Investigation of environmental change in two mesotrophic lakes in Mid-Wales: Llyn Eiddwen and Llyn Fanod

H. Bennion, T.E.H. Allott & E. Shilland
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Executive Summary

1. This is the final report to the Countryside Council for Wales under contract FC 73-01-71A: Investigation of environmental change in two mesotrophic lakes in Mid-Wales: Llyn Eiddwen and Llyn Fanod.

2. The report employs palaeolimnological techniques to evaluate the degree of environmental change at these two Nature Conservation Review sites.

3. The report describes the lithostratigraphies, and presents results of spheroidal carbonaceous particle analysis, and diatom analysis of ten levels from a sediment core from each site.

4. The appropriate diatom transfer functions are applied to the core data to generate quantitative reconstructions of pH and total phosphorus (TP) for each site, following taxonomic harmonization between the training sets and core species data. The pH reconstructions are calculated using the Surface Water Acidification Programme (SWAP) calibration set of 167 lakes from the UK and Scandinavia (Stevenson *et al.*, 1991), and the TP reconstructions are calculated using a Northwest European calibration set of 152 lakes (Bennion *et al.*, 1996).

5. The study shows that Llynnau Eiddwen and Fanod have not been recently acidified. However both sites have undergone surface water alkalization of 0.7 - 0.8 pH units since approximately 1850. This trend is most likely to be related to land-use practices within the lake catchments. The lakes have both been mesotrophic (cf. OECD, 1982) throughout the post-1850 period. There is no evidence of nutrient enrichment at Llyn Fanod. There is evidence of recent (post-1950s) trends in the diatom assemblages of Llyn Eiddwen which possibly reflect a slight increase in TP levels at this site. Although this change is within the error of the TP reconstruction technique, and therefore difficult to interpret with confidence, it may represent an early floristic response to increasing nutrient levels at Llyn Eiddwen.

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Table of Contents

Table of Contents continued

List of Figures

List of Tables

1 Objectives

Mesotrophic lakes, according to the OECD trophic classification scheme, are defined as having total phosphorus concentrations in the range 10 to 35 μg TP l^{-1} and chlorophyll *a* concentrations in the range 2.5 to 8 μg l^{-1} (OECD, 1982). They occur relatively infrequently in the United Kingdom and are largely confined to the margins of upland areas in the north and west. A mesotrophic lakes *Action Plan* has been produced which highlights artificial enrichment as a potential threat to this habitat and further research is proposed in this area (CCW, 1997). The action plan stresses the requirement for measures to counteract enrichment or other forms of pollution where they have occurred.

Llyn Eiddwen and Llyn Fanod in mid-Wales are the two best known examples of mesotrophic lakes in Wales (CCW, 1997). A recent survey of their lake water chemistry characteristics (Monteith, 1995) has confirmed their designation as mesotrophic sites. Further research is now required on these two Nature Conservation Review sites to determine if there have been any recent changes in their nutrient (phosphorus) or pH status which could have influenced their current mesotrophic condition.

This project, therefore, employs palaeolimnological techniques to determine the phosphorus and pH histories of the two lakes. Transfer functions are applied to the fossil diatom assemblages preserved in a sediment core from each site to reconstruct lake pH and total phosphorus concentrations for the post 1850 period. The time period represented by the core and the approximate sediment accumulation rates are established using carbonaceous particle profiles. This allows the onset, rate and extent of any environmental change at the two lakes to be assessed.

2 Methods

2.1 Coring and Lithostratigraphic Analyses

Long cores, approximately 80 cm, were taken from the deepest point of both sites using a Mackereth piston corer, operated from an inflatable boat. The cores were extruded in the laboratory and sliced at 0.5 cm vertical intervals to a depth of 20 cm and subsequently at 1 cm intervals to the core base. The core from Llyn Eiddwen was coded EIDW2 and the core from Llyn Fanod was coded FNOD2.

The percentage dry weight (%dw) for each sample was calculated by weighing approximately 1g of wet sediment in a pre-weighed crucible, from each pre-homogenised sediment layer, drying the sediment at 105°C for at least 16 hours, then reweighing the crucible. Approximate organic matter content was then determined (as a percentage loss on ignition %loi) by placing the crucible containing the dried sediment in a muffle furnace at 550°C for two hours and then reweighing.

2.2 Spheroidal Carbonaceous Particle (SCPs) Analyses

Analysis for spheroidal carbonaceous particles (SCPs) followed the procedure described in Rose (1994) involving the removal of unwanted sediment fractions by selective chemical attack. HNO_3, HF and HCl were used to remove the organic matter, mineral and biogenic silicates and carbonate minerals respectively from 20 levels of each core. A sub-sample of the resulting concentrate was evaporated onto a coverslip, mounted onto a microscope slide and counted at 400 x magnification using a light microscope.

SCP profiles in lake sediments in the United Kingdom show three main characteristics that enable approximate dates to be allocated to previously undated cores:

i) the start of the record linked to the start of high temperature fossil fuel combustion in the 1850s,
ii) the rapid increase in concentration following increases in energy demand after the Second World War in c.1950;
iii) the peak in SCP concentration attributed to changes in the trends in energy production in 1978 ± 2 years.

For a full account of the techniques used for dating using SCP profiles refer to Rose *et al.* (1995).

2.3 Diatom Transfer Functions

In the absence of long-term historical water chemistry data, the sediment accumulated in lakes can provide a record of past events and past chemical conditions (e.g. Smol, 1992). Diatoms (unicellular, siliceous algae) are particularly good indicators of past limnological conditions, for example lake pH, nutrient concentrations and salinity. In recent years, quantitative approaches have been developed, of which the techniques of weighted averaging (WA) regression and calibration, developed by ter Braak (e.g. ter Braak & van Dam, 1989), are currently the most statistically robust and ecologically appropriate. WA has become a standard technique in palaeolimnology for reconstructing past environmental variables. The methodology and the advantages of WA over other methods of regression and calibration are well documented (e.g. ter Braak & van Dam, 1989; ter Braak & Juggins, 1993).

Using the technique of WA, a predictive equation known as a transfer function can be generated that enables the inference of a selected environmental variable from fossil diatom assemblages, based on the relationship between modern surface-sediment diatom assemblages and contemporary environmental data for a large training set of lakes. This approach has been successfully employed in recent years to quantitatively infer lake pH (e.g. Birks *et al.*, 1990) and lake total phosphorus (TP) concentrations (e.g. Anderson *et al.*, 1993; Bennion, 1994; Bennion *et al.*, 1996), whereby modern diatom pH and TP optima are calculated for each taxon based on their distribution in the training set, and then past pH and TP concentrations are derived from the weighted average of the optima of all diatoms present in a given fossil sample. These models are able to provide estimates of baseline pH and TP concentrations in lakes, and coupled with dating of sediment cores (radiometric or SCPs), enable the timing, rates and possible causes of acidification and enrichment to be assessed for a particular site. This information can be used to assist in lake classification system design and can be incorporated into lake management and conservation programmes.

In this study, ten levels from each core were prepared and analysed for diatoms using standard techniques (Battarbee, 1986). At least 300 valves were counted from each sample using a Leitz research quality microscope with a 100 x oil immersion objective and phase contrast. The data were expressed as percentage relative abundance. Cluster analysis was performed on the percentage diatom data of each core to facilitate description by zones, using CONISS (Grimm, 1987), implemented by TILIA and TILIAGRAPH (Grimm, 1991). CONISS is a program for stratigraphically constrained cluster analysis by the method of incremental sum of squares.

The appropriate transfer functions were applied to the core data to generate quantitative reconstructions of pH and TP for each site, following taxonomic harmonization between the training sets and core species data. The pH reconstructions were calculated using the Surface Water Acidification Programme (SWAP) calibration set of 167 lakes from the UK and Scandinavia (Stevenson *et al.*, 1991), and the TP reconstructions were calculated using a Northwest European calibration set of 152 lakes (Bennion *et al.*, 1996). The pH results presented in this report are based on simple WA with classical deshrinking, which is more appropriate than inverse regression when the current pH of the site being reconstructed lies at the end of the pH gradient spanned by the training set. The TP results are based on WA partial least squares (WA-PLS), which is simply an extension of WA that uses the residual correlation in the diatom data to improve the predictive power of the WA regression coefficients (ter Braak & Juggins, 1993). This is done through the selection of a small number of components, the optimum number of components being estimated by jack-knifing cross-validation. The optimum number of components in the TP model used here was two (see Bennion *et al.*, 1996 for further details). The TP data used in the model were $\log_{10}$-transformed annual mean concentrations. The reconstructions were implemented using CALIBRATE (Juggins & ter Braak, 1993).

3 Llyn Eiddwen (SN 605 670)

3.1 Lithostratigraphy and Dating

An 80 cm core was taken from Llyn Eiddwen (EIDW2) on 21-6-97 using a Mackereth piston corer. The core was obtained from a depth of 7 m in the main basin of the lake.

The lithostratigraphy of core EIDW2 is shown in Figure 1. Below 40 cm the lithostratigraphy was characterised by fluctuating %loi values of between 60 and 70%, and relatively stable dry weight (c. 12%). At 38 cm there was a clear and rapid change in lithostratigraphy with an increase in %loi to >80% by 34 cm, accompanied by a decrease in dry weight values to <10%. At 30 cm there was a second rapid change in lithostratigraphy, with a decline in %loi values to < 50% and an increase in dry weight. Above the 25 cm level dry weight values were relatively stable at c. 12%. However, %loi values continued to vary, with a rapid increase to >60% at 18 cm followed by a gradual decline to c.30% in the surface sediment sample.

The results of spheroidal carbonaceous particle analysis (SCP) from Llyn Eiddwen, core EIDW2, are given in Table 1 and illustrated in Figure 2. The concentration data are presented in the Appendix Table I. The results suggest that the core contains a continuous undisturbed stratigraphic record. The subsurface peak exhibited at 1 cm is a feature consistent with those shown in other SCP profiles for Welsh cores (Rose *et al.*, 1995), and this horizon is typically dated to 1978 ±2. The falling levels of SCPs above this horizon represent the trend in improvement of particle removal from flue gases as a result of more stringent pollution legislation. The second of the three features commonly observed in SCP profiles, namely the beginning of a sudden increase in SCP concentration commensurate with rapidly increasing electricity generation occurring in the early 1950s, was also clearly visible at around 9 cm. This feature was very clear in the profile.

An important anomaly seen when Llyn Eiddwen's profile was compared with other Welsh examples was that the SCP concentration did not diminish to zero towards the base of the core. Possible reasons for this include slight sediment smearing during core extrusion or the possible inclusion of inorganic ash spheres in the counts. The above notwithstanding, extrapolation from the 9 cm SCP feature along a gradient typically seen in other Welsh core profiles (Rose *et al.*, 1995) established a date of approximately 1850 at a depth of c. 40 cm.

Using depths of 0 cm, 1 cm, 9 cm and 40 cm and dates of 1997, 1978, 1950 and 1850 respectively it was possible to calculate sediment accumulation rates down the core of 3.1 mm yr^{-1} between 1850 and 1950, 2.9 mm yr^{-1} from 1950 to 1978 and 0.5 mm yr^{-1} between 1978 and 1997 when the core was taken (Table 1).

Table 1 Spheroidal carbonaceous particle dating results for Llyn Eiddwen

Depth	Approx. Date	Approx. Acc. Rate
1 cm	1978±2	0.5 mm yr^{-1}
9 cm	1950	2.9 mm yr^{-1}
40 cm	1850	3.1 mm yr^{-1}

