Diatoms as indicators of water quality in the Jukskei-Crocodile river system in 1956 and 1957, a re-analysis of diatom count data generated by BJ Cholnoky

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Abstract

South Africa has a long legacy of diatom research. The eminent diatomist Dr BJ Cholnoky spent much of his working life examining and enumerating diatom communities found in Southern Africa. Most if not all of Cholnoky's collected diatom material in the form of mounted material on glass slides accompanied by diatom analysis sheets is stored in the South African Diatom Collection currently housed at the CSIR in Durban. As Cholnoky only employed enumeration methods yielding a margin of error of 2% or less, Cholnoky's results should provide an accurate reflection of the structure of the diatom communities that he examined. It is the aim of the present study to demonstrate the value of these historical diatom analyses for inferring past water quality conditions using the diatom-based index method. Data for the Jukskei-Crocodile River system were obtained from the South African Diatom Collection for the period 1956/1957. The nomenclature of the diatoms listed on Cholnoky's data sheets was modernised and the data then entered into OMNIDIA v3.1. Diatom index scores generated from OMNIDIA v3.1 were in general in agreement with Cholnoky's own assessment of water quality (especially with reference to organic pollution). It is concluded that the diatom analysis records housed in the South African Diatom Collection constitute a valuable resource for the assessment of past conditions of rivers and streams.

Keywords: BJ Cholnoky, historical diatom analyses, diatom indices, historical water quality

Introduction

Over many years the work of Dr BJ Cholnoky provided an invaluable contribution to the knowledge of the taxonomy and ecology of diatom species he encountered in a variety of southern African habitats. Cholnoky's ecological work attempted to provide a reflection of water quality based on the specific pollution tolerances of diatom species, and especially to nitrogenous compounds. In addition Cholnoky was one of the first people to predict pH of a water-body based on its diatom community (Cholnoky, 1958). Cholnoky was only able to relate several key species from a particular diatom community to different pollutants; later workers have had the luxury of using statistical techniques such as correspondence analysis (Ter Braak and Prentice, 1988) to determine the relationships between the abundances of all diatom species encountered in a certain community and the chemical composition of their aquatic environment. Consequently inferred tolerances can be assigned to diatom species for a whole range of water quality variables rather than just for nitrogen or pH.

When Cholnoky's (1968) definitive work on the diatoms *Die Ökologie Der Diatomeen in Binnengewässern* is examined it is noted that Cholnoky painstakingly dealt with all practical aspects relevant to diatom ecological studies. He first stressed that any person studying ecology should have a sound taxonomical background; secondly he carefully determined margins of error for diatom analysis. Most importantly he tested various counting procedures and determined whether different slides from the same site need to be counted to generate an accurate result, how many individual cells should be counted and the manner in which diatom cells should be counted. Cholnoky only employed methods yielding a margin of error of 2% or less. Thus, Cholnoky's diatom analysis sheets should provide an accurate reflection of the structure of the diatom communities that he encountered. If Cholnoky's diatom community analysis is considered to be accurate then the ecological conclusions drawn from his data should be equally sound.

An explanatory note follows about working with diatom species encountered in South Africa: When diatom publications were written by various authors (Cholnoky, Giffen, Schoeman and Archibald) it was with the intention either to describe all diatom species encountered in a given sample (i.e. community structure), or to describe novel species from a particular locality. The method of illustrating these publications was with line drawings, which are both time-consuming and difficult to generate. Thus common species were usually not illustrated and the reader is most often referred to the works of Hustedt or other authors for illustrations of the species in question. Thus we have a large amount of South African literature that has few, or no, illustrations of commonly encountered diatom species, only novel and rare species. In the late 1980s workers such as Schoeman and Archibald used photographic images to illustrate articles, such as the work done in Namibia at the Gross Barmen Thermal Springs (Schoeman and Archibald, 1988). In this work common species with their variations are illustrated using photomicrograph images.

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Another obstacle encountered in relating older publications to current data and literature lies in the taxonomy and nomenclature of the diatoms. Internationally, diatom nomenclature has undergone several major upheavals and changes in the past 15 years. Since the publication of Round et al. (1990) *The Diatoms: Morphology and Taxonomy of the Genera*, the taxonomical trend has been to split large genera into smaller groups, establish synonyms between con-specific taxa, and to generally rearrange the diatom species into more natural groupings. In addition, many of the species described by Cholnoky have been established as synonyms for taxa described from Europe, while on the other hand many of his species have been validated and found to occur in Europe. Cholnoky also described many "African" forms of extant species, adding to taxonomical confusion. Schoeman (1973), writing after Cholnoky's death, comments: *"transitional forms (of diatoms), linking certain species with their forms and varieties... clearly indicate that the demarcation into varieties or forms is often entirely superfluous and can serve no purpose at all*." This comment creates doubt about the validity of Cholnoky's "African" forms.

The lack of illustration of common species together with vast changes in diatom taxonomy over the last decade has led to misconceptions about diatom taxa encountered in South Africa. The vast majority of common diatom taxa found in South Africa are cosmopolitan both in distribution (see Krammer and Lange-Bertalot, 1986 to 1991), and environmental tolerances. There are a number of diatom species endemic to South or Southern Africa (see Schoeman and Archibald, 1976 to 1980), but the dominant diatom species in a given community are well-known, well-documented cosmopolite species. This is illustrated in the present analysis where the majority of species occurring on Cholnoky's analysis sheets were described from Europe. Although the nomenclatural changes mentioned above can be problematic for the practical diatomist, the taxonomy and nomenclature of diatom species encountered in South Africa can be quickly updated using the wealth of modern literature and electronic databases such as OMNIDIA (Lecointe et al., 1993) - as this study demonstrates.

South Africa is in possession of an enormous database of literature, diatom material (slides and preserved material) and most importantly diatom analysis sheets currently housed in the South African Diatom Collection at the CSIR in Durban. To draw correct inferences about the water quality of a given river or stream using diatom analysis methods, several hours are needed behind a high-power microscope to determine the relative species composition of the sampled community. In addition, to evaluate the structure of a diatom community the person performing this analysis needs to have a very good knowledge of diatom taxonomy. However, the South African Diatom Collection has many original diatom analysis sheets composed from samples taken over a number of decades, commencing in the mid 1950s. These analysis sheets are available for many of South Africa's rivers. Thus when historical data is needed for a particular river system (e.g. to determine the extent of degradation over a period of time), the most time-consuming and painstaking part of using diatom indices has already been completed. It now only remains to convert these previously composed diatom analysis sheets to digital format and then generate historical ecological information based on the diatom communities using modern diatom pollution indices that have been developed and tested over several decades in Europe and elsewhere.

Diatom indices function in the following manner: In a sample from a body of water with a particular level of determinand (e.g. salinity), diatom taxa with their optimum close to that level will be most abundant. Therefore an estimate of the level of that determinand in the sample can be made from the average of the optima of all the taxa in that sample, each weighted by its abundance. This means that a taxon that is found frequently in a sample has more influence on the result than one that is rare. A further refinement is the provision of an "indicator value" which is included to give greater weight to those taxa which are good indicators of particular environmental conditions. In practice, the first step to be completed when using diatom indices is the compilation of a list of taxa in a sample, together with their absolute abundance. It is this step which has been completed for many samples by Cholnoky and his co-workers. The final index value is expressed as the mean of the optima of the taxa in the sample, weighted by the abundance of each taxon. The indicator value acts to further increase the influence of certain species (Kelly, 1998).

