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Defining lake restoration targets at Llyn Cadarn: a palaeolimnological approach

Final report to the CCW

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Executive summary

This is the final report to the Countryside Council for Wales under contract FC 73-02-355: Defining Lake restoration targets at Llyn Cadarn: a palaeolimnological approach. The report employs palaeolimnological techniques to evaluate the degree of environmental change at Llyn Cadarn, Anglesey.

A single large diameter 75 cm long core (CADA3) was extracted from Llyn Cadarn in September 2007. The report describes the lithostratigraphy of CADA3 and presents results of spheroidal carbonaceous particle (SCP) analysis. Sedimentary phosphorus concentrations were determined for the core. Plant and animal macrofossil and cladoceran data was carried out on ten levels of the core. In addition a new technique for the identification of *Characeae* from their oospores was applied to the oospores found in CADA3.

The SCP chronology was not reliable for dates prior to 1950 but provided dates for the period after 1950. Prior to this dates were ascribed to the core but must be treated with caution. The physical, chemical and biological data for the core were in good agreement of the timing and nature of change in the biological structure and function of Llyn Cadarn. A point at between 45 and 40 cm in the core represents time at which eutrophication appears to have deleteriously impacted upon the site.

The macrofossil data for the site suggest that there were important changes in the submerged flora of the site before 45 cm. The oospores data indicate there were at least three species of *Chara* present below 65 cm, consisting of *C. vulgaris* type, *C. hispida* and *C. aspera* type, along with *Potamogeton* and *Callitriche* spp. These remains changed above 65 cm suggesting a shift from *Chara* to fine-leaved *Potamogeton* by 45 cm, a change often associated with nutrient enrichment.

The analysis of cladoceran data showed a shift from the dominance of benthic to pelagic taxa over the period represented by the core. *Daphnia* became more abundant above 45 cm and pelagic taxa became more numerous than plant associated taxa, a pattern which has been shown to reflect nutrient enrichment.

If the assemblages at the base of the core, which is almost certainly at least 200 years old are taken as a ‘reference’ community this study has gone some way to defining the vegetation targets for Llyn Cadarn. The community should contain a number of *Chara* species including *C. vulgaris* type, *C. hispida* and *C. aspera* along with *Potamogeton* species.

INTRODUCTION AND PROJECT OBJECTIVES

Background

Llyn Cadarn is a small lake within Cors Goch SSSI and National Nature Reserve, and part of the Anglesey Fens Special Areas of Conservation (SAC). The lake is a kettle-hole less than 1ha in area but about 6m deep and is designated as a 'Hard water with *Chara*'. It has a dense floating fringe of *Cladium* / *Phragmites* swamp, with a narrow band of water lilies (*Nymphaea alba* and *Nuphar lutea*) and has been recorded as supporting various uncommon macrophytes including the near threatened rugged stonewort *Chara rudis* and long-leaved pondweed *Potamogeton* x *zizii* (Stewart 2004). Llyn Cadarn is a well buffered, calcium rich lake with pH values consistently above 7.5, reflecting the carboniferous limestone dominance in the catchment, reflected in a high alkalinity of 2995 µ-equivalents. Phosphorus concentrations require further investigation (2005 / 2006 data to follow), but an annual mean SRP value of 12 μgl^{-1} and chlorophyll *a* values greater than 10 μgl^{-1}, suggests slightly elevated nutrient status (mesotrophic) consistent with the low-lying nature of the site and high percentage of improved agricultural land in the catchment. Nitrate levels are relatively high with an annual mean of 1.64 mgL^{-1} and a winter high of 3.08 mgL^{-1} (Goldsmith et al. 2006) which has been associated with declines in hydrophyte species richness (James et al. 2005). Further details of the site can be found in Stewart (2004), Goldsmith et al. (2006) and Burgess et al. (2006).

The decline in ecological quality and conservation value of European fresh waters is an all too common phenomenon. In lowland Britain the main anthropogenic impact on aquatic systems is that associated with elevated nutrient loading. There has been a general decline in the ecological quality and conservation value of the fresh waters as a result of eutrophication, with one of the main symptoms being elevated algal productivity. One of the changes in the ecological structure and functioning of shallow lakes in response to enrichment is an alteration in their macrophyte flora (Riis & Sand-Jensen 2001) and in extreme cases there may be the complete loss of submerged plants (Scheffer *et al*. 1993). The loss of the diversity of the macrophyte flora in shallow lakes is one of the contributing factors to the decline in their conservation value.

Recent surveys in 2003 and 2005 failed to find any charophytes (Stewart 2004; Burgess *et al*. 2006) and the site failed to attain favourable condition (Burgess *et al*. 2006), with only, *Fontinalis antipyretica* and *Lemna trisulca* were the only submerged macrophytes. There is concern that water quality in the lake may be affected by pollution in the catchment, including discharge from a disused quarry now used as a landfill site.

The extent of past *Chara* cover in Llyn Cadarn is unknown. In the absence of reliable historical information on past aquatic macrophyte communities, analysis of sedimentary macro-remains of plants (the seeds, fruits and remains of stems, leaves and rhizomes) provide a means of determining changes in the aquatic flora of a site (Birks 1980). Recent work has indicated that plant macrofossils provide a reliable means for tracking shifts in the dominant components of the submerged aquatic flora in shallow lakes (Davidson et al. 2005a).

Study Aims

The primary objective of this project is to characterise the environmental history of Llyn Cadarn, with particular reference to charophytes. In particular, the study will attempt to establish whether charophytes have been the dominant species in the recent past (i.e. since around 1900). This information will be used to set appropriate restoration and management targets for the lake.

METHODS

Coring and Lithostratigraphic Analyses

A sediment core was collected on the 22/09/2007 from the South West side of the lake using the 'Big Ben' corer, a custom designed and built wide diameter (150mm internal diameter) piston corer (Goldsmith et al. unpublished). The core was extruded at 1cm intervals in the field and the main characteristics of the sediment and any stratigraphic changes were noted.

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^{o}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^{o}C for two hours and then reweighing. Carbonate content was calculated by returning the crucible to the furnace for two hours at 925^{o}C and then re-weighing.

Spheroidal carbonaceous particle (SCP) analysis

Sediment samples were analysed for SCPs following the method described in Rose (1994). Dried sediment was subjected to sequential chemical attack by mineral acids to remove unwanted fractions leaving a suspension of mainly carbonaceous material and a few persistent minerals in water. SCPs are composed mostly of elemental carbon and are chemically robust. The use of concentrated nitric acid (to remove organic material), hydrofluoric acid (siliceous material) and hydrochloric acid (carbonates and bicarbonates) therefore does them no damage. A known fraction of the resulting suspension was evaporated onto a coverslip and mounted onto a microscope slide. The number of SCPs on the coverslip were counted using a light microscope at 450× magnification and the sediment concentration calculated in units of 'number of particles per gram dry mass of sediment' (gDM-1). The criteria for SCP identification under the light microscope followed Rose (2008). Analytical blanks and SCP reference material (Rose 2008) were included in each batch of sample digestions. Reference concentrations agreed with the expected values while no SCPs were observed in the blanks. The detection limit for the technique is c. 100gDM-1, and concentrations have an accuracy of c. ± 45gDM-1.

The dating of the core follows the method described in Rose et al. (1995) whereby three main features of the SCP profile are used to provide dates: the start of the record, the rapid increase in SCP concentration and the peak in SCP concentration. A later approach using cumulative SCP inventory profiles (Rose and Appleby 2005) is not applicable to CADA3 as this method requires that a full record be present so that percentiles from the cumulative curve can each be ascribed a date. This is not possible where the record is incomplete. Hence, for CADA3 the former method is used.

Macrofossil analysis

In the initial screening of the core CADA3 low numbers of oospores were recorded. Thus, the back-up core taken on the same day was also extruded and screened, but did not have any greater densities of oospores. In order to maximise the number of oospores larger volumes of sediment than used in the standard methods, were analysed with adjacent levels amalgamated where necessary, thus the total volume was up to 100cm^{3}. Ten levels from CADA3 were examined for macrofossils. Samples were sieved at 350 and 125 microns, the exact sample volume being measured by water displacement. The entire residue on the 350 micron sieve was examined under a stereo-microscope at magnifications of 10-40× and plant and animal macrofossils were enumerated. A quantitative sub-sample, approximately one tenth of the sample, from the 125 micron sieve was analysed for

smaller remains, such as leaf spines. All material was identified by comparison to reference material.

