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Palaeoecological study of South Milton Ley, South Devon

Final Report to Faber Maunsell Ltd.

A. Burgess, P. Appleby, G. Piliposian, S. Turner, N. Rose, H. Bennion

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Environmental Change Research Centre
Department of Geography
University College London
Pearson Building, Gower Street
London. WC1E 6BT

List of contributors

Amy Burgess — ENSIS Ltd. / Environmental Change Research Centre,
University College London, Pearson Building,
Gower Street, London. WC1E 6BT

Peter Appleby — Environmental Radioactivity Research Centre,
Department of Mathematical Science, Room 425,
M & O Building, University of Liverpool.

Gayane Piliposian — Environmental Radioactivity Research Centre,
Department of Mathematical Science, Room 425,
M & O Building, University of Liverpool.

Simon Turner — ENSIS Ltd. / Environmental Change Research Centre,
University College London, Pearson Building,
Gower Street, London. WC1E 6BT

Neil Rose — ENSIS Ltd. / Environmental Change Research Centre,
University College London, Pearson Building,
Gower Street, London. WC1E 6BT

Helen Bennion — ENSIS Ltd. / Environmental Change Research Centre,
University College London, Pearson Building,
Gower Street, London. WC1E 6BT

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Table of contents

List of Figures

List of Tables

Palaeoecological study of South Milton Ley, South Devon

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1 Project Specification

1. Attend South Milton Ley and obtain 6 sediment cores from 3 different areas of the ley to investigate the impact of discharges from the sewage treatment works (STW).
2. From each of the 3 locations, extrude one master core at appropriate intervals and describe its stratigraphy.
3. From each of the 3 locations, measure the dry weight and organic matter content of selected levels of the master core.
4. Date the master core from each of the 3 locations to provide a chronology of the ley sediments using radiometric dating methods and/or spheroidal carbonaceous particles (SCPs).
5. Analyse the diatom assemblages in five to ten samples from selected depths of each master core.
6. Apply a diatom-phosphorus transfer function to the diatom assemblages of each master core to reconstruct total phosphorus concentrations and in turn determine the nutrient loading history of the ley.
7. Produce a summary report of the findings.

2 Methods

2.1 Coring and lithostratigraphic analysis

On 25th May 2006, two to three sediment cores were taken from each of three locations across South Milton Ley (see Figure 1). A Livingstone piston corer was used to extract cores from the open water location (site C) and a Russian corer was used to core areas of the ley with little or no overlying water (sites A and B). Coring locations were recorded by GPS and are detailed along with summary core descriptions in the results section in Table 1. Water depth, secchi depth, water colour, pH and conductivity were also determined at each coring location and are similarly detailed in Table 1.

Master cores from sites B (SML B/1) and C (SML1) were extruded in the laboratory at 1 cm intervals and any visible stratigraphic changes were noted. For reasons discussed in the results section, no master core from site A was extruded or described. The percentage dry weight (%DW) which gives a measure of the water content of the sediment, and percentage loss on ignition (%LOI) which gives a measure of the organic matter content, were determined in the laboratory on every sample by standard techniques (Dean 1974).

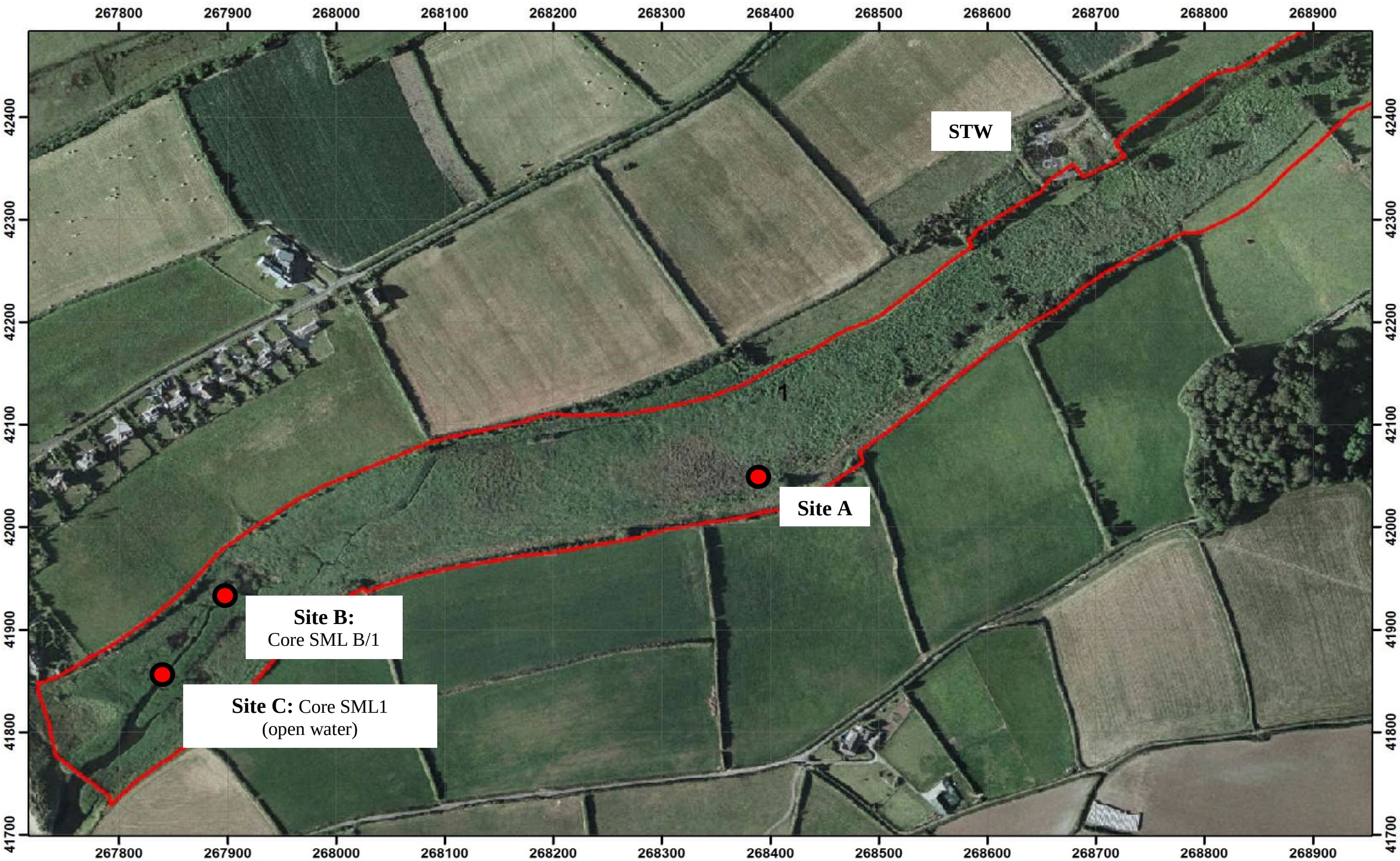

Figure 1: Location of the sediment coring sites across South Milton Ley. The location of the sewage treatment works (STW) is also shown.

2.2 Radiometric dating

Dried samples from South Milton Ley cores SML1 and SML B/1 were analysed for ^{210}Pb, ^{226}Ra, and ^{137}Cs by direct gamma assay in the Liverpool University Environmental Radioactivity Laboratory, using Ortec HPGe GWL series well-type coaxial low background intrinsic germanium detectors (Appleby *et al.* 1986). ^{210}Pb was determined via its gamma emissions at 46.5 keV, and ^{226}Ra by the 295 keV and 352 keV γ-rays emitted by its daughter isotope ^{214}Pb following 3 weeks storage in sealed containers to allow radioactive equilibration. ^{137}Cs was measured by its emissions at 662 keV. The absolute efficiencies of the detectors were determined using calibrated sources and sediment samples of known activity. Corrections were made for the effect of self-absorption of low energy γ-rays within the sample (Appleby *et al.* 1992).

