WATER QUALITY AND FAUNAL STUDIES IN THE UMZIMVUBU CATCHMENT, EASTERN CAPE, WITH PARTICULAR EMPHASIS ON SPECIES AS INDICATORS OF ENVIRONMENTAL CHANGE

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by

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1 EXECUTIVE SUMMARY

1.1 AIM

The primary aim of the project was to establish a water quality database and an inventory of aquatic fauna for the Umzimvubu River and its four main tributaries. The identification of species that are sensitive to environmental threats and that might be used as future indicators of environmental change, was the secondary aim. The results are outlined in Chapters 2, 3 and 4, while Chapter 5 reflects on conclusions and recommendations for further research. Based on the water quality data in Chapter 2 and macro-invertebrate scores (SASS4 and ASPT) in Chapter 3, the quality of water is good, suggesting that the catchment is not significantly degraded, except threats by soil erosion (Fig.2.15) leading to very high TSS loads (see Appendices 1- 3).

1.2 BACKGROUND AND MOTIVATION FOR THE STUDY

In South Africa, the majority of ecological impact studies on rivers were (and still are) based on comparing sites above and below the point of impact, e.g a dam. Such comparisons have, however, been shown to be inconclusive since rivers vary naturally along their length. These variations arise through geological factors and are amplified by anthropogenic activities in the catchment. The Umzimvubu River catchment is one of the few rivers in South Africa not yet impounded despite its potential for damming. However, the unregulated state of the system is being threatened by the possibility of impoundments in the near future. The most likely development in the catchment will be agricultural with increased pressure on irrigation, which can lead to nutrient enrichment from return flows. There is very little data about river ecology in the former Transkei. The aim of the study was to develop a database of water quality and fauna as a basis for resource management. Prior to any resource allocation (e.g. licensing for water abstraction) the water requirements of the river ecosystem must be established. This is only possible if the water quantity and quality requirements (ecological reserve) of the system are known.

Such data is also vital in determining both reference and biomonitoring sites in the national programmes aimed at monitoring river health, such as the national River Health Programme (RHP). Because the catchment is relatively undeveloped (commercially), its major threats are unplanned and unconstrained catchment practices, such as subsistence crop and stock farming (leading to more soil erosion).

1.3 CATCHMENT DESCRIPTION

The Umzimvubu River catchment is about 20 060km^2 in extent and provides land for more than one and a half million people. It is in the middle of rural former Transkei. undeveloped and dominated by subsistence farming. The Umzimvubu River and its four main tributaries originate from the east of the Drakensberg Mountains and flow through hilly country to the Indian Ocean. Very flat foothills in the upper middle reaches result in the formation of meandering rivers and small wetlands. The basin receives an average of 800mm rainfall per annum, considerably above the South African average of 500mm; the annual run-off is ±3 000x10^6 m^3. The catchment experiences a range of temperatures from warm coastal subtropical temperatures to relatively cold (winter) in mountainous areas with occasional snowfall. The soils of the Beaufort series, such as the podsolic, dominate the catchment. Geologically, these soils originate from sedimentary rock formations. Some intrusions of hard dolerite soils from igneous rock occur mainly around the Drakensberg Mountains. The upper plateau is dominated by sourveld, while the middle plateau is characterised by dohnveld, false karoo veld trees and Southern Tall Grass veld. The coastal valleys (lower plateau) are composed of valley bush forests, sourveld, ngongoni veld and the Eastern Cape thornveld.

1.4 SEDIMENTATION

Southern African rivers transport between 120 to 150 million tons of sediment annually. The Eastern Cape contributes between 4 and 881tons/km^2/yr (Dardis *et al.* 1991; Rooseboom, 1992; Rooseboom *et al.* 1992). The highest proportion is in the form of fine particle size less than 0.2mm. Such particles remain in suspension for a long time making rivers appear turbid longer. The study catchment is dominated by soils of the Beaufort series known to be highly susceptible to soil erosion. The potential sediment yields in the upper reaches (upper plateau) of the catchment is between 50 and 120 $t.yr^{-1}$, while in the middle reaches (central plateau) it is between 35 and 100$t.yr^{-1}$ and between 30 to 80 $t.yr^{-1}$ in the lower reaches (coastal plateau) (Midgley *et al.*1994). Figure 2.15 shows the highest mean (826,14g/l) concentrations of automatically sampled TSS ever recorded in South Africa during floods. The high erosivity index, sparse vegetation cover, steep landscape and high rainfall lead to immense river sedimentation. Though the rivers are not regulated, an increase in population size is expected to increase the pressure on land (e.g. crop and stock farming) leading to an increase in soil erosion and sedimentation. The limited access points to the rivers and few weirs make sediment estimations difficult. Besides that, there must be differences between land-use in the vicinity of the sampling sites (mainly gorges) and flatter land of the catchment, with most of the catchment degradation taking place on "flatter land". If the catchment is ultimately regulated, the resulting low flows will not be able to transport the ever-increasing high loads of sediment. Vegetation encroachment (e.g. reeds) onto deposited sediments tend to bind the deposition, permanently altering the channel morphology. In a similar manner, the estuarine ecosystem will be degraded by deposition from the upper catchment. Accurate measurement of sediment is therefore of importance and in this study a method was employed for automatic sampling of sediment, which was the first of its kind in South Africa.

1.5 TOLERANCE TESTS

The second phase of the study was aimed at establishing sediment tolerance limits by running laboratory-based experiments with selected macro-invertebrate groups in which kaolin was used as an analogue for natural sediment. The laboratory studies were backed up by biomonitoring assessment of water quality using SASS4, an invertebrate monitoring index.

1.6 STUDY OBJECTIVES

- Collection of water quality information. This objective was successfully met during the period from spring 1996 to summer 1998. Chapter 2 presents details on background, methods / procedures, results etc.
- Development of faunal inventory. This objective was also successfully met during the same period. Chapter 3 describes the background, methods / procedures, results, etc.
- Identification of environmental impacts. Progress of this objective is reported in Chapter 4, which deals with tolerance tests on selected indigenous macro-invertebrates.
- Input into a mathematical or GIS model of the system. This objective is still planned, as it requires more data than is available at present and will be a separate proposal to the WRC.
- Guidelines for future monitoring and management. The findings and discussion reported in Chapters 2 and 3 outline how the data collected can be incorporated into national programmes, such as RHP. Water managers, catchment management agencies and resource developers can use the research results. Monitoring of selected sites will continue beyond the end of the project.

1.7 BRIEF SUMMARY OF THE MAJOR RESULTS AND CONCLUSIONS

1.7.1 WATER QUALITY AND MACRO-INVERTEBRATES

The results of the survey on water quality and fauna revealed that the Umzimvubu River system is one of very few systems in South Africa, which are slightly degraded (except by the increased sedimentation from catchment degradation). Though sampling excluded mountain streams on the Drakensburg (starting around foothills) (Fig.1.2 – 1.6), the quality of water is good, based on nutrients, trace and heavy metals (Fig .2.2 – 2.5 and Appendix 1) as well as macro-invertebrate community composition (Fig 3.6 – 3.13 and Appendix 2). However, the study was conducted during a very wet period (1996 – 1998, see Figure 2.17). The mean seasonal range for nitrates, ammonium, nitrites and phosphates were, 0.03-1.12; 0.04-0.08; 0.01-0.04 and 0.01-0.065 mg/l, respectively (see Appendix 1). These averages were within the acceptable limits for the protection of aquatic ecosystems (Kempster *et al.* 1980). The mean physicochemical parameters, i.e.

temperature (16,5°C); oxygen (94,9 % saturation) and pH (8.19), were similarly within the limits. Due to wet season, it was not easy to detect seasonal trends, except for TDS, TSS and temperature. The mean levels of calcium and alkalinity (as $CaCo_3$) were recorded as 14.09mg/l and 85.2mg/l respectively. Other ions were very low, sometimes below detection limits (see Appendix 1).

The dendrogram on water quality (Fig. 2.18) revealed great similarity across all sites. The mean seasonal SASS4 scores were 88, 114, 135 and 90, indicating water of good quality (Chutter, 1998) for summer, spring, autumn and winter respectively. The ASPT scores seemed more consistent across sites and seasons as well as being independent of habitat values (or biotope diversity) compared to SASS4 scores (Davies *et al.* 1998). The mean seasonal ASPT scores were 7.6, 7.8, 7.3, and 7.3, for summer, autumn, winter and spring respectively. These scores suggest good to excellent water quality (Thirion *et al.* 1995). The seasonal dendrogram of macro-invertebrates (Fig.3.5) showed a great similarity and overlapping of sites in all seasons, except summer. The lower similarity in summer was attributed to inaccessibility of some biotopes due to peak flow leading to a bias in the data. Some macro-invertebrates usually grouped as sensitive taxa, such as Hydropsychidae, Trichorythidae, Prosopistomatidae, Oligoneuridae, etc., occurred from the upper to lower reaches. Outstanding observations included the occurrence of the Blephariceridae at the Umzimvubu River site 1 and the Kinira River site 10. Another interesting observation was the occurrence throughout the sampling period of *Macrostema capense* at Umzintlava River site 7 only. The Global test (Spearman adjusted for ties) revealed that the physical variables and macro-invertebrate community structure were closely related. The relationship was 71.1%, 84.5%, 88.4% and 94.2%, for winter, autumn, summer and spring respectively. Though not identified to species level, the records of the intermediate hosts (Planorbidae and Physidae) for schistosoma, a parasite which causes bilharzia (Thirion *et al.*1995) is of significant importance to community health.

1.7.2 SEDIMENTATION

The variable of greatest concern is TSS. The results from sediment studies revealed serious levels of erosion in the catchment (Fig.2.12 – 2.16). Clear evidence of sedimentation was noted at the Umzimvubu River site 2 and the Tsitsa River site 13, both in the foothills of the respective rivers (Fig.1.2 – 1.6). Riverbeds were completely covered with sand. Though this apparent sedimentation must be of natural origin at lower gradients, commercial farming (crop and stock) must have exacerbated the situation. From the middle reaches, all rivers start to drop steeply, reducing sand deposition which increases again in the lower reaches.

1.7.3 TOLERANCE TESTS ON SELECTED MACRO-INVERTEBRATES

The preliminary results of tolerance tests using kaolin (as a sediment analogue) showed that the caddisflies (Trichoptera : Hydropsychidae), *Cheumatopsyche afra* and *Hydropsyche longifurca* as test organisms were more tolerant than expected (Chapter 4). Some researchers often refer to Ephemeroptera, Plecoptera and Trichoptera as sensitive (indicator) groups (De Pauw *et al.* 1983; Nelson *et al.* 1996). Though tested trichopterans may be sensitive to other substances, they did not show similar sensitivity to sediment and more sensitive species need to be used instead. Since kaolin is non-toxic, chronic tests may be another option for caddis flies. The preliminary results of kaolin tests may also suggest that the sparse (low abundance / number of taxa) occurrence of macro-invertebrates (Appendices 2 and 3) in the rivers may be as a result of adaptation (i.e. they must be adapted to survive under fluctuating seasonal TSS concentrations).

1.8 PROJECT OUTCOMES AND CONTRACT OBJECTIVES

Amongst the objectives of the project was the establishment of a water quality and faunal baseline information. A detailed macro-invertebrate study was conducted for the first time in the former Transkei. Water quality data were also collected in a more detailed manner than before. To this extent therefore the objectives were met. The macro-invertebrate specimens collected will be lodged with the national database through the invertebrate department, Albany Museum Grahamstown. The rest of the collection will be stored in the zoology department, University of Transkei for future cross-reference and teaching. Investigation is still underway on the third objective, i.e. the establishment of TSS tolerance limits. Determination of sediment load (TSS) (including its effects on selected macro-invertebrates) was given priority consideration, given the threat that sediment poses in the present and future of the study catchment and elsewhere in the country. The automatic method for sampling of sediment employed in this study was an improvement on grab samples that are bound to be misrepresentative, considering the rate at which sediment is transported at peak flows and during floods. Another significant breakthrough was that for a method in which kaolin was kept in suspension and circulation during the tolerance test. Previously the kaolin settled out considerable during tests (Fig.4.2) reducing the concentration by far more than 15% (APHA, 1995).

1.9 RECOMMENDATIONS FOR FURTHER RESEARCH

- Further sediment studies are required to replicate the measurements of sediment load (TSS) since the reported TSS was based on one set of samples from a flood at one site. In view of sediment loads (TSS), precautionary measures will have to be adhered to (DWAF) should the proposal to dam the rivers go ahead in the catchment. Inadequate measures can lead to shorter dam life span than expected. More data need to be collected regarding sedimentation.
- The automatic sediment sampling method needs to be refined by collecting more data using different box designs and different installation methods.
- The roles of wetlands need to be investigated.
- In the light of possible upstream impoundment, the present ecological status of the Umzimvubu River estuary needs to be established.
- Involvement of local rural people in catchment management needs to be investigated, particularly in relation to sedimentation.

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The steering committee responsible for this project consisted of the following persons:

- Dr.S.A. Mitchell. (Research Manager, WRC)
- Dr.P-A .Scherman. (IWR-Rhodes University)
- Dr. C. Dickens (Umgeni waters)
- Ms. H.S. Dallas (Southern Waters, University of Cape Town)
- Mr. S. Jooste (Institute of Water Quality Studies, DWAF)
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- Prof: D.P.Cyrus (CRUZ -University of Zululand)
- Prof: J. Faniran (Department of chemistry, University of Transkei)
- Mrs. C.M. Smit (Committee Secretary)

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LIST OF ACRONYMS

AQV = Aquatic Vegetation.

ASPT = Average Score per Taxon

Au = Autumn

BMWP = Biological Monitoring Working Party

CCWR = Computing Centre for Water Research

DWAF = Department of Water Affairs and Forestry

FFG's = Functional Feeding Groups

FR = Following Rainfall

GIS = Geogrphical Information System

HABSI = Habitat Scoring Index

IBT's = Inter-basin Transfers

IFR's = Instream Flow Requirements

IWQS = Institute for Water Quality Studies

Ki1 = Potential dam site at the upper reaches of the Kinira River

Ki2 = Potential dam site at the Kinira River

MAE = Mean Annual Evaporation

MAP = Mean Annual Precipitation

MAR = Mean Annual Run-off

MV = Marginal Vegetation

NTU = Nephelometric Turbidity Units

RHP = River Health Programme

RWQO = Receiving Water Quality Objectives

SASS4 = South African Scoring System version 4

SIC = Stones in Current

SOOC = Stones Out Of Current

Sp = Spring

SRP = Soluble Reactive Phosphorus

Su = Summer

Ti1 = Potential dam site at the Tina River

T13 = Potential dam site at the Tina River

TDS = Total Dissolved Solids

TS5 = Potential dam site at the Tsitsa River

TS8 = Potential dam site at the Tsitsa River

TWQR = Target Water Quality Range

TSS = Total Suspended Solids

Vu3 = Potential dam site at the Umzimvubu River

Vu9 = Potential dam site at the Umzimvubu River

Vu6 = Potential dam site at the Umzimvubu River

Wn = Winter

WRC = Water Research Commission

CHAPTER.1

1.1 BACKGROUND AND MOTIVATION

1.1.1 CATCHMENT

The Umzimvubu River catchment is approximately 20 060km^2 in extent (DWAF, 1994) and provides land for more than one and a half million people (1,555 983 m, Eastern Cape 1996 census by district), the majority of whom rely on untreated river water. The catchment is dominated by subsistence farming of both crops and livestock. The Umzimvubu main stream (408km) and its four main tributaries (Umzintlava; Kinira; Tina and Tsitsa Rivers) originate from the Drakensberg mountains (eastern escarpment) and drain the catchment through relatively flat foothills (central plateau) and hilly coastal valleys down to the Indian Ocean.

The catchment receives a relatively high mean annual rainfall (800mm) with a MAR. of about 3 000 x10^{6}m^3 (Midgley *et al.* 1994). The erratic, unpredictable summer rains transport huge volumes of very turbid water, resulting in high sediment deposition. The potential for impoundment of these water resources with a view to augmenting the Vaal water supply (DWAF, 1994), prompted this pre-impoundment study.

1.1.2 RESEARCH RECORDS ON THE CATCHMENT

Very little research has been conducted on water quality and quantity in the catchment. A general survey was conducted by du Preez in 1985 followed by a study on bilharzia by Mqoqi in 1991. The present study was conducted to establish a much needed water quality and macro-invertebrate database, to be used as a baseline against which future comparisons will be made in the light of catchment development. Broadly, the study aimed at developing a database on water quality and aquatic fauna, as well as identifying species that can be used in studying sediment tolerance limits. Such limits can be incorporated in the national water quality guidelines for the protection of aquatic ecosystems (DWAF, 1996).

1.1.3 PROJECT APPROACH AND OUTLINE

The project was conducted in two phases.

- The first phase investigated water quality parameters [temperature, oxygen, pH, electrical conductivity, flow, Total Suspended Solids, nutrients (nitrogenous and phosphates) and metals] and macro-invertebrate communities.

Unlike most studies that relied only on grab samples for suspended sediment sampling, this study also employed automatic suspended sediment sampling.

- The second phase employed laboratory based experiments on sediment tests (using kaolin as sediment analogue 0.47 to 589μm^2 particle size) using species identified in Phase one.

Information gathered by this research attempted to close a gap that existed in our knowledge of freshwater (lotic systems) ecology in the former Transkei, and to contribute to a national water quality database. Such knowledge is also important for the establishment of a regional / national biomonitoring network (such as the national River Health Programme) and for other water-related management plans, such as river regulation and subsequent monitoring of aquatic ecosystem condition.

1.2 LITERATURE REVIEW

1.2.1 INTRODUCTION

With its dry climate the Eastern Cape is similar to much of South Africa (Howard *et al.*1984; cited in Hart *et al,* 1984) and faces a huge challenge in meeting economic development in the light of escalating human population (O'Keeffe, 1989). The often conflicting demands for water by various users has led to increased river regulation in the form of impoundments and inter-basin water transfers (IBT's). There are presently some 420 dams in South Africa, capable of holding about 50% of South Africa's mean annual run-off (Davies *et al.* 1993). South Africa uses about 50% of its available water resources for agriculture, especially irrigation, leaving the rest to be shared amongst other users, for domestic, industrial, recreational and environmental purposes (Allanson, 1995).

1.2.2 RIVER REGULATION

Attempts to augment water supply in South Africa must involve river regulation, which is always associated with ecosystem degradation (Howard *et al.*1984 cited in Hart *et al.* 1984). This necessitates the involvement of limnologists and river ecologists in dam construction, and any other river regulation, so that pre-impoundment studies can be conducted with a view to reserving some water (in-stream flow needs) to maintain downstream ecological integrity (Walmsley *et al.* 1984; Palmer *et al.*1990; Gordon *et al.* 1992; Allanson, 1995). The Water Act recognises the priority of resource allocation for basic human needs followed by aquatic systems before any authorised (licensed) usage by other users (Water Act, No. 36, DWAF 1998). This is only possible if the ecological water requirements have been established (Herschy, 1978; O'Keeffe *et al.* 1991).

The most obvious result of damming a river is reduction of flow, which inevitably modifies the river ecosystem for a considerable distance downstream of the impoundment. The general response of macro-invertebrates to reduced flow are changes in community composition or diversity, when compared to upstream conditions (Petts, 1984; Pollard *et al.* 1996). Although many suggestions have been proposed to account for such community changes, the volume and release pattern of the dam tend, to determine the severity of the effect (Ward *et al.* 1984; cited in Hart *et al.* 1984; Palmer, 1990). An example of this is the fact that prior to the Orange-Great Fish River water transfer *Simulium chutteri* (a blood feeding simuliid on stock) was not a pest in the Fish River catchment (O'Keeffe, 1985; O'Keeffe *et al.* 1988). In this case the alteration of flow from seasonal to perennial and the rapid population increase of *Smulium chutteri* species, was a consequence of river regulation. Impoundments can also lead to the creation of new niches for pest organisms, such as Schistosoma, blackflies, etc, and loss of rural land with its associated historic structures (archaeological). Alternatively, damming can improve fisheries, control floods, provide a reliable source of water and allow impurities to settle out (O'Keeffe 1988; Smith, 1992)

1.2.3 WATER QUALITY AND INVERTEBRATES

Macro-nutrients, such as phosphate and nitrogenous compounds, are generally non-toxic, however, their non-toxicity can be changed depending on other environmental parameters such as pH, temperature, etc. (Hoffman, 1995). These nutrients are commonly regarded as major contributors to ecosystem enrichment (eutrophication), or as limiting to algal and macrophyte growth. Their occurrence is closely linked to activities in the catchment, such as agriculture, effluent discharge, etc (Dallas *et al.*1993). Normally, rivers do not become nutrient enriched as they self-purify during periodic floods and peak flows. Only during low flow, which allows for more retention time, can fast-growing fauna and flora, such as Daphnia and diatoms, flourish. As a result of self-purification, nutrients normally occur in low concentrations in lotic systems, (Chapman *et al.*1992 cited in Chapman 1992), except when there is an external input. Apart from nutrients, variations in temperature, total suspended solids, conductivity and other variables following impoundment have been reported (O'Keeffe *et al.* 1990).

