 214. CCW, Bangor.

Moore JA 1986*. Charophytes of Great Britain and Ireland*. BSBI Handbook Number 5. 140pp. BSBI publishing, London

NBN Atlas website at http://species.nbnatlas.org/species/NBNSYS0000004478. *Elodea nuttallii.* Accessed 26 February 2018.

Preston CD. 1995. *Pondweeds of the British Isles and Ireland*. BSBI Handbook Number 8. 352pp. BSBI publishing, London

Seddon B. 1964. Aquatic plants of Welsh lakes. *Nature in Wales*, **9**, 3-8.

Shilland EM, Monteith DT. 2010. Aquatic Macrophytes. In: *UK Acid Waters Monitoring Network 20 Year Interpretative Report*, ENSIS Ltd, Environmental Change Research Centre, University College London, London. pp.112-125

Stace C. 1997. *New Flora of the British Isles*. 2nd edition. Cambridge University Press, Cambridge.

Stewart, NF. (2004). *Important Stonewort Areas. An assessment of the best areas for stoneworts in the United Kingdom (summary)*. 15pp. Plantlife International, Salisbury, UK.

Trow AH. 1911. *The flora of Glamorgan, including the spermaphytes & vascular cryptogams, with index.* Printed for the Society by W. Lewis, Cardiff.

Wade PM. 1980. *Survey of the Aquatic Flora of 14 Welsh Lakes, Snowdonia, North Wales.* Loughborough University.

Wade PM. 1999. The Impact of Human Activity on the Aquatic Macroflora of Llangorse Lake, South Wales. *Aquatic Conservation: Marine and Freshwater Ecosystems.* **9**, 441-60.

WFD-UKTAG 2014. UKTAG Lake assessment methods: macrophyte and phytobenthos. Macrophytes (Lake Leafpacs2). ISBN: 978-1-906934-45-3. Available online: http://wfduk.org/resources/lakes-macrophytes

Willby NJ, Pitt J-A, Phillips GL. 2010. *The ecological classification of UK lakes using aquatic macrophytes*. Environment Agency Science Report SC010080/SR

8. Appendices

8.1. Appendix I: Aquatic species data for all sites

Table 20. Summary of all aquatic and macrophyte species for the 16 lakes. Figures represent per cent frequency based on the LEAFPACS method; invasive alien species (INV) are shaded in orange.

	Hanmer Mere	Llynau Mymbyr	Llyn Fach	Llyn Maelog	Llanbwchllyn Reservoir	Llyn Llygeirian	Bosherston Lilly Ponds – East	Bosherston Lilly Ponds - Central	Bosherston Lilly Ponds – West &	Llyn Penrhyn	Llyn Llywenan	Llangorse Lake	Llyn Tegid/Lake Bala	Llwyn-On Reservoir	Llyn Mwyngill (Tal y Llyn)	Llyn Gwynant
Apium inundatum									1							
Batrachospermum sp.		0.6														
Butomus umbellatus							0.7				0.8	2.1				
Callitriche brutia var. *brutia*					1											
Callitriche brutia var. *hamulata*		0											4.3	4.6	8.1	1.4
Callitriche hermaphroditica				1.6												
Callitriche sp.															0.7	
Callitriche stagnalis											0.9					
Callitriche truncata										2.5						
Ceratophyllum demersum	31.7				0.5	0.1				14.1		7.7				
Chara globularis				0.8	4.4		3.8			1.2		6.2				
Chara hispida								49.3	5.9							
Chara virgata								0.7	6.3	3						4.8
Crassula helmsii																0.2
Elatine hexandra				0.8									3.3		1.8	0.7
Elatine hydropiper	1.7									3.4	4					
Eleocharis acicularis				0.9		0.1					2.3	0.3	0.7		0.1	