Figure 1 **Lithostratigraphic data for Llyn Eiddwen**

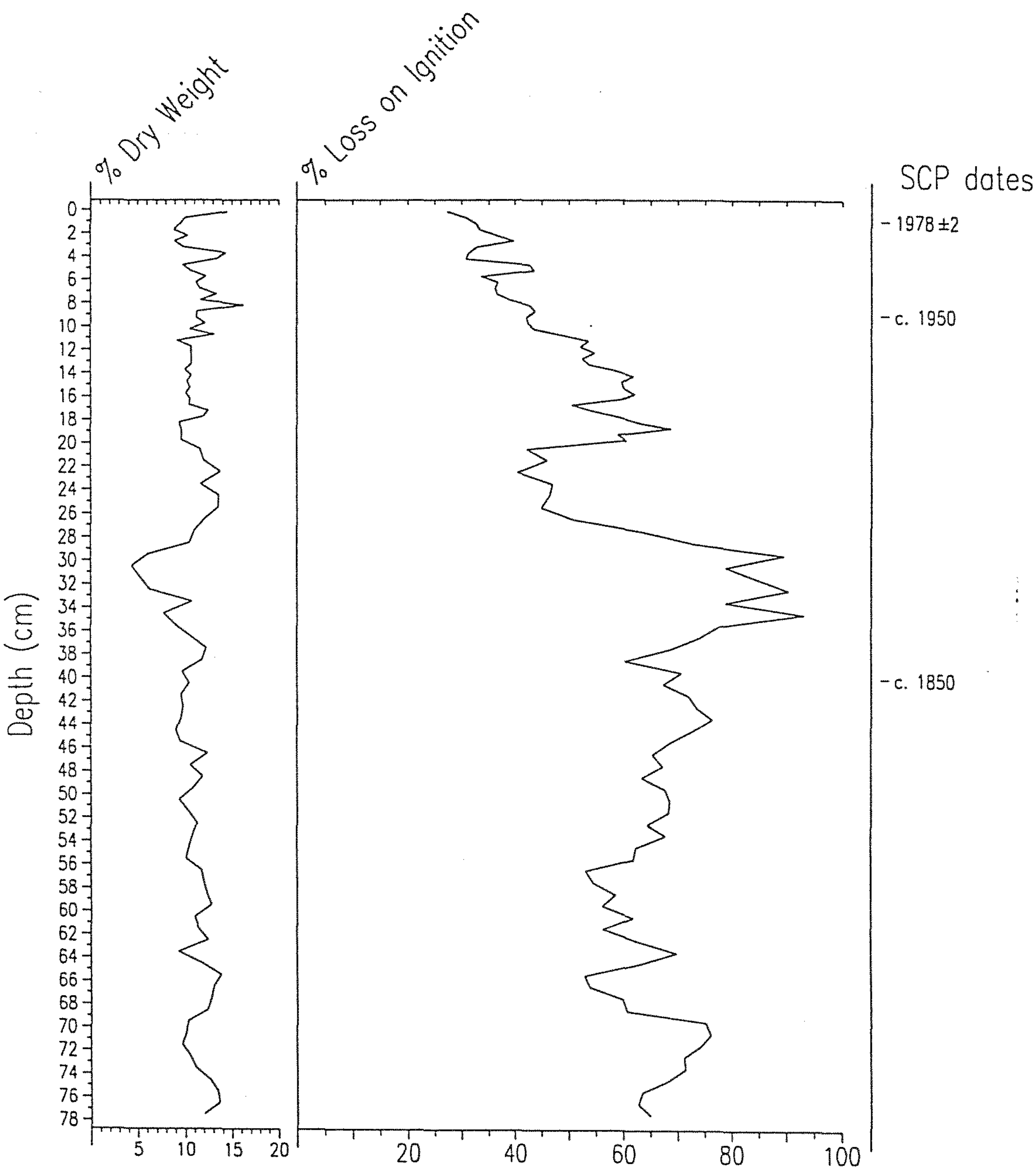
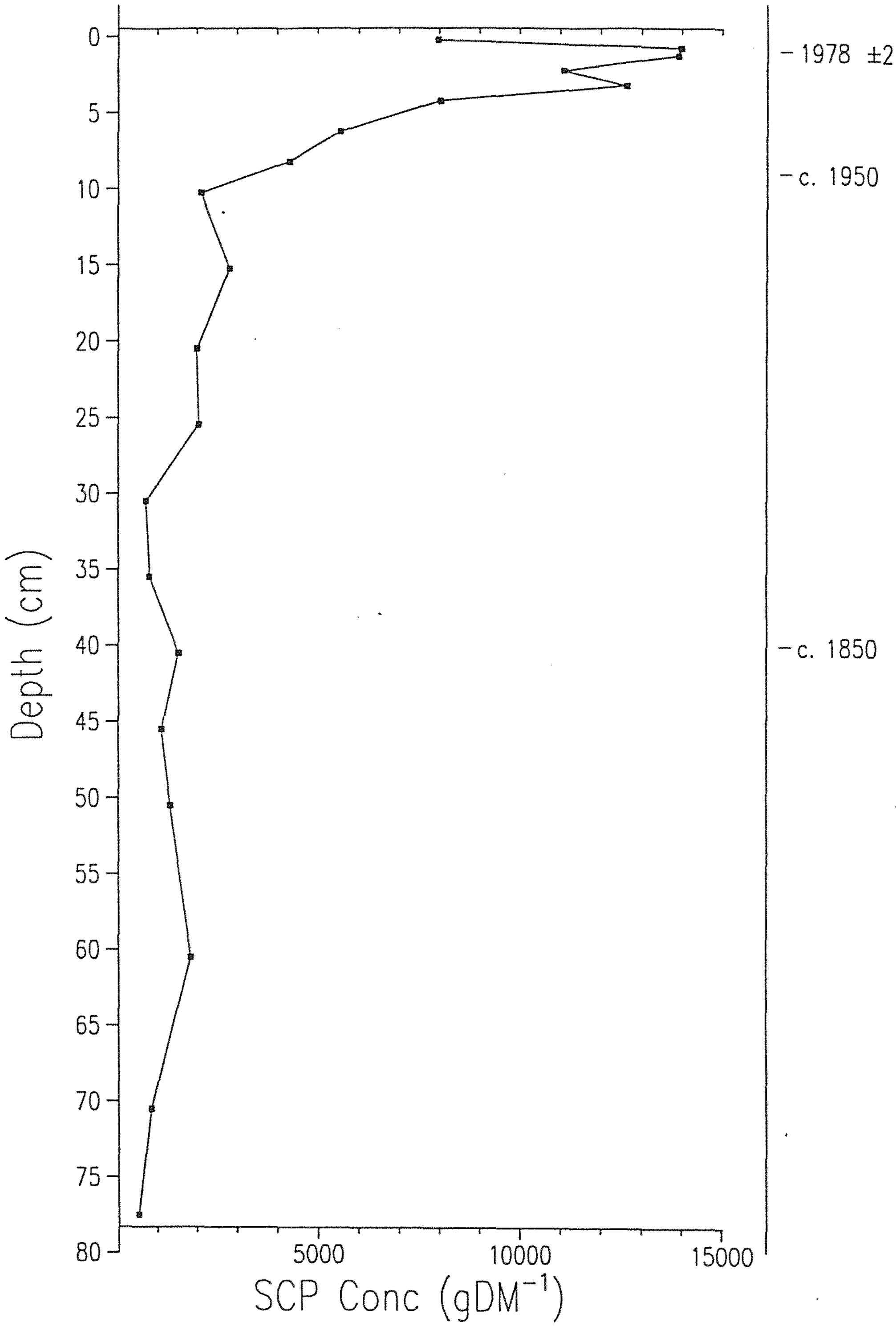


Figure 2 **Spheroidal carbonaceous particle profile for Llyn Eiddwen**



3.2 Diatom Stratigraphy

The ten stratigraphic levels selected for diatom analysis from the core (EIDW2) were 0-0.5 cm, 2-2.5 cm, 4-4.5 cm, 6-6.5 cm, 8-8.5 cm, 10-10.5 cm, 14-14.5 cm, 20-21 cm, 30-31 cm and 40-41 cm. These levels were selected to cover the period since approximately 1850 with the emphasis on the post-1950 period (see SCP chronology). This strategy was designed to allow pre-anthropogenic baseline pH and nutrient values to be estimated (ie. 1850) as well as for the recent trends and directions in water quality to be assessed.

The fossil data contained 129 diatom taxa and preservation was good throughout the core. The diatom assemblages were diverse with the total number of taxa observed in each sample ranging from 54 to 73. The diatom record of Llyn Eiddwen exhibited a number of marked changes and has been zoned into three diatom assemblage zones, as defined by cluster analysis, for the purposes of description. A list of the complete diatom percentage counts, names and codes for each sample are given in the Appendix Tables III and V. A summary diatom diagram of the major taxa is shown in Figure 3.

Assemblages in Zone 1 (40 - 25 cm; c. 1850-1900) were characterised by high abundances of *Fragilaria construens* var. *venter* and *Tabellaria flocculosa*. Other common taxa in this zone included *Fragilaria virescens* var. *exigua*, *Pinnularia irrorata*, *Achnanthes minutissima* and *Achnanthes pusilla*. *Eunotia incisa* and *Navicula minima* were also present. The assemblages included taxa associated with both acidic waters (e.g. *T. flocculosa*, *P. irrorata*) and more circumneutral conditions (e.g. *A. minutissima*).

Zone 2 (25 - 9 cm; c. 1900 - 1950s) was characterised by increased abundances of *A. minutissima*, with *A. pusilla*, *F. virescens* var. *exigua*, *F. construens* var. *venter* and *Cymbella gracilis* also common. The acidophilous *E. incisa* was still present, but *T. flocculosa* and *P. irrorata* declined in abundance. The assemblages here were indicative of circumneutral to slightly acid conditions.

Zone 3 (9 - 0 cm; 1950s - 1997) was characterised by a significant and continued increase in the abundance of *Synedra nana*. This was present in abundances <3% below 8 cm, but dominated the uppermost samples. The taxonomy of *S. nana* is problematic, as the taxon is difficult to distinguish reliably from *S. tenera*, *S. acus* var. *angustissima* and finer forms of *S. acus*. In the Surface Waters Acidification Project (SWAP) diatom training set *S. nana* and *S. tenera* were recognised as distinct species (Stevenson *et al.* 1991). However in the training set of Bennion *et al.* (1996) it was decided that diatoms within the *S. nana-S. tenera-S. acus* var. *angustissima* complex could not be reliably separated, and were therefore combined into *S. nana*. The taxonomy of this group in the current report follows Bennion *et al.* (1996). Note that Monteith (1995) reported the dominant *Synedra* species in the surface sediments of Llyn Eiddwen to be *S. acus*. Re-inspection of this material indicated that this identification should be re-assigned to *S. nana* sensu Bennion *et al.*(1996).

Several other species were also abundant in Zone 3 including *A. minutissima* and *F. virescens* var. *exigua*, with *A. pusilla* and *F. construens* var. *venter* also common. *E. incisa* declined in abundance in the uppermost samples. The surface sediment was characterised by the sudden appearance in significant abundance (>10%) of the planktonic *Cyclotella glomerata*.

3.3 pH Reconstruction

Following taxonomic harmonization for consistency with the SWAP training set (Stevenson *et al.* 1991) core EIDW2 contained 124 taxa, 84 of which were present in the training set. Species analogues were generally good with greater than 90% of the fossil assemblage being used in the pH reconstructions in the upper sediments, and greater than 85% being used in the lower sections of the core (see Table 2).

The pH reconstruction (Table 2 and Figure 4) shows relatively low DI-pH values in the lower section of the core. The DI-pH value at 40 cm (c.1850s) was c.6.1 and this fell to c.5.9 at the 30 cm level (late 1880s) due to increased abundances of the acidophilous taxa *F. rhomboides.* var. *saxonica* and *P. irrorata*. Above this level there was a clear increase in DI-pH values due to increased abundance of the circumneutral *A. minutissima*, and between 20 - 10 cm (early 1900s) the DI-pH was c.6.3. The upper section of the core (10 - 0 cm; post 1950s) was characterised by a further trend of increasing DI-pH, principally due to increasing abundance of *S. nana*. The DI-pH value in the surface sediment was 6.9, which represents a higher value than the measured lake-water pH of 6.55 in 1994-95 (Monteith,1995). The surface sediment sample is characterised by high abundance of *C. glomerata*, possibly representing a recent bloom in this taxon, resulting in the relative elevation of DI-pH. The DI-pH value at the 2 cm level is c.6.65 and represents a relatively close match to the measured mean lake-water pH value of 6.55 from the 1994-95 CCW survey (Monteith,1995).

The DI-pH data therefore indicate an increase in lake-water pH by approximately 0.7 - 0.8 units since the late 1800s.

3.4 TP Reconstruction

Following taxonomic harmonization for consistency with the TP training set (Bennion *et al.*, 1996) core EIDW2 contained 128 taxa, 93 of which were present in the training set. Species analogues were generally good with greater than 87% of the fossil assemblage being used in the TP reconstructions for most of the samples (see Table 2). The exceptions were the samples at 14 cm, 30 cm and 40 cm, where c.80% of the fossil assemblages were used in the reconstructions and the species analogues were therefore moderate. These levels contain acidophilous taxa which are not represented in the training set, such as *P. irrorata*.

The TP reconstruction (Table 2 and Figure 4) indicates relatively stable DI-TP values of 18-20 μg TP l^{-1} between 40 cm and 8 cm. An exception was the sample at 30 cm, which had a depressed DI-TP value of c.12 μg TP l^{-1} due to the increased abundance of *F. rhomboides* var. *saxonica* (TP optimum 9 μg TP l^{-1}). Above 8 cm there was a clear trend of increasing DI-TP with values reaching maximum values c.28 μg TP l^{-1} at the 2 cm level. This increase in DI-TP was driven by the increased abundance of *S. nana* which has a relatively high TP optima (85 μg TP l^{-1}) in the training set. The DI-TP value for the surface sediment sample (c.23 μg TP l^{-1}) was slightly higher than the measured mean lake-water TP value of 20.5 μg TP l^{-1} in the 1994-95 CCW survey (Monteith, 1995).

Table 2 Diatom-inferred total phosphorus (DI-TP) and pH (DI-pH) results for Llyn Eiddwen - EIDW2

Depth cm	*DI-TP (μg l^{-1})*	*TP Analogues %*	*DI-pH*	*pH Analogues %*
0-0.5	23	91	6.89	90
2-2.5	28	89	6.66	91
4-4.5	24	93	6.67	91
6-6.5	21	87	6.53	88
8-8.5	18	89	6.40	92
10-10.5	19	87	6.35	88
14-14.5	19	80	6.24	87
20-21	17	88	6.35	90
30-31	12	78	5.86	85
40-41	20	81	6.13	87