The diatom indices used in this analysis are known as Descy's Index or DES (Descy, 1979); the Generic Diatom Index or GDI (Coste and Ayphassorho, 1991); the Specific Pollution Sensitivity Index or SPI (Coste in CEMAGREF, 1982); the Biological Diatom Index or BDI (Lenoir and Coste, 1996); the Eutrophication/Pollution Index or EPI (Dell'Uomo, 1996); the Artois-Picardie Diatom Index or APDI (Prygiel et al., 1996); Sládeček's Index or SLA (Sládeček, 1986); Leclercq and Maquet's Index or LMI (Leclercq and Maquet, 1987); the Commission of Economical Community Index or CEC (Descy and Coste, 1991); Schiefele and Schreiner's Index or SHE (Schiefele and Schreiner, 1991); Rott's Index or ROT (Rott, 1991); the Trophic Diatom Index or TDI (Kelly and Whitton, 1995); and the Watanabe Index or WAT (Watanabe, 1986; 1990). In all cases except in the CEC, SHE, TDI and WAT Index, the diatom indices are calculated using the formula of Zelinka and Marvan (1961). For all of the above indices, except TDI (maximum value of 100), the maximum value of 5 (converted to 20 by the software package OMNIDIA; Lecointe et al., 1993) indicates a high quality or pristine water resource.

Most of the diatom indices listed above were designed to give an indication of general water quality. The indices differ in respect to the diatom species included in the calculation and in the number of taxa included in the calculation. The first index to be developed was that of Descy. This index was followed by the SPI, which has the broadest species base of all of the indices. Several refinements followed on the SPI index that eventually culminated in the BDI, which incorporates 14 parameters of water quality. 70% of the variation in the scores of the BDI index can be explained using 14 water quality variables. The remaining 30% of the variation is ascribed to physical factors such as light penetration, current speed and general habitat integrity (Lenoir and Coste, 1996). Several indices were designed to reflect eutrophication including the EPI and the TDI. The calculation of correct scores for the TDI index is dependent on the percentage of pollution- tolerant diatom taxa in the sample (%PT), more than 20% PT valves indicate organic pollution rather than eutrophication. Sládeček (SLA index) and Watanabe (WAT index) developed diatom indices which were designed to reflect degrees of organic pollution.

At this point it may be useful to define the terms organic pollution and eutrophication in the context of the present paper. Organic pollution refers to unnatural addition of dissolved and particulate organic matter to an aquatic ecosystem. Organic discharges are those produced or derived from living organisms. Organic pollution of an aquatic ecosystem may result in various chemical (dissolved oxygen, nutrient levels) and physical (turbidity and suspended solids) changes that in turn drive biological changes in the receiving water body (Dallas and Day,

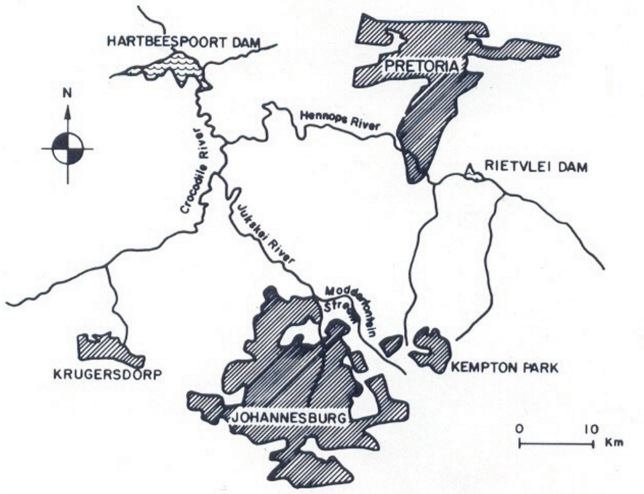

Figure 1
Location of the Jukskei-Crocodile River catchment area (Schoeman, 1982)

2004). A widely accepted definition of eutrophication is that of the Organisation for Economic cooperation and Development (OECD, 1982) which describes the process as "*… the nutrient enrichment of waters which results in the stimulation of an array of symptomatic changes, amongst which is the increased production of algae and aquatic macrophytes, deterioration of water quality and other symptomatic changes that are found to be undesirable and interfere with water uses*". In the classification of Nauman (1919) and Rast and Thornton (1996) the term oligotrophic means the presence of low levels of nutrients and water quality problems; mesotrophic means intermediate levels of nutrients, with emerging signs of water quality problems; and eutrophic means high levels of nutrients and an increased frequency of water quality problems.

The aim of this study is to demonstrate the value of historical diatom analysis sheets by showing that they can be used as the basis for calculating a diatom index score for a particular site. This diatom index core can in turn be useful for drawing conclusions about the past condition (up to 50 years ago) of South African rivers.

Methods

The Jukskei-Crocodile River system drains an area of 2 046 km^2 between Johannesburg and the Hartbeespoort Dam at an altitude of between 1 200 and 1 800 m (see Fig. 1). Climatically this region is cold and dry in winter and warm to hot in summer. About 80 to 90 % of the rainfall occurs in the six summer months, i.e. between November and April (Allanson, 1961). The southern catchment area (northern Johannesburg) is densely populated and heavily industrialised, whereas the northern part consists mainly of agricultural areas. At the time of Cholnoky's work the Jukskei-Crocodile River system received effluent from many different sources including power station blow-down (mineralising effect), industrial and sewage effluent (Allanson, 1961; Schoeman, 1976). The Crocodile River drained what was then a predominantly agricultural area and accordingly contained water of a higher quality (Schoeman, 1982).

This study aims to demonstrate the usefulness of historical diatom community analysis sheets. However, several problems were encountered in using these analysis sheets. Firstly the data sheets needed to be converted to a digital format. In the present study this was achieved by entering the data first into spreadsheets and then into the OMNIDIA database. The first entry into MICROSOFT EXCEL was necessary as the data had to be electronically captured. However, if the person entering the data is proficient in the use of the OMNIDIA Database the data can be directly entered without a first, time-consuming, entry into spreadsheets. OMNIDIA (Lecointe et al., 1993) was developed for the management of diatom samples and calculation of diatom indices from abundance data generated from diatom community analysis. Data entry into OMNIDIA only requires a species acronym together with absolute abundance of the relevant diatom species. From these data the program generates the full species name and relative abundance of the species in the community, and hence is far less time-consuming than entering species data into spread- sheets. Results obtained from OMNIDIA are in the form of individual diatom analysis sheets together with site information, relative abundance of the species, population, diversity, evenness and a number of diatom index scores generated from the diatom community data (see discussion above). Alternatively diatom analysis sheets can be grouped together up to 20 at a time saving repetitive mention of species. These files can then in turn be exported to EXCEL or some other similar program.