	Hanmer Mere	Llynau Mymbyr	Llyn Fach	Llyn Maelog	Llanbwchllyn Reservoir	Llyn Llygeirian	Bosherston Lilly Ponds – East	Bosherston Lilly Ponds - Central	Bosherston Lilly Ponds – West &	Llyn Penrhyn	Llyn Llywenan	Llangorse Lake	Llyn Tegid/Lake Bala	Llwyn-On Reservoir	Llyn Mwyngill (Tal y Llyn)	Llyn Gwynant
Eleocharis multicaulis		0.7														
Eleogiton fluitans			12.8													
Elodea canadensis	14			7.7		17.9	18.6		6	8.5	41.3	8.6				
Elodea nuttallii												20.8	1.1		0.6	
Filamentous algae	7.2	32.4	11.7	4		2.3	23.6	3.7	20	18.5	8	5.4	12.4		25.1	1.7
Fontinalis antipyretica			0.2					1.4	2.5				2.7	5.1	0.7	2.7
Hydrocharis morsus-ranae						2.1										
Hydrodictyon reticulatum				0.5						0.02	0.5					
Isoetes echinospora			21.1													
Isoetes lacustris		22.1											6.4		12.9	23.3
Juncus bulbosus		9.1	10.6										0.01			0.1
Lagarosiphon major															26.7	
Lemna minor	13.6			1.4		2.8	4			4	5.7	4				
Lemna minuta							0.1			0.8						
Lemna trisulca	1.7				10.9	8.6		2.9	2.1	9.5		8.7				
Littorella uniflora		9.9	0.8			1.2							3	18.8	11	11.4
Lobelia dortmanna		6.6	17.9													8.4
Luronium natans													1			
Lythrum portula														4.5		
Menyanthes trifoliata		0.7	1.4		2.9	4.5				1.7	1.6	1.9			2.7	
Myriophyllum alterniflorum		10	6.1		2.3	11.6										23.6
Myriophyllum spicatum					11.4		8.9		15.6	3		6.6				
Nitella flexilis agg.	0.7	2.5			6.6	4.8			2				1.8		6.2	5.7
Nitella gracilis		0.8														
Nitellopsis obtusa												2.8				
Nuphar lutea	7.9	3.3			3.8					0.9	0.7	5.1				

	Hanmer Mere	Llynau Mymbyr	Llyn Fach	Llyn Maelog	Llanbwchllyn Reservoir	Llyn Llygeirian	Bosherston Lilly Ponds – East	Bosherston Lilly Ponds - Central	Bosherston Lilly Ponds – West &	Llyn Penrhyn	Llyn Llywenan	Llangorse Lake	Llyn Tegid/Lake Bala	Llwyn-On Reservoir	Llyn Mwyngill (Tal y Llyn)	Llyn Gwynant
Nymphaea alba	2.4				3.9	0.9	0.5	29.4	10.3	4		0.9			2	
Nymphoides peltata												4.1				
Persicaria amphibia	0.1			3	2.4	3.3	3.4	2.9	2.3	1.7	2.5	2.7		5.3		
Potamogeton berchtoldii	6.9	1.7					0.1		0.5				0.4		0.1	1.5
Potamogeton crispus	6.6				1		18.9		20.3							
Potamogeton lucens												3.1				
Potamogeton natans		1.3	4		1.7								0.05			
Potamogeton obtusifolius					11.3											
Potamogeton pectinatus					1		2.7		3.1	3.6		0.2				
Potamogeton perfoliatus				1.9		0.8				3.8		0.1				
Potamogeton polygonifolius		0	3.1													1.4
Potamogeton praelongus					5.6											
Potamogeton pusillus				2.7		4.6				5.3	13.7	0.1				
Potamogeton trichoides	2.3															
Ranunculus aquatilis agg.											0.1		0.4			
Ranunculus circinatus					1							0.05				
Ranunculus lingua					1					0.7		2				
Sparganium emersum									2			0.5				
Sphagnum (aquatic indet.)		1.5	3.3													
Spirodela polyrhiza												4.2				
Subularia aquatica																0.3
Utricularia sp.																0.2
Utricularia vulgaris		1.9														
Zannichellia palustris	3.7								0.04							

8.2. 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 4 digits of the photo file name stored in folder “NRW_2017_Section_Photos” the NRW data archive (see Appendix 7.3)

Table 21. Survey section OS National Grid References and photo numbers for the 16 lakes.

