CHAPTER 5

The use of aquatic invertebrates as biological indicators of ecological integrity of the Klip River System.

5.1 INTRODUCTION

Biological communities reflect overall ecological integrity (i.e. chemical, physical, and biological integrity). They have the ability to integrate the effect of different stressors and thus provide a broad measure of their aggregate impact (USEPA, 1996). Biological monitoring (biomonitoring) can be defined as the systematic use of biological responses to evaluate changes in the environment, with the intent to use this information in a quality control program (Matthews *et al.*, 1982). Macroinvertebrates, together with algae, are the two groups of organisms most often recommended for use in assessing water quality, although macroinvertebrates are by far the most commonly used group (Hellawell, 1986). Aquatic macroinvertebrates are greatly dependant on the quality and quantity of the water they live in for their health and survival. Macroinvertebrate taxa furthermore have differential tolerances towards changes in the environment. Some groups of invertebrates are very sensitive to specific changes, such as nutrient enrichment or metal pollution, and can be utilized as indicators of such changes. It is all of these characteristics that render them useful indicators in the assessment of ecosystem health. Apart from these characteristics, South Africa is also regarded as the country with the third most threatened invertebrate species in the world, after the USA and Australia (Ash, 2001). This is a clear indication that anthropogenic activities are presently threatening our invertebrate diversity, making them of even greater importance to use in biological monitoring programmes.

Benthic invertebrates have been used with great success around the world in various biomonitoring programmes and aquatic studies, as indicators of environmental degradation or restoration (Loeb and Spacie, 1994; Metcalfe-Smith, 1994; Resh, 1995; DeShon, 1995; Zamora-Munoz, 1995; USEPA 1996, Barbour *et al.*, 1999). The South African Scoring System (SASS) as developed by Chutter is one example of such a successful, rapid biomonitoring tool, based on macro-invertebrate diversity present at a river site (Thirion *et al.*, 1995). This index is also the most commonly used biological index in South Africa, and is accepted as one of the main protocols used in the River Health Programme of South Africa. The SASS version 4 was applied during this study as a rapid biomonitoring tool to assess spatial and temporal variation in ecological integrity of the Klip River. The invertebrate composition of the soft bottom sediments was also assessed in an attempt to identify areas currently impacted by pollutants and other anthropogenic activities.

5.2 MATERIALS AND METHODS

5.2.1 Aquatic Invertebrate Diversity of the soft-bottom substrates

The sampling of invertebrates from soft (sand, mud and silt) bottom substrates was performed by using a Birge-Eckman grab (sampling an area of $0.020736m^2$; factor of 48.225). Three grab samples were then taken within the most representative soft-substrate type at the site. Clay and silt particles present in the sample were washed out with the use of a net with a very fine mesh size (0.5 mm). A biological dye, "Rose Bengal", was then added to the sample in an attempt to colour all living organisms red. This ensured that the organisms could be more easily observed under a dissection microscope. Approximately one hour later, the sample was preserved in a 4% formalin solution. In the laboratory, the sample was washed and most of the sand and gravel removed. The rest of the sample was then examined under a dissection microscope and all organisms present were identified and counted. Identification was done using existing keys and literature on invertebrates.

5.2.2 South African Scoring System (Version 4) – SASS4

Benthic macro-invertebrate communities of the Klip River were also used to determine site-specific ecological integrity, using the South African Scoring System, version 4 (SASS4) approach. This method is based on the British Biological Monitoring Working Party (BMWP) method and has been adapted for South African conditions (Thirion *et al.*, 1995). Sampling at the selected localities was conducted seasonally. An invertebrate net (30 x 30 cm square with a 0.5 mm mesh netting) was used for the collection of the organisms. The available biotopes at each site were identified on arrival. Each of the biotopes was then sampled separately and by different methods. Sampling in different biotopes were done as follow:

- *Stones in current (SIC):* Movable stones of at least cobble size (3 cm diameter) to approximately 20 cm in diameter, within the fast and slow flowing sections of the river. Kicksampling was used to collect organisms in this biotope. This was done by putting the net on the bottom of the river, just downstream of the stones to be kicked, in a position where the current will carry the dislodged organisms into the net. The stones were then kicked over and against each other to dislodge the animals (kicksampling) for ± 2 minutes.
- *Stones out of current (SOOC):* Where the flow was quiet, such as behind a sandbank or ridge of stones or in backwaters. Collection was again done by method of kicksampling, but in this case the net was swooped across the area sampled to catch the dislodged biota. Approximately 1 m^2 was sampled in this way.
- *Sand*: These included sand banks within the river, small patches of sand in hollows at the side of the river or sand between the stones at the side of the river. This biotope was sampled by stirring the substrate, shuffling or scraping of the feet was done for half a minute, whilst the net was continuously swept over the disturbed area.
- *Gravel*: Gravel typically consists of smaller stones (2-3 mm up to 3 cm). Sampling was similar to that of sand.
- *Mud:* It consisted of very fine particles, usually as dark-coloured sediment. Mud usually settled to the bottom in still or slow flowing areas of the river. Sampling was also similar to that of sand.
- *Marginal vegetation (MV):* This included the overhanging grasses, bushes, twigs and reeds from the riverbank. Sampling was done by holding the net perpendicular to the vegetation (half in and half out of the water) and then sweeping it back and forth in the vegetation (± 2m of vegetation).
- *Aquatic vegetation (AQV):* Rooted, submerged or floating aquatic weeds such as *Potamogeton*, *Aponogeton* and *Nymphaea*. It was sampled by pushing the net (under the water) against and amongst the vegetation in an area of approximately one square meter.

The organisms sampled in each biotope were then identified with the use of existing manuals and identification keys. A score, based on the sensitivity of the family to poor water quality, is assigned to each family used in the SASS4 index. A final score was calculated by adding all scores of those families observed at a site. This was done for each separate biotope, as well as for all biotopes combined. The relative abundance of organisms was also noted on the score sheet. Habitat assessments, based on invertebrate specific criteria, were also performed during biological sampling. This was important due to the fact that changes in habitat can be responsible for changes in SASS4 scores. The habitat assessments were done by the application of SASS orientated habitat assessment indices. The habitat indices used were HABS1, which is an indication of the number of different biotopes sampled at a site, and the Habitat Quality Index (HQI) which gives an indication of the condition of the habitat at a site (Thirion *et al*., 1995). Interpretation of the SASS4 and Habitat Indices results were based on a general categorization of the scores in quality classes (Table 5.1).

Table 5.1: Categories used to classify SASS4, ASPT and habitat values into quality classes (From Thirion *et al.*, 1995).

HQI (%)	SASS4	ASPT	Condition
>75	>140	>7	Excellent
60 – 75	100 - 140	5 - 7	Good
44 – 59	60 - 100	3 - 5	Fair
30 – 43	30 - 60	2 - 3	Poor
< 30	<30	<2	Very poor

5.3 RESULTS

5.3.1 Aquatic invertebrate diversity.

All biotopes available at a site (aquatic and marginal vegetation, stones in and out of current, soft bottom substrates - sand, mud & gravel) were sampled at each of the selected biomonitoring localities. A total of 49 aquatic invertebrate taxa were observed at the 9 sites within the Klip River Catchment (Table 5.2). In the Suikerbosrand River, 41 aquatic invertebrate taxa were observed at a single site (reference locality) (Table 5.2). The lowest invertebrate taxa richness in the Klip River was observed at locality 9, where only 16 taxa were identified over the study period (Table 5.2). Other sites with relatively low taxa richness in the Klip River were localities 2 (21 taxa), 6 (22 taxa), 1 and 4 (24 taxa), 3 (25 taxa) and 8 (26 taxa). The highest number of aquatic invertebrate taxa was observed at locality 5 (31 taxa), while locality 7 also had a high diversity of 29 taxa. Locality 10 (reference site – Suikerbosrand River) had the highest taxa richness of all sites investigated (41 taxa).

Table 5.2: Invertebrate taxa observed at the different localities sampled.

TAXON	LOCALITY									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
CNIDARIA										
Hydra sp.		**B**		**B**					**B**	
TURBELLARIA										
Planarians	**S**		**S**	**S**	**S**	**S**	**S**	**S**		**B,S**
NEMATODA		**B**			**B**		**B**			
ANNELIDA										
Oligochaeta	**B,S**	**B,S**	**B,S**	**B,S**	**B,S**	**B,S**	**B,S**	**B,S**	**B,S**	**B,S**
Hirudinae	**S**		**B,S**	**S**	**S**	**S**	**B,S**	**S**	**S**	**S**
CRUSTACEA										
Daphnia	**B**									
Cyclops						**B**	**B**	**B**		
Ostracoda			**B**				**B**		**B**	
Crabs			**S**	**S**	**S**	**S**	**S**	**S**		**S**
Shrimps					**S**					**S**
HYDRACARINA										
Hydrachnellae	**S**	**S**		**S**	**S**		**S**			**S**
EPHEMEROPTERA										
Baetidae	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**B,S**
Heptageniidae										**S**
Leptophlebiidae								**S**		**S**
Tricorythidae										**S**
Caenidae		**S**			**S**	**S**	**S**	**S**	**S**	**B,S**
ODONATA										
Coenagriidae		**S**	**S**		**S**		**S**	**S**	**S**	**S**
Chlorocyphidae					**S**					
Gomphidae					**S**	**S**	**S**	**S**	**S**	**S**
Corduliidae	**B**				**S**			**S**		
Aeshnidae	**S**		**S**				**S**			**S**
Libellulidae	**S**						**S**			**S**

