ENVIRONMENTAL WATER QUALITY MONITORING FOR RICHARDS BAY MINERALS: SMELTER SITE AREA

Report for 2008

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Executive summary

This document reports on a programme monitoring environmental water quality of surface waters in the vicinity of the Smelter site of Richards Bay Minerals. Data reported on were collected during spring, summer, autumn and winter.of 2008 (summer data for diatoms is from 2007). Indices indicating ecological health or suitability were calculated for each site/season combination based on water quality, habitat quality, macro-invertebrate community structure and diatom community structure.

Indices for each site are presented in Table 1. A provisional overall ecological health assessment for each of the sites assessed is included. (Note: there is no health index for the habitat score [IHAS] as it was designed to interpret the South African Scoring System (SASS) results and it is included here for that reason). It must be noted that the methods used to provide the subsequent categories are largely based on expert opinion and assessment of the available data. In addition, the boundary values for the categories are based on the default values provided by the ecological Reserve method and require site-specific refinement.

Table I A summary of main index score results to provide an overall assessment for each of the sites.

Site	ASPT	IHAS	Water Quality	Diatoms	Overall ecological health assessment
1	5.4 Fair	53	Good	5.0 Clean	Good
7	5.7 Fair	62	Good	1.8 Fair/Stressed	Fair
10	4.5 Poor	48	Fair	3.8 Clean/Fair	Fair/Poor
11	4.9 Poor	48	Good	3.8 Clean/Fair	Fair
12	5.8 Fair	53	Good	4.8 Clean	Good
13	6.3 Good	53	Good/Fair	4.3 Clean/Fair	Good/Fair
14	5.8 Fair	53	Good	3.3 Fair	Fair/Good

Overall, the scores indicate that the rivers assessed were in good condition at the top of their reaches, and that water quality degrades as one moves downstream. For the most part, degradation in condition seems to be associated with the presence of human habitations.

Macro-invertebrate ASPT scores are lower in 2008 compared to their 2007 values. This may a function of a reduction in habitat availability consequent on lowered water levels in 2008. An apparent consequence of this is that the ASPT score for Site 1, the uppermost site on the Mpisini and designated a reference site, is unusually low for a reference site. However, water quality measures and a healthy diatom community suggests the site is in a good condition. Site 12, the uppermost site on the Mdibi river is in good condition and can probably be used as a reference site on that river.

The results from the diatom community assessment score indicate a clear degradation of water quality between sites 1 and 7 on the Mpisini River. This is not reflected in the scores based on macro-invertebrates or the physicochemical parameters that were used in this assessment. The smelter complex is situated immediately upstream of Site 7, and as there appears to be limited impact from human settlements, it is possible that this water quality impairment may be related to the vicinity of the smelter.

Further monitoring including a broader range of physiochemical parameters will be necessary in order to clearly identify the cause of this decrease in water quality at this point.

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1 Introduction

The Unilever Centre for Environmental Water Quality, based within the Institute for Water Research at Rhodes University, was appointed by Richards Bay Minerals (RBM) to undertake environmental water quality monitoring of the surface waters in the vicinity of the RBM Smelter Site during 2008.

Richards Bay Minerals is situated in northern KwaZulu-Natal, producing titania slag, pig iron, rutile and zircon through processes of dune mining, mineral separation, smelting and beneficiation. The RBM Smelter Site is adjacent to the KwaBonambi State Forest and is situated within a larger afforested area. The area around the smelter site and the Tisand Mineral Lease area is drained by several small streams which flow into the Mdibi River and ultimately into Lake Mzingazi (Figure 1).

There is concern that the RBM activities at the smelter site may be compromising the ecological health of the rivers near the smelter site. Contaminants from the RBM Smelter premises can reach the rivers either directly, via surface water run-off to the rivers (e.g. from pollution incidents, via effluent pipes or rainfall run-off), or indirectly, via the groundwater contamination. The natural drainage from the RBM Smelter Site is towards the Mpisini and Manzamnyana Rivers, which drain into the Mdibi River, which subsequently flows into Lake Mzingazi.

The specific tasks for 2008 were to:
1. Undertake aquatic macro-invertebrate biomonitoring at the identified sites in Smelter Site area over four sampling seasons. Water quality data (dissolved oxygen, pH, electrical conductivity and temperature) were collected as part of this exercise.
2. Undertake diatom biomonitoring at the identified sites over four sampling seasons.
3. Undertake additional water quality sampling, namely nutrient analysis (specifically, Total Inorganic Nitrogen (TIN) and Soluble Reactive Phosphorus (SRP)) and chlorophyll-*a* analysis at the identified biomonitoring sites over four sampling seasons.

2 Methods and materials

2.1 Sampling sites

Biomonitoring and water quality sampling was undertaken at seven sites: 1, 7, 10, 11, 12, 13, 14 (Figure 1). The biotopes sampled at each site are depicted in the Individual Site Summaries section, along with a description of each site (Tables 1-7). Fieldtrips took place during Autumn (March), Winter (June), Spring (September) and Summer (December).

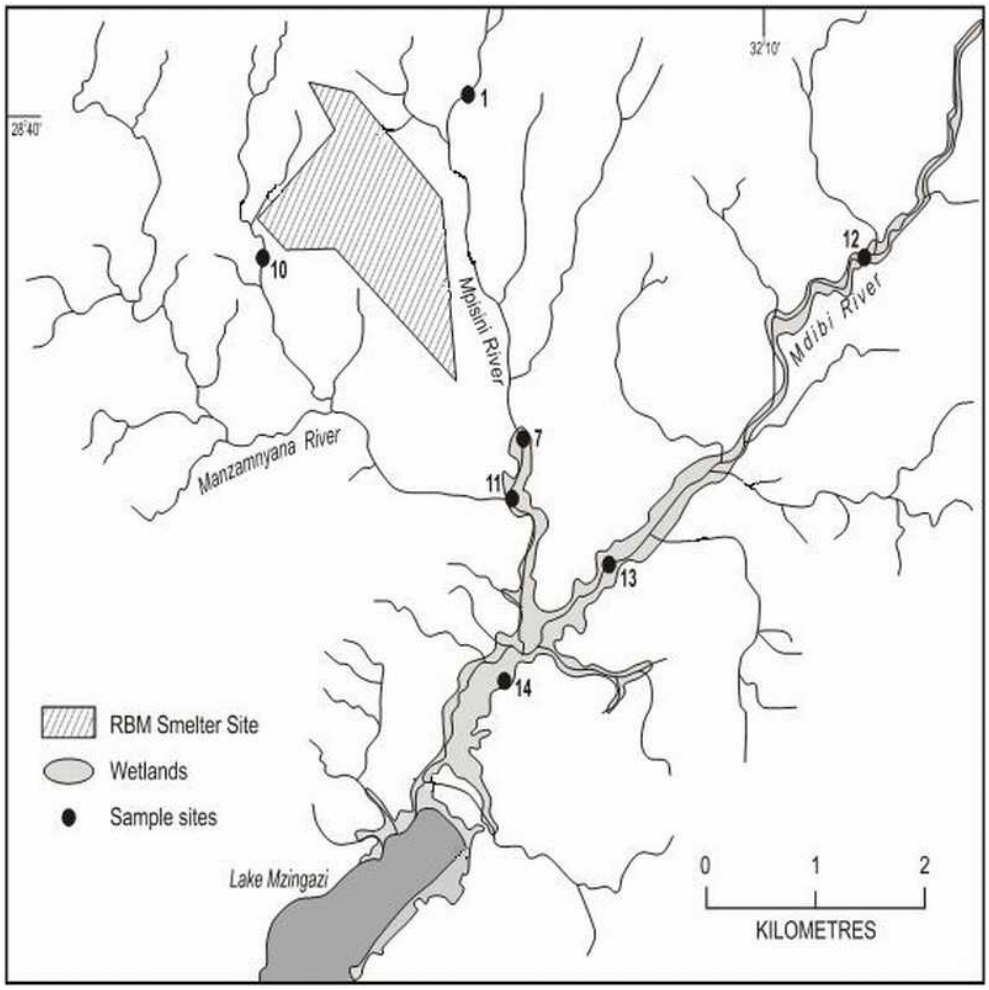

Figure 1 Monitoring points sampled in the Smelter Site area.

2.2 Water quality assessment

Water samples were collected at each of the biomonitoring sites and kept at 4℃ for analysis at the Institute for Water Research, Rhodes University, Grahamstown. The following parameters were measured: NO_2-N, NO_3-N, NH_4-N and PO_4 (SRP). The nitrogen data were combined to obtain Total Inorganic Nitrogen (TIN) concentrations. Assessing only dissolved nutrient status (TIN and SRP) can lead to an incorrect conclusion regarding the nutrient enrichment of the water body. Dissolved nutrients are directly available for uptake by plants, consequently during active plant growth periods the concentrations of these nutrients will be a poor indicator of nutrient enrichment. The measurement of algal biomass (periphyton and phytoplankton) using chlorophyll *a* concentration provides additional information when assessing the level of nutrient enrichment as algae causes most of the problems associated with

nutrient enrichment (Palmer et al., 2004). Periphyton and phytoplankton samples were collected following methods described by Holm-Hansen and Riemann (1978) and analysed for chlorophyll-*a* concentrations, as an additional indication of nutrient status of the surface waters.

In addition to the parameters described above, on-site measures of dissolved oxygen, electrical conductivity, temperature and pH (using appropriate hand-held meters) were recorded during the biomonitoring exercise.

Data were interpreted using the default benchmark boundary values for ecological health as provided for in the ecological Reserve methodology for water quality assessments (Palmer et al. 2004).