1.2.4 SEDIMENT

The fate of sediments in river ecosystems in South Africa has been well documented (Chutter, 1968; Stegman, 1974; Piterse, 1978; Grobbelaar *et al.* 1980). Collectively rivers in southern Africa (south of the Limpopo River) transport between 100 and 150 million tonnes of sediment per year (Dardis *et al.* 1991). Eastern Cape is considered to have the second highest sediment runoff after the Orange River basin in South Africa (Rooseboom *et al.* 1992). Various factors, such as slope, soil type, rainfall erosivity and vegetation cover, have been suggested as being influential in determining river sediment load (Klinge, 1964; Hanvey *et al.* 1991). The sediment originates from fragmented material in the catchment, river - banks and river - bed as well as from the air (Forbes *et al* 1970; van Breda, 1988). The major component of transported sediment consists of particles less than 0.2mm, which tend to remain in suspension for long periods of time (Grobbelaar *et al.* 1980; Gippel, 1994). According to Doornkamp *et al.* (1973) the highest sediment yields in the country occur around the Great escarpment, including the Eastern Cape. Based on data collected at reservoir inlets between 1974 and 1987, it is estimated that the Eastern Cape rivers transport between 4 and 881t $km^{-2}yr^{-1}$ (Rooseboom, 1992; Rooseboom *et al.* 1992). They postulated that the former Transkei has a high erosivity index arising from the fact that soils of the Beaufort series of the Karoo sequence are the dominant parent material in the area (Rooseboom, 1978; Keulder, 1982). Palmer *et al.* (1990) noted that the Elandsdrift dam (12,83 x 10^8m^3-full capacity) in the Great Fish River filled with sediment to 25% of its capacity in less than 5 years. Sediment yields in the Great Fish and Sunday Rivers are between 202 and 223t $km^{-2}yr^{-1}$. O'Keeffe, (1987 cited in Davies *et al.* 1993) reported that the Colleywobbles weir (8,8x106m^3 or 11m.wall) in the Mbashe River filled completely (following floods) with sediment within one year of its completion. Most if not all the data published on sediment sampling has been based on total suspended sediment samples obtained through grab sampling during site visits. Since most of the sediment is transported during heavy flows, such as floods and peak flows, when a site visit may not be feasible, valuable data is missed. The approach in this study was to use automatic sediment samplers that are installed and left in rivers so they can automatically sample as the level (stage) of water rises (Gordon *et el.*1992; Gippel, 1989, 1994,1996; Grayson *et al.* 1996).

1.2.5 TOLERANCE TESTS AND BIOMONITORING

Biomonitoring and bioassessment are often used synonymously or interchangeable by many reporters. Davies (*et al.* 1998) defines the terms as follows, "Biomonitoring is the monitoring of living organisms, usually as indicators of habitat integrity", while "bioassessment is the use of living organisms to assess conditions (usually with reference to some aspect of conservation)"

Though biomonitoring is still a relatively new concept (particularly the use of SASS) in South African river ecology, various workers have noted that some organisms are more sensitive than others to pollutants (Roback, 1974; Coetzer, 1978; Hart *et al.* 1991; Norris *et al.* 1993 cited in.Rosenberg *et al* 1993; Cao *et al.* 1996). As Roux (1994 cited in Uys, 1994) commented, water quality monitoring was traditionally based on the assessment of physical and chemical parameters. Biomonitoring, in addition to monitoring physical and chemical parameters, is justified by the fact that some species can indicate the condition of the water in which they live, making short and long-term monitoring more comprehensive and cost effective. Furthermore Dallas *et al.* (1994) believes that the synergistic and antagonistic effects of ions can not be identified by physical and chemical methods alone.

However, biomonitoring depends on a thorough understanding of the ecological and behavioural requirements of species. Hence temporal and spatial (natural) variations must be accounted for. The use of field invertebrates in biomonitoring, particularly in South Africa, is restricted by a number of problems, such as lack of identification skill and difficulty in keeping invertebrates in captivity for laboratory bioassays or toxicity / tolerance tests (Chutter *et al.* 1993; Rosenberg *et al.* 1993). The use of wild stock in tests is hampered by the usual lack of historical information, such as genetic variation (within species), health status, previous exposure, age differences, etc (Snell, 1991).

In South Africa in - stream invertebrate bioassessments is undertaken on the basis of a modification of the methodology used by the British Monitoring Working Party (BMWP). This system is referred to as the South African Scoring System (SASS). This is a simplified field manual intended to reduce both the time and expertise required for identification of organisms (especially to species level) and is currently in its fourth version (Chutter 1994 cited in Uys 1994; Thirion *et al.* 1995; Chutter, 1998). SASS:4 was employed in the present study to compare water quality conditions across study sites.

1.2.6 UMZIMVUBU CATCHMENT PROJECT

Most of the studies on river ecosystems in South Africa are based on comparisons of sites below the impacted areas with those above them, or rely on tributaries and adjacent rivers as reference sites. As Chutter *et al.* (1993) indicates, such comparisons are often inconclusive because rivers are dynamic longitudinal systems that display natural changes as one moves downstream. Unlike other studies, this study on the Umzimvubu River catchment was conducted prior to any serious pollution, except for sedimentation. The study was aimed at establishing baseline information on water quality and aquatic fauna in the Umzimvubu River catchment and its selected tributaries. It was also aimed at bioassays testing sediment tolerance limits on selected macro-invertebrates in order to add on national data collected to protect aquatic ecosystems against sediment effects (DWAF, 1996).

1.2.7 CATCHMENT DESCRIPTION

1.2.7.1 TOPOGRAPHY

The Umzimvubu River catchment lies in the middle of rural former Transkei in the Eastern Cape, South Africa, between latitudes, 30^{o} 00' & 31^{o} 45'S and between longitudes 28^{o} 00' & 29^{o} 45'E. The basin is about 20 060 km^2 in extent (DWAF, 1994) (Fig. 1).

For convenience, the catchment in this study was sub-divided into upper plateau or upper reaches (ca 2688-1900m.a.s.l.) central plateau (foothill and middle reaches) (ca 1900-900m.a.s.l.) and coastal plateau or lower reaches (ca 900m.a.s.l. - Indian Ocean). The catchment is drained by steeply dropping rivers from the eastern escarpment (Drakensberg Mt.) through the rolling hills of the central plateau and very deep valleys of the coastal plateau to empty into the Indian Ocean 408.5 km from the source.

There are four major tributaries, i.e. Tsitsa, Tina, Kinira and Umzintlava Rivers, draining into the main stream of the Umzimvubu River. Figures 1.2-1.6 show longitudinal profiles of the rivers. These rivers arise at an average height of 2195m.a.s.l. and drop to about 1000m.a.s.l. in about

20km, with slopes of 3.2^0; 4.5^0; 2.6^0; 1.7^0 and 2.3^0 in the Kinira, Tina, Tsitsa, Umzintlava and Umzimvubu Rivers, respectively. Their mean slopes (from source to their respective outlets) are 0.4^0; 0.6^0; 0.5^0; 0.4^0 and 0.3^0, respectively (Gordon *et al.* 1992). Extensive wetlands occur on the lower upper reaches of the Umzintlava (Franklin area), Umzimvubu (Cedarville area) and the Kinira Rivers (Mount Currie area). While these are not considered further in this study, investigation of these ecosystems is suggested because of their role in flow modification, settling of impurities and nutrients, habitat variation and likely high species diversity (Klotze *et al.* 1994).

1.2.7.2 CLIMATOLOGY AND RAINFALL

South Africa is a semi-arid to arid country with unpredictable seasonal rainfall characterised in the east by wet summers and dry winters (Schulze, 1974; Suran, 1994). More than fourteen percent (14.9%) of South Africa's mean annual precipitation falls in the Transkei area, exceeding by 1.4% that of the Orange River basin (Davies *et al.* 1993). Midgley *et al* (1994) reports that, for a period between 1920 and 1989, the upper, central and coastal plateaux of the Umzimvubu River catchment received on average 701mm; 604mm and 1138mm, respectively. In the Eastern Cape (similar to the rest of the country) there is more evaporation (MAE.1 200-1 400 mm) than precipitation (see above) and this increases from east to west (Buys *et al.* 1975; Middleton *et al.* 1982). Table 1.1 gives general hydrological information including MAR for the system. Coastal temperatures are warm subtropical (average 25±3 °C) with warm interiors in summer. Winter snow occurs in the upper plateau, and frost is common in the central plateau (Schulze, 1974).

1.2.7.3 GEOLOGICAL FORMATIONS, SOILS AND LANDUSE

Generally the basin is dominated by podsolic soils with dolerite intrusions throughout (du Plessis *et al.* 1984). Basaltic soils occur on the Drakensberg, while ferralitic soils are found on the upper central plateau (van Wyk, 1968; Middleton *et al.* 1982). With the exception of dolerite, which is from igneous parent material and relatively more resistant to weathering, most soils in the catchment are formed from highly erodible sedimentary parent rock material (e.g. mudstone, sandstones and shale) (van der Merwe, 1962). These sedimentary rocks are mostly of the Beaufort series with some Ecca, Dwyka and Elliot. The catchment is dominated by subsistence farming activities although some commercial farming occurs on the lower upper plateau. Generally human activities, such as vegetation clearing for firewood and ploughing, burning (common in winter), and overgrazing mainly in the central plateau, result in severe erosion (Hanvey *et al.* 1991).

1.2.7.4 VEGETATION COVER

The upper plateau is very rich in sourveld (pure grassveld) which stretches to the central plateau (temperate and transitional forest and schrub types) wherein dohneveld appears with easterly encroaching false Karoo veld trees and some intrusions of Southern Tall Grass veld. The coastal plateau is dominated by valley bush forests, composed of coastal tropical forests and thornveld, Pondoland coastal plateau sourveld, Nngongoni veld and Eastern Province thornveld (Acocks, 1975; Middleton *et al.*1982).

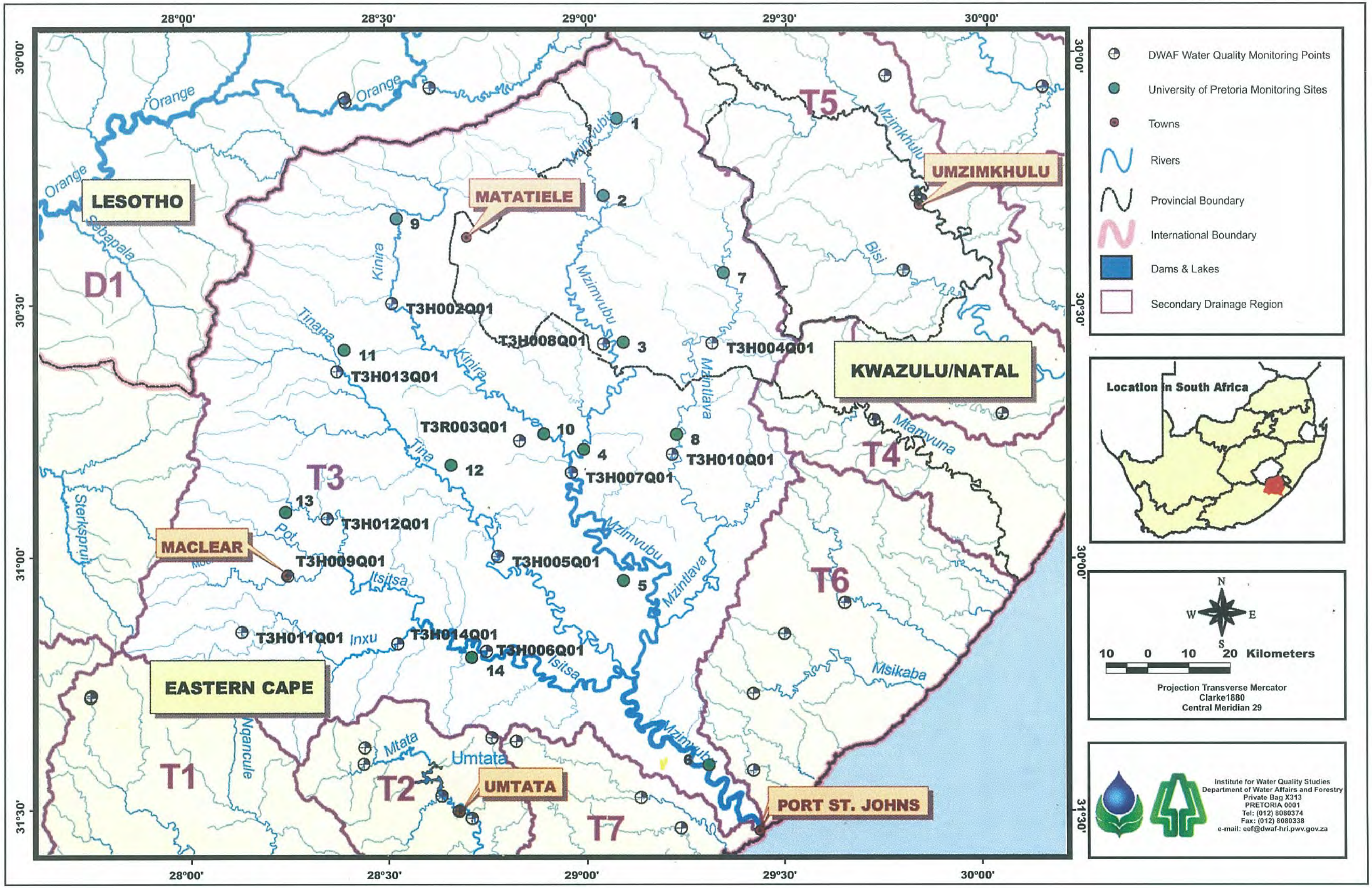

Fig. 1.1 The Umzimvubu River catchment map, (adapted from DWAF, 1994 with some modifications).

Table 1.1 The hydrological information and sampling sites on the Umzimvubu River catchment, (Midgley *et al.* 1994).

River name	Weirs	MARx10^6m^3	Site	Lat:S	Long:E
Umzimvubu	T3H007	n/a	1	30° 05'	29° 11'
	T3H008	n/a	2	30° 15'	29° 09'
			3	30° 34'	29° 12'
			4	30° 48'	29° 06'
			5	31° 03'	29° 12'
			6	31° 29'	29° 25'
Umzintlava	T3H010	n/a	7	30° 25'	29° 27'
	T3H004	94	8	30° 46'	29° 20'
Kinira	T3H002	312	9	30° 18'	28° 38'
			10	30° 46'	29° 00'
Tina	T3H005	501	11	30° 35'	28° 24'
			12	30° 42'	28° 45'
Tsitsa			13	30° 56'	28° 21'
	T3H006	853	14	31° 15'	28° 49'

Note: Flow data was not available for Umzimvubu (1st. & 2nd. weirs) and Umzintlava (1st.weir).

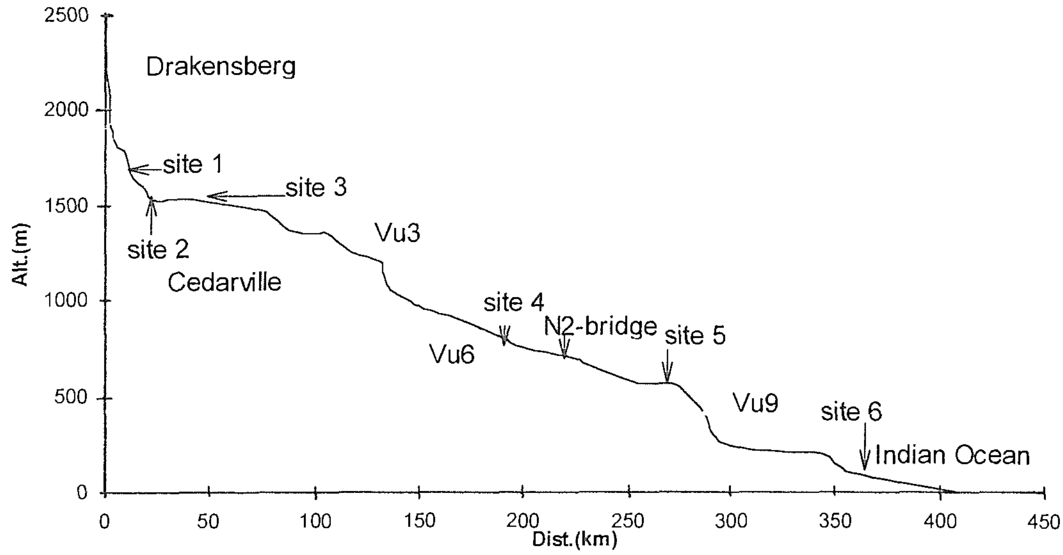

Fig. 1.2 Umzimvubu River profile showing sampling sites and potential dam sites (DWAF, 1994) in ellipses.

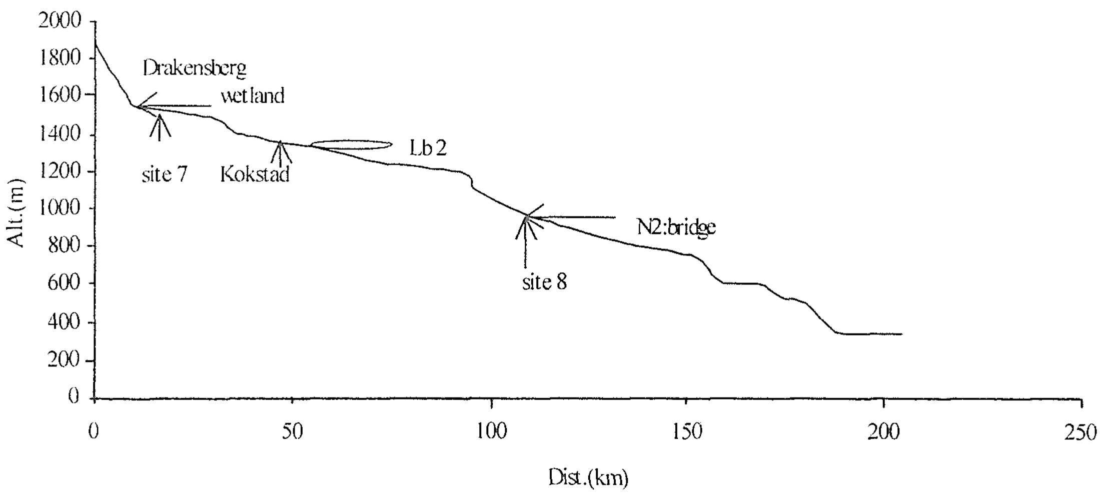

Fig. 1.3 Umzintlava River profile showing sampling sites and a potential dam site (DWAF 1994) in an ellipse.

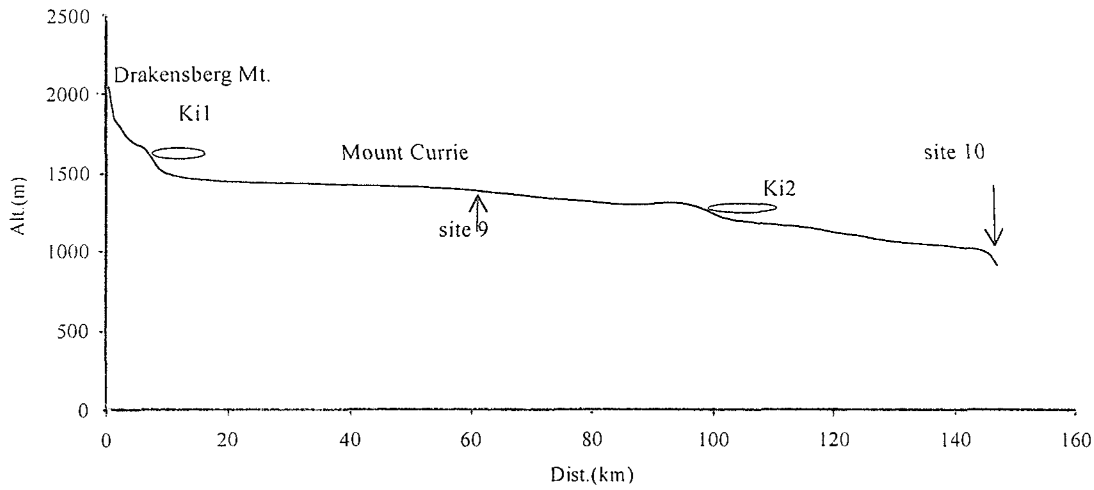

Fig.1.4 Kinira River profile showing sampling sites and potential dam sites (DWAF, 1994) in ellipses.

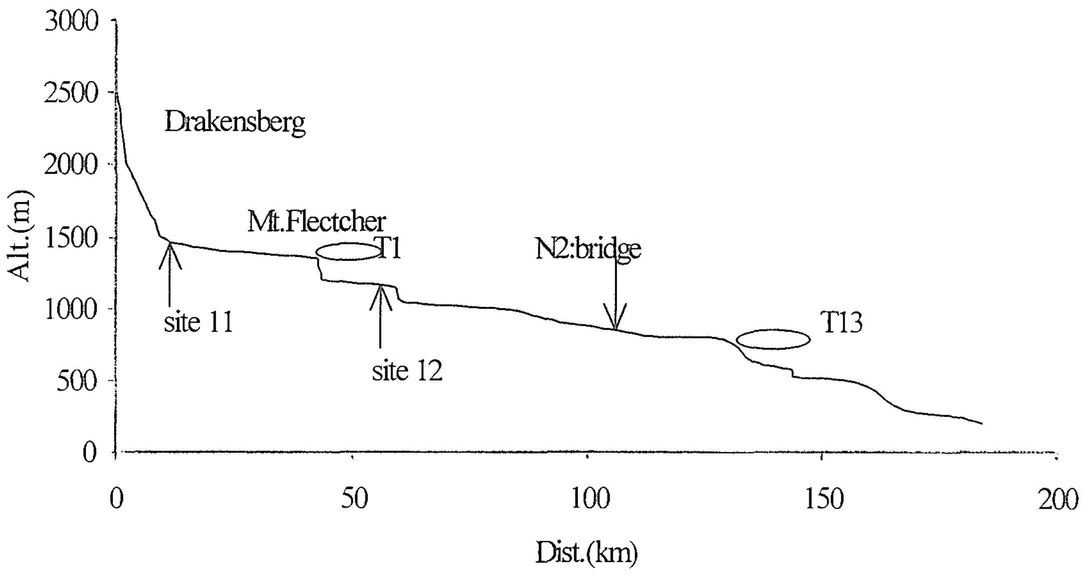

Fig.1.5 Tina River profile showing sampling sites and potential dam sites (DWAF, 1994) in ellipses

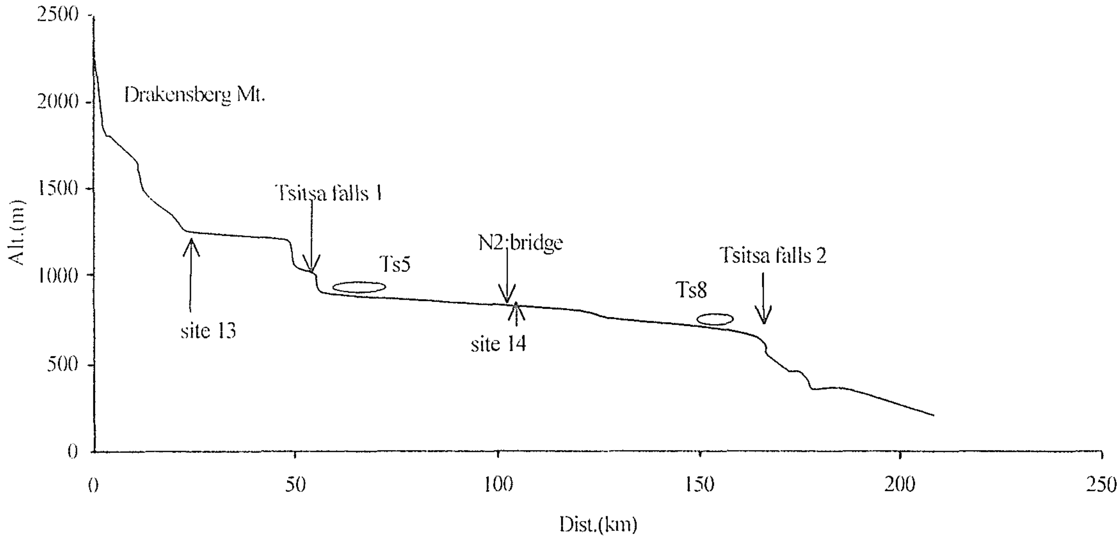

Fig.1.6 Tsitsa River profile showing sampling sites and potential dam sites (DWAF, 1994) in ellipses.