2.3 Spheroidal carbonaceous particle (SCP) dating

In the event that radiometric dating of the South Milton Ley sediments was not possible, an alternative dating method was also used. Samples from selected depths of the two master cores (SML1 and SML B/1) were prepared and analysed for spheroidal carbonaceous particles (SCPs). Sample preparation and analysis followed the method described in Rose (1994). Dried sediment was subjected to sequential chemical attack by mineral acids to remove unwanted fractions leaving carbonaceous material and a few persistent minerals. 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 numbers of SCPs on the coverslip were counted using a light microscope at x400 magnification and the sediment concentration calculated in units of ‘number of particles per gram dry mass of sediment’ (gDM^{-1}). The detection limit for the technique is c. 100 gDM^{-1} and concentrations have an accuracy of c. ± 45 gDM^{-1}. A sediment reference standard was analysed along with the SML1 and SML B/1 samples.

2.4 Diatom analysis

Cores were initially screened to ensure sufficient diatom preservation for full diatom analysis. Preliminary analysis revealed that the master core from the ‘reference’ location (SML A/3) had poor diatom preservation and as such was unsuitable for full diatom analysis. SML B/1 (core from potentially impacted reedbed site) appeared to have good diatom preservation throughout and SML1 (open water core) had good diatom preservation for approximately half its overall length - diatoms were broken and dissolved further down. A small number of subsamples from both SML1 and SML B/1 were prepared for full diatom analysis following standard methods (Battarbee *et al*. 2001). Selections of samples for full diatom analysis were chosen according to the lithostratigraphic profiles. Unfortunately, as discussed in the results section, samples could not be chosen to ensure inclusion of key historic dates. The diatom data were manipulated in the program C^2 (Juggins, 2003). Diatom stratigraphic diagrams are presented and data are expressed as percentage relative abundances, with diatom taxa ordered by weighted averages.

2.5 Application of the diatom-inferred TP (DI-TP) transfer function

The technique of weighted averaging (WA) regression and calibration (ter Braak & van Dam 1989) has become a standard technique in palaeolimnology for reconstructing past environmental variables. A predictive equation known as a transfer function is generated that enables the inference of a selected environmental variable (e.g. TP) from fossil diatom assemblages, based on the relationship between modern surface-sediment diatom assemblages and contemporary environmental data for a large training (or calibration) set of lakes. This approach has been successfully employed to infer lake pH (e.g. Birks *et al*. 1990) and total phosphorus (TP) concentrations (Hall & Smol 1999), whereby modern diatom pH and TP optima and tolerances 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. The methodology and the advantages of WA over other methods of regression and calibration are well documented (e.g. ter Braak & van Dam 1989).

A diatom transfer function was applied to the diatom data for cores SML1 and SML B/1, following taxonomic harmonisation between the training set and the fossil data. Reconstructions of diatom-inferred TP (DI-TP) were produced using a Northwest European training set of 152 relatively shallow lakes (< 10 m maximum depth) with a median value for the dataset of 104 µg TP l^{-1} and a root mean squared error of prediction (RMSEP) of 0.21 $\log_{10}$ µg TP l^{-1} for the weighted averaging partial least squares two-component (WA-PLS2) model (Bennion *et al*. 1996). All reconstructions were implemented using C^2 (Juggins 2003).

2.6 Application of the 'DARLES' (Diatom Assessment of River and Lake Ecological Status) tool

A recent output from the DARES (Diatom Assessment of River Ecological Status) / DALES (Diatom Assessment of Lake and Loch Ecological Status) Consortium (Kelly *et al*. 2006) has been 'DARLES', a Microsoft Windows® program for the assessment of freshwater status classification using periphytic diatoms. Periphytic diatoms are diatom taxa that live on a substrate e.g. on mud (benthic); rocks (epilithic) or plants (epiphytic). The program implements a classification algorithm using a metric based on a revised Trophic Diatom Index (TDI). Details of the metric, algorithm and derivation of the status class boundaries are given in Kelly *et al.* (2006). The program takes the diatom count data for individual samples and calculates the TDI score and ecological status class for each sample.

The 'DARLES' tool has been applied to the diatom data from cores SML B/1 and SML1 to provide an alternative means of assessing the diatom species shifts in the two cores in terms of ecological status. Taxonomic harmonisation between the diatom taxa in the DARLES database and the fossil diatom assemblages in the cores was carried out prior to implementing the classification algorithm. For each sample, tool output consists of an ecological status classification – 'poor', 'moderate', 'good' or 'high' – expressing the ecological quality of the sample as inferred from its benthic diatom assemblage.

3 Results

3.1 Core descriptions, diagrams and lithostratigraphies

Coring date	Site code	Core code	Coring location / water depth (m)	Coring location	Core length (cm)	Core type	Secchi depth (m)	Water colour	pH	Cond (uScm^{-1})
25.05.06	SML	SML A/3	Upper reedbed: Not submerged	SX 68394 42051	100	Russian	-	-	6.65	332
25.05.06	SML	SML B/1	Lower reedbed: 1.0 m	SX 67898 41934	62	Russian	0.2	turbid	6.63	860
25.05.06	SML	SML1	Open water: 2.2 m	SX 67841 41857	41	Livingstone	0.2	turbid	7.00	1900 (surface) 3800 (@ 2m)

Table 1: Details of the 3 master sediment cores taken from each of 3 locations across South Milton Ley.

Full descriptions and diagrams are only provided for the 2 master cores selected for further analysis. SML B/1 is the master core from site B and SML1 is the master core from site C. As discussed in section 3.4, the cores from site A had poor diatom preservation, therefore further analysis of a master core from this location was not pursued.

3.1.1 Core SML B/1: Russian master core from site B

Figure 2 illustrates the core diagram for core SML B/1 and Figure 4 illustrates in more detail SML B/1's lithostratigraphic profile.

SML B/1 was taken from the lower reedbed at grid reference SX6789841934, in an area potentially impacted by discharges from the STW. The coring location was at the edge of dense reedbed in an area sparsely covered with *Phragmites australis*. An earlier site visit suggested that the core site was probably saturated for most/all of the year, but not usually submerged. However following significant rainfall in the 1-2 week period prior to coring, site B was submersed under approximately 1 m of overlying water.

Despite the growth of *P. australis* at site B and its evidence in the upper sediments of core SML B/1, the organic content of the sediment was not particularly high (<40%). Peats have an organic content of ≥80%, therefore site B's sediments cannot be considered at all peaty. Fragments of *Phragmites* (roots and stems) within a sediment matrix appear to account for the small peaks in %LOI in the core.

It is probable that the relatively low organic accumulation at site B is due to a combination of factors influencing the formation of wetland soils. The highest rate of organic accumulation occurs in saturated, anaerobic soils, whereas features such as drainage ditches act to reduce soil water content and hence the development of organic sediments. Oxygenation of soils at depth by *Phragmites* roots also allows aerobic respiration of organic matter, thus precluding the development of peats.

A fragment of charcoal was found at 18-19 cm. It is unlikely that this indicates a burn event within the ley, instead it probably originated from a beach barbeque and was transported into the ley during a high tide.

Sedimentological change is apparent at 50–40 cm. There is a discernable steady increase in organic content. This perhaps suggests a phase of increased organic accumulation/preservation and possibly a less impacted state. During this phase there was potentially greater biomass accumulation that may in turn be consistent with a more diverse wetland with less *Phragmites*. The timing of this change may relate to pre-sewage works construction and pre-channelisation of drainage.

3.1.2 Core SML1: Livingstone Open Water Piston Core

The core diagram for core SML1 is illustrated in Figure 3 and a more detailed lithostratigraphic profile is illustrated in Figure 5.

SML1 was taken at grid reference SX6784141857, from the edge of an open water channel in the lower reedbed. In common with the location of core SML B/1, SML1 was taken in an area potentially impacted by discharges from the STW.