Figure 3 **Summary diatom diagram for Llyn Eiddwen**

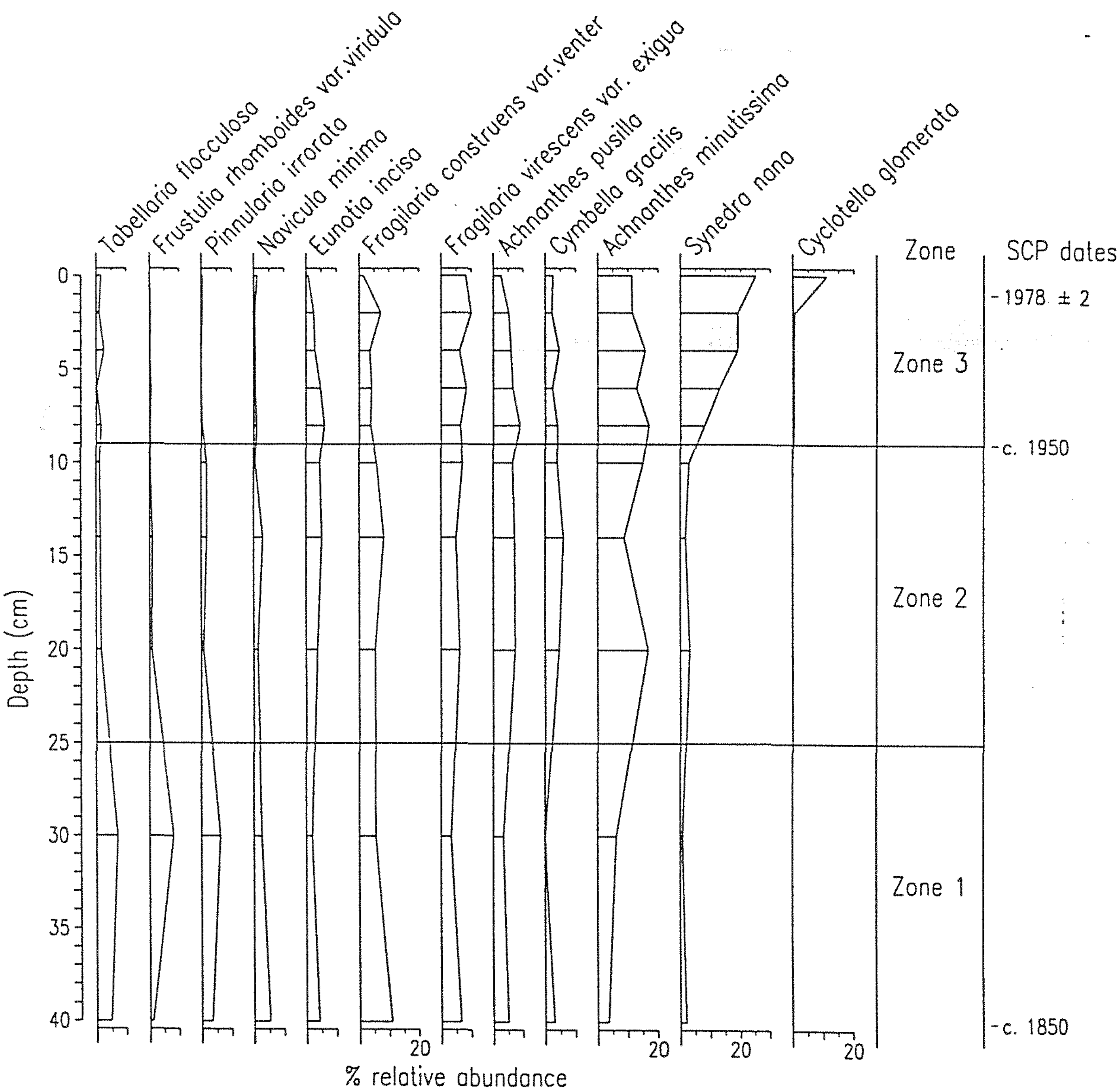
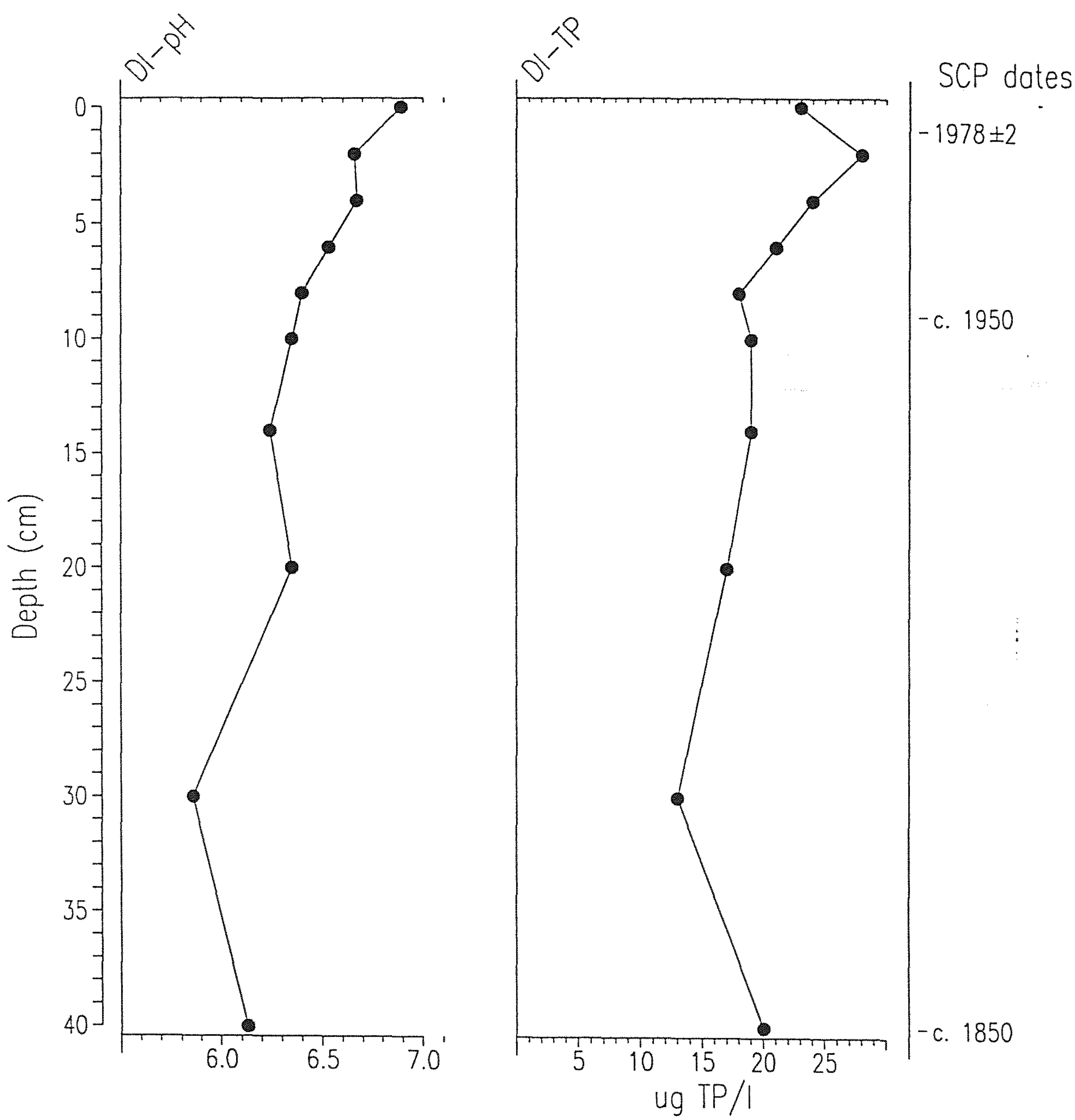


Figure 4 **pH and TP reconstructions for Llyn Eiddwen**



4 Llyn Fanod (SN 603 643)

4.1 Lithostratigraphy and Dating

An 80 cm core was taken from Llyn Fanod (FNOD2) on 21-6-97 using a Mackereth piston corer. The core was obtained from a depth of 8 m in the main basin of the lake.

The %loi profile for Llyn Fanod (Figure 5) indicated that there was a gradual increase in the percentage organic content from c. 18% at the core base to c. 30% at 45 cm. This was followed by a decline to values similar to those at the bottom of the core by the 30 cm level. A marked increase followed with values peaking at 45% at approximately 15 cm in the core. The values fluctuated considerably in the section 20-10 cm but remained high, and then decreased significantly from c. 35% at 10 cm to c. 25% at the core surface. This pattern was not reflected by the %dw profile which was much smoother. The %dw remained at c. 25-30% for the whole of the lower core section (80-30 cm). There was a decrease, however, coincident with the marked increase in %loi from 30 to 20 cm, with %dw values declining to c. 20%. A further decrease in %dw occurred in the upper 10 cm of the core, with values of only 10% at the surface.

The results of spheroidal carbonaceous particle (SCP) analysis from Llyn Fanod, core FNOD2, are given in Table 3 and illustrated in Figure 6. The concentration data are presented in the Appendix Table II. The profile obtained conforms well with those shown as typical for the UK by Rose *et al.* (1995). This suggests that the sediment has experienced minimal disturbance and that the record is complete and continuous.

Two of the three main features commonly exhibited in spheroidal carbonaceous particle (SCP) profiles were readily discernible in the Llyn Fanod core. At 2.25 cm the SCP concentration reached its peak of c. 16400 particles gDM^{-1}, corresponding to the timing of improvements in particle arresting techniques. From their analysis of Welsh sediment cores, Rose *et al.* (1995) found this peak represented 1978 ±2. The second key feature, that of the rapid increase associated with post-War electricity generation industry expansion, occurred very clearly at around 10 cm in the core, dating this level to the 1950s. The SCP concentration tailed off gradually to a concentration of zero at 40 cm. This level would, by extrapolation of the curve down from 15 cm and reference to the inferred approximate sediment accumulation rates above 15 cm, appear to represent the point at which high temperature fossil fuel combustion began around 1850. The samples below 40 cm had very low concentrations of SCPs, resulting from a count of a single particle and may be the consequence of minimal amounts of smearing during core extrusion.

Sediment accumulation rates calculated using the three obtained dates displayed in Table 3 suggest approximately 3 mm yr^{-1} between 40 cm and 10 cm, 2.8 mm yr^{-1} from 10 cm to 2.25 cm and 1.1 mm yr^{-1} between 2.25 cm and the surface.

Table 3 Spheroidal carbonaceous particle dating results for Llyn Fanod

Approx. Depth	Year	Approx. Acc. Rate
2.25 cm	1978±2	1.1 mm yr^{-1}
10 cm	c. 1950	2.8 mm yr^{-1}
40 cm	c. 1850	3 mm yr^{-1}

Figure 5 **Lithostratigraphic data for Llyn Fanod**

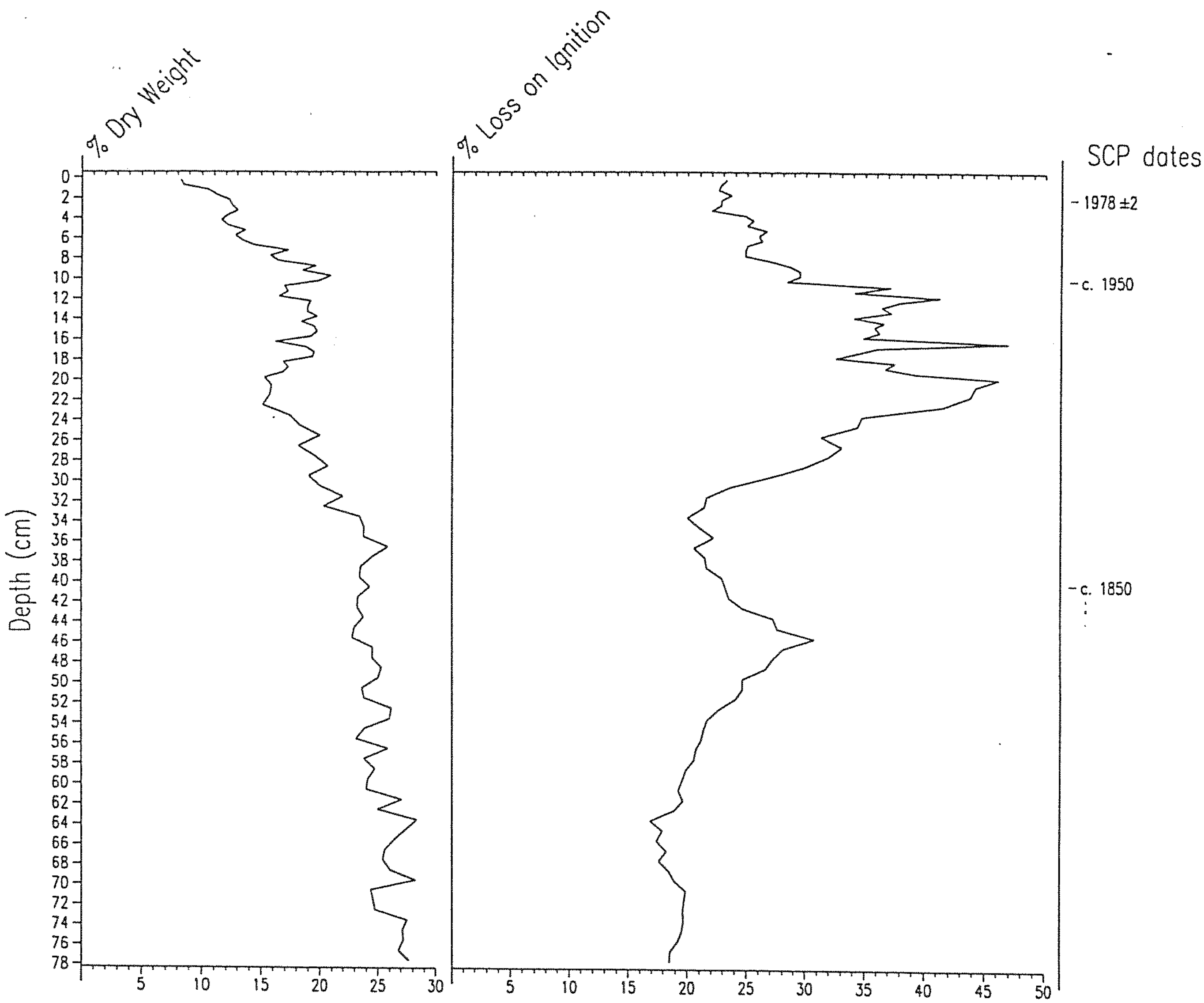
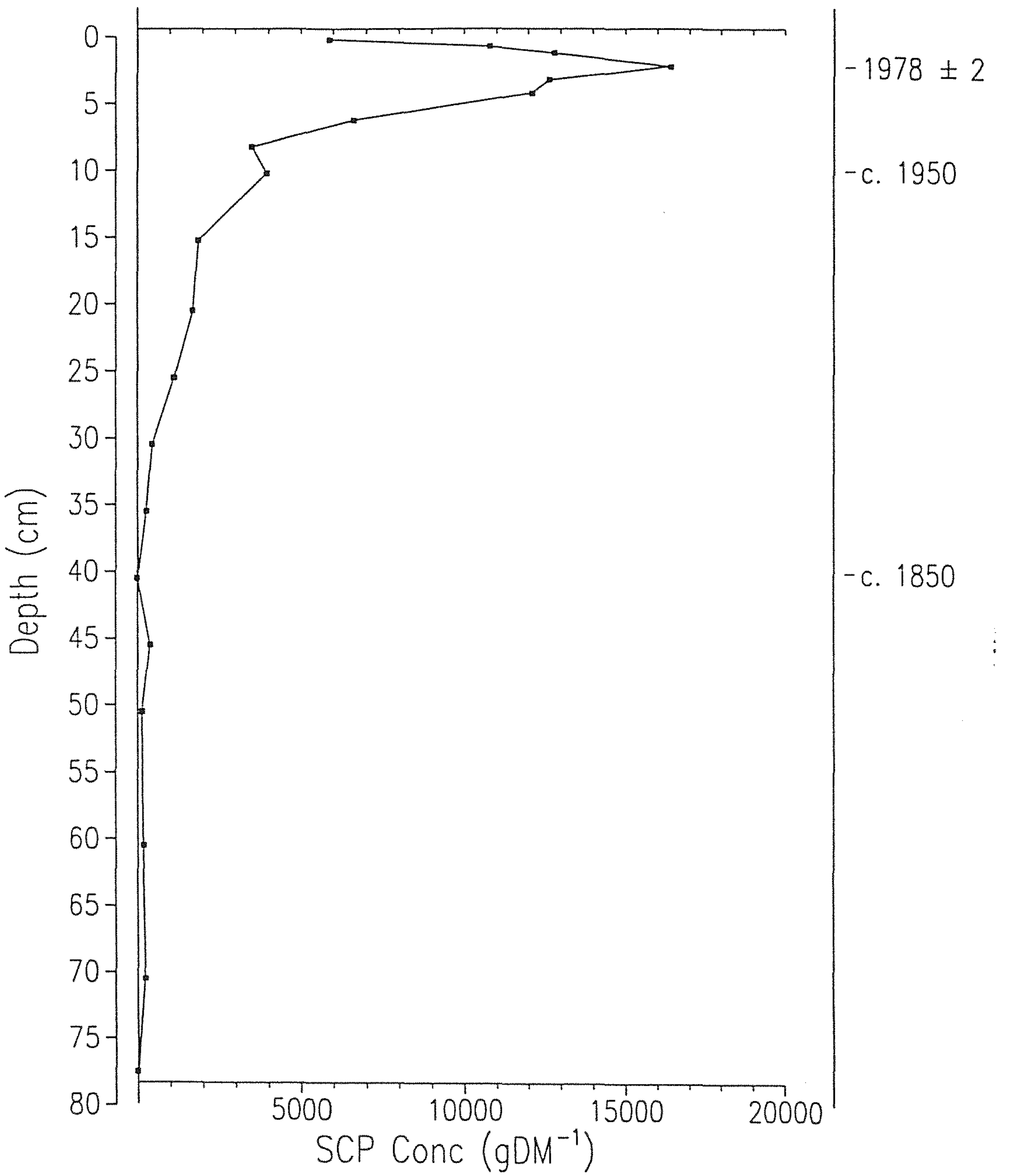


Figure 6 **Spheroidal carbonaceous particle profile for Llyn Fanod**



4.2 Diatom Stratigraphy

The ten stratigraphic levels selected for diatom analysis from the core (FNOD2) were 0-0.5 cm, 2-2.5 cm, 4-4.5 cm, 6-6.5 cm, 8-8.5 cm, 10-10.5 cm, 16-16.5 cm, 20-21 cm, 30-31 cm and 40-41 cm. These levels were selected to cover the period since approximately 1850 with the emphasis on the post-1950 period (see SCP chronology). As for Llyn Eiddwen, this strategy was designed to allow pre-anthropogenic baseline pH and nutrient values to be estimated (ie. 1850) as well as for recent trends and directions in water quality to be assessed.