B – Present in Benthos sample **S – Present in SASS4 sample.**

Table 5.2 (Continue)

TAXON	LOCALITY									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
HEMIPTERA										
Notonectidae	S		S	S				S		S
Pleidae	S			S	S	S	S	S	S	S
Naucoridae	S	S		S	S	S	S	S		S
Nepidae				S						S
Belostomatidae			S	S				S		S
Corixidae	S	S	S	B,S	S	S	S	S	S	B,S
Gerridae										S
Veliidae	S	S	S	S	S	S	S	S	S	S
TRICHOPTERA										
Hydropsychidae	S	S	S	S	S	S	S	S	S	S
Ecnomidae		B,S		B,S		S		S	S	S
Movable case larvae:	S	S	S	S	S	S				S
Leptoceriidae	B									
COLEOPTERA										
Dytiscidae	S		S	S	S			S		S
Elmidae			S		S		S			S
Gyrinidae	S	S	S	S	S	S	S	S		S
Haliplidae					S					
Helodidae										S
Hydraenidae			S		S	S				
Hydrophilidae	S			S	S					S
DIPTERA										
Tipulidae	S	B,S								S
Culicidae										S
Simulidae	S	S	S	S	S	S	S	S	S	S
Chironomidae	B,S	B,S	B,S	B,S	B,S	B,S	B,S	B,S	B,S	B,S
Ceratopogonidae	B,S	B	B,S	S	S			S		B,S
Tabanidae							S			S
Empididae		S			S					S
Muscidae	S		S							S
GASTROPODA										
Lymnaeidae		S					B,S			
Planorbidae							S			
Physidae		S	S		S	S	S			
Ancylidae			S	S	B,S	B,S	B,S	S		S
PELECYPODA										
Sphaeridae	B		B,S			S	B,S	S	B,S	S
Number of taxa in benthos sample.	7	7	6	5	4	4	9	3	5	7
Number of taxa in SASS4 sample	22	18	24	23	30	21	26	25	14	41
Total Number of taxa observed.	24	21	25	24	31	22	29	26	16	41

B – Present in Benthos sample **S – Present in SASS4 sample.**

Invertebrate taxa that were sampled at all sites included the families Oligochaeta, Beatidae, Corixidae, Veliidae, Hydropsychidae, Simulidae and Ceratopogonidae (Table 5.2). Taxa that were very scarce in the Klip River (only observed at one of the sites) included the families of Atyidae, Leptophlebiidae, Chlorocyphidae, Nepidae, Tabanidae and Planorbidae (Table 5.2). Invertebrate taxa observed at the reference site but absent from the Klip River included Tricorythidae, Gerridae, Helodidae and Culicidae.

5.3.2 Invertebrates of the soft-bottom substrates

A total of 19 taxa were present in the soft-bottom substrate samples assessed in the Klip and Suikerbosrand Rivers (Appendix 5.1 to 5.4). The soft bottom substrate of the Klip River was generally dominated by the Oligochaeta family (Figures 5.1 to 5.4; Appendix 5.1 to 5.4). Individuals of the Chironomidae family were the second most abundant family observed in the soft bottom sediments of the Klip River. Other invertebrate taxa that were abundant in the soft bottom substrates included Hydra spp. (locality 9), Nematoda (locality 7), Ceratopogonidae (locality 2), Ostracoda (localities 3, 7 and 9), Planarians (locality 10) and Caenidae (locality 10).

Localities falling within the abundance class D (>10 000 individuals/m^2) were 3, 8, 9 and 10 (Figures 5.1 to 5.4 and Appendix 5.1 to 5.4). The soft bottom sediment of locality 3 fell within abundance class D for all the surveys where soft bottom sediments were assessed (August 1998, November 1998, February 1999 and May 1999). Localities with very low abundance (class A, < 100 individuals/m^2) were 2, 5, and 6 (Appendix 5.1 to 5.4).

5.3.3 South African Scoring System, version 4 (SASS4)

The total SASS4 scores in the Klip River ranged from 1 (locality 2 – 08/97) to 79 (locality 5 – 11/97). Total SASS4 scores for locality 10 (Suikerbosrand River) ranged from 64 (08/1997) to 173 (05/99). Average score per taxon (ASPT) values ranged from 1 (locality 2 – 08/1997) to 5.3 (locality 5 – 05/1999) in the Klip River. At locality 10 in the Suikerbosrand River, the ASPT values ranged from 4.4 (08/1998) to 7 (02/1998). Habitat Quality Index values (HQI) determined for the Klip River sites ranged from 28 (locality 9 – 05/1998) to 76 (localities 7 & 8 – 11/98). At locality 10, HQI values ranged between 67

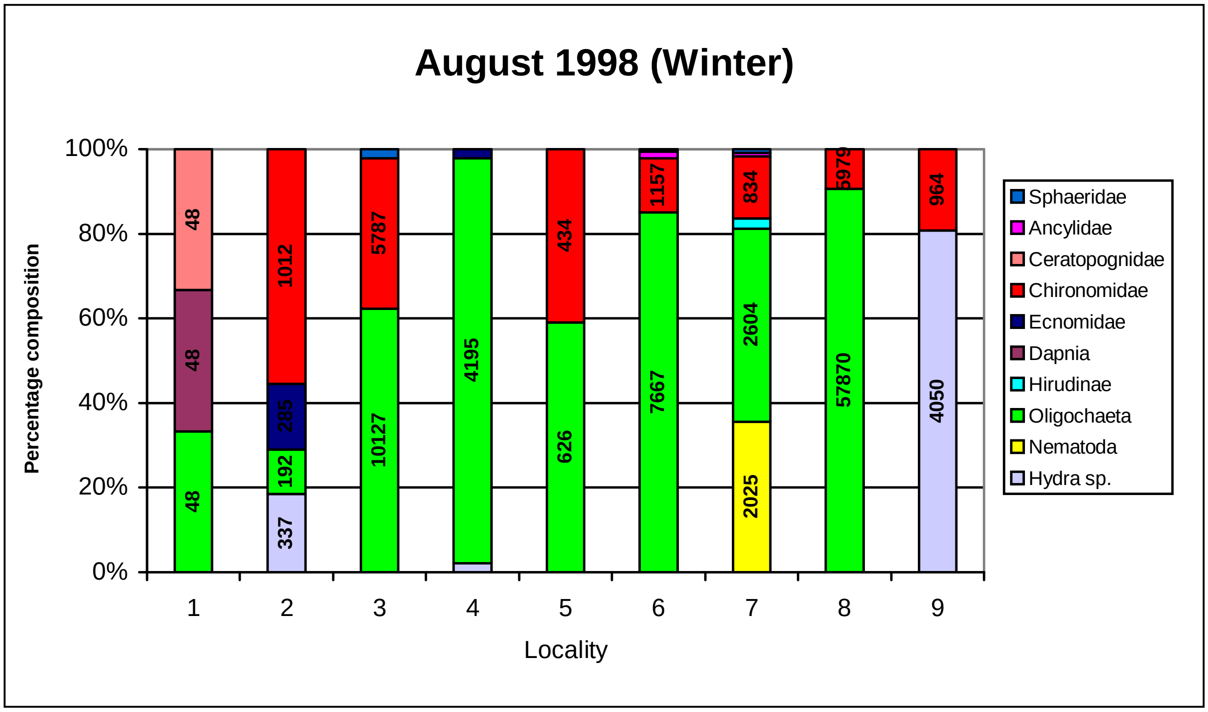

Figure 5.1: Percentage composition and number of individuals per square meter of the different invertebrate taxa of the soft bottom substrates, as determined for August 1998 (winter).

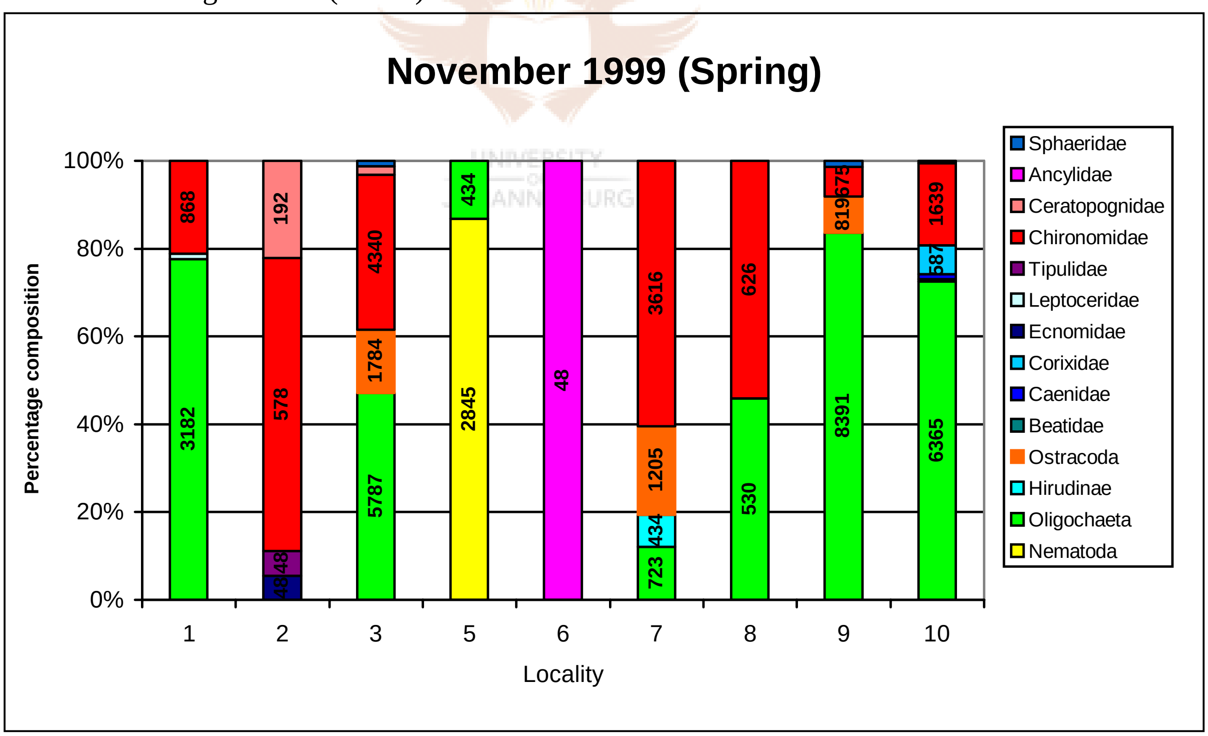

Figure 5.2: Percentage composition and number of individuals per square meter of the different invertebrate taxa of the soft bottom substrates, as determined for November 1998 (Spring).

