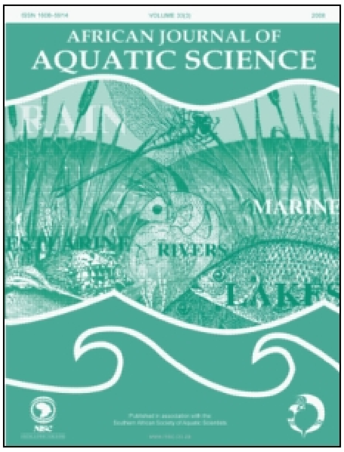

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miniSASS — A novel technique for community participation in river health monitoring and management

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Reliable indicators of water quality and river health are often difficult and expensive to derive. This paper reports on a process to develop a low technology, scientifically reliable and robust technique to monitor water quality in rivers and streams. With these requirements in mind the authors set about developing a simplified method of biomonitoring based on the tried and tested SASS (South African Scoring System) technique. This involved reducing the taxonomic complexity of SASS to a few aquatic invertebrate 'groupings' which would act as surrogates for the complete suite of SASS taxa.
To be efficient the technique had to satisfy the following requirements:
1. **minimise the number of aquatic invertebrate groupings necessary to perform miniSASS;**
2. **aquatic invertebrate groups should be easily identifiable;**
3. **the method should be robust and produce results comparable to the full SASS technique; and**
4. **be geographically widely applicable.**

These requirements were met in this development and for a large set of data (>2 000 records) covering the Mpumalanga / Eastern Seaboard (Umgeni Water) and Western Cape regions there appear to be no statistically significant differences between SASS and miniSASS scores. However, once the data becomes split into various water quality classes (as defined in the Draft Procedures for the Water Quality Reserve, Department of Water Affairs and Forestry 2002) statistically significant differences between SASS and miniSASS become apparent. Nonetheless, these differences are relatively small and are usually less than 1 ASPT score different.

Potentially, every school, environmental or community group in the country could become a monitoring cell, and with this geographical spread use the miniSASS tool as a 'red flag' for the identification of aquatic pollution sources and events in their immediate environment. The parallel and supporting initiative, to be able to enter this 'real aquatic biomonitoring data' onto an internet web-based mapping programme (see www.riverhealth.co.za), extends the application of the resource making networking and broad based catchment water quality monitoring a real possibility.

miniSASS can therefore be used with some confidence, producing data which vary slightly from SASS, but which is sufficiently accurate to be of value to all stakeholders with an interest in river health. The increased opportunity for communities to become involved, use a scientifically valid tool and undertake real biomonitoring of their river systems is probably the most important aspect of the development of this resource. Through this involvement, live, real-time monitoring and investigation of pollution sources in their systems is possible, and the opportunity for improved environmental management a reality.

Keywords: aquatic invertebrates, biomonitoring, SASS

Introduction

Reliable indicators of water quality and river health are often difficult and expensive to derive. Taking water samples to a local testing laboratory for testing further distances the user from the resource and a potential engagement with the water quality issues. This paper reports on a process to develop a low technology, scientifically reliable and robust technique to monitor water quality and river health in rivers and streams.

It could be argued that modern science has provided reliable tools for understanding the impacts of, and for providing solutions to, water pollution. The next step is to communicate these solutions to the public and, through this process, the public becomes informed and the problems of (water) pollution should largely disappear. To this end various carefully-orchestrated campaigns have attempted to communicate 'the message' through both formal and informal educational programmes and the mass media. However, as noted by Taylor (1992), these messages have generally failed to effect the desired changes because social change does not necessarily come about merely through people receiving clearly-communicated messages. Taylor highlights the common origins of the words 'communication' and 'community,' and notes that 'community' comes from shared experiences, dialogue and the building of mutual trust. This cannot be achieved by simplistic, one-way or top-down methods of communication for 'getting the conservation/pollution message across'. Real change will occur only when the public is able to relate with and share in a similar enquiry to the one that enabled the scientists to come to their understanding. Instead of trying to change human behaviour by 'giving the findings of science away', what is needed is the involvement of people and 'giving the *tools* of science away' and in interactions with the findings of scientific enquiry (Taylor *op. cit.*). It is in this social and environmental context that miniSASS has been developed as an environmental education tool for use by communities to monitor the 'health of their rivers and streams'. This paper reports on the development of miniSASS.

A summary of the miniSASS 'method', i.e. how and where to apply the technique, is provided in Appendix 1.

The development of SASS (and hence of miniSASS) as a biomonitoring tool

The use of biological organisms to indicate the health of ecosystems is not new, and earliest man undoubtedly chose 'healthy' water resources over polluted ones. This was more than likely done on the basis of their taste, odour, appearance and local history related to disease. More recently the science has come of age and is now commonly referred to as biomonitoring or bioassessment (e.g. James and Levison 1979). Benthic aquatic macroinvertebrates are ideal candidates for biomonitoring for several reasons:

- They are ubiquitous in aquatic systems.
- They are relatively sedentary, and this allows spatial impacts of pollution to be detected.
- Different taxonomic groups have different sensitivities to pollution.
- They are generally easy to collect and identify.
- They act as continuous water quality monitors. Unlike chemical monitoring, which provides information about water quality at the time of measurement, biological monitoring can provide information about past and/or episodic pollution.