The sedimentary profile of this core comprises a fairly homogeneous dark grey brown mud containing numerous sand grains. Despite the absence of surface vegetation at the core site, the sediments of SML1 have a greater mean value of %LOI throughout the profile than core SML B/1. This could be attributable to the permanently saturated conditions at the core site, which may in turn have led to the preservation of a greater quantity of organic matter originating from both the ley itself and from catchment drainage.

The %DW and %LOI profiles pick out changes in sediment texture/composition in the top 20 cm of SML1, from less compact, to more compact. 20 cm may represent the depth at which overlying compaction has an effect on pore water concentrations. The %LOI profile also suggests compositional change of the sediments at approximately 20 cm depth. The changes observed at 20 cm might therefore be synchronous with changes in drainage within the reedbed and/or catchment.

The peak in %LOI at 31 cm corresponds to the presence of *Phragmites* stem fragments in the sediments at this depth. The occurrence of these stem fragments may relate to plant matter washing into the core site from upstream. Alternatively it could represent a relic of an earlier phase of a more extensive *Phragmites* wetland.

Below 32 cm there appears to be a compositional change in the sediments. This may be diachronous with the changes seen at 50-40 cm depth in core SML B/1, perhaps relating to a period prior to channelisation, disturbance and sewage works construction.

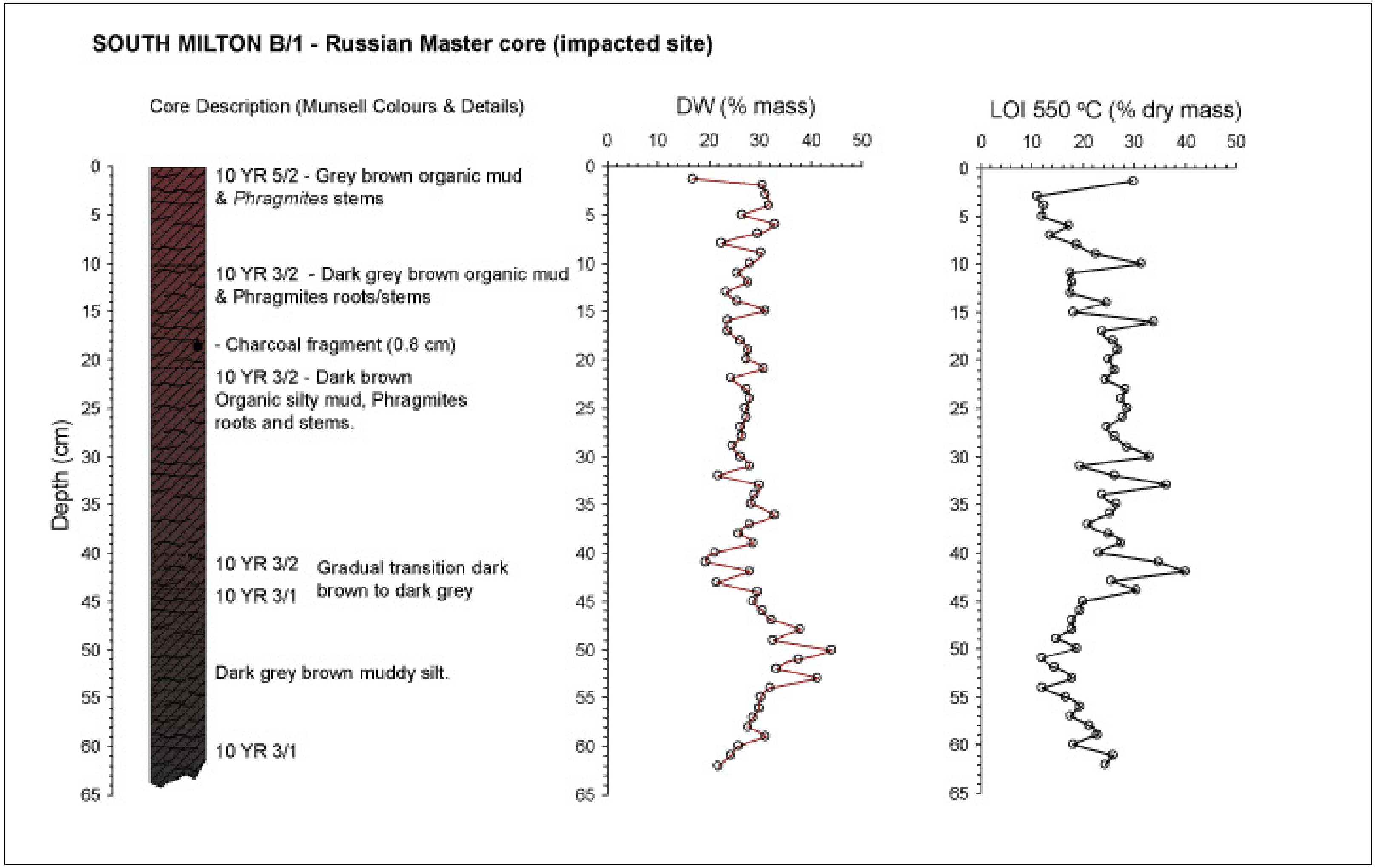

Figure 2: Core diagram of SML B/1 - Russian master core (potentially impacted reedbed site)