Site	WBID	Survey ID	Section Number	Wader start GPS	Wader end GPS	Boat Shore GPS	Boat Lake GPS	Start Photo	Section Photo	End Photo	Submerged Photo
Hanmer Mere	34780	15/08/17	**1**	SJ4508038820	SJ4512638745	SJ4509938783	SJ4522239029	604	605	608	606
			2	SJ4533939131	SJ4529739042	SJ4532739100	SJ4530439241	614	615	617	616
			3	SJ4550539345	SJ4542639317	SJ4548539318	SJ4545139389	619	618	621	620
			4	SJ4525839596	SJ4539239616	SJ4529139608	SJ4531039587	622	623	625	624
Llynnau Mymbyr	33932	17/08/17	**1**	SH7114857746	SH7124657756	SH7119857757	SH7122357727	641	642	643	644
			2	SH7123757498	SH7114357444	SH7120457462	SH7112957612	646	647	651	649
			3	SH7062757070	SH7054457016	SH7059157035	SH7052657107	658	659	660	661
			4	SH7025357081	SH7022157174	SH7021457117	SH7038657152	663	662	665	664
Llyn Fach	41210	17/08/17	**1**	SN9063803696	SN9054003701	SN9058803688	SN9060603754	002	003	009	008
			2	SN9052003839	SN9042303803	SN9047103831	SN9050403764	020	021	023	022
Llyn Maelog	33160	18/08/17	**1**	SH3233673029	SH3241373091	SH3236673062	SH3257172971	679	680	684	681
			2	SH3292973396	SH3284473371	SH3288673362	SH3289573307	671	670	675	676
			3	SH3248072769	SH3256072721	SH3252272751	SH3262673011	690	691	693	692
			4	SH3285573053	SH3278272978	SH3282173017	SH3256972947	689	687	686	turbid
Llanbwch-llyn Lake	39267	18/08/17	**1**	SO1220946273	SO1219046169	SO1221346236	SO1202846303	035	036	037	034
			2	SO1190746222	SO1179746196	SO1185146221	SO1182246302	040	041	060	051
			3	SO1183046472	SO1174946506	SO1179746456	SO1181946419	061	068	069	072

Site	WBID	Survey ID	Section Number	Wader start GPS	Wader end GPS	Boat Shore GPS	Boat Lake GPS	Start Photo	Section Photo	End Photo	Submerged Photo
Llyn Llygeirian	32435	19/08/17	**1**	SH3467089660	SH3461989702	SH3463889663	SH3470789911	699	700	707	702
			2	SH3462890052	SH3453590005	SH3458490011	SH3471889892	715	712	711	713
			3	SH3472390057	SH3480590017	SH3475890013	SH3470789911	719	720	721	turbid
			4	SH3483889815	SH3485289895		SH3474089843	716	717	718	turbid
Bosherston Lily Ponds – Eastern Arm	47013	19/08/17	**1**	SR9775395814	SR9774095713	SR9774895762	SR9771195776	076	077	085	084
			2	SR9767595816	SR9766295711	SR9767185765	SR9770895761	110	111	117	116
			3	SR9777995166	SR9778795069	SR9776095105	SR9771695094	120	126	125	124
			4	SR9772994868	SR9764994807	SR9769194841	SR9770894810	128	129	130	133
Bosherston – Central Arm	47014	20/08/17	**1**	SR9733894885	SR9731194797	SR9731994833	SR9729094835	208	205	204	206
			2	SR9728694722	SR9736294672	SR9733194699	SR9734094723	210	211	214	213
Bosherston – Western Arm & Central Lake	47015	20/08/17	**1**	SR9713894692	SR9703494725	SR9708794709	SR9706494688	154	155	171	165
			2	SR9721494541	SR9731994539	SR9726494538	SR9725294595	177	178	179	181
			3	SR9751194527	SR9759794500	SR9755594527	SR9757494560	184	189	185	188
			4	SR9763794590	SR9760994687	SR9762194621	SR9757094604	193	194	195	202
Llyn Penrhyn	32968	20/08/17	**1**	SH3130777271	SH3127777173	SH3127777220	SH3127477039	731	730	728	732
			2	SH3162076853	SH3160276803	SH3160876829	SH3146976817	736	735	733	734
			3	SH3137376648	SH3127476660	SH3133876650	SH3133976773	744	745	n/a	n/a
			4	SH3102476897	SH3099376816	SH3103176851	SH3115876747	739	738	737	742
Llyn Llywenan	32746	21/08/17	**1**	SH3466581138	SH3455981139	SH3460981152	SH3480781608	751	752	754	753
			2	SH3496981561	SH3492181486	SH3494081534	SH3482081599	756	755	758	757
			3	SH3460281991	SH3463482077	SH3462482035	SH3482881990	768	767	778	777
			4	SH3492882026	SH3499981987	SH3497682022	SH3485981829	761	760	763	764
Llangorse Lake	40067	21/08/17	**1**	SO1302726237	SO1292826242	SO1297626241	SO1306126435	271	273	278	275
			2	SO1375725869	SO1373625958	SO1374225914	SO1378325908	215	225	224	219
			3	SO1378126718	SO1387226695	SO1382026712	SO1379726614	259	246	245	249