One of the original biomonitoring resources available to the environmental education community in South Africa was the so-called 'water slide' (Figure 1). This simple slide (adapted for South African use from the UK based 'Stream-Watch Indicator') consisted of one's being able to identify eleven aquatic invertebrate taxa. Their presence or absence could then be used to indicate a range of five water quality classes or conditions (ranging from 'clean water' to 'serious pollution'). Unfortunately, there was no quantitative index that could be derived from this system to use in on-going monitoring. The water-slide also does not provide clear sampling techniques, meaning that comparative sampling is unreliable. Furthermore, there was no direct relationship between the water slide results and more scientifically rigorous systems of biomonitoring.

A more rigorous method of biomonitoring is the South African Scoring System (SASS) developed by Chutter (1998). While SASS is a relatively simple technique for a trained practitioner, for the layman it is generally beyond reach because of the need to be able to identify up to 90 different aquatic invertebrate families that form the backbone of the technique. For non-invertebrate taxonomists this requires a moderately high degree of training and therefore restricts the technique to a small number of 'specialists' able to identify the taxa.

With the obvious shortcomings, i.e. low quality data, of the 'water slide' and the relatively sophisticated identification skills needed by the SASS system, there was a need for an intermediate level of biomonitoring that provides reliable water quality / river health data, that could be applied by non-specialists. To be credible the technique should be based on a technique of known pedigree.

With these requirements in mind the authors set about

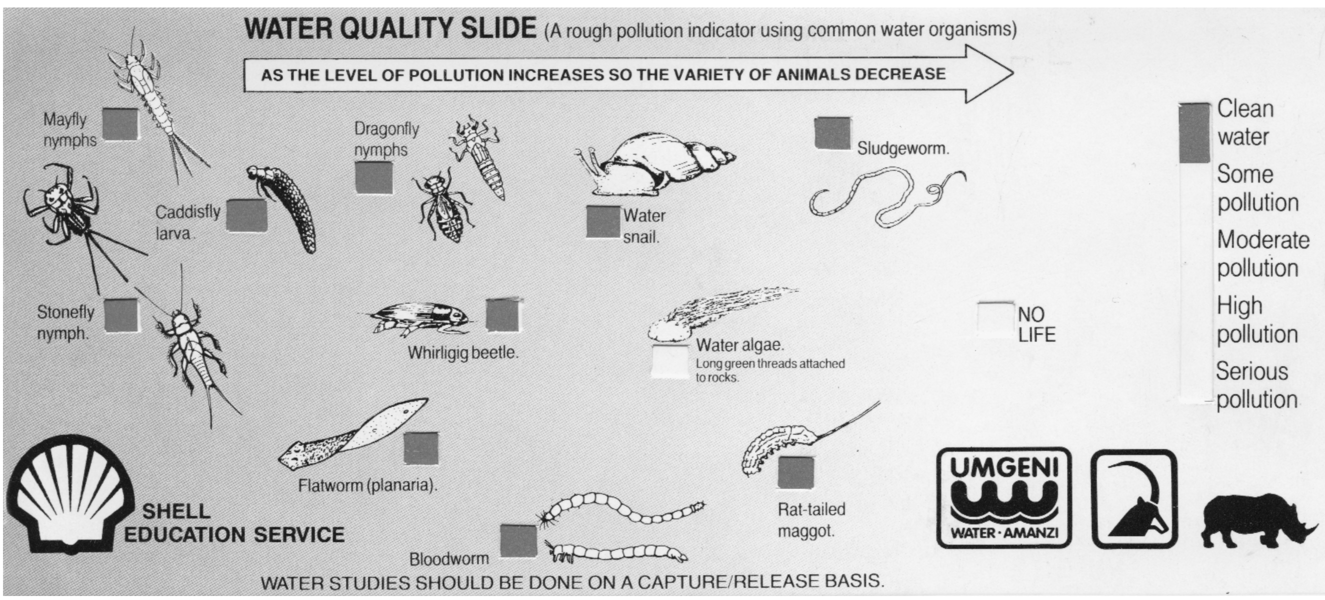

Figure 1: Water quality slide — an early resource for biomonitoring

developing a simplified method of biomonitoring based on the tried and tested SASS technique. This involved reducing the taxonomic complexity of SASS down to a few aquatic invertebrate 'groupings' which would act as surrogates for the complete suite of SASS taxa. To be efficient the technique had to satisfy the following requirements:

1. minimise the number of aquatic invertebrate groupings necessary to perform miniSASS;
2. aquatic invertebrate groups should be easily identifiable;
3. the method should be robust and produce results comparable to those of the full SASS technique and,
4. be geographically widely applicable.