A new technique developed in an attempt to determine species or species group level identification of *Chara* from their oospores (Davidson *et al*. in prep) was applied to the oospores found in the core. This model has been developed using the U.K. reference dataset of pressed charophyte specimens. Oospores taken from identified live material have been morphologically characterised and the features which best separate the oospores identified by a classification tree (Breiman *et al*. 1984). This model, calibrated by the morphological characteristics of oospores from reference material, can then be used to identify the oospores from core material based on these morphological characteristics. It was not always possible to identify the oospores to species level, in these cases the taxonomic level of species group was used.

Cladoceran analysis

The remains of cladocerans have been shown to reflect past changes in macrophyte abundance and fish community (Jeppesen *et al*. 2001). This technique can provide invaluable information on the mechanisms and causes of any observed change in the macrophyte flora at the site.

Cladocera remains will be analysed using an adaptation (Davidson *et al*. 2007) of standard techniques (Frey 1986; Korhola & Rautio 2000). Ephippial remains were separated and counted along with macrofossil remains using a binocular microscope, thus the counts are based on the analysis of at least 30cm^3 of sediment. Chitinous remains (head shields, carapaces and post abdomens) along with small ephippia were counted using a light microscope at 40× to 400×. Remains were identified using Frey (1958, 1959, 1964) Flössner (1972) and Alonso (1996). Counting of individuals will follow the minimum number method, where head shields, carapaces and post-abdominal claws are tabulated separately, and the count for each species is the number of the most numerous remains. The occurrences of the various taxa represented by chitinous remains are expressed as percentages or relative abundances. The remains of species best represented by ephippial remains are expressed as a relative abundance weighted by total ephippia abundance.

XRF analysis

In addition to the biological analyses completed in accordance with the project specification the sediments from CADA3 were analysed using X-ray fluorescence (XRF) in order to provide an estimate the phosphorus load in the sediment. The units are slightly complicated in that they are estimates of concentration in mg g^{-1} of sediment expressed as diphosphorus trioxide (P_2O_3). The method provides no information of the form of P and as there will be multiple, in the form absorbed, adsorbed and even co-precipitated in the carbonate structure and the method cannot differentiate between them. Thus, no information on bioavailability or mobility of P is provided, but it does provide an estimate of P loading over time and sediment content over-time. Furthermore, the sediment concentrations cannot be related those in pore waters as the analysis takes place on dried sediments. Thus, the method provides no means of reconstructing values for phosphorus concentrations in the water column, but does provide an idea of change in loading over time.

Constrained cluster analysis

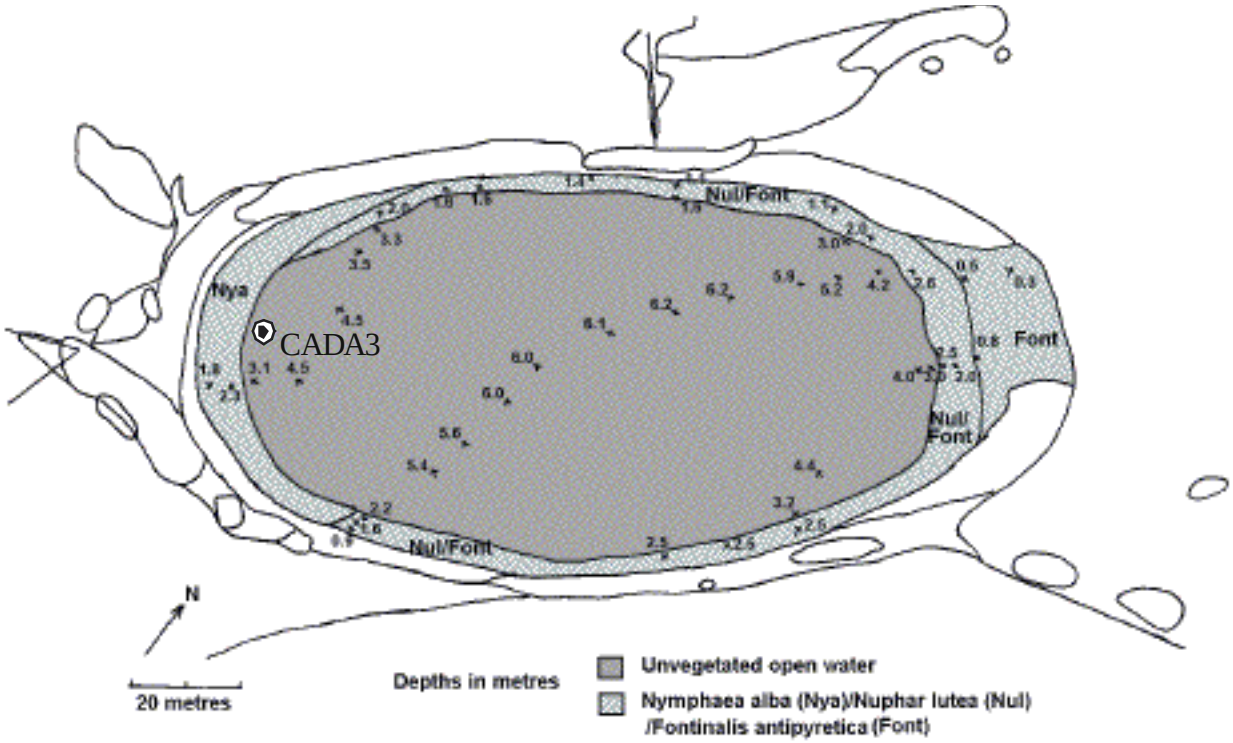
Cluster analysis was performed on both plant and animal macrofossil data to facilitate the description of zones for the core. A variety of constrained clustering techniques were employed using the program ZONE (Juggins 1991). This suite of techniques is used as all clustering techniques have weaknesses and in certain circumstances provide misleading zones. In order to obviate this problem the results of a number of methods were compared, and only the patterns which were consistent in a number of the techniques were employed.

RESULTS

Site and core description

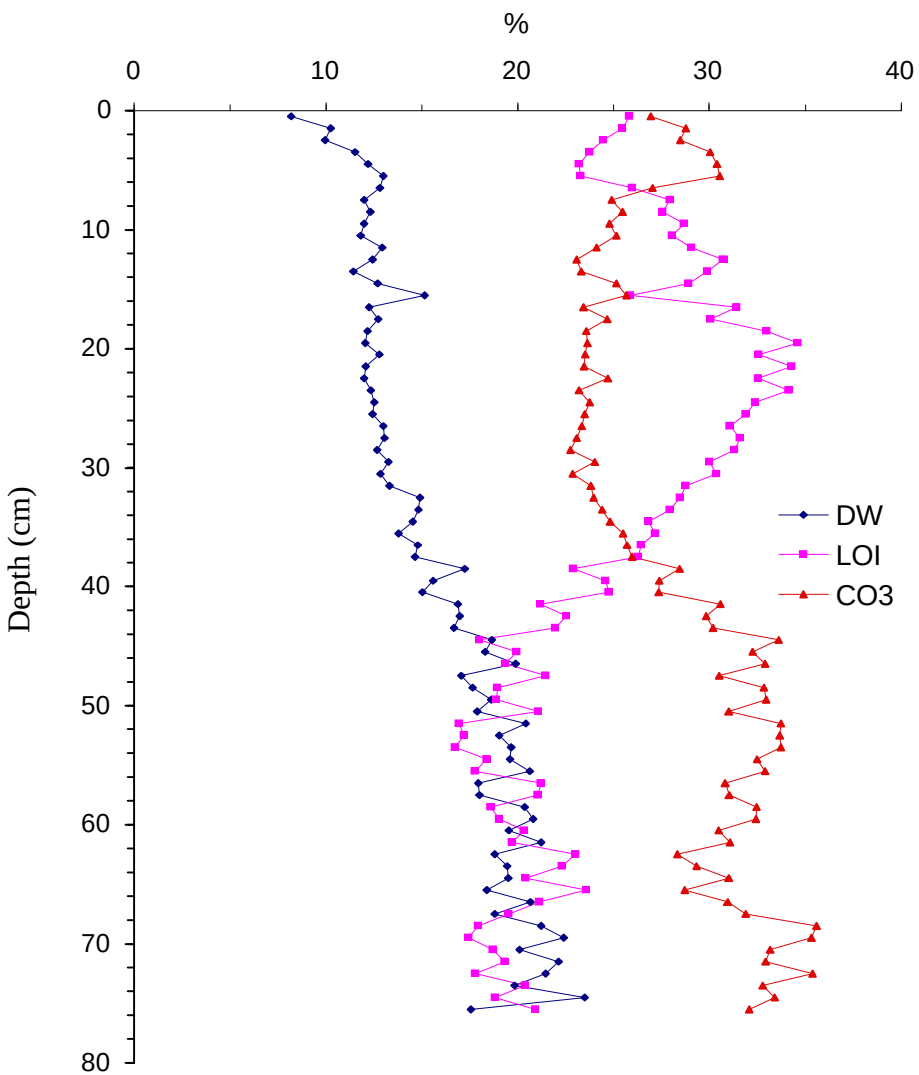
Llyn Cadarn (SH492811) is a relatively small (1.2 ha) kettle hole. A 76 cm core (CADA3) was collected from the South Western end of the lake in a depth of 2.5 metres (Fig. 1).