CHAPTER 2

WATER QUALITY

2.1 INTRODUCTION

Previous research on water quality largely ignored former Transkei. Exceptions are the reports by du Preez (1985), who reported findings of a general freshwater survey (metals and nutrients) of the entire former Transkei, and O'Keeffe (1988) working on the Mbashe river, western Transkei. Nutrients, (nitrogenous and phosphate compounds) occur naturally in low concentrations, 0.001-0.1mg/l (Chapman *et al.* 1992 cited in: Chapman 1992). The excessive occurrence of these growth-limiting nutrients, such as from sewage disposal, agricultural run-off etc., can lead to eutrophication. This occurs as a result of the failure of self-purification processes in a river (Chapman *et al.* 1992 cited in: Chapman 1992; Dallas *et al.* 1994; Hoffman, 1995). Nutrients and salts can show a slight increase in concentration during reduced flow (as in winter) due to a decrease in dilution water (Steffan *et al.* 1988) and to evaporation. Most salts and some nutrients, such as phosphates, are easily adsorbed onto sediment particles, thereafter they are deposited or continue with the flow downstream (Furness *et al.* 1978; Green *et al.* 1978; Klotze 1985). Seasonal variations have been reported in water quality parameters, such as conductivity, Total Suspended Solids (TSS), pH, temperature, and oxygen (Nelson *et al.* 1996). In the case of an impounded river, the concentrations of sediments, dissolved salts, and other parameters released (impoundment) depend on the release pattern of the dam (bottom or surface), and can affect aquatic organisms for up to 200km downstream (O'Keeffe *et al.* 1990; Palmer *et al.*1990). The toxicity of some salts is strongly influenced by the dynamics of other parameters, such as pH. For an example, Aluminium is non-toxic at high pH, but toxic at low pH levels (Dallas *et al,* 1994). Nitrogenous compounds can also be changed from non-toxic form (NH_4-N) to toxic, (NH_3-N) depending on other parameters, such as temperature and pH. Besides other factors, such as substrate, slope, energy flow, etc., water quality conditions affect community composition and biodiversity. Organisms such as *Baetis harrisoni*, which can survive low pH, are rare except in the Western Cape (Harrison, 1985c cited in Davies *et al.* 1993). Metzeling (1986a, cited in Hart *et al.* 1991) studied the effects of salinity on Ephemeroptera, recorded no survival when conductivity was raised to 324.9mSm^{-1}. Following the introduction of control measures on the release of zinc in the Arkansas River, Colorado, U.S.A, Ephemeroptera, Plecoptera and Trichoptera showed a remarkable recovery within a year, after 45 years of exposure to this pollutant (Nelson *et al.* 1996). In the present study, water quality status of the Umzimvubu River was investigated in order to establish the baseline information prior to impoundment. Such data can also be used in the selection criteria of reference / or monitoring sites in national bimonitoring programmes, such as RHP and in resource development and protection (Brown *et al.* 1996).

2.2. MATERIALS AND METHODS

Water quality studies in the Umzimvubu River catchment began in spring (October/ November) 1996. Sampling was conducted once per season at six sites on the Umzimvubu River and two sites on each of the four tributaries (Table 1.1 and Fig. 1.2-1.6). Prior to field trips, polypropylene leak-proof translucent plastic bottles used for collecting water samples, were cleaned by adding about 20ml concentrated sulphuric acid and shaking vigorously, then rinsing in tap water three times and finally rinsing in distilled water (du Preez, 1985). To stop bacterial activity and preserve water samples 40mg mercury chloride was added to each bottle (Brezonik *et al.* 1966; Heron, 1968). Water samples were collected from the middle of every river to avoid shoreline influence (APHA, 1995). The depth integrative sample bottle (Gordon *et al.*1992) was used to sample water (x3-replicates) in a way that integrates or mixes water in the column from near the surface, middle and down to 90mm above the river bed. This ensures that no bed load was sampled. The following physicochemical parameters were recorded in the field at each site: pH, dissolved oxygen, temperature, electrical conductivity, depth and flow, using a Microprocessor pH-meter 325, Microprocessor Oximeter 325, Mercury thermometer, Metrohm conductometer E587, Meter-stick and Mebflugel current meter respectively. To estimate river discharge the area velocity method, as suggested by Gordon *et al.* (1992) was used.

The samples were returned to the laboratory and stored in darkness at 4°C before filtration and the analysis of nutrients, turbidity and TSS (Sharaawi *et al.* 1984; Billet *et al.* 1996). If the analysis could not be done within 24 hours of collection, filtered samples were kept in the same condition or below zero (-50°C if not filtered) for no longer than a week from the date of collection (Klingaman *et al.* 1976; Britton, 1991). Samples were vacuum-filtered using 0.45µm membrane filters (Gordon *et al.*1992; van Vuren *et al.* 1994; APHA, 1995). A spectrophotometer (Spectroquant-SQ.118) was used to analyze membrane filtered samples for nitrates, nitrites, ammonium and phosphorus (orthophosphate as soluble reactive phosphorus- SRP), all of which were expressed in mg/l (Chapman *et al.* 1992). Unpreserved ad-hoc water samples were collected in spring 1998 for analysis of mainly trace and heavy metals by IWQS (Institute for Water Quality Studies), DWAF.

Turbidity was determined spectrophotometrically from unfiltered water samples and expressed in nephelometric turbidity units (NTU). A gravimetric method was used to determine (TSS) (Furness *et al.* 1978; APHA, 1995; Gordon *et al.* 1992). In order to account for unsampled bed-load, the calculated sediment concentration in mg/l was multiplied by 1.3 (du Preez, 1985; Rooseboom, 1992).

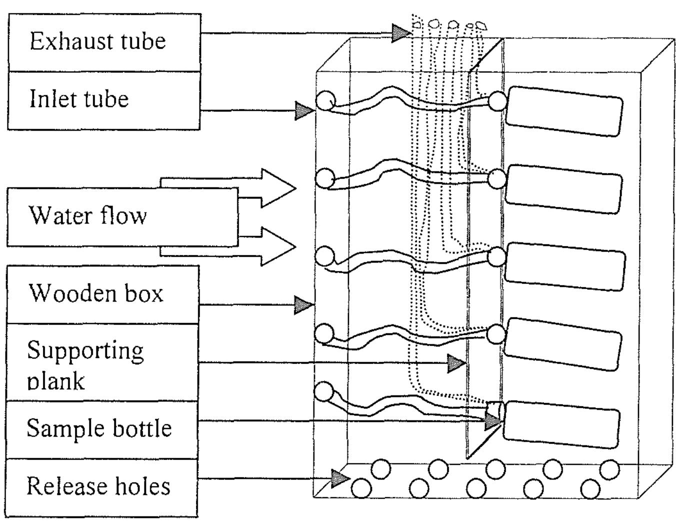

Fig. 2.1 The schematic representation of a rising stage sampler (2m high), used to automatically sample TSS (Simplified from Gordon *et al.* 1992).

Description of a rising stage sampler's components.

- Exhaust tube = releases air from the bottle to the surface above water level.
- Inlet tube = allows water to enter the bottle via the slightly curved copper tube.
- Current flow = the box must be installed to face water flow (current).
- Wooden box = the box with one side opened to expose the contents.
- Supporting plank = the plank which provides strength and keep bottles at an angle.
- Sample bottle = a rising stage sampler carries 15 x1L polyethylene bottles.
- Release holes = holes designed to release extra water and sediment that enters the box during submergence.
- The distance between bottles (or inlet tubes) was the same 10mm. (see Fig. 2.15 for bottle heights above the river bed)

The boxes were installed in such a way that they were somewhat hidden from the direct current (turbulence) and away from danger of being hit by drifting pieces of wood, etc. In this position, water and TSS is expected to flow in through the inlet tube smoothly. The kink in the inlet tube ensures that the bottle's inlet is slightly above the sample bottle at an angle to allow the bottle to fill (Gordon *et al.* 1992).

Automatic rising stage samplers (Plate 1 and Fig. 2.1) were installed in spring 1997 before the summer wet season at five bridges. Collected samples were evaporated (gravimetric method) in order to determine TSS concentrations. These samples were further sorted into particle size composition following the Wentworth scale (Gray 1981; Gordon *et al.* 1992).

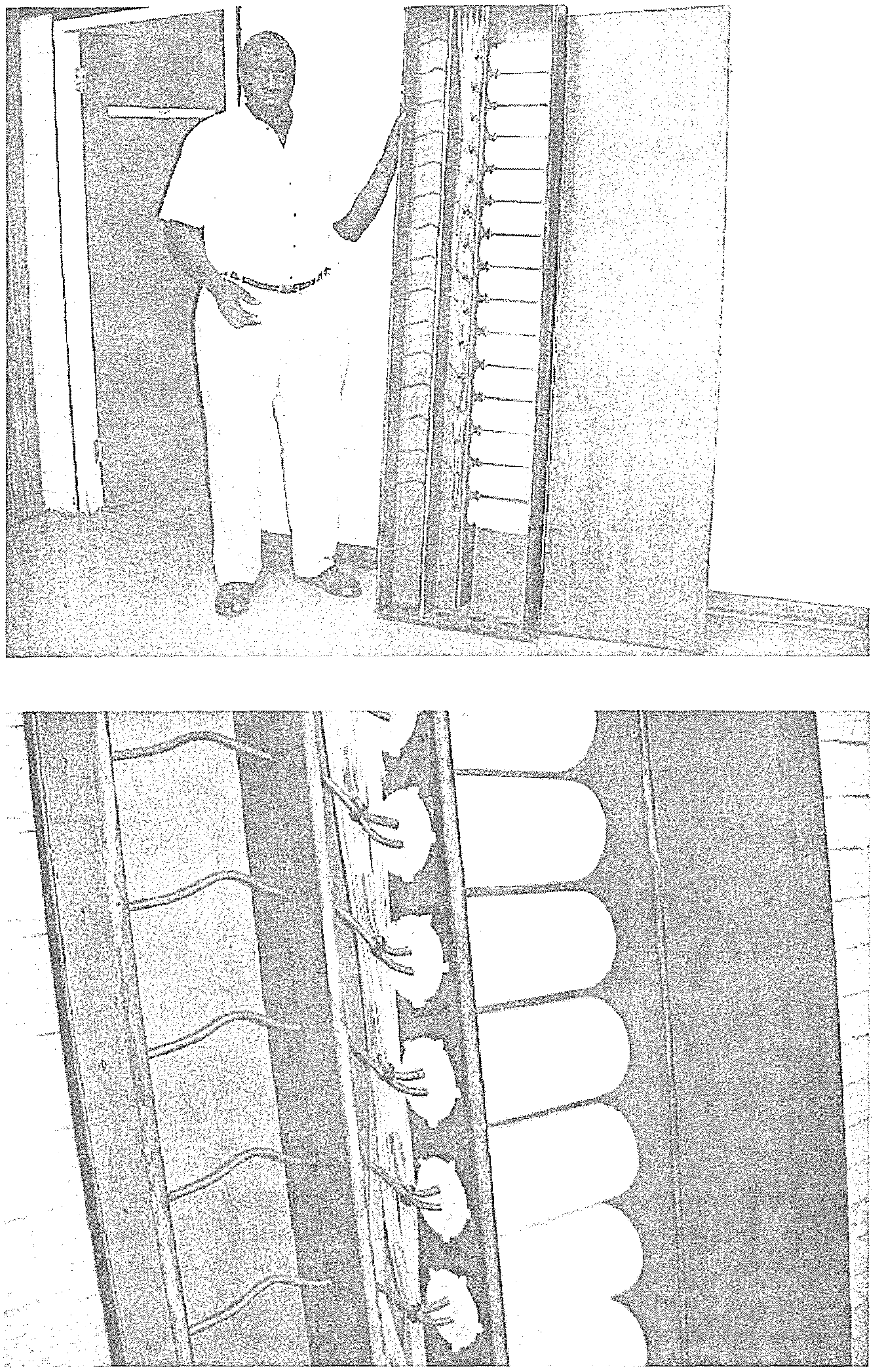

Plate 1. The digital photo of a rising stage sampler (whole box with one side opened –top picture and bottom picture is the same box at a closer look showing the sample bottle arrangement and their position in relation to inlet tubing). See also Fig 2.1 for description.

2.3 RESULTS

Except where Umzimvubu River site six was inaccessible due to persistent high flows (autumn 1997) and unrest (summer 1998), a total of fourteen sites (Table 1 and Fig.1.2-1.6) were sampled seasonally from spring 1996 to summer 1998. It is important to note that the study was conducted during an unusually wet period including, usually dry or low flows in winter and spring (Fig.2.17), hence the results are representative of an unusually wet year, and could be quite different during a dry year.

2.4 NUTRIENTS

Non-toxic ammonium (NH_4-N) concentrations (Fig.2.2) at most sites were below 0.1 mg/l. A few records showed higher concentrations, such as at the Umzimvubu site 2, 3 and 4 (just below 0.5mg/l) during spring 1996, winter 1997 and summer 1998, respectively. Fluctuating concentrations were also evident in tributaries. Fig.2.2 also shows a slight increase in the concentration of ammonium in summer at most sites, as well as an increasing downstream trend i.e. from upper to lower reaches in all seasons, both in the main stream (Umzimvubu River) and tributaries. Similarly, Fig.2.3 indicates manily low concentrations of NO3-N (seasonal range of 0.03 to 1.12mg/l) while at some sites and seasons elevated levels of nitrates were recorded. The Umzimvubu River site 4 in winter and the Kinira river site 10 (Fig.2.3) in summer show much higher concentrations of nitrates than at any other site.

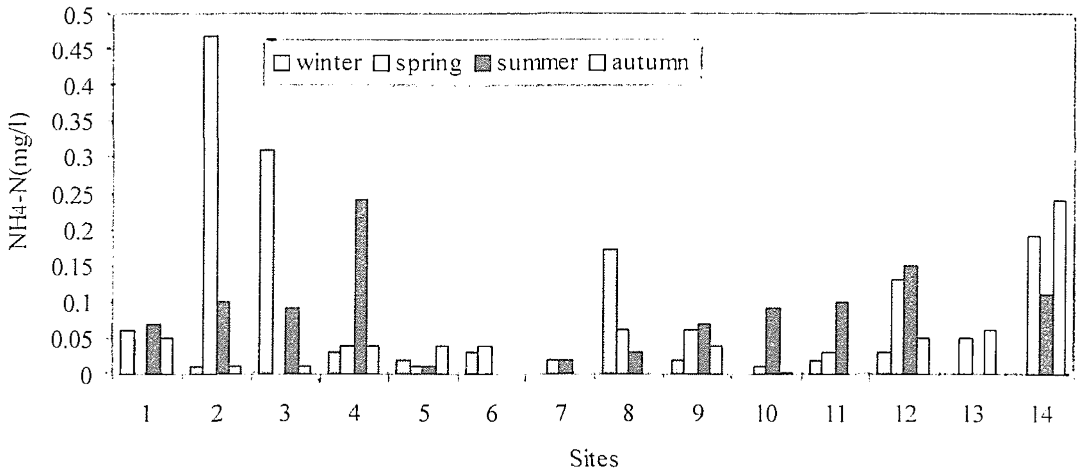

Fig. 2.2 The seasonal concentrations of ammonium for the sites from the Umzimvubu River and its selected tributaries (spring 1996 to summer 1998 - Refer to Fig.1.2 – 1.6, Chapter 1 for site positions). Note that the Umzimvubu River site 6 was not sampled in summer and autumn.

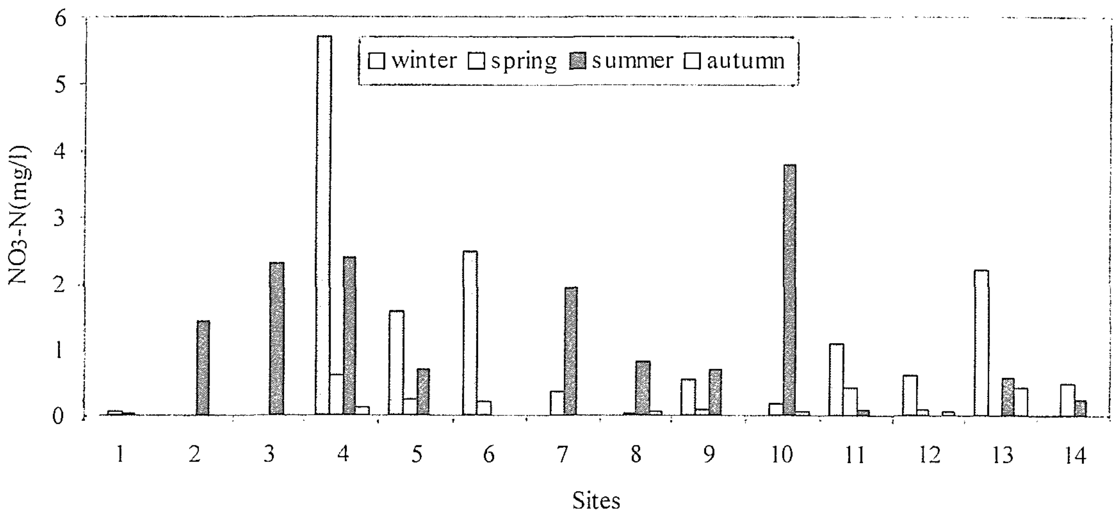

Fig. 2.3 The seasonal concentrations of nitrates for the sites from the Umzimvubu River and its selected tributaries (spring 1996 to summer 1998 - Refer to Fig.1.2 – 1.6, Chapter 1 for site locations). Note that the Umzimvubu River site 6 was not sampled in summer and autumn.

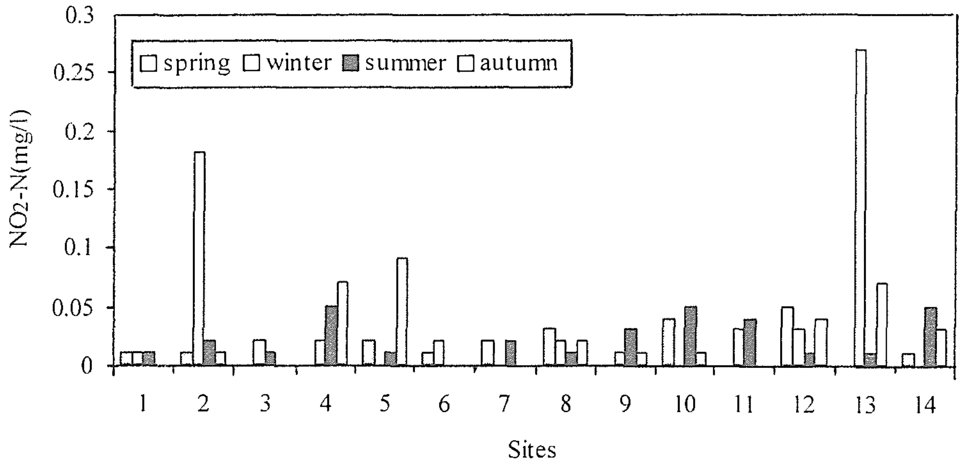

Fig.2.4 The seasonal concentrations of nitrites for the sites from the Umzimvubu River and its selected tributaries (spring 1996 to summer 1998 - Refer to Fig.1.2–1.6, Chapter 1 for site locations). Note that the Umzimvubu River site 6 was not sampled in summer and autumn.

Though variable, the concentration of nitrates is considerably higher at most summer and winter sites than in the other two seasons. Lowest values were recorded in autumn. With the exception of the Umzimvubu River site 2 and the Tsitsa River site 13 (Fig.2.4) in winter 1997, nitrites (seasonal range of 0.01 to 0.04mg/l) were mostly below 0.05mg/l regardless of the site location and season. Most of the phosphate (seasonal range of 0.01 to 0.065mg/l) records were below 0.05mg/l (Fig.2.5), with a few records above this. Summer records were generally higher (up to 0.23mg/l) than those for winter and autumn, with spring concentrations all below 0.05mg/l.

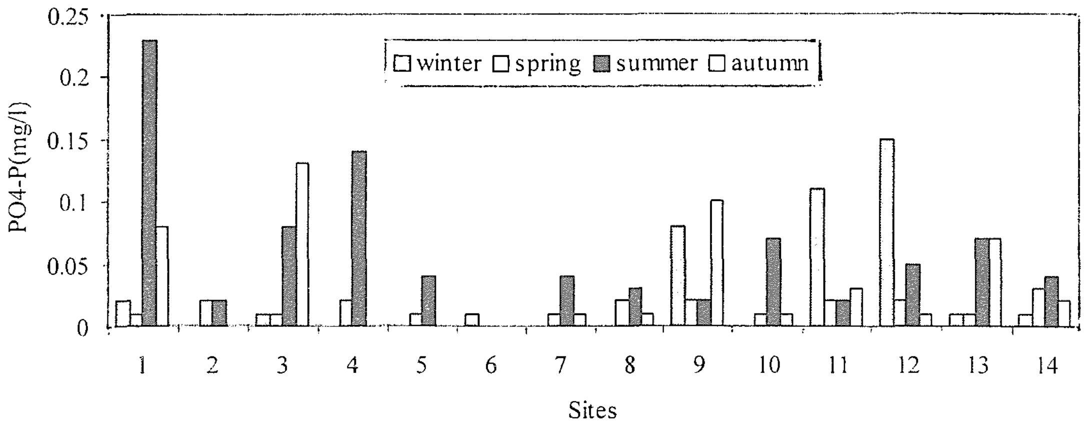

Fig.2.5 The seasonal concentrations of phosphates for the sites from the Umzimvubu River and its selected tributaries (spring 1996 to summer 1998 - Refer to Fig.1.2–1.6, Chapter 1 for site locations). Note that the Umzimvubu River site 6 was not sampled in summer and autumn.