The SASS (South African Scoring System, Chutter 1998) system of biomonitoring has been extensively used throughout South Africa. Institutions using the method include water boards (e.g. Umgeni Water), irrigation boards (e.g. Umlaas Irrigation Board), the CSIR, DWAF, various universities and consultants. The technique has been used to good effect as:

- a routine biomonitoring tool around known impacts (e.g. Dickens and Graham 1998);
- for following up on specific Environmental Impact Assessment (EIA) type problems or pollution cases (e.g. Graham 1999);
- in Instream Flow Requirement (IFR) studies (O'Keeffe and Dickens 2000);
- a key indicator in State of the Rivers reporting throughout South Africa (e.g. State of the Rivers Report — Crocodile; Sabie-Sand and Olifants Rivers Systems 2001);
- State of Environment Reporting (Archer *et al*. 1998);
- one of the principal biomonitoring tools for the National River Health Programme (e.g. Uys *et al*. 1996, Dallas 1997);
- a tool for environmental management and compliance monitoring by the major commercial timber growers in the country (e.g. SAPPI, MONDI, SAFCOL and NCT) as part of their requirements for ISO 14 000 and Forestry Stewardship Council (FSC) accreditation/certification (e.g. Diedericks 2001).

After various revisions and modifications over the years, the SASS system is now on version 5 (Dickens and Graham 2002). The essence of the method lies in allocating a quality score to specific and readily identifiable aquatic invertebrate taxa. The score is an indication of the taxon's sensitivity to pollution. Samples of aquatic invertebrates are collected from the river using standardised methods, immediately examined on the riverbank, and then the sample is 'scored', based on the prescribed scores allocated to each taxon. After a fixed identification period the scores of the taxa found are summed to derive a Sample Score. The total number of SASS taxa identified is counted and an Average Score Per Taxon (ASPT) may be calculated by dividing the Sample Score by the total number of taxa. Each of these three measures, or indices, provide useful information as to the biological condition of the river. Generally, the higher the Sample Scores, Number of Taxa and ASPT, the better the biological condition or health of that river (Dickens and Graham 2002). Chutter (1998) has provided a guide to the values of these indices and their interpretation.

With the relative abundance and wide geographic spread of SASS Version 4 data available in South Africa, this version provided the foundation upon which to develop the miniSASS method.

Note: Initial indications are that SASS5 and SASS4 ASPT scores are close enough to mean that SASS5 and miniSASS ASPT scores are likely to be closely related. More data will, however, be needed to confirm this.

Methods and rationale

Pilot study and miniSASS invertebrate groups quality score selection

A pilot study was undertaken to determine if the proposed miniSASS approach was a viable project. This study had two key objectives:

- Create a reduced list of easily identifiable, groups of aquatic invertebrate taxa (from the full SASS list)
- Assign 'best fit' quality scores to these new groups

The following taxa were considered to be too cryptic, rarely encountered or difficult/confusing in their identification and were eliminated from potential incorporation into the simplified miniSASS.

- Porifera, *Hydra* sp., Hydrachnellae, Corydalidae and Nymphulidae (highlighted in Appendix 2).
- However their contributions to actual scores ***were*** accounted for in the testing of miniSASS against 'real' SASS4 data:

To achieve these objectives a subset of comparatively easily identified aquatic invertebrates (e.g. damselflies, dragonflies, water bugs, flies etc.) were derived, and then modelled against a relatively small set (n = 21) of real SASS4 data to determine the best quality scores to assign to the respective new groups. The objective was to minimise the differences in ASPT scores attainable with the miniSASS compared to that of a full SASS4 analysis.

The sites selected represented a range of water quality conditions on the Mkomaas, Mgeni, Karkloof, Mhlatuzana, Mbilo, Mvoti and Dorpspruit Rivers and the Mthinzima Stream (all in KwaZulu-Natal (KZN)), and had a relatively broad geographical spread, represented both large and small rivers and streams, and covered near pristine water quality to highly polluted waters.

The results of this investigation are summarised in Tables 1 and 2.

The results (Table 2) were encouraging, and showed small differences between ASPT scores achieved by miniSASS and a full SASS4 analysis. This suggested that miniSASS warranted further development.

All options (choices of different aquatic invertebrate groupings) had reasonably good agreement between miniSASS and SASS. After some consideration, and given the perceived miniSASS target audience, Option 4 (Table 2) was chosen as being the most pragmatic.

To test how miniSASS would perform over a wider geographical and water quality range it was decided to test it on as much data as was reasonably available and in much the same way as occurred in the Pilot Study. This formed the most rigorous testing of the technique. Only the Option 4 grouping of taxa was tested further.