Figure 1 Depths and coring location of CADA3



The major changes in colour in CADA3 corresponded closely to variation in dry weight (DW), organic content (LOI) and carbonate content (CO_3) (Fig. 2). The base of the sequence (75cm) had a pale marl colour, high carbonate content and low LOI. At around 45cm there was a colour change as the sediment became darker, LOI increased and the percentage carbonate content fell from relatively high levels (>30%) to moderate, but still high levels (20-25%). The values and colour all remained relatively stable above 40cm. There was a sharp rise in carbonate and a fall in LOI at around 5 cm which was followed by a decline in carbonate and rise in LOI above 5 cm.

Figure 2 Sediment core stratigraphy of CADA3

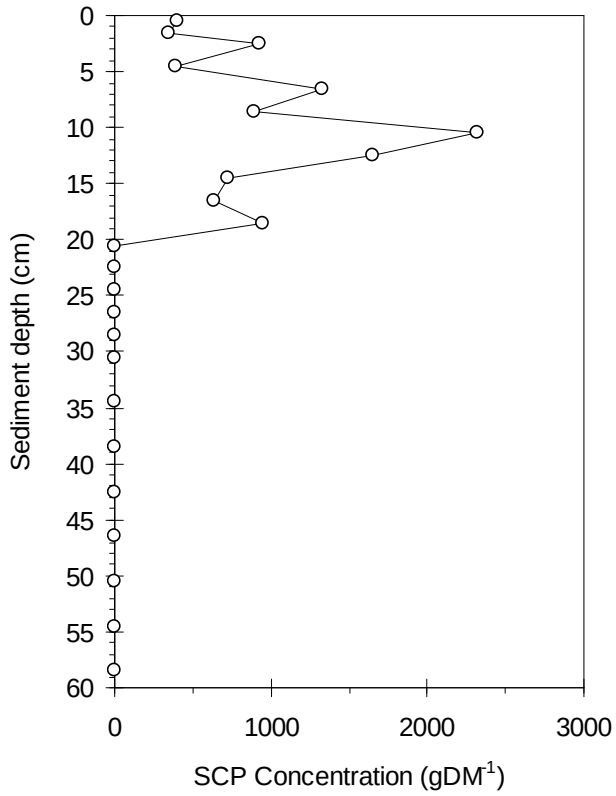


Depth (cm)	Sediment colour
0-45	Grey brown
45-75	Pale-grey marl

SCP dating

The SCP concentrations for CADA3 from Llyn Cadarn are shown in Figure 3 below. Low SCP numbers were observed throughout the core resulting in low concentrations and large confidence intervals. Low concentrations could result from a high sediment accumulation rate or low levels of contamination. North Wales is an area known to have received high levels of deposited contamination historically and hence these data may be indicative of rapid sediment accumulation rate in the coring location.

Figure 3 SCP concentration in CADA3



A first presence of SCPs occurred at 18-19cm and concentrations increased rapidly to a peak concentration of over 2300gDM^{-1} at 10-11cm. Concentrations then declined irregularly to the sediment surface. Despite the low concentrations, if it is assumed that the SCP concentration peak represents the period of maximum deposition then 10-11 cm may be ascribed the date 1978 (± 5) years. This produces a mean sediment accumulation rate for the most recent 29 years of 0.362cm yr^{-1} (0.309-0.438cm yr^{-1}). If this rate is extrapolated below 11cm, then 1950, usually indicated by a rapid increase in SCP concentration, would be expected to occur at 20-21cm (17.5-25cm). In cores where SCP numbers / concentrations are low, this rapid increase may be observed as the start of the SCP record as the concentration moves from below to above the analytical limit of detection for the first time. Such a situation would explain the profile observed in CADA3 but would also require that the mean sediment accumulation rate has not changed over the most recent 50 -60 years.

Extrapolating this same mean sediment accumulation rate would place 1850 at 56-57 cm (48-68cm) but it should be stressed that confidence is low in this earlier estimate, not only because it requires no change in mean sediment accumulation rate over a 150 year period, but also because the ascribed dates are based on low SCP concentrations and hence errors are likely to be high.

The best available chronology is summarised in the following Table 1. All dates should be treated with caution but data extrapolated below the SCP profile (shown in italics) especially so.

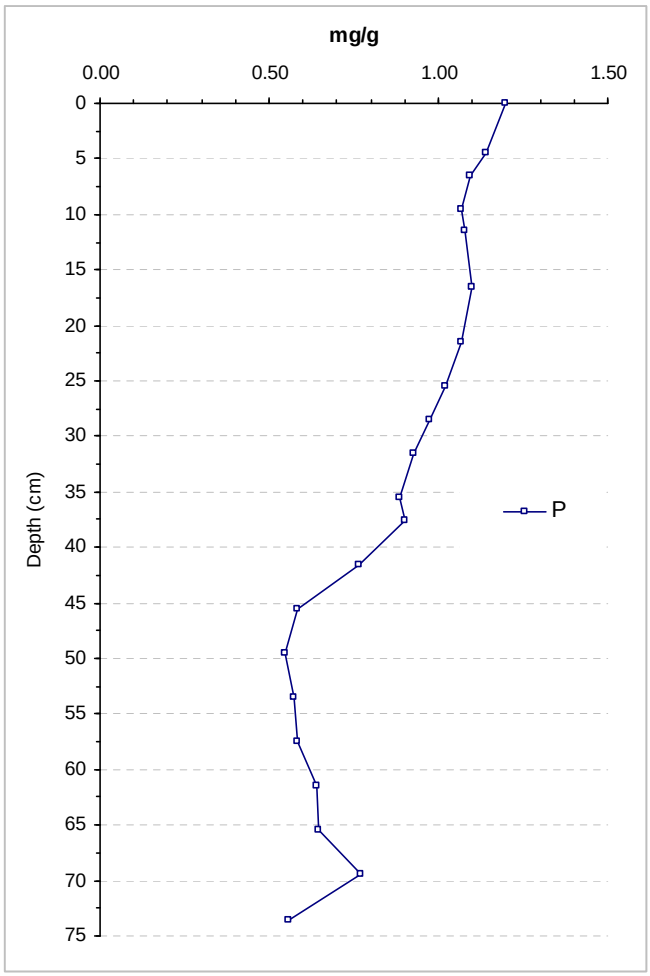
Table 1 SCP chronology for CADA3

Sediment depth (cm)	Age (Years)	Date
0	0	2007
5	14 ± 2	1993 ± 2
10	28 ± 4	1979 ± 4
15	41 ± 7	1966 ± 7
20	55 ± 10	1952± 10
30	*83 ± 15*	*1924 ± 15*
40	*110 ± 20*	*1897 ± 20*
50	*138± 25*	*1869± 25*

XRF determined phosphorus concentration in CADA3

The was a fairly marked change in the concentration of P in the sediments of CADA3 in the time period covered by the core (Fig. 4). Below 45cm the concentration was stable at around 0.5 mg g^{-1} above 45cm there was a sharp increase to 40cm in which time the value doubled. Above 40cm there was a more gradual increase in the value of P concentration in the sediments to the surface of the core. The core surface concentration of 0.12 mg g^{-1} is the highest sediment P concentration in the recent history of Llyn Cadarn.