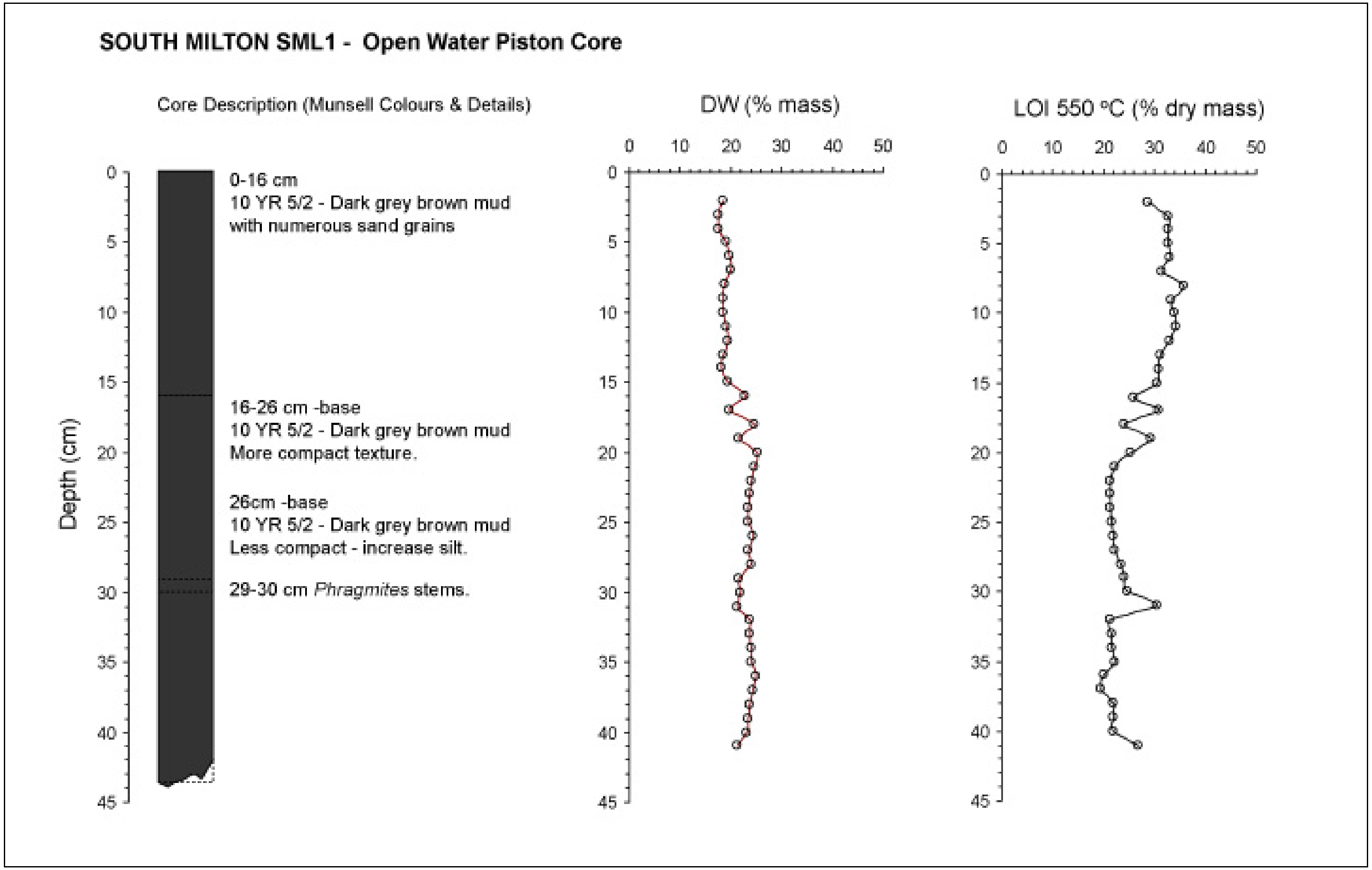

Figure 3: Core diagram of SML1 (Open water piston core)

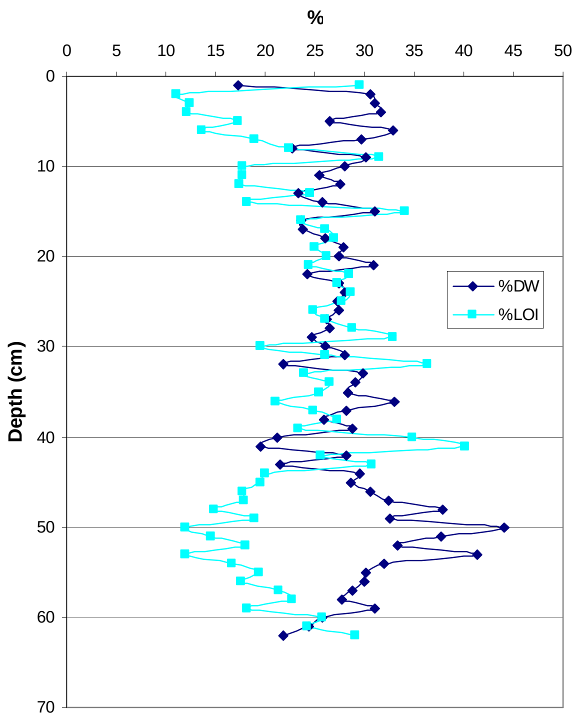

Figure 4: Dry weight and organic matter profiles for core SML B/1 (Russian master core)

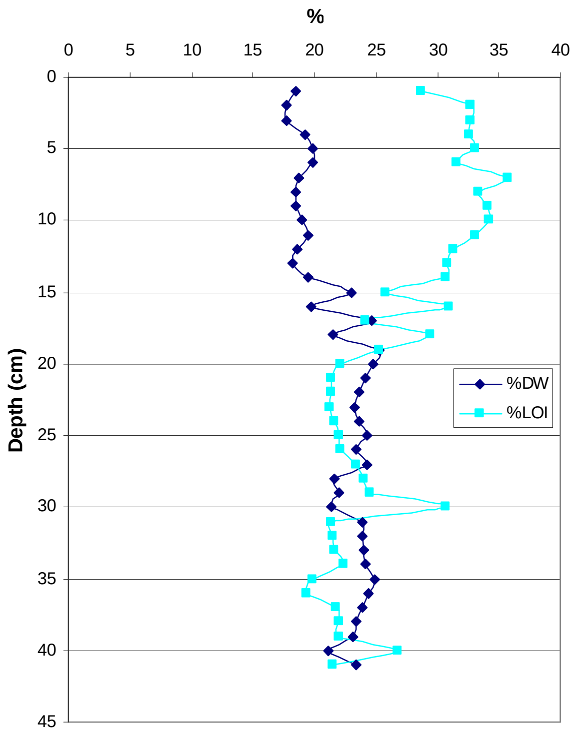

Figure 5: Dry weight and organic matter profiles for core SML 1 (Open water core)

3.2 Radiometric analysis results

The results of the radiometric analyses are given in Tables 2a and 2b and shown graphically in Figures 6 and 7. In both cores the concentrations of fallout radionuclides in all samples analysed were close to or below levels of detection. ^{210}Pb inventories corresponded to supply rates of ~3 Bq m^{-2} y^{-1}, less than 5% of the atmospheric flux. The ^{137}Cs inventory in SML B/1, in which some traces were detected, was less than 30 Bq m^{-2}, again just a few percent of the fallout value. In consequence it was not possible to date these cores either by ^{210}Pb or ^{137}Cs. Small amounts of ^{137}Cs at 5-10 cm in SML B/1 could indicate a mid 1960s date for these sediments, though in view of the poor record this is entirely speculative. The most likely cause of these results is the steady erosion of sedimenting particles from these core sites by lateral currents in the Ley.

Depth		^{210}Pb Total		^{210}Pb Unsupported		^{210}Pb Supported		^{137}Cs	
cm	g cm^{-2}	Bq kg^{-1}	±	Bq kg^{-1}	±	Bq kg^{-1}	±	Bq kg^{-1}	±
0.5	0.10	20.1	5.1	-3.6	6.6	23.7	4.3	0.0	0.0
1.5	0.31	19.1	4.0	2.6	4.4	16.5	1.9	0.0	0.0
3.5	0.72	16.7	4.6	-0.4	4.8	17.1	1.5	0.0	0.0
5.5	1.17	17.1	4.7	0.7	5.0	16.4	1.6	0.0	0.0
7.5	1.60	18.9	3.3	1.2	3.7	17.7	1.8	0.0	0.0
9.5	2.02	16.9	6.1	-5.7	6.4	22.6	1.9	0.0	0.0
15.5	3.36	16.6	6.1	6.1	6.3	10.5	1.8	0.0	0.0
28.5	6.93	16.6	7.7	0.8	7.8	15.9	1.5	0.0	0.0
39.5	9.96	14.3	2.7	0.1	3.3	14.3	1.8	0.0	0.0

Table 2a Fallout radionuclide concentrations in SML1

Depth		^{210}Pb Total		^{210}Pb Unsupported		^{210}Pb Supported		^{137}Cs	
cm	g cm^{-2}	Bq kg^{-1}	±	Bq kg^{-1}	±	Bq kg^{-1}	±	Bq kg^{-1}	±
0.5	0.10	41.7	10.8	20.4	11.0	21.2	2.0	2.0	1.5
1.5	0.38	28.4	7.6	-3.6	7.8	32.0	2.0	0.0	0.0
3.5	1.15	33.6	9.2	1.7	9.6	31.9	2.7	0.0	0.0
5.5	1.87	33.2	9.6	-3.8	9.9	37.0	2.5	0.6	1.5
7.5	2.57	35.3	10.1	4.6	10.5	30.8	2.5	1.8	1.5
9.5	3.24	29.6	9.1	-8.6	9.5	38.2	2.8	0.6	1.7
14.5	4.82	24.1	10.3	4.2	10.5	19.9	2.1	0.0	0.0
29.5	9.62	18.9	4.4	4.9	4.8	14.1	1.8	0.0	0.0
39.5	12.96	20.8	6.0	-2.0	6.2	22.8	1.7	0.0	0.0
49.5	16.59	21.2	6.7	-4.3	7.1	25.5	2.3	0.0	0.0
59.5	20.72	21.4	6.8	3.9	7.0	17.5	1.6	0.0	0.0

