Short communication

Diatoms as indicators of historical water quality: A comparison of samples taken in the Wemmershoek catchment (Western Province, South Africa) in 1960 and 2008

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ABSTRACT

Historical diatom records provide a means of retrospectively determining water quality and inferring ecological condition in rivers and streams. In this study we re-sampled sites originally sampled 48 years previously. We then determined the scores for the Biological Diatom Index (BDI) and the South African Diatom Index (SADI) for each dataset. The results revealed that the present day conditions in this relatively undisturbed locality were almost identical to those reflected by the samples collected half a century before. This illustrates the value of historical diatom data for the purposes of determining antecedent water quality.

Keywords: diatoms, water quality, South Africa, Biological Diatom Index, South African Diatom Index

INTRODUCTION

Diatoms serve as powerful bio-indicators for aquatic environments, determined either from historical or contemporary samples (e.g. Telford et al., 2002). The routine use of diatoms is well established in many countries (e.g. Kelly et al., 1998), but is an approach new to South Africa. Diatoms are now being used with increasing regularity in South Africa, as indicators of water quality (e.g. Harding et. al., 2005; Taylor et. al. 2007a), and applied within the scope of the River Health Programme (RHP, 2005). Diatom records contained in curated collections provide the basis for a robust interpretation of past conditions that, in the majority of cases, is not possible by other means (Harding et al., 2005; Taylor et al., 2005; Yallop et al., 2009; Kelly et al., 2012). South Africa benefits from a substantial diatom collection spanning the period from the late-1950s to the present (Taylor et al., 2011). The bulk of the early samples span the post-WWII period from the 1950s to the 1970s, i.e., prior to and through a period of substantial economic development in South Africa and the accompanying anthropogenic impact. As such, the South African National Diatom Collection (SANDC) provides an unequalled resource of historical 'reference condition' material spanning much of South Africa, as well as Namibia and other locations in southern Africa (Harding et al., 2004; Harding and Taylor, 2011).

The SANDC contains a vast amount of material besides the usual collection materials (slides, samples, etc.). The South African diatomologist Bela Cholnoky and his students, Archibald and Schoeman, determined and enumerated almost every slide examined and both the published and unpublished analysis sheets may be found in the SANDC. Modern biomonitoring standards, to which present-day South African analysts adhere, dictate that at least 400 valves be enumerated from each sample (Taylor et al., 2005). The majority of the analysis sheets from as early as 1950 contain community composition counts of approximately 400 valves. This makes these sheets eminently suitable for calculating diatom index valves based on these historical analyses.

In 1957 the City of Cape Town (Western Cape Province, South Africa) commissioned the Wemmershoek Dam, located near the town of Paarl. Subsequent to the dam being flooded for the first time, the appearance in 1960 of some perceived water quality problems in the form of dense populations of chironomids, caused the local authority to commission a diatom-based assessment of the condition of the feeder rivers and streams (Cholnoky and Claus, 1961). This was probably the first application of diatoms for water quality monitoring in South Africa.

This paper examines the findings of a comparison of the diatom samples collected and analysed by Cholnoky from localities within the Wemmershoek Dam catchment area, with samples collected from the same sites and analysed by these authors 48 years later.

STUDY AREA

Wemmershoek Dam (33.833 S, 19.083 E) is located in a mountainous valley and fed by 4 seasonal rivers and several small streams. The catchment watercourses combine to form the Wemmershoek River (see Figs 1 and 2). The climate is Mediterranean with rainfall during the winter. Since the commissioning of the dam, land use in the catchment has been limited to silviculture (*Pinus pinaster* Aiton) on the northern shoreline and in the Olifants River valley to the east of the dam. Some derelict farm buildings and ruins from the former