Generally the concentration of nutrients in the catchment proved to be low (see Appendix 1). Other water quality variables, such as oxygen, temperature, pH, total dissolved solids and flow (Fig.2.6, 2.7, 2.8, 2.9 and 2.17) closely follow the expected seasonal and longitudinal (downstream change) distribution, although the wet spring / winter and low autumn temperatures affected the trend. There were no oxygen records (Fig.2.6) for autumn and winter due to technical problems. The mean oxygen concentration in spring (111%) was higher than summer records (97%), probably due to increased TSS and temperatures. The lowest (4°C) temperature was recorded in autumn at site one of the Umzimvubu River, while the highest ones (±28°C) were recorded in summer. The seasonal and downstream increasing TDS values are shown in Fig.2.9. Fig. 2.10 shows $CaCo_3$ and total dissolved solids extracted from the spring ad-hoc data. Flow was measured successfully in three seasons with only three sites measured in summer due to peak flow (Fig.2.11). The ad-hoc spring 1998 un-preserved water samples also displayed generally low concentrations of water quality variables (see Appendix 1). The dominant ions (from ad-hoc samples) were sodium (9mg/l), magnesium (8.5mg/l) and calcium (14.09mg/l), with chloride (19mg/l) usually less than

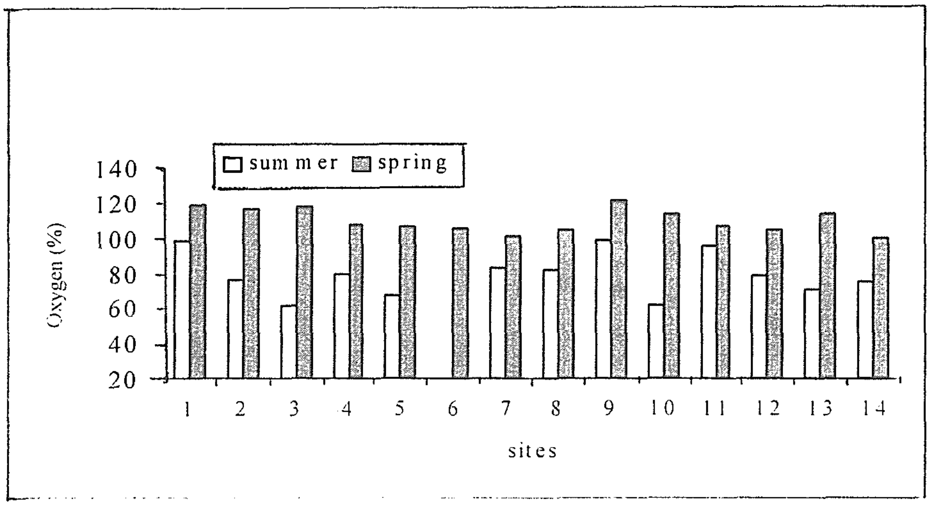

Fig.2.6 Oxygen concentration (% saturation) during spring 1996 and summer 1998 from the Umzimvubu River and its selected tributaries (see Fig. 1.1 – 1.6, Chapter 1 for site locations). Note that the Umzimvubu River site 6 was not sampled in summer.

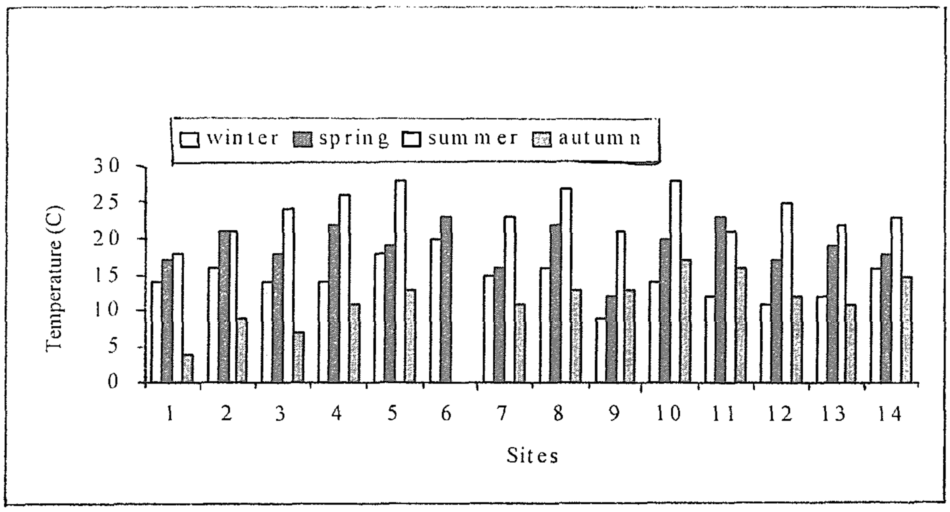

Fig.2.7 Seasonal temperatures of the Umzimvubu River and its selected tributaries (see Fig. 1.1 – 1.6, Chapter 1, for site locations). Note that the Umzimvubu River site 6 was not sampled in summer and autumn.

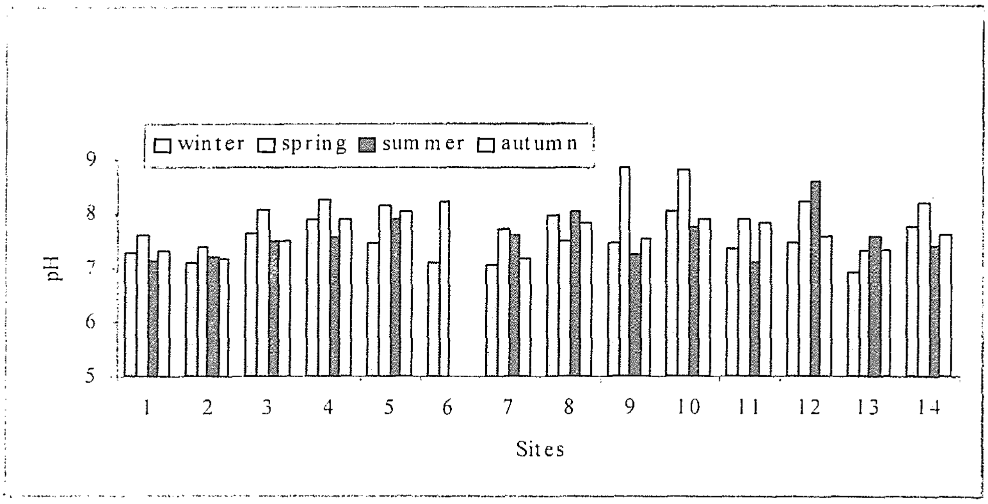

Fig.2.8 Seasonal pH levels of the Umzimvubu River and its selected tributaries (spring 1996 to summer 1998 - see Fig. 1.2- 1.6 in Chapter 1, for site locations). Note that the Umzimvubu River site 6 was not sampled in summer and autumn.

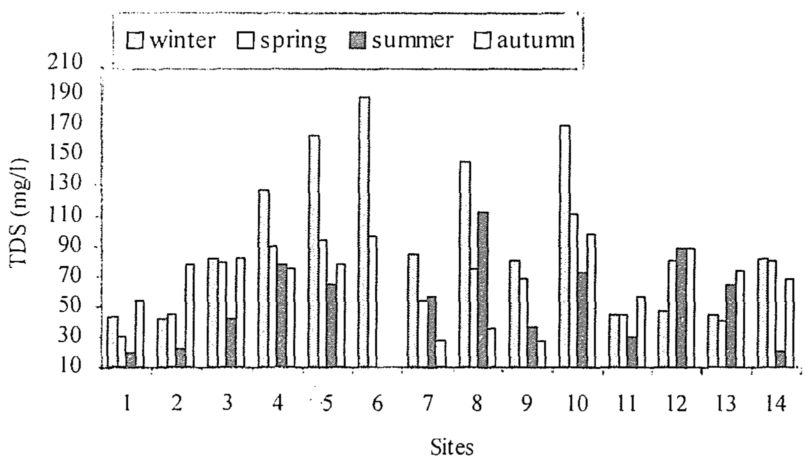

Fig.2.9 Total dissolved solid concentrations of the Umzimvubu River and its selected tributaries (spring 1996 to summer 1998 - see Fig.1.1 – 1.6, Chapter 1, for site locations). Note that the Umzimvubu River site 6 was not sampled in summer and autumn.

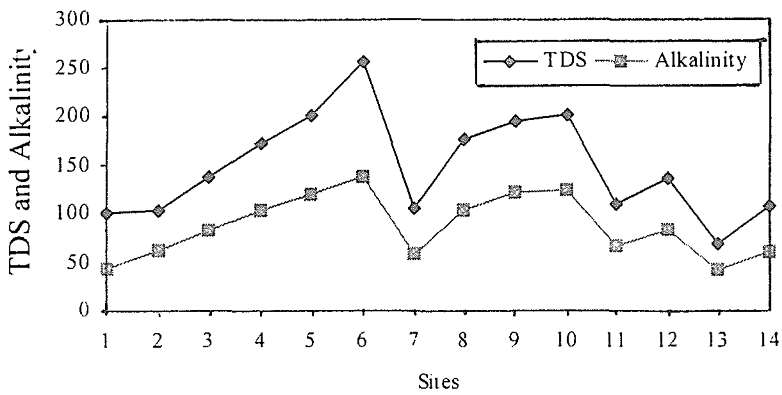

Fig.2.10 Total dissolved solid and alkalinity concentrations from the spring 1998 ad-hoc samples of the Umzimvubu River and its selected tributaries (see Fig.1.1 – 1.6 Chapter 1 for site locations)

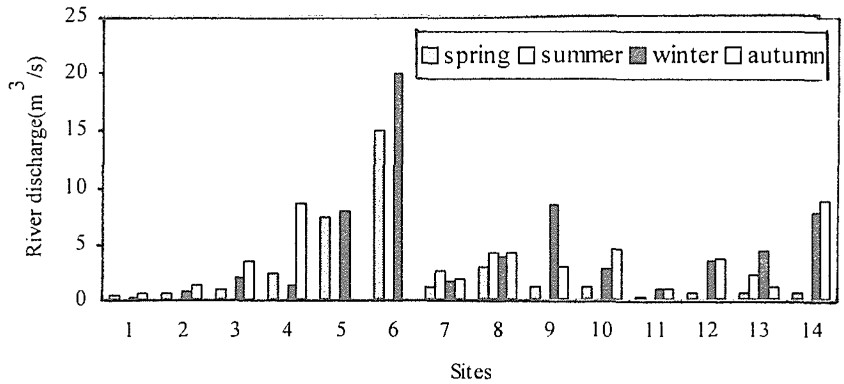

Fig.2.11 The measured river discharge (m^3/s) during sampling at different sites of the Umzimvubu River and its selected tributaries (spring 1996 to summer 1998 - see Fig.1.1 - 1.6 Chapter 1, for site locations). Note that the Umzimvubu River site 6 was not sampled in autumn and many other sites in summer (see Appendix 1).

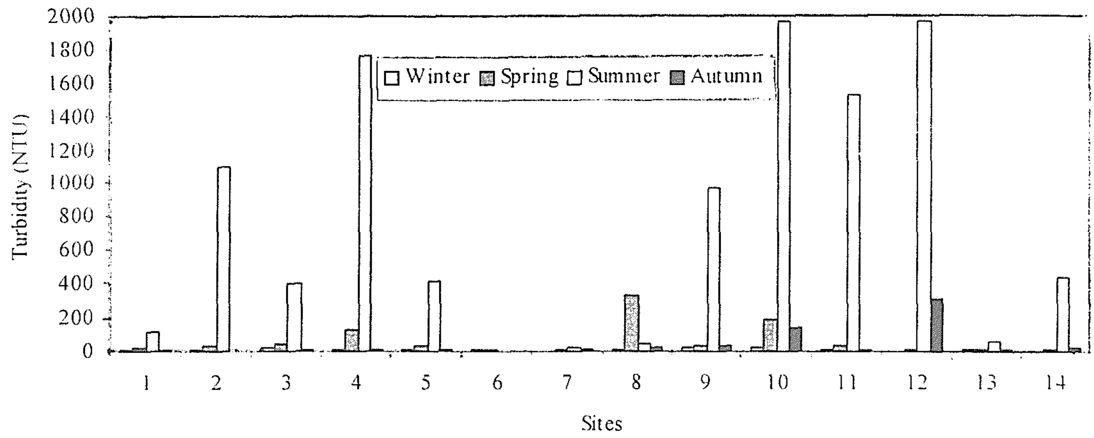

Fig. 2.12 The seasonal turbidity levels of the Umzimvubu River and its selected tributaries (spring 1996 to summer 1998 - refer to Fig 1.2 – 1.6, Chapter 1 for site locations). Note that the Umzimvubu River site 6 was not sampled in summer and autumn.

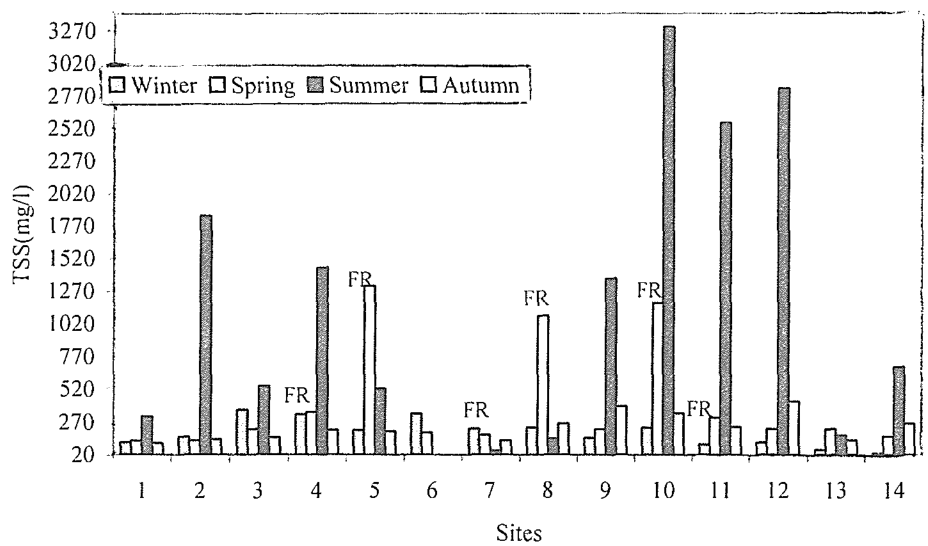

Fig 2.13 The seasonal TSS concentrations of the Umzimvubu River and its selected tributaries (spring 1996 to summer 1998 - see Fig.1.1 to 1.6 Chapter 1, for site locations). Note : FR, refers to sampling following rainfall. Note that the Umzimvubu River site 6 was not sampled in summer and autumn.

10mg/l, the chloride's detection limit (see Appendix 1). Chlorides and sulphates (6.5mg/l) were recorded at the Umzimvubu River sites five and six only. Alkalinity was determined as calcium carbonate (85.2mg/l). Except for Al (0.46mg/l). Fe (0.14mg/l), and Si (6.92mg/l) most trace metals were below the detection limits (see Appendix 1). Because the ad-hoc samples were recorded once, the values are not based on averages.

2.3.2 SEDIMENT

Only suspended sediment (TSS) was sampled during the routine trips (the normal site visits) while random sampling (TSS) was done in summer of 1996, 1997 and 1998 (Fig.2.12 – 2.14). Automatic sampling of TSS was done in summer of 1997/8 only (Fig.2.15 – 2.16). With the exception of sites 7 and 8 from the Umzintlava River and the Tsitsa River site 13 (Fig. 2.13), the TSS concentration at all sites was higher than 250 mg/l in summer. The highest TSS concentration (3 302mg/l) was measured in summer at the Kinira River site 10, while the lowest (51mg/l) came from the Umzintlava River site 7 (Fig.2.13). In the other three seasons, TSS measured less than 500mg/l, except in the Umzimvubu, Umzintlava and the Kinira Rivers at sites 5, 8 and 10 (Fig. 2.13) respectively, where TSS measured more than 1.0g/l in spring. At these sites sampling was done following rainfall (see FR. in Fig. 2.13). As expected, turbidity (Fig. 2.12) measures followed the same trend as TSS (Fig. 2.13). However, highest records of TSS at a particular site did not automatically translate into highest turbidities, possible particle size composition was different (Fig.2.12). Turbidity levels from the Umzimvubu, Kinira and the Tina Rivers, sites 4, 10 and 12 respectively were between 1 800 and 2 000 NTU. Summer random samples (Fig.2.14) at selected sites in the middle reaches showed higher TSS concentrations than summer routine samples. Once again, the Kinira River site 10 received the highest TSS concentration (8 532mg/l) and more than double the routine summer sampling record (3 302mg/l) of 1998. The Kinira River was not randomly sampled in summer 1996. The results of automatic sediment sampling (Tsitsa River site 14) showed the highest concentrations of TSS from this study (Fig. 2.15). Out of 15 x 1 liter plastic bottles packed in a box (Fig. 2.1 and Plate 1), the 14th bottle from the bottom received the highest concentration of sediment (970g/l), while the lowest concentration came from bottle No. 2 (604g/l). The average TSS concentration was 826.14g/l. When the sediment was sorted into particle size composition the cumulative weight percent showed that the 0.125mm particle size was dominant (Fig. 2.16 a-c) in all 15 bottles. Clay and silt were not separated and treated as one component. The slight difference in particle size composition (Fig. 2.16.b and c) from the 6^{th} bottle to the 14^{th} bottle could be due to the heavy particles transported closer to the bottom rather than finer and lighter particles suspended in the water column.

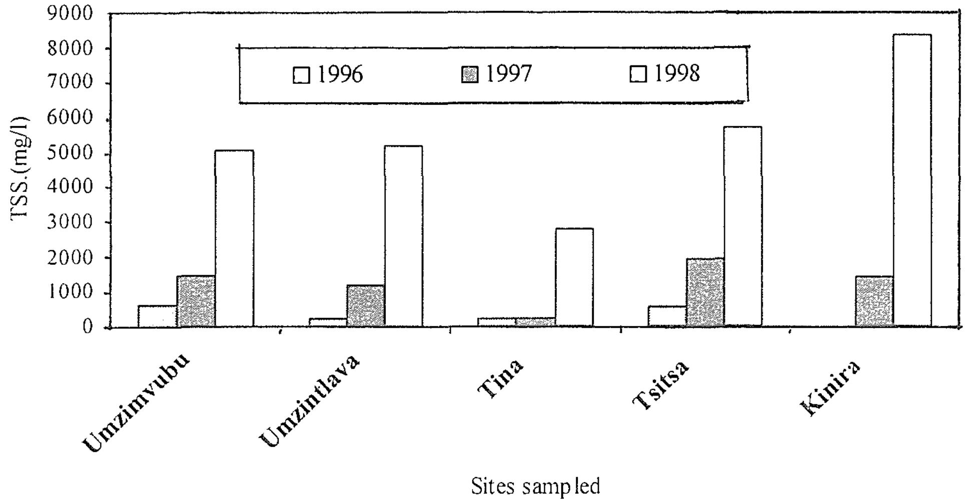

Fig 2.14 Random TSS concentrations of selected sites (middle reaches) from the Umzimvubu River and its selected tributaries.

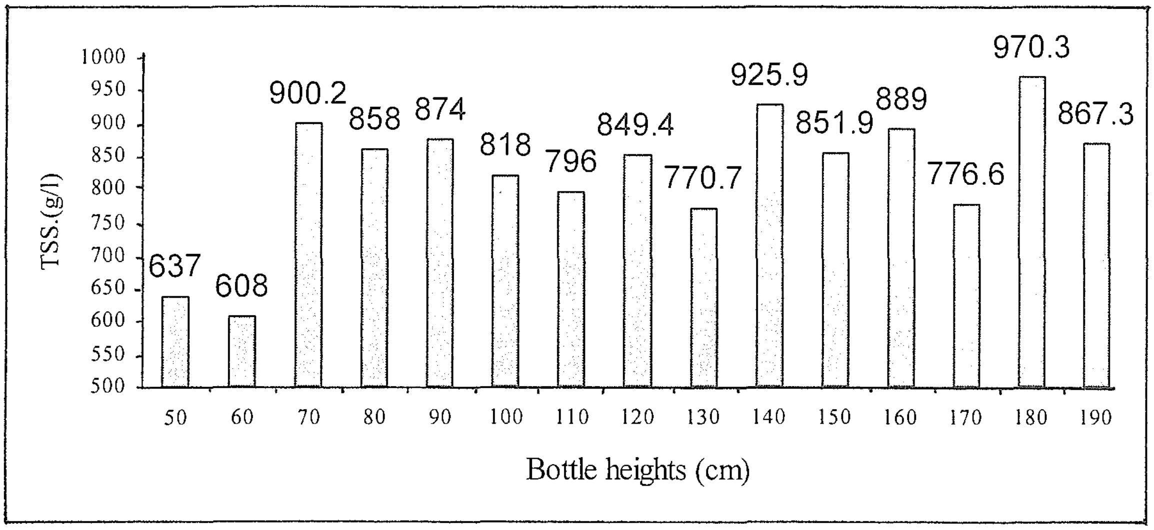

Fig. 2.15 range of automatically sampled suspended sediment concentrations during a summer 1997/8 flood in the middle reaches of the Tsitsa River (Bottles successively filled as the flood rose, such that bottle one represent the beginning of the flood and bottle fifteen a later stage of the flood (See also Fig.2.1).