The entry of diatom data of a historical nature using the acronym method poses several problems for the inexperienced user. The first complication that arises is whether the species name used by the original author of the analysis sheets is currently valid and recognized by the software? The validity of species names can be checked in OMNIDIA or, failing that, in a number of literature resources. If the specific or generic epithet is no longer valid then the accurate synonym can be obtained in the OMNIDIA program, or alternatively from literature resources such as Krammer and Lange-Bertalot (1986 to 1991) or Kellogg and Kellogg (2002). Secondly, the relevant acronym for data entry needs to be identified. There is a printable list of acronyms in OMNIDIA for about 9 000 species, or alternatively an electronic search may be conducted by typing the full species name into OMNIDIA. The acronym construction follows certain rules and once the operator is familiar with these rules most of the acronyms can many times be determined without resorting to either a manual or electronic search.

Once the data had been entered, the database (OMNIDIA) calculated the indices listed above in the introduction. In the following section the diatom index results for this analysis will be presented and discussed.

Results and discussion

A complete species list (including synonymy) composed from the analysed data sheets is presented in **Appendix 1**. Species names highlighted in bold are those used in Cholnoky's original analysis sheets.

The diatom index scores generated from the diatom community analysis sheets are presented in Table 2, and should be interpreted using Table 1.

The results as presented in Table 2 can be seen to give an accurate indication of a highly impacted river system (as per Schoeman, 1976). However, caution should be exercised in interpreting the data yielded by those samples with a population lower than the 350 minimum recommended by Cholnoky in his book (Cholnoky, 1968), and later by European authors (e.g. 300 by Prygiel et al., 2002). All of the species listed on Cholnoky's diatom analysis sheets could be entered into the OMNIDIA database with the exception of *Cymbella bengalensis*. There is no

TABLE 1 Class limit values for diatom indices (Eloranta & Soininen, 2002)		
Class	**Trophy**	**Index score**
high quality	oligotrophy	>17
good quality	oligo-mesotrophy	15 to 17
moderate quality	mesotrophy	12 to 15
poor quality	meso-eutrophy	9 to 12
bad quality	eutrophy	<9

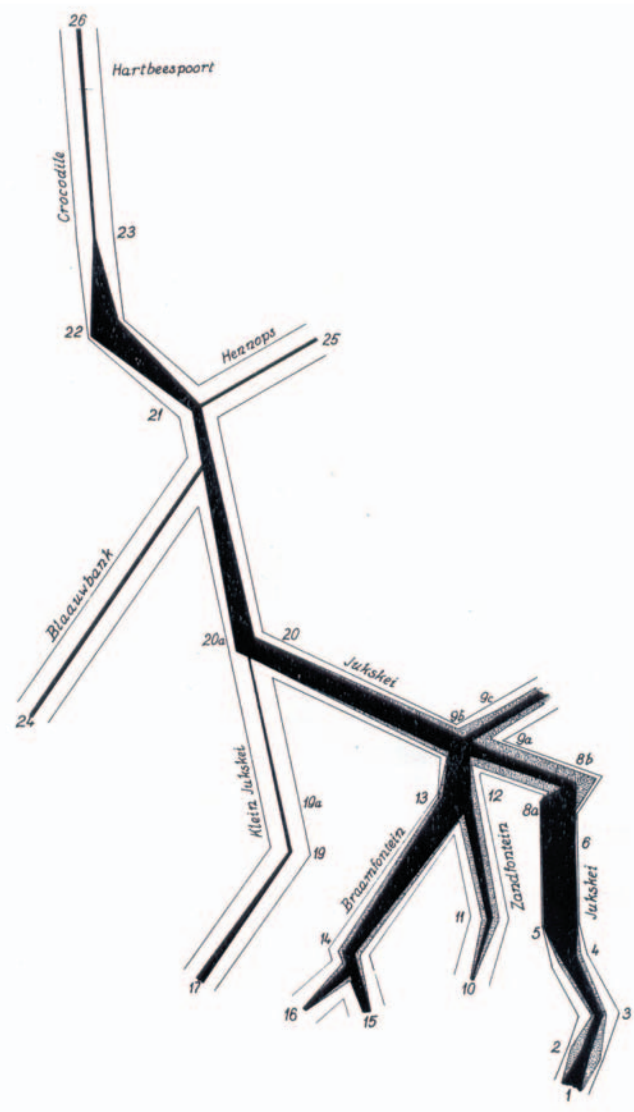

Figure 2
Abundance of the pollution tolerant diatom species Nitzschia palea *(black) and* Sellaphora (Navicula) seminulum *(grey) in the Jukskei-Crocodile River system (Cholnoky, 1968)*

acronym for this species or any of its synonyms in OMNIDIA v3.1. However, *C. bengalensis* was present in only two samples (5 and 7 individuals respectively), and its absence from the index calculation is not considered to exert an influence on the final score in any way. Prygiel (2003) cautions that when dominant species are not included in the index calculation then one runs the risk of incorrect assessments; however, this does not hold true for sub-dominant species.

It is interesting to compare the diatom-index data with the diagram that Cholnoky drew of the Jukskei-Crocodile River system, based on his diatom analysis at the same sampling stations he used in 1956/7 (see Fig. 2). Cholnoky constructed the diagram based on the relative abundance of two diatom species, *Nitzschia palea* and *Sellaphora (Navicula) semminulum*, both species known for their tolerance to organic pollution. It is evident from a comparison of Fig. 2 with Table 2 that the sampling stations on Cholnoky's diagram having the lowest percentage of *N. palea* and *S. seminulum* in the communities (hence higher quality water) have the highest scores generated from modern diatom indices. Cholnoky's diagram also agrees with the calculated percentage of pollution tolerant diatoms (%PT) using the TDI index of Kelly and Whitton (1995; Table 2).

It can also be deduced from Table 2 that some of the sampling stations have a diatom-index score that is representative of pristine water quality. The authors of this report consider this to be an erroneous assessment. If the samples classified as pristine (diatom index score >17; Table 2) are related to the abundance sheets it can be noted that all these sites have high abundance of *Achnanthidium minutissimum* (*Achnanthes minutissima*). At several of the sites with index scores indicating pristine conditions, there is a high abundance of *Gomphonema parvulum*. *G. parvulum* is known to be tolerant to several forms of pollution and indicates disturbed conditions; Cholnocky was later to add *G. parvulum* to his list of pollution tolerant species (Cholnoky, 1970). The occurrence of *G. parvulum* in a community dominated by *A. minutissimum* alerts one to the fact that there is at least moderate pollution at the site. From a re-examination of the original material it can be seen that although *A. minutissimum* composed some portion of the diatom community, the additional portion of the diatoms recorded as *A. minutissimum* is in fact *A. saprophilum* (*Achnanthes minutissima* var. *saprophila*). This species or variety cannot have been noted as separate to *A. minitissimum* in 1956 or 1957 as it was only described in 1982 (Kobayasi and Mayama, 1982) from severely polluted rivers in the vicinity of Tokyo. The valve morphology of this taxon closely resembles *A. minutissimum*. *A. saprophilum* has a very high tolerance to organic pollution and often occurs as the dominant taxon even in poly-saprobic water. If the TEM illustrations of *A. minutissimum* from Pretoria salt pan found in the work of Schoeman and Ashton (1982) are compared with those presented by Mayama and Kobayasi (1989), it can be seen that several of the photographs depicting *A. minutissimum* are undoubtedly *A. saprophilum* (see Fig. 3). The similarity in outline, pore structure and arrangement of striae should be noted in this figure.