Table 2b Fallout radionuclide concentrations in Core SML B/1

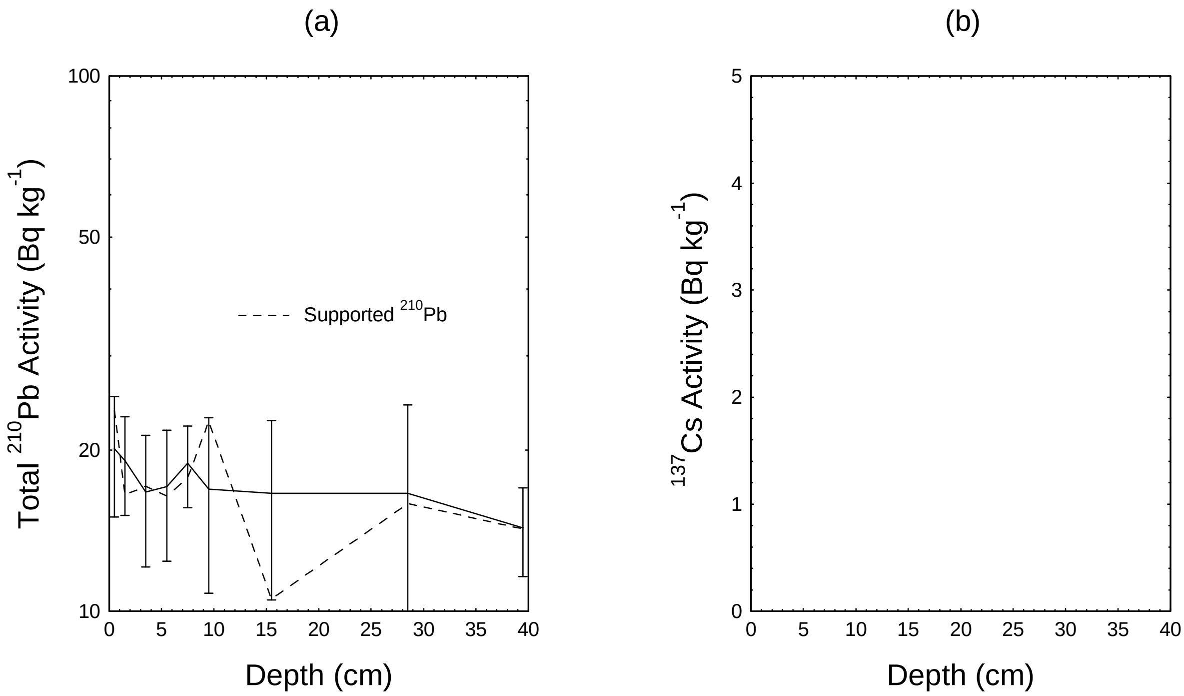

Figure 6: Fallout radionuclides in South Milton Ley core SML1 showing (a) total and supported ^{210}Pb, (b) ^{137}Cs concentrations versus depth. ^{137}Cs concentrations were below levels of detection in all samples analysed from this core.

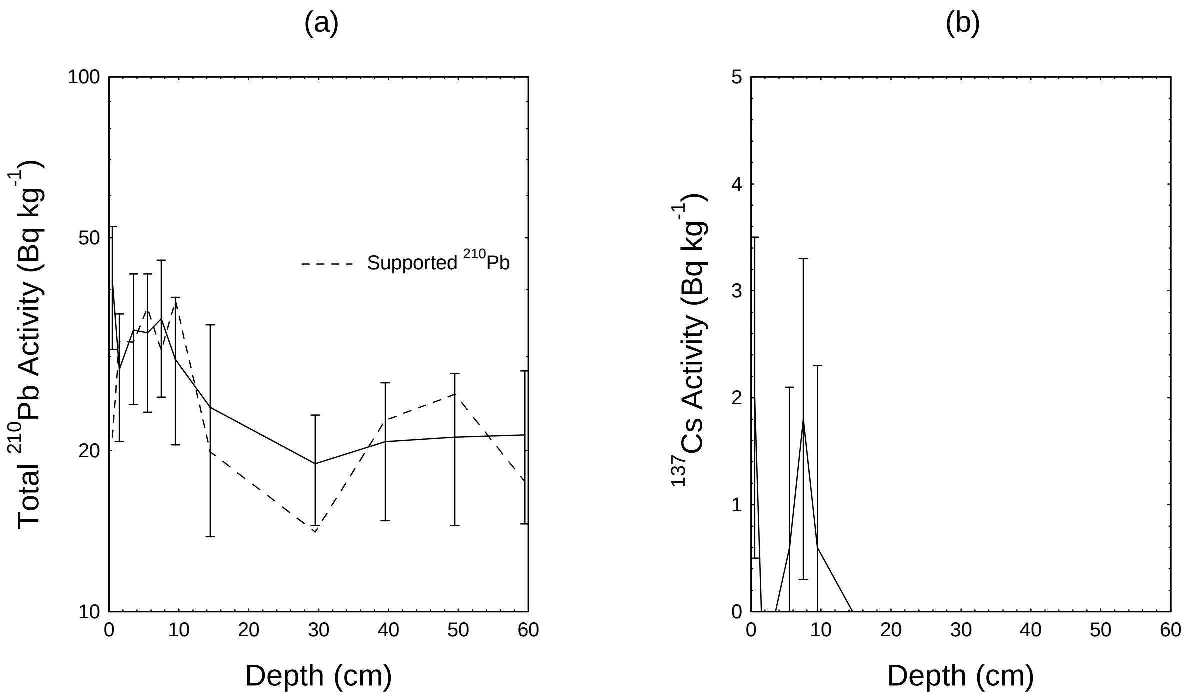

Figure 7: Fallout radionuclides in South Milton Ley core SML B/1 showing (a) total and supported ^{210}Pb, (b) ^{137}Cs concentrations versus depth.

3.3 Spheroidal carbonaceous particle results

In the absence of a chronology derived from radiometric dating methods, SCP dating techniques were also employed. Every 10 cm sample from core SML1 from 0-40 cm (5 samples) and the top 4 samples from core SML B/1 (0, 10, 20, 30 and 40 cm) were analysed for SCPs. One SCP was found in the uppermost sample of each core, but no further particles were found in any other sample from either core. The absence of SCPs in the South Milton Ley sediments could suggest that some SCP-free sediment has diluted the sediments. Since the ^{210}Pb record is also absent, this could indicate significant re-working of old material. Alternatively, the coring locations may have a very fast sediment accumulation rate, resulting in concentrations of sedimentary SCPs below the detection limit.

3.4 Diatom stratigraphies, application of the DI-TP transfer function and 'DARLES' tool

Stratigraphic diagrams illustrating the percentage relative abundance of the dominant diatom taxa (occurring at >2%) in cores SML B/1 and SML1 are illustrated in Figures 8 and 9 respectively. Taxa are ordered according to weighted average (WA) from left to right. The full lists of diatom taxa identified in the two cores are detailed in Appendices 1 and 2.

The diatom stratigraphies of both SML B/1 and SML1 are dominated by periphytic diatom taxa, in particular small benthic *Fragilaria* spp. (predominantly *Fragilaria elliptica* and *F. construens* and its varieties) and to a lesser extent, the larger motile *Navicula* spp. (including *N. gregaria*, *N. lanceolata* and *N. rhyncocephala*). Benthic diatom taxa live on the sediment surface and require shallow water and/or good light penetration to the sediment surface for their growth. Another group common in the two cores are epiphytic taxa i.e. those that live on plants. Common epiphytic taxa include *Amphora* spp., *Cymbella* spp., *Epithemia* spp. and *Gomphonema* spp.