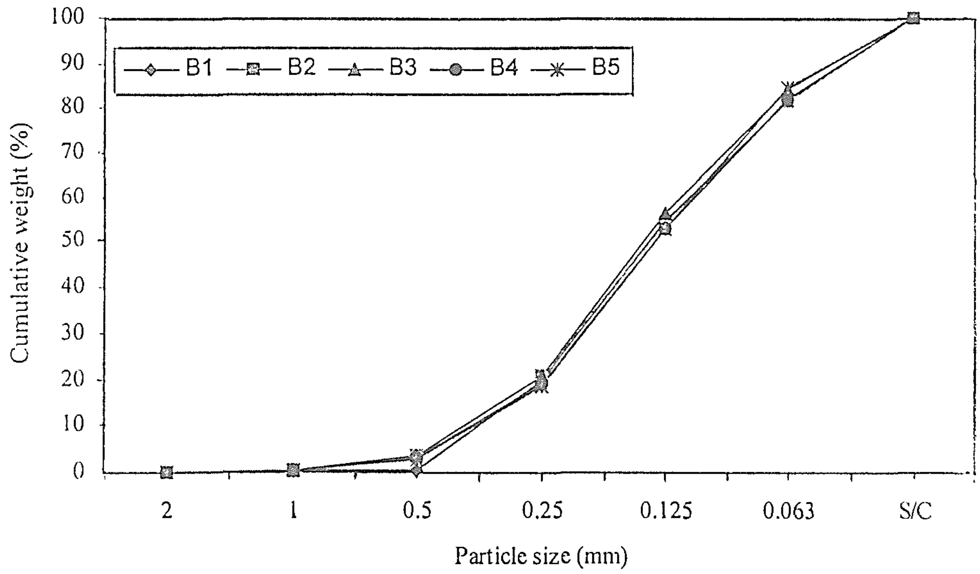

Fig.2.16(a) The particle size composition from the first group of five bottles of the automatic TSS sampler from the Tsitsa River site 14 (summer 1997/8).(s/c = silt and clay)

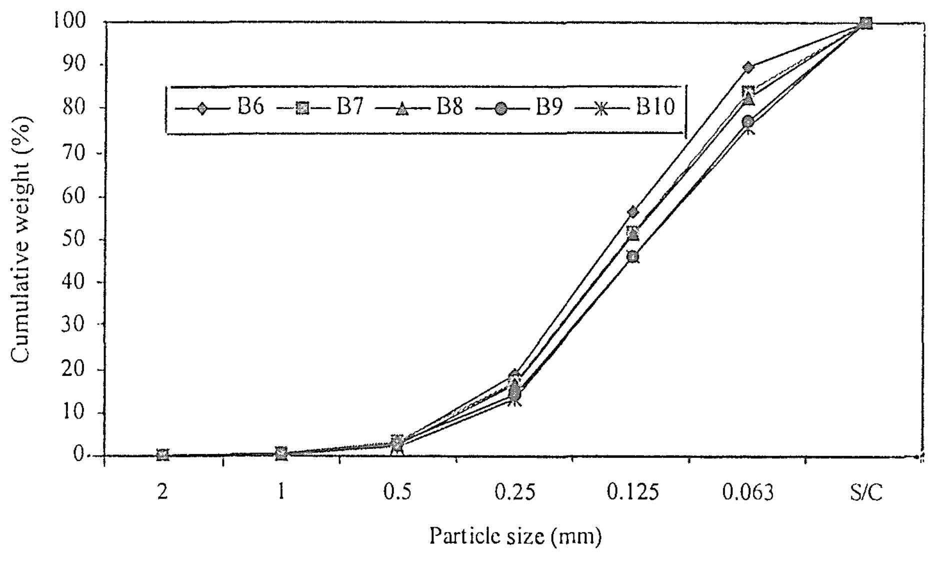

Fig.2.16(b) The particle size composition from the second group of five bottles of the automatic TSS sampler from the Tsitsa River site 14 (summer 1997/8). (s/c = silt and clay)

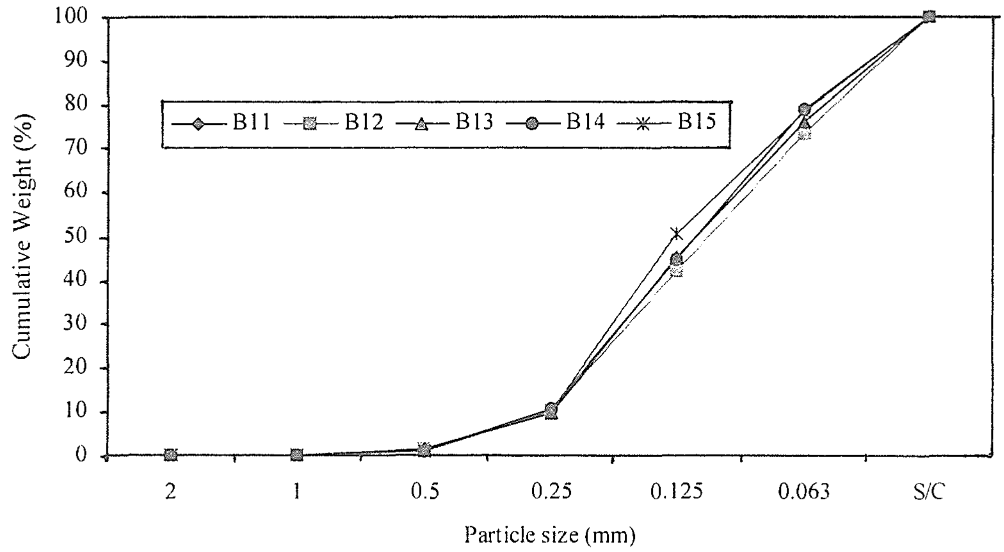

Fig. 2.16(c) The particle size composition from the third group from the five bottles of the automatic TSS sampler from the Tsitsa River site 14 (summer 1997/8). (s/c = silt and clay)

To get an overall picture of the water quality in the catchment, samples between sites and seasons were compared using a clustering technique based on Bray-Curtis Similarity matrices (Gordon *et al.* 1992; Uys *et al.* 1997) (Fig.2.18 and Table 2.1). The analysis showed that the sites were very similar (70 - 95%) with respect to the overall suite of water quality variables.

Table 2.1 Key to site numbering used in comparing water quality variables (Bray–Curtis Similarity) across all sites and seasons.

Seasons	Spring	Summer	Autumn	Winter
River-names	site	site	site	site
Umzimvubu 1	Sp1	Su1	Au1	Wn1
Umzimvubu 2	Sp2	Su2	Au2	Wn2
Umzimvubu 3	Sp3	Su3	Au3	Wn3
Umzimvubu 4	Sp4	Su4	Au4	Wn4
Umzimvubu 5	Sp5	Su5	Au5	Wn5
Umzimvubu 6	Sp6	Su6	Au6	Wn6
Umzintlava 7	Sp7	Su7	Au7	Wn7
Umzintlava 8	Sp8	Su8	Au8	Wn8
Kinira 9	Sp9	Su9	Au9	Wn9
Kinira 10	Sp10	Su10	Au10	Wn10
Tina 11	Sp11	Su11	Au11	Wn11
Tina 12	Sp12	Su12	Au12	Wn12
Tsitsa 13	Sp13	Su13	Au13	Wn13
Tsitsa 14	Sp14	Su14	Au14	Wn14

Key: sp = spring, su = summer, au = autumn and wn = winter.

Despite the great similarity (Fig.2.18), sites can be grouped into at least three categories. Category one represented six sites from summer, category two represented nine sites (all from middle reaches) from three seasons (spring, summer and autumn), category three had sites from all seasons. In these three groups, overlapping of sites from upper, middle and lower reaches occurred. The strong overlapping (between reaches and seasons) coupled with the low measurable water quality deterioration downstream, suggest similarity in water quality variables regardless of site position in the catchment. However, some significant differences occur between sites and seasons (see also Fig.2.2 to 2.13 and Appendix 1).

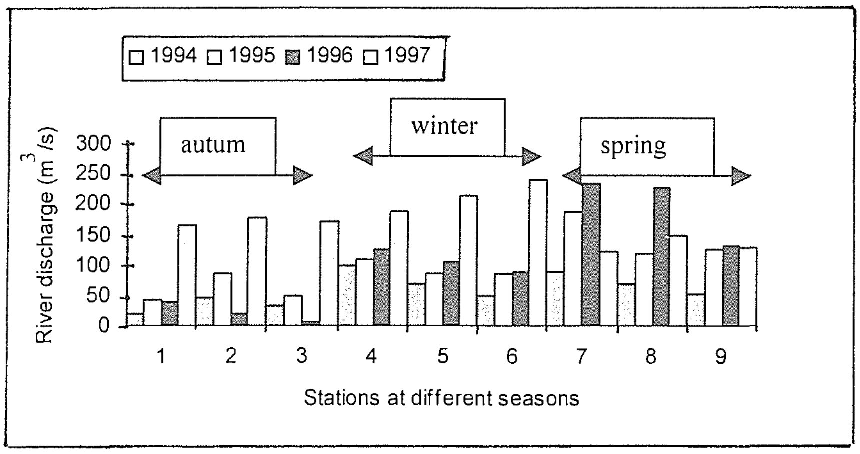

Fig.2.17 The river discharge from the three selected weirs in the middle reaches of the Umzintlava River (weir:T3H004), the Umzimvubu River (weir:T3H008) and the Tsitsa River (weir:T3H006). Note: Numbers. 1, 4 and 7 refer to the Umzintlava R., while numbers 2, 5 and 8 refer to the Umzimvubu R. and numbers 3, 6 and 9 refer to the Tsitsa R. according to seasons shown in the legends.

The graph (Fig.2.17) shows that the river discharge in the catchment as represented by the selected weirs was higher during the sampling period (spring1996 – March 1998) than in 1994/5. Unfortunately data for 1998 had not been processed (DWAF) at the time this report was prepared.

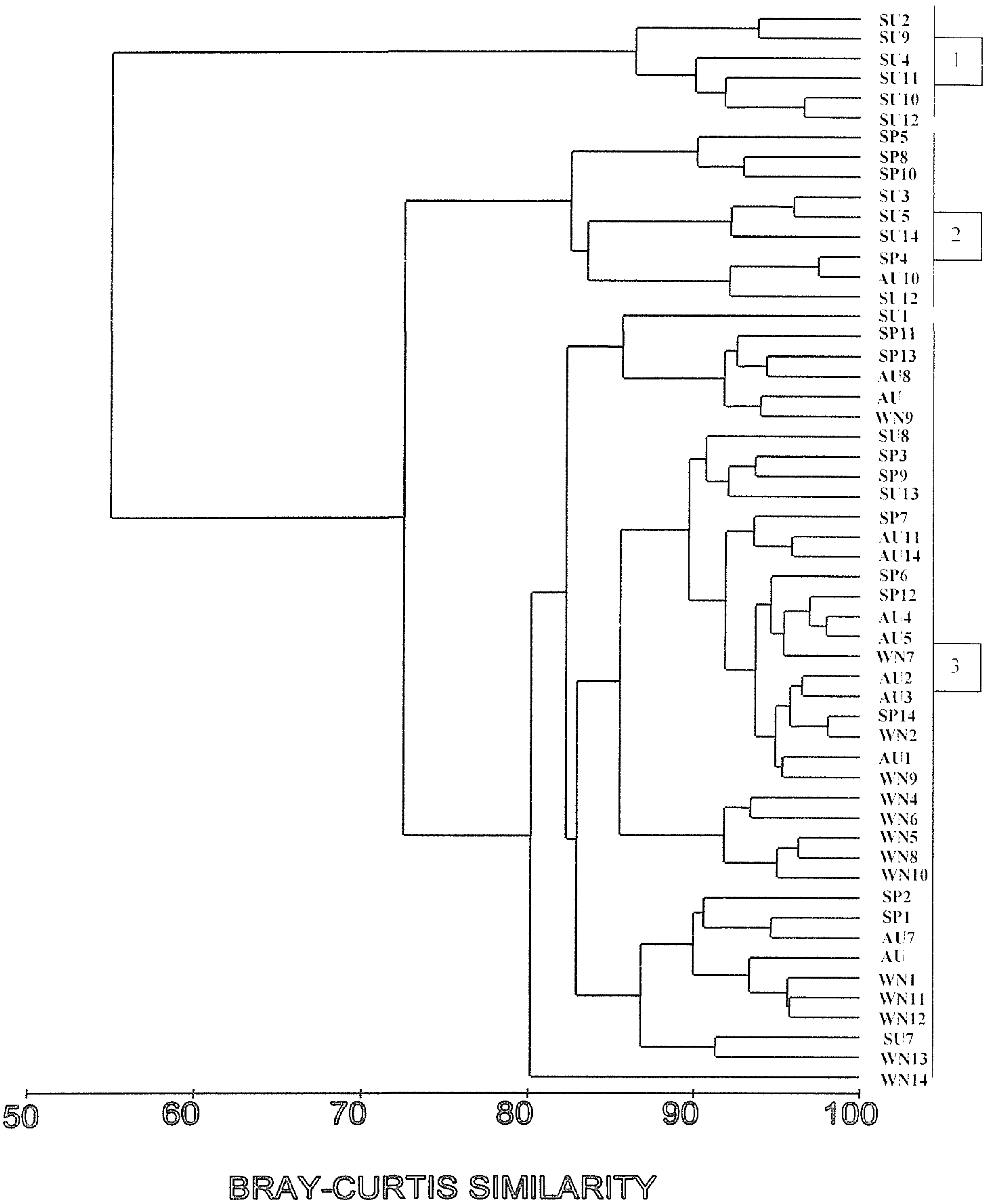

Fig.2.18 Dendrogram for hierarchical cluster analysis of seasonal water quality variables from the Umzimvubu River and its selected tributaries (spring 1996 – summer 1998).

2.3.3 DISCUSSION

The natural deterioration of water quality (due to hydrological, hydraulic, gradient, and geomorphologic factors, as well as accumulation of impurities) longitudinally down the river profile (Dallas *et al.* 1994) is often exacerbated by human impact on the catchment as well as in the river itself, such as water abstractions. The New National Water Act (Act No.36 DWAF, 1998) provides for environmental allocation of water. It explicitly provides for the reservation of water as a priority for environmental and domestic needs through the determination of the reserve.

When analysis of water samples can not be done on site, proper preservation becomes the only alternative. Sharaawi *et al.* (1984) suggested that the changes in concentration occur between sampling and analysis. Even preservation coupled with refrigeration (4°C) is not enough to prevent those changes. They further discovered that nutrients are released when plant / animal material (in a water sample) break or rupture during freezing and thawing. Heron (1962) also observed variable increases in concentration of phosphate using different preservation methods. Though mercury chloride ($HgCl_2$) is an effective preservative, it does not maintain original concentrations between collection and analysis in the laboratory (Brezonik *et al.* 1966). Generally researchers believe *in-situ* analysis is the best way to avoid these effects.

2.3.3.1 Ammonium

In the present study ionized ammonium (NH^+_4-N) (Fig.2.2) showed a downstream increase in concentration in summer samples from the tributaries, but not in the main Umzimvubu River. This increase can be attributed to natural downstream deterioration of water quality as well as from the early summer runoff from the catchment. The low concentration of ammonium in the Umzintlava River site 7 may be ascribed to the settling of impurities in the wetland (Fig.1.3, Chapter 1) immediately above the site (Klotze, 1985). The slightly high concentration of ammonium in the Umzimvubu River (first four sites in summer) may be the consequence of wastes washed in from commercial farming (afforestation, crop and stock farming) land.

2.3.3.2 Nitrates

With the exception of the Umzimvubu River site 4, nitrates (Fig 2.3) were generally low. However, the high levels of nitrates at this site in summer and in winter might have its source from summer surface runoff from the catchment (especially the nearby cabbage farm), decomposition of animal defecation and perhaps from ground water (O'Keeffe *et al.* 1996). The turbidity in summer could also mean low light penetration and hence low uptake by autotrophic plants and bacteria. The low concentration in autumn may be attributed to dilution following summer flow and consistent high rainfall during autumn. Nitrate levels recorded during the study compare well with those recorded by Keulder (1978) (2.9mg/l) from the upper reaches of the Orange River, and 2.1 mg/l recorded by Forbes *et al.* (1970) from the upper reaches of the Sundays River. These three catchments have a relatively similar geology, composed of soils of the Beaufort series.

2.3.3.3 Nitrites

Nitrites (Fig.2.4) represent the least naturally occurring nitrogen compound, because it often forms the transition from nitrates to ammonium or vice versa depending on bacterial action. Brezonik *et al.* (1966) recorded up to 1mg/l nitrites in a natural water environment. With the exception of the Umzimvubu River site 2 and the Tsitsa River site 13, (both in spring) nitrites were recorded in very low quantities. Besides being in the foothills of their respective rivers (with riverbed covered completely with sand), the two sites are in the commercial farming areas and new pine plantations. Nitrites and phosphates (Grobler *et al.* 1987) may also be released slowly from sediment by bacterial action on organic nitrogen, biological mineralization and wind generated turbulent flows that can disturb sediment (Klingaman, 1976).

2.3.3.4 Phosphorus (SRP)

The other nutrient of importance for plant growth is the phosphorus (SRP) (Fig.2.5). This nutrient (like others) occurred in slightly higher concentration in summer, and mainly in the first four sites of the Umzimvubu River (commercial farming area). Elevated concentrations of phosphorus were also recorded from the Kinira River site 9 and the

Tina River sites 11 and 12 in winter (Fig.2.5). The increased concentration could be due to surface run-off (return flow from commercial agriculture) (Hill *et al.* 1977) or reduced dilution in winter and in spring. High levels of phosphorus can be expected from the study catchment because it is dominated by soils from sedimentary rock formation (Grobler *et al*, 1987). Very high concentration of nutrients particularly phosphorus (4mg/l) were recorded from the upper reaches of the Buffalo River. A substantial contribution originates from rural settlements in the form of animal and laundry waste (van Ginkel *et al.* 1996). Such contributions, though not investigated, should be expected in the rural Transkei catchments (O'Keeffe, 1988). Prior to 1978, Keulder reported that the oligomesotrophic Gariep dam (formally known as Hendrik Verwoed dam) required 1.39mg/l (threshold) of Phosphorus m^{-2} a^{-1} for eutrophication to occur. In the Umzimvubu River's under-developed catchment, phosphate levels (Fig.2.5) were below the standard limits (1mg/l) (Grobler *et al.* 1987). Elsewhere in the country, they are so high that the Rand Water Board for example had to increase the standard operations for the release of phosphates (1mg/l) into the highly developed Vaal River catchment by half (Grobler *et al.* 1987).

2.3.3.5 Conductivity, Alkalinity and pH

Low concentrations of TDS were recorded in summer (Fig.2.9). This may be due to dilution. Fairly low concentrations of sodium and chloride were recorded in the Umzimvubu River catchment (Present study) compared to 25.8mg/l of sodium and 31.6 mg /l of chlorides recorded by Forbes *et al.* (1970) in the upper reaches of the Sundays River. Except for Al, Fe and Si, most trace metals were below the detection limits, while sulphates and chlorides were recorded at the Umzimvubu River sites 5 and 6 only suggesting low levels of ions in the catchment. Slightly alkaline water in the Umzimvubu Rriver catchment may be due to higher concentration of calcium and magnesium recorded in this study compared to those recorded (5.1mg/l and 5.3mg/l, respectively) by Forbes *et al.* (1970) for the upper reaches of the Sundays River (see Appendix 1). However, salinity (TDS) was comparatively low (Fig.2.9 and 2.10). Slightly alkaline water conditions were indicated by pH, and calcium carbonate (Fig.2.8 - 2.10).

2.3.3.6 Oxygen and Temperature

The low oxygen concentration (Fig.2.6) in summer compared to spring values may be attributed to sediment loads, low photosynthesis rates and increased temperatures (Fig.2.7) (Palmer *et al.* 1990; O'Keeffe *et al.* 1996). However, most of the rivers had on average well oxygenated water (97%) (DWAF, 1996).

2.3.3.7 Flow, Sediment and Turbidity

Flow (Fig.2.11) seemed to increase downstream as the river order (width) and contributions from tributaries increased. Many researchers (Doornkamp *et al.* 1973; Rooseboom *et al.* 1992) have reported a proportional increase in TSS with flow (m^3/s) until a point is reached where sediment sources (mainly from the catchment) can no longer supply enough sediment to maintain the linear relationship. The results of this study indicate that more TSS was collected during random sampling and automatic sampling (Fig 2.14 and 2.15) than during the routine sampling. This is when flow was particularly high (during peak flow and floods). Usually the high loads of sediments are transported during the first surface runoff following long periods of no rain. This is called "first flush" (Klotze, 1995). According to Strunk (1992) different discharges (m^3/s) transport different quantities of sediment. This was apparent in the concentration of sediment per bottle (Fig.2.15). The high and complex variation in TSS concentration transported downstream at any time (Kelly, 1992) requires a shift from grab sampling method to a more "accurate" automatic sediment monitoring / sampling. Gippel (1994; 1995) and Grayson *et al.* (1996) used a turbiditimeter (*in-situ*) to monitor turbidity automatically. However their method was hampered by the color of the water, shape and size of the particles as well as by power supply and maintenance problems. The method also assumes that turbidity is directly proportional to TSS which is not always the case (Doornkamp *et al.* 1973; Gippel, 1989), and limits the utility of the method. This lack of linear relationship is illustrated in Fig.2.12 and 2.13. Note the difference between the scales in the figures. The automatic TSS sampling of sediment conducted in summer

1997 / 98 revealed that automatically sampled sediment during floods was two orders of magnitude higher than that of random and routine sampling during base flows (Fig.2.13 – 2.15). The results explicitly show how much sediment comes down from the catchment and how much normal grab sampling misses during floods. The Kinira River site 10 seemed to carry consistently higher loads of sediment. The reason for this is unclear. The results of sediment sorting (Fig.2.16 a-c) concur with the general view that the dominant particle size of sediment (Grobler *et al.* 1987) in South Africa is less than 0.2mm.

Brown (1960, cited in Hellawell. 1986) recorded an average of 300 g/l of TSS in rivers in the United Kingdom. This is about the half of the lowest TSS levels recorded in this study (Fig.2.15). Note that the TSS was recorded in the Northern Hemisphere (known to carry less sediment than rivers in the arid Southern Hemisphere) more than three decades ago. Hellawell (1986) reported an increase in TSS from 67 – 1400mg/l following logging without leaving a 60m buffer zone of untouched riparian vegetation. The Umzimvubu River catchment is characterized by overgrazing, ploughing down to the river- banks and ploughing on the valleys or steep land. It is also dominated by easily eroded soils of the Beaufort series. The good rainfall (mean 604 – 1 138mm) and high erosivity index combined with the above factors result in severe soil erosion (Rooseboom *et al.* 1992). Keulder (1978) studying the upper reaches of the Orange River reported 4 600mg/l of TSS using grab sampling. The highest record of TSS in the Umzimvubu River catchment using random grab sampling was 8 232mg/l (Fig.2.14).

