Environmental Change Research Centre

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A Palaeolimnological Investigation at Crazy Well Pool, Dartmoor
Report to Westcountry Rivers Trust

B. J. Goldsmith, N. Solovieva, N. L. Rose & E. Shilland

November 2003

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Executive Summary

This report presents the results from a short sediment core taken at Crazy Well Pool, Dartmoor. In addition to physical sediment analysis (loss on ignition and dry weights), siliceous microfossils (diatoms) have been used in an attempt to reconstruct lake pH changes and other water quality parameters. The core has also been dated using a technique based on the concentration of spheroidal carbonaceous particles (SCPs).

The core showed a reliable chronology spanning in excess of 150 years and the diatoms were well persevered. A total of 65 species of diatom were recorded. A notable switch from benthic taxa at the base of the core to more planktonic species towards the core top was observed. Diatom pH reconstructions inferred that the lake has become slightly less acid over a post-industrial timescale, which is contrary to many other studies of UK lakes on base-poor geology. These results suggest that changes in catchment management have resulted in pH increases in the lake, despite evidence of acid deposition at the site. Information on diatom habitat requirements also suggests that lake levels have been lower in the past.

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1
Introduction

1.1 Site Details

Crazy Well Pool is a small lake on the western side of Dartmoor. With an apparent lack of any natural lakes on Dartmoor, Crazywell Pool is one of the few areas of standing water which pre-dates the larger reservoirs (e.g. Burrator and Fenworthy) and thus provides a rare opportunity for palaeolimnological studies covering in excess of 150 years. The origin of Crazy Well Pool is from the tin mining activities which were wide spread in this area for many centuries.

Site Details:

Location:	Dartmoor, Devon
OS Grid Ref:	SX 582 705
Surface area:	0.3 ha
Maximum Depth:	6.5 m
Altitude:	365 m

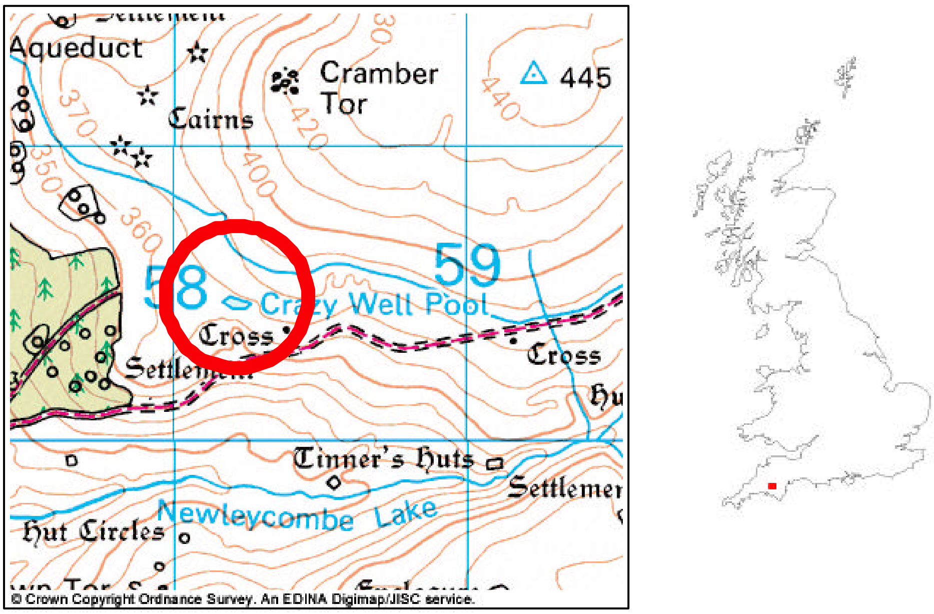

Figure 1. Location of Crazy Well Pool.

1.2 Project Aims:

- To obtain a sediment core from Crazy Well Pool covering at least 150 years.
- To establish the core chronology and to date the core.
- To use diatoms to infer past lake pH.
- To use diatoms to infer changes in water quality.

1.3 History of Crazy Well Pool

Evidence of tin streaming goes back to the twelfth century on Dartmoor (DNPA 2001). By the 14th century open cast mines were in operation and it is likely that Crazy Well Pool was either an open cast mine or used as a reservoir to feed water to lower mines to aid ore extraction.

In common with many ares on Dartmoor, Crazy Well Pool is steeped in superstition. The following extract is from Anon (2003).

> *"It* [Crazy Well Pool] *was thought that it was bottomless and that the water level rose and fell with the tides at Plymouth. This was believed to have been confirmed when the parishioners of nearby Walkhampton brought up the bell ropes from the parish church to test its depth. They tied the ropes together, weighted the end and lowered them into the water, but were unable to reach the bottom of the pool.*
> *Another superstition is that, during the middle-ages, the pool was haunted by the Witch of Sheepstor who used to give her clients a lot of bad advice. One such instance was Piers Galveston who was a favourite of Edward II. She advised him to return to the Court at Warwick where 'his humbled head shall soon be high'. Taking her advice, he returned to Warwick and was promptly executed. There was, however, some truth in the prophecy in that his severed head was set up on the battlements of the castle.*
> *Other superstitions include the waters calling out at dusk the name of the next Walkhampton parishioner to die. Also, that at midnight on Midsummer's Eve you can see the face of the next parishioner to die in the still waters of the pool."*

2
Methods

2.1 Sediment Coring

A 40 cm sediment core was taken using a gravity corer (Glew corer) in 6.2 meters of water (GPS coordinates: 258223,70463). Figure 2 and figure 3 show the coring location and core respectively. The existing ECRC site code is CZSX57 but the Pool has not previously been cored. The core code is CZSX57a.