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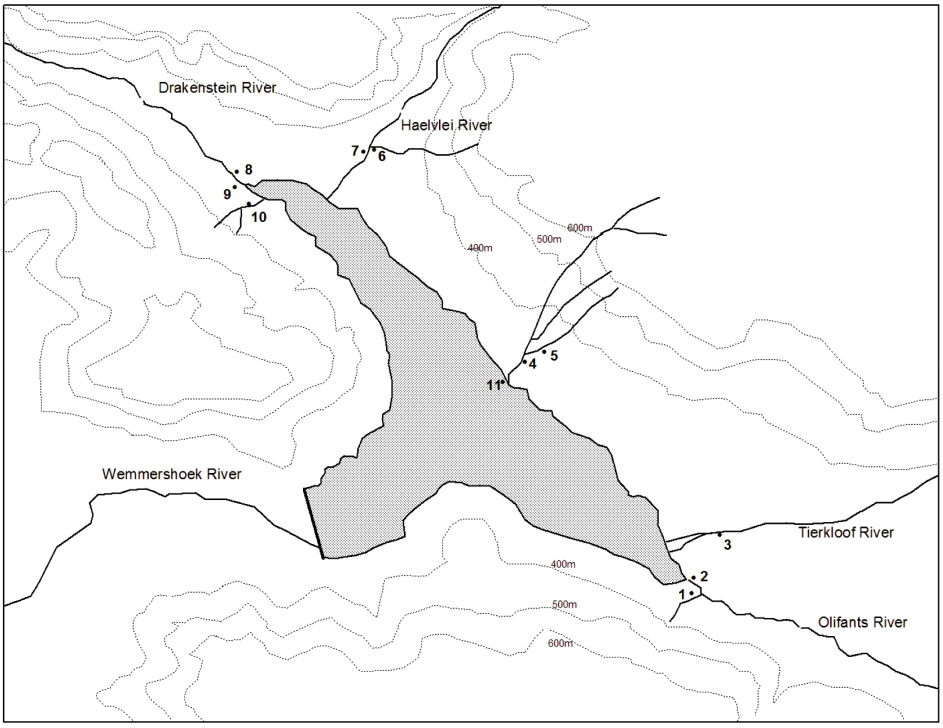

Figure 1
Map of Wemmershoek Dam showing the watercourses relevant to this study. Local topography is shown as the 400–600 m contours. North is above and the length of the dam wall (southwest) is 580 m. The sample sites as used in the 1960 assessment are shown numbered from 1–11.

Figure 2
View northwest of the Olifants River entering Wemmershoek Dam. The inflow of the Drakenstein River lies directly opposite (see Fig. 1)

Winterhoek farm are scattered to the north and east of the dam. The natural water quality of this region is typified by acidic conditions, with humic-stained waters draining from fynbos-dominated mountain catchments (Allanson et al. 1990). In summary, the catchment has remained essentially unaltered since the dam was constructed.

TABLE 1
Details of sample locations used in the 1960 and 2008 Wemmershoek Dam diatom assessments

Site Number*	Site description
1	Small tributary stream to Olifants River (dry in December 2008)
2	Olifants River mainstem
3	Tierkloof River mainstem
4	'Farm Stream'
5	Small tributary of the Farm Stream (dry in December 2008)
6	Small tributary of unnamed river (dry in December 2008)
7	Haelvlei River mainstem
8	Drakenstein River mainstem
9	Large spring emerging from the cliff-face
10	Small spring higher on the cliff-face (dry in December 2008)
11	Littoral zone in the dam adjacent to the mouth of the Farm Stream

**as per Cholnoky and Claus, 1961*

METHODS

The original set of samples was collected from 11 sites on 25 October 1960 (Cholnoky and Claus, 1961). The samples for this comparative assessment were collected on 2 December 2008. Some of the smaller watercourses were dry and sample collections were only possible from 7 sites, as detailed in Table 1 and shown in Fig. 1.

The samples were collected, preserved, processed and analysed as described in Taylor et al. (2007b). At all sites the samples were brushed off cobbles as per the described methods. The original diatom analysis sheets were sourced from the South African National Diatom Collection and taxonomically updated to reflect contemporary nomenclature. Thereafter both sets of data were analysed using the OMNIDIA v. 5.3 software package (Lecointe et al., 1993) to generate values for the Biological Diatom Index (BDI) and for the recently developed South African Diatom Index (SADI), based on the French Specific Pollution sensitivity index or SPI (Harding and Taylor, 2011).

Collection of physico-chemical field data was limited to the in situ measurement of electrical conductivity (EC, milli-Siemens per meter), using a Hach SensIon EC meter.

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RESULTS AND DISCUSSION

Seven samples were collected in 2008 from the sites as shown in Table 1. Measurements of electrical conductivity were typical of mountain stream water in the region and ranged from 1.2–3.7 $mS \cdot m^{-1}$.