2.3 Biomontoring

2.3.1 Habitat assessment

A habitat assessment was undertaken at each site, using the Integrated Habitat Assessment System (IHAS; McMillan, 1998). Although IHAS was initially developed for use with SASS4 (i.e. to adjust the SASS4 score), it provides a useful assessment of the habitat available at a site as the diversity of macro-invertebrates can be influenced by the availability of biotopes and physical characteristics of the river, and surrounding land-use impacts. In this case, IHAS was used to assess and aid interpretation of the final SASS and ASPT results.

2.3.2 Macro-invertebrate sampling

At each of the sites, South African Scoring System Version 5 (SASS5) samples were taken from available biotopes and scored accordingly (Dickens and Graham, 2002). Once the SASS evaluation was complete, the samples were preserved and a further two samples from each of the biotopes were collected and preserved. The standard SASS protocol (described in Dickens and Graham (2002) as well as the standard data sheet) was utilised to collect the SASS samples as well as the replicate samples. All samples were further enumerated at the UCEWQ-IWR laboratories, providing accurate counts for each of the taxa for data analysis (invertebrate diversity and richness assessment). The SASS scores and total number of families were used to obtain the Average Score per Taxon (ASPT) for each of the sites (Dickens and Graham, 2002). ASPT scores were classified according to default ecological Reserve categories for an estimation of ecological health (Palmer et al. 2004).

2.3.3 Diatom assessment

Diatom data reported on here are from samples collected from sample sites during Summer (December 2007), Autumn (March 2008), Winter (June 2008), and Spring (September 2008).

Diatom samples were collected from hard substrates (vegetation or rock) on site and fixed in 20% ethanol for transport. Samples were prepared for examination using the potassium permanganate and hot hydrochloric acid method recommended by Taylor *et al*. (2007a). Cleaned frustules were mounted in Pleurax on microscope slides and examined at 1000× magnification using bright field and phase contrast optics. Only whole frustules in valve view were used for identification. One hundred frustules per slide were identified.

Where possible, diatoms were identified to species level or below. Morphospecies were assigned where species identification was unclear and these were maintained throughout the analysis. Environmental preferences of common taxa as presented by Taylor et al. (2007b) were used to derive information on the ecological health of the

site. Water quality indices based on diatoms, such as the Specific Pollution sensitivity Index (SPI) have been successfully applied in South Africa (de la Rey et al., 2004). However, current indices, including the SPI, were not developed for South African conditions and are not always applicable when too many tropical taxa are found. They may also be misled when marine influences are pronounced. For both these reasons, this analysis will not calculate SPI. For the purpose of summarizing the results of this analysis, samples are scored according to the following classification.

- Clean: Samples where all or most taxa found are characteristic of unpolluted oligotrophic to mesotrophic water with low to moderate levels of electrolytes. Dominant taxa must be typical of these conditions. (Score 5)
- Fair: Dominant taxa not consistently indicative of clean conditions, and the sample has taxa typical of clean and stressed condition. (Score 3)
- Stressed: Most taxa present are tolerant of at least moderate levels of pollution, or typical of eutrophic or osmotically stressed conditions. (Score 1)

Sites are ranked according to scores assigned according to the above scheme. Where sites fall between classes, intermediate scores are assigned e.g. 4 represents a classification of Clean to Fair.

Only taxa that were well represented in each sample were used to infer water quality class, as these will best indicate the prevailing and recent water quality. For the purposes of this analysis, dominant taxa are the one taxon with the greatest abundance in the sample. Where other taxa have abundances not less than 10% less than the dominant taxon, they are classed as co-dominant. Other taxa that are less common than the dominant taxa and that make up 10% or more of the sample are classed as subdominant and are used to infer water quality. Taxa present in lower quantities are only used in this analysis where information from dominant and subdominant taxa is insufficient for site classification.

2.3.4 Statistical analysis

Statistical analyses of water quality parameters and biological indices were undertaken using STATISTICA software package and utilized the ANOVA test for normally distributed data and Kruskal-Wallis test for non-normal data. Significance is measured at $p<0.05$. Multivariate statistical analysis was undertaken using non-metric multi-dimensional scaling (NMDS). NMDS and analysis of similarity utilized the PRIMER V5 programme (Clark and Warwick 2001).

Analysis of variance and post-hoc testing of diatom scores was undertaken using R 2.8.0 with base and stats packages (R Development Core Team, 2008). Alpha diversities were calculated using the package vegan (Oksanen et al., 2008).

3 Results

Individual site summaries detailing: site information observed by the samplers; water quality parameters measured and; biological monitoring results are presented in Tables 1-7. Generally, the water levels observed at all sampling sites were lower on the four occasions sampled in 2008 than those observed in 2007.

3.1 Water quality assessment

Recorded water temperatures at sampling sites were not significantly different from one another (Figure 2A). Seasonal variation in water temperatures was recorded however.

Dissolved oxygen (DO) was significantly lower at Site 10 compared to other sites sampled, falling within a Poor ecological category (Figure 2B). The low DO measured at this site can possibly be attributed to the large proportion of ground water feeding the wetland lake immediately upstream and limited surface flow. DO varied seasonally at each site, being significantly higher during the cooler sampling seasons of winter and spring.

There were significant differences measured in pH at sampling sites, with the uppermost sites on each river being more acidic (Figure 2C). All sites, however, were classed either Natural or Good.

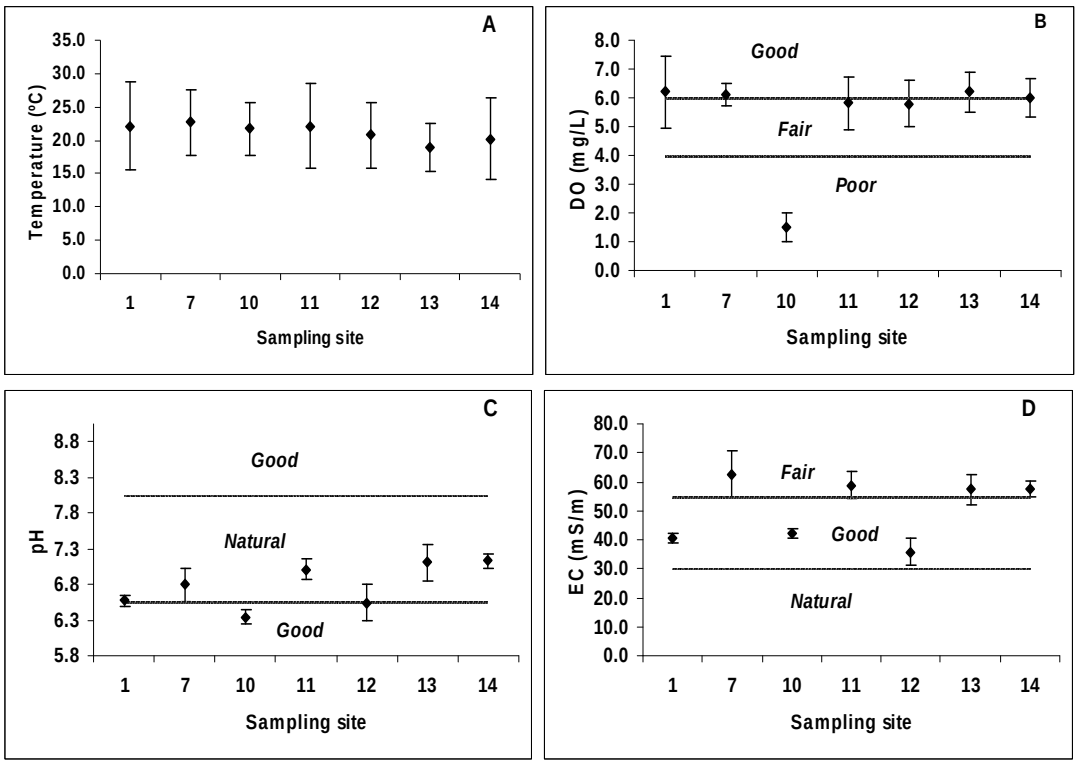

Figure 2A-D. Means (with standard deviations) of selected water quality parameters measured at sampling sites over four seasons. Default ecological categories based on ecological Reserve determination methodologies are superimposed on the graphs.
(DO: Dissolved oxygen; EC: electrical conductivity)

Electrical conductivity (EC) at uppermost sites on each river (Sites 1, 10 and 12) was significantly lower than sites further downstream (Figure 2D). Uppermost sites were classified as being in a Good category, with remaining sites in a Fair category. The high EC could be attributed to both human settlements and activities at the smelter site. It is difficult to generalize regarding the relative contributions of these two landuses to increased EC, however it does appear that the smelter site is contributing to the higher EC at Site 7 as no other cause for the increase could be identified.

Total inorganic nitrogen (TIN) was highest at the uppermost sites on the Manzamnyana (Site 10) and Mpisini (Site 1) rivers (Figure 3A). These sites were classed as Poor and Fair respectively. TIN levels were highly variable over different seasons, with concentrations in autumn being significantly lower (Figure 4A). Soluble reactive phosphorus (SRP) concentrations were classed as Good or Good/Fair at all sites (Figure 3B). There were large seasonal variations in SRP, with significantly higher concentrations in autumn compared to the other seasons and higher concentrations in winter compared to spring (Figure 4B). Phytoplankton chlorophyll-*a* concentrations at all sites were classed as Natural (Figure 3C), with no statistically significant seasonal variations, although concentrations were particularly high in autumn at Site 10 (Figure 4C). Periphyton chlorophyll-*a* concentrations were highest at Site 10 which was classed as Fair along with Sites 7, 13 and 14 (Figure 3D). Remaining sites were classed Good. Chlorophyll-*a* concentrations from periphyton were significantly higher in autumn compared to winter (Figure 4D).