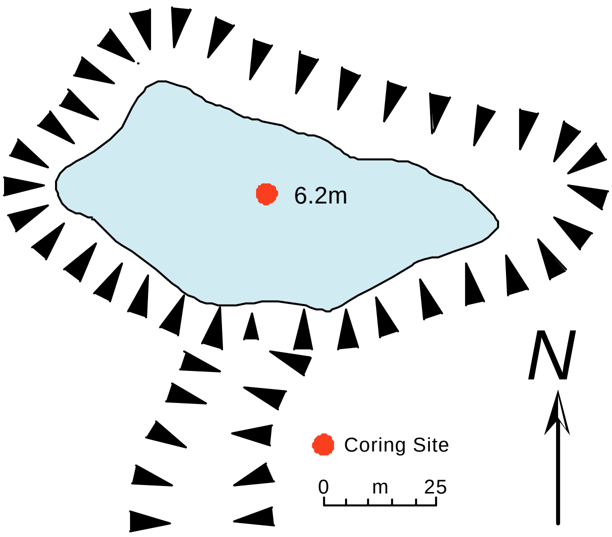

Figure 2. Crazy Well Pool showing coring site

Figure 3. 40 cm Glew Core

The core was extruded and sliced at 0.5 cm intervals for the top 10 cm and at 1.0 cm intervals for the remaining 30 cm. Sediments have been dried and are catalogued and archived at UCL.

2.2 Sediment Analysis

2.2.1 Dry Weight and Organic Content

A sub-sample from each level of the core was weighed in small crucibles and dried to a constant weight at 105 °C to obtain the dry weight. The samples are then re-heated to 550 °C for 2 hours and re-weighed to obtain the percentage of organic matter burnt off. This latter process, known as loss on ignition (LOI) is helpful in identifying changes in the sediment composition which can be attributed to land use changes in the catchment or changes in sediment sources. Twenty five levels between 0 - 40 cm were analysed from core CZSX57a.

2.3 Sample Preparation and Enumeration

2.3.1 Spheroidal Carbonaceous Particles

Background

Spheroidal Carbonaceous Particles (SCPs) are only produced by the high temperature burning of fossil fuels and are thus a feature of post-industrialisation. Their production rose steadily in Europe since 1850 to a peak in 1970 when concerns about the use of fossil fuels finally prompted a switch to other fuel sources. In lake sediments, these particles form an unambiguous record of atmospheric deposition of industrial pollutants. The main temporal trends of these sediment records have been found to be remarkably consistent over wide geographical areas and these features can be used to ascribe dates to cores. SCPs are relatively easy to extract and enumerate and following extensive calibration with other dating methods and through comparison with documentary evidence can now be reliably used to date post-industrial lake sediments.

SCPs should not be confused with 'fume' or 'soot'. Fume particles are sub-micron spheres (or clusters of spheres) derived from the condensation of volatilised non-combustible material. Soot is formed during the combustion process (as opposed to SCPs which result from the incomplete combustion of the fuel) and although carbonaceous, is usually sub-micron in size and bears no morphological resemblance to SCPs.

Preparation

SCPs are composed of elemental carbon and, although physically fragile, this makes them extremely resistant to any form of chemical attack. Strong reagents such as concentrated nitric and hydrofluoric acids can be used to dissolve away the organic and siliceous components of a sediment sample to leave only the carbon fractions. A known weight of sediment is treated in this way and a measured fraction of the resultant solution is permanently mounted on to a microscope slide. The SCPs, which usually range from 5-50 µm in diameter, are then enumerated under light microscopy (x400 magnification). The concentration of SCPs can therefore be determined per gram of dry sediment. The core dates are derived from fixed time markers such as the maximum concentration (1970) and point at which SCPs first appear (1850). Other dates can then be interpolated from the plotted curved and errors assigned. For a full description of the methods see Rose (1994). Twelve samples were prepared and analysed from core CZSX57a, at evenly spaced intervals down the core.

2.3.2 Diatoms

Background

Diatoms (*Bacillariophyceae*: unicellular, siliceous algae) were selected as the most appropriate microfossil group for inferring environmental trends at Crazy Well Pool. Diatoms a very sensitive to changes in water quality and pH and in addition they can also be used for inferring changes in available lake habitats.

Preparation

In order to identify the diatoms from their highly ornamented, silica cell-walls, it is necessary to treat the sediment samples to remove organic material and other mineral material. This is done by gently heating the sediment samples with 30% hydrogen peroxide until the sample no longer effervesces. The sample is then washed with distilled water and treated with hydrochloric acid to remove any soluble mineral components. A sub-sample of the suspension is the allowed to settle out and evaporate on to a grade “0” cover slip. The dry cover slip is then mounted onto a microscope slide using, a high optical index mountant (Naphrax). A full description of these methods is given in Battarbee (1986).

Twenty-five levels from the sediment core were prepared and analysed for diatoms. The levels were taken at 1 cm intervals from 0-10 cm of the core and at 2 cm intervals thereafter to the core base. At least 300 valves were counted from each sample using a Leitz research microscope with a 100x oil immersion objective under phase contrast. Principal floras used for species identification were Krammer & Lange-Bertalot (1986, 1988, 1991a, b) and Kelly

(2000). All slides are archived at UCL.

2.4 Data Analysis

The diatom data were analysed to give two different measures of down-core environmental change. A transfer function approach was used to infer pH changes and the Trophic Diatom Index (TDI) used to investigate any other general water quality change.

2.4.1 Diatom Transfer Function

A transfer function is a quantitative approach to environmental reconstruction which has been developed based on a predictive equation that models the relationship between diatom assemblage composition and lake-water chemistry, e.g. pH. The transfer function is generated using a calibration, or training, data set of modern surface-sediment diatom samples and contemporary water chemistry data from a large number of lakes spanning the environmental gradient of interest. This allowed weighted average optima and tolerances for nearly 300 diatom taxa to be determined. The model then uses this information to calibrate diatom data from sites of unknown pH or more specifically from down-core samples, enabling the past changes in pH to be inferred.