Diatom assemblages

The diatom assemblages and count data are presented for the original and contemporary samples in, respectively, Tables 2 and 3. Table 2 reflects the nomenclature used by Cholnoky and Claus, as well as the contemporary nomenclature.

Diatom communities from both surveys were dominated by those taxa that typically indicate acidic, oligotrophic waters with a low mineral content (as reflected by the low EC values). Both sets of analysis showed communities dominated by the acidophilic diatom genus *Eunotia* Ehrenberg. Interestingly, there seems to have been some grounds for the concerns of the Cape Town City council as Cholnoky's analysis shows that at Site 5 there is a slight (but not dramatic) increase in the taxa indicative of water quality impacts (e.g., the genus *Nitzschia* Hassall, especially *Nitzschia palea* (Kützing) W.Smith). Cholnoky, as an early pioneer of water quality monitoring using diatoms, used an early metric of impact that he dubbed his measure of 'heterotrophic diatoms'. This measure was a simple percentage calculation that included the taxa that he, in previous studies, had observed to be flourishing in nutrient/organic material enriched conditions (e.g. *Sellaphora (Navicula) seminulum* (Grunow) D.G. Mann, *Nitzschia palea* and other *Nitzschia* taxa. This metric proved remarkably useful for classifying impact in streams (see discussion in Taylor et al., 2005) and matches well with modern metrics such at the % Pollution Tolerant Valves (usually used in association with the Trophic Diatom Index, TDI) (Kelly and Whitton, 1995). See Table 1.

Comparison of index values

The comparison of the BDI and SADI index values for the 1960 and 2008 samples is provided in Table 4. While the dataset is too small for statistical comparison, simple observation reveals that the values are essentially identical, despite the intervening period of 48 years. This, combined with the similarity in species assemblage, indicates that the contemporary stream conditions and those assessed 48 years previously are virtually unchanged.

CONCLUSION

The results clearly demonstrate the value of historically-curated diatom samples for the purposes of determining historical conditions. Similarly, these can be compared with contemporary values to inform the level of ecosystem change and, where relevant, utilise ecological information gleaned from the diatom assemblage to infer the possible cause thereof. As with other work, such as that for the Jukskei River catchment (Gauteng Province, South Africa), this assessment illustrates the value of the historical diatom data, as well as the use of diatoms for determining the ecological status of rivers and streams (Taylor et al., 2005).

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TABLE 2
Relative abundance of diatom species per 100 valves in the 1960 Wemmershoek samples

Taxon		Site									
Name as cited by Cholnoky & Claus 1961	**Synonym/recent nomencatural change**	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**	**Site 7**	**Site 8**	**Site 9**	**Site 11**
Achnanthes desperata Cholnoky				0.3			1.4	4.1			
Achnanthes kenyae Cholnoky		0	5.5	0.9	0	0.9	0		2.6	0	0.3
Achnanthes microcephala (Kützing) Grunow	*Achnanthidium macrocephalum* (Hustedt) Round & Bukhtiyarova	0	0.6	0	0.3	1.1	0	0.8	0		0.6
Anomoeoneis brachysira (Brèbisson) Cleve	*Brachysira brebissonii* Ross	10.5	0		0.9	0	0		0.6	0	
Anomoeoneis exilis (Kützing) Cleve	*Brachysira neoexilis* Lange-Bertalot	0.6	0.9	0	0	0	0		0.3	0.3	1.7
Caloneis chasei Cholnoky	*Caloneis hyalina* Hustedt	0	0	0		2.3	0	0	0	0	
Cymbella classeniae Cholnoky		0	0		1,5	0	0		0.6	11.6	1.4
Cymbella perpusilla A.Cleve		0.0	0.0		1.5	0.0	0.0	0.0	0.0	0.0	
Cymbella raytonensis Cholnoky		0.0	0.0	0.0	0.0	0.0	0.0	0.0		1.4	0.0
Eunotia exigua (Brèbisson) Rabenhorst		25.4	62.2	0.3	57.3	28.8	63.9	19.5	40.9	66.1	16.4
Eunotia flexuosa (Brèbisson) Kützing		0.6	0.0	0.0	0.0		0.9	0.5	2.0	0.0	10.3
Eunotia pectinalis (Kützing) Rabenhorst + var. *minor* (Kützing) Rabenhorst		0.6	1.2	0.6	2.1	1,1	0.0	0.0	0.0		0.3
Eunotia pseudoveneris Hustedt		20.7	6.7	5.2	1.8	2.3	2.8	13.4	10.6	0.9	0.3
Eunotia rhomboidea Hustedt		9.2	4.3	81.6	19.0	0.0	5.4	22.5	16.6	0.0	19.2