Site	WBID	Survey ID	Section Number	Wader start GPS	Wader end GPS	Boat Shore GPS	Boat Lake GPS	Start Photo	Section Photo	End Photo	Submerged Photo
			4	SO1245326813	SO1244026815	SO1247526859	SO1297526626	280	281	284	279
			5	SO1408525944	SO1409826043	SO1406725991	SO1405525986	227	228	240	237
			6	SO1359126880	SO1353526960	SO1357426927	SO1345426814	264	265	268	267
Llyn Tegid / Bala Lake	34987	22/08/17 23/08/17	**1**	SH8906631114	SH8902031183	SH8904231149	SH8907531181	780	781	782	783
			2	SH8975331563	SH8966831576	SH8971031557	SH8972031603	792	793	794	795
			3	SH9021233314	SH9015133253	SH9019033275	SH9018633284	801	802	804	803
			4	SH9251835408	SH9242735378	SH9248135377	SH9236035244	824	825	819	822
			5	SH8913231986	SH8922831988	SH8920931965	SH8917731983	788	789	790	791
			6	SH9090832838	SH9083332789		SH9085532822	798	797	799	800
			7	SH9142034777	SH9149134829	SH9145334803	SH9148434788	806	807	808	809
			8	SH9209334190	SH9218134238		SH9215034238	812	813	815	816
Llwyn-On Reservoir	40648	22/08/17	**1**	SO0078212578	SO0075912481	SO0076312532	SO0072012531	303	304	312	306
			2	SO0048012189	SO0049812289	SO0049812245	SO0050712247	297	299	300	301
			3	SO0069411559	SO0060111645	SO0062911593		285	286	287	288
			4	SO0097511799	SO0106011750	SO0101711781		292	293	296	295
Llyn Mwyngill (Tal-y- Llyn Lake)	36405	24/08/17	**1**	SH7221010146	SH7228710142	SH7224510113	SH7212410235	833	834	836	835
			2	SH7186510203	SH7180910127	SH7182710168	SH7190910092	837	838	841	840
			3	SH7130109888	SH7123209843	SH7126809864	SH7137709775	843	842	845	844
			4	SH7148109524	SH7151909587	SH7151609565	SH7139909715	827	828	829	830
Llyn Gwynant	34153	16/08/17 22/09/17	**1**	SH6381851506	SH6390951572	SH6387151539	SH6389351462	317	318	319	316
			2	SH6423651959	SH6428152023	SH6424851991	SH6428151986	313	314	n/a	n/a
			3	SH6487952012	SH6492452079	SH6490752035	SH6476552096	638	633	635	634
			4	SH6446551712	SH6455551760	SH6451051741	SH6449751764	320	321	322	323

8.3. 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_2017_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_2017.xls]

[C] A full set of digital photographs from the surveys in [jpg] format in folder [NRW_2017_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_2017_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.

Published by:
Natural Resources Wales
Maes y Ffynnon
Penrhosgarnedd
Bangor
Gwynedd
LL57 2DW

0300 065 3000

Further copies of this report are available from:

Email: library@cyfoethnaturiolcymru.gov.uk