The method used to infer pH from the diatom samples at Crazy Well Pool was Weighted Averaging – Partial Least Squares (WA-PLS, ter Braak and Juggins 1993). The training set data used were collected from 167 lake sites in the UK - the Surface Water Acidification Project data (Stevenson *et al.* 1991). At each site mean annual pH was recorded and diatom samples collected from the surface sediments and live material. The analyses were performed using the computer program Calibrate version 0.81 (Juggins and ter Braak 1997) and resultant plots of both pH and species data were made using C2 data analysis (Juggins 2003).

The performance of the WA-PLS model can be statistically tested. The strength of the relationship between diatom-inferred pH (DI-pH) and measured values is described by the coefficient of determination known as r^2 (0 = no fit; 1 = perfect fit). The errors of the models are described by the root mean square error (RMSE) which summarises the difference between the measured values for the training set of lakes and the diatom inferred values generated by the model. These are calculated based on the original training set (the apparent RMSE) and more realistically on a cross-validated test set (the RMSE of prediction or RMSEP). The lower the error, the better the model performs. The SWAP data set provides a WA-PLS model with relatively low errors of prediction (2 component model RMSEP = 0.2986).

2.4.2 Trophic Diatom Index (TDI)

The TDI was developed by Kelly and Whitton (1995) and subsequently refined (Kelly *et al.* 2001) with the intention of monitoring the water quality of lowland rivers. Its application in the palaeoecological study of lakes is not therefore expected to yield the same ecological information that can be gained by its use in rivers. TDI results do however show changes in the major taxonomic groups and thus TDI data are presented and discussed below.

The Trophic Diatom Index is calculated using a simple weighted average equation for which taxa have been assigned a score of 1-5 for pollution sensitivity (1 being low pollution) and a score of 1-3 for the indicator value (1 being widely tolerant and 3 being narrowly tolerant and therefore a better indicator). Unlike the transfer function approach outlined above, the TDI uses a finite number of taxa, many of which are only identified to genus level. Identification to species level is only used where particularly indicative species can give additional information. See Kelly *et al.* (2001) for a full description of the methods.

3
Results

3.1 Core Dating

The SCP concentrations in the sediments showed a typical profile suggesting that the sediment record at Crazy Well Pool is undisturbed and that a reliable chronology can be obtained. No SCPs were found below 29 cm which provides strong evidence that the base of the core pre-dates 1850. Figure 4 shows the SCP concentrations from core CZSX57a and Table 1 shows the interpolated dates calculated from the profile. The age/depth graph is plotted along with 90% confidence limits in Figure 5.

Mean sediment depth	SCP Date
0	2003 ± 0 yrs
3.25	1991 ± 1 yr
6.25	1978 ± 3 yrs
8.5	1970 ± 5 yrs
9.75	1966 ± 6 yrs
10.75	1965 ± 5 yrs
12	1962 ± 8 yrs
12.75	1960 ± 10 yrs
13.5	1955 ± 14 yrs
14	1940 ± 15 yrs
14.75	1920 ± 20 yrs
15.5	1910 ± 20 yrs
18.5	1890 ± 20 yrs
30	1850 ± 25 yrs

Table 1. Interpolated dates for core CZSX57a

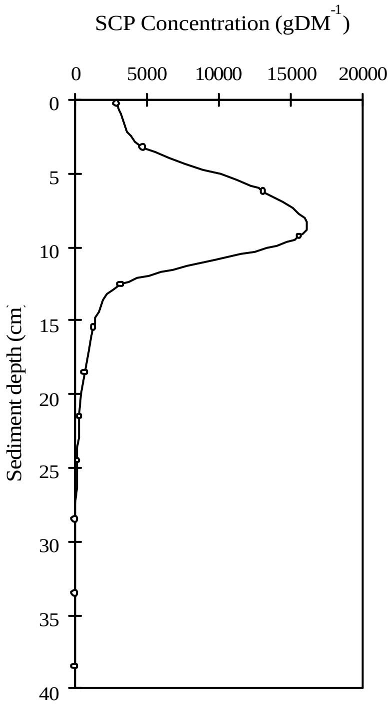

Figure 4. Down-core SCP concentrations

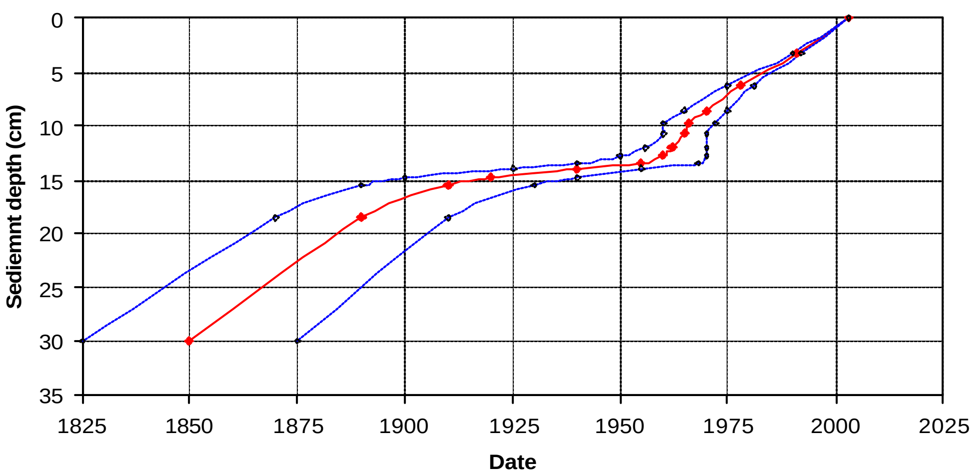

Figure 5. SCP age/depth curve for core CZSX57a (red line) showing 90% confidence limits (blue dashed lines).