Table 1: Potential miniSASS taxa (groupings) investigated (range of potential scores (from SASS4) in brackets)

Number of taxa groupings	Option 1 minimum initial miniSASS aquatic invertebrate groupings		Option 2 as Option 1 but flies split into low and high scores groupings		Option 3 as Option 1 but bugs and beetles combined as one group		Option 4 as Option 1 but bugs and beetles and all caddisflies combined (respectively)	
1	Planaria	(3)	Planaria	(3)	Planaria	(3)	Planaria	(3)
2	Worms	(1)	Worms	(1)	Worms	(1)	Worms	(1)
3	Leeches	(3)	Leeches	(3)	Leeches	(3)	Leeches	(3)
4	Crustacea	(3–8)	Crustacea	(3–8)	Crustacea	(3–8)	Crustacea	(3–8)
5	Stoneflies	(12)	Stoneflies	(12)	Stoneflies	(12)	Stoneflies	(12)
6	Minnow mayflies	(4–12)	Minnow mayflies	(4–12)	Minnow mayflies	(4–12)	Minnow mayflies	(4–12)
7	Mayflies	(6–15)	Mayflies	(6–15)	Mayflies	(6–15)	Mayflies	(6–15)
8	Damselflies	(4–10)	Damselflies	(4–10)	Damselflies	(4–10)	Damselflies	(4–10)
9	Dragonflies	(4–8)	Dragonflies	(4–8)	Dragonflies	(4–8)	Dragonflies	(4–8)
10	Water bugs	(3–7)	Water bugs	(3–7)	Bugs and bettles	(3–10)	Bugs and bettles	(3–10)
11	Netspinner caddis	(4–12)	Netspinner caddis	(4–12)	Netspinner caddis	(4–12)	All caddisflies	(4–20)
12	Other caddisflies	(8–20)	Other caddisflies	(8–20)	Other caddisflies	(8–20)	Flies	(1–13)
13	Water beetles	(5–10)	Water beetles	(5–10)	Flies	(1–13)	Snails	(3–6)
14	Flies	(1–13)	Low flies	(1–3)	Snails	(3–6)		
15	Snails	(3–6)	High flies	(5–15)				
16			Snails (3–6)					

Table 2: Summary of optimal quality scores assigned to the respective miniSASS groupings during pilot study development

Aquatic invertebrate groupings (and SASS4 quality score range)		Option 1 Optimal score	Option 2 Optimal scores	Option 3 Optimal scores	Option 4 Optimal scores
Planaria	(3)	1	1	1	1
Worms	(1)	1	1	1	1
Leeches	(3)	3	3	3	3
Crustacea	(3–8)	4	4	5	5
Stoneflies	(12)	15	15	15	13
Minnow mayflies	(4–12)	7	7	7	7
Mayflies	(6–15)	12	12	12	12
Damselflies	(4–10)	4	4	4	3
Dragonflies	(4–8)	6	6	6	6
Water bugs	(3–7)	4	4		
Netspinner caddisflies	(4–12)	11	11	11	
Other caddises	(8–20)	10	9	10	
Water beetles	(5–10)	6	4		
Flies	(1–13)	1		1	1
Snails	(3–6)	3	3	3	3
Low flies	(1–3)		1		
High flies	(5–15)		8		
Bugs and bettles	(3–10)			4	4
All caddisflies	(4–20)				14
Average absolute difference		0.55	0.59	0.53	0.55
Median absolute difference		0.38	0.41	0.29	0.40
Maximum (absolute difference)		1.30	1.33	1.31	1.47
Minimum (absolute difference)		0.02	0.02	0.04	0.02

Testing of miniSASS on a national scale

Sources of data

There were three principal geographical sources of SASS4 data that miniSASS was tested against: the eastern seaboard (KZN — Umgeni Water data), the Western Cape (Southern Waters — UCT, and Cape Metro Council data), and the Mpumalanga region (sourced from the Rivers Database, version 1.0). This probably represented the largest coverage of data where historical biological monitoring using SASS4 had taken place.

For the eastern seaboard, data were extracted from the Umgeni Water Laboratory Information Management System (LIMS) database. This covered data collected from January 1993 to June 1999, and included 61 sites throughout the 24 000km^2 of Umgeni Water's operational area, and represented some 1 170 records.

The Western Cape data, made available firstly through Helen Dallas (1999) of Southern Waters, and then also Candice Haskins (1999) of Cape Metro Council, amounted to 452 records and covered some 408 sites. Lastly the

Mpumalanga data provided by DWAF (505 records, comprising 198 sites) were extracted from the Rivers Database. It was thus possible to test the robustness of miniSASS against a total of 2 127 discrete SASS records.

Minimisation of differences between miniSASS and SASS ASPTs.

As in the pilot study, the quality scores assigned to the miniSASS aquatic invertebrate groupings required optimisation to minimise the differences obtained between full SASS and miniSASS ASPT results. Due to the relatively large size of the data set (and range of possible scores that could be assigned to the 13 groups) linear programming within a spreadsheet environment was used to solve the minimisation objective. In essence this process juggled *all* the quality scores assigned to the miniSASS groups whilst aiming to minimise the difference in ASPT scores obtained between miniSASS and SASS analyses respectively. The linear programming optimisation was constrained to keep some of the scores assigned to various groupings within reason e.g. positive and not too high or too low (based on biological and previous SASS experience).

Within these constraints it was possible to derive 'best fit' quality scores to be assigned to the new miniSASS aquatic invertebrate groups.