Figure 4 P concentrations (mg g^{-1} as P_2O_3) in CADA3



Macrofossil data

Oospore identification

The number of oospores found in CADA3 were rather low. Three distinct oospore morphotypes were identified. The model developed (Davidson et al. in prep) identified the oospores present as *Chara vulgaris* type (which includes *C. vulgaris* and *C. contraria*), *Chara hispida*, and *Chara aspera* type (which includes *C. aspera*, *C. curta* and *C. virgata*).

Plants remains

The summary stratigraphy of plant remains found in CADA3 can be seen in Figure 5. *Potamogeton* leaves are identified to the highest possible taxonomic level. The *Potamogeton* leaves unidentified fragments are sections of leaf too small and/or degraded to be identified as either broad-leaved or fine-leaved and the highest appropriate level is *Potamogeton* spp.

Plant Zone 1 (75-63cm)

Zone 1 was dominated by a large number of *Chara vulgaris* type with an abundance of 237 per $100cm^3$ in the lowest sample, which fell in number towards the top of the zone. Small numbers of oospores of *Chara hispida* and *Chara aspera* type occurred in zone 1. The lowermost sample also contained a relatively small number of *Nymphaeaceae* trichosclerids (these are 'star' cells from the plants leaf) remains, *Callitriche* seeds, *Lemna trisulca* leaves and a fragment of a *Nymphaea alba* seed. The remains of some fine leaved *Potamogeton* species were also present in Zone 1 and increased in abundance towards the top of the zone.

Plant Zone 2 (63- 43cm)

Zone 2 was dominated by fine leaved *Potamogeton* species remains, with *Potamogeton berchtoldii/ pusillus* and *Potamogeton obtusifolius* remains found within this zone. The numbers of *Chara* oospores fell at this time when compared with zone 1 and all morphotypes were virtually absent by the top of the zone. *Nymphaeaceae* trichosclerid remains increased slightly within this zone.

Plant Zone 3 (43-0cm)

Nymphaeaceae trichosclerid remains dominated this zone increasing to maximum abundance at 20cm. However, overall plant macrofossil remains are relatively sparse in Zone 3 with minimal numbers oospores of *Chara vulgaris* type and reduced numbers of fine-leaved *Potamogeton* remains.

Figure 5 Summary plant macrofossil stratigraphy from CADA3

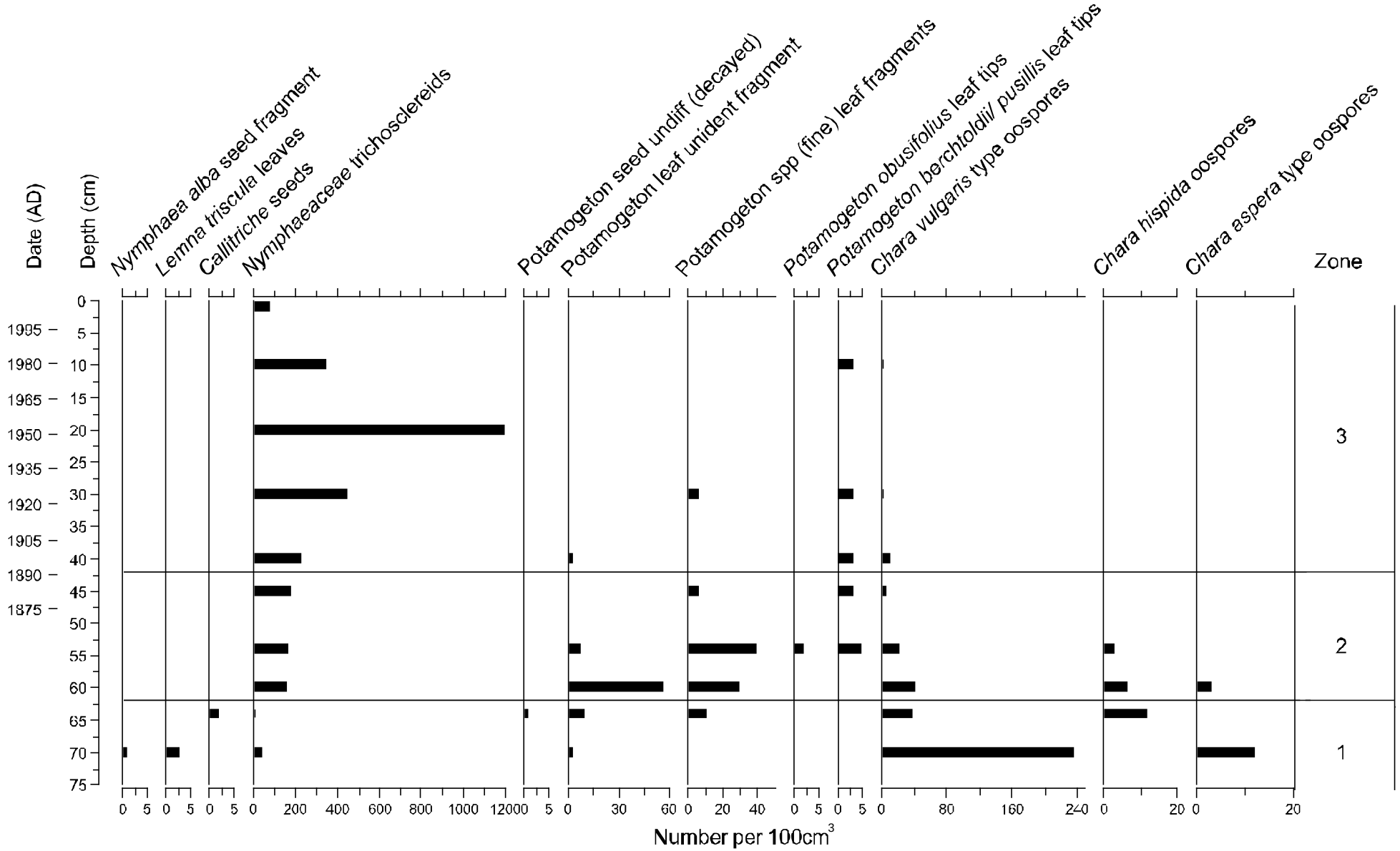
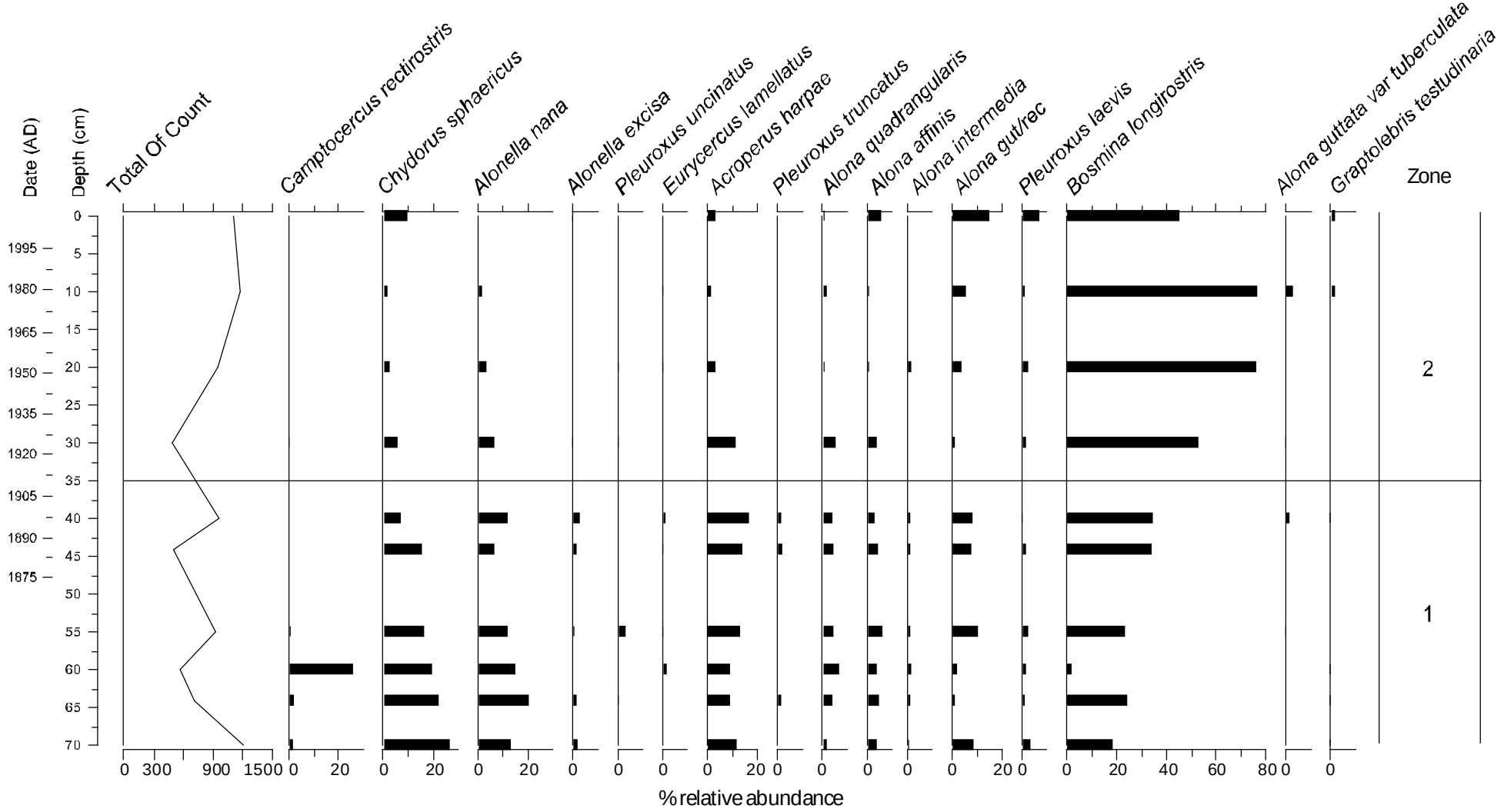