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TABLE 2 (continued)
Relative abundance of diatom species per 100 valves in the 1960 Wemmershoek samples

Eunotia subaequalis Hustedt		0.0	0.0	0.0		1.4	0.0	0.0	0.0	0.0	
Fragilaria fonticola Hustedt	*Tabularia tabulata* (C.A.Agardh) Snoeijs	0.0	0.0	0.0		1.4	0.0	0.0	0.0	0.0	
*Fragilaria intermedi*a Grunow	*Fragilaria vaucheriae* (Kützing) Petersen	0.0	0.0	0.0		4.0	0.0	0.0	0.0	0.0	
Frustulia magaliesmontana Cholnoky		4.1	1.4	0.0	0.3	0.0	4.2	0.0	1.4	0.0	7.2
Frustulia rhomboides (Ehrenberg) De Toni + var. *saxonica* (Rabenhorst) De Toni		10.8	2.3	0.0	1.8	2.6	0.9	4.7	0.3	0.0	1.1
Gomphonema parvulum (Kützing) Kützing		0.0	2.3	0.0	0.6	6.6	0.0		0.3	0.0	0.3
Navicula abbotti Cholnoky		0.0		2.1	0.0		0.3	1,6	0.0	0.0	
Navicula arvensis Hustedt		0.0	0.0	0.0		2.9	0.0	0.0	0.0	0.0	
Navicula bryophila Boye Petersen	*Adlafia bryophila* (Petersen) Moser, Lange-Bertalot & Metzeltin	0.0	0.0	0.0	0.0		6.2	6.0	16.3	5.4	0.0
Navicula disjuncta Hustedt	*Sellaphora disjuncta* (Hustedt) D.G. Mann	0.0	0.0	0.0	0.0	0.0		1.1	0.0	0.0	
Navicula longicephala Hustedt		0.0	0.0	0.0		2.0	0.0	0.0	0.0	0.0	
Navicula mediocris Krasske	*Chamaepinnularia mediocris* (Krasske) Lange-Bertalot	0.0	0.0	0.0	0.0		0.3	12.1	0.0	0.0	
Navicula scottiae Cholnoky		0.0	0.0	0.0	0.0	0.0		3.0	0.0	0.0	
Navicula subtilissima Cleve	*Kobayasiella subtilissima* (Cleve) Lange-Bertalot	7.0	0.0	0.6	0.6	0.3	1.4	4.4	3.4	2.0	0.0
Neidium affine var. *amphirrhynchus* (Ehrenberg) Cleve		0.0	0.0	0.0	0.0		1.0	0.0	0.0	0.0	
Nitzschia gracilis Hantzsch		0.0	0.0	0.0		14.2	0.0	0.3	0.0		2.5
Nitzschia kuetzingiana Hilse	*Nitzschia pusilla* (Kützing) Grunow	0.0	0.0	0.0		1.7	0.0	0.0	0.0	0.0	
Nitzschia palea (Kützing) W.Smith		0.0	0.0	0.0		5.1	0.0	0.0	0.0	0.0	
Nitzschia tropica Hustedt		0.0	0.0		3.3	0.9	0.0	0.0	0.0		3.3
Pinnularia acoricola Hustedt		0.3	0.0		1.5	0.0		0.5	0.0	0.0	
Pinnularia minuta (Østrup) Cleve-Euler		0.0	0.0	0.0		0.9	0.0	0.3	0.0	1.1	0.0
Pinnularia subcapitata Gregory		0.0		0.3	2.4	5.4	0.0	0.5	0.0		2.5
Stauroneis abottii Cholnoky		5.1	0.0	3.0	0.0	0.0	0.0	0.0		9.7	0.0
Stauroneis anceps f. *linearis* (Ehrenberg) Grunow		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		1.4
Surirella delicatissima var. *africana* Cholnoky		0.0	2.9	0.0	0.3	3.4	7.9	0.3	0.0	0.9	0.8
Surirella tenera Gregory		0.0	0.0	0.0		5.1	0.0	0.0	0.0	0.0	
Synedra rumpens Kützing	*Fragilaria rumpens* (Kützing) Carlson	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Tabellaria flocculosa (Roth) Kützing		1.0	6.7	3.6	0.0	1.7	0.9	2.2	0.0		28.4
Unkown taxon		4.1	1.8	1.5	6.3	5.0	2.5	3.8	4.1	0.6	2.0