3.2 Sediment Analysis

The Crazy Well Pool core shows only a very gradual increase in organic matter (% LOI) from base to top (Figure 6). The Pool has no surface inflow or outflow and thus major erosional events or changes in catchment structure are less likely to appear in the sediments. The gradual increase in organic matter over time may therefore represent a slight increase in the internal productivity of the Pool. This is natural process seen in lakes, and particularly young lakes, as they develop over time.

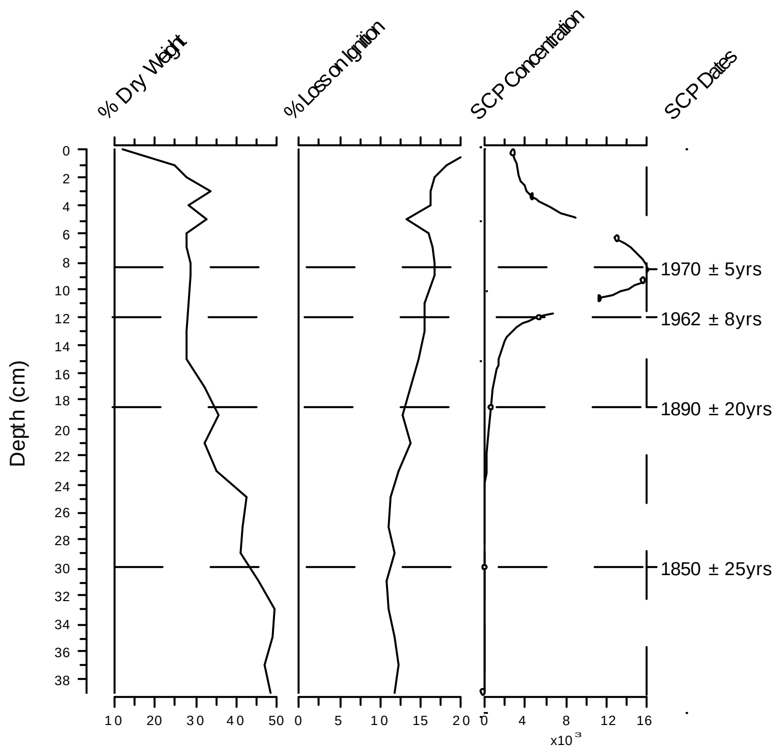

Figure 6. Dated sediment profiles for LOI and dry weight from Crazy Well Pool.

3.3 Diatom Analysis

A total of 65 species of diatom were identified from the Crazy Well Pool core (see Appendix I for the full species list). Of these 38 species occurred at greater than 2% abundance or in at least 5 samples. The dominant species are plotted in figure 7 below. The bottom 10 cm of the core is dominated by species of *Cymbella*, *Eunotia* and *Surirella* in addition to various species of *Achnanthes* which also appear further up in the core. These species are primarily periphytic (i.e. living on the surface of rocks, plant sediments etc.). Above 30cm there is a gradual switch from the periphytic taxa to *Aulacosira* spp. which are dominant in the top 20 cm of the core. *Aulacosira* spp. are usually planktonic. There appears to have been a major shift therefore from benthic to planktonic taxa. Reasons for this are discussed below