Water from the Umzimvubu River catchment seems to be of reasonably good quality (Kempster *et al.* 1980; DWAF, 1996 and Appendix 2), with TSS being the only variable of serious concern. Strictly seasonal rainfalls in South Africa result in great differences in seasonal TSS and turbidity levels (Fig 2.12 and 2.13). The dendrogam (Fig. 2.18) revealed high (70 – 90%) similarity amongst sites, regardless of location (Fig.1.1–1.6 and Table 1, Chapter 1). Due to the rural nature, relatively low catchment development (no industrialization) and rejuvenation in the middle and lower reaches, (Brown *et al.* 1996) the Umzimvubu River catchment presently maintains water of good quality.

CHAPTER 3

3 AQUATIC INVERTEBRATES

3.1 INTRODUCTION

Assessing the diversity of macro-invertebrate communities as a biological indicator of river health is gaining some popularity to supplement traditional physicochemical indicators. Camago (1991) and Williams (1996) reported on the modification of invertebrate community structures as a result of municipal treatment plant releases. Apart from anthropogenic activities, natural variables such as altitude, food web characteristics, functional feeding groups (FFG's), substrate, flow (seasonal or perennial), etc., all variously affect community structure (Ward *et al.* 1984 cited in Hart *et al.* 1994; Palmer *et al.* 1992). A long life cycle, abundance and ease of collection, local occurrence, variable levels of sensitivity, etc., are some of the attributes that make macro-invertebrates suitable for water quality assessment. Unless a rapid biological assessment method such as SASS4, is used, biomonitoring can be hampered by the need to identify organisms to fine levels of taxonomy such as species, when few experts are available (de Pauw, 1983). Natural hazards such as floods and drought can also place limits on the successful use of invertebrates in water quality monitoring. For example Chutter *et al.* (1993) recorded re-appearance of invertebrates in a stream following a short period of no flow. A similar response was reported by Uys *et al.* (1997) while working on an intermittent stream. Successful application and use of biomonitoring data is only possible when the biological and behavioural responses of invertebrates subjected to natural and anthropogenic perturbations are understood.

Receiving Water Quality Objectives (RWQO) is an attempt to ensure the continued fitness of water for use downstream as an alternative to the uniform effluent standard approach (van der Merwe *et al.* 1989). The approach is based on water quality requirements of in-stream aquatic biota. In order to sustain biodiversity downstream of an impact point (e.g. a dam), ideally the same water quality conditions prior to impact must be maintained. Different water users have different water quality and quantity requirements which can only be met through the determination of the ecological reserve (National Water Act No.36 DWAF, 1998). The idea is to ensure that "enough water" of good quality is left in a river to sustain aquatic life, following abstraction. Ideally, a comprehensive biological and hydrological data is required prior to determination of the reserve (Herschy, 1978; King *et al.* 1998). The only information on aquatic fauna in the former Transkei was that reported by Mqoqi (1991) and Schramm (1993) who studied Schistosoma and fish lake production, respectively. Since there is little information available on macro-invertebrates in the Umzimvubu River catchment, this project was aimed at generating a baseline data on aquatic fauna. Such data will be lodged with the national database for aquatic invertebrates through the department of invertebrates, Albany Museum. Organizations, such as RHP will be expected to apply the data in provincial and national biomonitoring programmes as well as water resource developers, e.g. river regulation (DWAF, 1994).

3.2 MATERIALS AND METHODS

Macro-invertebrates were sampled at the same sites and times as those used for water quality measurements (see Chapter 2). Benthic macro-invertebrates were sampled from all available biotopes. Depending on the size of a biotope, one to three samples were taken. The following biotopes occurred, though not at all sites; stones in current (SIC.), stones out of current (SOOC.), sediment (e.g. sand, mud or combination), aquatic vegetation (AQV.), marginal vegetation (MV.) and kick sample or gravel (Thirion *et al.* 1995).

To sample SOOC and SIC a 350x350mm (182µm mesh) net was held a few centimeters downstream of cobbles (stones, 64 – 256 mm) so that dislodged invertebrates could be caught. Five cobbles (3-replicates per site at different points) were removed and put in a bucket and the attached invertebrates were physically brushed off. Kick samples were obtained by disturbing the substrate surface (gravel, 4mm-16mm) (Gray, 1981) while at the same time the same mesh was held about a meter downstream to catch dislodged invertebrates (Coetzer, 1978). Sampling of sand was done in the same way as kick sampling, the only difference being that a net was swept to and fro over the disturbed substrate. Marginal vegetation was sampled by disturbing the submerged part of vegetation with the net just below the water surface. All samples were labeled according to their biotopes, placed in 500ml sample bottles, then filled with 70% ethanol on site before being returned to the laboratory for formal identification. All SASS scores were done in the laboratory not on the river sites as required by standard method (SASS) due to taxonomic difficulties. Each site was mapped (sketch) and photographed.

3.3 RESULTS

3.3.1 Macro-invertebrates

At the same times as water quality sampling, fourteen sites were seasonally sampled for macro-invertebrates over the period 1996 to 1998 (Table 1 and Fig. 1.1 to 1.6, Chapter 1). However, in summer and autumn Umzimvubu River site 6 was not sampled due to unrest in the area and persistent high flows. This reduced the number of sites sampled from 14 to 13 (Table 3.1).

3.3.2 Similarity analysis

Analysis, based on abundance of macro-invertebrates at each site in autumn is shown in Fig.3.1 and Table 3.1. The sites in Fig. 3.1 can be grouped into three categories. Sites Au2 and Au12 in the Umzimvubu and Tsitsa Rivers are in the foothills of their respective rivers. They seem to be a separate pair from the rest of other sites. The second group, just less than 70% similar (Au4, Au5 and Au9) are two sites from the Umzimvubu and one site from the Kinira Rivers in the middle reaches. The larger third group combined sites from upper and middle reaches (Au1, Au3, Au6, Au7, Au8, Au10, Au11 and Au13). Some sites within this group are more similar (>70%) than others. The apparent overlapping of sites from upper to middle reaches suggests more similar distribution of macro-invertebrates in autumn across the catchment.

There is even more variation and dissimilarity (<70%) in the dendrogram for summer (Fig.3.2). Broadly, the dendrogram can be broken down into three groups. The two Umzimvubu sites (Su2 and Su3, see Table 3.1) seem to pair separately from the rest of the other summer sites. The second group is the Umzimvubu, Kinira, Tina and Tsitsa River sites Su1, Su9, Su11 and Su13, all the first sites of their respective rivers, though not necessarily at the same altitudes (see Fig.1.1 and Table 1.1, Chapter 1). The last group was made up of sites Su4, Su5, Su7, Su8, Su10, Su12 and Su14, first two sites from the Umzimvubu, two sites from the Umzintlava, a site from the Kinira, the Tina and the Tsitsa Rivers. Except for the Umzintlava River site Su7 which is at the foothill below the wetland, the others are in the middle reaches.

Table 3.1 Key table to site numbering used in comparing (site six was not sampled in autumn and summer) seasonally sampled macro-invertebrate abundance in a Bray-Curtis similarity dendrogram.

River name and site number	Seasons			
	Summer	Autumn	Winter	Spring
Umzimvubu 1	Su1	Au1	Wn1	Sp1
Umzimvubu 2	Su2	Au2	Wn2	Sp2
Umzimvubu 3	Su3	Au3	Wn3	Sp3
Umzimvubu 4	Su4	Au4	Wn4	Sp4
Umzimvubu 5	Su5	Au5	Wn5	Sp5
Umzimvubu 6	Su6	Au6	Wn6	Sp6
Umzintlava 7	Su7	Au7	Wn7	Sp7
Umzintlava 8	Su8	Au8	Wn8	Sp8
Kinira 9	Su9	Au9	Wn9	Sp9
Kinira 10	Su10	Au10	Wn10	Sp10
Tina 11	Su11	Au11	Wn11	Sp11
Tina 12	Su12	Au12	Wn12	Sp12
Tsitsa 13	Su13	Au13	Wn13	Sp13
Tsitsa 14	Su41	Au14	Wn14	Sp14

Key: su = summer, au = autumn, wn = winter and sp = spring.

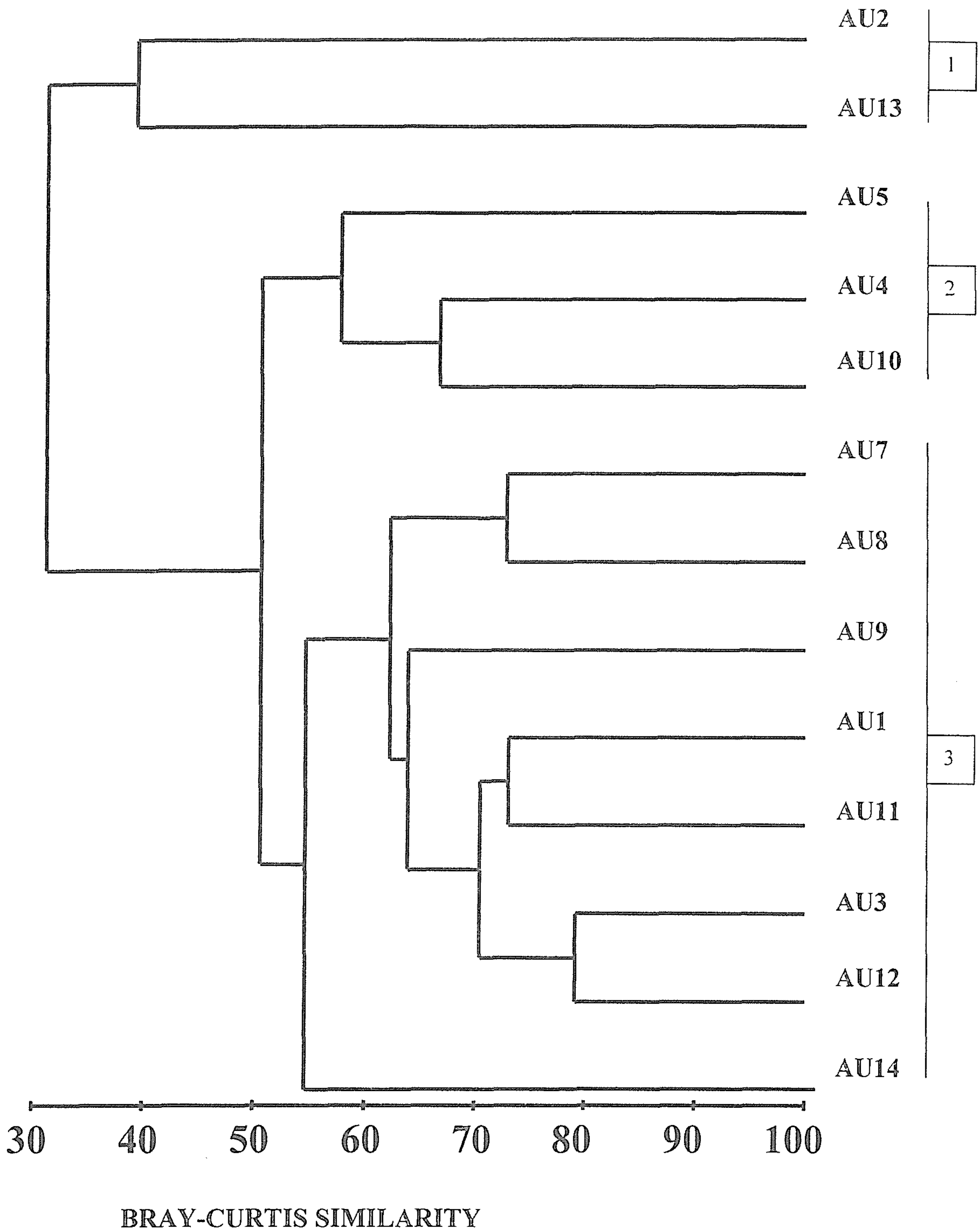

Fig.3.1 Dendrogram for hierarchical cluster analysis of autumn macro-invertebrate samples sorted to family level from the Umzimvubu River and its selected tributaries. Site 6 was not sampled in autumn.

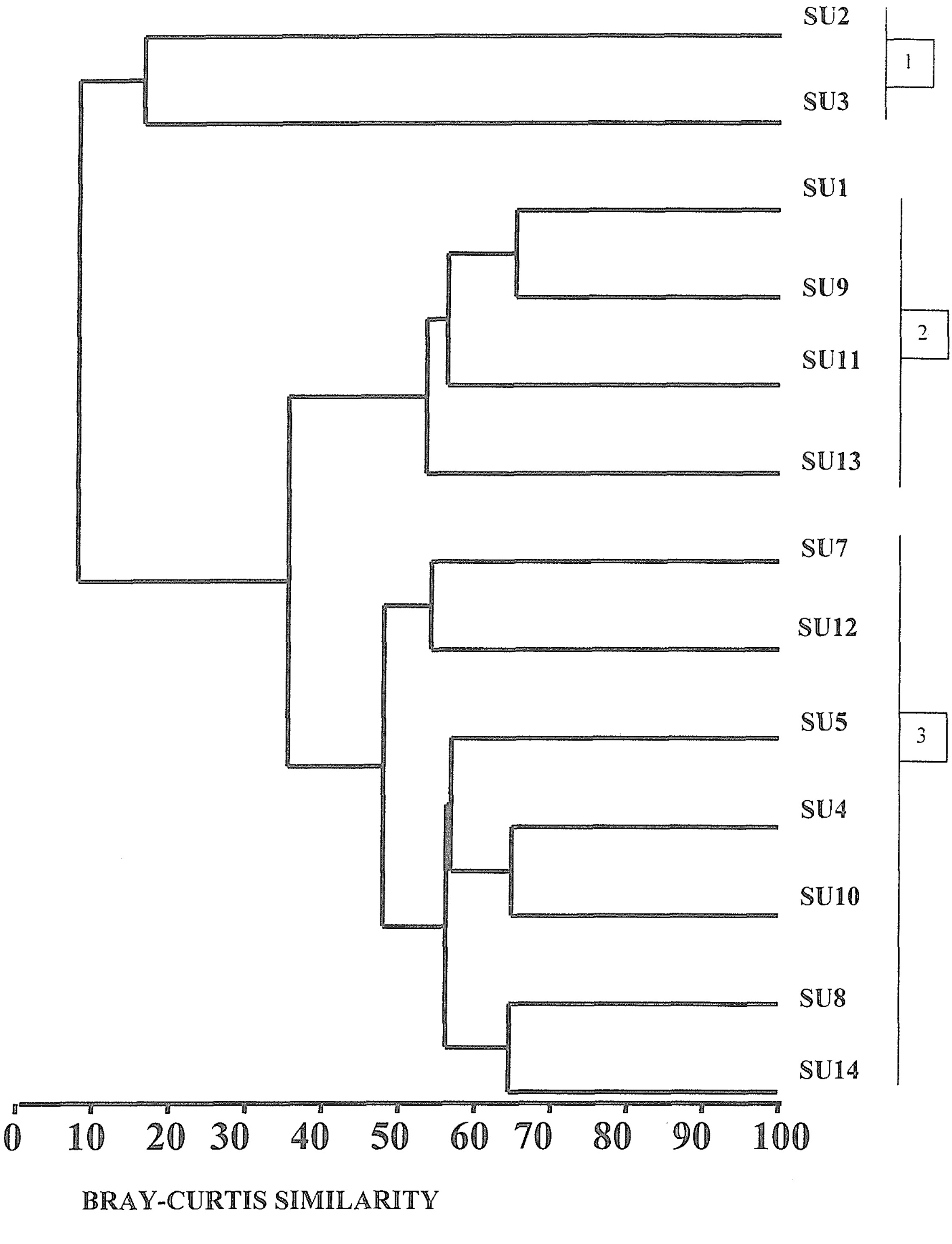

Fig 3.2 Dendrogram for hierarchical cluster analysis of summer macro-invertebrate samples sorted to family level from the Umzimvubu River and its selected tributaries. Site 6 was not sampled in summer.

Table 3.2 Key to site numbering used in comparing macro-invertebrate abundance of the Umzimvubu River and its selected tributaries in all seasons using Bray-Curtis similarity dendrogram. Note seasonal site codes and biotopes sampled per site, (see also Fig.3.8).

River-name and site No.	spring		summer		autumn		winter	
	site	biotopes	site	biotopes	site	biotopes	site	biotopes
Umzimvubu 1	Sp1	sic, sooc, sand.	Su1	aqv.	Au1	sic,sooc,sand,aqv,k /sample.	Wn1	sic,sooc,aqv,sand,k/sample
Umzimvubu 2	Sp2	aqv, sand.	Su2	aqv.	Au2	aqv,sand.	Wn2	aqv,sand
Umzimvubu 3	Sp3	sic,sooc,aqv,mv, sand, k/sample.	Su3	aqv.	Au3	sic,sooc,aqv,sand,k /sample.	Wn3	sic,sooc,aqv,sand,k/sample
Umzimvubu 4	Sp4	sic,sooc,sand,k/samp le.	Su4	sic,sooc.	Au4	sic,sooc,sand,k/sam ple	Wn4	sic,sooc,sand,k/sample
Umzimvubu 5	Sp5	sic, sooc, sand.	Su5	sic.	Au5	sic,sooc,sand	Wn5	sic,sooc,sand
Umzimvubu 6	Sp6	sic,sooc,sand,k/samp le.	Su6	N/a	Au6	n/a	Wn6	sic,sooc,sand,k/sample
Umzintlava 7	Sp7	sic,sooc,aqv.	Su7	sic,sooc, aqv,mv.	Au7	sic,sooc,aqv,mv	Wn7	sic,sooc,aqv,mv
Umzintlava 8	Sp8	sic,sooc,aqv,sand.	Su8	sic,sooc, aqv,sand.	Au8	sic,sooc,aqv,sand, mv	Wn8	sic,sooc,aqv,sand
Kinira 9	Sp9	sic,sooc,aqv,sand.	Su9	sic,sooc. aqv.	Au9	sic,sooc,aqv,sand	Wn9	sic,sooc,aqv,sand
Kinira 10	Sp10	sic,sooc,sand	Su10	sic,sooc,	Au10	sic,sooc,sand	Wn10	sic,sooc,sand

Table 3.2 (continues)

River-name and site No.	spring		summer		autumn		winter	
	site	biotopes	site	biotopes	site	biotopes	site	biotopes
Tina 11	Sp11	sic,sooc,aqv,sand	Su11	aqv	Au11	sic,sooc,aqv,k/sample	Wn11	sic,sooc,sand,k/sample
Tina 12	Sp12	sic,sooc,aqv,sand	Su12	sic,sooc, aqv	Au12	sic,sooc,aqv,mv,sand	Wn12	sic,sooc,aqv,mv,sand
Tsitsa 13	Sp13	aqv,sand	Su13	aqv	Au13	aqv,sand	Wn13	aqv,sand
Tsitsa 14	Sp14	sic,sooc,aqv,sand	Su14	sic,sooc, aqv,sand	Au14	sic.sooc.aqv,sand	Wn14	sic,sooc,aqv,sand

Key: sp = spring, su = summer, au = autumn, and wn = winter.

Sites in winter seem to be very similar (around 70%) (Fig.3.3). Though the Umzimvubu and the Tsitsa Rivers (sites Wn2 and Wn13, see also Table 3.1) do not pair in winter as they did in autumn, these sites still have little in common with other sites.

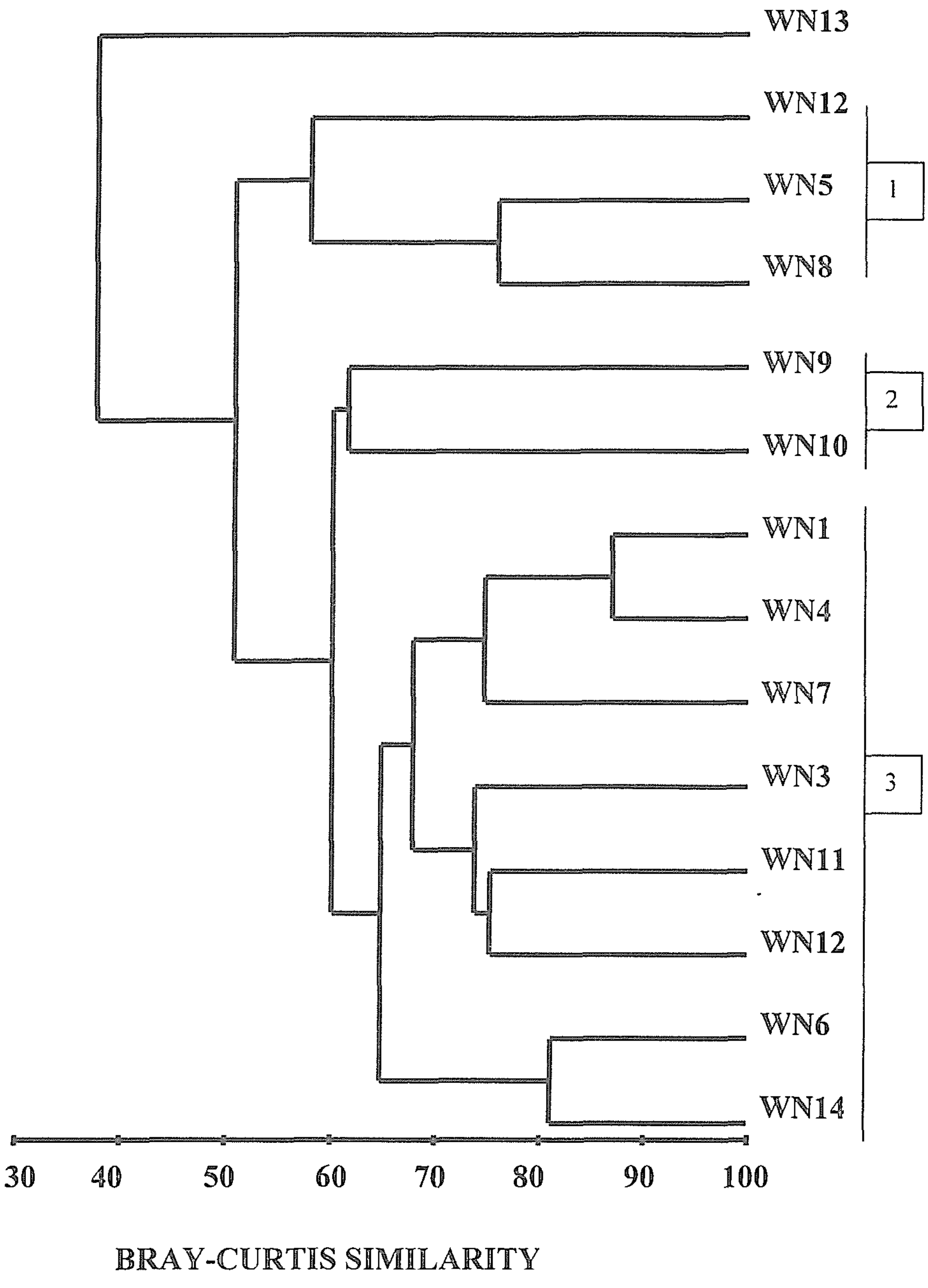

Fig 3.3 Dendrogram for hierarchical cluster analysis of winter macro-invertebrate samples sorted to family level from the Umzimvubu River and its selected tributaries.