The fossil data contained 113 diatom taxa and preservation was good throughout the core. The diatom assemblages were diverse with the total number of taxa observed in each sample ranging from 39 to 62. The diatom record of Llyn Fanod exhibited a number of marked changes and has been zoned into three diatom assemblage zones, as defined by cluster analysis, for the purposes of description. A list of the complete diatom percentage counts, names and codes for each sample are given in the Appendix Tables IV and VI. A summary diatom diagram of the major taxa is shown in Figure 7.

Zone 1 from 40 cm to 25 cm (c. 1850 -1900) was dominated by two *Eunotia* taxa, *E. incisa* (20%) and *E. intermedia* (6%), *Fragilaria construens* var. *venter* (10%), *Gomphonema parvulum* (8%) and *Achnanthes minutissima* (10%). Other taxa were present in abundances of <5%, but included *Tabellaria flocculosa*, *Achnanthes subatomoides*, *Achnanthes linearis, Cymbella gracilis* and *Fragilaria virescens* var. *exigua*. These are all non-planktonic forms found either in epiphytic communities (attached to plants) or in epilithic habitats (attached to rocks and stones). They can also be found in benthic habitats on the lake bed attached to the sediment. The assemblages contained taxa that are usually associated with slightly acidic waters (eg. *E. incisa* and *F. virescens* var. *exigua*), as well as taxa more commonly observed in circumneutral to slightly alkaline waters (eg. *A. minutissima* and *G. parvulum*).

Zone 2 from 25 cm to 13 cm (c. 1900 - 1930s) differed slightly from Zone 1 in that the two *Eunotia* taxa declined in relative abundance whilst the percentages of *Tabellaria flocculosa* (in particular), *Achnanthes subatomoides* and two *Navicula* taxa, *N. seminulum* and *N. schassmannii* increased. However, there were no clear species replacements and the species lists for Zones 1 and 2 were very similar.

Zone 3 from 13 cm to the surface (c. 1930s-1997) exhibited more marked changes than those observed in the lower zones. The most significant being the gradual increase in the importance of *A. minutissima* to 30% of the total assemblage in the 8 cm sample. Other notable changes were increases in *F. virecens* var. *exigua* and *F. construens* var. *venter* to approximately 15%, and the appearance of a planktonic diatom *Cyclotella stelligera* from the 15 cm level upwards, representing 6% in the surface sample. Consequently, those taxa that dominated Zone 2 declined in relative abundance, particularly *T. flocculosa, A. subatomoides, N. seminulum, G. parvulum* and *N. schassmannii. E. intermedia* disappeared from the record from the 16 cm sample. A number of other taxa, though not particularly abundant, increased in this zone, namely *Fragilaria intermedia, Fragilaria capucina* and *Tabellaria fenestrata.* A few specimens of *Asterionella formosa*, a planktonic diatom commonly associated with nutrient-rich waters, were observed in the 2-2.5 cm and 4-4.5 cm samples but it was not observed in the surface sample.

4.3 pH Reconstruction

Following taxonomic harmonisation with the SWAP training set (Stevenson *et al.*, 1991), 68 of the 113 taxa present in the Llyn Fanod core were present in the pH training set. Species analogues were good, with greater than 80% of the fossil data being used in the reconstructions. Species analogues were highest for the upper core section, above 10 cm (see Table 4).

The DI-pH results are shown in Table 4 and the reconstruction is plotted in Figure 8. The DI-pH values ranged from 5.83 in the 30 cm sample to 6.47 for the surface sample, indicating that the lake has always been slightly acid. The model results suggest that lake pH has increased slightly in recent decades with on average higher DI-TP values for the samples above the 10 cm level than for the samples below 10 cm. This trend of increasing DI-pH appeared to be principally due to a decline in the abundance of the acidophilous taxon *E. incisa* and an increase in the abundance of more circumneutral taxa such as *A. minutissima* and *F. construens* var. *venter.* The DI-TP value for the surface sample compares favourably with the measured annual mean pH for 1994-5 of 6.71 (Monteith, 1995), although the model does appear to slightly under-estimate.

The DI-pH data therefore indicate an increase in lake-water pH by approximately 0.7 units since the late 1800s.

4.4 TP Reconstruction

Following taxonomic harmonisation with the Bennion *et al.* (1996) TP training set, 73 of the 112 taxa present in the Llyn Fanod core were present in the training set. Species analogues varied from good, with greater than 85% of the fossil data being used in the reconstructions for the samples above 10 cm, to moderate, with less than 85% being used for the samples below 10 cm. Analogues between the fossil and training set species data were poorest for the 16-16.5 cm and the 20-21 cm samples (see Table 4), largely due to the absence of *Achnanthes subatomoides* in the TP training set..

The DI-TP results are shown in Table 4 and the reconstruction is plotted in Figure 8. The values are indicative of mesotrophic conditions, lying in the range 15-22 μg TP l^{-1}. The DI-TP value for the surface sample was 16 μg TP l^{-1}, which compares well with the mean annual lake-water TP concentration of 18 μg TP l^{-1} recorded in 1994-5 (Monteith, 1995), indicating that the model reconstructions are accurate for this site. There was some variation in TP values throughout the core, although there were no clear trends or directions in the nutrient changes.

Table 4 **Diatom-inferred total phosphorus (DI-TP) and pH (DI-pH) results for Llyn Fanod - FNOD2**

Depth cm	*DI-TP (μg l⁻¹)*	*TP Analogues %*	*DI-pH*	*pH Analogues %*
0-0.5	16	87	6.47	89
2-2.5	18	89	6.38	89
4-4.5	19	88	6.45	87
6-6.5	19	90	6.28	88
8-8.5	15	87	6.33	88
10-10.5	15	84	6.32	80
16-16.5	21	73	6.08	81
20-21	19	77	6.02	82
30-31	16	80	5.83	84
40-41	22	78	6.08	82

Figure 7 **Summary diatom diagram for Llyn Fanod**

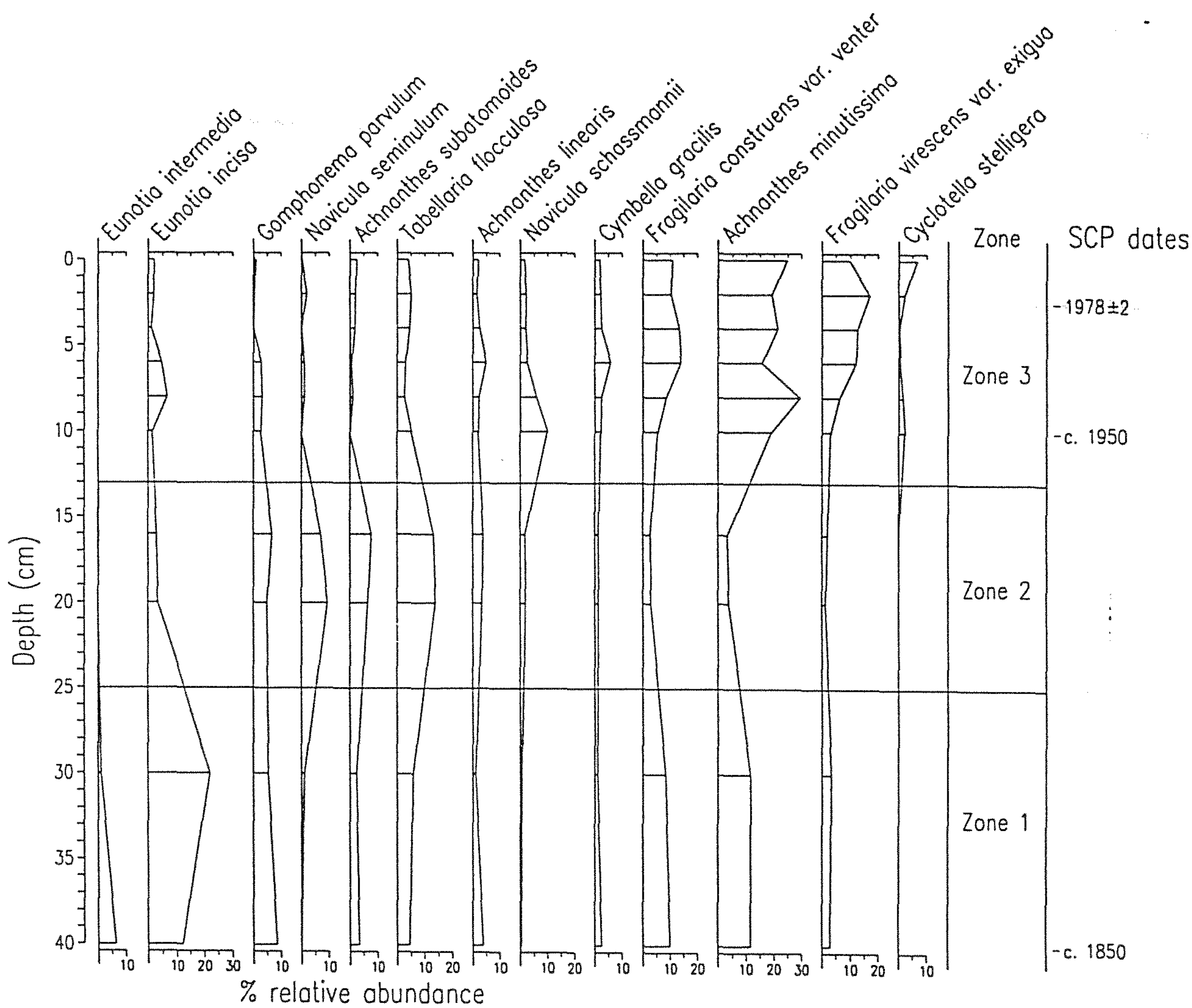
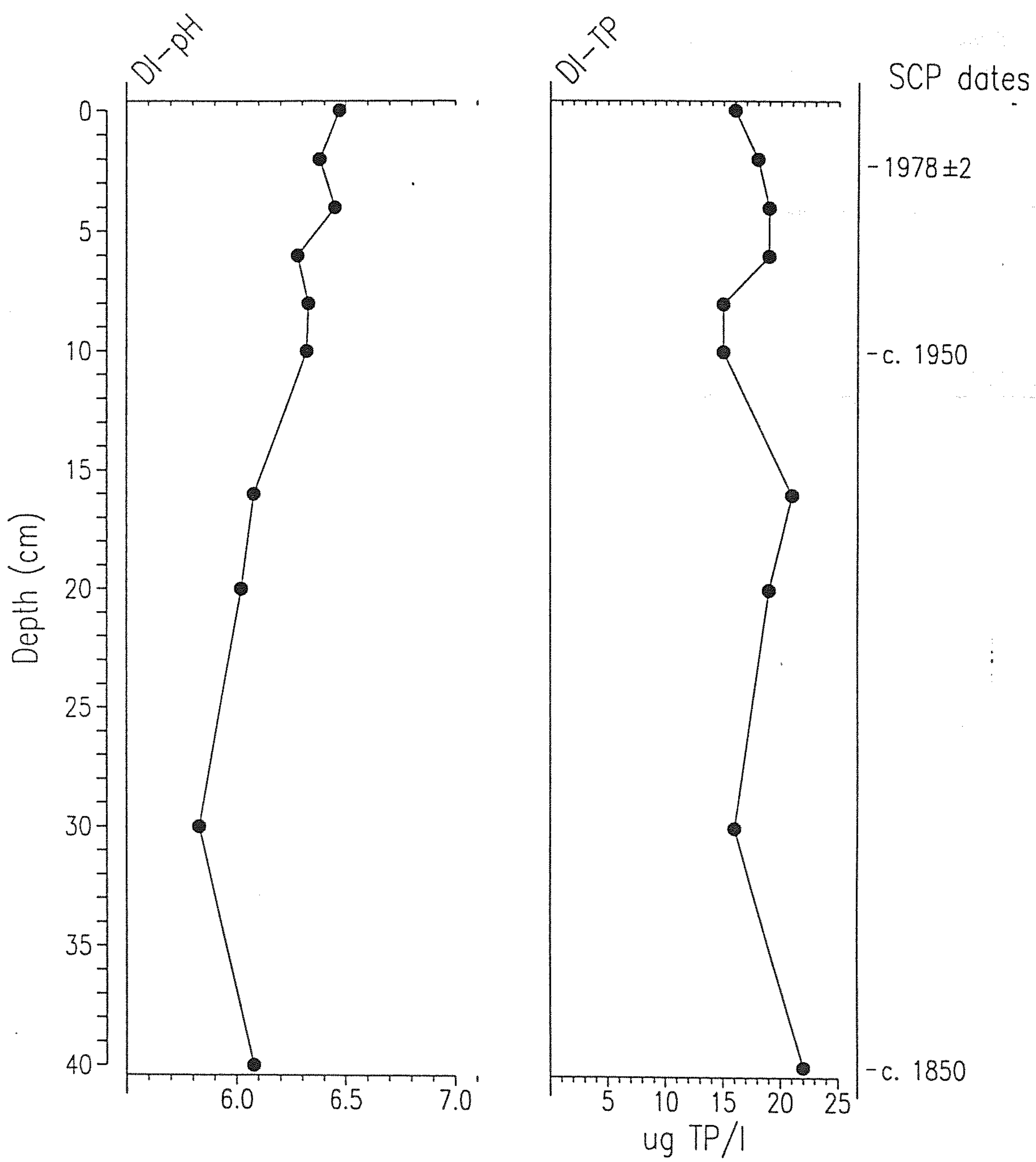


Figure 8 **pH and TP reconstructions for Llyn Fanod**



5 Discussion

5.1 Llyn Eiddwen

5.1.1 Lithostratigraphy and Catchment Disturbance

There were clear changes in the lithostratigraphic record of EIDW2 (Figure 1) which can be interpreted as representing changes in the sources of sediment. Below 40 cm (c. 1850) there were minor fluctuations in %loi, but it is difficult to interpret the significance of these with confidence. However, there was a clear episode of increased organic sediment between 36 and 28 cm (late 1800s). Such increases in %loi are sometimes attributed to increased autochthonous organic matter production following nutrient enrichment. However, this interpretation cannot be supported at Llyn Eiddwen as there is no evidence of significantly increased DI-TP levels during this episode (see Table 2 and Figure 4). It seems likely that the episode is associated with a change in the supply of sediment from the catchment area related to catchment disturbance. In particular it may represent a period of peat inwash from the peaty deposits surrounding the lake (see Adams, 1983 and Monteith, 1995). Similar episodes of peat inwash have been recorded from a range of upland lakes in the UK, and Stevenson *et al.* (1990) have argued they are associated with burning and grazing activity.