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TABLE 3
Relative abundance of diatom species per 100 valves in the 2008 Wemmershoek samples

Taxon	Site						
	Site 2	Site 3	Site 4	Site 7	Site 8	Site 10	Site 11
Achnanthidium macrocephalum (Hustedt) Round & Bukhtiyarova	0.0	0.0	0.0	0.0	0.0		0.5
Achnanthidium minutissimum (Kützing) Czarnecki	0.0		8.8	0.0	0.0	0.0	
Achnanthidium sp.	3.5	0.8	0.0	0.3	0.3	7.3	0.3
Amphora sp.	0.3	0.3	0.0		0.8	0.0	
Brachysira brebissonii Ross	0.0	0.0	0.0		0.8	0.0	4.0
Brachysira neoexilis Lange-Bertalot	0.0	0.3	0.0	0.0	0.0		0.8
Chamaepinnularia mediocris (Krasske) Lange-Bertalot	0.5	0.0	0.5	0.0	0.0	0.0	
Craticula submolesta (Hustedt) Lange-Bertalot	0.0	0.0	0.0	0.0	0.0	0.0	
Cyclotella ocellata Pantocsek	0.0	0.0	0.0		0.3	0.0	
Cymbella raytonensis Cholnoky	0.0	0.0	0.0	0.0		1.0	0.0
Diploneis smithii (Brébisson) Cleve	0.0		0.3	0.0	0.0	0.0	
Encyonema krasskei (Krammer) Krammer	0.0	0.0	0.0	0.0	0.0		0.3
Eunotia bilunaris (Ehrenberg) Mills	0.0	2.5	0.0		0.8	1.0	0.8
Eunotia exigua (Brébisson) Rabenhorst	44.8	40.0	3.3	3.3	12.3	2.3	58.3
Eunotia flexuosa (Brébisson) Kützing	0.3	0.3	0.0	0.3	4.5	0.0	18.3
Eunotia implicata Nörpel, Lange-Bertalot & Alles	0.0	1.3	0.0	0.0	0.0	0.0	
Eunotia incisa Gregory	2.8	19.5	0.0	13.5	31.8	0.0	
Eunotia minor (Kützing) Grunow	0.0	0.3	0.0	0.0	0.0	0.0	
Eunotia naegeli Migula	0.0	0.0	0.0		0.3	0.0	0.3
Eunotia pectinalis (Dyllwyn) Rabenhorst	0.0	4.0	0.0	0.0	0.0		1.0
Eunotia pectinalis var. *undulata* (Ralfs) Rabenhorst	0.0	0.0	0.0	0.0	0.0	0.0	
Eunotia rhomboidea Hustedt	4.3	14.0	0.0	6.5	18.3	1.3	10.8
Eunotia sp. 1	24.5	9.3	8.3	61.3	25.8	0.0	0.5
Eunotia sp. 2	0.0	0.0	0.0	0.0		24.8	0.0
Eunotia sp. 3	0.0	0.0	0.0	0.0		1.3	0.0
Eunotia sp. 4	0.0	0.0	0.0	0.0	0.0	0.0	
Eunotia sp. 5	0.0	0.0	0.0	0.0		0.3	0.0
Eunotia sp. 6	0.0	0.0		0.3	0.0	0.0	
Eunotia tenella (Grunow) Hustedt	0.0	0.0	0.0	0.0		23.3	0.0
Fragilaria gracilis Østrup	0.5	0.0	0.0	0.0	0.0	0.0	
Fragilaria rumpens (Kützing) Carlson	0.0	0.3	0.5	0.0	0.0	0.0	
Frustulia cf. *magaliesmontana* Cholnoky	5.3	2.0	0.0		2.8	0.0	
Frustulia crassinervia (Brébisson) Lange-Bertalot & Krammer	0.0	0.5	0.3	0.0		0.5	0.0
Frustulia magna Metzeltin & Lange-Bertalot	0.0	0.0	0.0	0.0	0.0		0.3
Frustulia sp.	0.0	0.3	0.3	0.0		1.0	0.0
Gomphonema auritum A.Braun ex Kützing	0.0	0.0	0.0	0.0	0.0	0.0	
Gomphonema parvulum (Kützing) Kützing	0.0		0.8	0.0	0.0	0.0	
Gomphonema parvulum var. *exilissimum* Grunow	0.0	0.0	0.0	0.0	0.0	0.0	
Gomphonema sp.	0.0		1.8	0.0	0.5	0.0	
Kobayasiella sp.	0.0	0.0		2.0	1.0	0.0	
Kobayasiella subtilissima (Cleve) Lange-Bertalot	0.3	0.0	0.0	0.0		2.0	0.3
Luticola mutica (Kützing) D.G. Mann	0.0		0.3	0.0	0.0	0.0	
Mayamaea fossalis (Krasske) Lange-Bertalot	0.0	0.0		0.3	0.0	0.0	
Meridion circulare (Greville) C.A.Agardh	0.0	0.3	0.0	0.0	0.0	0.0	
Microcostatus sp.	0.0	0.0		0.3	0.0	0.3	0.0
Navicula angusta Grunow	0.5	0.0	0.0	0.0	0.0	0.0	
Navicula lepidula Grunow	0.0	0.0	0.0	0.0	0.0		0.3
Navicula notha Wallace	0.0	0.0	0.0	0.0	0.0		0.3
Navicula sp.	0.8	0.0	0.0	0.0	0.0	0.0	
Navicula tenelloides Hustedt	0.0	0.0	0.0	0.0	0.0	0.0	
Navicula veneta Kützing	0.0	0.0	0.0	0.0		0.3	0.0
Nitzschia acidoclinata Lange-Bertalot	0.0	0.0	0.0	0.0		0.3	0.0