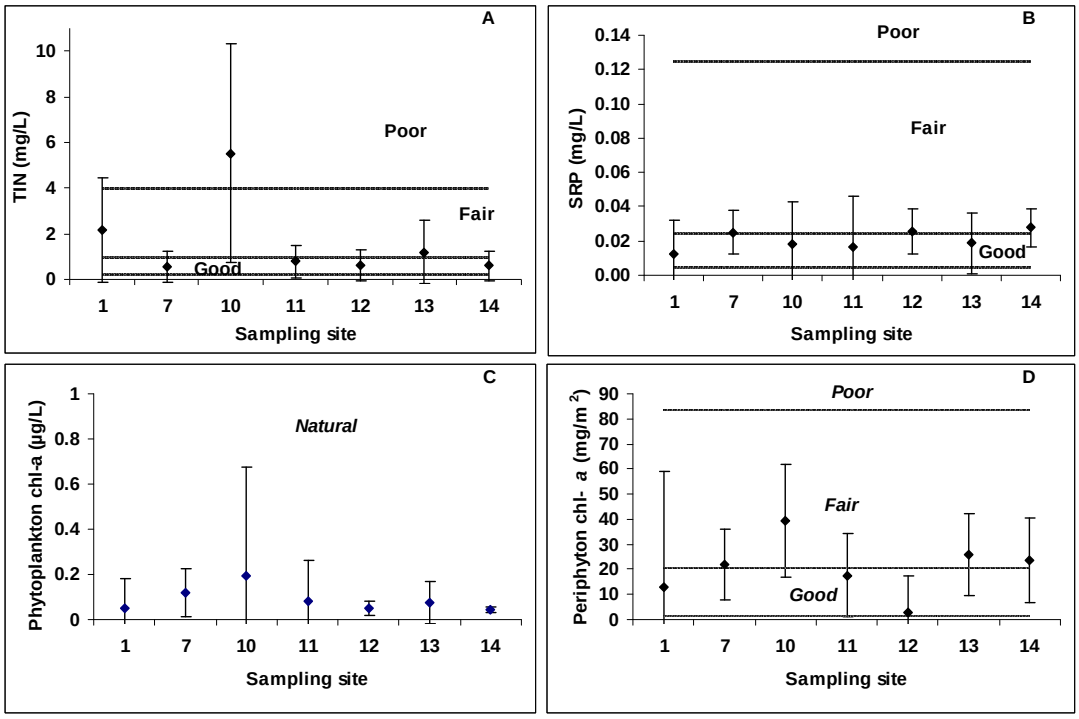

Figure 3 A-D. Median TIN, SRP, periphyton chlorophyll-*a* and mean phytoplankton chlorophyll-*a* (with standard deviations) measured at sampling sites over four seasons. Default ecological categories based on ecological Reserve determination methodologies are superimposed on the graphs.
(TIN: total inorganic nitrogen; SRP: soluble reactive phosphorus)

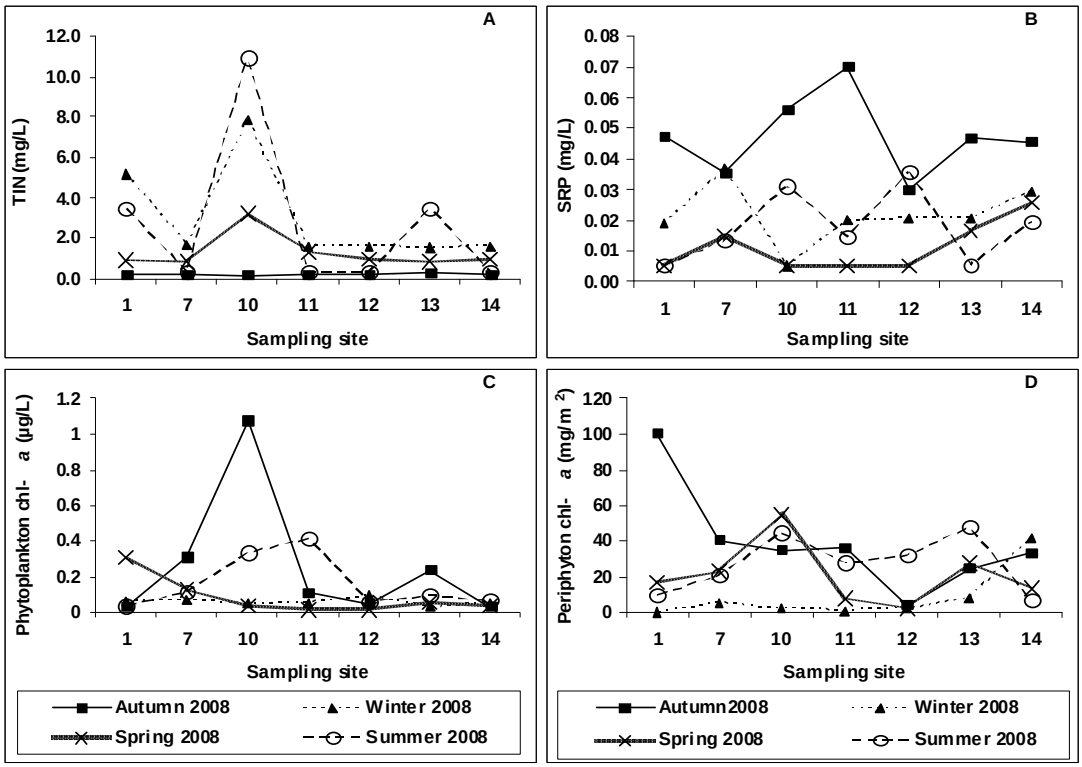

Figure 3 A-D. TIN, SRP, phytoplankton chlorophyll-*a* and periphyton chlorophyll-*a* measured at sampling sites over four seasons.
(TIN: total inorganic nitrogen; SRP: soluble reactive phosphorus)

Table 2. Summary of Site 1 on the Mpisini River

Site description: This site is upstream of the smelter site and chosen as a possible reference site. During 2008, low water levels have limited access to marginal vegetation, although aquatic vegetation is still available. GSM biotope is dominated by mud with limited sand available, usually covered with leaf litter. For the first time during the summer sample there was evidence of the site being used by cattle for drinking.

Water quality parameters: (DO: dissolved oxygen; EC: electrical conductivity; TIN: total inorganic nitrogen; SRP: soluble reactive phosphorous; Chlorophyll-*a* mg/m^3: phytoplankton chlorophyll-*a*; Chlorophyll-*a* mg/cm^2: periphyton chlorophyll-*a*) (water quality categories based on the ecological Reserve methodologies for water quality are provided below the values where relevant).

						Chlorophyll-*a*	
TºC	pH	DO (mg/L)	EC (mS/m)	TIN (mg/L)	SRP (mg/L)	Phytoplankton (µg/L)	Periphyton (mg/cm^2)
22.2	6.5 Natural	6.2 Good	40.8 Good	2.2 Fair	0.01 Good	0.05 Natural	12.9 Good

Biological and water quality indices: summary of the main index scores (ASPT: average score per taxon; IHAS: integrated habitat assessment system; diatoms; and water quality) (ecological health categories are largely based on those used for ecological Reserve determinations).

ASPT	IHAS	Diatoms	Water quality
5.4 Fair	53	5.0 Clean	Good

Overall ecological assessment: Good

Table 3. Summary of Site 7 on the Mpisini River

Site description: This site is immediately downstream of the Smelter Site. The surrounding land use is forestry (there is no impact from human settlements). Vegetation and GSM biotopes provide good sampling opportunities. This is the only site which contains gravel and limited stones (sampling of these areas is included in the GSM biotope). This is a cattle drinking site.

Water quality parameters: (DO: dissolved oxygen; EC: electrical conductivity; TIN: total inorganic nitrogen; SRP: soluble reactive phosphorous; Chlorophyll-*a* mg/m^3: phytoplankton chlorophyll-*a*; Chlorophyll-*a* mg/cm^2: periphyton chlorophyll-*a*) (water quality categories based on the ecological Reserve methodologies for water quality are provided below the values where relevant).

TºC	pH	DO (mg/L)	EC (mS/m)	TIN (mg/L)	SRP (mg/L)	Chlorophyll-*a* Phytoplankton (µg/L)	Chlorophyll-*a* Periphyton (mg/cm^2)
22.7	6.7 Natural	6.1 Good	62.6 Fair	0.6 Good	0.03 Good	0.12 Natural	21.9 Fair

Biological and water quality indices: summary of the main index scores (ASPT: average score per taxon; IHAS: integrated habitat assessment system; diatoms; and water quality) (ecological health categories are largely based on those used for ecological Reserve determinations).

ASPT	IHAS	Diatoms	Water quality
5.7 Fair	62	1.8 Fair/Stressed	Good

Overall ecological assessment: Fair

Table 4. Summary of Site 10 on the Manzamnyana River

Site description: This site consists of a deep wetland lake (picture left) which gradually becomes shallower (picture right) before flowing very slowly into a wetland. Surrounding land use is forestry with the Smelter Site in close proximity. There are no impacts from human settlements. Vegetation biotope is sampled in the wetland lake, consisting of marginal vegetation (reeds and grass) and aquatic vegetation. GSM biotope is sampled in the shallower part of the lake and consists of sand and anoxic mud. The GSM is regularly disturbed by cattle passing through and drinking.

Water quality parameters: (DO: dissolved oxygen; EC: electrical conductivity; TIN: total inorganic nitrogen; SRP: soluble reactive phosphorous; Chlorophyll-*a* mg/m^3: phytoplankton chlorophyll-*a*; Chlorophyll-*a* mg/cm^2: periphyton chlorophyll-*a*) (water quality categories based on the ecological Reserve methodologies for water quality are provided below the values where relevant).