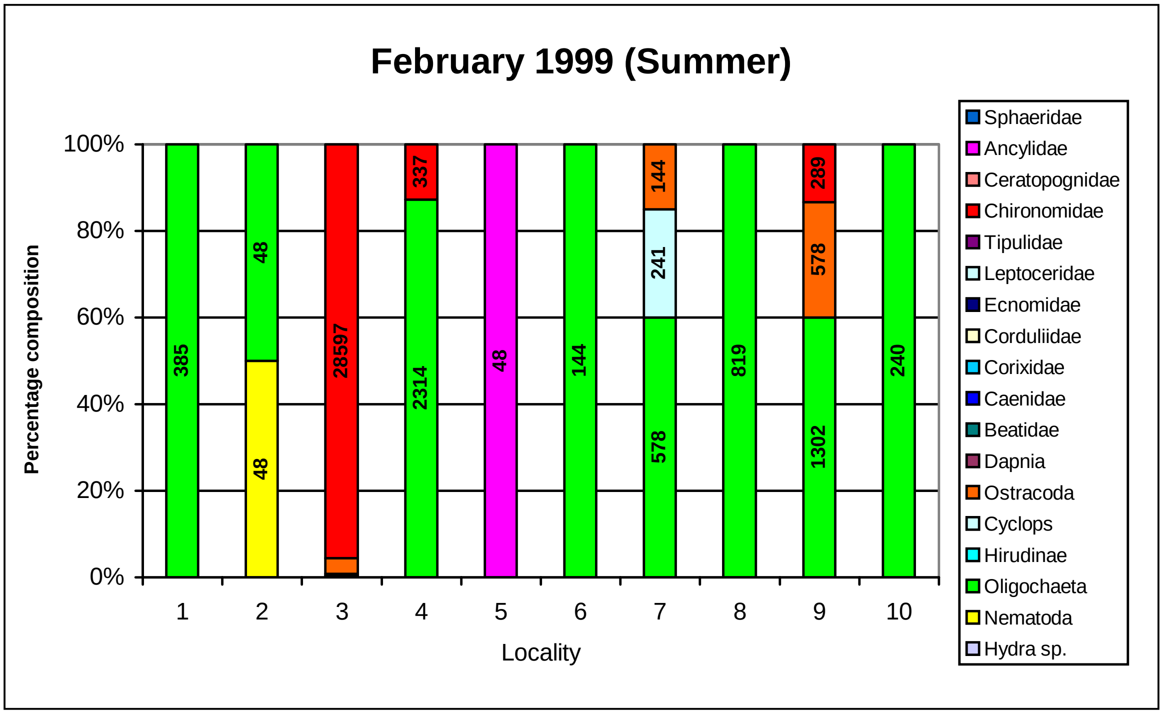

Figure 5.3: Percentage composition and number of individuals per square meter of the different invertebrate taxa of the soft bottom substrates, as determined for February 1999 (Summer).

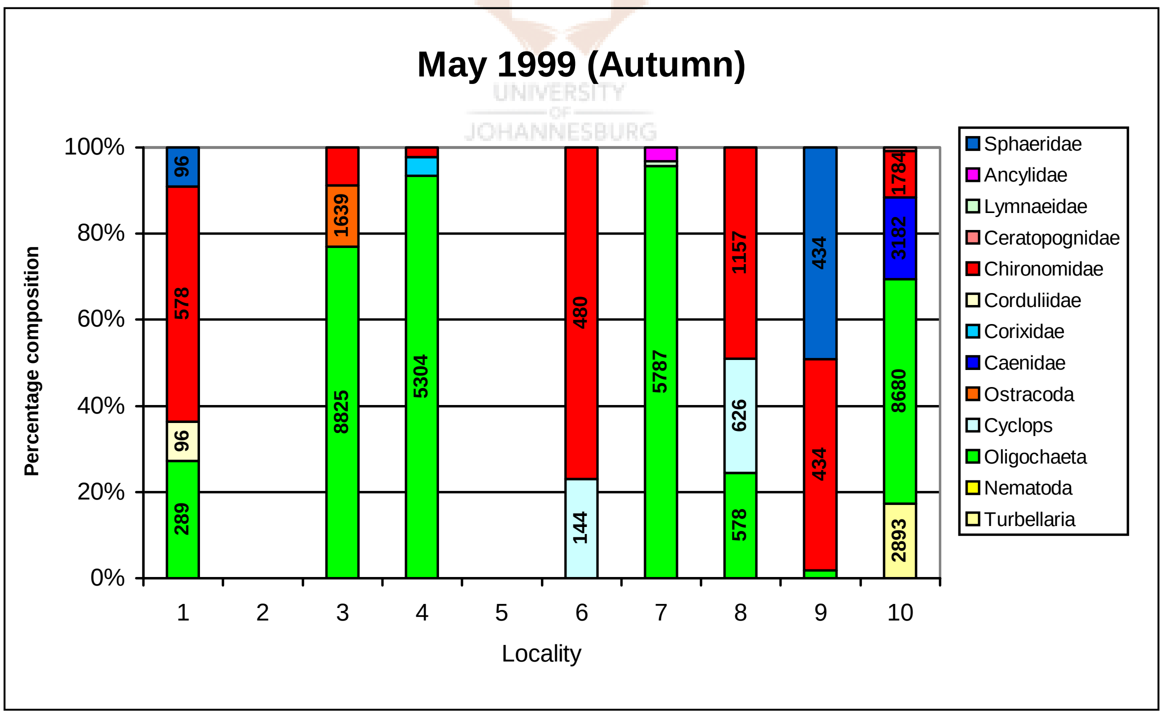

Figure 5.4: Percentage composition and number of individuals per square meter of the different invertebrate taxa of the soft bottom substrates, as determined for May 1999 (Autumn).

(11/1998) to 84 (08/1997). HABS1 values (habitat diversity sampled) in the Klip River ranged between 20 (locality 9) and 100 (localities 1, 3, 4 and 5). In the Suikerbosrand River, HABS scores ranged between 90 and 100 (Table 5.3).

Total SASS4 scores at locality 1 ranged between the very poor quality class and the fair quality class (Figure 5.5). ASPT values generally indicated fair conditions, although poor conditions were recorded during August 1997 (Figure 5.6). The Habitat Quality Index (HQI) values generally indicated good habitat quality while HABS1 index values were also generally high, which indicated good biotope diversity at this site (Figures 5.7 and 5.8). In general, the SASS4 scores improved over the study period, although the habitat quality and diversity remained relatively unchanged.

SASS4 scores determined for locality 2 ranged between the very poor and poor quality classes, but were mostly within the very poor class. ASPT scores were however generally within the fair class. HQI scores ranged between 41 (poor) and 67 (good) but were mostly in the fair to good class. HABS1 scores ranged from 55 to 90 at this site, but, in general, were adequate to support a diverse habitat for aquatic invertebrates in this area of the river.

At locality 3, the SASS4 scores ranged between 19 (very poor) and 71 (fair). ASPT scores generally fell within the fair class. Habitat Quality Index (HQI) scores at this site ranged between 60 (good) and 76 (excellent), and were primarily within the good class. HABS1 scores were mostly also high at this site.

SASS4 scores determined for locality 4 ranged between 23 (very poor) and 65 (fair), and fell predominantly within the poor quality class, while ASPT scores generally fell within the fair class. HQI scores ranged from 59 (fair) to 84 (excellent) and generally fell within the good quality class. The HABS 1 scores calculated for locality 4 ranged between 85 and 100 (Table 5.3).

Locality 5 had the highest SASS4 scores of all sites within the Klip River, ranging from 36 (poor) to 79 (fair) and fell predominantly in the poor class (Figure 5.5). ASPT scores ranged from 4 (fair) to 5.3 (good), and indicated a slight decrease over the study period (Table 5.3 & Figure 5.6). The HQI values at locality 5 ranged between 50 (fair) and 64 (good) while HABS1 scores ranged between 80 and 100 (Table 5.3 and Figures 5.7 and 5.8).

SASS4 scores at locality 6 ranged between 24 (very poor) and 50 (poor), and fell predominantly within the poor class (Figure 5.5). ASPT scores indicated fair conditions, ranging between 3.4 and 4.5. HQI scores fell within the poor (41) and good (65) quality classes. HABS1 values ranged between 55 and 80.