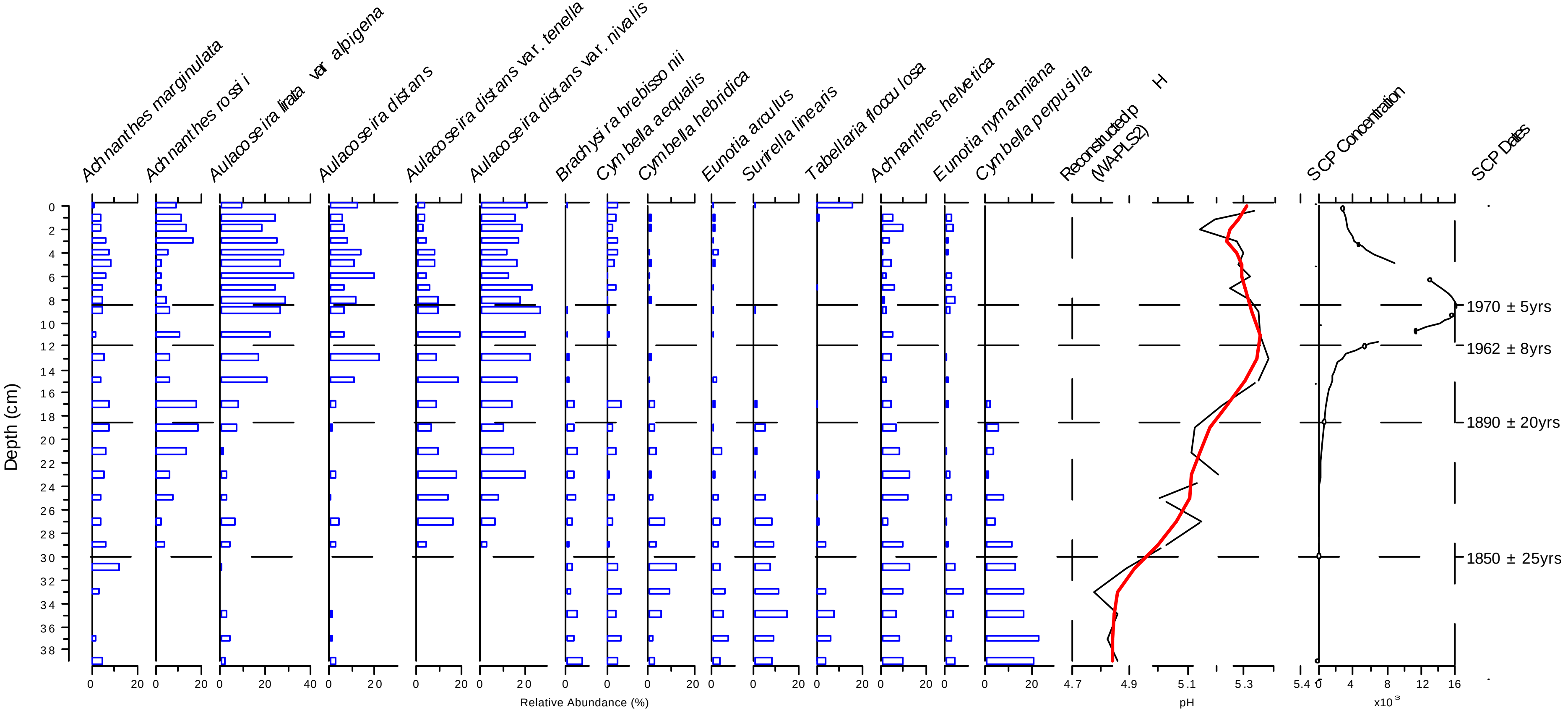

Figure 7. Stratigraphic plot showing the relative abundance of the dominant diatom taxa in the Crazy Well Pool core. SCP dates and modelled pH are also shown

3.3.1 Diatom Transfer Function (pH)

The performance statistics of the models based on the modern training set data (SWAP) files are shown in Table 2. The strength of the relationship (r^2) between diatom-inferred pH (DI-pH) and measured values is 0.91 for WA-PLS2. The errors of the models as described by the root mean square error (RMSE) were relatively low. These are calculated based on the original training set (the apparent RMSE) and more realistically on a cross-validated test set (the RMSE of prediction or RMSEP). The lower the error, the better the model performs. Table 2 shows that both models perform well and have relatively low errors of prediction. The WA-PLS2 has been used to infer pH due to having marginally better error statistics.

	WA-PLS1	*WA-PLS2*
Number of lakes	167	167
Number of diatom taxa	277	277
pH Range	4.33 - 7.25	4.33 - 7.25
Apparent r^2	0.87	0.91
Apparent RMSE	0.27	0.23
Predicted r^2	0.84	0.85
Predicted RMSEP(jack)	0.31	0.30

Table 2. Summary statistics of the diatom models for reconstructing pH

Of the 65 taxa observed in the diatom record, 43 were present in the training set after taxonic harmonisation. Over 90% of the fossil assemblage was represented by the training set in most samples and therefore, there were no major analogue problems when applying the transfer functions. However, *Achnanthes rossii* was not present in the training set and, therefore, analogues for samples where this occurred at greater abundance were lower at around 78-85% (sample depths 3-4 cm and 17-19 cm were most affected). The inferred pH from the Crazy Well Pool core ranged from 4.85 at the base, to 5.42 at the core top, a change of over 0.5 of a pH unit. It should be stressed here that the internal model errors are ± 0.30 of a pH unit. These data do however suggest that the lake has become less acid over the past 150+ years.

3.3.2 Trophic Diatom Index

The Values for the TDI were generally very low with the majority of scores below 30 which would generally be considered to be indicative of very good water quality (Figure 8). A very slight increase in the TDI score was seen from base to top. One of the main problems of using this technique in lakes however is that it does not take into account planktonic taxa and thus the *Aulacosira* spp. are not contributing to the TDI score. Greater numbers of valves are counted where plankton is dominant to ensure a representative count is made of “scoring” taxa, but this does not entirely overcome the problem.

Of greater ecological value is the “percentage of motile taxa” also calculated as a component of the TDI (Figure 8). Species of *Surirella, Brachysira* and to a lesser extent *Navicula* and *Stenopterobia* (not shown on the summary diagram), accounted for the majority of motile taxa. In rivers the presence of motile taxa is normally considered as indicative of organic pollution and therefore reduces the confidence that any observed change in TDI score is due to trophic change. Within a lake however it is more likely to simply be indicative of the availability of benthic habitats rather than organic pollution. The results from this core suggest a switch in the habitats available to diatoms from benthic to open water.