Above 28 cm (approximately post 1900) there is a general trend of declining %loi values, although there are some further fluctuations. This represents a shift towards more minerogenic sediments. Again, this is most likely to have resulted from changes in the sediment delivered from the catchment through erosion processes.

5.1.2 Evidence of Acidification

There is no evidence of acidification at Llyn Eiddwen from either the diatom record or application of the diatom-pH transfer function. The DI-pH values indicate an increase in lake-water pH of approximately 0.7-0.8 units over the period represented by the diatom record (e.g. post c.1850). This lack of acidification is consistent with predictions based on critical load modelling. Monteith (1995) applied two critical loads models to water chemistry data collected during the 1994-95 CCW survey and found no evidence of critical loads exceedance (i.e. no prediction of acidification). The palaeolimnological data confirm these findings and suggest that the lake has sufficient acid neutralizing capacity to buffer current levels of acidic deposition.

The trend of increasing DI-pH in the diatom record is a very unusual feature for a relatively low-alkalinity upland lake in Wales or Britain (cf. Battarbee *et al.,* 1988). It suggests alkalization rather than acidification over the period since c. 1850. This alkalization is most likely to be related to land-use practices within the catchment. There are two processes by which this might occur; base-cation leaching following catchment disturbance and cultivation, and agricultural improvement through catchment liming.

Renberg *et al.* (1993) provide evidence of alkalization of Swedish lakes following agricultural intensification and cultivation. They cite catchment burning as an important source of base cations to lake-waters, both through direct inputs via airborne ash and particulate matter and through the release of base cations from organic soil layers. They also discuss the possible important role of surface runoff from cultivated or ploughed land in increasing rates of base-cation leaching from catchment soils.

Adams (1983) presents a useful summary of recent land-use change on the Myndd Bach. It is clear that much of the area was cultivated during the sixteenth and seventeenth century, and Adams considers that until approximately 45 years ago many areas which are now unimproved grazing were ploughed. There is clear evidence for rural depopulation in the area over the last century and a gradual decline in the quality of grasslands (Adams, 1983).

These trends in land use are counter to those which would be expected to cause lake-water alkalization through disturbance induced base-cation leaching. However, Adams (1983) considers it likely that cultivation and ploughing at Llyn Eiddwen may have occurred during the First and Second World Wars, periods during which there was an increased demand for wheat. It is therefore possible that such processes have influenced the alkalization of Llyn Eiddwen. It is interesting to note that the alkalization occurs after the start of the period of catchment disturbance, as recorded in the %loi record (see section 3.1).

Many areas of upland Wales have been improved for sheep grazing, typically by the addition of lime to catchment soils to adjust soil pH and increase nutrient availability to the sward (Boon & Kay, 1990). Moore-Colyer (1988) provides an account of the location of lime kilns in Cardiganshire and describes the application of lime to both arable and pasture land in this region dating back to the eighteenth century. The current dominant form of land-use within the catchment is sheep grazing, and Newbold (1977) and Adams (1983) describe the sheep pasture in the catchment as unimproved. However, observations during the CCW survey of 1994-95 and subsequent inspection of aerial photographs indicate that although grassland adjacent to the lake is unimproved, much of the grazing in the catchment has been improved. This indicates that lime and/or fertilizer additions have been made in the past. It is therefore plausible that the alkalization is associated with agricultural liming of catchment soils for improved grazing.

Without more detailed land-use data, in particular data on lime additions to the catchment, stocking densities and a more detailed cultivation history, it is difficult to test these hypotheses. However it is clear that the lake-water pH was significantly lower than present values during the period represented by the diatom assemblages at 30 - 40 cm (late 1800s). This is most likely to be linked to increasing lake water base cation concentrations.

5.1.3 Evidence of Eutrophication

Application of the diatom-TP transfer function to core EIDW2 suggests that nutrient concentrations have been within the range 13- 28 μg TP l^{-1} throughout the period represented by the diatom record (approximately post 1850s). There is no coherent trend in DI-TP prior to the 8 cm level, with values fluctuating around 17 - 20 μg TP l^{-1}. However there is evidence of an increase in DI-TP in the upper section of the core, approximately representing the post 1950s period. The increase is restricted in magnitude, with a maximum DI-TP value of 28 μg

TP l^{-1} recorded in the 2 cm sample. This increase in DI-TP could be interpreted as representing slight post-1950s nutrient enrichment. If this is the case it could be a result of agricultural improvement due to fertilizer inputs onto catchment soils or nutrient release from soils associated with liming (see above).

However, the significance of the recent trend in DI-TP must be interpreted with caution for four reasons. Firstly, it is important to note that the taxonomy of the *S. nana* complex is poorly defined (see section 3.2). This taxon as recognised by Bennion *et al.* (1996) combines a number of similar morphotypes which cannot reliably and consistently be separated. Ecological understanding of the taxon is therefore limited, and it's TP tolerance according to Bennion *et al.* (1996) is high (30 - 240 μg TP l^{-1}). Secondly, the magnitude of DI-TP change is small (<10 μg TP l^{-1}), similar to the amount of seasonal variation in measured lake-water TP (Monteith, 1995) and within the errors of the reconstruction technique (e.g. the root mean squared error (RMSE) on a DI-TP value of 20 μg TP l^{-1} is 14 - 28 μg TP l^{-1}). Thirdly, although there is evidence of improved pasture within the catchment (see discussion above) detailed data on land use change in the catchment is sparse. Fourthly, there is no evidence of an increase in TP levels between surveys carried out in 1978-79 (Jones, unpublished) and 1994-95 (Monteith, 1995); both give mean annual TP levels of c. 20 μg TP l^{-1}. Nevertheless the post-1950s trend in the diatom assemblages may represent a signal of floristic response to changing nutrient levels, and in particular an early warning of increased nutrient concentrations (cf. Jones *et al.* 1997).

It is clear that Llyn Eiddwen has been a mesotrophic system (cf. OECD, 1982) throughout the period represented by the diatom data (e.g. post 1850). There is diatom evidence for floristic change in the post 1950s period which may represent an early indication of diatom response to nutrient enrichment, although this trend is difficult to interpret with confidence.

5.2 Llyn Fanod

5.2.1 Lithostratigraphy and Catchment Disturbance

The lithostratigraphic data (see Figure 5) indicate that percentage organic matter increased quite markedly from the period represented by 30 to 20 cm in the core, and remained high until the 10 cm level, where it then began to decrease to the present day, suggesting a higher percentage of minerogenic material in recent decades. The chronology derived from the SCP analysis estimated relatively high sediment accumulation rates (3 mm yr^{-1}) for the period of high organic matter content and substantially lower sediment accumulation rates (1.1 mm yr^{-1}) for the upper 10 cm of the core. These data seem to point to a period of catchment disturbance and increased erosion initiated in the late 1800s and continuing to the 1950s. In the absence of long term historical records of land use, it is unclear as to the exact nature of this catchment disturbance, and the reasons postulated in section 5.1.1. for Llyn Eiddwen could also be presented for Llyn Fanod.

5.2.2 Evidence of Acidification

There is no evidence of acidification at Llyn Fanod from either the diatom record or from the application of the diatom-pH transfer function. This is consistent with predictions made through critical loads modelling using contemporary water chemistry measurements (Monteith, 1995). The DI-pH values increase throughout the period represented by the diatom record (post c.1850) by approximately 0.7 pH units, suggesting that a process of alkalization has taken place. The close match between the current measured pH and the DI-pH value for the surface sample, and the good species analogues, suggest that the model results are reliable for this site. The Welsh Acid Waters Resurvey data for 1995 (Stevens *et al.*, 1997) estimated an annual geometric mean pH from monthly water samples of 6.55, whilst the 1994-5 survey (Monteith, 1995) gave a similar annual geometric mean pH value based on quarterly water samples of 6.71, compared to the DI-pH value of 6.4 for the surface sample.

The causes of the alkalization may be related to the factors discussed in section 5.1.2. One possibility is that there has been a history of liming in the catchment and that liming frequency and land improvement practices have increased. Alternatively the alkalization may be associated with an increase in the release of base cations from the catchment caused by disturbance events (cf Renberg *et al.*, 1993). However, in the absence of stocking density figures and liming frequency and intensity data, it is difficult to evaluate the relative importance of these two possible causes of the alkalization.

5.2.3 Evidence of Eutrophication

There is no evidence of eutrophication at Llyn Fanod from either the diatom record or from the application of the diatom-TP transfer function. The DI-TP concentrations fluctuate in the range 15-22 μg TP l^{-1} throughout the period represented by the core with no clear direction of change. There is some variation in the DI-TP concentrations (a range of 7 μg TP l^{-1}) but the significance of this must be viewed with caution as it is within both the error of the technique (the root mean squared error of the WA-PLS model is 14-28 μg TP l^{-1} on a reconstructed mean value of 20 μg TP l^{-1}) and the natural annual variation in water chemistry of the lake, recorded as 14-27 μg TP l^{-1} in 1994-5 (Monteith, 1995). As for the pH model, there is good agreement between the measured annual mean TP concentration of the lake (18 μg TP l^{-1}) and the DI-TP value for the surface sample (16 μg TP l^{-1}) and there were no serious species analogue problems, indicating that the reconstructions work well and are reliable for this site.

The results suggest that Llyn Fanod has been a mesotrophic lake (OECD, 1982) since at least c.1850 and TP concentrations have not altered significantly since that time.

5.3 Comparison of Sites

5.3.1 Catchment Disturbance

Moore & Thomas (1963) in their vegetation survey of the two lakes suggest that the whole of the marginal areas of the sites have been continuously grazed by sheep and cattle for many centuries, although no data are presented to support these comments. Detailed data on stocking densities would be useful to establish how grazing intensities in the catchments have changed but without such data it is not possible to determine with confidence to what extent land use change accounts for the lithostratigraphic trends observed in the cores. Moore & Thomas (1963) also report that although bog has developed since the late glacial times, peat development has occurred to a considerable extent at the end of the lakes with evidence of recent infilling particularly at the southern ends. This is less marked in Llyn Fanod than in Llyn Eiddwen, where evidence of peat cutting is extensive. Thus, erosion events may be a possible cause of the observed increased percentage organic matter.

It is interesting to note that the significant increase in organic matter in the cores precedes the most marked changes in the diatom assemblages, and in particular the trends in alkalization apparent in both lakes. These events may be related. Unfortunately, given the low resolution of the data produced (i.e only ten samples for diatom analysis) and the lack of detailed land use records, it is not possible to determine the cause and effect links between catchment disturbance and the changes in the diatom floras. Similarly, in the absence of such data it is not possible to account for the apparent decreases in percentage organic matter and sediment accumulation rates observed at the top of the cores from both lakes. This could, however, be interpreted as indicative of a recent decrease in catchment disturbance.

5.3.2 Diatom Floras

The diatom floras of the two lakes were similar with many of the major taxa present in both cores (cf. Tables III and IV), particularly *Tabellaria flocculosa, Eunotia incisa, Fragilaria construens* var. *venter, Fragilaria virescens* var. *exigua, Cymbella gracilis* and *Achnanthes minutissima.* Although all of these taxa are commonly observed in freshwaters, it is unusual to find these taxa in a single assemblage and no analogous assemblages were found in the diatom samples currently stored on the ECRC Amphora database. Taxa such as *E. incisa, T. flocculosa* and *F. virescens* var. *exigua*, for example, are more commonly associated with acid conditions, whilst taxa such as *F. construens* var. *venter* and *Achnanthes minutissima* are typical of more circumneutral waters (Stevenson *et al.*, 1990). The unusual nature of the assemblages of Llyn Eiddwen and Llyn Fanod suggests that the lakes exhibit features typical of slightly acid, relatively nutrient-poor systems, perhaps influenced to a certain extent by the marginal areas of acid peats, whilst maintaining some features characteristic of a circumneutral, somewhat richer system. The diatom floras, therefore, provide sufficient evidence to support the designation of the lakes as mesotrophic waters and as sites of nature conservation importance. The findings closely agree with those from other important biological indicator groups. For instance, Monteith (1995) described the aquatic macrophyte flora of the lakes as diverse, characteristic of nutrient poor but not strongly acid waters. The lakes display many biological features in common with more acid sites, for example. *Isoetes lacustris* and *Callitriche hamulata*, but also contain taxa intolerant of acid conditions such as the charophyte *Nitella* sp. Likewise, in a survey of the macroinvertebrates by Palmer (1979), the fauna was described as broadly oligotrophic/mesotrophic with both nutrient-poor and more nutrient-rich indicator taxa.

Despite the broad similarity of the diatom floras of the two study lakes, there were also a number of differences. The most noteworthy was the presence and marked recent increase of *Synedra nana* in Llyn Eiddwen, a taxon not observed in Llyn Fanod. The difficulties associated with the taxonomy of these fine *Synedra* forms is discussed above and the hence the ecology of such taxa is still largely unknown; it is, however, thought to be planktonic. Other differences were that *Cyclotella glomerata* appeared in the uppermost sample of the Llyn Eiddwen core, whilst *Cyclotella stelligera* appeared in the Llyn Fanod core. Both of these taxa have similar TP optima (17 µg TP l^{-1}) but *C. stelligera* has a somewhat lower pH optima (6.2) than *C. glomerata* (6.7). Furthermore, the acid-tolerant taxon, *E. incisa*, assumed greater importance at the base of the Llyn Fanod core than in the Llyn Eiddwen core. Given the similarity in the water chemistry of the two lakes it is not clear what factors may be responsible for these observed differences. Factors, other than water chemistry, such as turbidity, habitat availability and flushing rate may be important.

The surface samples from the two 1997 cores (EIDW2 & FNOD2) were compared with the surface samples from the cores taken in 1994 as part of the Integrated Classification and Assessment of Lakes in Wales survey (Monteith, 1995).