T°C	pH	DO (mg/L)	EC (mS/m)	TIN (mg/L)	SRP (mg/L)	Chlorophyll-*a* Phytoplankton (µg/L)	Chlorophyll-*a* Periphyton (mg/cm^2)
21.8	6.3 Good	1.5 Poor	42.2 Good	5.5 Poor	0.02 Good	0.19 Natural	39.4 Fair

Biological and water quality indices: summary of the main index scores (ASPT: average score per taxon; IHAS: integrated habitat assessment system; diatoms; and water quality) (ecological health categories are largely based on those used for ecological Reserve determinations).

ASPT	IHAS	Diatoms	Water quality
4.5 Poor	48	3.8 Clean/Fair	Fair

Overall ecological assessment: Fair/Poor

Table 5. Summary of Site 11 at confluence of the Mpisini and Manzamnyana Rivers

Site description: The site is within a forest at the confluence of the Mpisini and Manzamnyana Rivers, downstream of the Smelter Site. Surrounding land use is forestry with no effects from human settlements. There is very limited vegetation biotope available for sampling, particularly during the lower flows of 2008. Vegetation sampled usually consists of marginal vegetation leaves that dip into the water, root wads and twig snarls. GSM biotope consists of sand and mud. The sand biotope has become limited with low flows and disturbance from cattle.

Water quality parameters: (DO: dissolved oxygen; EC: electrical conductivity; TIN: total inorganic nitrogen; SRP: soluble reactive phosphorous; Chlorophyll-*a* mg/m^3: phytoplankton chlorophyll-*a*; Chlorophyll-*a* mg/cm^2: periphyton chlorophyll-*a*) (water quality categories based on the ecological Reserve methodologies for water quality are provided below the values where relevant).

TºC	pH	DO (mg/L)	EC (mS/m)	TIN (mg/L)	SRP (mg/L)	Chlorophyll-*a*	
						Phytoplankton (µg/L)	Periphyton (mg/cm^2)
22.1	7.0	5.8	58.9	0.8	0.02	0.08	17.6
	Natural	Fair	Fair	Good	Good	Natural	Good

Biological and water quality indices: summary of the main index scores (ASPT: average score per taxon; IHAS: integrated habitat assessment system; diatoms; and water quality) (ecological health categories are largely based on those used for ecological Reserve determinations).

ASPT	IHAS	Diatoms	Water quality
4.9	48	3.8	Good
Poor		Clean/Fair	

Overall ecological assessment: Fair

Table 6. Summary of Site 12 on the Mdibi River

Site description: This is the uppermost site on the Mdibi River and tentatively proposed as a reference site for this river. Surrounding landuse is forestry and some limited human settlement. The vegetation biotope (picture left) provides good sampling opportunities. The GSM biotope consists of mud and leaf litter decay with, at times, limited sand.

Water quality parameters: (DO: dissolved oxygen; EC: electrical conductivity; TIN: total inorganic nitrogen; SRP: soluble reactive phosphorous; Chlorophyll-*a* mg/m^3: phytoplankton chlorophyll-*a*; Chlorophyll-*a* mg/cm^2: periphyton chlorophyll-*a*) (water quality categories based on the ecological Reserve methodologies for water quality are provided below the values where relevant).

						Chlorophyll-*a*	
TºC	pH	DO (mg/L)	EC (mS/m)	TIN (mg/L)	SRP (mg/L)	Phytoplankton (µg/L)	Periphyton (mg/cm^2)
20.8	6.5 Natural	5.8 Fair	35.8 Good	0.6 Good	0.03 Good	0.05 Natural	3.1 Good

Biological and water quality indices: summary of the main index scores (ASPT: average score per taxon; IHAS: integrated habitat assessment system; diatoms; and water quality) (ecological health categories are largely based on those used for ecological Reserve determinations).

ASPT	IHAS	Diatoms	Water quality
5.8 Fair	53	4.8 Clean	Good

Overall ecological assessment: Good

Table 7. Summary of Site 13 on the Mdibi River

Site description: The site is located downstream of a bridge culvert. Surrounding land use includes forestry and settlements. Vegetation biotope is dominated by reed stalks and leaves, although there are some aquatic plants available. Low water levels have limited the availability of vegetation biotope for sampling during 2008. GSM biotope is limited, usually consisting of some mud and sand which is covered by thick shredded leaf litter.

Water quality parameters: (DO: dissolved oxygen; EC: electrical conductivity; TIN: total inorganic nitrogen; SRP: soluble reactive phosphorous; Chlorophyll-*a* mg/m^3: phytoplankton chlorophyll-*a*; Chlorophyll-*a* mg/cm^2: periphyton chlorophyll-*a*) (water quality categories based on the ecological Reserve methodologies for water quality are provided below the values where relevant).

						Chlorophyll-*a*	
T°C	pH	DO (mg/L)	EC (mS/m)	TIN (mg/L)	SRP (mg/L)	Phytoplankton (µg/L)	Periphyton (mg/cm^2)
19	7.1	6.2	57.5	1.2	0.02	0.07	25.9
	Natural	Good	Fair	Fair	Good	Natural	Fair

Biological and water quality indices: summary of the main index scores (ASPT: average score per taxon; IHAS: integrated habitat assessment system; diatoms; and water quality) (ecological health categories are largely based on those used for ecological Reserve determinations).

ASPT	IHAS	Diatoms	Water quality
6.3 Good	53	4.3 Clean/Fair	Good/Fair

Overall ecological assessment: Good/Fair

Table 8. Summary of Site 14 on the Mdibi River

Site description: This is the lowermost site on the Mdibi River, situated upstream from Lake Mzingazi. Surrounding land use is subsistence forestry and human settlements. Vegetation biotope usually consists of marginal reeds, grasses and aquatic plants, however during the summer sample there was very limited marginal vegetation due to low flows. GSM consists of good sand and mud sampling biotope.

Water quality parameters: (DO: dissolved oxygen; EC: electrical conductivity; TIN: total inorganic nitrogen; SRP: soluble reactive phosphorous; Chlorophyll-*a* mg/m^3: phytoplankton chlorophyll-*a*; Chlorophyll-*a* mg/cm^2: periphyton chlorophyll-*a*) (water quality categories based on the ecological Reserve methodologies for water quality are provided below the values where relevant).

						Chlorophyll-*a*	
T^{o}C	pH	DO (mg/L)	EC (mS/m)	TIN (mg/L)	SRP (mg/L)	Phytoplankton (µg/L)	Periphyton (mg/cm^2)
20.3	7.2 Natural	5.5 Good	57.3 Fair	0.6 Good	0.03 Good	0.05 Natural	23.4 Fair

Biological and water quality indices: summary of the main index scores (ASPT: average score per taxon; IHAS: integrated habitat assessment system; diatoms; and water quality) (ecological health categories are largely based on those used for ecological Reserve determinations).

ASPT	IHAS	Diatoms	Water quality
5.8 Fair	53	3.3 Fair	Good

Overall ecological assessment: Fair/ Good

3.2 Habitat assessment

Overall, IHAS scores are low due to the absence of a stones biotope at all sampling sites (although there are limited stones at Site 7, these are included in the GSM biotope). IHAS at Site 7 is statistically higher than Sites 10, 11 and 13 (Figure 5). Site 10 is characterized by a pool with slow moving water, and is disturbed by cattle. Site 11 is badly affected by low flows reducing available vegetation sampling habitat. At Site 13 the reduced availability of GSM biotope reduces IHAS score. The lower IHAS score for Site 1 this year compared to 2007 can also be attributed to low flows reducing available vegetation habitat (Muller et al., 2007).

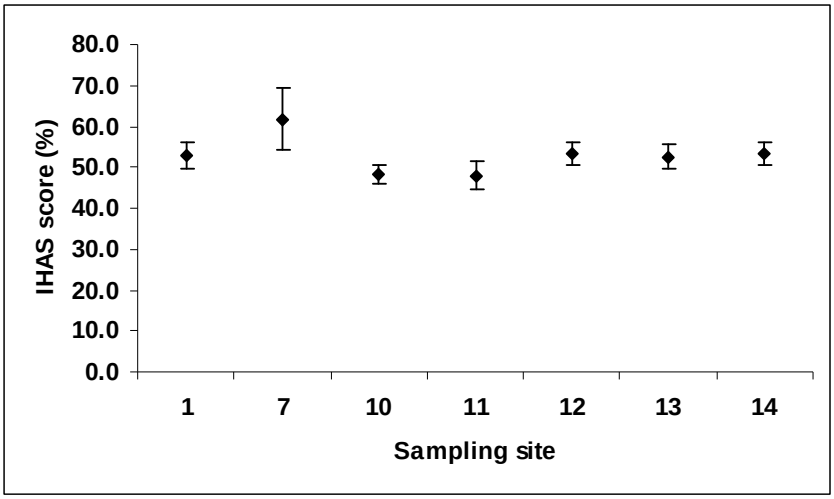

Figure 5. Mean Integrated Habitat Assessment System (IHAS) score (with standard deviation) per sampling site.

3.3 Macro-invertebrate assessment

As noted above, the water levels observed at all sampling sites were relatively low. As a consequence, sampling of the vegetation biotope was limited throughout the year at Site 11, and during the summer sample at Sites 1 and 14. Access to suitable gravel, sand and mud biotope (GSM) was limited throughout the year at Sites 10 and 13.