The dendrogram (Fig.3.3) can be simplified into three groups. The Umzimvubu and Umzintlava Rivers (sitesWn5 and Wn8) were more than 70% similar (both from middle reaches). The two sites from the Kinira River upper and middle reaches (sites Wn9 and Wn10) were both less than 70% similar in group two. The third group with great variation between sites (sites Wn1, Wn3, Wn4, Wn6, Wn7, Wn11, Wn12 and Wn14) was composed of sites from upper, middle and lower reaches of the Umzimvubu, Umzintlava, Tina and Tsitsa Rivers. Within this group, the Umzimvubu River, upper and middle reaches (sites Wn1 and Wn4) were close to 90% similar while the Umzimvubu and the Tsitsa Rivers (sites 6 and 14) were just more than 80% similar. The dendrogram again suggests lack of measurable dissimilarity among the sites sampled.

The spring macro-invertebrate dendrogram (Fig.3.4) showed some level of variability with a number of sites less than 70% similar, while some are more similar, such as the Umzimvubu and the Kinira Rivers (sites Sp1 and Sp10, see Table 3.1). The Umzimvubu River upper and the Kinira River middle reaches (sites Sp1 and Sp10) were more than 70% similar. (see also Fig.1.2 and 1.4 Chapter 1). The Umzintlava, Kinira and Tsitsa Rivers, sites Sp7, Sp9, and Sp14, respectively exhibited another high similarity (80%). Again these sites were from upper and middle reaches. Spring samples could be grouped into four categories. The Umzimvubu and the Tsitsa Rivers (sites Sp2 and Sp13) as in autumn, formed a separate group from the rest. The Umzimvubu River sites (Sp5 and Sp6) made up the second group from middle and lower reaches (see Fig.1.2, Chapter 1). The Umzimvubu, Kinira and the two Tina River sites (Sp1, Sp10, Sp11 and Sp12) from the upper and middle reaches composed the third group. The last category was composed mainly of sites from the middle reaches, except the Umzintlava and Kinira Rivers (sites Sp7 and Sp9) which were from upper reaches. Sites Sp3, Sp4, Sp8 and Sp14 were from the middle reaches. Similar to other comparisons, there was neither a clear trend between site locations (in terms of altitude) along a river from upper to lower reaches, nor between rivers.

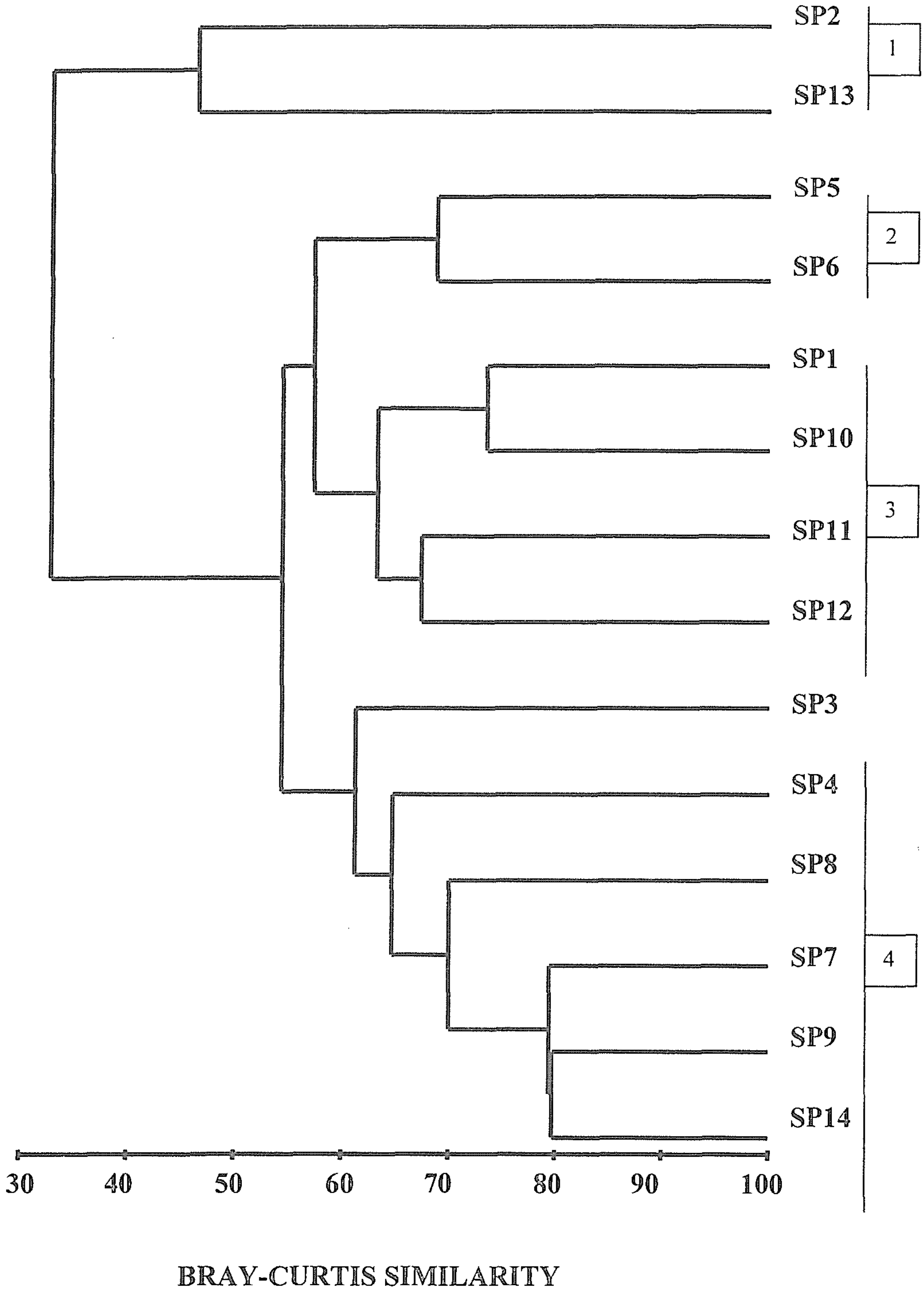

Fig.3.4 Dendrogram for hierarchical cluster analysis of spring macro-invertebrate samples sorted to family level from the Umzimvubu River and its selected tributaties.

Putting all sites from the four seasons together (Fig.3.5) it immediately became apparent that the summer (group 1) (with its own variability, <70%) had little overlap (<50%) with other seasons (sites 15 to 27, see Table 3.2).

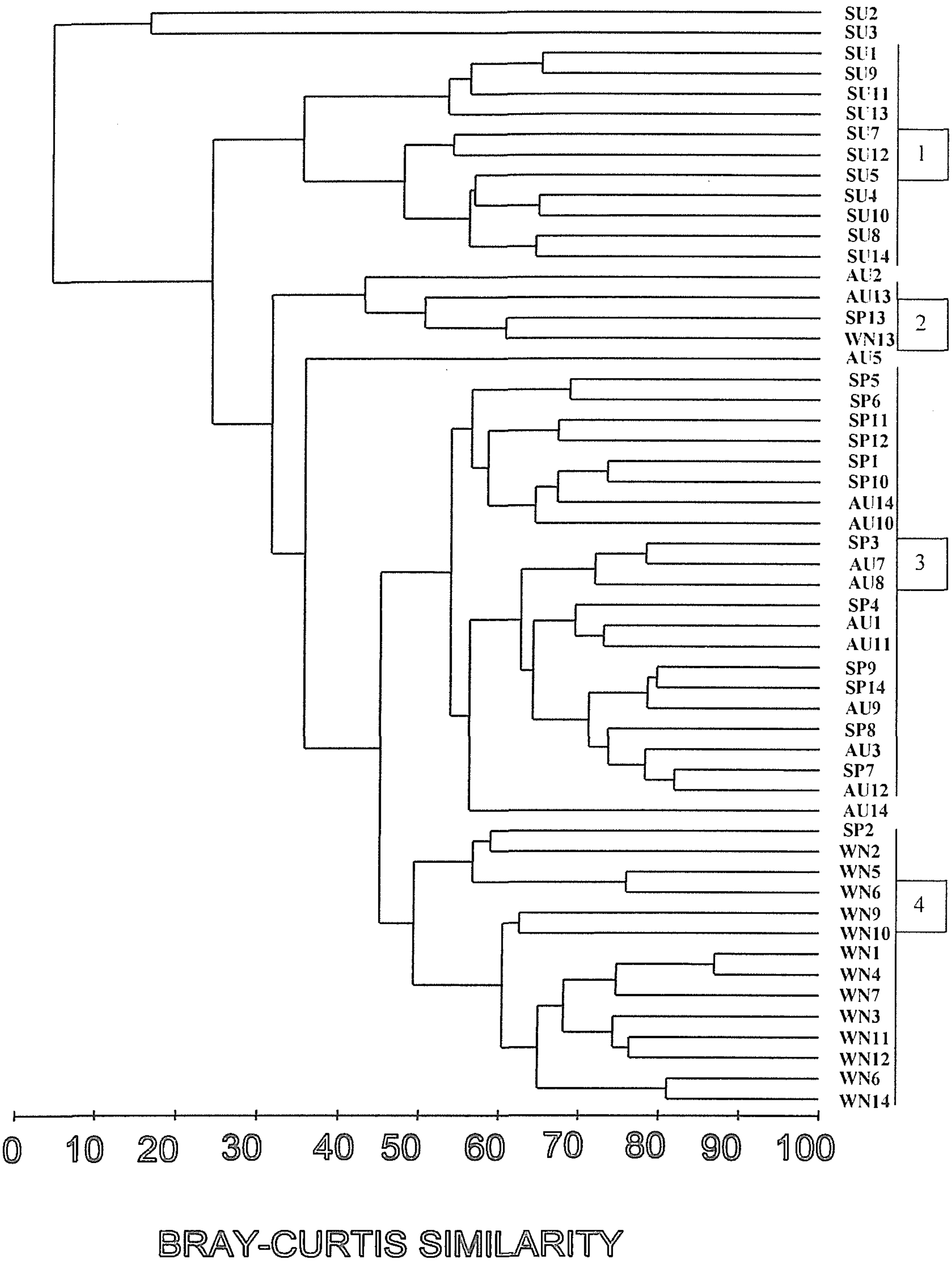

Fig.3.5 Dendrogram for hierarchical cluster analysis of all seasonal macro-invertebrate samples sorted to family level from the Umzimvubu River and its selected tributaries.

However, the Umzimvubu River sites Su2 and Su3 still retained their separation from the rest of other summer sites as well as those of other seasons. The second category was the consistent similarity over three seasons (spring, autumn and winter), where the Umzimvubu River site Au2 grouped with the Tsitsa River sites Sp13, Au13 and Wn13. The third group was a combination of spring and autumn samples (Sp1 to Sp14 and Au1 to Au14). Observable within this group was retention of strong similarity (>70%) between the Umzimvubu and the Kinira Rivers (Sp1 and Sp10, see Table 3.2) as in Fig.3.4. The fourth group which had very little overlap with other seasons is winter (sites Wn1 to Wn14, except Wn13), with most sites retaining their overlapping pattern between reaches as in winter dendrogram (Fig.3.3). Though Fig.3.5 can be simplified as outlined above, the three seasons (autumn, winter, and spring) are more similar (from 70 to 80%) than summer, which fell below the 70% mark. This suggests that invertebrate groups collected in these three seasons were more similar than those collected in summer.

A relate analysis which compares similarity matrices recorded that although there was generally a close relationship between biotic and abiotic factors, these varied seasonally. In spring there was 94.2% correspondence between the similarity matrices of abiotic and biotic variables, but decreased progressively through summer (88.4%), autumn (84.5%), and winter (71.1%). This indicates that while the suite of abiotic variables measured explains most of the community structure in spring, other factors, such as biotic interaction, and habitat variability, become important at other times.

3.3.3 Rapid biological assessment

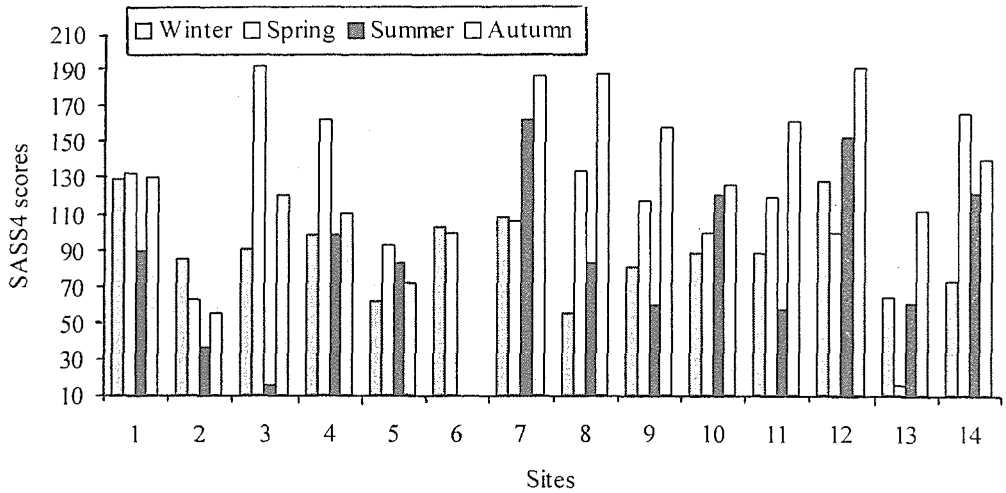

Fig.3.6 The seasonal distribution of SASS4 scores from the Umzimvubu River and its selected tributaries (Refer to Fig.1.1 to 1.6, Chapter 1 for site locations). Note that the Umzimvubu River site 6 was not sampled in summer and autumn.

With few exceptions (the Umzimvubu, Umzintlava, Kinira, Tina and Tsitsa Rivers, sites 4, 7, 10, 12 and 14, respectively) SASS4 scores (Fig.3.6) were generally poor in summer (Fig. 3.6). Since sampling was disturbed by high summer flows, the only sites fully sampled were those sites where sampling of all biotopes was possible. The autumn scores seemed to be generally high in tributaries, while the main stream Umzimvubu River sites 1, 3 and 4 were high in spring. Winter scores were variable and generally less than 100 (Fig.3.6 and Table 3.3). This seasonal trend was supported by the distribution of macro-invertebrate taxa presented in Fig.3.9. The variation in the number of taxa among seasons and within a site over time (seasons) is shown in Fig.3.9. The lowest number of taxa were generally found in summer except at sites 7,10, 12 and 14 where all biotopes were accessible and sampled. Therefore the low numbers in summer were not a true reflection in all sites. The seasonal ASPT scores (Fig.3.7 and Table 3.3) were greater than five at all sites.

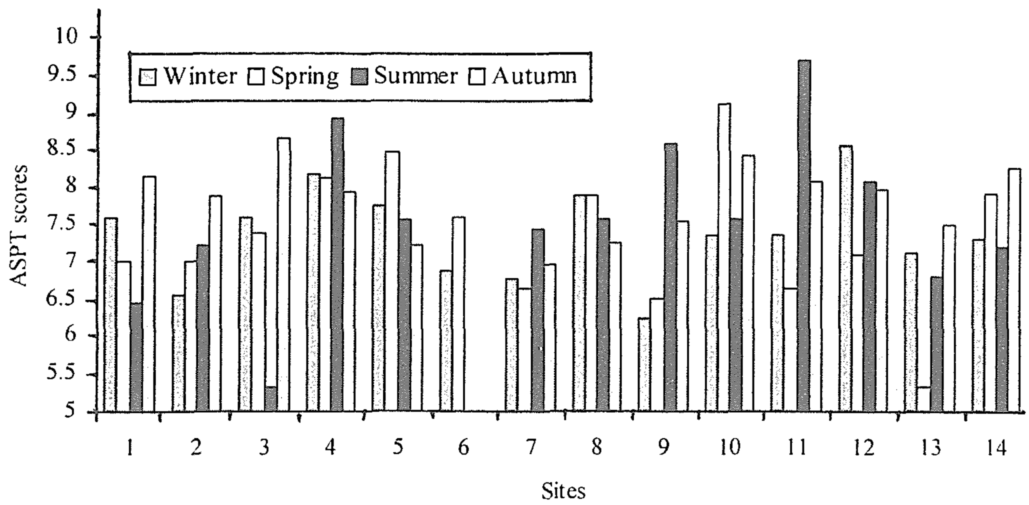

Fig.3.7 The seasonal ASPT scores from the Umzimvubu River and its selected tributaries (Refer to Fig.1.1 to 1.6, Chapter 1 for site location). Note that the Umzimvubu River site 6 was not sampled in summer and autumn.

Table 3.3 Categories used to classify habitat, SASS4 and ASPT scores. Note that habitat values were "calculated" by pairing method in HABSI (habitat scoring index). Adapted from SASS4 manual (Thirion *et al.* 1995).

HABITAT value	SASS4	ASPT	CONDITION
>100	>140	>7	Excellent
80 – 100	100 – 140	5 –7	Good
60 – 80	60 – 100	3 – 5	Fair
40 – 60	30 – 60	2 – 3	Poor
<40	<30	<2	Very poor

The habitat - scoring index (HABSI) in SASS4 manual shows how to evaluate habitats Thirion *et al* (1995). Most sites displayed low habitat values in summer because some biotopes were inaccessible due to high flows (Fig.3.8 and Table 3.3).

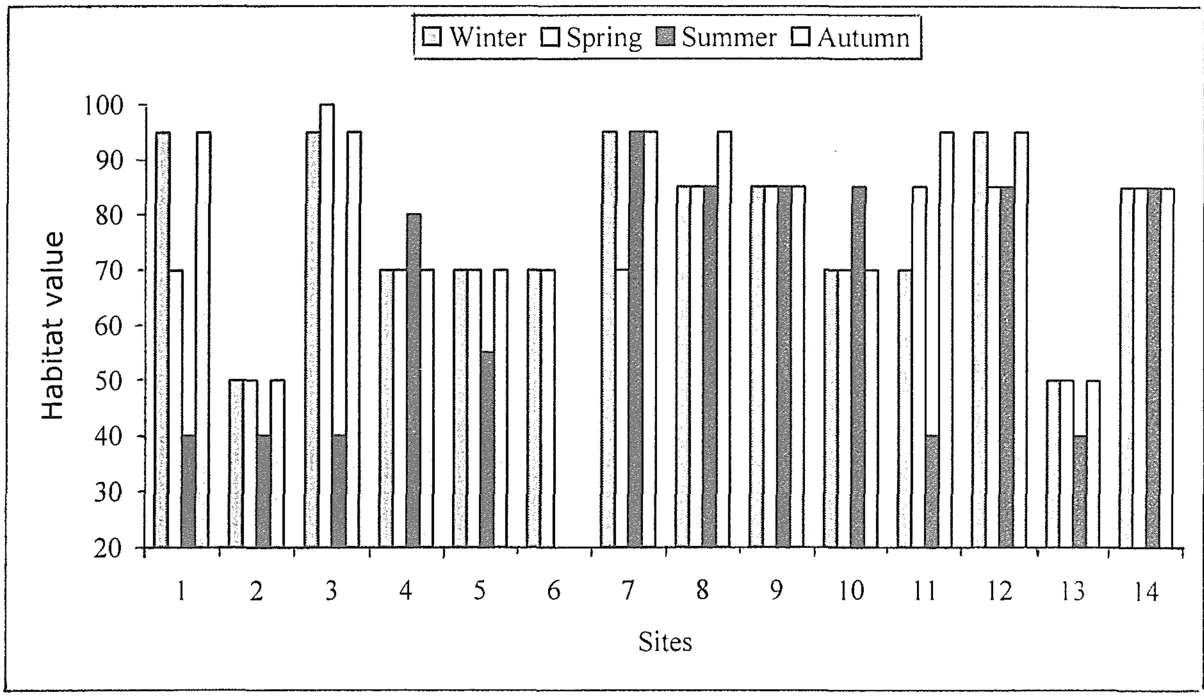

Fig.3.8 The seasonal habitat (biotopes) values from the Umzimvubu River and its selected tributaries (Refer to Fig.1.1 to 1.6, Chapter 1 for site locations). Habitat evaluation method was adopted from SASS4 manual (Thirion *et al.* 1995).

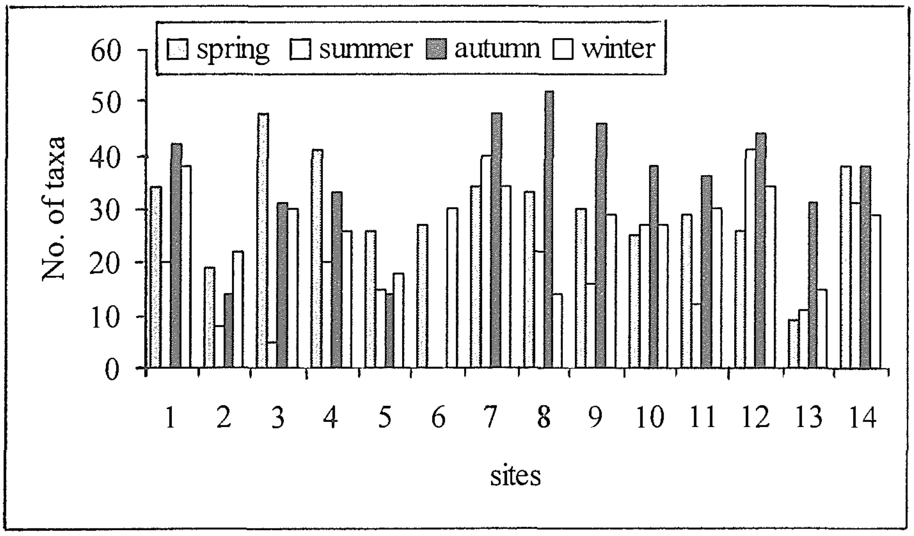

Fig.3.9 Seasonal variations in taxonomic numbers of macro-invertebrates from the Umzimvubu River and its selected tributaries (Refer to Fig.1.1 to 1.6, Chapter 1 for site locations). Note that the Umzimvubu River site six was not sampled in summer and autumn.