Figure 6 Summary cladoceran stratigraphy from CADA3



Cladoceran data

The results of the cladoceran analysis of CADA3 can be seen in Figure 6.

Cladoceran Zone 1 (70-30cm)
The chitinous sub-fossil cladoceran profile was dominated by benthic, macrophyte-associated species, *Acroperus harpae, Alonella nana, Chydorus sphaericus* and *Camptocercus rectirostris* (Hann 1989; Alonso 1996). The latter species has been associated with carbonate rich, macrophyte dominated conditions in Ireland (Duigan & Kovach, 1991). *Chydorus sphaericus* dominated at 70cm depth with a relative abundance of over 40%, which declined gradually up the core. The diversity of cladocerans within this bottom zone was relatively high, with a number of subordinate species including *Pleuroxus laevis, Camptocercus rectirostris, Simocephalus* spp. and several *Alona* spp. present. Pelagic species were present in this zone with low relative abundance of *Bosmina longirostris* and *Ceriodaphnia* spp. ephippia the most numerous ephippia type as *Daphnia hyalina* agg. was present but in relatively low numbers.

Cladoceran Zone 2 (30-0cm)
There was a significant shift in the cladoceran remains above 30cm depth. The shift was characterised by a decline in the diversity of cladoceran taxa and an increase in the relative and absolute abundance of pelagic taxa. The small-bodied pelagic cladoceran Bosmina longirostris dominated the chitinous remains with over 40% relative abundance. Furthermore, the numbers of ephippia of the larger pelagic cladocerans D. hyalina agg. increased in abundance. Ceriodaphnia ephippia numbers fell in the top zone though were still present in relatively high numbers.

DISCUSSION

The SCP technique applied to CADA3 provided a relatively good chronology for the core post 1950. It did not, however, provide a good estimate of accumulation rates and dates prior to 1950 and the dates ascribed are based on assumptions of little change in accumulation rate, which are unlikely to be true. It is, therefore, difficult to be certain about the time period covered by the core, as there are likely to have been changes in the accumulation rates, particularly given the changes in the physical and chemical properties and the biological assemblages that occurred around 45 cm, which could tentatively be said to be around 1900. It is very difficult to provide an estimate for the date at the base of the core, beyond saying it is older than 1800 and may well be older than that.

The number and diversity of plant remains found in CADA3 was generally lower than previous macrofossil work carried out by ENSIS and other published data (e.g. Odgaard & Rasmussen 2001; Davidson et al. 2005b; 2008). A number of studies have demonstrated that the analysis of plant macrofossils in sediments is unlikely to reconstruct absolute species diversity as rare species and those which leave fewer remains (e.g. *Potamogeton* species) are likely to be under-represented (Davis 1985; Dieffenbacher-Krall & Halteman 2000). The method has, however, been shown to provide a reliable means with which to track changes in the dominant components of the submerged vegetation of shallow lakes (Davidson et al. 2005a). Furthermore, the depth of Llyn Cadarn presented problems in identifying a suitable coring location and the site chosen was significantly deeper than that some of the other studies, perhaps resulting in less abundant remains. There were, however, relatively abundant remains in the lower sediments of the core. Thus, despite the fact there were fewer remains of plants in the sediments compared with other studies, (e.g. Davidson et al. (2005b, there were sufficient to provide some valuable insights on the nature of the historical flora of Llyn Cadarn.

Notwithstanding the problems with the dating and the relative paucity of plant remains in CADA3 there was very good agreement between the physical, chemical and biological elements analysed.

To summarise; the data suggest that at 40 - 45 cm, which may correspond to around 1900, a change was initiated in the ecological structure and function of the lake. At this time there was a decline in carbonate content, an increase in sediment organic content (LOI), an increase in sediment P and shifts in the macrofossil and cladoceran assemblages. Interestingly there is some historical evidence of some dredging activity around this time, *c*. 1900 (pers comm. John Ratcliffe). The ouflow channel of the lake may have been dredged in an attempt to drain the bog. This may have brought more sediment into the lake and led to the changes indicated by the palaeo record.

The fall in sedimentary carbonate content likely reflects a decline in carbonate precipitation, either on the surface of the *Chara* species present (Garcia and Chives 2004) or planktonic marl precipitation (Marshall et al. 2002) and may reflect the point at which charophytes were no longer abundant at the site. Why marl lakes stop precipitating marl is a moot point, the cessation of marl formation is associated with eutrophication but the actual mechanism at work it not clear. What is clear is that when marl production stops it is likely to exacerbate any nutrient enrichment as phosphate is no longer co-precipitated with the carbonate in the marl (Otsu and Wetzel 1972). This process sequesters phosphate from the water column into the structure of the carbonate, buffering marl lakes from the initial impacts of eutrophication, or at least the phosphorus driven aspects of eutrophication. The increase in which occurred in concert with the fall in carbonate fall and the shift in macrofossil assemblage LOI is also a well established, though not unequivocal, response to eutrophication and it matched the rise in sediment P concentration.

The biological response was a little more complicated, with the data suggesting substantial change in the macrophyte flora below 45cm. Below 64cm the data suggest plentiful *Chara* with *C. vulgaris* type abundant and *C. hispida* and *Chara aspera* type present with *Callitriche* spp., *N. alba* and *Potamogeton* spp. also found. *Nuphar lutea* may also have been present as the tichoschlerid remains can come from both *N. alba* and *N. lutea* but the seeds found were from only *N. alba*. Thus, we can only be completely certain of the presence of *N. alba*. Above 65-45cm there appears to have been a shift from *Chara* to the more nutrient tolerant angiosperms, such as fine-leaved *Potamogeton*, a pattern common to cases of nutrient enrichment (Blindow et al. 1992; Davidson et al. 2005a).

The response in the cladoceran assemblage in the core further confirm the historical changes in structure and function of Llyn Cadarn. There were some subtle changes below 45 cm which may reflect the shift from *Chara* to *Potamogeton* dominance. The main change, initiated at around 45cm was the increase in the relative and absolute abundance of pelagic species (*B. longirostris*, *D. hyalina* agg. and *Ceriodaphnia* spp.) which reflects the eutrophication induced increase in the proportion of pelagic productivity (Davidson *et al*. in press; Vadeboncoeur *et al*. 2005). The structure of pelagic zooplankton assemblages are strongly influenced by predators, particularly fish (Brooks & Dodson, 1965). Shifts in fish predation pressure are largely detected by changes in the relative abundance of the taxa of different body size. Thus, an increase in *B. longirostris* relative to *Daphnia* could reflect increased predation pressure as the larger taxa are preferentially selected by fish. However, there is no evidence that this occurred here as the abundance of *B. longirostris* and *Daphnia* spp. increased. The abundance of *Ceriodaphnia* spp. ephippia fell slightly which may indicate a fall in macrophyte abundance (Jeppesen et al. 2001). This strongly suggests an increase in habitat and food availability, i.e. open water (Lauridsen & Lodge 1996) and phytoplankton respectively (Lynch & Shapiro 1981, Davidson et al. in press). This is in good agreement with the observed changes in the macrofossil assemblage, showing an increase in phytoplankton production and a concomitant shift in macrophyte assemblage.