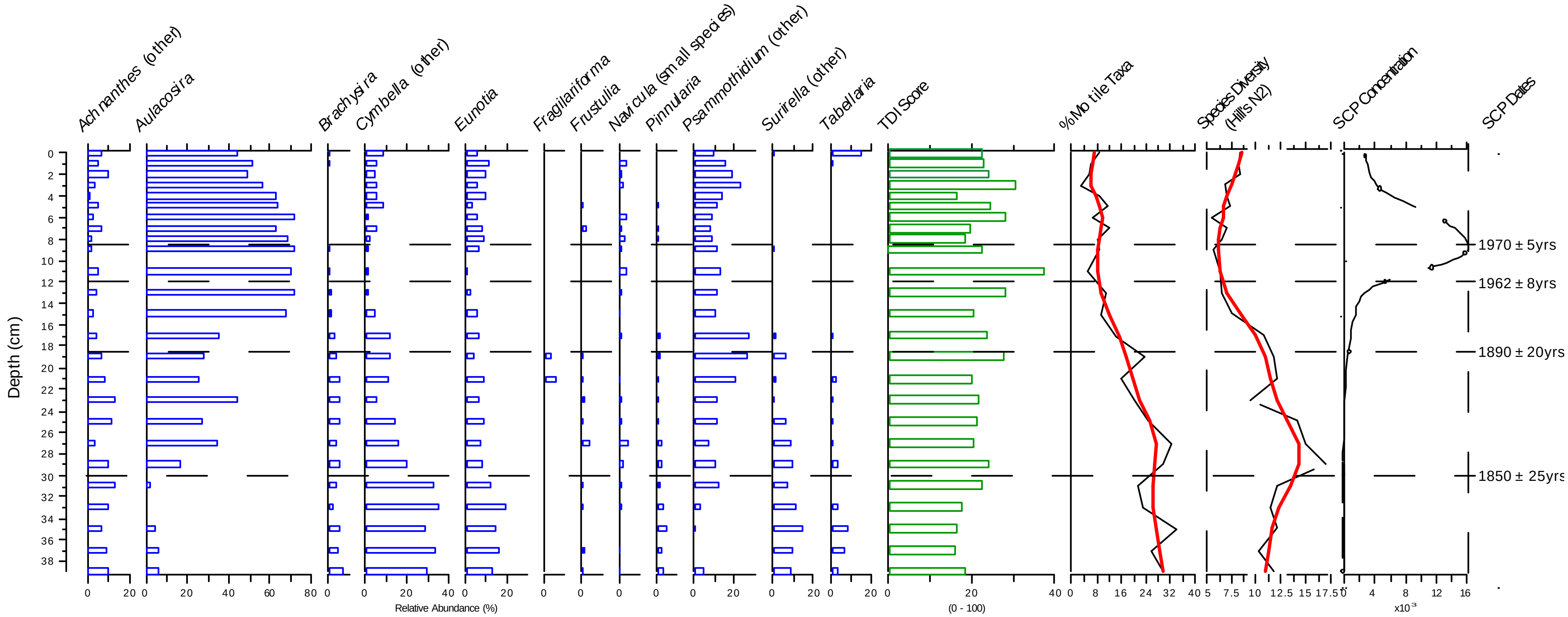

Figure 8. Stratigraphic plot showing the relative abundance of the dominant TDI groupings of taxa in the Crazy Well Pool core. TDI scores and species diversity are also shown.

4
Discussion

The SCP concentrations and LOI profile show the Crazy Well Pool core to be relatively undisturbed and continuous sediment record dating back over 150 years. Diatom preservation was very good throughout the core and a major shift in species was recorded from the core base to the top. These changes are discussed below with respect to two possible hypotheses: physical lake changes (i.e. water level) and changes in lake-water chemistry.

4.1 Water Level Change

The physical structure of a lake has a significant bearing on the types of diatom habitats available and hence the species composition seen in the sediments. In deep lakes, light penetration is a major controlling factor in the depth to which benthic diatom species can grow and therefore these species are restricted to the marginal areas where the light is sufficiently good for photosynthesis. Planktonic species overcome this problem by remaining suspended in the photic zone and can therefore utilise the entire lake surface area. In shallow lakes where light reaches the bottom over the majority of the lake, benthic species will usually dominate. In a small, steep-sided lake like Crazy Well Pool the ratio of marginal habitats to open water area will be relatively high and thus the current situation with approximately 50% planktonic taxa and 50% benthic is representative of the available habitats. In larger deep lakes one would expect plankton to dominate in the sediments.

From the diatom record in core CZSX57a the lake appears to have undergone only gradual change. Below 30 cm there are almost no planktonic taxa, between 17-30 cm there is a shift from benthic dominance to a more even ratio of planktonic and benthic species. Above 17 cm the diatom record is dominated by planktonic *Aulacosira* spp. until the core top where the ratio is even.

The observed changes in the diatom assemblages could therefore have been brought about by a change (i.e. increase) in the lake level over time. This hypothesis is very likely if the site was used as a reservoir for tin mining prior to c. 1850. A constant need for water would have resulted in the lake being lower than its present-day level, increasing the availability of benthic habitats. During the 19th Century mining methods developed without the need for so much water and later declined completely, negating the need for water altogether. This hypothesis links in to the core dates and would account for the observed species shifts. In addition to this however, the pH reconstruction infers an increase in pH over the past c. 200 years.

4.2 Lake Chemistry Changes

The diatom inferred pH suggests the lake has increased by a maximum of 0.5 of a pH unit over the span of the core sequence. This apparent increase in pH raises an interesting issue. Many sites in the UK, and particularly those with base-poor granitic catchments, have been shown to have become acidified over the past 150 years due to industrially derived acid deposition (Battarbee 1990). The majority of these studies have concentrated in the north and west of Britain but similar findings were also seen in the south of England in base-poor lakes in Hampshire (Beebee *et al.* 1990). Rose and Juggins (1994) have shown there to be a strong relationship between the occurrence of SCPs and acid deposition, demonstrating that as well as the source of SCPs and acid pollutants being the same, their atmospheric dispersal is also similar. These studies therefore show Crazy Well Pool to be rather unusual. The Pool lies on acid geology and this study has shown it to have SCPs present at relatively high concentrations suggesting it too would have been susceptible to acidification. The diatom record suggests the opposite has occurred. Not only does the lake appear to have buffered any acid deposition but it has become slightly more alkaline over the past 150+ years.

The reasons for apparent increase in pH are unclear, but changes in mining practice and land use have occurred over a similar period to the industrial age and could therefore have affected the water chemistry of the lake and buffered against acidification.. The TDI results suggest a very slight increase in trophic status, but the change is very small and problems with the method render the results inconcusive[1]. The percentage of motile taxa calculated from the TDI is of more value. Motile diatoms are more tolerant of disturbance and particularly high rates of sedimentation because their motility allows them to avoid being covered by silt. The higher abundance of motile taxa corresponds with relatively high sedimentation rates (according to the SCP dates) and may therefore be indicative of greater disturbance during the 19th Century due to mining activity or changes in land use. Higher turbidity is also less favourable to planktonic *Aulacosira* spp. Motile taxa would also have been more common if the lake was once shallower, as discussed above.

[1] The TDI was developed for the assessment of mainly enriched lowland rivers and thus the method is not considered as being suitable for this palaeolimnological study.

Conclusions

In an extensively exploited and managed landscape such as western Dartmoor there is a strong likelihood that no one environmental factor has resulted in the observed diatom assemblage in the sediments of Crazy Well Pool. A combination of disturbance, lake level change and land-use change are all likely to have had an effect on the lake. This is complicated by evidence that the lake would heve also received elevated levels of acid deposition in the last 150 years.