Throughout the study period, SASS4 scores determined for locality 7 fell within the poor quality class, ranging between 30 and 51. ASPT values again fell within the fair class, ranging between 3.5 and 4.6. The HQI values ranged between 50 (fair) and 76 (excellent) but were predominantly within the good class. HABS1 scores for this site ranged between 70 and 90.

At locality 8, the SASS4 score fell within the poor class throughout the study period, and ranged between 33 and 51. ASPT scores fell within the fair class and ranged between 3.5 and 4.6. HQI values ranged between 50 (fair) and 76 (excellent), while HABS1 scores fell between 60 and 95 at locality 8.

The SASS4 scores were very low at locality 9, always being within the very poor class, with scores ranging from 3 to 26. ASPT scores ranged between 1.5 (poor) and 4.4 (fair) and fell predominantly in the fair class. HQI values ranged between 28 (very poor) and 48 (fair) and can, in general, be classified as poor. The habitat diversity at this site was generally very poor, with HABS scores ranging from 20 to 45 (Table 5.3 and Figures 5.5 to 5.8).

SASS4 scores calculated for locality 10 (reference site in Suikerbosrand River), were always much higher than those calculated for the Klip River. The SASS4 scores at locality 10 ranged between 64 (fair) and 173 (excellent), and fell predominantly within the good class. ASPT scores ranged from 4.4 (fair) to 7 (good). HQI scores determined at this site ranged from 84 (excellent) to 67 (good), and indicated a slight decrease in habitat quality over the study period. The habitat diversity for macro-invertebrates was generally very good at this site, with HABS1 scores ranging between 90 and 100.

Spatial variation

Total SASS4 scores generally decreased from locality 1 to 2, while ASPT slightly increased. The habitat quality was slightly lower at locality 2 than at 1, while habitat diversity was quite similar. There was a general increase in SASS4 scores from locality 2 to 3, while the ASPT scores were relatively similar between these two sites. The habitat quality and diversity was, however, better at locality 3 than at locality 2. SASS4, ASPT scores and habitat diversity were generally very similar between localities 3 and 4, although the habitat quality was slightly better at locality 4 than at locality 3.

SASS4 and ASPT scores increased from locality 4 to 5, while habitat quality was lower at locality 5 than at 4. In general, the habitat diversity was very similar between these two sites. The SASS4 scores, ASPT values and HABS1 scores always decreased form locality 5 to 6, while the habitat quality remained generally unchanged. SASS4 scores and ASPT values were quite similar to, or slightly higher at locality 7 than 6. The habitat quality and diversity at locality 7 was slightly higher than that of locality 6. SASS4 scores, ASPT values, habitat quality and diversity were very similar between localities 7 and 8. There was a profound decrease in SASS4 scores and ASPT values from locality 8 to 9. Habitat quality and diversity were also very much lower at locality 9 than at 8.

In an attempt to classify the degree of degradation at each site in the Klip River, a classification system was used in which each site was compared to the condition observed at the reference site, taken as the reference condition for the macroinvertebrate component of the Klip River (Thirion *et al*., 1995; Dallas, 2000). Based on this classification system, locality 1 fell generally within the severely impaired class (Figure 5.9). All other sites in the Klip River fell predominantly within the ranges of the considerably impaired class. Localities 3, 5, 6 and 7 fell, at times, within the moderately impaired class. Based on this classification system, no sites in the Klip River could be classified as unimpaired, when the reference site is taken as the expected condition.

Table 5.3: SASS 4 scores, average score per taxon (ASPT), Habitat Quality Index (HQI) scores and HABS1 scores determined for each locality during the study period. (Excellent, Good, Fair, Poor, Very Poor).

Locality	Variable	Survey							
		08/97	11/97	02/98	05/98	08/98	11/98	02/99	05/99
1	SASS4	11	41	15	21	39	48	65	58
	ASPT	2.8	4.1	3.8	3.5	4.3	4.0	4.6	4.4
	HQI	65	73	56	64	60	67	64	65
	HABS1	90	85	80	50	60	65	100	90
2	SASS4	1	7	26	31	19	39	33	36
	ASPT	1	3.5	4.3	4.4	4.8	4.9	4.1	4.5
	HQI	64	59	46	52	41	59	67	67
	HABS1	85	80	80	70	55	85	75	90
3	SASS4	30	71	19	51	39	40	33	61
	ASPT	3.8	4.7	3.8	4.3	3.5	3.1	3.7	4.3
	HQI	69	60	69	60	64	63	69	76
	HABS1	80	90	90	95	85	85	100	95
4	SASS4	23	62	61	39	37	46	46	65
	ASPT	3.8	4.1	4.7	4.3	3.7	3.8	4.2	4.0
	HQI	70	70	61	70	59	75	62	84
	HABS1	90	90	90	85	95	90	90	100
5	SASS4	36	79	52	53	36	61	48	68
	ASPT	5.1	5.3	5.2	4.8	4	4.1	4.8	4.8
	HQI	61	64	53	61	50	56	60	64
	HABS1	90	95	90	95	85	80	85	100
6	SASS4	45	33	32	28	50	24	46	44
	ASPT	4.1	4.1	4.0	3.5	4.5	3.4	4.2	4.4
	HQI	65	50	53	55	41	60	53	58
	HABS1	70	60	70	60	55	80	80	55
7	SASS4	30	36	38	50	51	35	39	45
	ASPT	3.8	4.0	3.5	4.2	4.6	3.5	3.9	4.5
	HQI	64	64	60	59	50	76	73	66
	HABS1	85	85	70	70	70	90	85	70
8	SASS4	N/a	33	34	50	51	35	39	45
	ASPT	N/a	3.7	3.5	4.2	4.6	3.5	3.9	4.5
	HQI	N/a	59	60	59	50	76	73	66
	HABS1	N/a	60	70	70	70	90	85	70
9	SASS4	N/a	20	3	13	9	7	22	26
	ASPT	N/a	3.3	1.5	3.3	3.0	3.5	4.4	3.25
	HQI	N/a	48	40	28	31	33	41	47
	HABS1	N/a	20	20	20	20	20	45	40
10	SASS4	64	136	140	119	83	108	139	173
	ASPT	4.9	5.9	7.0	5.7	4.4	5.1	5.6	5.7
	HQI	84	80	75	75	70	67	73	73
	HABS1	95	90	90	95	100	95	100	90

N/a – Not available

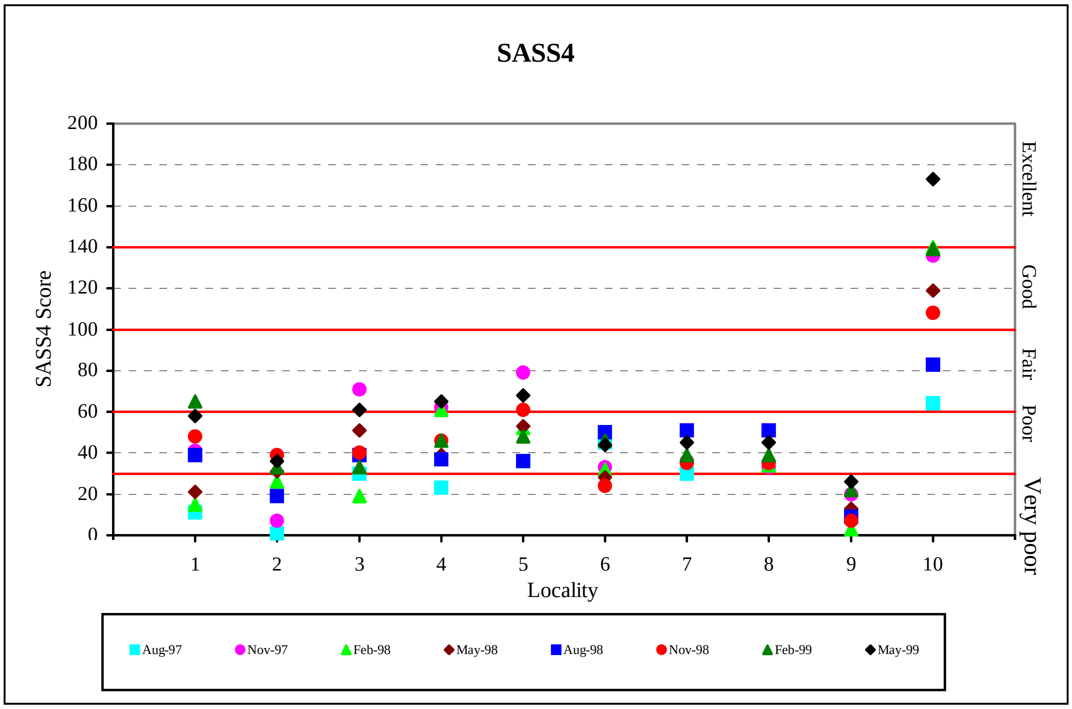

Figure 5.5: Temporal and spatial variation in SASS4 scores of the selected study localities.