In SML B/1, there is a subtle shift in the diatom species assemblage at ~40-45 cm depth. Above 40 cm, small *Fragilaria* spp. (*F. elliptica* and *F. construens* var. subsalina) dominate the assemblage, whereas below 40 cm the assemblage is more diverse, with *N. gregaria, N. rhyncocephala, N. lanceolata, Achnanthes minutissima*, *Amphora pediculus* and *F. capucina* var. *mesolepta* commonly found.

In SML1, there appears to be a shift in the diatom species assemblage between ~10-15 cm depth. Above 10 cm the assemblage comprises a large proportion of small *Fragilaria* spp. (*F. elliptica, F. pinnata*, *F. construens* var. *venter* and *subsalina*), although it is relatively diverse, with the epiphytic taxon, *Cocconeis placentula* commonly occurring in association with a number of other periphytic taxa. *A. minutissima* is common both above and below 10 cm. Below 10 cm, the diatom assemblage is also relatively diverse, with long, pennate periphytic taxa such as *Navicula radiosa*, *F. capucina* var. *gracilis*, *F. capucina* var. *distans*, *Tabellaria flocculosa* and *Synedra ulna*, commonly found alongside epiphytic taxa such as *Cymbella* spp. (*C. helvetica, C. microcephala*), *Epithemia adnata*, *Gomphonema gracile* and *Brachysira vitrea*. Many of the taxa in the samples below 10 cm are typically associated with lower nutrient environments.

Diatom preservation was good throughout core SML B/1. Core SML1 had good diatom preservation towards the core top, but diatom frustules in the 19.5 cm sample showed considerable evidence of breakage and dissolution. Below 19.5 cm diatom preservation was so poor that frustule concentrations were insufficient to enable the analysis of further samples. Dissolution and breakage can significantly influence the results of diatom analysis because highly silicified diatom taxa are more resistant to dissolution and breakage than finely silicified taxa. Results from samples affected by dissolution and breakage (19.5 cm) should be treated with some caution as they may be biased towards resistant taxa.

The diatom-inferred TP (DI-TP) concentrations for both cores are presented in Table 3. The results for SML1 suggest that phosphorus concentrations in South Milton Ley have increased from 37 μgl^{-1} TP at 19.5 cm to ~100 μgl^{-1} TP in more recent times. Conversely, the results from SML B/1 suggest that TP concentrations were higher in the past (~100-300 μgl^{-1}, reaching a peak at 39.5 cm) and have decreased towards the core top (~60-90 μgl^{-1} in the top 20 cm). The DI-TP concentration for the 29.5 cm sample should be treated with some caution because the percentage of this sample's diatom assemblage represented in the model is very low at only 63%.

Given the disparity between the domination of benthic diatom taxa in both cores and the plankton-dominated nature of the training set from which the reconstructions have been derived, the TP reconstructions may be unreliable and are therefore not included in Figures 8 and 9. The problems associated with benthic dominated assemblages and DI-TP reconstructions (with particular reference to shallow lakes) have been well documented e.g. Bennion (1995) and Sayer (2001). There are no known training sets with benthic-dominated diatom assemblages and therefore there are no alternative diatom inference models that can be applied. Factors other that TP concentrations may be of greater importance in determining the species composition of benthic diatom assemblages, therefore it is doubtful whether such a model would produce more reliable results.

Core	**Depth (cm)**	**DI-TP (μgl^{-1}) (WA-PLS2)**	**% fossil taxa in model**	**DARLES ecological classification**
SML B/1	0.5	61	89	Poor
	5.5	62	89	Poor
	9.5	64	87	Poor
	19.5	93	85	Poor
	29.5	70	**63**	Poor
	39.5	274	93	Poor
	49.5	158	93	Poor
	59.5	112	94	Moderate
SML1	0.5	96	90	Moderate
	5.5	103	91	Moderate
	9.5	90	91	Moderate
	15.5	45	94	Good
	19.5	37	90	Good

Table 3: Diatom-inferred TP (DI-TP) reconstructions and 'DARLES' ecological status classifications for cores SML B/1 and SML1.

Since the DI-TP reconstructions for SML1 and SML B/1 may be unreliable given the dominance of benthic diatom taxa throughout the cores (as discussed above), the recently developed 'DARLES' tool has also been applied. 'DARLES' was developed specifically from periphytic diatom assemblage data and may therefore be more appropriate for the assessment of diatom species shifts in a periphytic diatom-dominated reedbed such as South Milton Ley.

Results from 'DARLES' suggest that the diatom data throughout SML B/1 is indicative of 'poor' ecological status, except for the 59.5 cm sample, which is classed as 'moderate'. The 'moderate' classification for the core bottom sample is probably derived from the increased percentage abundance of taxa such as *Achnanthes minutissima* and *Fragilaria capucina* var *mesolepta*, which are associated with slightly less nutrient rich conditions than those taxa further up the core. The DI-TP reconstructions for SML B/1 appear to contradict the 'DARLES' classifications by inferring lower TP concentrations towards the core top. The 'DARLES' classifications may be more reliable given the nature of the diatom assemblages.

The results for SML1 show that from 0-10 cm depth, the diatom assemblage data indicates 'moderate' ecological status and that the diatom assemblages in the 15-20cm section of the core are indicative of 'good' ecological status. This corresponds well with the DI-TP reconstruction results (see Table 3) suggesting lower TP concentrations for the samples classified as 'good' (15-20 cm) and higher TP concentrations for the samples classified as 'moderate' (0-10 cm). The shift from long periphytic *Fragilaria*, *Tabellaria* and *Synedra* taxa in the 15.5 cm and 19.5 cm samples to more small benthic *Fragilaria* taxa in the 0-10 cm samples, could suggest that the site of core SML1 has experienced some infilling or shallowing in recent times, or that perhaps there is more vegetation present today than in the past.

Differences in the diatom profiles and ecological classifications of the two cores are difficult to understand given the relative proximity of the two coring locations. There does not appear to be a clear nutrient signal that can be teased out of the diatom data, although the 'DARLES' classifications suggest a subtle decrease in ecological status over time in both cores. This could potentially correspond to changes in wastewater discharges from the STW. However in the absence of dates for the diatom samples, it cannot be said whether the changes in ecological status inferred from the diatom assemblages are in any way related to discharges from the STW.

4 Summary

The sediment cores from South Milton Ley could not be radiometrically dated, nor could they be dated using SCPs. This problem is rarely encountered and explanations as to why dates could not be derived are speculative, but could include factors such as a) the steady erosion of sedimenting particles from the core sites by lateral currents in the Ley; b) the dilution of the sediments by some SCP-free sediment; c) fast sediment accumulation rates at the core sites, resulting in concentrations of sedimentary SCPs below the level of detection.

The diatom profiles from cores SML1 and SML B/1 are not straightforward to interpret and the DI-TP results are unreliable due to the non-planktonic nature of the diatom assemblages throughout both cores. However, results derived from the 'DARLES' tool may provide evidence that South Milton Ley has experienced a decline in ecological status and therefore some degree of nutrient enrichment over time. This trend is more apparent in SML1 than in SML B/1. The timing of this potential enrichment trend is not possible to determine due to the absence of dates for the sediment cores. Furthermore, if there is an enrichment trend, it cannot be directly attributed to discharges from the STW in the absence of dates.