The species of Charophyte that each oospore type corresponded to may be informed by current distribution and known historical presence. The *Chara vulgaris* type could be either of the species of perhaps both are found in the area, *C. vulgaris* is the more common species so may be the more likely occurrence. Of the *C. aspera* group: *Chara aspera* is very rare on Anglesey, although there

are records from the 19th century. This species tends to grow in shallow water and so its presence may have been less likely in Cadarn. *C. virgata* was widespread in NW Wales, and frequently grows in deeper water (e.g. L. Anafon.) and this may be the most likely candidate, it is however, generally less common in more alkaline waters. *C. curta* also occurs on the Anglesey fens and could have also grown in the lake. Thus, this group is likely to have been one of these two species. *C. hispida*: There are records for this species on several of the Anglesey Fens, though it's never been recorded from Cors Goch. *C. rudis*, formerly classified as a variety of *C. hispida* in the past has been recorded at the site. The oospores are, however, quite distinct and the model normally separates these two species, thus it is unlikely the oospores found were from *C. rudis*. *C. hispida* and *C. rudis* are perennial, so may not produce so many oospores per unit of biomass, which would be in good agreement with the low numbers of oospores found in the sediments.

In terms of defining restoration targets for Llyn Cadarn, the data presented here suggest that the lakes one had a macrophyte community dominated by *Chara* with a number of species present, perhaps including *C. vulgaris* type, *C. hispida* and *C. virgata* or *curta*, and various *Potamogeton* species present. There would likely have been a number of other, perhaps much less common subordinate species, such as *Callitriche* present at any one time. There are often a number of less common macrophyte species at a site and these are less likely to leave sedimentary remains (Davidson et al. 2005a). This fact, combined with the differential production of fossils between macrophyte groups is why we cannot use the palaeo record as an accurate record of past species richness, particularly for macrophytes. In terms of functional targets the other information provided from the sediment core suggests that the nutrient load at the site would have been significantly lower. The cladoceran assemblage suggests that the maintenance of clear water is now dependent upon a relatively abundant grazing cladoceran community, whereas previously, at the time of Chara dominance, planktonic productivity was likely to have been resource, i.e. nutrient, limited.

The role of nitrogen in the progressive eutrophication of Llyn Cadarn is largely not elucidated in this study. It is likely to have had a role and there is an increasing realisation of its impact upon hydrophyte species richness (James et al. 2005) and phyoplankton crop, in particular at moderate nutrient enrichment (Gonzalez et al. 2005). Nitrate supply is likely to have increased through air-pollution with the onset of the industrial revolution (Galloway et al. 2003) and has been shown to impact even isolated lakes (Wolfe et al. 2000). Thus, it is possible that the relatively early impact of eutrophication at Llyn Cadarn was due to air-borne nitrogen deposition. It might be possible to investigate this by analysing the isotopic composition of the nitrogen in the sediment core.

The impact of air-borne nitrogen deposition may not have impacted Llyn Yr Wyth Eidion, a lake proximal to Llyn Cadarn which does not appear to have undergone such substantial change as Llyn Cadarn as it reportedly still precipitates marl in the summer months (JNCC web site). A paired study of the two sites matching the existing study to Llyn Yr Wyth Eidion might provide information on the changes in Llyn Cadarn that led to the decline in ecological integrity and perhaps provide some early warning indicators of change for Llyn Yr Wyth Eidion. A similar palaeo study to Cadarn, perhaps with some contemporary aspects to aid interpretation of the sedimentary records of both sites, at Llyn Yr Wyth Eidion along with, perhaps the addition of nitrogen isotope analysis at both sites might provide valuable insights into what and how these marl lakes have changed over the last 200 years.

Management recommendations

The findings of the study suggest that the root cause of the changes in macrophyte flora observed over the last 200 years or so can be attributed to the elevation of nutrient levels. There is some evidence of disturbance to the bog around 1900 which, if it had changed the balance of groundwater to surfaces water influx may have impacted the water quality and thus the flora. This is conjecture, and it is difficult to see what management strategies could evolve even if this could be proved.

The most probable explanation to the changes in flora and fauna observed in the sediment record is increased nutrient concentrations in the water column. Lakes like Llyn Cadarn, which are relatively deep with few shallow areas for macrophytes to colonise, may be particularly sensitive to the decreased light availability that is likely to occur with eutrophication. The presence of a landfill site within the catchment may represent a threat to the site as it may result in some localised nutrient enrichment and it is important that this is monitored. If there are contemporary point sources of nutrient inputs, it is vital they are identified, for example the landfill site. If the area is a candidate nitrate sensitive zone and nitrogen is likely to become less plentiful then the site may recover.

The fish community, the impacts of which can cascade down the trophic levels and heavily impact water clarity and thus macrophyte communities (Carpenter et al. 1985) does not appear to have any impact on the zooplankton assemblages. There does not seem to be any fisheries management options which may improve the sites condition. Whilst this study has provided a wealth of information on the past condition of the site and the historical context and extent of the changes in the ecology of Llyn Cadarn it has not provide the information required for the management of the site. It has provided clear restoration aims, fulfilling the aims of the study which has the title 'Defining Lake Vegetation Monitoring Targets at Llyn Cadarn using Palaeolimnology' in the original project specification. Without further investigation, perhaps a study involving other marl lakes in the region to examine the causes of crucial changes in function associated with a decline in ecological quality, it is very difficult to outline management options which will restore the site to its former condition.

A detailed nutrient and sediment budget at the site may help in identifying both places and times when the nutrient load at the site is increased and management could be tailored accordingly. Further if air-borne nitrogen pollution were identified as having been crucial in the deterioration of the site, then with the reduction in this form of pollution it may be a question of waiting for recovery, or finding the means to precipitate such a recovery.

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APPENDICES

1. Lithostratigraphic data

CADA3

Top Depth	Base Depth	Mid Depth (cm)	Crucible	Cruc. & wet sed.	Cruc. & dry sed.	Cruc. & 550C sed.	Cruc & 950 sed.	Dry Wt %	LOI 550 % wt	CO3
0	1	0.500	6.2755	7.7177	6.3936	6.3631	6.3397	8.1889	25.8256	26.9467
1	2	1.500	5.7119	7.004	5.8442	5.8105	5.7825	10.2391	25.4724	28.7831
2	3	2.500	6.1451	7.9151	6.3213	6.2782	6.2413	9.9548	24.4608	28.4813
3	4	3.500	6.0058	7.8172	6.2144	6.1648	6.1187	11.5160	23.7776	30.0556
4	5	4.500	5.802	7.0316	5.9519	5.9171	5.8836	12.1910	23.2155	30.3936
5	6	5.500	5.8942	7.0068	6.0388	6.0051	5.9726	12.9966	23.3057	30.5671
6	7	6.500	5.9511	7.4594	6.1443	6.0941	6.0557	12.8091	25.9834	27.0311
7	8	7.500	5.9581	7.7168	6.1687	6.1098	6.0712	11.9748	27.9677	24.9269
8	9	8.500	5.9535	7.8378	6.1857	6.1217	6.0782	12.3229	27.5624	25.4780
9	10	9.500	5.7669	7.4104	5.9639	5.9074	5.8715	11.9866	28.6802	24.7838
10	11	10.500	6.5935	8.172	6.7801	6.7277	6.6932	11.8213	28.0815	25.1447
11	12	11.500	5.8401	7.5855	6.0657	6.0001	5.9601	12.9254	29.0780	24.1135
12	13	12.500	6.0814	7.6934	6.2818	6.2202	6.1862	12.4318	30.7385	23.0739
13	14	13.500	5.9762	7.9173	6.1978	6.1315	6.0935	11.4162	29.9188	23.3213
14	15	14.500	5.6708	7.5665	5.9113	5.8417	5.7972	12.6866	28.9397	25.1642
15	16	15.500	6.0836	7.2909	6.2663	6.219	6.1845	15.1329	25.8894	25.6814
16	17	16.500	5.7867	7.0085	5.9364	5.8894	5.8636	12.2524	31.3961	23.4389
17	18	17.500	5.4846	6.5924	5.6256	5.5832	5.5576	12.7279	30.0709	24.6922
18	19	18.500	5.9976	7.4124	6.1695	6.1128	6.083	12.1501	32.9843	23.5765
19	20	19.500	5.875	7.532	6.0747	6.0056	5.9709	12.0519	34.6019	23.6314
20	21	20.500	5.7677	7.7337	6.019	5.9372	5.8937	12.7823	32.5507	23.5416
21	22	21.500	5.8511	6.8962	5.9774	5.9341	5.9123	12.0850	34.2835	23.4743
22	23	22.500	5.9787	7.4497	6.1548	6.0975	6.0655	11.9714	32.5383	24.7132
23	24	23.500	5.5971	6.9118	5.7595	5.7041	5.6764	12.3526	34.1133	23.1970
24	25	24.500	6.0074	7.5558	6.2014	6.1386	6.1047	12.5291	32.3711	23.7649
25	26	25.500	5.7002	7.4183	5.9138	5.8457	5.8088	12.4323	31.8820	23.4944
26	27	26.500	5.9266	7.5893	6.1426	6.0755	6.0384	12.9909	31.0648	23.3593
27	28	27.500	6.147	7.4757	6.3202	6.2655	6.2361	13.0353	31.5820	23.0855