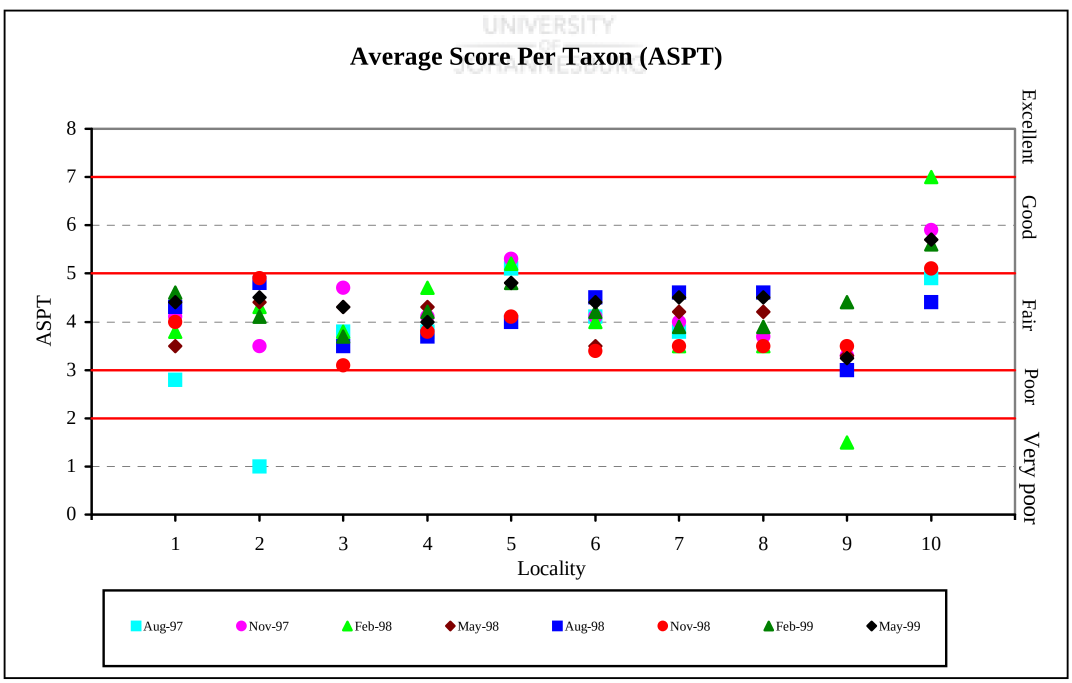

Figure 5.6: Temporal and spatial variation in ASPT scores of the selected study localities.

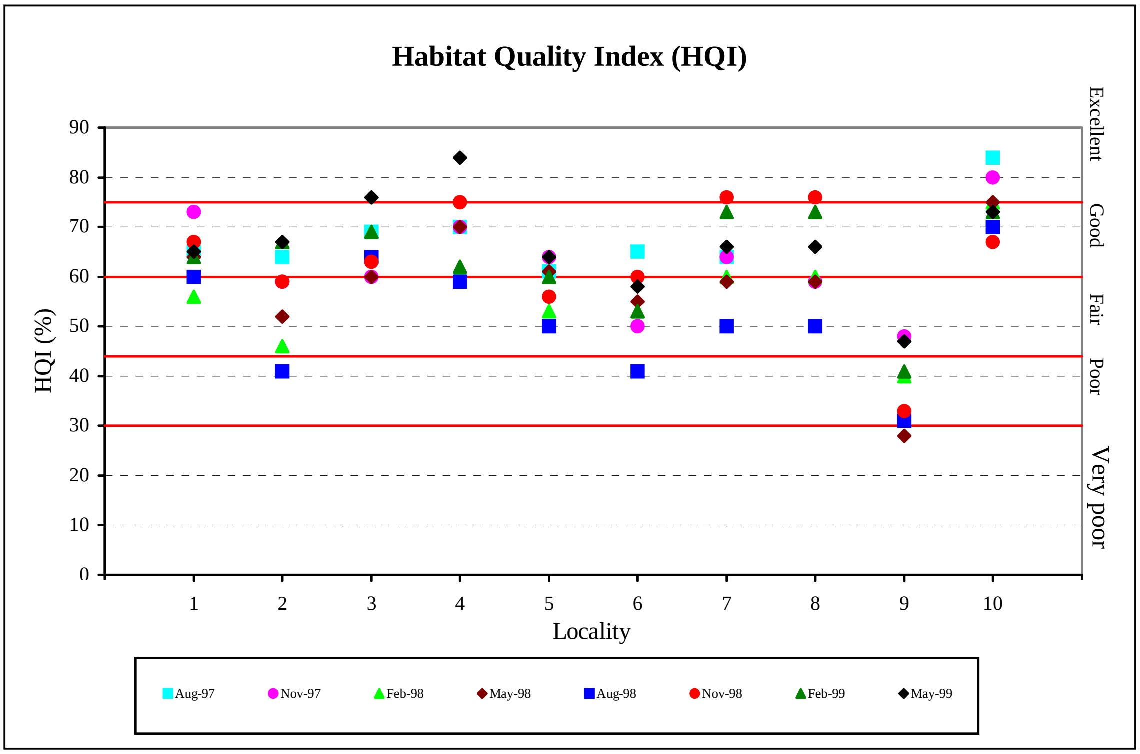

Figure 5.7: Temporal and spatial variation in HQI scores of the selected study localities.

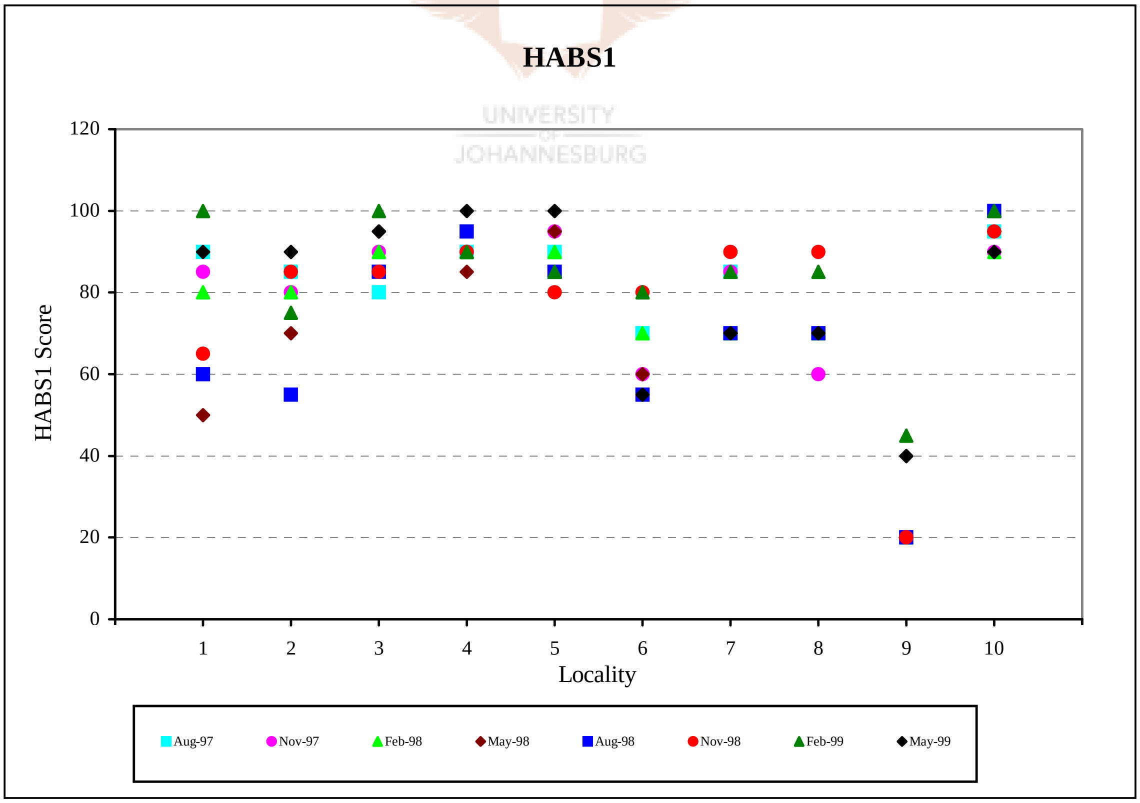

Figure 5.8: Temporal and spatial variation in HABS1 scores of the selected study localities.

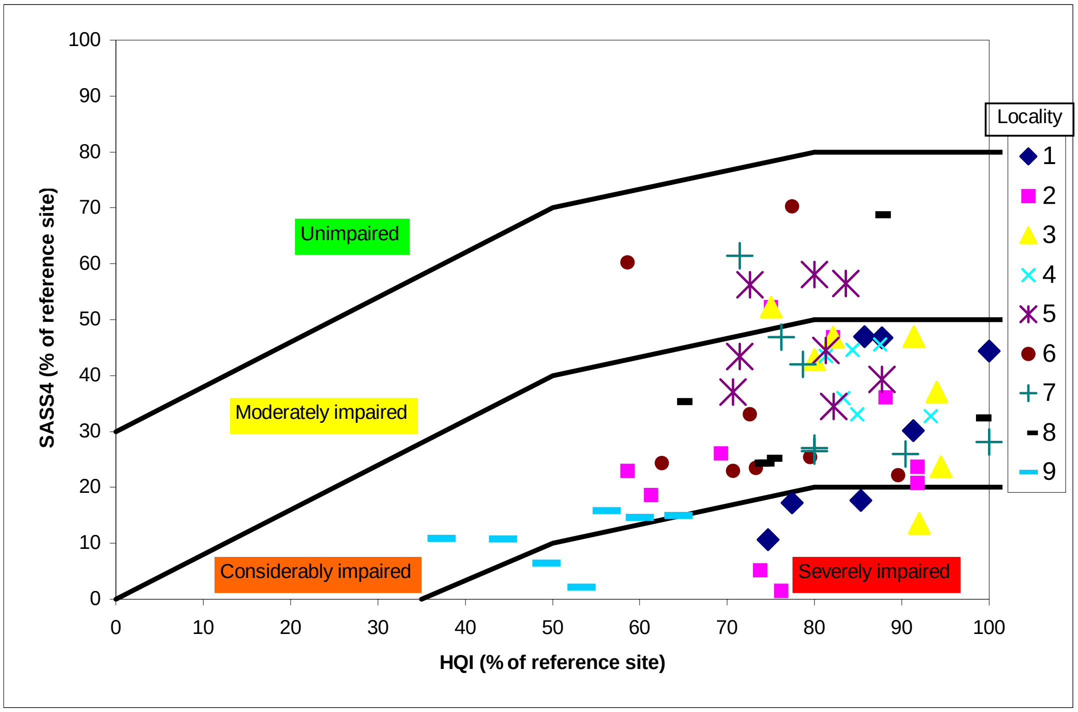

Figure 5.9: Classification of the sampling localities in different biotic integrity classes (in relation to the reference site), based on the SASS4 scores and HQI values.