The error of identification between the two species is very easy to remedy, in the samples where it is suspected that a portion of the count of *A. minutissimum* could be *A. saprophilum*, the original slide needs to be examined and the ratio between these two species calculated. Once the diatom analysis has been corrected in this way, the data can once more be used in accurate historical ecological assessments. It is important to do this when diatom indices are being used for assessment as the two species have different tolerance values in the diatom index equation. On re-counting the abundance of *A. minutissimum,* it was found that a percentage of the diatom valves was in fact *A. saprophilum,* the resultant relative abundance was re-calculated and when used in the diatom index calculation, lowered the index score by several points and in some cases transferred the sample to a lower water quality class (Table 1) as demonstrated in Table 3.

Of the specific indices, the EPI shows that most of the sites are eutrophic, with several falling into the meso-eutrophic class and others which could be classified as mesotrophic; no sites

TABLE 2
Diatom index scores generated from diatom analysis sheets for the Jukskei-Crocodile River system in 1956/57 (Authored by Dr BJ Cholnoky)

Sample number	Population	SPI	DES	LMI	SHE	ROT	CEC	APDI	BDI	GDI	SLA	WAT	EPI	TDI	%PT
JK 1 STA 8A	565	1.2	1.1	5.8	1.3	6.7	1.6	6.6	6.7	1.3	7.7	1.7	7.5	75.6	96.5
JK 2 STA 8A	604	1.3	1.2	5.9	1.6	5.5	1.8	6.8	6.5	1.5	7.9	2.3	7.0	75.7	95.2
JK3 STA 8A	323	2.0	1.5	6.0	3.2	5.5	1.6	7.8	6.5	2.5	7.9	4.5	7.5	75.6	84.2
JK 5 STA 6	288	5.0	3.6	7.4	4.5	9.7	4.8	8.2	9.9	9.0	9.2	10.5	7.1	93.5	83.0
JK 6 STA 6	549	1.7	1.2	6.2	1.6	7.0	1.8	7.9	6.9	2.0	8.2	2.9	6.7	75.0	89.6
JK 7 STA 6	387	11.1	8.5	10.5	8.9	11.2	9.6	12.0	14.0	11.8	11.5	13.2	10.6	64.3	31.5
JK 8 STA 5	538	1.5	1.2	5.8	2.3	4.1	1.6	4.9	6.5	1.8	8.0	2.6	7.7	75.4	91.1
JK 9 STA 4	562	1.5	1.4	5.8	2.0	6.0	2.1	6.3	6.2	2.0	7.8	2.8	7.2	75.2	92.7
JK10	471	2.7	2.2	6.5	4.2	6.1	2.7	7.1	7.3	3.8	8.8	5.9	7.7	78.7	79.8
JK 11	471	2.1	1.7	6.0	3.9	5.1	2.0	7.5	6.5	2.7	8.1	4.9	7.7	77.4	83.9
JK 12	532	1.8	1.4	5.8	3.2	4.3	1.8	7.6	6.2	2.3	7.7	4.1	7.6	76.1	89.8
JK 13 STA 20	507	12.3	6.7	6.8	13.0	13.9	7.7	5.7	11.0	16.5	12.8	5.8	9.6	92.1	25.2
JK 14 STA 20 A	509	4.3	3.7	7.6	6.1	9.6	6.3	5.4	11.3	3.8	10.9	7.9	8.1	70.2	56.2
JK 15	532	11.2	14.8	10.5	17.8	18.6	18.3	9.6	8.8	14.3	11.7	19.8	8.8	10.4	0.4
JK 16	528	12.9	14.5	10.5	18.1	18.4	17.2	9.5	13.9	14.3	12.1	19.8	9.8	9.4	0.2
JK 17	562	16.9	15.4	14.0	18.1	18.0	18.3	10.4	14.6	18.4	15.3	18.8	12.6	5.0	2.0
JK 18	523	11.4	13.5	10.6	16.5	16.8	16.8	9.6	9.3	14.2	11.8	19.6	9.1	26.4	0.8
JK 19	533	11.8	13.7	10.5	18.4	18.9	17.2	9.5	10.3	14.4	11.9	19.6	9.1	12.1	1.3
JK 101 STA 1	265	4.9	5.7	8.3	8.0	11.9	6.1	9.4	11.6	3.1	10.9	10.5	12.0	77.2	54.7
JK 102 STA 2	282	2.9	4.9	6.4	4.8	6.6	5.2	2.2	10.1	7.9	12.5	4.6	11.7	94.4	50.0
JK 103 STA 3	247	6.8	9.9	7.2	5.4	7.8	5.9	5.4	10.9	9.2	9.3	8.9	10.6	93.3	62.3
JK 103B STA 3	268	5.1	7.1	8.1	6.4	8.8	4.2	5.2	9.7	7.8	12.1	9.2	8.8	87.5	48.1
JK 104 STA 4	325	2.9	4.0	6.5	4.2	7.4	3.9	4.8	7.9	6.9	10.4	8.1	8.8	90.9	79.7
JK 105 STA 5	349	5.7	6.2	6.2	5.4	5.7	4.4	5.4	9.7	11.5	8.2	10.7	9.2	95.1	88.0
JK 106 STA 8A	347	6.4	9.1	8.9	10.8	8.9	4.2	8.6	8.7	10.4	12.9	11.5	8.0	83.2	46.4
JK 106B STA 8B	258	4.5	6.7	6.7	7.7	9.5	4.2	7.5	9.3	6.5	12.0	10.8	9.9	85.1	65.1
JK 107A STA 9A	318	4.1	5.5	6.0	2.9	8.4	4.8	5.0	9.1	9.3	10.9	14.0	9.5	97.5	78.6
JK 107B STA 9B	265	4.0	7.0	7.6	7.3	9.3	5.2	6.6	9.3	9.5	11.4	9.8	8.9	93.4	70.2
JK 107C STA 9C	287	5.0	8.2	8.0	7.0	9.2	5.4	5.5	10.4	8.0	12.1	8.8	9.2	90.0	36.6
JK 108 STA 10	301	18.5	14.3	14.3	15.3	15.2	18.7	5.8	17.0	13.4	14.7	20.0	12.5	100.0	10.3
JK 109A STA 11	349	4.7	4.5	7.6	6.4	7.1	3.3	2.3	7.3	8.9	10.2	11.0	8.3	95.5	25.5
JK 109B STA 11	338	3.9	4.7	6.7	5.1	6.8	4.6	4.8	8.0	8.5	9.8	10.5	9.2	94.7	64.2
JK 109C STA 11	313	4.2	5.8	7.3	6.4	6.7	3.7	2.6	7.5	9.1	10.2	10.3	9.1	95.3	26.2
JK 110A STA 12	157	6.1	6.8	8.5	8.6	9.9	5.8	7.7	9.6	9.8	11.1	9.6	9.5	87.7	55.4
JK 110B STA 12	310	12.9	14.7	14.6	13.4	14.0	12.0	14.2	12.3	12.2	14.5	11.0	8.8	55.2	6.8
JK 111 STA 13	299	2.6	3.2	6.3	3.2	11.3	4.4	8.1	8.5	3.3	9.6	6.2	10.7	82.4	81.6
JK 112 STA 14	272	4.0	6.2	6.6	5.8	7.7	7.1	5.6	10.1	8.4	10.1	9.7	10.3	93.8	72.8
JK 113 STA 15	351	12.0	10.6	12.1	13.7	15.2	16.2	8.9	16.1	1.8	13.7	16.4	12.8	78.7	20.2
JK 114 STA 16	263	10.4	11.8	11.1	11.5	11.7	11.1	7.8	12.8	9.8	12.3	16.4	10.3	87.5	31.2
JK 115 STA 20	262	3.8	4.8	7.3	5.4	8.6	3.5	4.6	7.9	8.8	12.3	8.1	9.1	91.7	87.4
JK 116 STA 20A	259	1.5	2.2	5.9	2.3	5.5	3.9	4.1	8.0	9.6	10.3	2.7	9.2	95.1	94.6
JK 117 STA 21	234	7.0	7.3	8.2	9.6	12.5	7.1	7.9	10.6	9.5	11.8	10.8	11.2	75.3	43.6
JK 119 STA 8B	347	3.3	2.9	6.7	4.5	5.5	2.9	1.8	10.7	7.5	12.9	2.4	8.0	93.6	24.2
JK 120 STA 10	345	18.4	14.3	14.4	15.6	15.2	13.5	5.8	17.3	10.8	14.8	19.8	12.6	98.3	8.1
JK 122 STA 9A	267	2.8	2.1	6.0	2.9	5.2	4.6	1.7	9.7	7.2	12.5	3.9	9.3	92.7	43.4
JK 123 STA 17	297	14.0	13.5	12.3	14.9	15.3	16.2	12.4	13.3	8.6	13.8	15.7	11.6	46.6	6.1
JK 124 STA 19A	367	17.5	15.9	14.0	15.9	16.2	17.3	7.6	16.8	13.7	14.6	18.8	12.2	45.4	6.3
JK 125 STA 20	309	10.3	14.0	10.1	14.3	11.8	11.5	7.2	13.0	11.4	10.7	12.3	8.1	64.2	13.6
JK 126 STA 2	280	6.1	7.0	6.5	3.2	6.8	5.9	4.6	9.5	12.3	11.3	16.1	9.5	98.7	70.0
JK 127 STA 3	313	4.2	2.6	7.2	3.9	9.6	4.4	9.4	9.5	6.9	8.4	7.9	7.1	89.6	87.5
JK 128 STA 4	164	6.7	9.4	8.4	9.6	8.1	6.3	5.9	9.7	7.0	10.3	12.9	8.0	95.1	48.2
JK 129 STA 5	281	1.6	1.5	6.1	2.3	7.9	3.5	8.8	7.3	2.6	8.0	3.3	7.3	79.4	93.6
JK 130 STA 6	347	4.4	2.9	6.7	9.2	9.0	1.8	5.9	6.9	2.0	8.5	7.9	7.0	80.1	36.6
JK 131 STA 8B	347	3.2	2.9	6.5	4.5	7.5	3.9	7.4	7.8	5.5	8.5	7.8	8.0	87.1	82.1
JK 132 STA 12	301	6.0	13.1	8.9	12.7	10.5	4.4	5.9	7.2	2.1	9.3	10.6	6.8	85.7	17.3