Results

The minimisation process (selection of best quality scores) and hence the testing of miniSASS, was conducted on both the entire dataset (i.e. from all geographical regions combined) as well as on the discrete geographical or regional areas. The results of the analysis are shown in Table 3

The results indicate that the 'best fit' quality scores assigned to most aquatic invertebrate groups were relatively stable between regions. Although the *combined dataset* (all SASS sites sampled in all regions) showed a mean difference between SASS and miniSASS ASPTs of 0.7, when these quality scores were applied to the Western Cape data set alone, the mean difference for this region rose to 1.1 (not shown in Table 3). To counter this problem, further fine-tunings of miniSASS quality scores were made. For the Western Cape, the quality scores for stoneflies and caddisflies were increased over those used for the rest of the country (Table 3). With this refinement it was possible to maintain the Western Cape mean difference between SASS and miniSASS ASPT at 0.8, whereas the difference for the rest of the country was reduced to 0.6.

What this means is that, within the limitations of the available data, a miniSASS analysis is able to predict the SASS ASPT score to within one ASPT unit. This means that miniSASS is a good predictor of biological water quality (in so far as SASS is able to predict this).

Frequency and statistical analyses of difference between SASS and miniSASS ASPT scores

Frequency analysis of differences between SASS and predicted miniSASS ASPT scores

Within the dataset of 2 127 records, for each SASS ASPT score there is a complementary miniSASS ASPT. The *difference* between these two respective ASPTs provides some measure as to how well miniSASS is able to predict the SASS ASPT. In other words, if the difference between the two ASPTs is zero, then miniSASS is predicting the SASS ASPT perfectly, and with greater deviation the differences would increase. To measure the overall co-relation between the two ASPTs, a simple frequency analysis was performed on the breakdown of the *differences* between SASS and corresponding miniSASS ASPT scores. A summary of the frequency of these differences is presented in Table 4

The results show that miniSASS results are within one ASPT unit of that obtained from a full SASS analysis in 80%

Table 3: Summary of 'best fit' quality scores obtained for aquatic invertebrate groups in various (and combined) geographical regions as well as the overall 'best fit' scores used in the finalised miniSASS sheet

	Best fit quality scores grouped according to region					
Aquatic invertebrate groupings	Combined data (all regions)	Western Cape	Mpumalanga (UW)	Eastern seaboard	Best overall fit	Western Cape refinements
Planaria	3	3	3	3	3	3
Worms	2	3	3	1	2	2
Leeches	3	3	3	2	2	2
Crustaceans	6	5	8	6	6	6
Stoneflies	18	25	18	16	14	26
Minnow mayflies	6	5	5	5	5	5
Mayflies	12	13	11	13	13	13
Damselflies	4	3	3	4	4	4
Dragonflies	5	5	7	6	6	6
Bugs and beetles	7	7	5	6	7	7
Caddisflies	10	18	8	8	9	16
Flies	1	3	1	2	1	1
Snails	4	2	5	5	5	5
Maximum difference between SASS and miniSASS ASPTs	6.9	3.6	6.2	2.9	6.6	3.7
Median difference between SASS and miniSASS ASPTs	0.6	0.6	0.5	0.5	0.5	0.6
Mean difference between SASS and miniSASS ASPTs	0.7	0.8	0.6	0.6	0.6	0.8

Table 4: Results from frequency analysis of differences between SASS and predicted miniSASS ASPT scores

	Classes for differences between SASS and miniSASS scores	Frequency	Cumulative proportion of total number of records
Mpumalanga and Eastern Seaboard (UW) data (1 675 records)	≤1	1 358	81.1%
	2	287	98.2%
	3	28	99.9%
	≥3	2	100.0%
Western Cape data (452 records)	≤1	305	67.5%
	2	111	92.0%
	3	26	97.8%
	≥3	10	100.0%

and 67% of cases in the Mpumalanga / Eastern Seaboard and Western Cape regions respectively. The conformity of ASPT scores rises to over 90% in all regions where the difference is less than two ASPT units.

Statistical analysis of differences between SASS and predicted miniSASS ASPT scores

Ideally, the choice of quality scores assigned to the miniSASS groups should have been such that there is *no difference* between SASS and miniSASS ASPT results.

This was tested using a t-test for paired differences (or dependent samples), the results of which are reported in Table 6 and graphically in Figure 2.

Whilst conducting this part of the investigation it was felt that it may also be useful to determine not only the overall significance of the relationship between SASS ASPT and miniSASS ASPT (i.e. all the data) but also how well miniSASS performed in different classes of water quality (as predicted by SASS and as defined by the Reserve Water Quality Classes (Table 5)). This investigation looked at the entire dataset as well as separating the data into the Mpumalanga/Eastern Seaboard and Western Cape regions.

For the entire data set there were no statistically significant differences between SASS and miniSASS scores ($P < 0.05$). However, once the data becomes split into the various water quality classes (as defined in the Draft Procedures for the Water Quality Reserve, Department of Water Affairs and Forestry 2002) statistically significant differences between the ASPT scores obtained by SASS and miniSASS become apparent.