5.4 DISCUSSION

The quality and availability of water, substrate and food sources determine the natural distribution of invertebrates in aquatic ecosystems. Alteration of the natural condition of any aquatic ecosystem will lead to a shift in equilibrium, and a change in the invertebrate community of that system. In the Klip River, a total of 49 aquatic invertebrate families were observed at nine localities, from its source, to the confluence with the Vaal River. At a single site in the Suikerbosrand River, a river within the same region as the Klip River but having far less human interference, 41 aquatic invertebrate families were observed at a single site. It therefore seems that the aquatic invertebrate diversity of the Klip River is presently lower than should be attainable under unimpacted conditions, thus indicating on decreased ecological integrity of the system.

It is surmised that the decreased invertebrate diversity is linked to both decreased water quality as well as to habitat changes, due to the extensive presence of human activities in its catchment. Water quality deterioration in the Klip River can primarily be attributed to industrial and mining effluent, formal and informal settlements, water care works (WCW) effluents and agricultural activities in its catchment (see Chapter 4). It is a well-known fact that some invertebrate families are more tolerant to water quality changes than others (Chutter, 1971; Thirion *et al*., 1995). The absence of intolerant aquatic invertebrate families from most Klip River localities would therefore be a definite indication of decreased water quality as a cause of degradation of ecological integrity.

The unnatural increase in flow, primarily attributable to various water care work (WCW) effluents discharged into the river, resulted in fast flowing habitats which dominate most of the lower section of the river. It can therefore be expected that aquatic invertebrates, which prefer slower habitat types, were influenced negatively by these human-induced flow modifications. The increased flows furthermore resulted in aggravated bank erosion, leading to a decrease in marginal vegetation habitats. Aquatic invertebrates favouring vegetated habitats can therefore also be expected to have been influenced by the increased flows. The impact of increased flow on aquatic invertebrate diversity was especially evident at locality 9 (most downstream site), which was dominated by fast runs and very little overhanging vegetation. Only 19 invertebrate families were observed at this site, a phenomenon that can probably be attributed to the absence of fast, shallow habitats (riffles and rapids) and marginal vegetation.

The highest aquatic invertebrate diversity in the Klip River was observed at localities 5 and 7. This phenomenon is likely to be attributable to the general high habitat diversity at these sites. The most common aquatic invertebrate families in the Klip River were Oligochaeta, Beatidae, Corixidae, Veliidae, Hydropsychidae, Simulidae and Chironomidae. Most of these families are tolerant to changes in the environment.

Oligochaeta and Chironomidae, both very tolerant aquatic invertebrate families, were especially common, occurring at most sites in the Klip River. The soft bottom substrates of most of the Klip River sites were generally dominated by the Oligochaeta family, with the Chironomidae family being the second most abundant family observed. These two groups of invertebrates are often used as indicators of organic enrichment or eutrophication (Rosenburg and Rosh, 1992, Davies *et al*., 1993, Adendorff, 1997). Furthermore, they furthermore predominate in habitats where depositing sediment accumulates (Hellawell, 1986) and are also especially abundant in filamentous algae (Pennak, 1989). Both Oligochaeta and Chironomidae have been observed to be the last survivors after mining impacts (Aagaard and Sivertsen, 1997). The high numbers of these two groups often found in the soft bottom sediment of the Klip River, is a definite indication of organic enrichment of this system. It is envisaged that organic pollution and nutrient enrichment, originating from informal settlements and WWTW's, were responsible for the high number of Oligochaeta and Chironomidae individuals observed in the soft-bottom substrates of the Klip River. This phenomenon was especially evident at locality 3 in the Klip River. The Klip River flows through an informal settlement area (western Soweto), directly upstream of locality 3, and this settlement area is probably responsible for organic pollution, giving rise to the extremely high abundances of Oligochaeta and Chironomidae at this site.

Localities with very high abundances of aquatic invertebrates (>10 000 individuals/m^2) were sites 3, 8, 9 and 10. In most cases, these abundances were attributed to high numbers of individuals from the Oligochaeta and Chironomidae families. Soft-bottom substrates of locality 3 had very high invertebrate abundances, of more than 10 000 individuals/m^2, for all surveys. A study conducted in this section of the Klip River during the early 1970's already revealed extremely high densities of up to 14 781 individuals/m^2, observed during a summer survey (Viljoen, 1972). During the present study, densities at locality 3 ranged between 11 476 individuals/ m^2 (autumn) and 29 946 individuals/ m^2 (summer). Based on these results, densities observed during the summer months have increased significantly since 1972, and therefore also indicate nutrient enrichment in this area over the past few years (see Chapter 3).

A very low abundance (< 100 individuals/m^2) of invertebrates was observed in the soft-bottom substrates of localities 2, 5 and 6. Viljoen (1974) recorded no organisms in the soft-bottom substrates of the upper reaches of the Klip River during the early 1970's. Although the diversity observed during this study was also low at localities 1 and 2, ranging between 0 to 4 taxa, it at least indicates a slight improvement in biotic integrity of the upper reaches of the Klip River since the 1970's. This might be an indication of reduced impacts from mining activities in the area, due to improved management and decreased mining activities, and also reduced mining water effluents.

The more intolerant invertebrates, such as Atyidae, Leptophlebiidae, Chlorocyphidae, Nepidae, Tabanidae and Planorbidae were very scarce and only observed at single sites in the Klip River. Intolerant invertebrates observed in the Suikerbosrand River, but absent from the Klip River, included Tricorythidae, Heptageniidae, Gerridae, Helodidae and Culicidae. This would be an indication that the Suikerbosrand River has a higher potential to sustain intolerant invertebrates than the Klip River. It is therefore evident that the ecological integrity of the Klip River is highly degraded, when compared to a less impacted river system such as the Suikerbosrand River.

South African Scoring System (Version 4).

Macroinvertebrates are by far the most commonly used group of organisms in assessing water quality (Hellawell, 1986). Benthic macroinvertebrates offer many advantages in biomonitoring, which explains their popularity. Firstly they are ubiquitous, therefore they can be affected by environmental perturbations in many different types of aquatic systems and in habitats within those waters. Secondly, the large number of species involved offers a spectrum of responses to environmental stresses. Because many benthic macroinvertebrates have limited migration patterns or a sessile mode of life, they are particularly well suited for assessing site-specific impacts (USEPA, 1996). They furthermore have relatively long life cycles, which allows detection of temporal changes caused by perturbation (Rosenberg and Resh, 1992). Macroinvertebrates should, however, not be seen as the ultimate biomonitor that could give the answers to all water quality assessments. A previous study has indicated that in some cases invertebrates do not respond to anthropogenic activities, while other biota would be affected negatively (Rosenburg and Resh, 1992). It is therefore essential that macroinvertebrates should be used in conjunction with other biomonitoring protocols to ensure holistic assessments and effective management.

The SASS4 scores in the Klip River ranged between 1 (locality 2) and 79 (locality 5), indicating on very poor to fair conditions prevailing. SASS4 scores in the Suikerbosrand River (control site) ranged between 64 and 173, indicating on fair to excellent condition. Average Score Per Taxon (ASPT) values generally indicated on similar conditions, with the only exception being locality 5, which fell into the good quality class. Habitat Quality Index (HQI) scores in the Klip River indicated a range between very poor and excellent conditions, while the reference site (locality 10) generally had good to excellent habitat quality.

The SASS4 scores at locality 1 ranged between the very poor and the fair class, mostly falling within the poor class. The habitat quality, based on the Habitat Quality Index scores (HQI) and habitat diversity, based on the HABS1 scores were generally high, with the habitat quality mostly falling within the good class. It may therefore be assumed that the poor SASS4 scores observed at this site is likely attributable to poor water quality or quantity, as habitat quality and diversity were adequate to sustain a viable macroinvertebrate population. The water quality at this site was however generally good, with only magnesium and phosphates reaching unacceptable levels at stages (see Chapter 3). It should be noted that the use of biological communities, such as aquatic invertebrates, provides a longer term picture of the conditions prevailing at a site, due to the fact that biotic communities have the ability to accumulate stresses over time (USEPA, 1996). Water quality measures give an instantaneous value, whereas an interpretation of the water quality using macroinvertebrates is representative of the water quality during, but also prior to the survey (Chutter, 1994). Secondly, the nature of the pollutant causing the change in the macroinvertebrate fauna is frequently obscured (Chutter, 1994). Emphasis should therefore not be too strong on the water quality measured at a site during the time of biological sampling, as the biotic community could have been affected by impacts prior to the survey, that may not be revealed in a water quality sample. Water quality variables measured in concerning levels at the time of sampling, may however be the likely cause for the decreased biotic integrity.