TABLE 2 (continued)															
Sample number	**Popu-lation**	**SPI**	**DES**	**LMI**	**SHE**	**ROT**	**CEC**	**APDI**	**BDI**	**GDI**	**SLA**	**WAT**	**EPI**	**TDI**	**%PT**
JK 133 STA 16	308	10.8	13.5	10.9	11.8	12.8	11.1	8.9	10.7	9.3	12.3	13.7	8.9	63.7	18.5
JK 134 STA 17	313	15.1	14.1	10.9	16.2	14.2	14.9	11.3	13.1	14.3	12.0	16.8	10.8	59.5	3.5
JK 135 STA 19	375	15.3	14.0	12.3	15.3	17.0	16.4	11.5	15.0	15.2	14.7	17.8	12.6	45.0	5.3
JK 136 STA 20A	300	2.0	2.0	6.2	1.6	7.0	3.5	6.3	6.2	4.1	8.3	6.8	7.7	85.6	92.3
JK 137 STA 21	423	17.6	15.0	14.7	17.5	16.9	17.7	8.0	16.1	16.8	15.3	18.9	12.7	9.9	0.5
JK 138 STA 22	344	3.3	2.0	6.7	4.5	7.0	4.6	6.1	5.7	3.7	8.0	6.2	7.6	75.4	89.0
JK 139 STA 23	351	12.3	14.4	12.3	11.8	10.2	12.4	7.1	14.2	11.0	11.4	15.6	10.7	82.4	2.8
JK 140 STA 24	338	14.5	14.4	13.0	15.3	15.4	15.6	12.9	14.3	12.4	13.6	16.5	11.9	55.8	7.1
JK 141 STA 24	328	16.3	13.7	12.5	15.9	15.7	17.0	13.9	15.5	15.1	13.8	16.6	11.5	43.2	3.4
JK 142 STA 26(1)	431	13.3	13.3	12.0	14.0	13.4	14.3	12.2	16.5	11.4	12.6	16.1	11.6	62.2	9.5
JK 143 STA 26(2)	363	16.0	17.5	13.5	18.4	13.2	17.0	14.4	15.4	12.3	14.1	7.9	12.5	89.5	0.3
JK 144 STA 26 (3)	407	14.6	15.1	12.9	14.3	13.1	14.3	11.5	16.3	12.7	13.1	17.8	12.1	54.6	4.4
JK 145 STA 1	341	15.3	12.7	13.3	15.3	15.0	18.1	5.8	16.9	15.8	14.2	17.9	12.9	77.7	10.9
JK 146 STA 2	404	3.2	2.7	5.9	3.2	5.0	5.0	1.7	10.4	8.7	12.6	4.2	9.4	96.7	35.4
JK 147 STA 3	300	3.3	3.1	6.4	4.5	6.3	3.7	4.3	8.1	5.8	9.3	6.6	7.0	89.3	67.0
JK 148 STA 4	163	4.4	4.6	7.1	6.1	8.6	5.0	5.6	8.3	6.3	10.2	9.3	9.6	90.1	61.3
JK 149 STA 5	204	3.4	3.2	6.5	5.4	6.2	3.5	7.5	7.4	5.0	8.5	7.5	8.0	82.7	71.6
JK 150 STA 6	361	7.0	3.5	8.1	6.7	9.2	4.2	9.5	10.8	11.3	11.2	10.5	6.6	89.6	59.6
JK 151 STA 8B	259	3.4	2.8	6.6	5.1	6.3	2.9	6.4	7.3	4.5	9.1	6.5	7.3	80.2	71.0
JK 152 STA 9A	623	1.2	1.0	5.8	1.3	4.8	1.6	1.8	7.0	1.7	8.6	1.3	8.3	77.7	91.3
JK 153 STA 9B	424	2.3	1.7	6.0	2.9	5.3	3.3	2.3	8.2	5.1	10.8	4.1	8.9	87.7	67.9