Table 5: The water quality (Reserve) class boundaries for biotic composition (SASS) (modified from Draft Procedures for the Water Quality Reserve, Department of Water Affairs and Forestry 2002)

Class boundary	Lower boundary ASPT scores
Natural	7
Good	6
Fair	5
Poor	≤5

Conclusions

For the entire data set covering both regions there is no statistically significant difference between ASPT results obtained using miniSASS and those obtained using the normal, or full, SASS analysis. Once the data are split into different classes, however, there are statistically significant differences between certain SASS and miniSASS ASPT scores. Nonetheless, when the means of each class are examined (Figure 2) these differences are small and are always less than one ASPT score.

Potentially, every school, environmental/community group or NGO in South Africa could become a monitoring cell, and with this geographical spread, miniSASS could become a powerful tool as a 'red flag' for the identification of aquatic pollution sources and events. The parallel and supporting initiative is to be able to enter this biomonitoring data onto an Internet webbased mapping programme (see www.riverhealth.co.za). This extends the application of miniSASS, making networking and broader community-based catchment monitoring a real possibility.

miniSASS can therefore be used with confidence, producing data which vary slightly from those of SASS, but which nonetheless are sufficiently close to be of immense value to all stakeholders with an interest in river health. The increased opportunity for community user groups to *become involved* and to use a scientifically valid tool doing *real biomonitoring* of their river systems is probably the most important aspect of the development of miniSASS. Through this involvement the live, real-time monitoring and investigation of pollution sources is possible and the opportunity for improved environmental management becomes a reality.

Acknowledgments — The authors would like to sincerely thank Umgeni Water management for access to raw SASS data from the Umgeni Water operational area and time to develop this tool; Helen Dallas (Southern Waters) and Candice Haskins (Cape Metro Council) for access to raw SASS data from the Western Cape region, which allowed adaptation of miniSASS to Western Cape conditions; Christa Thirion (IWQS) for the bulk of the Mpumalanga data available on the Rivers Database; Rob O'Donoghue (ex KZN Nature Conservation Service) for creative ideas and encouragement in getting this work started, and Steve Camp (Umgeni Water External Education Services) for requesting a 'tool' of this nature. Randall Abrahams from Cape Metro Council for support in the development of the miniSASS website.

Table 6: Summary of statistical comparisons (t test for paired differences) between SASS and miniSASS ASPT predictions for all data and data separated regionally and into water quality (Reserve) classes (modified from Draft Procedures for the Water Quality Reserve, Department of Water Affairs and Forestry 2002)

Data source	Water quality class		Mean	Variance	Observations (n)	Pearson correlation (r^2)	Probability
Entire data set (Mpumalanga / Eastern Seaboard / Western Cape)	All data	SASS ASPT	5.57	2.39	2 127	0.82	NS (>0.05)
		miniSASS ASPT	5.54	1.58			
Mpumalanga / Eastern Seaboard data	All data	SASS ASPT	5.52	2.01	1 675	0.81	NS (>0.05)
		miniSASS ASPT	5.55	1.37			
	Poor WQ (ASPT <5)	SASS ASPT	3.92	0.74	554	0.78	Sig. (<0.01)
		miniSASS ASPT	4.45	1.29			
	Fair WQ (ASPT 5–5.9)	SASS ASPT	5.45	0.09	432	0.33	Sig. (<0.01)
		miniSASS ASPT	5.64	0.36			
	Good WQ (ASPT 6–6.9)	SASS ASPT	6.46	0.08	429	0.23	Sig. (<0.01)
		miniSASS ASPT	6.21	0.38			
	Natural WQ (ASPT >7)	SASS ASPT	7.51	0.22	260	0.05	Sig. (<0.01)
		miniSASS ASPT	6.63	0.40			
Western Cape data	All data	SASS ASPT	5.76	3.77	452	0.83	Sig. (<0.01)
		miniSASS ASPT	5.53	2.36			
	Poor WQ (ASPT <5)	SASS ASPT	4.06	0.34	211	0.54	Sig. (<0.01)
		miniSASS ASPT	4.40	0.75			
	Fair WQ (ASPT 5–5.9)	SASS ASPT	5.48	0.08	52	0.25	NS (>0.05)
		miniSASS ASPT	5.38	0.66			
	Good WQ (ASPT 6–6.9)	SASS ASPT	6.42	0.09	61	0.26	Sig. (<0.01)
		miniSASS ASPT	6.04	0.68			
	Natural WQ (ASPT >7)	SASS ASPT	8.38	0.82	128	0.39	Sig. (<0.01)