28	29	28.500	6.4037	7.4499	6.5363	6.4948	6.4726	12.6744	31.2971	22.7692
29	30	29.500	5.7854	6.8954	5.9326	5.8884	5.8624	13.2613	30.0272	24.0217
30	31	30.500	6.2904	7.3595	6.4277	6.386	6.3629	12.8426	30.3714	22.8813
31	32	31.500	5.9577	7.2088	6.1244	6.0764	6.0472	13.3243	28.7942	23.8224
32	33	32.500	5.6724	6.9013	5.8556	5.8034	5.7711	14.9076	28.4934	23.9782
33	34	33.500	5.9553	7.363	6.1641	6.1057	6.0682	14.8327	27.9693	24.4253
34	35	34.500	5.7175	7.2191	5.9354	5.8769	5.8371	14.5112	26.8472	24.8408
35	36	35.500	6.139	7.4815	6.324	6.2737	6.239	13.7803	27.1892	25.5092
36	37	36.500	5.8413	7.5099	6.0879	6.0227	5.9761	14.7789	26.4396	25.6999
37	38	37.500	5.7574	7.323	5.9866	5.9263	5.8825	14.6398	26.3089	25.9895
38	39	38.500	6.1257	7.4898	6.3609	6.307	6.2578	17.2421	22.9167	28.4490
39	40	39.500	6.3167	8.1411	6.6008	6.5309	6.4737	15.5722	24.6040	27.3819
40	41	40.500	6.0819	7.6037	6.3105	6.2539	6.2079	15.0217	24.7594	27.3666
41	42	41.500	5.7684	7.5507	6.0696	6.0058	5.9381	16.8995	21.1819	30.5684
42	43	42.500	5.8028	7.5286	6.0957	6.0296	5.9653	16.9718	22.5674	29.8559
43	44	43.500	5.9517	7.907	6.2778	6.2062	6.1338	16.6777	21.9565	30.1944
44	45	44.500	5.8944	7.413	6.1778	6.1268	6.0568	18.6619	17.9958	33.5921
45	46	45.500	5.7857	6.9012	5.9898	5.9491	5.9007	18.2967	19.9412	32.2509
46	47	46.500	5.9269	7.1998	6.1801	6.1311	6.0699	19.8916	19.3523	32.8720
47	48	47.500	5.7167	6.7338	5.8901	5.8529	5.814	17.0485	21.4533	30.5098
48	49	48.500	5.8744	7.5692	6.1734	6.1167	6.0445	17.6422	18.9632	32.8401
49	50	49.500	5.7671	7.2699	6.047	5.9941	5.9263	18.6252	18.8996	32.9432
50	51	50.500	6.4029	8.0864	6.704	6.6405	6.5719	17.8854	21.0893	30.9851
51	52	51.500	5.8631	7.3077	6.1583	6.1083	6.0351	20.4347	16.9377	33.7236
52	53	52.500	5.5959	6.7727	5.8201	5.7815	5.726	19.0517	17.2168	33.6664
53	54	53.500	6.3168	7.7201	6.5927	6.5465	6.4781	19.6608	16.7452	33.7166
54	55	54.500	5.699	6.9836	5.9507	5.9044	5.8443	19.5936	18.3949	32.4736
55	56	55.500	6.1153	7.6089	6.4237	6.3689	6.2943	20.6481	17.7691	32.8975
56	57	56.500	5.9272	7.3161	6.1766	6.1237	6.0672	17.9567	21.2109	30.8099
57	58	57.500	6.0006	7.8028	6.3249	6.2566	6.1826	17.9947	21.0607	31.0330
58	59	58.500	6.1338	7.5411	6.4206	6.3673	6.2989	20.3795	18.5844	32.4351
59	60	59.500	5.6739	7.5666	6.068	5.993	5.8991	20.8221	19.0307	32.4040
60	61	60.500	5.198	6.3209	5.4174	5.3728	5.3236	19.5387	20.3282	30.4977
61	62	61.500	5.8887	6.9827	6.1209	6.0751	6.0221	21.2249	19.7244	31.0422
62	63	62.500	5.8499	7.1912	6.1023	6.0442	5.9916	18.8176	23.0190	28.3423
63	64	63.500	6.138	7.6997	6.4419	6.3741	6.3085	19.4596	22.3100	29.3570
64	65	64.500	6.1253	7.2669	6.3481	6.3026	6.2518	19.5165	20.4219	31.0090

65	66	65.500	6.2897	8.1408	6.63	6.5497	6.4778	**18.3837**	**23.5968**	28.7346
66	67	66.500	4.8639	6.0917	5.1176	5.064	5.0063	**20.6630**	**21.1273**	30.9310
67	68	67.500	6.0833	7.1864	6.2906	6.2501	6.2015	**18.7925**	**19.5369**	31.8842
68	69	68.500	5.4834	6.5948	5.7192	5.6769	5.6152	**21.2165**	**17.9389**	35.5861
69	70	69.500	5.7837	6.9374	6.0422	5.9971	5.93	**22.4062**	**17.4468**	35.3021
70	71	70.500	5.5934	6.6125	5.7982	5.7599	5.71	**20.0962**	**18.7012**	33.1367
71	72	71.500	5.7565	6.7853	5.9842	5.9402	5.8851	**22.1326**	**19.3237**	32.9100
72	73	72.500	5.6415	6.8008	5.8904	5.8461	5.7814	**21.4699**	**17.7983**	35.3524
73	74	73.500	5.6849	6.9416	5.9343	5.8834	5.8233	**19.8456**	**20.4090**	32.7731
74	75	74.500	4.922	6.4062	5.2707	5.205	5.1194	**23.4941**	**18.8414**	33.3857
75	76	75.500	5.9962	7.473	6.2558	6.2015	6.1403	**17.5785**	**20.9168**	32.0616

2. CADA3 SCP concentrations

Mean depth (cm)	SCP conc (gDM^{-1})	90% Conf. int. (gDM^{-1})
0.5	406	397
1.5	345	338
2.5	927	524
4.5	392	384
6.5	1327	751
8.5	895	620
10.5	2320	1017
12.5	1651	1144
14.5	722	707
16.5	636	441
18.5	943	924
20.5	0	0
22.5	0	0
24.5	0	0
26.5	0	0
28.5	0	0
30.5	0	0
34.5	0	0
38.5	0	0
42.5	0	0
46.5	0	0

50.5	0	0
54.5	0	0
58.5	0	0

3. CADA Phosphorus sediment concentration, expressed as mg g^{-1} as P_2O_3

Level	Depth	P
cada001	0	1.20
cada002	4.5	1.14
cada003	6.5	1.10
cada005	9.5	1.07
cada006	11.5	1.08
cada007	16.5	1.10
cada008	21.5	1.07
cada009	21.5	1.03
cada010	25.5	1.02
cada011	28.5	0.97
cada012	31.5	0.93
cada014	35.5	0.89
cada015	37.5	0.90
cada016	41.5	0.77
cada017	45.5	0.58
cada019	49.5	0.55
cada020	53.5	0.57
cada021	57.5	0.58
cada022	61.5	0.64
cada023	65.5	0.65
cada024	65.5	0.66
cada025	69.5	0.77
cada026	73.5	0.56