SPI; Specific Pollution Sensitivity Index, DES; Descy's Index, LMI; Leclercq & Maquet's Index, SHE; Schiefele and Schreiner's Index, ROT; Rott's Index, CEC; Council for European Communities Index, APDI; Artois-Picardie Diatom Index, BDI; Biological Diatom Index, GDI; Generic Diatom Index, SLA; Sládeček's Index, WAT; Watanabe's Index, EPI; Eutrophication/Pollution Index, TDI; Trophic Diatom Index, %PT; Percenage Pollution Tolerant Species

TABLE 3
Diatom index scores before and after reclassification of *Achnanthidium minutissimum* and *A. saprophilum*

	Index score with all species as *A. minutissimum*				
Site	SPI	SHE	BDI	WAT	ROT
JK 141 STA 24	16.3	15.9	15.5	16.6	15.7
JK 143 STA 26 (2)	16	18.4	15.4	7.9	13.2
JK 144 STA 26 (3)	14.6	14.3	16.3	17.8	13.1
	Index score after splitting of *A. minutissimum* and *A. saprophilum*				
JK 141 STA 24	15.5	13.7	13.4	14.2	13.4
JK 143 STA 26 (2)	14.9	16.8	12	5.8	9.3
JK 144 STA 26 (3)	13.6	12.4	14.9	15.6	11.3

SPI; Specific Pollution Sensitivity Index, SHE; Schiefele and Schreiner's Index, BDI; Biological Diatom Index, WAT; Watanabe's Index, ROT; Rott's Index

warrant the classification of oligotrophic. The TDI is included for the %PT valves as the index itself was developed for monitoring sewage outfall (orthophosphate-phosphorus concentrations) and not organic pollution or general stream quality (Kelly and Whitton, 1995). The index cannot be used accurately if the %PT valves are above 20. The %PT valves do however, demonstrate that for the most part the Jukskei-Crokodile system was subject (as it still is) to high loading with organic pollutants. The GDI has a lower resolution being based only on the genus of the taxa composing the diatom communities. Although far simpler to use than indices that rely on species level identification it seems to yield comparable results in most cases.

The diatom index scores were correlated to the average water quality variables at 10 of the sites for which average annual data were available and the results are presented in Table 4.

It is interesting to note that the strongest correlations are between nitrogen and the diatom index scores, with no significant correlation to either orthophosphate-phosphorus or to total phosphate. This would suggest that the major impact in the system is from waste containing nitrogenous compounds. This finding is in agreement with Cholnoky's assessment at the time, showing that at some sites almost all of the diatom species encountered were tolerant to organic pollution, which in turn may result in nutrient enrichment (Dallas and Day, 2004). Other strong correlations exist between the diatom index scores and electrical conductivity and the major ions. This correlation between ionic compounds matches a descriptive assessment of the Jukskei-Crocodile system as being heavily impacted by industrial and agricultural runoff and effluents.

TABLE 4
Correlation between water quality variables at selected sites in the Jukskei-Crocodile system and diatom index scores generated from re-analysis of historical data sheets
Marked correlations are significant at $p < 0.05$
n =10 (Casewise deletion of missing data)

	SPI	DES	LMI	SHE	ROT	CEC	APDI	BDI	GDI	SLA	WAT	EPI
pH	0.67	0.64	0.77	..	0.64	0.74	..	0.81	..	0.64	0.77	0.77
EC	..	-0.68	..	..	-0.67	..	-0.86	..	-0.81	..	..	..
Temp.	0.68	0.64	0.69	..	0.73	0.76	..	0.72	0.35	0.86	0.69	0.81
COD	..	..	..	..	..	..	-0.89	..	-0.65	..	..	..
NH_4-N	-0.85	-0.86	-0.86	-0.79	-0.84	-0.82	-0.78	-0.85	..	-0.69	-0.86	-0.76
NO_2-N	-0.78	-0.82	-0.76	-0.74	-0.79	-0.74	-0.85	-0.74	..	..	-0.77	-0.64
NO_3-N	..	..	..	..	..	..	-0.76	..	-0.73	..	..	..
KJ-N	-0.82	-0.85	-0.82	-0.79	-0.83	-0.78	-0.87	-0.78	..	-0.65	-0.82	-0.68
PO_4-P	..	..	..	..	..	..	..	..	..	..	..	..
Total P	..	..	..	..	..	..	..	..	..	..	..	..
Na^+	..	-0.65	..	..	-0.64	..	-0.87	..	-0.76	..	..	..
K^+	..	..	..	..	..	..	..	..	-0.75	..	..	..
Ca^{2+}	..	..	..	..	..	..	-0.80	..	-0.86	..	..	..
Mg^{2+}	-0.74	-0.75	-0.66	-0.74	-0.79	-0.70	..	-0.67	..	-0.69	-0.68	..
SO^{4-}	-0.77	-0.80	-0.73	-0.74	-0.80	-0.73	-0.90	-0.68	-0.71	-0.66	-0.74	..
Cl^-	-0.69	-0.73	-0.66	-0.67	-0.73	-0.66	-0.90	..	-0.74	..	-0.67	..

Variables were measured in mg.ℓ^{-1} except for temperature (°C), electrical conductivity (µS.cm^{-1})

SPI; Specific Pollution Sensitivity Index, DES; Descy's Index, LMI; Leclercq & Maquet's Index, SHE; Schiefele and Schreiner's Index, ROT; Rott's Index, APDI; Artois-Picardie Diatom Index, CEC; Council for European Communities Index, BDI; Biological Diatom Index, GDI; Generic Diatom Index, SLA; Sládeček's Index, WAT; Watanabe's Index, EPI; Eutrophication/Pollution Index

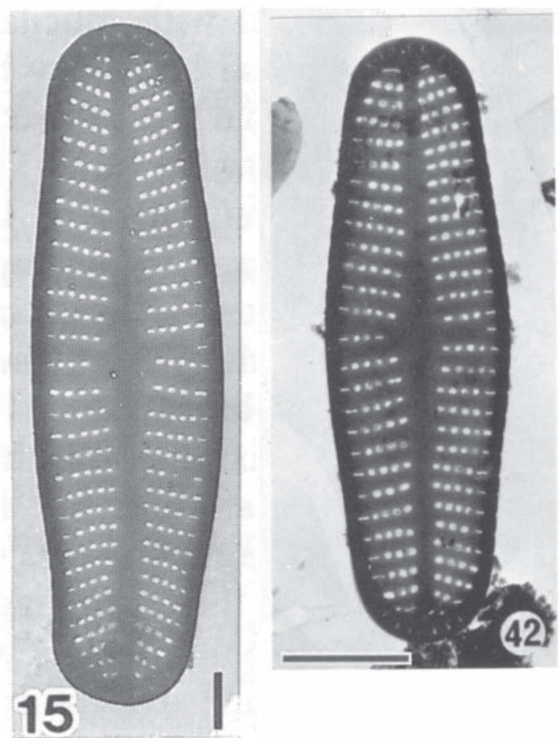

Figure 3
15; Achnanthidium saprophilum *(Mayama and Kobayasi, 1989), scale bar = 1 µm. 42;* Achnanthidium minutissimum *(Schoeman and Ashton, 1982), scale bar = 2 µm*

Conclusions

In general it can be concluded from the preceding sections that the diatom analysis sheets authored by Dr Cholnoky constitute a valuable resource from which accurate inferences may be drawn concerning the past ecological status of the rivers and streams for which data exist in the SA Diatom Collection dating from the mid 1950s. The classification of the various sampling stations carried out by Cholnoky yields similar results to those gained by using modern diatom indices. The use of diatom indices relies on information stored in a database rather than the operator's own knowledge, and thus provides a relatively rapid and more efficient assessment technique when compared to those employed by Cholnoky half a century ago.