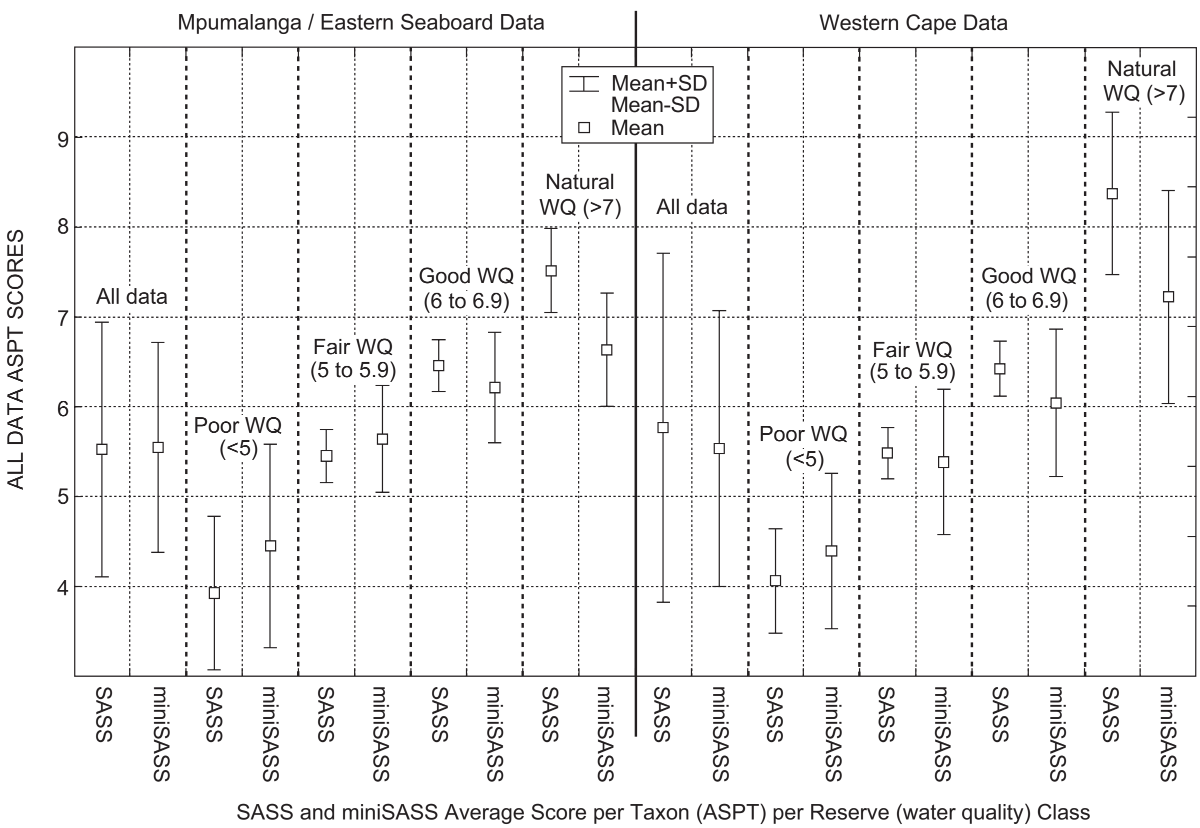

Figure 2: Comparative performance of SASS and miniSASS ASPT for the entire data sets and in the respective water quality (Reserve) classes in both the Mpumalanga / Eastern Seaboard and Western Cape regions

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Appendix 1: Summary of the miniSASS method

Where and how to sample

The best sites to sample are those where there are stones in fast-flowing water, and also where there is vegetation growing in the water at the sides of the river. If these habitats are not available, one will just have to look harder in those habitats that are available. Look for invertebrates in as many of the different habitats (biotopes) you can find at a river site. Invertebrates are collected by holding a small net (flexible mosquito netting formed around a wire coat hanger or a kitchen sieve will do) in the current, and then disturbing the stones, vegetation, sand etc. using your feet (with boots on!) or hands just upstream of the net. Be bold in turning the stones and disturbing the substrate that the invertebrates are clinging to. The invertebrates will be dislodged and will flow into the net. Do this for about five minutes while ranging across the river to cover a number of different habitats. Try not to get too many leaves and other debris in the net, as this will make subsequent invertebrate identification more difficult. You can also lift stones and pick off the invertebrates with your fingers or forceps or you can brush off the underside of the stones with a paintbrush into the net. Rinse any mud out of the net then turn the contents into a plastic tray and identify each group using the guide and according to the groupings as shown in Table A1. If the river is in reasonable condition you should have several hundred individual insects and other invertebrates in the sample.

Table A1: Aquatic invertebrate groupings used in miniSASS and their respective sensitivity scores for different geographic regions of South Africa

	Sensitivity Scores	
Aquatic invertebrate groupings	All Provinces, except the Western Cape	Western Cape
Planaria	3	3
Worms	2	2
Leeches	2	2
Crustaceans	6	6
Stoneflies	14	26
Minnow mayflies	5	5
Mayflies	13	13
Damselflies	4	4
Dragonflies	6	6
Bugs and beetles	7	7
Caddisflies	9	16
Flies	1	1
Snails	5	5

Calculation of the miniSASS score

For each of the groups found in your sample, circle the score given in the Table. Total the scores thus circled and divide by the number of groups found to get an average score. This score can be interpreted using the information below. miniSASS produces only one score, which is similar and comparable to the ASPT (average score per taxon) produced by the more complex version of SASS)

Interpretation of the miniSASS Score

0–2 Highly impacted stream
2–4 Impacted stream
4–6 Slightly impacted stream
>6 Good quality stream

On rare occasions an incorrect result will be obtained where the average score is high but the sample only contained a few (1–3) insect groups. When this happens this means that the river is impacted or disturbed but in a way that has favoured some sensitive organisms (e.g. certain chemical spills).