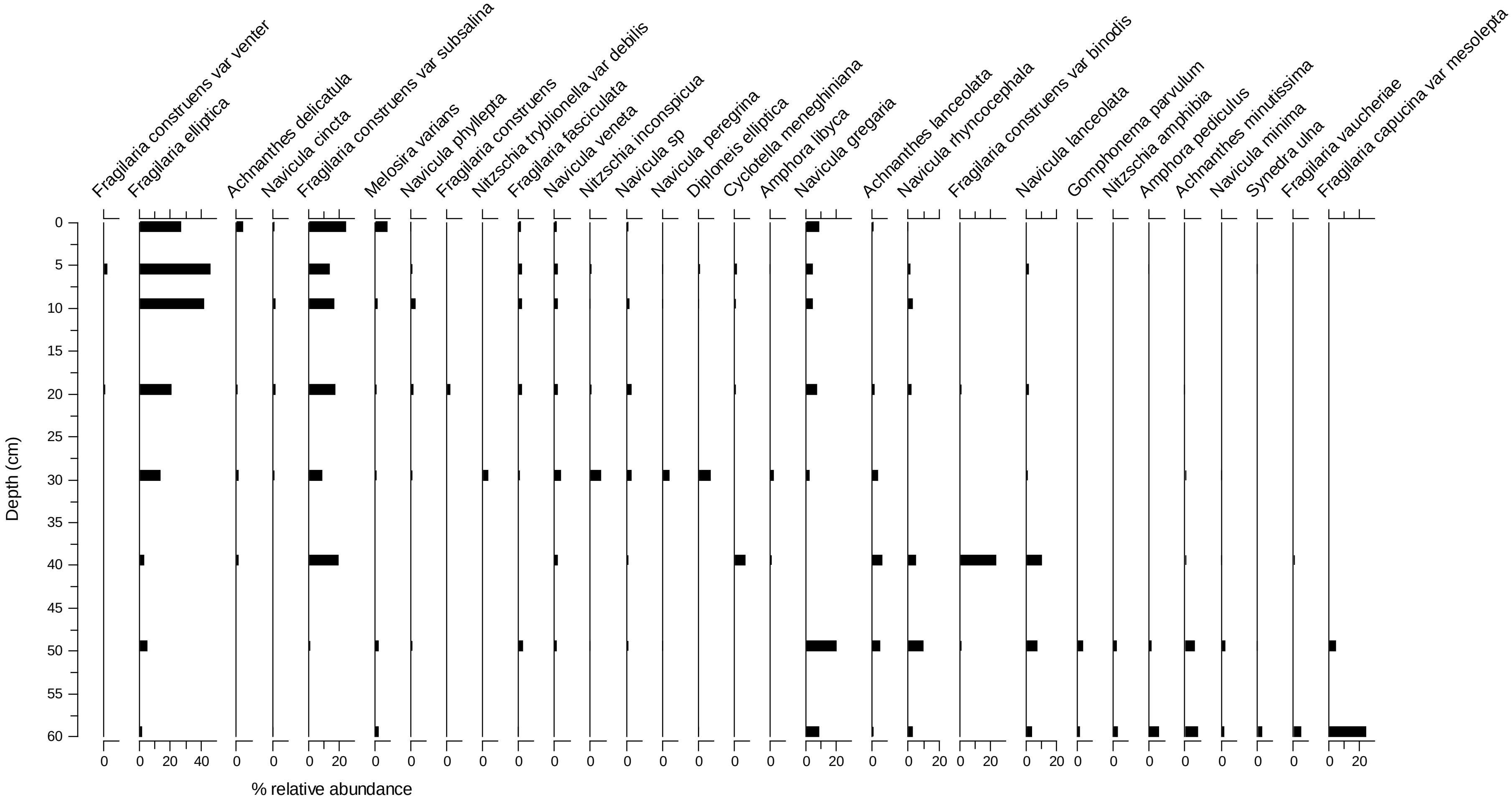

Figure 8: Stratigraphic diagram illustrating the percentage relative abundance of the dominant diatom taxa (>2%) in core SML B/1 (Russian master core from impacted site). Taxa are ordered by weighted average (WA) from left to right. Diatom preservation was good throughout the core.

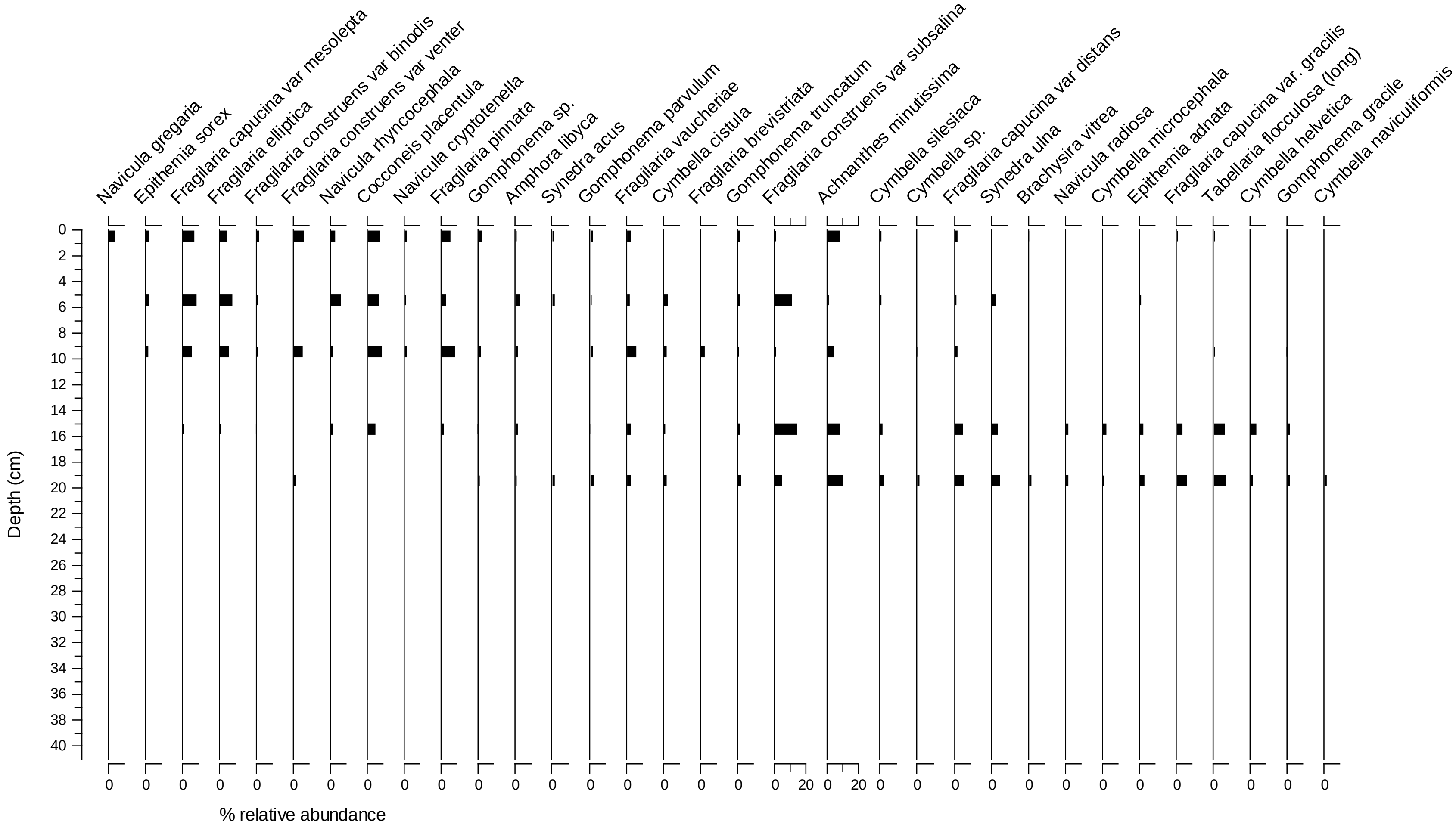

Figure 9: Stratigraphic diagram illustrating the percentage relative abundance of the dominant diatom taxa (>2%) in core SML 1 (open water core). Taxa are ordered by weighted average (WA) from left to right. Diatoms were broken / dissolved in the 19.5cm sample and dissolution was extensive between this depth and the core bottom.