4. Macrofossil data

Depth (cm)	1	10	20	30	40	45	54	60	64	70
Plant remains										
Potentilla seeds	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
Nymphaea alba seed fragment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
Nymphaeaceae trichosclerids	83.33	353.33	1250.00	450.00	233.33	183.33	170.00	166.67	10.00	50.00

Silene seeds	0.00	3.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chara aspera type oospores	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.33	0.00	12.00
Chara vulgaris oospores	0.00	3.33	0.00	3.33	11.67	6.67	24.00	41.67	39.00	237.00
Chara hispida oospores	0.00	0.00	0.00	0.00	0.00	0.00	3.00	6.67	12.00	0.00
Selliginella selaginoides megaspores	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	0.00
Lemna triscula leaves	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00
Glyceria seeds	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	1.00
Juncus seeds	16.67	0.00	0.00	0.00	16.67	0.00	61.00	16.67	50.00	20.00
Moss leaves (sphagnum)	0.00	0.00	0.00	0.00	0.00	6.67	11.00	0.00	16.00	5.00
Epilobium seeds	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.33	0.00	0.00
Carex seed (triangular)	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	1.00
Fern sporangium	16.67	83.33	283.33	216.67	183.33	366.67	260.00	316.67	360.00	250.00
Callitriche seeds	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00
Potamogeton seeds unident (part decayed)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
Potamogeton spp (fine) leaf fragments	0.00	0.00	0.00	6.67	0.00	6.67	40.00	30.00	11.00	0.00
Potamogeton obtusifolius leaf tips	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00
Potamogeton seed undiff.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00
Potamogeton berchtoldii/ pusillus leaf tips	0.00	3.33	0.00	3.33	3.33	3.33	5.00	0.00	0.00	0.00
Moss leaves golden	3886.67	5020.00	1076.67	560.00	303.33	280.00	407.00	606.67	2498.00	8670.00
Cladium type seeds	0.00	0.00	0.00	3.33	0.00	0.00	0.00	0.00	1.00	0.00
Clear Gelatinous balls	0.00	0.00	0.00	0.00	0.00	166.67	0.00	0.00	0.00	0.00
Invertbrate remains										
Case of Trichoptera (Fragments)	0.00	3.33	3.33	6.67	16.67	3.33	6.00	3.33	2.00	1.00
Agraylea case	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
Plumatella statoblasts	0.00	33.33	66.67	116.67	83.33	66.67	170.00	233.33	150.00	830.00
Oribatid mite heads	0.00	33.33	36.67	0.00	16.67	66.67	41.00	50.00	20.00	1.00
Testate amoeba conical flask	0.00	33.33	33.33	66.67	83.33	66.67	150.00	416.67	140.00	30.00
Testate amoeba round	500.00	250.00	50.00	83.33	133.33	233.33	130.00	200.00	670.00	610.00
Frontoclypeal apotome (unknown)	6.67	6.67	16.67	26.67	16.67	3.33	4.00	23.33	2.00	32.00
Cristatella statoblasts	0.00	36.67	16.67	16.67	6.67	0.00	3.00	0.00	9.00	0.00
Erpobdella egg cocoon	0.00	0.00	6.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gastropod shells										
Gyraulus crista	0.00	0.00	3.33	0.00	6.67	0.00	3.00	0.00	5.00	10.00
Lymnaea peregra	0.00	0.00	6.67	0.00	13.33	0.00	3.00	10.00	3.00	0.00
Bathyomphalus contortus	0.00	3.33	0.00	0.00	0.00	3.33	0.00	0.00	0.00	2.00
Psidium shells	0.00	26.67	66.67	53.33	200.00	36.67	16.00	23.33	12.00	0.00
Hippeutis complanata	0.00	3.33	3.33	3.33	0.00	0.00	0.00	0.00	0.00	1.00

Valvata cristata		3.33	133.33	16.67	0.00	90.00	30.00	16.00	30.00	24.00	60.00
Valvata piscinalis		0.00	36.67	6.67	10.00	50.00	16.67	9.00	3.33	5.00	20.00
Ostracods (halves >125µm)		96.67	973.33	846.67	1146.67	2136.67	746.67	366.00	1803.33	560.00	101.00
Cladoceran ephippia											
Ceriodaphnia spp. ephippia		66.67	33.33	41.67	125.00	116.67	41.67	10.00	66.67	20.00	30.00
Simocephalus spp. ephippia		0.00	0.00	0.00	0.00	3.33	3.33	0.00	0.00	10.50	0.50
Daphnia hyalina agg. ephippia		105.00	136.67	103.33	58.33	18.33	6.67	5.00	5.00	10.50	14.50
Daphnia pulex agg. ephippia		10.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
Fish remains											
Fish vert/ bones		0.00	16.67	6.67	6.67	3.33	3.33	8.00	0.00	3.00	2.00

5. Cladoceran data

Depth (cm)	0	10	20	30	40	44	55	60	64	70
Total Of Count	1096.63	1165.62	948.66	492.54	957.95	510.65	923.11	574.80	719.30	1213.18
Acroperus elongatus	0.00	0.00	0.41	0.24	0.70	0.16	0.00	0.15	0.00	0.00
Acroperus harpae	3.81	1.80	3.66	11.58	16.75	14.12	13.04	9.37	9.22	11.95
Alona affinis	5.57	0.94	1.13	4.40	3.17	4.58	6.43	4.09	5.16	4.35
Alona costata	0.82	0.31	0.26	4.95	0.12	0.39	0.32	0.10	0.94	2.51
Alona gut/rec	15.49	5.93	4.07	1.82	8.19	8.09	10.71	2.01	1.72	8.69
Alona guttata var tuberculata	0.00	2.91	0.67	0.16	1.58	0.00	0.25	0.00	0.00	0.00
Alona intermedia	0.47	0.78	2.27	0.55	1.82	1.71	1.45	2.01	1.72	1.09
Alonella nana	0.47	1.94	3.72	6.60	12.00	6.85	11.91	15.39	20.53	13.55
Alona quadrangularis	1.17	1.88	1.29	5.60	4.16	4.58	4.67	7.10	4.31	2.09
Alona rustica	0.00	0.00	0.10	0.00	0.00	0.00	2.14	0.00	0.00	0.00
Alonella exigua	0.23	0.31	0.00	0.55	0.93	0.31	0.13	0.00	0.31	0.23
Alonella excisa	0.23	0.00	0.00	0.16	3.17	1.71	1.20	0.59	1.72	2.17
Bosmina coregoni	4.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bosmina longirostris	45.44	76.83	76.04	53.08	34.97	34.27	23.89	2.01	24.21	18.47
Camptocercus rectirostris	0.00	0.00	0.00	0.16	0.79	0.54	0.83	26.16	1.93	1.70
Chydorus piger	0.00	0.00	0.21	0.00	0.23	0.00	0.25	2.86	0.61	1.31
Chydorus sphaericus	9.83	2.04	3.14	6.31	7.45	15.76	16.71	20.10	22.59	26.89
Daphnia claw	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00
Eurycercus lamellatus	0.00	0.24	0.10	0.32	1.70	0.16	0.13	2.16	0.46	0.34
Graptolebris testudinaria	2.21	2.25	0.31	0.32	0.12	0.31	0.00	0.07	0.08	0.23
Leydigia acanthocercoides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00
Leydigia leydigii	0.00	0.00	0.00	0.00	0.12	0.00	0.06	0.82	0.61	0.00

Monospilus dispar	2.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phrixura rostrata	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pleuroxus aduncus	0.00	0.00	0.00	0.00	0.00	0.54	0.06	2.24	0.00	0.88
Pleuroxus spp.	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00
Pleuroxus laevis	7.58	1.75	2.37	2.20	0.23	1.87	2.52	2.01	1.72	3.54
Pleuroxus truncatus	0.00	0.00	0.00	0.55	1.82	1.87	0.32	0.30	1.72	0.00
Pleuroxus uncinatus	0.00	0.00	0.10	0.16	0.00	0.00	2.91	0.30	0.15	0.00
Psuedochydorus globosus	0.12	0.08	0.05	0.00	0.00	0.16	0.06	0.07	0.15	0.00
Rhynchotalona falcata	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sida crystalina	0.00	0.00	0.00	0.00	0.00	1.87	0.00	0.00	0.15	0.00