The low SASS4 scores at locality 1 are most probably attributable to a natural limited aquatic invertebrate community, often observed in the upper reaches of rivers, even under unperturbed conditions. This phenomenon can primarily be attributed to the low energy levels in the system due to a lack of nutrients (Davies *et al*., 1993; Loeb and Spacie, 1994). Stream size and temperature furthermore plays an important role in taxa richness, with smaller streams and colder streams generally having a lower taxa richness than larger and/or warmer rivers (Loeb and Spacie, 1994; Zamora-Munoz *et al*., 1995). The highest SASS4 score (65) at locality 1 was attained during the summer of 1999, indicating that fair biotic conditions should be attainable at this site during the summer months. The previous summer (1998) survey revealed a SASS4 score of only 15 (very poor). The habitat quality and diversity were slightly better during the summer 1999 survey, which could have contributed to the increased SASS4 scores. Improvement in water quality over the study period can, however, not be ruled out as a probable cause for the improved biotic integrity observed at this site, as mining activities also decreased in the area. A SASS4 score attained during a summer survey at locality 1, falling below the fair class, should be seen as a potential concern that may be indicating a deteriorating biotic integrity in this section of the river.

The SASS4 scores obtained at locality 2 indicated that very poor to poor biotic conditions prevailed at this site during the study period, based on the macro-invertebrates. Although the habitat quality was slightly lower at locality 2 than at locality 1, the decrease in SASS4 scores from locality 1 to 2 cannot be attributed to lacking habitat components. The primary cause for the poor biotic conditions at locality 2 is rather attributed to decreased water quality, as various water quality variables generally decreased from locality 1 to 2. These included chemical oxygen demand (COD), turbidity, electrical conductivity (EC), total dissolved solids (TDS), water hardness, calcium (Ca), total alkalinity, magnesium (Mg), potassium (K), sodium, nitrates, chloride (Cl), Fluoride (F) total iron (Fe) and manganese (Mn) levels (Chapter 3). High concentrations of most of these variables have been indicated as being sub-lethal and even lethal to invertebrate communities (Zamora-Munoz et al., 1995; Dallas & Day, 1993). Toxicity is furthermore not only associated with high concentrations of these water quality variables, but also by the nature of the compounds and synergism. Mortality of invertebrates due to electrical conductivity or TDS is, for instance not only linked to their concentrations, but also to the nature of the salt (Goetsch & Palmer, 1997). It is therefore evident that various water quality variables indicated water quality deterioration from locality 1 to 2, which could be responsible for the decrease in biotic integrity between these two sites. The decreased water quality at locality 2 is most probably due to gold mining activities in the area, which may be the source of increased metals and other pollutants. Reduced total abundance and species richness, and changes in macroinvertebrate dominance often occur in aquatic systems polluted by heavy metals (Rosenberg and Rosh, 1992; Aagaard and Sivertsen, 1979; Adendorff, 1997). The habitat quality and diversity at locality 2 should be adequate to sustain a viable aquatic invertebrate community, if water quality could be improved in this section of the Klip River.

SASS4 scores indicated a slight improvement in biotic conditions from locality 2 to 3. The habitat quality and diversity was, however, also slightly better at locality 3 than at 2. Habitat changes could therefore be partly responsible for the increased macro-invertebrate diversity observed at locality 3. Water quality variables such as EC and TDS, water hardness as $CaCO_3$, Ca, Mg, Na, total Zn and dissolved Al generally improved from locality 2 to 3. Dissolved O_2, suspended solids, turbidity, total alkalinity, ammonia, ortho-phosphates, phosphates, nitrate, chloride and total manganese, however, generally decreased from locality 2 to 3 (Chapter 4). Poor water quality at this site can primarily be attributed to formal and informal settlement runoff directly upstream of this site, as well as the prolonged impact of the mining activities in the vicinity of locality 2. The very poor to fair biotic conditions observed at this locality 3 could again rather be attributed to poor water quality than to lacking habitat diversity and condition. There was a profound decrease in SASS4 scores at this site from 71(fair) during 11/1998 to 19 (very poor) during 02/1999, although the habitat quality stayed similar. This might be an indication that (sporadic) pollution incidents may occur in this area of the Klip River from time to time, which could be responsible for the extreme reduced biotic integrity. The relevant authorities should further investigate the potential sources of such pollution incidences in this section of the Klip River.

There was generally no definite improvement or deterioration in SASS4 scores from locality 3 to 4 during the study period and no profound changes in water quality could be seen between these two sites. SASS4 scores at locality 4 ranged between the very poor and fair classes, but fell mainly within the poor quality class. The habitat quality and diversity were generally good at this locality, and the poor biotic integrity, based in macro-invertebrates, is again most probably not related to lacking habitat components. It is therefore evident that the poor water quality at locality 4 was the primary cause for the degradation in the biotic integrity of this site. Water quality deterioration at this site is most probably related to the impact of the Klipspruit water entering the Klip River just upstream of locality 4. It however appears that this impact is lessened by dilution which occurs due to large amounts of water being released from the Olifantsvlei Wastewater Treatment Works (WWTW's), directly upstream of locality 4. Dickens and Graham (1998) indicated that WWTW were responsible for significant deterioration of invertebrate fauna in rivers with good water quality in KwaZulu/Natal. Wastewater treatment effluents however had no significant decrease in rivers with already poor water quality (Dickens and Graham, 1998), similar to the scenario observed in this section of the Klip River. The water from the WWTW could have been responsible for degradation of some water quality variables, such as chlorides and nitrates. Extensive growth of filamentous algae generally occurred downstream from this site. This scenario has already been observed in a study conducted by Viljoen in the early 1970's (Viljoen, 1974). It is attributed to nutrient enrichment, originating primarily from informal settlements and WWTW's. The extensive algal growth caused embeddedness of the substrates, and could therefore also have contributed to further degradation of biotic integrity of this section of the Klip River.

SASS4 scores generally increased slightly towards locality 5, where the highest SASS4 score in the Klip River was also recorded (score = 79). Habitat quality was lower at locality 5 than at locality 4, while habitat diversity were very similar between these two sites. The increased biotic integrity can therefore probably be related to improved water quality. Although it seems that an improvement occurred in this section of the river, the biotic integrity was still highly degraded with SASS4 scores still primarily falling within the poor quality class.

There was always a significant decrease in SASS4 scores from locality 5 to 6. This decrease can be partly attributed to lower habitat quality and significantly lower habitat diversity at locality 6. There was also, however, a degradation in many water quality variables between locality 5 and 6 (Chapter 4). Water quality variables deteriorating from locality 5 to 6 included dissolved oxygen, chemical oxygen demand, suspended solids, EC, TDS, hardness as $CaCO_3$, Ca, Mg, Na, ortho-phosphates, phosphates, Cl, total Fe and dissolved Al. The deteriorating water quality, and thus biotic integrity, between localities 5 and 6 are primarily attributed to the impact of the Rietspruit. The Rietspruit drains a highly populated area with active mining and industrial areas, which are the primary cause for the poor water quality of this river system. Increased metal levels, due to the influence of the Rietspruit, could again have been a major factor responsible for the decreased biotic integrity observed at locality 6, as heavy metal pollution is especially responsible for reduced biotic communities (Rosenberg and Rosh, 1992; Aagaard and Sivertsen, 1979; Adendorff, 1997).

The SASS4 index did not indicate a significant improvement or deterioration in conditions between localities 6 to 7. Habitat quality and diversity were only slightly better at locality 7 than at 6 and water quality was also generally very similar between these two sites. It was therefore evident that no further degradation in biotic conditions, based on macro-invertebrates, occurred in this section of the river. However, no improvement was achieved either. The SASS4 scores at this site always fell within the poor quality class, indicating that the biotic condition at this site is highly degraded. The poor biotic conditions prevailing can be attributed primarily to poor water quality, as the habitat at this site would have been adequate to sustain viable macro-invertebrate populations, if the water quality permitted it. Agricultural activities, together with WWTW effluents upstream of locality 7 generally resulted in an increase in turbidity at this locality (see Chapter 3). High loads of inorganic matter may affect aquatic macroinvertebrate life histories directly by obstructing respiration, interfering with feeding, and also through the loss of habitat or habitat stability. Indirect effects may occur as a result of dilution or altered production of an important food resource (Rosenberg and Rosh, 1992). Species richness, density, and biomass decrease as inert sediment loading increases (Hellawell, 1986). The high turbidity levels often observed at locality 7 could therefore be of great concern as a possible cause for degradation of the macroinvertebrate communities at this site.

SASS4 scores again stayed relatively similar between localities 7 and 8. Habitat quality and diversity were relatively similar between these two sites, and it can therefore be assumed that the water quality also did not deteriorate or improve enough to cause any significant changes in the macro-invertebrate communities. The SASS4 scores again indicated poor conditions, which could primarily be attributed to poor water quality, as habitat components were adequate to meet the basic requirements for macro-invertebrates.