In the case of Llyn Eiddwen, although the two samples contain similar assemblages, there are some notable differences in the relative proportions of the major taxa. In particular the 1997 core top contains a significantly higher proportion of *Synedra nana* than occurs in the 1994 sample (25% and 5% respectively: note that this taxon was reported as *S. acus* in Monteith (1995)). The 1997 core top also contains > 10% *C. glomerata*, a taxon unimportant in the 1994 sample. This probably represents a major bloom of this planktonic taxon. *F. construens* var. *venter* is much less abundant in the 1997 sample than in the 1994 sample (1% and 10% respectively). Similarly the importance of *E. incisa* declines between the 1994 and 1997 samples (8% and 1% respectively). These differences may relate to post-1994 lake-wide changes in the diatom flora, particularly increased abundances of the planktonic *C. glomerata* and *S. nana*.

In the case of Llyn Fanod, the two samples were almost identical. The relative abundances of the major taxa for the 1994 and 1997 samples respectively were: *A. minutissima* - 17 and 25%; *F. construens* var. *venter* - 10 and 11%; *F. virescens* var. *exigua* - 12 and 10%; *T. flocculosa* - 5 and 4%; *C. stelligera* - 3 and 6%; *E. incisa* - 3 and 2%; and *F. intermedia* - 5 and 3%. These data indicate that the diatom flora of Llyn Fanod has not changed over the last three years and that the sediment cores taken on both occasions provide a good representation of the annual average diatom community in the lake.

5.3.3 Changes in Water Quality

It is clear from the diatom data that Llynnau Eiddwen and Fanod have undergone lake-water alkalization within the last 100-150 years. The causes of these trends are uncertain, but are most likely to be related to land-use practices within the lake catchments (see sections 5.1.2 and 5.2.2). Although alkalization of lowland waters is relatively common, trends of alkalization are highly unusual for relatively low alkalinity (< 200 µeq l^{-1}) surface waters in Wales and Britain. For example, there are no examples of such clear post-1850 alkalization in the ECRC's palaeolimnological database of c. 80 acid-sensitive lakes across Britain. However, there have been few palaeolimnological studies of upland sites such as Llynnau Eiddwen and Fanod, whose catchments have undergone a significant amount of agricultural improvement.

An important consideration is the extent to which the diatom assemblages and the DI-pH values at the base of the studied diatom records represent pre-alkalization conditions. Although there is evidence that DI-pH values do not increase in the lowermost zones of the two cores (see Figures 4 and 8), there are too few samples to make the inference that these represent stable, pre-alkalization conditions. Further study of the pre-1900 diatom assemblages, with emphasis on the analysis of pre-1850 samples, would be required to accurately identify the start of the alkalization trend and define pre-alkalization conditions with confidence.

An important aspect of the diatom evidence for alkalization is that it implies that surface water acid neutralizing capacity and base cation concentrations have increased in both the lakes in the post-1850 period. In consequence the acid neutralizing capacities and critical loads of the lakes will also have increased. Although current critical loads for the sites are not exceeded, they are still relatively low (e.g. <2 keq H^{+} ha^{-1} yr^{-1}) (Monteith, 1995). It is therefore possible that alkalization through catchment land use practices has protected the lakes from surface water acidification due to acid deposition.

The alkalization trends at Llynnau Eiddwen and Fanod represent the most significant water quality changes identified in this study.

The Biodiversity Action Plan for mesotrophic lakes expresses particular concern over potential nutrient enrichment (CCW, 1997). In the case of Llyn Eiddwen there is some diatom evidence of a slight post-1950s increase in TP concentrations which might represent early floristic evidence of nutrient enrichment (cf. Jones *et al.* 1997) (see section 5.1.3). In contrast, there is no evidence of increased TP levels over the last twenty years on the basis of comparison of the chemical surveys from 1978-79 (Jones, unpublished) and 1994-95 (Monteith, 1995). These surveys both give mean annual TP levels of c. 20 μg TP l^{-1}, with a range of 9 - 40 μg TP l^{-1} in 1978 -79 and 15 - 25 μg TP l^{-1} in 1994-95. In the case of Llyn Fanod there is no diatom evidence of nutrient enrichment. In terms of measured lake-water chemistry, according to the 1994-5 survey (Monteith, 1995) both soluble reactive phosphorus and TP remained low throughout the year and average chlorophyll *a* concentrations were only 3 μg TP l^{-1}. Monthly water chemistry data from the survey carried out in 1978-9 (Jones, unpublished) produced similar TP concentrations with a range of 10-30 μg TP l^{-1} over the study period and a mean of 18 μg TP l^{-1}, demonstrating that the nutrient status of the lake has been stable for at least the last twenty years.

The relatively base poor geology and the infertile, thin soils of the catchments of both sites mean that the catchment land use is a mix of semi-improved with some improved pasture, and *Juncus* moorland. Neither of these land uses are likely to act as major sources of nutrients, and therefore nutrient enrichment would not be expected to be a problem unless significant changes in land management were implemented (e.g. heavy fertiliser use or increased stocking densities) or a point source of nutrients was introduced.

The current water chemistry of the lakes support their designation as mesotrophic lakes and the findings of the diatom study indicate that they have been mesotrophic throughout the post-1850 period.

5.4 Recommendations

There is clear diatom-based evidence of lake-water alkalization at both Llynnau Eiddwen and Fanod. However, given the limited number of samples analysed within this study it has not been possible to identify with confidence the timing of the start of the alkalization trends, the pre-alkalization conditions of the two lakes, or the cause-effect relationships between land-use practices and these chemical trends. In order to clarify these issues we recommend:

- that improved data on catchment stocking densities, cultivation and agricultural liming are sought, for example parish summary data from the Annual Agricultural Census Returns is available for the post-1860 period from the Public Records Office at Kew, London, and older data might be available from farm accounts held at the National Museum of Wales at Aberystwyth;

- that the diatom record is analysed below the 1850 level;

- that the core chronology for both sites is improved by the use of ^{210}Pb dating.

Although there is no clear evidence of ecologically significant nutrient enrichment from either site, recent changes in the diatom assemblages of Llyn Eiddwen have been noted which may be represent an early signal of nutrient change. In the light of concern with regard to enrichment of mesotrophic lakes (CCW, 1997), we recommend:

- periodic chemical monitoring of the nutrient concentrations of Llyn Eiddwen to detect current trends in nutrient status;

- consideration of similar chemical monitoring of Llyn Fanod.

On the basis of the study findings no changes to the conservation designations of the two sites are recommended. The study has confirmed the atypical chemistry and biology of Llynnau Eiddwen and Fanod compared to other upland sites in Wales and Britain.

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APPENDICES

Table I Spheroidal Carbonaceous Particle data for Llyn Eiddwen

Depth (cm)	Particles (gDM^{-1})
0.0 - 0.5	7967
0.5 - 1.0	13975
1.0 - 1.5	13903
2.0 - 2.5	11107
3.0 - 3.5	12643
4.0 - 4.5	8034
6.0 - 6.5	5547
8.0 - 8.5	4299
10.0 - 10.5	2111
15.0 - 15.5	2820
20.0 - 21.0	2003
25.0 - 26.0	2045
30.0 - 31.0	708
35.0 - 35.0	803
40.0 - 41.0	1545
45.0 - 46.0	1109
50.0 - 51.0	1328
60.0 - 61.0	1845
70.0 - 71.0	839
77.0 - 78.0	505

Table II Spheroidal Carbonaceous Particle data for Llyn Fanod

Depth (cm)	Particles (gDM^{-1})
0.0 - 0.5	5883
0.5 - 1.0	10786
1.0 - 1.5	12804
2.0 - 2.5	16402
3.0 - 3.5	12649
4.0 - 4.5	12110
6.0 - 6.5	6615
8.0 - 8.5	3499
10.0 - 10.5	3953
15.0 - 15.5	1861
20.0 - 21.0	1692
25.0 - 26.0	1123
30.0 - 31.0	452
35.0 - 35.0	277
40.0 - 41.0	0
45.0 - 46.0	384
50.0 - 51.0	140
60.0 - 61.0	184
70.0 - 71.0	237
77.0 - 78.0	0

Table III List of all species present in Llyn Eiddwen with full names, codes and authorities.

AC002A	Achnanthes linearis (W. Sm.) Grun. in Cleve & Grun. 1880
AC013A	Achnanthes minutissima minutissima Kutz. 1833
AC014B	Achnanthes austriaca minor L. Grannoch (RJF) 1986
AC014C	Achnanthes austriaca helvetica Hust. 1933
AC019A	Achnanthes nodosa A. Cleve-Euler 1900
AC022A	Achnanthes marginulata Grun. in Cleve & Grun. 1880
AC025B	Achnanthes flexella alpestris Brun 1880
AC034A	Achnanthes suchlandtii Hust. 1933
AC035A	Achnanthes pusilla pusilla Grun. in Cleve & Grun. 1880
AC039A	Achnanthes didyma didyma Hust. 1933
AC044A	Achnanthes levanderi Hust. 1933
AC046A	Achnanthes altaica (Poretzky) A. Cleve-Euler 1953
AC136A	Achnanthes subatomoides (Hust.) Lange-Bertalot & Archibald
AC9999	Achnanthes sp.
AM011A	Amphora libyca Ehr.
AS001A	Asterionella formosa formosa Hassall 1850
AU002A	Aulacoseira ambigua (Grun. in Van Heurck) Simonsen 1979
AU010B	Aulacoseira perglabra floriniae
AU020A	Aulacoseira subarctica (O.Mull.) Haworth
AU9999	Aulacoseira sp.
BR001A	Brachysira vitrea (Grun.) R. Ross in Hartley 1986
CM004A	Cymbella microcephala microcephala Grun. in Van Heurck 1880
CM010A	Cymbella perpusilla A. Cleve 1895
CM015A	Cymbella cesatii cesatii (Rabenh.) Grun. in A. Schmidt 1881
CM018A	Cymbella gracilis (Rabenh.) Cleve 1894
CM020A	Cymbella gaeumannii Meister 1934
CM031A	Cymbella minuta minuta Hilse ex Rabenh. 1862
CM042A	Cymbella tumida tumida (Breb. ex Kutz.) Grun. in Van Heurck 1880
CM049A	Cymbella failaisensis (Grun.) Krammer & Lange-Bertalot 1985
CM103A	Cymbella silesiaca Bleisch ex Rabenh. 1864
CM9999	Cymbella sp.
CO001B	Cocconeis placentula euglypta (Ehrenb.) Grun. 1884
CO005A	Cocconeis pediculus Ehrenb. 1838
CY004A	Cyclotella stelligera (Cleve & Grun. in Cleve) Van Heurck 1882
CY007A	Cyclotella glomerata Bachm. 1911
CY019A	Cyclotella radiosa Hakansson
CY052A	Cyclotella rossii Hakansson 1990
CY054A	Cyclotella krammeri Hakansson 1990
CY9999	Cyclotella sp.
DP9999	Diploneis sp.
EP9999	Epithemia sp.
EU002A	Eunotia pectinalis pectinalis (O.F. Mull.) Rabenh. 1864
EU002B	Eunotia pectinalis minor (Kutz.) Rabenh. 1864
EU002C	Eunotia pectinalis ventralis (Ehrenb.) Hust. 1911
EU002D	Eunotia pectinalis undulata (Ralfs) Rabenh. 1864
EU002E	Eunotia pectinalis minor impressa (Ehr.) Hust.
EU004A	Eunotia tenella (Grun. in Van Heurck) A. Cleve 1895
EU009A	Eunotia exigua exigua (Breb. ex Kutz.) Rabenh. 1864
EU011A	Eunotia rhomboidea Hust. 1950
EU017A	Eunotia flexuosa flexuosa Kutz. 1849
EU020A	Eunotia meisteri meisteri Hust. 1930
EU021A	Eunotia sudetica O. Mull. 1898
EU025A	Eunotia fallax A. Cleve 1895
EU032A	Eunotia serra serra Ehrenb. 1837
EU040A	Eunotia paludosa Grun. 1862
EU047A	Eunotia incisa W. Sm. ex Greg. 1854
EU049A	Eunotia curvata curvata (Kutz.) Lagerst. 1884
EU051A	Eunotia vanheurckii vanheurckii Patr. 1958
EU051B	Eunotia vanheurckii intermedia (Krasske) Cleve
EU056A	Eunotia minutissima A. Cleve-Euler 1934
EU9999	Eunotia sp.
FR001A	Fragilaria pinnata pinnata Ehrenb. 1843
FR002A	Fragilaria construens construens (Ehrenb.) Grun. 1862
FR002C	Fragilaria construens venter (Ehrenb.) Grun. in Van Heurck 1881
FR005D	Fragilaria virescens exigua Grun. in Van Heurck 1881
FR009A	Fragilaria capucina capucina Desm. 1825
FR010A	Fragilaria constricta constricta Ehrenb. 1843
FR013A	Fragilaria oldenburgiana Hust.
FR018A	Fragilaria elliptica Schum. 1867
FR019A	Fragilaria intermedia Grun. in Van Heurck 1881
FR045A	Fragilaria parasitica (W. Sm.) Grun. in Van Heurck 1881
FR9999	Fragilaria sp.
FU002B	Frustulia rhomboides saxonica (Rabenh.) De Toni 1891
FU002F	Frustulia rhomboides viridula (Breb. ex Kutz.) Cleve 1894

Table III continued: List of all species present in Llyn Eiddwen with full names, codes and authorities.

GO004A	Gomphonema gracile Ehrenb. 1838
GO006A	Gomphonema acuminatum acuminatum Ehrenb. 1832
GO010A	Gomphonema constrictum Ehrenb. ex Kutz. 1844
GO013A	Gomphonema parvulum parvulum (Kutz.) Kutz. 1849
GO9999	Gomphonema sp.
NA002A	Navicula jaernefeltii Hust. 1942
NA003A	Navicula radiosa radiosa Kutz. 1844
NA003B	Navicula radiosa tenella (Breb. ex Kutz.) Grun. ex Van Heurck 1885
NA005A	Navicula seminulum Grun. 1860
NA006A	Navicula mediocris Krasske 1932
NA008A	Navicula rhyncocephala rhyncocephala Kutz. 1844
NA013A	Navicula pseudoscutiformis Hust. 1930
NA014A	Navicula pupula pupula Kutz. 1844
NA015A	Navicula hassiaca Krasske 1925
NA017A	Navicula ventralis Krasske 1923
NA032A	Navicula cocconeiformis cocconeiformis Greg. ex Greville 1855
NA033A	Navicula subtilissima Cleve 1891
NA037A	Navicula angusta Grun. 1860
NA038A	Navicula arvensis Hust.
NA042A	Navicula minima minima Grun. in Van Heurck 1880
NA068A	Navicula impexa Hust. 1961
NA099A	Navicula bremensis Hust. 1957
NA115A	Navicula difficillima Hust. 1950
NA133A	Navicula schassmannii Hust. 1937
NA766A	Navicula heimansioides Lange-Bertalot 1991
NA9999	Navicula sp.
NE9999	Neidium sp.
NI005A	Nitzschia perminuta (Grun. in Van Heurck) M. Perag. 1903
NI008A	Nitzschia frustulum (Kutz.) Grun. in Cleve & Grun. 1880
NI009A	Nitzschia palea palea (Kutz.) W. Sm. 1856
NI017A	Nitzschia gracilis Hantzsch 1860
NI025A	Nitzschia recta Hantzsch ex Rabenh. 1861
NI042A	Nitzschia acicularis (Kutz.) W. Sm. 1853
NI9999	Nitzschia sp.
OP001A	Opephora martyi Herib. 1902
PI011A	Pinnularia microstauron microstauron (Ehrenb.) Cleve 1891
PI018A	Pinnularia biceps biceps Greg. 1856
PI022A	Pinnularia subcapitata subcapitata Greg. 1856
PI022B	Pinnularia subcapitata hilseana (Janisch ex Rabenh.) O. Mull. 1898
PI023A	Pinnularia irrorata (Grun. in Van Heurck) Hust. 1939
PI9999	Pinnularia sp.
SA001B	Stauroneis anceps gracilis Rabenh. 1864
SA004A	Stauroneis alpina Hust. 1943
SU005A	Surirella linearis linearis W. Sm. 1853
SY001A	Synedra ulna ulna (Nitzsch) Ehrenb. 1836
SY002A	Synedra rumpens rumpens Kutz. 1844
SY003A	Synedra acus acus Kutz. 1844
SY009A	Synedra nana Meister 1912
SY010A	Synedra minuscula Grun. in Van Heurck 1881
SY9999	Synedra sp.
TA001A	Tabellaria flocculosa flocculosa (Roth) Kutz. 1844
TA002A	Tabellaria fenestrata (Lyngb.) Kutz. 1844
TA9996	Tabellaria flocculosa agg.
UN9998	Unknown naviculaceae
UN9999	Unknown

Table IV List of all species present in Llyn Fanod with full names, codes and authorities.