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TABLE 3 (continued) Relative abundance of diatom species per 100 valves in the 2008 Wemmershoek samples							
Nitzschia hantzschiana Rabenhorst	0.0		0.3	0.0	0.0	0.0	
Nitzschia sp.	0.0	0.5	0.0		0.3	0.0	
Nupela sp.	0.0	0.0		11.8	0.0	0.0	
Pinnularia divergens W.M.Smith	0.0	0.0	0.0	0.0	0.0	0.0	
Pinnularia sp.	0.3	0.5	0.0	0.5	0.0	1.3	0.0
Placoneis sp.	0.0	0.0	0.0	0.0		0.3	0.0
Psammothidium abundans (Manguin) Bukht. & Round	0.0		18.3	0.0	0.0	0.0	
Psammothidium chlidanos (Hohn & Hellerman) Lange-Bertalot	11.3	2.0	0.0	0.0	0.0	0.0	
Psammothidium oblongellum (Østrup) Van de Vijver	0.3	0.0	55.8	0.0	0.0	0.0	
Sellaphora seminulum (Grunow) D.G. Mann	0.0		0.8	0.0	0.0	0.0	
Stauroneis kriegeri Patrick	0.0		0.3	0.0	0.0	0.0	
Stenopterobia delicatissima (Lewis) Brébisson	0.0	1.3	0.0	0.0		32.0	2.5
Tabellaria flocculosa (Roth) Kützing	0.3	0.3	0.0	0.0	0.0		1.0

TABLE 4
Comparison of the BDI and SADI values for the 1960 and 2008 Wemmershoek samples

	1960			2008		
	%PTV	BDI	SADI	%PTV	BDI	SADI
Site 1	0	20	19.5	Not sampled		
Site 2	2	20	19.6	0	20	19.4
Site 3	0	20	15.6	0	20	19
Site 4	4	20	18.7	1.8	18.9	17.7
Site 5	30.3	17.2	14.7	Not sampled		
Site 6	0	20	19.7	Not sampled		
Site 7	12.4	20	17.9	0	20	19
Site 8	0	20	19.1	0	20	18.5
Site 9	0	20	19.8	0.3	20	19.8
Site 11	6.1	20	18.4	0	20	19.5

PTV = Pollution Tolerant Valves; BDI = Biological Diatom Index; SADI = South African Diatom Index. Max Index Value = 20

Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and therefore the NRF does not accept any liability in regard thereto.

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