Although changes in the lake level will have had an effect on the species composition, the results of the pH reconstruction are considered as reliable. The SWAP training set (Stevenson 1991) has an extensive coverage of lake sites in the 4.5-5.5 pH range and the species found in core CZSX57a are well represented in the training set. The lake can therefore be assumed to have become less acid over the past c. 200 years.

Evidence of any other water quality changes are less reliable. The TDI values are deemed unsuitable for this study. The gradual increase in organic matter from the base to core top suggests either greater in-wash of organic material or greater internal productivity. This may therefore be an indication of slight catchment enrichment, but no supporting evidence was obtained for this hypothesis.

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Appendix I

Full diatom species list with authorities

Diatcode	Species	Authority
AC042A	*Achnanthes detha*	Hohn and Hellerm 1963
AC134A	*Achnanthes helvetica*	(Hustedt) Lange-Bertalot in LB & K 1989
AC044A	*Achnanthes levanderi*	Hust. 1933
AC022A	*Achnanthes marginulata*	Grun. in Cleve & Grun. 1880
AC116A	*Achnanthes rossii*	Hust. 1954
AU005A	*Aulacoseira distans*	(Ehrenb.) Simonsen 1979
AU005E	*Aulacoseira distans var nivalis*	(W. Smith) Haworth 1988
AU005D	*Aulacoseira distans var tenella*	Nygaard) R. Ross in Hartley 1986
AU004D	*Aulacoseira lirata var alpigena*	(Grun.) Haworth
AU010A	*Aulacoseira perglabra*	(Oestrup) Haworth 1988
BR006A	*Brachysira brebissonii*	R. Ross in Hartley 1986
BR004A	*Brachysira styriaca*	(Grun. in Van Heurck) R. Ross in Hartley 1986
BR001A	*Brachysira vitrea*	(Grun.) R. Ross in Hartley 1986
CA002A	*Caloneis bacillum*	(Grun.) Cleve 1894
CI9999	*Craticula sp.*	
CM014A	*Cymbella aequalis*	W. Sm. ex Grev. 1855
CM017A	*Cymbella hebridica*	(Grun. ex Cleve) Cleve 1894
CM047A	*Cymbella incerta*	Grun. in Cleve & Moller 1878
CM009A	*Cymbella naviculiformis*	Auersw. ex Heib. 1863
CM010A	*Cymbella perpusilla*	A. Cleve 1895
CM045A	*Cymbella prostrata*	(Berkeley) Brun 1880
EU112A	*Eunotia arculus*	(Grunow) LB & Norpel 1991
EU013A	*Eunotia arcus*	Ehrenb. 1837
EU070B	*Eunotia bilunaris var. mucophila*	LB & Norpel 1991
EU109A	*Eunotia circumborealis*	Norpel & LB 1991
EU016A	*Eunotia diodon*	Ehrenb. 1837
EU010A	*Eunotia faba*	(Ehrenb.) Grun. in Van Heurck 1881
EU018A	*Eunotia formica*	Ehrenb. 1843
EU107A	*Eunotia implicata*	Norpel, Lange-Bertalot & Alles 1991
EU047A	*Eunotia incisa*	W. Sm. ex Greg. 1854
EU045A	*Eunotia nymanniana*	Grun. in Van Heurck 1881
EU040A	*Eunotia paludosa*	Grun. 1862
EU002D	*Eunotia pectinalis var. undulata*	(Ralfs) Rabenh. 1864
EU003A	*Eunotia praerupta*	Ehrenb. 1843
EU011A	*Eunotia rhomboidea*	Hust. 1950
EU004A	*Eunotia tenella*	(Grun. in Van Heurck) A. Cleve 1895
FR002C	*Fragilaria construens var. venter*	(Ehrenb.) Grun. in Van Heurck 1881
FR015A	*Fragilaria lata*	(Cleve-Euler) Renberg 1977
FR005D	*Fragilaria virescens var. exigua*	Grun. in Van Heurck 1881
FU002A	*Frustulia rhomboides var rhomboides*	(Ehrenb.) De Toni 1891
FU002B	*Frustulia rhomboides var saxonica*	(Rabenh.) De Toni 1891
GO004A	*Gomphonema gracile*	Ehrenb. 1838
NA046A	*Navicula contenta*	Grun. in Van Heurck 1885
NA175A	*Navicula gerloffi*	Schimanski 1978
NA006A	*Navicula mediocris*	Krasske 1932

Diatcode	Species	Authority
NA048A	*Navicula soehrensis*	Krasske 1923
NA9999	*Navicula sp.*	
NA033A	*Navicula subtilissima*	Cleve 1891
NE003A	*Neidium affine var. affine*	(Ehrenb.) Pfitz. 1871
NE003B	*Neidium affine var. longiceps*	(Greg.) Cleve 1896
NE006A	*Neidium alpinum*	Hust. 1943
NE036A	*Neidium ampliatum*	(Ehren) Krammer 1985
NE004A	*Neidium bisulcatum*	(Lagerst.) Cleve 1894
NE001A	*Neidium iridis*	(Ehrenb.) Cleve 1894
NI009A	*Nitzschia palea*	(Kutz.) W. Sm. 1856
PE002A	*Peronia fibula*	(Breb. ex Kutz.) R. Ross 1956
PI014A	*Pinnularia appendiculata*	(Ag.) Cleve 1896
PI001A	*Pinnularia gibba*	(Ehrenb.) Ehrenb. 1843
PI051A	*Pinnularia lata*	(Breb.) W. Sm. 1853
PI011A	*Pinnularia microstauron*	(Ehrenb.) Cleve 1891
PI022A	*Pinnularia subcapitata*	Greg. 1856
SP006A	*Stenopterobia curvula*	(W Smith) Krammer 1987
SP005A	*Stenopterobia delicatissima*	(Lewis) M. Perag. 1897
SU005A	*Surirella linearis*	W. Sm. 1853
TA001A	*Tabellaria flocculosa*	(Roth) Kutz. 1844