AC002A	Achnanthes linearis (W. Sm.) Grun. in Cleve & Grun. 1880
AC013A	Achnanthes minutissima minutissima Kutz. 1833
AC022A	Achnanthes marginulata Grun. in Cleve & Grun. 1880
AC034A	Achnanthes suchlandtii Hust. 1933
AC035A	Achnanthes pusilla pusilla Grun. in Cleve & Grun. 1880
AC039A	Achnanthes didyma didyma Hust. 1933
AC044A	Achnanthes levanderi Hust. 1933
AC083A	Achnanthes laevis Ostr. 1910
AC134A	Achnanthes helvetica Flower and Jones 1989
AC136A	Achnanthes subatomoides (Hust) Lang.-Bert. & Archibald in Krammer & Lange Bert. 1985
AC141A	Achnanthes bioretii Germain 1957
AC167A	Achnanthes daonensis Lange Bertalot 1989
AC9999	Achnanthes sp.
AP001A	Amphipleura pellucida (Kutz.) Kutz. 1844
AS001A	Asterionella formosa formosa Hassall 1850
AU002A	Aulacoseira ambigua (Grun. in Van Heurck) Simonsen 1979
AU020A	Aulacoseira subarctica (O.Mull.) Haworth
AU031A	Aulacoseira alpigena (Grunow) Krammer 1990
AU9999	Aulacoseira sp.
BR001A	Brachysira vitrea (Grun.) R. Ross in Hartley 1986
CM004A	Cymbella microcephala microcephala Grun. in Van Heurck 1880
CM016A	Cymbella amphicephala amphicephala Naegeli ex Kutz. 1849
CM018A	Cymbella gracilis (Rabenh.) Cleve 1894
CM029A	Cymbella ehrenbergii Kutz. 1844
CM031A	Cymbella minuta minuta Hilse ex Rabenh. 1862
CM068A	Cymbella brehmii Hust. 1912
CM103A	Cymbella silesiaca Bleisch ex Rabenh. 1864
CM9999	Cymbella sp.
CO009A	Cocconeis thumensis A. Mayer 1919
CY004A	Cyclotella stelligera (Cleve & Grun. in Cleve) Van Heurck 1882
CY9999	Cyclotella sp.
EP007A	Epithemia adnata adnata (Kutz.) Rabenh. 1853
EU002B	Eunotia pectinalis minor (Kutz.) Rabenh. 1864
EU002D	Eunotia pectinalis undulata (Ralfs) Rabenh. 1864
EU009A	Eunotia exigua exigua (Breb. ex Kutz.) Rabenh. 1864
EU017A	Eunotia flexuosa flexuosa Kutz. 1849
EU020A	Eunotia meisteri meisteri Hust. 1930
EU025A	Eunotia fallax A. Cleve 1895
EU040A	Eunotia paludosa Grun. 1862
EU047A	Eunotia incisa W. Sm. ex Greg. 1854
EU049A	Eunotia curvata curvata (Kutz.) Lagerst. 1884
EU051A	Eunotia vanheurckii vanheurckii Patr. 1958
EU108A	Eunotia intermedia (Hust) Norpel, Lange-Bertalot & Alles 1991
EU111A	Eunotia soleirolii (Kutz) Rabenhorst 1864
EU9999	Eunotia sp.
FR001A	Fragilaria pinnata pinnata Ehrenb. 1843
FR002A	Fragilaria construens construens (Ehrenb.) Grun. 1862
FR002C	Fragilaria construens venter (Ehrenb.) Grun. in Van Heurck 1881
FR005A	Fragilaria virescens virescens Ralfs 1843
FR005D	Fragilaria virescens exigua Grun. in Van Heurck 1881
FR006A	Fragilaria brevistriata brevistriata Grun. in Van Heurck 1885
FR009A	Fragilaria capucina capucina Desm. 1825
FR009H	Fragilaria capucina gracilis (Oestrup) Hustedt 1950
FR010A	Fragilaria constricta constricta Ehrenb. 1843
FR013A	Fragilaria oldenburgiana Hust.
FR019A	Fragilaria intermedia Grun. in Van Heurck 1881
FR026A	Fragilaria bidens Heib. 1863
FR056A	Fragilaria pseudoconstruens Marciniak 1982
FR9999	Fragilaria sp.
FU002F	Frustulia rhomboides viridula (Breb. ex Kutz.) Cleve 1894
GO004A	Gomphonema gracile Ehrenb. 1838
GO006A	Gomphonema acuminatum acuminatum Ehrenb. 1832
GO010A	Gomphonema constrictum Ehrenb. ex Kutz. 1844
GO013A	Gomphonema parvulum parvulum (Kutz.) Kutz. 1849
GO050A	Gomphonema minutum (Ag.) Ag. 1831
GO9999	Gomphonema sp.
NA002A	Navicula jaernefeltii Hust. 1942
NA003A	Navicula radiosa radiosa Kutz. 1844
NA005A	Navicula seminulum Grun. 1860
NA006A	Navicula mediocris Krasske 1932
NA007A	Navicula cryptocephala cryptocephala Kutz. 1844
NA008A	Navicula rhyncocephala rhyncocephala Kutz. 1844
NA013A	Navicula pseudoscutiformis Hust. 1930
NA014A	Navicula pupula pupula Kutz. 1844
NA037A	Navicula angusta Grun. 1860
NA042A	Navicula minima minima Grun. in Van Heurck 1880

Table IV continued: List of all species present in Llyn Fanod with full names, codes and authorities.

NA045A	Navicula bryophila bryophila J.B. Petersen 1928
NA068A	Navicula impexa Hust. 1961
NA084A	Navicula atomus (Kutz.) Grun. 1860
NA114A	Navicula subrotundata Hust. 1945
NA133A	Navicula schassmannii Hust. 1937
NA134A	Navicula subminuscula Manguin
NA190A	Navicula agrestis Hust. 1937
NA590A	Navicula pseudoventralis Hust. 1953
NA745A	Navicula capitoradiata Germain 1981
NA751A	Navicula cryptotenella Lange-Bertalot 1985
NA766A	Navicula heimansioides Lange-Bertalot 1991
NA9999	Navicula sp.
NI002A	Nitzschia fonticola Grun. in Van Heurck 1881
NI005A	Nitzschia perminuta (Grun. in Van Heurck) M. Perag. 1903
NI008A	Nitzschia frustulum (Kutz.) Grun. in Cleve & Grun. 1880
NI009A	Nitzschia palea palea (Kutz.) W. Sm. 1856
NI015A	Nitzschia dissipata (Kutz.) Grun. 1862
NI017A	Nitzschia gracilis Hantzsch 1860
NI020A	Nitzschia angustata angustata (W. Sm.) Grun. in Cleve & Grun. 1880
NI9999	Nitzschia sp.
PE002A	Peronia fibula (Breb. ex Kutz.) R. Ross 1956
PI004A	Pinnularia interrupta W. Smith
PI005A	Pinnularia major major (Kutz.) W. Sm. 1853
PI011A	Pinnularia microstauron microstauron (Ehrenb.) Cleve 1891
PI022A	Pinnularia subcapitata subcapitata Greg. 1856
PI023A	Pinnularia irrorata (Grun. in Van Heurck) Hust. 1939
PI9999	Pinnularia sp.
SA001A	Stauroneis anceps anceps Ehrenb. 1843
SU074A	Surirella bifrons Ehrenb. 1843
SU9999	Surirella sp.
SY001A	Synedra ulna ulna (Nitzsch) Ehrenb. 1836
SY003A	Synedra acus acus Kutz. 1844
SY009A	Synedra nana Meister 1912
TA001A	Tabellaria flocculosa flocculosa (Roth) Kutz. 1844
TA002A	Tabellaria fenestrata (Lyngb.) Kutz. 1844

Table V **Diatom data from Llyn Eiddwen core EIDW2. Data are expressed as % relative abundance.**

The diatom taxa are shown as codes. See Table III for full names and authorities.

					Sample depth in cm					
	0.0	2.0	4.0	6.0	8.0	10.0	14.0	20.0	30.0	40.0
Taxa										
AC002A	0.3	0.3	1.5	0.3	1.2	0.9	0.3	0.3	0.0	0.3
AC013A	11.3	11.4	15.8	13.0	17.0	15.0	8.8	16.8	6.2	3.6
AC014B	0.0	0.0	0.3	0.0	0.3	0.6	0.8	0.0	0.0	0.3
AC014C	0.0	0.3	0.3	0.0	0.3	0.0	0.8	0.6	1.3	1.0
AC019A	0.6	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0
AC022A	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
AC025B	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AC034A	0.0	0.3	0.0	0.3	0.3	1.7	0.8	1.9	0.7	1.0
AC035A	2.6	5.1	6.1	6.6	8.9	6.6	7.1	7.4	3.3	4.9
AC039A	0.3	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.7
AC044A	1.7	0.6	0.9	1.8	0.3	1.7	0.3	0.3	0.3	1.0
AC046A	0.0	0.3	0.0	0.3	0.0	0.0	0.5	0.6	0.3	1.0
AC136A	0.0	0.6	0.3	0.6	0.6	1.2	2.2	1.3	2.6	3.0
AC9999	0.6	0.6	0.6	0.3	0.3	1.2	0.8	1.3	1.0	1.6
AM011A	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AS001A	3.2	2.6	2.4	1.5	1.2	0.9	0.3	1.0	0.7	3.3
AU002A	0.0	0.3	0.6	0.6	0.0	0.0	1.4	0.0	0.3	0.7
AU010B	0.0	0.0	0.0	0.3	0.3	0.0	0.3	0.0	0.0	0.0
AU020A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	1.3
AU9999	0.3	0.0	0.0	0.0	0.3	1.4	0.5	0.6	0.3	0.3
BR001A	2.6	2.6	3.0	3.0	3.5	1.2	1.1	2.6	0.7	1.0
CM004A	1.4	1.4	0.6	2.1	0.9	0.0	0.3	2.3	0.3	0.3
CM010A	0.6	0.0	0.3	0.0	0.0	0.9	0.3	1.0	1.6	1.0
CM015A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
CM018A	2.6	2.3	4.6	2.4	4.0	4.0	6.0	4.5	2.0	3.0
CM020A	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0
CM031A	0.3	0.0	0.3	0.0	0.6	0.9	0.8	0.0	2.0	0.3
CM042A	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CM049A	0.3	0.6	0.0	0.6	0.3	0.0	0.0	0.0	0.0	0.0
CM103A	0.3	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.3	0.0
CM9999	0.0	0.6	0.0	0.6	0.3	0.0	0.3	0.6	1.3	0.0
CO001B	0.0	0.0	0.3	0.0	0.3	0.3	0.3	0.0	0.3	0.3
CO005A	0.0	0.3	0.3	0.0	0.3	0.0	0.0	0.0	0.0	0.0
CY004A	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
CY007A	11.0	0.6	0.3	0.3	0.3	0.0	0.0	0.0	0.0	0.0
CY019A	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CY052A	0.0	0.0	0.0	0.0	0.0	0.9	0.5	0.3	0.0	0.3
CY054A	0.0	0.0	0.0	0.6	0.0	1.2	0.5	0.3	1.0	0.0
CY9999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
DP9999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
EP9999	0.0	0.0	0.3	0.3	0.0	0.3	0.5	0.0	0.3	0.0
EU002A	0.0	0.3	0.3	0.3	0.6	0.3	1.4	1.3	1.6	0.0
EU002B	0.3	1.4	1.2	1.2	1.2	1.2	1.1	1.6	2.3	1.3
EU002C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
EU002D	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
EU002E	0.3	1.1	0.3	1.2	1.4	1.2	0.8	1.3	1.3	0.7
EU004A	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.3	0.3	0.0
EU009A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
EU011A	0.6	0.3	0.0	0.3	0.6	0.9	0.0	1.6	0.7	0.3
EU017A	0.0	0.6	0.0	0.3	0.3	0.3	0.3	0.0	0.0	0.3
EU020A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
EU021A	0.3	0.6	1.2	0.3	0.3	0.3	0.0	0.3	0.0	0.0
EU025A	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
EU032A	0.3	0.3	0.0	0.6	0.3	0.3	0.0	0.3	0.3	0.0
EU040A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.3
EU047A	0.9	2.6	3.0	4.8	6.1	4.6	5.2	3.9	2.0	4.3
EU049A	0.3	0.0	0.0	0.3	0.3	0.0	0.0	0.3	0.3	0.3

Table V continued: **Diatom data from Llyn Eiddwen core EIDW2. Data are expressed as % relative abundance.**

The diatom taxa are shown as codes. See Table III for full names and authorities.