SASS4 scores decrease significantly from locality 8 to 9. This decrease can primarily be attributed to degradation in habitat quality, and much lower habitat diversity at locality 9. Water quality deterioration between localities 8 and 9 can, in general, be ruled out as the cause for the significant decrease in SASS4 scores, as most water quality variables stayed relatively similar between these two sites (Chapter 3). It is envisaged that the degraded habitats at this site can predominantly be attributed to flow modifications. The water level at this site is much higher than can be expected under natural conditions, primarily due to WWTW's effluents and other return flows. The unnaturally high flow resulted in a decrease in habitat diversity, with slow and shallow habitats generally being absent in this section of the river. The increased flow also caused high levels of bank erosion, thereby decreasing marginal vegetation biotopes. The very poor biotic conditions observed in this section of this river are attributable to degraded habitat conditions and diversity, as well as poor water quality originating from the upper and middle catchment of the Klip River.

Apart from the degraded water quality, the poor SASS4 scores attained throughout the Klip River can also be attributed to flow modification. Due to the unnaturally high return flow, mainly attributable to WWTW's effluents and urban runoff, the natural flows of the Klip River have been largely changed from its natural regimes. In general, the flow in the river, especially so in the middle and lower reaches, is much higher than what should be naturally expected, and also lacks natural variation in water levels and velocities. These high flows are responsible for a loss of habitat diversity, as fast-deep habitat types dominated most of the sites in the lower section of the river. The presence and even abundance of various invertebrate species are affected by stream velocities (Viljoen, 1974). Previous studies have also indicated that the highest numbers of invertebrate taxa, SASS4 families and their abundance, and thus SASS4 scores, most often occurred at low flows, and these variables generally decreased with increasing flows (Palmer, 1997). Most invertebrates also take time to disappear after floods (Palmer, 1997). The high flow in the Klip River occurs constantly, therefore not allowing the invertebrates to survive flows that they may have been able to survive for short periods. The invertebrates of the stones-in-current habitat types (riffles, rapids) are also generally the most intolerant invertebrate taxa (Chutter, 1971). In many areas of the Klip River, the unnaturally high flow has, to a large extent, inundated the riffles and rapids. The absence of this biotope from a locality, due to flow modification, is therefore critical in the deterioration of biological integrity of a site. It is therefore evident that flow modifications, and especially the lack of natural low flows in the Klip River, are a major factor responsible for decreased biotic integrity of this system.

In a study conducted in the Orange River, the highest number of taxa and highest SASS4 scores were usually recorded in October or November (Palmer, 1997). In the Klip River there were no definite trends in this regard, and the highest SASS4 score recorded at sites ranged across all seasons. The general trend was, however, that the upstream sites (localities 1 to 5) generally had the highest SASS4 scores and ASPT during the summer (February) or spring (November) surveys. The highest SASS4 scores and ASPT values in the lower section of the river were again generally recorded during winter (August) and autumn (May) surveys. In the Orange River study, the highest ASPT scores were, similar to some upstream localities in the Klip River, also recorded during the January to February (summer) season (Palmer, 1997). The presence of a more diverse invertebrate community during the spring and summer months may be attributed to increased habitat diversity. During the summer months, the vegetation biotopes (aquatic and especially marginal) are more abundant due to natural seasonal trends in growth. This scenario has often resulted in increased HABS1 (habitat diversity) scores at sites, and this could have played a role in the increased SASS4 scores recorded during spring and summer months. Increased flows during the spring and summer surveys, due to rainfall in the catchment, could also have been responsible for dilution of pollutants, which could have led to improved water quality, and thus improved SASS4 scores. Another factor that could have contributed to lowered SASS4 scores during the winter and autumn surveys is surface water temperature (Zamora-Munoz *et al*., 1995). Palmer (1997) indicated that SASS4 scores in the Orange River were generally lower at temperatures below 15°C. Most of the upstream sites, where lower SASS4 scores were recorded during the winter/autumn surveys, as compared with the summer/spring surveys, had temperatures below 15°C during the winter and autumn surveys (Chapter 3). The expected scenario for the rivers in the region would be that higher SASS4 scores should be attained during the summer months, as habitat diversity and quality should be higher during the warmer rainy season. This scenario was observed in the upper reaches of the Klip River, but was reversed in the lower reaches. This might therefore again be attributed to the impact of flow modification, as there was generally a lack of natural flow variation in the lower section of the river.

The SASS4 scores calculated for the reference locality in the Suikerbosrand River was always much higher than those of the Klip River. SASS4 scores ranged between the fair and excellent quality classes, but were mostly within the good class. Although slightly better habitat conditions could have played a minor role, the higher SASS4 scores in the Suikerbosrand River can primarily be attributed to water of much higher quality prevailing in this river, when compared to that of the Klip River (Chapter 3). Although the habitat quality at locality 10 decreased over the study period, SASS4 scores were still very high. This would further indicate that the water quality of this section of the Suikerbosrand River was very good during the study period. The major cause for decreased habitat quality was decreased flow due to upstream damming and irrigation. The scenario observed by Palmer (1997) where the highest SASS4 scores were attained during the lowest flows, therefore also occurred at locality 10 in the Suikerbosrand River. The major human impacts at this site are agricultural activities, which seem to have had no significant impact on the macro-invertebrate diversity of this section of the Suikerbosrand River. There has, over the past few years, been an increase in the use of macroinvertebrate studies to identify special "Outstanding Resource Waters" and other high quality aquatic habitats throughout the world (Loeb and Spacie, 1994). Using macroinvertebrates, it was shown in this study that the reference site in the Suikerbosrand River was still of excellent quality. This renders this river system of critical importance in the Vaal River Catchment, as most of the rivers in the region have been highly degraded by human activities. Management strategies and monitoring of this system is therefore of cardinal importance and should be implemented to gauge and limit future degradation of this valuable system.

The Suikerbosrand River, being relatively natural and in the same region as the Klip River, should therefore provide a valuable indication of conditions that should be attainable in the Klip River under natural or unimpacted conditions. The scenarios observed at Locality 10 were therefore used as the expected natural condition of the Klip River. It should be noted that this might be slightly inaccurate for some sites, especially the upstream sites that are of different stream orders than the reference site, and may naturally have lower macro-invertebrate diversities. Using this comparison, locality 1 generally fell within the severely impaired class. It should however be noted that this was the most upstream site in the Klip River, and it may therefore be upgraded due to naturally expected low macroinvertebrate diversity. All other sites were classified as considerably impaired, while localities 3, 5, 6 and 7 were the only sites, at times, to reach the moderately impaired class. From this, it was again obvious that, based on macro-invertebrate communities, the Klip River is a highly degraded system which has been considerably modified from its natural conditions.

Although the SASS protocol has been proven in present and previous studies as being a valuable tool to assess the health of rivers, it should not be seen as the only way to utilize macroinvertebrates in aquatic ecosystem assessments of South African rivers. The SASS index presently only utilizes the presence/absence of taxa of a specific tolerance to environmental change (mostly water quality based), to evaluate the condition of a site in a river system. It can, however, be expected that changes in the community structure and relative composition of different taxa could occur at a site, long before a taxon will totally disappear. Physiological, morphological and behavioral changes in macroinvertebrates can often give a good indication of the specific stressor responsible for the degradation, and would therefore allow for more effective addressing of the actual sources of pollution. In sensitive systems, or areas of high conservation importance, biological indices that respond to proportional changes, and not only to the presence/absence of a group of organisms, such as in the SASS4 protocol, may therefore be more effective as a biomonitoring tool. This type of biotic index may be developed to monitor specific types of pollution or degradation (such as WCW effluents), or may be specific to the geographical area involved (Rosenberg and Resh, 1992). An example of such an index, incorporating proportional metrics, is the Index of Biotic Integrity (IBI) for macroinvertebrates, as used throughout the USA. It is essential that an "ecosystem perspective" should be integrated into biomonitoring programs. This approach offers the opportunity to understand not only species, but also their interaction and roles in the whole ecosystem. The ecosystem perspective shifts our focus from small to large-scale phenomena, from population to community, and from structure to process. In this way, we can learn not only what species are present, but also how they fit in and how they contribute to the functioning of the ecosystem (Rosenberg and Resh, 1992). It is therefore recommended that future studies should investigate the potential of such indices, to be used as a monitoring tool that may be more sensitive to detect changes in aquatic ecosystems of special concern.

5.5 CONCLUSIONS

The results gained from this study indicated that the invertebrate composition of the Klip River has greatly deviated from its naturally expected condition. The diversity was generally low throughout the Klip River when compared to a site in the less impacted Suikerbosrand River. Very high abundances of invertebrates in the soft-bottom substrates, dominated by the tolerant Chironomidae and Oligochaeta, were indicative of nutrient enrichment in the Klip River catchment. This was especially evident in the section of the Klip River in the vicinity of locality 3. When compared to a previous study, it furthermore seems that nutrient enrichment has increased in the Klip River over the past three decades.

The SASS4 protocol was determined to be an effective biological monitoring tool, to assess both changes in water and habitat quality effectively. It was evident from the use of the SASS4 protocol, that the Klip River is a highly degraded river system, with conditions ranging between very poor to fair. In general, the ecological integrity of this system, based on macroinvertebrates, can be classified as being poor. The greatest areas of concern identified with the SASS4 protocol were locality 2 and locality 6, where significant degradations in integrity occurred. The deterioration of the ecological integrity of the Klip River was attributed to both poor water quality and habitat degradation. Flow modification, especially in the lower section of the Klip River, contributed greatly to the poor condition observed.

The Suikerbosrand River in the area of the reference site (locality 10) was found to be in fair to excellent condition, with very good water and habitat quality prevailing. It is recommended that a more intensive study be conducted in this river system, as to attain better baseline information of expected conditions for rivers of the region. This information would furthermore be essential for management purposes to prevent degradation of this important aquatic ecosystem.

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