Appendix II

TDI Counts and Results

Core Depth (cm) \ TDI Taxa	*Achnanthes - other*	*Aulacosira*	*Brachysira*	*Caloneis*	*Craticula*	*Cymbella - other*	*Eunotia*	*Fragilaria - other*	*Fragilariforma*	*Frustulia*	*Gomphonema - other*	*Navicula cryptotenella* (type)	*Navicula - small species*	*Neidium*	*Nitzschia acicularis*	*Nitzschia palea*	*Peronia fibula*	*Pinnularia*	*Psammothidium* (other)	*Psammothidium subatomoides*	*Staurosira*	*Stenopterobia*	*Surirella* (other)	*Tabellaria*	**TDI**	**%motile**
0-0.5	25	154	4	3	0	30	22	0	0	0	0	0	0	0	0	0	3	2	35	2	0	5	3	52	**22.74**	9.14
1.0-1.5	19	164	4	1	0	18	36	0	0	1	0	0	13	0	0	0	1	1	50	0	0	0	2	5	**23.27**	5.96
2.0-2.5	30	152	2	2	0	15	33	0	0	1	0	0	7	0	0	0	1	1	59	0	0	3	0	1	**24.57**	5.81
3.0-3.5	14	177	1	0	0	18	18	0	0	0	0	0	8	0	0	0	2	1	72	0	0	2	0	0	**30.83**	2.94
4.0-4.5	5	190	2	0	0	18	31	0	0	0	0	0	0	0	0	0	1	0	43	0	0	7	1	0	**16.48**	9.26
5.0-5.5	16	195	1	0	0	27	12	0	0	3	0	0	2	0	0	0	0	4	38	0	0	4	1	2	**25.00**	11.82
6.0-6.5	9	224	0	0	0	7	18	0	0	1	0	0	13	0	0	0	1	0	30	0	0	3	2	2	**28.49**	6.98
7.0-7.5	22	201	0	0	0	19	26	0	0	8	0	0	7	1	0	0	0	5	27	0	0	1	0	1	**19.76**	11.97
8.0-8.5	6	215	1	0	0	8	29	0	0	2	0	0	9	2	0	0	0	3	30	0	0	2	0	2	**18.82**	8.51
9.0-9.5	9	242	3	0	0	5	23	0	0	1	0	0	6	0	0	0	0	1	40	0	0	0	3	1	**22.82**	8.70
11.0-12.0	18	223	3	0	0	6	5	0	0	0	0	0	12	0	0	0	3	1	42	0	0	0	1	2	**37.60**	5.38

Appendix II continued

TDI Taxa / Core Depth (cm)	*Achnanthes - other*	*Aulacosira*	*Brachysira*	*Caloneis*	*Craticula*	*Cymbella - other*	*Eunotia*	*Fragilaria - other*	*Fragilariforma*	*Frustulia*	*Gomphonema - other*	*Navicula cryptotenella* (type)	*Navicula - small species*	*Neidium*	*Nitzschia acicularis*	*Nitzschia palea*	*Peronia fibula*	*Pinnularia*	*Psammothidium* (other)	*Psammothidium subatomoides*	*Staurosira*	*Stenopterobia*	*Surirella* (other)	*Tabellaria*	**TDI**	**%motile**
13.0-14.0	14	224	6	0	0	7	9	0	0	1	0	0	5	0	0	0	1	1	39	0	2	2	0	0	**28.48**	11.49
15.0-16.0	10	223	6	0	0	17	21	0	2	0	0	0	4	0	0	0	1	2	36	0	3	2	0	1	**20.81**	9.52
17.0-18.0	15	109	11	0	0	38	21	0	0	1	0	0	4	0	0	0	2	7	82	0	0	3	6	3	**23.85**	14.51
19.0-20.0	23	87	13	0	0	38	13	0	12	3	0	0	2	0	1	4	0	8	84	0	0	4	20	0	**27.96**	23.56
21.0-22.0	28	84	20	0	0	36	30	0	19	3	0	0	3	0	0	0	2	5	65	0	0	2	7	10	**20.23**	16.09
23.0-24.0	38	128	16	0	0	17	20	0	2	5	0	0	6	0	0	3	2	4	35	0	0	0	4	5	**21.88**	20.38
25.0-26.0	39	88	20	1	1	48	31	0	2	4	0	0	7	5	0	1	1	5	40	0	0	5	21	3	**21.20**	24.79
27.0-28.0	13	118	14	0	0	54	26	0	0	14	0	0	18	4	0	0	1	10	25	0	0	2	30	6	**20.68**	32.26
29.0-30.0	32	51	18	1	3	60	26	0	0	0	1	0	8	3	0	8	0	9	33	0	0	3	31	13	**24.55**	29.32
31.0-32.0	43	9	14	1	1	109	41	0	0	4	2	0	5	8	0	10	0	9	43	2	0	2	27	1	**23.00**	21.12
33.0-34.0	31	1	8	1	4	112	63	0	0	3	0	0	5	5	0	2	0	13	11	0	0	4	37	14	**17.86**	23.00
35.0-36.0	22	16	17	4	2	85	45	0	0	1	0	0	1	2	0	1	0	16	4	0	0	9	45	25	**16.94**	34.05
37.0-38.0	29	21	14	2	1	104	52	0	0	6	0	0	4	2	0	1	0	10	0	0	0	9	31	22	**16.43**	25.78
39.0-40.0	31	20	23	1	8	93	41	1	0	3	0	1	4	4	0	3	2	13	16	0	0	5	28	14	**18.81**	29.21