The diatom analysis sheets contained in the SA Diatom Collection are likely to prove to be a valuable resource for obtaining historical data against which present-day and/or future environmental assessments may be compared, and provide a measure of either degradation of restoration since the time of original sampling. OMNIDIA proves to be both useful as a database and as a tool for calculating diatom index scores.

It has been demonstrated that the species listed on the diatom analysis sheets can be related to current nomenclature (synonyms; see **Appendix 1**) when necessary, and entered into the electronic database OMNIDIA. The diatom analysis sheets provide enough data for the calculation of accurate diatom index scores. Results generated from diatom analysis sheets with a population count of less than 300 should be regarded with caution.

Besides the difficulties encountered caused by the identification of *Achnanthidium minutissimum,* the historical species data sheets contained in the SA Diatom Collection are of a quality sufficient to allow for the generation of accurate, high-confidence results that support the formulation of ecologically-based inferences on past ecosystem condition.

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APPENDIX 1
Species list and updated nomenclature

Taxon
Achnanthes amoena **Hustedt**
Achnanthidium exiguum (Grun.) Czarn. ***Achnanthes exigua*** **Grun. *in* Cleve & Grun.**
Achnanthidium exiguum var.*heterovalva* (Krasske) Czarn. ***Achnanthes exigua*** **var.*heterovalva* Krasske**
Achnanthidium minutissimum (Kütz.) Czarn. ***Achnanthes minutissima*** **Kütz.**
Achnathidium microcephalum (Kütz.) *vide* Rabenh. ***Achnanthes microcephala*** **(Kütz.) Grun**.
Amphipleura pellucida **Kütz.**
Amphora coffeaeformis **(Agardh) Kütz.**
Amphora montana Krasske ***Amphora submontana*** **Hustedt**
Amphora ovalis **(Kütz.) Kütz.**
Amphora pediculus (Kütz.) Grun. ***Amphora ovalis*** **var. *pediculus* (Kütz.) Van Heurk**
Amphora veneta **Kütz.**
Anomoeoneis sphaerophora **(Ehr.) Pfitzer**
Aulacoseira granulata (Ehr.) Simonsen ***Melosira granulata*** **(Ehr.) Ralfs**
Aulacoseira granulata var. *angustissima* (O.Müll.) Simonsen ***Melosira granulata*** **var. *angustissima* O.Müll.**
Aulacoseira italica (Ehr.) Simonsen ***Melosira italica*** **(Ehr.) Kütz.**
Brachysira vitrea (Grunow) Ross *in* Hartley ***Anamoneis exilis*** **(Kütz.) Cleve**
Caloneis aequatorialis **Hustedt**
Caloneis bacillum **(Grun.) Cleve**
Caloneis schumanniana **var. *biconstricta* (Grun.) Reichert**
Caloneis silicula (Ehr.)Cleve ***Caloneis ventricosa*** **(Ehr. Donkin) Meister**
Cocconeis pediculus **Ehr.**
Cocconeis placentula **Ehr.**
Craticula ambigua (Ehr.) Mann *in* Round, Crawford & Mann ***Navicula cuspidata*** **var. *ambigua* (Ehr.) Cleve**
Craticula cuspidata (Kütz.) Mann *in* Round, Crawford & Mann ***Navicula cuspidata*** **Kütz.**
Cyclotella meneghiniana **Kütz.**
Cyclotella operculata **(Agardh) Kütz.**
Cyclotella stelligera **Cleve *et* Grun. *in* Van Heurk**
Cymatopleura solea **(Bréb.) W.Smith** *Cymatopleura librile* (Ehenberg) Pantocsek
Cymbella amphicephala **Naegeli**
Cymbella amphicephala **var. *hercynica* (A.Schmidt) Cleve**
Cymbella aspera **(Ehr.) Cleve**
Cymbella begalensis **Cleve**
Cymbella cistula **(Ehr.)Kirchner**
Cymbella kappii **Cholnoky**
Cymbella kolbei **Hustedt**
Cymbella turgida **Gregory**
Diadesmis confervacea Kütz. ***Navicula confervaceae*** **(Kütz.) Grun.**
Diadesmis contenta var. *biceps* (Grun. *ex* V.Heurk) Mann *in* Round, Crawford & Mann ***Navicula contenta*** **Grun.**
Diploneis ovalis **(Hilse) Cleve**
Diploneis smithii **var. pumila (Grun.) Hustedt**
Diploneis subovalis **Cleve**
Encyonema minutum (Hilse in Rabenhorst) Mann in Round, Crawford & Mann *Cymbella minuta* Hilse *ex* Rabenhorst ***Cymbella ventricosa*** **Kütz.**
Encyonema muelleri (Hustedt) Mann in Round, Crawford & Mann ***Cymbella muelleri*** **Hustedt**
Encyonopsis aequalis (W.Smith) Krammer ***Cymbella aequalis*** **W.Smith**
Encyonopsis microcephala (Grun.) Krammer ***Cymbella microcephala*** **Grun**.
Eolimna minima (Grun.) Lange-Bertalot ***Navicula minima*** **Grun.**
Eolimna subminuscula (Manguin) Lange-Bertalot & Metzeltin ***Navicula subminuscula*** **Manguin** *Navicula frugalis* Hustedt ***Navicula perparva*** **Hustedt**
Fallacia pygmaea (Kütz.) Stickle & Mann *in* Round, Crawford & Mann ***Navicula pygmaea*** **Kütz.**
Fragilaria capucina Desmazieres ***Synedra rumpens*** **Kütz.**
Fragilaria capucina **var. *acuta* (Ehr.) Rabenhorst**
Fragilaria capucina var. *vaucheriae* (Kütz.) Lange-Bertalot ***Synedra vaucheriae*** **Kütz.**
Fragilaria construens **(Ehr.) Grun.**
Fragilaria delicatissima (W.Smith) Lange-Bertlot ***Synedra acus*** **var. *radians* (Kütz.) Hustedt**
Frustulia rhomboides **(Ehr.) De Toni**
Frustulia vulgaris **(Thwaites) De Toni**
Geissleria decussis (Østrup) Lange-Bertalot & Metzeltin *Navicula decussis* Østrup *Navicula canoris* Hohn & Hellerman ***Navicula exiguiformis*** **Hustedt**
Gomphonema clavatum **Ehr.**
Gomphonema clevei **Fricke**
Gomphonema gracile **var. *subcapitata* Gandhi**
Gomphonema gracile **Ehr.**
Gomphonema gracile **var. *lanceolata* (Kütz.) Cleve**
Gomphonema parvulum **Kütz.**
Gomphonema pumilum (Grun.) Reichardt & Lange-Bertalot ***Gomphonema intricatum*** **var. *pumila* Grun. *in* V.Heurck**
Gomphonema schweickerdtii **Cholnoky**
Gomphonema truncatum **Ehr.**
Gomphonema truncatum **var. *capitatum* (Ehr.) Patrick**
Gyrosigma nodiferum **(Grun.) Reimer** *Gyrosigma spencerii* var. *nodifera* (Grun.) Cleve
Gyrosigma scalproides **(Rabenhorst) Cleve**
Gyrosigma spencerii **(Quekett) Griffith**
Hantzschia amphioxys **(Ehr.) Grun. *in* Cleve & Grun.**
Hantzschia amphioxys **var. *africana* Hustedt**
Hippodonta capitata (Ehr.) Lange-Bertalot & Metzeltin *in* Witkowski ***Navicula capitata*** **Ehr.**
Hippodonta hungarica (Grun.) Lange-Bertalot & Metzeltin *in* Witkowski ***Navicula hungarica*** **Grun.**
Kobayasiella subtilissima (Cleve) Lange-Bertalot ***Navicula subtilissima*** **Cleve**
Lemnicola hungarica (Grun.) Round & Basson ***Achnanthes hungarica*** **Grun. *in* Cleve & Grun.**
Luticola mutica (Kütz.) Mann *in* Round, Crawford & Mann ***Navicula mutica*** **Kütz.**