5. References

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Appendix 1: DIATCODES & diatom taxon names for SML B/1

DIATCODE	Species name
AC016B	*Achnanthes delicatula*
AC001A	*Achnanthes lanceolata*
AC013A	*Achnanthes minutissima*
AM011A	*Amphora libyca*
AM012A	*Amphora pediculus*
AM004A	*Amphora veneta*
CA006A	*Caloneis amphisbaena*
CA002A	*Caloneis bacillum*
CA003A	*Caloneis silicula*
CA9999	*Caloneis sp*
CO010A	*Cocconeis disculus*
CO001A	*Cocconeis placentula*
CY003A	*Cyclotella meneghiniana*
CM016A	*Cymbella amphicephala*
CM006A	*Cymbella cistula*
CM027A	*Cymbella leptoceras*
CM004A	*Cymbella microcephala*
CM031A	*Cymbella minuta*
CM103A	*Cymbella silesiaca*
CM9999	*Cymbella sp.*
CM103A	*Cymbella silesiaca*
DE001A	*Denticula tenuis*
DT004A	*Diatoma tenuis*
DP009A	*Diploneis elliptica*
EU070A	*Eunotia bilunaris*
EU107A	*Eunotia implicata*
EU110A	*Eunotia minor*
EU9999	*Eunotia sp.*
FR006A	*Fragilaria brevistriata*
FR009M	*Fragilaria capucina var distans*
FR009H	*Fragilaria capucina var. gracilis*
FR009B	*Fragilaria capucina var mesolepta*
FR002A	*Fragilaria construens*
FR002B	*Fragilaria construens var binodis*
FR002E	*Fragilaria construens var subsalina*
FR002C	*Fragilaria construens var venter*
FR018A	*Fragilaria elliptica*
FR057A	*Fragilaria fasciculata*
FR045A	*Fragilaria parasitica*
FR001A	*Fragilaria pinnata*
FR060A	*Fragilaria tenera/ nana*
FR007A	*Fragilaria vaucheriae*
GO006A	*Gomphonema acuminatum*
GO073A	*Gomphonema angustum*
GO013A	*Gomphonema parvulum*
GO023A	*Gomphonema truncatum*
GO9999	*Gomphonema sp.*
ME015A	*Melosira varians*
MR001A	*Meridion circulare*

DIATCODE	Species name
NA084A	*Navicula atomus*
NA066B	*Navicula capitata var hungarica*
NA745A	*Navicula capitoradiata*
NA051A	*Navicula cari*
NA021A	*Navicula cincta*
NA007A	*Navicula crytocephala*
NA751A	*Navicula cryptotenella*
NA060A	*Navicula digitoradiata*
NA345A	*Navicula elegans*
NA023A	*Navicula gregaria*
NA009A	*Navicula lanceolata*
NA042A	*Navicula minima*
NA562E	*Navicula peregrina*
NA058A	*Navicula phyllepta*
NA014A	*Navicula pupula*
NA052A	*Navicula pusilla*
NA010A	*Navicula pygmaea*
NA003A	*Navicula radiosa*
NA008A	*Navicula rhyncocephala*
NA035A	*Navicula salinarum*
NA133A	*Navicula schassmannii*
NA048A	*Navicula soehrensis*
NA9999	*Navicula sp*
NA054A	*Navicula veneta*
NI014A	*Nitzschia amphibia*
NI015A	*Nitzschia dissipata*
NI002A	*Nitzschia fonticola*
NI209A	*Nitzschia incognita*
NI043A	*Nitzschia inconspicua*
NI009A	*Nitzschia palea*
NI006A	*Nitzschia sigma*
NI9999	*Nitzschia sp.*
NI013B	*Nitzschia tryblionella var debilis*
NI048A	*Nitzschia tubicola*
PI9999	*Pinnularia sp.*
RC002A	*Rhoicosphenia abbreviata*
RH009A	*Rhopalodia brebissonii*
RH001A	*Rhopalodia gibba*
SA001A	*Stauroneis anceps*
ST9999	*Stauroneis sp.*
SY001A	*Synedra ulna*
SY003A	*Synedra acus*
SY008A	*Synedra pulchella*
TA9998	*Tabellaria flocculosa (long)*

Appendix 2: DIATCODES & diatom taxon names for SML1

DIATCODE	Diatom species name	DIATCODE	Diatom species name
AC001A	*Achnanthes lanceolata*	GO073A	*Gomphonema angustum*
AC013A	*Achnanthes minutissima*	GO004A	*Gomphonema gracile*
AC035A	*Achnanthes pusilla*	GO013A	*Gomphonema parvulum*
AM011A	*Amphora libyca*	GO080A	*Gomphonema pumilum*
AM012A	*Amphora pediculus*	GO023A	*Gomphonema truncatum*
AS001A	*Asterionella formosa*	GO9999	*Gomphonema sp.*
BR001A	*Brachysira vitrea*	GY005A	*Gyrosigma accuminatum*
CA003A	*Caloneis silicula*	MR001A	*Meridion circulare*
CA9999	*Caloneis sp*	NA071A	*Navicula bacillum*
CO001A	*Cocconeis placentula*	NA066B	*Navicula capitata var hungarica*
CC002A	*Cyclostephanos invisitatus*	NA745A	*Navicula capitoradiata*
CY003A	*Cyclotella meneghiniana*	NA007A	*Navicula crytocephala*
CM006A	*Cymbella cistula*	NA751A	*Navicula cryptotenella*
CM013A	*Cymbella helvetica*	NA060A	*Navicula digitoradiata*
CM027A	*Cymbella leptoceras*	NA023A	*Navicula gregaria*
CM004A	*Cymbella microcephala*	NA009A	*Navicula lanceolata*
CM009A	*Cymbella naviculiformis*	NA042A	*Navicula minima*
CM103A	*Cymbella silesiaca*	NA014A	*Navicula pupula*
CM9999	*Cymbella sp.*	NA010A	*Navicula pygmaea*
DE001A	*Denticula tenuis*	NA003A	*Navicula radiosa*
DT004A	*Diatoma tenuis*	NA008A	*Navicula rhyncocephala*
DP012A	*Diploneis marginestriata*	NA035A	*Navicula salinarum*
EP007A	*Epithemia adnata*	NA9999	*Navicula sp*
EP004A	*Epithemia turgida*	NA054A	*Navicula veneta*
EP001A	*Epithemia sorex*	NI014A	*Nitzschia amphibia*
EU070A	*Eunotia bilunaris*	NI015A	*Nitzschia dissipata*
EU107A	*Eunotia implicata*	NI002A	*Nitzschia fonticola*
EU110A	*Eunotia minor*	NI209A	*Nitzschia incognita*
EU002A	*Eunotia pectinalis*	NI031A	*Nitzschia linearis*
EU9999	*Eunotia sp.*	NI009A	*Nitzschia palea*
SY001A	*Synedra ulna*	NI025A	*Nitzschia recta*
SY003A	*Synedra acus*	NI9999	*Nitzschia sp.*
SY008A	*Synedra pulchella*	PI9999	*Pinnularia sp.*
FR006A	*Fragilaria brevistriata*	RC002A	*Rhoicosphenia abbreviata*
FR009M	*Fragilaria capucina var distans*	RH001A	*Rhopalodia gibba*
FR009H	*Fragilaria capucina var. gracilis*	ST001A	*Stephanodiscus hantzschii*
FR009B	*Fragilaria capucina var mesolepta*	TA9998	*Tabellaria flocculosa (long)*
FR002B	*Fragilaria construens var binodis*	TA9997	*Tabellaria flocculosa (short)*
FR002E	*Fragilaria construens var subsalina*		
FR002C	*Fragilaria construens var venter*		
FR008A	*Fragilaria crotonensis*		
FR018A	*Fragilaria elliptica*		
FR057A	*Fragilaria fasciculata*		
FR045A	*Fragilaria parasitica*		
FR001A	*Fragilaria pinnata*		
FR060A	*Fragilaria tenera/ nana*		
FR007A	*Fragilaria vaucheriae*		
GO006A	*Gomphonema acuminatum*		