3.3.1 SASS assessment

At each site, results from vegetation and GSM biotopes were combined to provide total site scores for SASS score, number of families and ASPT score (Figure 6A-C). Generally scores followed a similar pattern, with Sites 10 and 11 lower than other sites sampled. This pattern mirrors the IHAS score suggesting available habitat may be a driving factor in macro-invertebrate presence/absence. The ASPT score is generally considered to be the least variable of the SASS assessment scores and thus preferred when assessing river health. The ASPT score at Site 10 was found to be statistically lower than that at Site 13, with these sites being classed as being in Poor and Good categories for ASPT score respectively (Figure 6C). The remaining sites were classed as Fair. Low DO and limited GSM biotope at Site 10 on the Manzamnyana River are possible causes of low SASS and ASPT scores, however by Site 11 scores begin increasing, possibly due to the input from the Mpisini River (Site 7 on the Mpisini, immediately upstream of Site 11 has one of the highest ASPT scores).

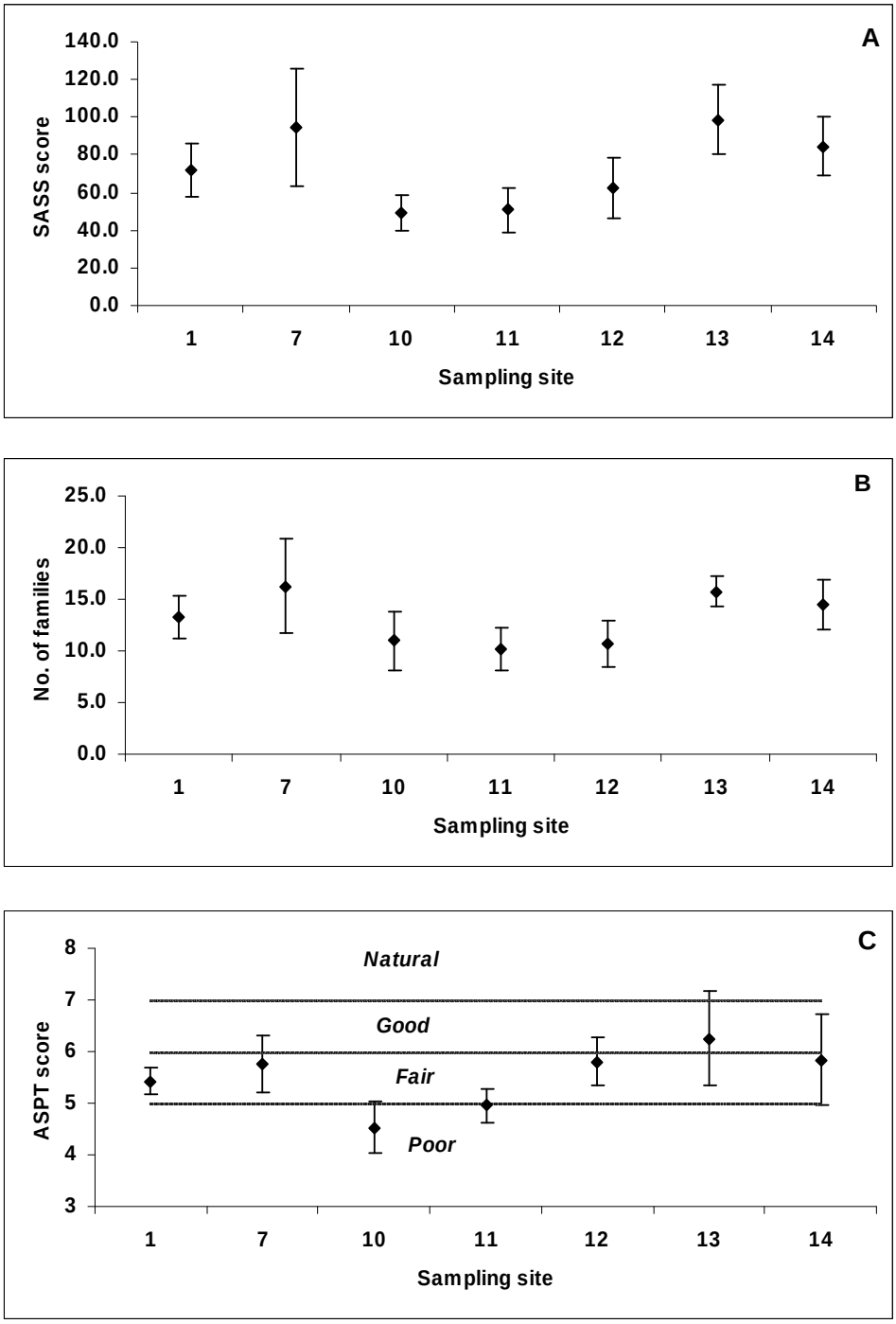

Figure 6A-C. Mean South African Scoring System (SASS) scores, number of families/taxon sampled and Average Score Per Taxon (ASPT) scores (with standard deviations for sites sampled over four seasons. Default ecological categories based on ecological Reserve determination methodologies are superimposed on the graph C.

There is no statistical difference in ASPT scores between Site 1 (reference site) and Site 7 (immediately down stream Smelter Site) on the Mpisini River. In fact scores at

Site 7 are generally higher, possibly due to the presence of gravel and some stones at this site. Furthermore, during 2008 low water levels have reduced available vegetation sampling biotope at Site 1, reducing the number of families sampled compared to Site 7 (low water levels had less of an impact at Site 7)(Figure 6B).

Along the length of the Mdibi, the ASPT score increases from Fair at the Site 12 (reference site) to Good at Site 13. However, after the input of the combined waters from the Manzamnyana and Mpisini Rivers, the ASPT class drops to Fair again. In attempting to determine the cause of the lower ASPT score, the impact of water from the Manzamnyana and Mpisini Rivers cannot be separated from the potential effects caused by dense human settlements upstream of Site 14.

There was a significant difference between the biotopes in terms of SASS scores, number of families and ASPT scores in sites, with the vegetation biotope scoring higher in all three measures.

3.3.2 Macro-invertebrate diversity assessment

An analysis of similarity of enumerated family-level macro-invertebrate data collected during four seasonal samples showed that all sites were significantly different from one another. The NMDS plot shows Site 10 is considerably different from the remaining sites, while Sites 7, 13 and 14 form a group that is to a lesser degree different from Sites 1, 12 and 11 (Figure 7).

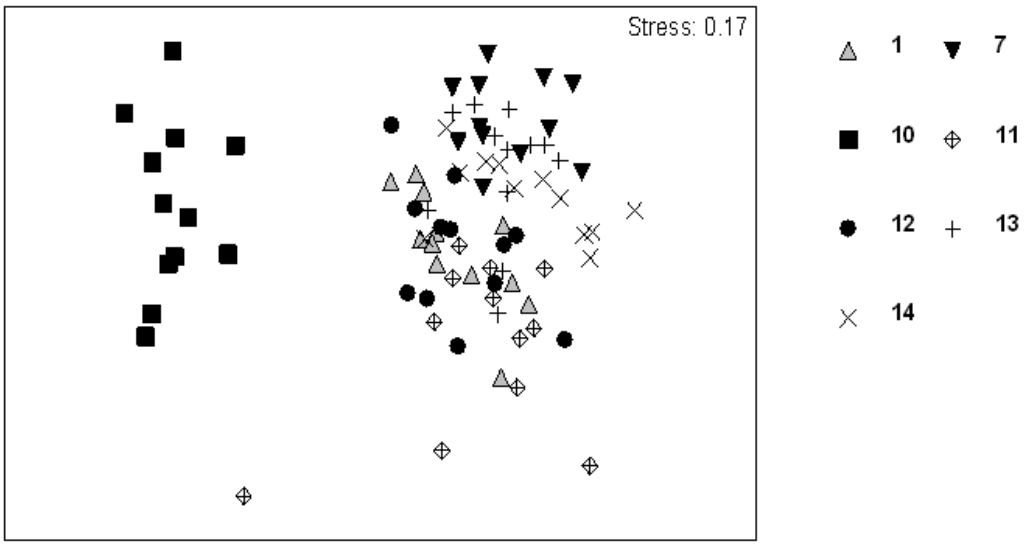

Figure 7 Non-metric multi-dimensional scaling plot of enumerated macro-invertebrate data, analysed according to location sampled.

3.4 Diatom assessment

Seasonal scores per site are presented in Table 9.

Site 1 (Upper Mpisini)

A number of the taxa found at this site are unusual or as yet unknown. As a result it was not always possible to assign a name to taxa found at this site.

December 2007

Ten species were present in this sample. Shannon diversity was 1.81. The dominant taxon was an unknown species of *Eunotia*. *Eunotia* as a genus often prefers oligotrophic, acid water. Only one taxon was subdominant. This was an unknown species of *Gomphonema*. The taxa present at abundances of 5–10% include several characteristic of oligotrophic, circumneutral water, and most are characteristic of electrolyte-poor conditions.

March 2008

Twelve taxa were present in this sample. Shannon diversity was 1.64. Three taxa were co-dominant; of these, one is a new species of *Brachysira*, and no ecological information is available for another (*Achnanthes pulviscula*). The third is characteristic of circumneutral, oligotrophic and electrolyte-poor streams. No taxa are present in the quantities that would class them as subdominant. *Achnanthidium minutissimum*, an indicator of well oxygenated and clean water, has an abundance of 9%.

June 2008

Nine taxa were present in this sample. Shannon diversity was 1.40. The dominant taxon was the unknown species of *Brachysira* co-dominant in the June sample. *Achnanthes pulviscula w*as subdominant. *Achnanthes oblongella*, indicative of circumneutral, oligotrophic, electrolyte-poor conditions, was present at an abundance of 9.5%.