Luticola nivalis (Ehr.) Mann *in* Round, Crawford & Mann ***Navicula mutica* var. *nivalis* (Ehr.) Hustedt**
Mayamaea atomus var. *permitis* (Hustedt) Lange-Bertalot *Navicula atomus* var. *permitis* (Hustedt) Lange-Bertalot ***Navicula muralis* Grun.**
***Melosira varians* Agardh**
***Navicula bryophila* Boye Petersen**
Navicula capitatoradiata Germain ***Navicula cryptocephala* var. *intermedia* Grun.**
***Navicula cincta* (Ehr.) Ralfs *in* Pritchard**
***Navicula cryptocephala* Kütz.**
Navicula cryptotenella Lange-Bertalot ***Navicula radiosa* var. *tenella* (Bréb.) Cleve & Möll.**
***Navicula gregaria* Donkin**
Navicula kotschyi Grun. ***Navicula grimmei* Krasske**
Navicula lanceolata (Agardh) Ehr. ***Navicula viridula* var. *avenacea* (Brébison *in* Grun.) V.Heurk**
***Navicula menisculus* Schumann**
***Navicula menisculus* var. *upsaliensis* Grun.**
***Navicula minusculoides* Hustedt**
***Navicula muticoides* Hustedt**
***Navicula radiosa* Kütz.**
***Navicula rhynchocephala* Kütz.**
***Navicula rostellata* Kütz.**
***Navicula schroeteri* Meister**
***Navicula tenelloides* Hustedt**
***Navicula zanoni* Hustedt**
***Neidium affine* (Ehrenberg) Pfitzer**
***Nitzschia acicularis* (Kütz.) W.M.Smith**
Nitzschia acidoclinata Lange-Bertalot ***Nitzschia perminuta* (Grun.) M. Peragallo**
***Nitzschia amphibia* Grun.**
Nitzschia capitellata Hustedt *in* A.Schmidt *et al*. ***Nitzschia allanssoni* Cholnoky**
***Nitzschia clausii* Hantzsch**
***Nitzschia communis* Rabenhorst**
***Nitzschia debilis* (Arnott) Grun.**
***Nitzschia denticula* Grun.**
***Nitzschia desertorum* Hustedt**
***Nitzschia dissipata* (Kütz.) Grun.**
***Nitzschia elliptica* Hustedt**
***Nitzschia epiphytica* O.Müll. *sensu* Hustedt 1949**
***Nitzschia fonticola* Grun. *in* Cleve & Möll.**
Nitzschia frustulum (Kütz.) Grun. ***Nitzschia frustulum* var. *perpussila***
***Nitzschia intermedia* Hantzsch *in* Cleve**
***Nitzschia linearis* (Agardh) W.M.Smith**
***Nitzschia microcephala* Grun. *in* Cleve**
Nitzschia nana Grun. *in* V.Heurck ***Nitzschia ignorata* Krasske**
***Nitzschia palea* (Kütz.) W.Smith**
Nitzschia paleacea (Grun.) Grun. *in* V.Heurk ***Nitzschia bacata* Hustedt**
***Nitzschia parvuloides* Cholnoky**
Nitzschia pusilla (Kütz.)Grun. ***Nitzschia kuetzingiana* Hilse**
***Nitzschia sigma* (Kütz.) W.M.Smith**
***Nitzschia sinuata* var. *tabellaria* (Grun.) Grun.**
Nitzschia solgensis Cleve-Euler ***Nitzschia interurupta* (Reichelt) Hustedt**
***Nitzschia tropica* Hustedt**
Nitzschia umbonata (Ehr.) Lange-Bertalot ***Nitzschia thermalis* (Kütz.) Auerswald**
***Pinnularia eburnea* (Carlson) Zanon**
***Pinnularia gibba* Ehr.**
***Pinnularia gibba* var. sancta (Grun.) Meister**
***Pinnularia interrupta* W.M.Smith**
***Pinnularia viridis* (Nitzsch) Ehr.**
Placoneis dicephala (W.Smith) Mereschkowsky *Navicula dicephala* (Ehr.) W.Smith ***Navicula dicephala* var. *neglecta* (Krasske) Hustedt**
Planothidium lanceolatum (Bréb.) Round & Bukhitiyarova ***Achnanthes lanceolata* (Bréb.)Grun.**
***Rhopalodia gibba* (Ehr.) O.Müll.**
***Rhopalodia gibberula* (Ehr.) O.Müll.**
Sellaphora pupula (Kütz.) Mereschkowksky *Navicula pupula* Kütz. ***Navicula nyassensis* O.Müll.**
Sellaphora seminulum (Grun.) Mann ***Navicula seminulum* Grun.**
***Stauroneis anceps* Ehr.**
Staurosira construens var. *venter* (Ehr.) Hamilton ***Fragilaria constuens* f. *venter* (Ehr.) Hustedt**
Staurosirella pinnata (Ehr.) Williams & Round ***Fragilaria pinnata* Ehr.**
***Stephanodiscus hantzschii* Grun. *in* Cleve**
***Surirella angusta* Kütz.**
***Surirella ovalis* Bréb.**
***Surirella tenera* Gregory**
***Synedra ulna* (Nitzsch) Ehr.**
***Tabellaria fenestrata* (Lyngbye) Kütz.**
Tryblionella apiculata Gregory ***Nitzschia apiculata* (Gregory) Grun.**
Tryblionella hungarica (Grun.) Mann *in* Round, Crawford & Mann ***Nitzschia hungarica* Grun.**
Tryblionella levidensis W. Smith ***Nitzschia levidensis* (W.Smith) Grun. *in* V Heurk**
Tryblionella victoriae Grun. ***Nitzschia levidensis* var. *victoriae* Grun.**