	Sample depth in cm									
	0.0	2.0	4.0	6.0	8.0	10.0	14.0	20.0	30.0	40.0
Taxa										
EU051A	0.3	0.3	0.3	0.6	0.3	0.0	0.0	0.0	0.0	0.0
EU051B	0.0	0.0	0.0	0.0	0.3	0.6	0.8	1.0	1.0	1.0
EU056A	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EU9999	0.6	1.1	1.2	1.2	2.3	1.4	0.5	1.0	0.7	0.3
FR001A	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.3	0.0
FR002A	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
FR002C	1.4	7.4	3.6	4.2	3.7	6.1	8.5	5.5	5.6	10.9
FR005D	8.1	10.0	6.1	8.5	6.3	7.2	4.9	6.1	3.3	6.6
FR009A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	2.6
FR010A	0.0	0.3	0.9	0.3	0.3	0.3	0.0	0.3	1.6	1.6
FR013A	0.3	0.3	0.0	0.9	0.3	0.0	1.9	0.6	3.3	1.0
FR018A	0.6	0.3	0.6	1.2	1.2	1.4	1.1	1.6	1.0	0.3
FR019A	2.6	4.0	3.3	2.4	1.7	2.9	3.3	3.2	1.0	0.7
FR045A	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FR9999	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
FU002B	0.0	0.0	0.3	0.6	0.3	0.6	1.1	0.3	1.0	0.7
FU002F	0.0	0.6	0.3	0.6	0.3	0.6	1.1	1.0	8.2	1.0
GO004A	0.6	0.0	0.0	2.1	4.0	3.2	1.4	2.6	0.3	2.3
GO006A	0.0	0.6	1.2	0.3	0.6	1.7	1.4	0.6	0.0	0.0
GO010A	0.0	0.3	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
GO013A	0.3	1.7	1.2	2.1	0.9	3.5	1.9	1.6	0.0	1.3
GO9999	0.3	0.0	0.9	0.6	0.9	0.9	0.5	0.0	0.0	0.3
NA002A	0.0	0.3	0.0	0.6	0.0	0.0	0.3	0.6	0.0	1.3
NA003A	0.0	1.4	1.5	0.9	0.3	0.3	0.3	0.0	0.3	0.0
NA003B	0.0	0.0	0.3	0.3	0.3	0.0	0.8	0.3	0.0	0.0
NA005A	1.2	1.1	1.2	1.2	1.4	1.2	2.2	1.6	0.7	1.0
NA006A	0.0	0.0	0.0	0.0	0.9	0.3	0.0	0.0	0.0	0.0
NA008A	0.0	0.6	0.6	0.3	0.3	0.0	0.0	0.0	0.0	0.0
NA013A	1.2	0.0	0.0	0.9	0.9	0.0	0.3	0.6	0.0	0.0
NA014A	0.0	0.6	0.9	0.0	0.0	0.3	0.8	0.3	1.0	0.0
NA015A	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
NA017A	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0
NA032A	0.3	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
NA033A	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NA037A	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
NA038A	0.0	0.3	0.0	0.0	0.3	0.6	0.0	0.0	0.0	0.0
NA042A	1.2	0.3	0.6	0.6	0.9	0.6	3.0	1.3	2.6	5.3
NA068A	0.0	0.3	0.3	0.9	0.9	1.7	2.5	0.6	0.7	1.3
NA099A	0.0	0.6	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.7
NA115A	0.6	0.0	0.6	0.0	0.9	0.0	1.6	0.0	3.3	1.3
NA133A	0.0	0.3	0.3	0.3	0.3	0.0	0.3	1.0	0.0	0.0
NA766A	2.9	2.0	1.8	3.6	1.4	1.4	1.6	1.6	2.0	1.6
NA9999	0.0	1.1	0.6	0.6	0.6	0.9	2.5	0.6	2.9	3.3
NE9999	0.9	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0
NI005A	0.0	0.0	0.0	0.0	1.2	0.3	0.5	0.3	0.0	0.0
NI008A	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
NI009A	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0
NI017A	1.2	0.3	0.3	0.0	0.3	0.0	0.0	0.0	0.3	0.3
NI025A	0.6	0.6	0.6	0.6	0.6	0.3	0.3	0.3	0.0	0.0
NI042A	1.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NI9999	0.0	0.0	0.3	0.3	0.0	0.3	0.5	1.3	0.0	0.3
OP001A	0.0	0.3	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.3

Table V continued: **Diatom data from Llyn Eiddwen core EIDW2. Data are expressed as % relative abundance.**

The diatom taxa are shown as codes. See Table III for full names and authorities.

					Sample depth in cm					
	0.0	2.0	4.0	6.0	8.0	10.0	14.0	20.0	30.0	40.0
Taxa										
PI011A	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.3	0.3
PI018A	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.3	0.0
PI022A	0.0	0.0	0.0	0.3	0.0	0.3	0.0	0.0	0.3	0.0
PI022B	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.7
PI023A	0.3	0.3	0.0	0.0	0.3	1.7	1.6	0.6	6.2	3.3
PI9999	0.3	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.3	0.0
SA001B	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SA004A	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.3	0.0	0.3
SU005A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
SY001A	0.0	0.0	0.0	0.3	0.0	0.0	0.3	0.0	0.0	0.0
SY002A	0.0	0.0	0.3	0.6	0.0	0.6	0.0	0.0	0.0	0.0
SY003A	2.0	1.7	1.5	1.8	0.9	0.6	0.5	1.3	0.0	0.0
SY009A	25.1	19.1	19.1	13.0	8.1	2.9	1.6	3.2	0.7	2.0
SY010A	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.3	0.3	1.0
SY9999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
TA001A	1.7	1.1	2.7	0.3	1.7	1.2	1.4	1.6	7.2	4.9
TA002A	0.3	0.3	0.0	0.0	0.6	0.3	0.3	0.3	0.3	0.7
TA9996	0.0	0.3	0.3	0.3	0.3	0.0	0.0	0.0	0.0	0.0
UN9998	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
UN9999	0.0	0.0	0.3	0.3	0.0	0.6	0.3	0.0	0.0	0.7

Table VI **Diatom data from Llyn Fanod core FNOD2. Data are expressed as % relative abundance.**

The diatom taxa are shown as codes. See Table IV for full names and authorities.

					Sample Depth in cm					
	0.00	2.00	4.00	6.00	8.00	10.00	16.00	20.00	30.00	40.00
Taxa										
AC002A	2.05	1.71	2.51	5.04	2.38	2.16	3.89	3.44	1.17	3.80
AC013A	24.85	19.43	21.32	15.65	29.46	19.14	3.33	3.75	11.73	11.71
AC022A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00
AC034A	0.00	0.29	0.31	0.00	0.30	0.00	0.28	0.00	0.29	-0.00
AC039A	0.00	0.00	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AC044A	1.46	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.32
AC083A	0.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00
AC134A	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.31	1.47	0.95
AC136A	2.63	2.00	1.88	0.80	1.19	1.85	8.06	6.56	2.64	3.48
AC141A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32
AC167A	0.00	0.86	0.31	0.00	0.00	0.00	1.11	1.25	0.00	0.00
AC9999	0.00	0.29	0.63	0.27	0.00	0.31	0.28	0.94	1.47	1.58
AP001A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.32
AS001A	0.00	0.57	2.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AU002A	0.00	0.29	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AU020A	0.00	0.29	0.00	0.00	0.30	0.93	0.83	0.00	0.59	1.90
AU031A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.59	0.00
AU9999	0.00	0.57	0.31	0.27	0.00	0.00	0.56	0.00	0.00	0.00
BR001A	4.39	3.43	4.70	2.92	1.19	3.09	1.39	0.94	4.69	0.95
CM004A	0.29	0.57	0.31	0.27	0.30	0.93	0.28	0.00	0.00	0.00
CM016A	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.32
CM018A	1.75	2.29	2.51	5.84	2.38	2.16	1.39	1.25	1.17	2.53
CM029A	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CM031A	0.00	0.00	0.00	0.27	0.00	0.31	0.28	1.25	0.29	0.00
CM068A	0.00	0.00	0.00	0.27	0.60	0.00	0.56	0.31	0.00	0.00
CM103A	0.88	0.86	1.25	1.06	0.00	0.00	0.83	0.62	0.59	1.58
CM9999	0.29	0.57	0.31	0.27	0.00	0.31	0.00	0.31	0.00	0.63
CO009A	0.00	0.00	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.00
CY004A	6.43	2.29	0.31	0.53	1.49	2.16	0.00	0.00	0.00	0.00
CY9999	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.32
EP007A	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU002B	0.88	3.14	2.82	3.45	3.87	4.94	1.94	1.25	1.47	3.16
EU002D	0.00	0.00	0.00	0.27	0.00	0.00	0.83	0.00	0.59	0.00
EU009A	0.00	0.00	0.00	0.53	0.00	0.93	0.56	4.38	0.00	0.00
EU017A	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU020A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.59	0.00
EU025A	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00
EU040A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.56	0.59	0.00
EU047A	2.05	2.00	1.25	4.77	6.55	1.54	3.06	3.44	21.99	12.34
EU049A	0.29	0.00	0.31	0.53	0.00	0.00	0.28	0.62	0.00	0.00
EU051A	0.58	0.29	0.00	0.27	0.30	0.31	0.83	0.00	1.47	0.63
EU108A	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	1.17	6.33
EU111A	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU9999	0.88	0.86	1.57	1.06	0.00	0.93	0.83	1.25	1.47	0.95
FR001A	0.00	0.29	0.00	0.00	0.00	0.93	0.28	0.00	0.00	0.00
FR002A	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FR002C	10.82	10.57	13.48	14.06	8.63	5.56	2.78	3.12	8.50	10.13
FR005A	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00
FR005D	9.94	17.14	12.54	12.20	6.25	3.09	1.94	1.25	3.23	2.85
FR006A	0.58	0.00	0.00	0.00	0.00	0.62	0.28	0.00	0.29	0.32
FR009A	0.29	0.29	0.31	2.12	2.08	4.01	2.50	1.25	0.00	3.48
FR009H	1.46	2.57	1.57	0.53	2.08	2.78	0.56	0.00	2.05	0.95
FR010A	0.58	0.29	0.00	0.00	0.30	0.31	0.28	0.31	0.00	0.32
FR013A	1.17	0.00	1.57	1.59	1.79	0.62	2.50	1.25	0.88	1.27
FR019A	2.92	2.00	4.70	3.18	1.79	2.78	0.83	0.62	0.29	0.32
FR026A	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FR056A	0.00	0.00	0.31	0.00	0.30	0.00	0.28	0.00	0.00	0.00

Table VI continued: Diatom data from Llyn Fanod core FNOD2. Data are expressed as % relative abundance.

The diatom taxa are shown as codes. See Table IV for full names and authorities.

				Sample Depth in cm						
	0.00	2.00	4.00	6.00	8.00	10.00	16.00	20.00	30.00	40.00
Taxa										
FR9999	0.88	1.14	0.31	0.00	0.00	0.62	0.56	0.00	0.88	0.00
FU002F	0.88	0.86	2.51	1.33	2.38	2.78	3.33	2.50	1.76	0.95
GO004A	0.00	1.14	0.31	1.06	0.00	0.31	0.00	0.00	0.00	0.00
GO006A	0.58	0.29	0.94	0.80	0.00	0.00	0.28	0.62	0.00	0.63
GO010A	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00
GO013A	0.88	0.57	0.00	2.92	3.27	2.78	6.94	5.00	5.57	8.54
GO050A	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.00	0.00	0.00
GO9999	0.00	0.00	0.63	0.00	0.00	1.23	0.28	0.00	0.00	0.00
NA002A	0.00	0.00	0.00	0.00	0.60	0.00	0.00	0.00	2.35	0.63
NA003A	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NA005A	0.29	2.00	0.00	1.06	1.19	0.00	6.94	9.38	1.17	0.00
NA006A	0.00	0.00	0.00	0.27	0.00	0.31	0.28	0.00	0.29	0.32
NA007A	1.17	0.86	0.00	0.00	0.00	0.00	0.28	0.62	0.29	0.00
NA008A	0.00	0.29	0.00	0.00	0.00	0.31	0.00	0.00	0.00	0.00
NA013A	0.58	0.00	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.63
NA014A	0.00	0.29	0.31	0.00	0.60	1.23	2.22	3.44	0.00	1.27
NA037A	1.17	0.29	0.00	0.00	0.00	0.00	0.28	0.31	0.00	0.00
NA042A	0.29	0.86	0.31	0.27	0.00	0.31	1.67	2.19	1.76	0.63
NA045A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32
NA068A	0.88	0.29	0.31	1.06	0.60	2.16	3.06	0.62	0.00	0.32
NA084A	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.62	0.00	0.32
NA114A	0.00	1.14	0.31	0.00	0.00	0.00	0.28	0.00	0.00	0.00
NA133A	1.46	2.29	1.88	2.65	5.95	10.19	1.67	1.88	0.59	0.32
NA134A	0.00	0.00	0.00	0.00	0.60	0.31	0.00	0.00	0.00	0.95
NA190A	0.00	0.00	0.00	0.53	0.60	3.09	1.67	3.44	0.88	0.63
NA590A	0.00	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.59	0.32
NA745A	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NA751A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32
NA766A	0.00	0.00	1.57	1.86	2.98	0.93	0.56	0.94	0.59	0.32
NA9999	2.05	0.86	0.31	1.06	0.60	1.54	1.94	1.56	1.17	1.27
NI002A	0.88	0.57	0.63	1.33	0.00	0.00	0.00	0.31	0.29	0.00
NI005A	0.58	0.00	0.00	0.27	2.08	0.31	0.00	0.62	0.29	0.32
NI008A	0.00	0.00	0.31	0.27	0.00	0.00	0.00	0.00	0.00	0.00
NI009A	0.58	0.00	0.31	0.00	0.00	0.00	0.83	0.94	0.00	0.00
NI015A	0.00	0.29	0.31	0.00	0.00	0.31	0.00	0.31	0.00	0.00
NI017A	0.00	0.00	0.31	0.00	0.00	0.00	0.83	0.31	0.00	0.00
NI020A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.63
NI9999	0.29	0.29	0.00	0.00	0.00	0.00	0.28	0.31	0.00	0.32
PE002A	0.00	0.00	0.00	0.27	0.89	0.00	0.00	0.00	0.00	0.00
PI004A	0.00	0.00	0.00	0.53	0.60	0.62	1.67	1.88	1.47	0.00
PI005A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.32
PI011A	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.31	0.00	0.00
PI022A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.00
PI023A	0.29	0.00	0.00	0.00	0.00	0.93	3.89	4.06	0.29	0.32
PI9999	0.00	0.00	0.31	0.00	0.30	0.00	0.28	0.62	0.29	0.00
SA001A	0.29	0.29	0.31	0.00	0.00	0.00	0.00	0.31	0.29	0.32
SU074A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.00
SU9999	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.00
SY001A	0.29	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.59	0.32
SY003A	0.58	0.86	0.63	0.27	0.00	0.00	0.00	0.00	0.00	0.00
SY009A	0.29	0.86	0.00	0.27	0.00	0.62	0.00	0.00	0.00	0.32
TA001A	4.09	5.14	4.39	3.18	2.68	5.25	13.33	14.06	5.87	4.43
TA002A	0.88	1.14	1.57	0.27	0.00	0.93	0.83	0.31	0.00	0.32