September 2008

Twelve taxa were present in this sample. Shannon diversity was 1.78. The dominant taxon was the same unknown species of *Brachysira* that was found in prior samples. *Achnanthes oblongella*, an indicator of circumneutral, oligotrophic, electrolyte-poor conditions, was subdominant. As before, *Achnanthes pulviscula* was present in significant numbers. A second unknown *Brachysira* species was also subdominant. *Achnanthidium minutissimum*, indicative of well oxygenated and clean water, made up 5% of the sample.

Table 9. Seasonal diatom assessment scores for the seven sites surveyed

	Dec 2007	Mar 2008	Jun 2008	Sep 2008	Overall
Site 1 (Upper Mpisini)	5	5	5	5	5.0
Site 7 (Lower Mpisini)	1	2	3	1	1.8
Site 10 (Upper Manzamnyana)	4	4	4	3	3.8
Site 11 (Confluence)	3	4	4	4	3.8
Site 12 (Upper Mdibi)	4	5	5	5	4.8
Site 13 (Middle Mdibi)	4	4	5	4	4.3
Site 14 (Lower Mdibi)	3	3	4	3	3.3

Clean sites are scored as 5, and Stressed sites are scored as 1.

Site 7 (Lower Mpisini)

December 2007

Sixteen taxa were present in this sample. Shannon diversity was 2.08. The sample was dominated by *Navicula schroeteri*, which is highly pollution tolerant and cosmopolitan in eutrophic, electrolyte-rich waters. *Gomphonema parvulum*, a pollution-tolerant taxon found in a range of conditions, is the only subdominant taxon. Other taxa present are tolerant of pollution, with several preferring eutrophic conditions.

March 2008

Fifteen taxa were present in this sample. Shannon diversity was 1.85. *Nitzschia palea*, the dominant taxon, is a cosmopolitan species found in eutrophic and heavily polluted water with moderate to high electrolyte content. *Nitzschia fonticola*, the only subdominant taxon, is cosmopolitan in water with moderate to high electrolyte content, but is not tolerant of pollution. This suggests that the water at this site has elevated electrolyte levels as this would support the growth of both taxa. The taxa with abundances between 5–10% are characteristic of waters with high electrolyte levels.

June 2008

Seventeen taxa were present in this sample. Shannon diversity was 2.45. The sample was dominated by *Nitzschia fonticola*, present in the March 2008 sample, and indicative of elevated electrolyte levels. An unknown species of *Nitzschia* was co-dominant, and another unidentified *Nitzschia* was subdominant. Of the more common non-dominant taxa, several of the more abundant taxa are indicative of cleaner water with low to moderate electrolyte levels.

September 2008

Twenty-nine taxa were identified in this sample. Shannon diversity was 2.83. The sample was dominated by an unknown species of *Nitzschia* and by *Navicula gregaria*, a species indicative of polluted conditions and particularly common in eutrophic water with a moderate to high electrolyte level. All other species that made up 5% or more of the sample, bar *Nitzschia solita*, whose environmental preferences are not known, are tolerant of at least moderate electrolyte levels, and most are typical in eutrophic conditions.

Site 10 (Upper Manzamnyana)

December 2007

Fifteen taxa were present in this sample. Shannon diversity was 1.16. The site was heavily dominated by *Brachysira brebissonii*, an indicator of naturally acidic water with no anthropogenic impact. No taxa were common enough to be classed as subdominant. More common non-dominant taxa are generally pollution-tolerant and may be found in elevated electrolyte levels.

March 2008

Twenty-two taxa were found in this sample. Shannon diversity was 2.29. The dominant taxon is *Achnanthidium minutissimum*, which is characteristic of well oxygenated water with low levels of organic pollution. The only subdominant taxon was an unknown species of *Brachysira*. More common non-dominant taxa include taxa characteristic of electrolyte-rich conditions along with taxa common in eutrophic conditions.

June 2008

Twenty-one taxa were found in this sample. Shannon diversity was 2.23. As in the March 2008 sample, *Achnanthidium minutissimum* was dominant. Two taxa were subdominant: *Nitzschia archibaldii*, tolerant of slight to moderate pollution and preferring moderate electrolyte levels (reportedly lead and zinc tolerant); and the same unidentified *Brachysira* species in the March 2008 sample. Non-dominant taxa were commonly pollution tolerant and indicative of at least moderate electrolyte levels.

September 2008

Thirteen taxa were present in this sample. Shannon diversity was 1.84. The sample was dominated by an unknown species of *Brachysira* that was also present in September samples from Site 1. *Nitzschia capitellata*, an extremely pollution tolerant species typical of water with high electrolyte levels, was subdominant. All other taxa that were present in significant numbers are species commonly found in water with moderate to high electrolyte levels.

Site 11 (Confluence)

December 2007

Fifteen taxa were present in this sample. Shannon diversity was 1.89. Two taxa were co-dominant: *Gomphonema pumilum* var. *rigidum*, cosmopolitan and found in meso- to eutrophic conditions with moderate electrolyte levels; and *Achnanthes oblongella*, found in circumneutral, oligotrophic, electrolyte-poor waters. No taxa were subdominant. The more common non-dominant taxa include species indicative of oligo- to mesotrophic conditions along with species tolerant of eutrophic conditions.

March 2008

Seventeen taxa were present in this sample. Shannon diversity was 2.07. *Achnanthes oblongella*, co-dominant in the December 2007 sample and indicative of circumneutral, oligotrophic, electrolyte-poor streams was dominant. No taxa were common enough to be classed as subdominant. Non-dominant taxa included representatives of oligotrophic, electrolyte-poor water as well as taxa tolerant of elevated electrolyte levels.

June 2008

Ten taxa were present in this sample. Shannon diversity was 0.71. The population was heavily dominated by *Achnanthidium minutissimum*, an indicator of well oxygenated clean water. No taxa were subdominant. More common non-dominant taxa include those that are common in meso- to eutrophic water as well as taxa common in oligotrophic, electrolyte-rich water.

September 2008

Eighteen taxa were present in this sample. Shannon diversity was 2.20. The most common was *Gomphonema parvulum* var. *rigidum*, a species often found in meso- to eutrophic water with moderate electrolyte levels. An unidentified species of *Cocconeis* also present in samples from sites 13 and 14 was co-dominant. Other species present in significant numbers are indicative of low nutrient and electrolyte levels.

Site 12 (Upper Mdibi)

December 2007

Ten taxa were present in this sample. Shannon diversity was 1.52. The dominant taxon was *Achnanthes oblongella*, characteristic of circumneutral, oligotrophic, electrolyte-poor water. *Gomphonema parvulum*, a highly cosmopolitan species that is pollution tolerant, was subdominant. A second, less common subdominant was an unidentified species of *Eunotia*. More common non-dominant taxa are generally pollution-intolerant and indicative of oligotrophic, electrolyte-poor conditions.

March 2008

Seventeen taxa were present in this sample. Shannon diversity was 1.75. As in December 2007, *Achnanthes oblongella* was dominant. *Achnanthidium minutissimum*, an indicator of well-oxygenated, clean water was subdominant. The most common non-dominant taxon was *Brachysira* sp., present in all samples from site 1. Other common non-dominant taxa were unidentified *Eunotia* species and cosmopolitan species.

June 2008

Twelve taxa were found in this sample. Shannon diversity was 1.69. The dominant taxon was *Achnanthidium minutissimum*, generally indicative of clean water. The only subdominant taxon was *Achnanthes oblongella*, which was dominant in December 2007 and March 2008 samples.

September 2008

Ten species were present in this sample. Shannon diversity was 0.86. The sample was very heavily dominated by *Achnanthes oblongella*, an indicator of clean water. No other species was present in significant numbers. The more common of these species were *Eunotia incisa* and *Diadesmis contenta*, both indicative of acid, oligotrophic water.

Site 13 (Middle Mdibi)

December 2007

Nineteen taxa were present in this sample. Shannon diversity was 2.34. No taxon was clearly dominant, rather four were co-dominant, with no taxa subdominant. Co-dominants were: *Achnanthidium minutissimum*, indicative of well-oxygenated water; an unidentified species of *Navicula*; *Gomphonema parvulum*, a cosmopolitan and pollution-tolerant species; and *Achnanthes oblongella*, indicative of circumneutral, oligotrophic, electrolyte-poor water. More common non-dominant taxa include those tolerant of organic enrichment as well as species found at upstream sites.

March 2008

This sample has twenty-one taxa. Shannon diversity was 2.30. The more common taxa are all *Achnanthidium* species with different ecological requirements. *Achnanthidium minutissimum*, an indicator of well oxygenated water with little organic pollution, is dominant. Subdominant in this sample are *Achnanthidium eutrophilum* and *Achnanthidium saprophilum*. The former is found in well-oxygenated eutrophic water, and the latter in eutrophic fresh water. More common non-dominant taxa are cosmopolitan species tolerant of moderate electrolyte levels and, in most cases, meso- to eutrophic conditions.

June 2008

Fifteen taxa are present in this sample. Shannon diversity was 1.92. *Achnanthidium minutissimum*, common in December 2007 and March 2008 samples, is dominant. There are two subdominants: an unidentified species of *Eunotia*; and *Gomphonema*

exilissimum, indicative of circumneutral oligotrophic, electrolyte-poor water. Non-dominants include cosmopolitan taxa as well as several that are electrolyte-tolerant but not pollution-tolerant.

September 2008

Fourteen species were present in this sample. Shannon diversity was 1.75. The dominant species in this sample was *Achnanthes oblongella*, typical of oligotrophic, electrolyte-poor water. Subdominants were the same unidentified *Cocconeis* species that was present in the September sample from sites 11 and 14, and *Achnanthidium biasollettianum*, typical of oligo- to mesotrophic water with moderate to high electrolyte levels.