Appendix 2: List of aquatic invertebrate taxa routinely identified for the South African Scoring System (SASS4) analysis of water quality. Their quality values (sensitivity to pollution), common names, and whether they were considered for incorporation into miniSASS are also indicated. (Families not considered for incorporation into miniSASS development marked *)

Order	Family	Quality Value	Common name
PORIFERA	Sponges (*)	5	
COELENTERATA	Hydra sp. (*)	1	
TURBELLARIA	Planaria	3	Flat worms
ANNELIDA	Oligochaetae	1	Sludge / tubifex worms
	Hirudinae	3	Leeches
CRUSTACEA	Amphipoda	15	Sideswimmers
	Potamonautidae	3	Crabs
	Atyidae	8	Shrimps
	Paleomonidae	10	Freshwater shrimps
HYDRACARINA	Hydrachnellae (*)	8	Water mites
PLECOPTERA	Notonemouridae	12	Nemourid broadbacks
	Perlidae	12	Common stoneflies
EPHEMEROPTERA	Beatidae	4–12	small minnow mayflies
	Caenidae	6	Small square-gills
	Ephemeridae	15	Common burrowers
	Heptageniidae	10	Flat-headed mayflies
	Leptophlebiidae	13	Prong-gills
	Oligoneuridae	15	Brushleg mayflies
	Polymitarcyidae	10	Pale burrowers
	Prosopistomatidae	15	Water speck
	Trichorythidae	9	Little stout crawlers
ODONATA — ZYGOPTERA	Calopterygidae / Agriidae	10	Damselflies
	Chlorocyphidae	10	
	Chlorolestidae	8	
	Coenagrionidae	4	Narrow-winged damsels
	Lestidae	8	Spread-winged damsels
	Platycnemidae	10	
	Protoneuridae	8	Protoneuridae
ODONATA — ANISOPTERA	Aeshnidae	8	Dragonflies (darners)
	Corduliidae	8	Greeneyed skimmers
	Gomphidae	6	Clubtails
	Libellulidae	4	Common skimmers
LEPIDOPTERA	Nymphulidae (*)	15	Aquatic moths (catepillars)
HEMIPTERA	Belastomatidae	3	Giant waterbugs
	Corixidae	3	Water boatmen
	Gerridae	5	Long legged water striders
	Naucoridae	7	Creeping waterbugs
	Nepidae	3	Water scorpions
	Notonectidae	3	Back-swimmers
	Pleidae	4	Pygmy backswimmers
	Veliidae	5	Short-legged water-striders
MEGALOPTERA	Corydalidae (*)	8	Fishflies and dobson flies
TRICHOPTERA	Ecnomidae	8	Caseless caddises
	Hydropsychidae	4–12	Common netspinnners
	Hydroptilidae	6	Micro caddisflies
	Philopotamidae	10	Fingernet caddisflies
	Polycentropodidae	12	Trumpet-net caddisflies
	Pychomiidae	8	Net-tube caddisflies
	Other moveable case larvae	8–50	Other moveable case larvae
COLEOPTERA	Dytiscidae	5	Predaceous diving beetles
	Elmidae / Dryopidae	8	Riffle beetles
	Gyrinidae	5	Whirlygig beetles
	Haliplidae	5	Crawling water beetles
	Helodidae	12	Marsh beetles
	Hydraenidae	8	Minute moss beetles
	Hydrophilidae	5	Water scavenger beetles
	Lymnichidae	10	Minute marsh-loving beetles
	Psephenidae	10	Water pennies
DIPTERA	Athericidae	10	Watersnipe flies
	Blepharoceridae	15	Netwinged midges
	Ceratopogonidae	5	Biting midges

Appendix 2 cont.

Order	Family	Quality Value	Common name
	Chironomidae	2	Non-biting (red) midges
	Culicidae	1	Mosquitoes
	Dixidae	13	Dixid (meniscus) midges
	Empididae	6	Aquatic dance flies
	Ephydridae	3	Shore flies
	Muscidae	1	Aquatic house flies
	Psychodidae	1	Sand (moth) flies
	Simulidae	5	Black flies
	Syrphidae	1	Rat-tailed maggots
	Tabanidae	5	Horse and deer flies
	Tipulidae	5	Crane flies
GASTROPODA	Ancylidae	6	Limpets
	Bulininae	3	
	Hydrobiidae	3	
	Lymnaedae	3	Pond snails
	Physidae	3	Bladder snails
	Planorbinae	3	
	Thiaridae (Melaniidae)	3	
	Viviparidae	5	
PELECYPODA	Sphaeriidae	3	Clam, seed shells
	Unionidae	6	Fresh water mussels