Site 14 (Lower Mdibi)

December 2007

Thirteen taxa were present in this sample. Shannon diversity was 1.90. Two taxa were co-dominant, with two more subdominant. In order of decreasing abundance, co-dominant taxa were: an unidentified species of *Eunotia* (present as a subdominant at RBM sites 13 and 12, and present with 9% abundance at RBM site 1); and *Gomphonema gracile*, cosmopolitan and electrolyte-tolerant but only moderately pollution tolerant. Subdominant were two species of *Gomphonema*: *Gomphonema pseudoaugur*, cosmopolitan in meso- to eutrophic water but only moderately pollution tolerant; and *Gomphonema parvulum*, cosmopolitan and tolerant of extreme levels of pollution. More common non-dominant taxa were all *Eunotia* species, one unidentified and one *E. minor*, found in circumneutral pools and springs.

March 2008

Twelve taxa were present in this sample. Shannon diversity was 1.89. An unknown species of *Cocconeis*, found at other sites upstream, was dominant. *Gomphonema parvulum* and *Gomphonema angustatum* were subdominant; the former cosmopolitan and extremely pollution-tolerant, the latter cosmopolitan but only common in oligotrophic waters. The more common non-dominants are all *Gomphonema* species, generally preferring oligotrophic waters, with taxa that prefer low electrolyte levels as well as several often found in waters with moderate electrolyte levels.

June 2008

Only four taxa were present in this sample. Shannon diversity was 0.56. One taxon was heavily dominant in this sample, an unidentified species of *Cocconeis*, also dominant in the March 2008 sample from this site. No taxa were subdominant. The two more common non-dominant taxa were both indicative of non-polluted water.

September 2008

Thirty-four taxa were identified from this sample. Shannon diversity was 3.15. No taxon was distinctly dominant in this sample. *Achnanthidium minutissimum*, an indicator of clean water, was most common and made up 12% of the sample. An unidentified *Cocconeis* found in September samples from sites 11 and 13 was the next most common taxon. Other non-dominant taxa present include indicators of eutrophic water such as *Achnanthidium eutrophilum*, *Achnanthidium saprophilum*, *Navicula vandamii* and *Navicula gregaria*.

Overall assessment

Generally, diatom community structure at upstream sites in all streams indicates relatively good water quality. Samples from Site 10 (Upper Manzamnyama) have a lower mean diatom score than other upstream sites, but, due to variation over the year, cannot be clearly statistically separated from other upstream sites. Thereafter, with the exception of Site 7, diatom scores decrease steadily as one moves downstream. Site 14, the lowest site in the catchment, has a statistically lower diatom score than Sites 1 and 12, upstream sites on the Mpisini and Mdibi rivers respectively.

The majority of the downstream variation in diatom community structure is matched by increases in pH and conductivity in water samples. As the streams flow from areas largely used for forestry to areas with increasing human settlement it seems these gradual changes are most likely due to runoff and baseflow from residential areas.

The site with the worst water quality as indicated by diatom population composition is Site 7 (Lower Mpisini), which has a diatom community reflecting statistically significantly lower water quality than any other site sampled ($p=0.017$). There is a dramatic change in the diatom populations in a 3 km stretch along the Mpisini between sites 1 and 7 ($p<0.001$). Site 1 is consistently classed as Clean, while site 7 is at best Fair, but is more frequently Stressed (Table 9). The diatoms collected at Site 1 are mostly typical of oligotrophic conditions with low levels of electrolytes. Those from Site 7 are generally indicative of eutrophic conditions with high levels of electrolytes.

The reason for this sharp change, in a space of approximately 3km, is not clear. Levels of nitrogen fall between the sites, while phosphate increases insignificantly (Figure 3A, 3D). A significant increase in electrical conductivity is found between the two sites (Figure 2D). The increase in conductivity between the sites cannot alone account for the change in diatom populations, as Sites 11, 13 and 14 have comparative conductivity, but none have diatom populations like those sampled at Site 7. Changes in major nutrients that were monitored also cannot account for changes in diatom population structure.

Sources of stressors that may be entering the Mpisini between Sites 1 and 7 are inflow from groundwater and runoff from the smelter area. There are three drains from the RBM smelter area to the Mpisini between Sites 1 and 7. In a prior report on water quality, Muller and Gordon (2005) note that flow from these was relatively rare; however, drainage, perhaps combined with surface runoff and/or groundwater seepage, resulted in increasing pH and conductivity at Site 7, as well as elevated $MgSO_4$ levels, and to a lesser extent NaCl levels. These changes seemed to be due to the quality of water draining from the smelter site. As increased pH and conductivity at Site 7 is noted in the 2008 data, it seems likely that the Mpisini is being impacted by the smelter's activities at this site. As noted above, the water quality parameters responsible for changes in diatom community composition cannot be identified from this study and further monitoring of a broader range of physiochemical parameters would be necessary to determine what is entering the river between sites 1 and 7. It would also be advantageous to determine whether effluent is entering the Mpisini via the drains or via surface sunoff or through the groundwater.

The water quality below Site 7 recovers relatively rapidly and at Site 11, the first site downstream of Site 7 at the confluence of the Mpisini and Manzamnyama rivers, the diatom assessment score is classed as Clean/Fair. This may be to some extent a function of dilution from the Manzamnyama River.

There was a statistically significant change in overall scores with time (p=0.001). Samples collected from sites during June reflected overall better water quality, and in particular were better than samples from December (p=0.001) and September (p=0.033).

4 Discussion

A summary of the indices measured is provided in Table 10. A provisional overall ecological health assessment for each of the sites assessed is provided. (Note: there is no health index for IHAS as it was designed to interpret the South African Scoring System (SASS) results and it is included here for that reason). It must be noted that the methods used to provide the subsequent categories are largely based on expert opinion and assessment of the available data. In addition, the boundary values for the categories are based on the default values provided by the ecological Reserve method and require site-specific refinement.

The macro-invertebrate ASPT scores were lower in 2008 compared to 2007, possibly due to lower water levels and associated reduction in available habitat. The ASPT score for Site 1, uppermost site on the Mpisini, was particularly low for a reference site, however water quality parameters and diatom community composition suggest that this site is probably unimpacted. Site 12, the uppermost site on the Mdibi is also in a Good ecological status and can probably be considered a reference site for this river.

Although only reflected in the diatom community assessment score, there appears to be a significant water quality impact occurring between Site 1 and Site 7. The smelter complex is situated immediately upstream of Site 7, and as there appears to be limited impact from human settlements, it is possible that this water quality impairment may be related to the activities of the smelter. The water quality parameters responsible for these changes in diatom community composition cannot be identified from this study and further monitoring of a broader range of physiochemical parameters is necessary in order to identify the cause of this water quality impairment.

Table 10 A summary of main index score results to provide an overall assessment for each of the sites.

Site	ASPT	IHAS	Water Quality	Diatoms	Overall ecological health assessment
1	5.4 Fair	53	Good	5.0 Clean	Good
7	5.7 Fair	62	Good	1.8 Fair/Stressed	Fair
10	4.5 Poor	48	Fair	3.8 Clean/Fair	Fair/Poor
11	4.9 Poor	48	Good	3.8 Clean/Fair	Fair
12	5.8 Fair	53	Good	4.8 Clean	Good
13	6.3 Good	53	Good/Fair	4.3 Clean/Fair	Good/Fair
14	5.8 Fair	53	Good	3.3 Fair	Fair/Good

The biological data collected so far will go towards establishing better site-specific reference conditions, and may be useful in assessing the validity of recalibrating the benchmark boundary values for water quality parameters to yield site specific boundary values.

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Appendix 1

Diatom abundances from sample sites in the Smelter area December 2007–September 2008 follow on the next page. All data are proportions of identified frustules in each sample made up of each particular taxon. Where diatoms could not be identified, morphospecies were assigned and used in all analyses.

	1				7				10				11				12				13				14			
	2007	2008			2007	2008			2007	2008			2007	2008			2007	2008			2007	2008			2007	2008		
	Dec	Mar	Jun	Sept	Dec	Mar	Jun	Sept	Dec	Mar	Jun	Sept	Dec	Mar	Jun	Sept	Dec	Mar	Jun	Sept	Dec	Mar	Jun	Sept	Dec	Mar	Jun	Sept
Achnanthes oblongella	0.07	0.23	0.1	0.23	0.01	0	0	0.02	0	0.01	0	0	0.3	0.43	0.01	0.18	0.42	0.52	0.22	0.81	0.13	0	0.01	0.49	0	0.02	0.04	0.04
Achnanthes pulviscula	0	0.31	0.27	0.15	0	0.01	0.08	0.04	0	0	0	0	0.02	0.05	0	0	0.03	0	0	0.02	0	0	0	0	0	0	0	0
Achnanthidium affine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0
Achnanthidium biasolettianum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.14	0	0	0	0
Achnanthidium crassum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0	0	0	0
Achnanthidium eutrophilum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.13	0	0	0	0	0	0.09
Achnanthidium macrocephalum	0	0	0	0.02	0	0	0	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Achnanthidium minutissimum	0.01	0.09	0.05	0.04	0.03	0	0.06	0.03	0.01	0.38	0.34	0	0.02	0.06	0.85	0.03	0.02	0.18	0.42	0	0.2	0.3	0.38	0	0	0	0.09	0.12
Achnanthidium saprophilum	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0.01	0	0	0	0	0.07	0.16	0	0.01	0.01	0	0	0.06
Amphora acutiuscula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0.01
Amphora sp1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0
Amphora sp2	0	0	0	0	0	0.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bacillaria paradoxa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04	0	0	0	0	0	0	0	0	0	0	0	0.03
Brachysira aff steindorfiana	0.07	0.3	0.5	0.35	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0.07	0.1	0.02	0.02	0	0.02	0	0	0	0	0
Brachysira brebissonii	0	0	0	0	0	0	0	0	0.74	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0
Brachysira sp2	0	0	0	0.14	0	0	0	0	0	0.14	0.13	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0
Caloneis bacillum	0	0	0	0	0	0	0	0	0.01	0.01	0	0	0	0	0	0.02	0	0	0	0	0	0.01	0	0	0	0	0	0
Caloneis hyalina	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0
Caloneis sp1	0	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Capartogramma crucicula	0	0.01	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cocconeis pediculus	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cocconeis placentula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04	0	0	0	0	0	0	0.06	0	0	0	0	0
Cocconeis placentula var. euglypta	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cocconeis sp1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.23	0	0	0	0	0.07	0.1	0	0.15	0	0.37	0.85	0.11
Craticula accomodiformis	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyclostephanos invisitatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0
Cyclotella meneghiniana	0	0	0	0	0	0.11	0	0	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cymbella tumida	0	0	0	0	0.04	0	0.01	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cymbella turgidula	0	0	0	0	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diadesmis contenta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0.01	0.02	0.03	0	0	0	0	0	0	0	0.01
Diploneis puella	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Encyonema minutum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0
Encyonema silesiacum	0	0	0	0	0	0	0.04	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eolimna subminiscula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0	0	0
Eunotia aff. *minor*	0.44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eunotia bilunaris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0

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Eunotia incisa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.06	0	0	0	0	0	0	0	0
Eunotia minor	0	0	0.01	0	0.01	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0.05	0	0	0.01
Eunotia sp1	0.01	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0	0	0	0.03	0	0	0	0	0	0	0.05	0	0.02	0
Eunotia sp2	0.09	0.01	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.04	0.15	0	0.01	0.02	0.19	0	0.28	0	0	0
Eunotia sp3	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0
Fragilaria biceps	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0.02	0	0	0
Fragilaria capucina var. *vaucheriae*	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0
Fragilaria ulna	0	0	0	0	0.06	0	0	0	0	0	0	0	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Frustulia crassinerva	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0
Frustulia vulgaris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02
Geissleria decussis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01
Gomphonema aequatoriale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.03	0	0
Gomphonema aff. *gracile*	0	0	0	0.02	0	0	0	0	0.08	0	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0.01	0	0	0
Gomphonema aff. *insigne*	0.11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gomphonema aff. *lagenula*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0
Gomphonema affine	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0.01	0	0	0.04	0	0.03
Gomphonema angustatum	0.08	0	0.04	0	0	0	0	0	0	0	0.01	0	0	0.01	0	0	0	0	0	0.02	0	0	0	0	0	0.12	0	0.02
Gomphonema exilissimum	0.09	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0	0.16	0	0	0.04	0	0
Gomphonema gracile	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0.05	0.01	0	0	0.01	0.02	0.06	0	0.25	0.06	0	0
Gomphonema grovei var. *lingulatum*	0	0	0	0	0	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gomphonema insigne	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0
Gomphonema lagenula	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0.02	0.01	0	0	0	0.03	0	0	0	0.01	0.01	0	0
Gomphonema minutum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0
Gomphonema parvulum	0.03	0	0.01	0	0.16	0.01	0.01	0.02	0.01	0	0.02	0	0.08	0	0.02	0.01	0.31	0.02	0	0.01	0.15	0.03	0.04	0	0.14	0.22	0	0
Gomphonema parvulum f. *saprophilum*	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gomphonema pseudoaugur	0	0	0	0	0	0	0	0.01	0	0	0	0	0.03	0.01	0	0	0	0	0	0.01	0	0	0.01	0.01	0.16	0	0	0
Gomphonema pumilum	0	0	0	0	0.04	0	0.05	0	0	0	0	0	0	0.09	0.01	0	0	0	0	0	0.05	0	0.01	0	0	0	0	0
Gomphonema pumilum var. *rigidum*	0	0	0	0	0	0	0	0.02	0	0	0	0	0.35	0	0	0.24	0	0	0	0	0	0.03	0	0.06	0	0.08	0	0
Gomphonema sp1	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gomphonema venusta	0	0	0	0	0	0	0.06	0	0	0	0	0	0.07	0.09	0.01	0.07	0	0	0	0	0	0	0	0.02	0	0	0	0
Gomphosphenia aff *oahuensis*	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gomphosphenia oahuensis	0	0	0	0	0	0	0.04	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hippodonta luenebargensis	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Luticola kotschyi	0	0	0.01	0	0	0	0	0	0.03	0	0.01	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0
Mastogloia dansei	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0
Navicula angusta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0

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Navicula antonii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0
Navicula arvensis var. *maior*	0	0	0	0	0	0	0	0	0	0	0.04	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula cryptocephala	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula cryptocephala var. *exilis*	0	0	0	0	0	0	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula elkab	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.03	0	0	0	0
Navicula erifuga	0	0	0	0	0	0.01	0	0.01	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0.01
Navicula germainii	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0
Navicula gregaria	0	0	0	0	0.01	0.01	0	0.16	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0.01	0	0.02	0	0.01	0	0.04
Navicula longicephala	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01
Navicula molestiformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0
Navicula ranomfenesis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0.02
Navicula reichardtiana	0	0	0	0	0	0	0	0	0.01	0	0.02	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0
Navicula rostellata	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01
Navicula schroeteri	0	0	0	0	0.39	0	0.05	0.05	0	0	0	0	0	0.03	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula sp2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.18	0	0	0	0	0	0	0
Navicula sp3	0	0	0	0	0.04	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula subrhynchocephala	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula symmetrica	0	0	0	0	0	0.01	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula tenelloides	0	0	0	0	0	0	0	0	0.01	0.02	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.03
Navicula vandamii	0	0	0	0	0	0.02	0.01	0.02	0	0	0	0.01	0	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0.06
Navicula veneta	0	0.01	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0	0	0
Navicula viridula	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula zanonii	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0
Neidium affine	0	0	0	0	0	0	0	0	0	0.01	0	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Neidium sp1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0
Nitzschia agnewii	0	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nitzschia archibaldii	0	0	0	0	0	0	0	0	0	0.06	0.17	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nitzschia bacillum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0
Nitzschia capitellata	0	0	0	0	0.08	0	0	0	0	0.02	0	0.23	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0.03
Nitzschia clausii	0	0.01	0	0	0	0.01	0.01	0.01	0	0	0	0.03	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0.01
Nitzschia communis	0	0	0	0	0	0	0.04	0	0	0.03	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02
Nitzschia desertorum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0	0
Nitzschia dissipata	0	0	0	0	0	0	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nitzschia elegantula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0.01	0	0	0	0	0	0
Nitzschia filiformis	0	0	0	0	0	0.06	0	0.05	0	0	0	0	0	0.09	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nitzschia fonticola	0	0	0	0	0	0.17	0.22	0.01	0	0	0	0	0.01	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0	0

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	2007	2008			2007	2008			2007	2008			2007	2008			2007	2008			2007	2008			2007	2008		
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Nitzschia frustulum	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0.01	0	0	0	0	0.01	0	0.01	0	0	0	0	0	0	0.01
Nitzschia liebertruthii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04	0	0	0	0	0	0	0	0	0	0	0	0.04
Nitzschia linearis	0	0	0	0	0	0	0	0.01	0	0.01	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0.01	0	0	0	0
Nitzschia longissima var. *reversa*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01
Nitzschia microcephala	0	0.01	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0.01
Nitzschia nana	0	0	0	0	0.01	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nitzschia obtusa var. *kurzii*	0	0	0	0	0.01	0.01	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nitzschia palea	0	0	0	0	0	0.44	0.05	0.06	0.01	0.01	0	0.09	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0	0	0.01
Nitzschia paleacea	0	0	0	0	0.08	0	0	0	0	0	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01
Nitzschia perspicua	0	0	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0
Nitzschia plicatula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0
Nitzschia pura	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0
Nitzschia pusilla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0
Nitzschia sigma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01
Nitzschia solita	0	0	0	0	0	0	0	0.15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nitzschia sp	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0
Nitzschia sp10	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nitzschia sp3	0	0	0	0	0	0	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nitzschia sp4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0
Nitzschia sp5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0	0	0
Nitzschia sp6	0	0	0	0	0	0	0.11	0.16	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.07
Nitzschia subacicularis	0	0	0	0	0	0	0	0	0	0	0	0	0	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nitzschia subcommunis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0
Nitzschia sublinearis	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nitzschia supralitorea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0
Nitzschia valdecostata	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinnularia gibba	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinnularia joculata	0	0	0	0	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinnularia sp2	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinnularia sp3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01
Pinnularia viridiformis	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinnularia viridis	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Placoneis sp1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0
Planothidium engelbrechtii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.03	0	0	0	0
Planothidium rostratum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02
Rhopalodia operculata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.08	0	0	0	0	0	0

	1				7				10				11				12				13				14			
	2007	2008			2007	2008			2007	2008			2007	2008			2007	2008			2007	2008			2007	2008		
	Dec	Mar	Jun	Sept	Dec	Mar	Jun	Sept	Dec	Mar	Jun	Sept	Dec	Mar	Jun	Sept	Dec	Mar	Jun	Sept	Dec	Mar	Jun	Sept	Dec	Mar	Jun	Sept
Sellaphora pupula	0	0	0	0.01	0	0	0	0	0.05	0.08	0	0.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sellaphora seminulum	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sellaphora stroemii	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stauroneis kriegerii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0
Stauroneis pachycephala	0	0	0	0	0	0	0	0	0	0.05	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0
Stauroneis phoenicenteron	0	0	0	0	0	0	0	0	0	0.07	0.09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synedra sp1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01
Tabularia fasciculata	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0