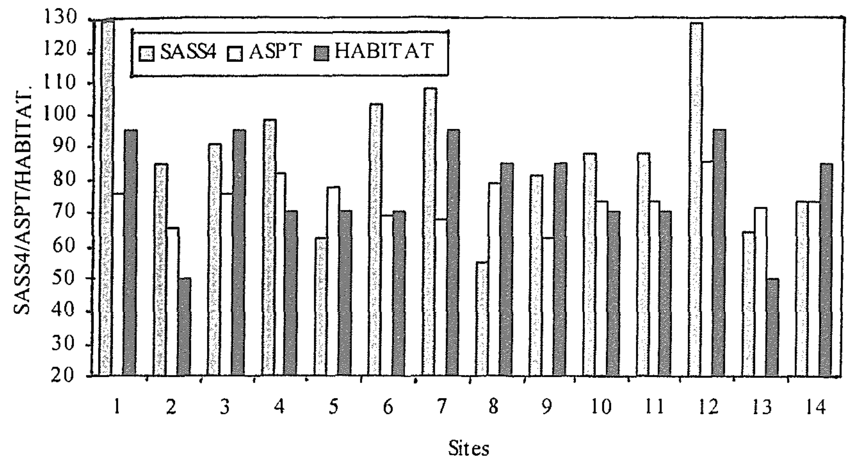

Fig. 3.10 Winter 1997 SASS4, ASPT and habitat values of macro-invertebrates collected from Umzimvubu River and its selected tributaries. Note that all the ASPT scores were multiplied by 10 to fit the scale.

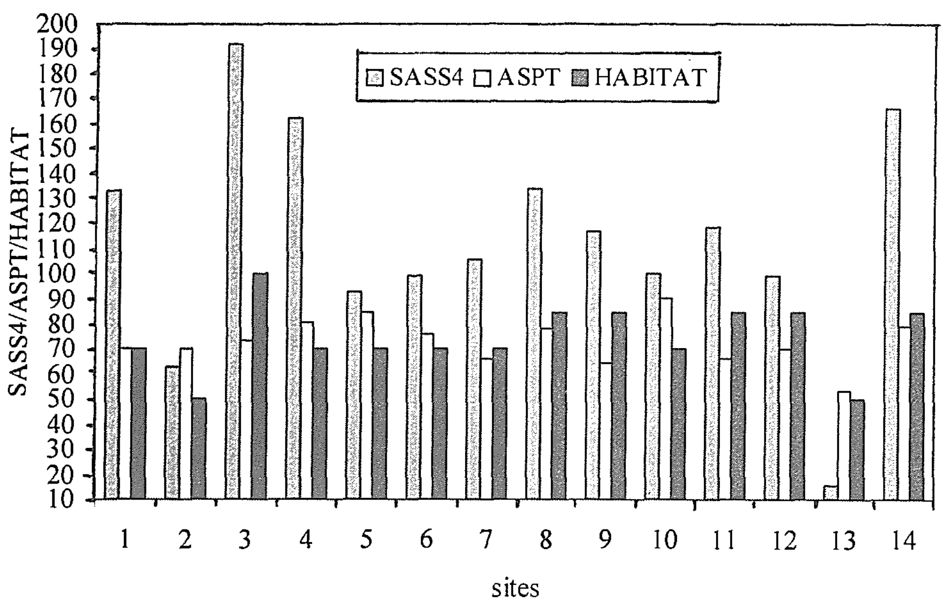

Fig. 3.11 Spring 1996 SASS4, ASPT and habitat values of macro-invertebrates collected from the Umzimvubu River and its selected tributaries. Note that all the ASPT scores were multiplied by 10 to fit the scale.

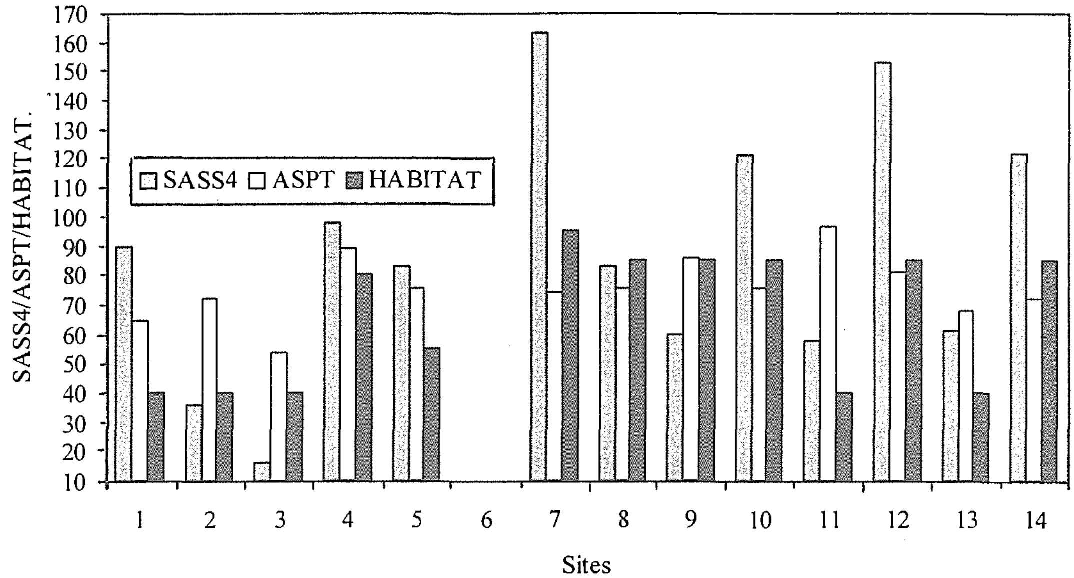

Fig.3.12 Summer 1998 SASS4, ASPT and habitat values from the Umzimvubu River and its selected tributaries. Note that the Umzimvubu site 6 was not sampled in summer. Also note that all the ASPT scores were multiplied by 10 to fit the scale.

The fluctuations in SASS4 and habitat values were not reflected in the ASPT values (all were above 5, see Fig.3.7 and Table 3.3) during the 1996 to 1998 macro-invertebrate sampling of Umzimvubu River and its selected tributaries (Fig 3.10 to 3.13). Refer to Appendices 2 and 3 for examination of macro-invertebrate community composition and their distribution across sites and seasons. The most abundant macro-invertebrates were Chironomidae, Simuliidae particularly, *Simulium medusaeforme.* Both of these families belong to order Diptera. The other common group was the family Baetidae of which *Baetis harrisoni* was the most common species. Besides other caddis-flies which occurred at the Umzintlava River site 7, *Macrostema capense,* (Trichoptera: Hydropsychidae) did not occur at any other river other than Umzintlava in the catchment (see Appendix 2 and 3).

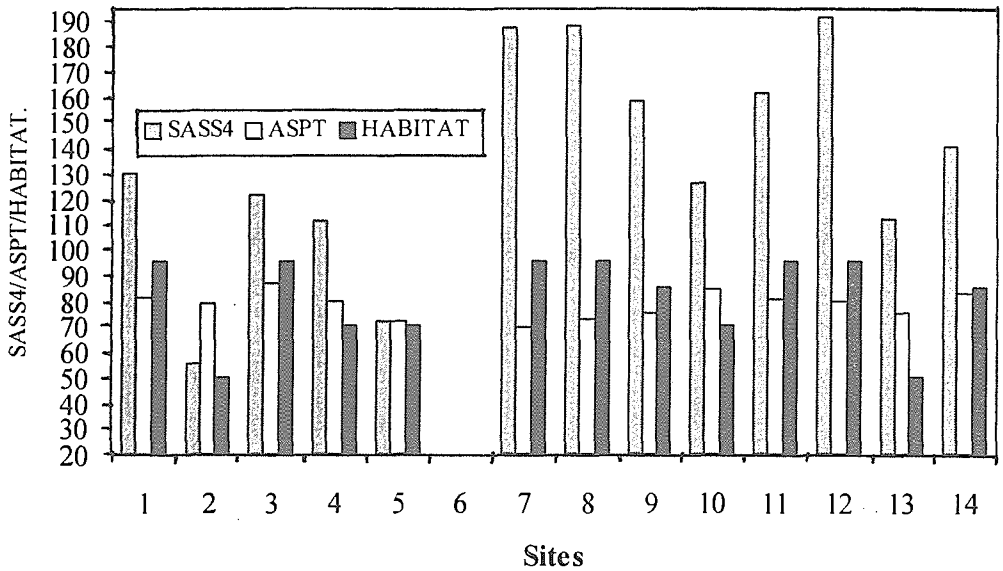

Fig. 3.13 Autumn 1997 SASS4, ASPT, and habitat values of macro-invertebrates sampled from the Umzimvubu River and its selected tributaries. Note that the Umzimvubu River site 6 was not sampled in autumn. Also note that all the ASPT scores were multiplied by ten to fit the scale.

Another unexpected occurrence was that of Blephariceridae (Diptera) at Umzimvubu River site 1 (upper reaches) and at Kinira River site 10 (middle reaches). This is a very sensitive dipteran, usually restricted to mountain streams. The troublesome black fly *S.chutteri* was also found in the catchment, at the Kinira River sites 9 and 10, the Tina River site 12 and the Tsitsa River site 14 (Fig.1.1). Although in summer many biotopes were inaccessible (Fig.3.8 and 3.10) as a result of rising water level, in other sites marginal vegetation was inundated creating new biotopes. Some "new" families, such as Nepidae, Torrindincolidae, were collected only in summer (Table 3.1) at the Umzimvubu River sites Su2 and Su3 as well as at the Tsitsa River site Su12 and Su13, perhaps because the newly inundated marginal vegetation (MV) was sampled at this time.

3.4 DISCUSSION

The identification of macro-invertebrates collected between 1996 to 1998 revealed 104 different taxa. The number of taxa identified was restricted by lack of expertise. Some invertebrates were identified only to phylum, family, order, or genus level. There was no positive identification of Chironominae and Tanytarsini, hence they were treated as one group (see Appendix 2 and 3). A similar taxonomic difficulty was encountered in distinguishing between *Simulium impukane* and S. *alcocki*. However, all Simuliidae, Baetidae, Caenidae, Leptophlebiidae, Trichorythidae, Prosopistomatidae, Hydropsychidae, Perlidae, Ancylidae, Planorbidae, Physidae were identified to species or genus level.

Unless water quality conditions are different, sites which have similar hydrological, hydraulic, and habitat conditions (substrates) will be expected to show similar macro-invertebrate community composition (Brown *et al.* 1996). The Umzimvubu River site 2 and the Tsitsa River site 13 occur in the foothills of their respective rivers (Fig.1.1, 1.2 and 1.6, Chapter 1) and their substrates are similar. The biotopes or habitats found were marginal vegetation along the riverbanks and sand across the riverbed. Sand is a shifting habitat, while vegetation is sometimes not inundated, therefore restricting the types of taxa that can survive. The pairing of the Umzimvubu River site 2 and the Tsitsa River site 13 (Fig. 3.1 and 3.4) in autumn and spring (low flow) should be expected since water quality conditions were also comparable (see Appendix 1). The non-pairing in winter is not yet clear. Summer high flows caused full inundation of marginal vegetation at the Umzimvubu River sites 2 and 3, resulting in only one type of biotope occurring, the marginal vegetation. Habitat, however is not the only feature that can make sites similar. The SASS4 and ASPT scores as well as the number of taxa (Fig. 3. 6, 3.8 and 3.9) were also comparable. The dissimilarity between the summer and other three seasons can only be attributed to the inaccessibility of most biotopes due to summer high flows. Though summer had low SASS4 scores and habitat values, mainly below 100 (Fig.3.6, 3.8 and 3.12), except where all biotopes were accessible, such as in the Umzintlava River site 7, the Tina River site 12 and the Tsitsa River site 13, the ASPT scores (Fig. 3.7, 3.10 -3.12) remained above five and comparable to other seasons. Similarly the lowest number of taxa were recorded in summer (Fig 3.9 and Appendix 2). Variation in SASS4 scores longitudinally downstream and between rivers while ASPT scores remained fairly constant was, reported by Dallas (1997) from the Berg River, Western Cape. A similar condition was observed in the results of this study. Altitude and gradient were reported by Palmer *et al.* (1994) and Suren (1994) to have an influence on the community structure. Palmer *et al.* (1994) reported no link between food availability and community composition from the upper reaches of the Buffalo River. Hubert *et al.* (1991) also noticed that macro-invertebrate distribution tends to be associated with particular biotopes. On the other hand, De Pauw (*et al.* 1991, cited in Rynolds *et al.* 1997) suggested that the distribution of plecopterans was governed by water quality and biotope availability. In the Eerste River, Western Cape, the distribution of macro-invertebrates downstream was strongly influenced by deterioration in physicochemical variables (King, 1981). Besides habitat, slopes, energy flow and physicochemical variables, scores (SASS4 and ASPT) are also influenced by the organisms that occur at different sites (Hubert *et al.* 1996; Dallas, 1997). Table 3.3 summarizes the condition of water quality based on these scores. In spring 1996 (Fig. 3.4 and 3.5), the Kinira River site 10 and the Umzimvubu River site 1 showed more than 70 % similarity, despite their locations (Fig. 1.1, 1.2 and 1.4, Chapter 1) in the catchment (middle and upper reaches, respectively). The similarity between these two sites could be attributed to the occurrence of Blephariceridae (see Appendix 2 and 3). Blephariceride is a very sensitive dipteran (scores 15 on SASS4 score sheet) usually restricted to high quality mountain stream water (Thirion *et al.* 1995). Perhaps this indicator group needs to be identified to species level in order to establish whether it is not a species complex. Drifting from the upper reaches is difficult to imagine (Dallas, 1997) since no Blephariceridae were recorded from the Kinira River top site (site 9) (Fig.1.4, Chapter 1). However, it should be noted that the Kinira River site 9 is not at the mountain stream zone. With the exception of summer, the mean flows (2.85 and 2.52 m/s) from the SIC's of the Umzimvubu and Kinira River sites 1 and 10, respectively over three seasons (autumn, winter and spring) were virtually the same. Perhaps the strong and the fast flow at the site (river rejuvenation) (Fig.1.4, Chapter 1) provided the favorable conditions for the dipteran.

The strong similarity (>70 %) amongst the three seasons may be attributed to the occurrences of similar macro-invertebrates, e.g. *Neorpela spio* (Plecoptera), *Cheumatopsyche afra* (Trichoptra), Blephariceridae, ubiquitous midges (Diptera) and others (see Appendix 2 and 3) across sites (spatial) and seasons (temporal). Mqoqi (1991) reported the occurrence of intermediate hosts (molluscs) of schistosoma (parasite responsible for bilharzia) around the Port St Johns area (the lower reaches of the Umzimvubu River). The other intermediate hosts (Planorbidae and Physidae – both Gastropods) (Thirion *et al.* 1995) were recorded only from the Umzintlava River site 7 MV (marginal vegetation) in quiet backwaters. As they prefer quiet backwaters, impoundment of the Umzimvubu River and its selected tributaries may exacerbate the spread of bilharzia. The occurrence of *Simulium chutteri* should be of some concern, since this is a blood sucking (stock–sheep goats, cattle) black fly which has caused problems in the regulated Orange, Vaal and the Great Fish Rivers (O'Keeffe, 1985; Palmer, 1996).

Generally, the macro-invertebrates were dominated by Chironomidae, particularly, Orthocladinae (sub–family), Baetidae, such as *Baetis harrisoni* and Simuliidae, such as *S. medusaeforme*. Suren (1994), studying macro-invertebrates of the Western Nepal streams, reported dominance of his samples by amongst others, Ephemeroptera (especially baetids). However, the effects of catchment activities such as logging, mining, and sand deposition downstream reduced the abundance. Amongst the least common taxa recorded in this study was a caddis fly, *Macrostemum capense*. Palmer (*et al,* 1994) reported the occurrence of *M. capense* from the upper reaches of the Buffalo River while there were no records from the study catchment, except at the Umzintlava River sites 7 and 8 (see Appendix 2 and 3). Palmer (1996) reported on the sporadic records (low numbers and diversity) of invertebrates from middle and lower reaches of the Orange River and attributed that to river regulation and silt. Unlike the Orange River, the Umzimvubu River and its tributaries are not regulated, but the results indicate low numbers of taxa (perhaps as limited by identification skill) and abundance. The qualitative analysis (Appendix 3) of macro-invertebrates in all seasons showed that an average 27 taxa at family level were recorded from the Umzimvubu River and its selected tributaries. Since high suspended sediment concentrations often cause drifting (Chutter, 1968), the macro-invertebrates of the study catchment must survive through adaptation. It is a common belief that organisms evolve to adapt to conditions where they live (Brutton, 1988).

Many researchers (de Pauw, e*t al.* 1983; Nelson, *et al.* 1996) have a tendency to comment generally on the sensitivity of Ephemeroptera, Plecoptera and Trichoptera, without specifying the particular family, genus or the species. In the current study Plecoptera (*N. spio*), family perlidae was the only stone fly recorded and it occurred from the middle to lower reaches. Similarly, *B. harrisoni*, family Baetidae was recorded from the upper to the lower reaches. The trichopterans (Family:Hydropsychidae) such as *C. thomasseti, C. afra* and *Hydropsche longifurca* were recorded from the upper to the lower reaches. They showed variable abundance (see Appendices 2 and 3). Another trichopteran (as reported earlier), *M capense* occurred only at the Umzintlava River sites 7 and 8. The general reference also in SASS4 (Thirion *et al.* 1995) can be misleading at times. The practical example is family Leptophlebiidae. It scores 13 as a family, when in actual fact *Euthraulus elegans* is probably more tolerant and widely distributed than other species within the family. In the current study this species was sometimes recorded alone in the middle and lower reaches. It is therefore important that the limitations in taxonomy (de Pauw, *et al.* 1983; Furse, *et al.*1986 cited in Bowman *et al*, 1997) are not allowed to undermine the efforts put on the process of taxonomic identification, the purpose of biological monitoring, extrapolation and river classification. Bowman *et al.* (1997) believes that for quality assessment in marine ecology, the level of taxonomic resolution or "taxonomic sufficiency" (be it anything from phylum to species) is not important. They further suggested that research into the need for identifying organisms to species level in freshwater quality assessment be conducted.

CHAPTER 4

4 TOLERANCE TESTS

4.1 INTRODUCTION

The health of aquatic organisms reflects the quality of the water in which they live. The suitability of benthic macro-invertebrates as ecological indicators of environmental change has been supported by many workers (McCafferty, 1981; Chutter, 1998; Thirion *et al.* 1995; Palmer *et al.* 1996). It is now widely accepted that the traditional ways of assessing water quality (physical and chemical methods) are insufficient to assure the ecological integrity of rivers and maintenance of aquatic life (Rand *et al.* 1985; APHA, 1995), hence the need for tolerance tests and in-stream biomonitoring. Although biomonitoring will not identify the cause of water quality degradation, it certainly provides early warnings of environmental threats (Chapman *et al.* 1992 cited in.Chapman, 1992). The collective use of both physicochemical and biological monitoring techniques is however, a more holistic approach to water quality monitoring (Dallas *et al.* 1994; O'Keeffe *et al.* 1996).

Besides reduction of dam capacity and a reduction in the extent of the photosynthetic zone (Shalash, 1982; Schramm, 1993; Dallas *et al.* 1994), siltation leads to increased invertebrate drift, physical abrasion (especially of the gills), smothering of nets and eggs, blocking of gills and modification of stream channel (Bruton, 1988; du Preez *et al.* 1996; O'Keeffe *et al.* 1996). Jubb (1976, cited in Palmer *et al.* 1996) observed lethal effects of silt concentrations (700mg/l) on the mollusc, *Unio caffer,* the mayfly *Baetis glocus* showed some tolerance to silt elevation between 1 to 2 g/l (Scott *et al.*1980 cited in Palmer *et al.* 1996). De Moor (1992) concluded that TSS influenced the distribution of caddis flies. Quinn *et al.* (1992) noted a decrease in invertebrate diversity in his study of the impact of TSS. Sediment sometimes effect aquatic life indirectly, such as when toxicants are adsorbed (sediment-bound) onto clay particles, transported downstream or sink to the bottom where they can be re-suspended into the water column and cause further damage when made bioavalable through bacterial actions. Furthermore, "non-lethal toxicants" can be accumulated by higher organisms (bioaccumulation) such as fish

(Reynolds, 1987; de Wet *et al.* 1994; Ingersol, 1991; van Vuren *et al.* 1994) until they reach lethal levels. However, not all aquatic invertebrates are equally susceptible to pollutants (Diamond *et al.* 1992). Bruton (1988) suggested that some organisms might have evolved adaptive ways of surviving under impacted conditions as a result of long term exposure.

The use of laboratory-based artificial streams has received some criticism, mainly that the use of the single species tests and variables do not simulate the synergistic or antagonistic realism of natural streams (Lamberti *et al.* 1993; Roux. *et al.* 1996). Alternatively, other authors believe that complicated natural systems can be fully understood when reproducible laboratory studies are correctly and cautiously interpreted (Mackay, 1981; Sloof, 1983; Palmer *et al.* 1996). Sloof (1983) adds that since some species are pollutant specific, the use of multiple species experiments without an understanding of single species responses can only confound results.

Although turbidity is not a new phenomenon in South Africa, very little data are available on lethal or sub-lethal concentrations of silt on macro-invertebrates. In this study individuals representative of different groups of macro-invertebrates with a wide geographic distribution, were subjected to sediment tolerance tests in order to contribute to national water quality guidelines for the protection of aquatic ecosystems (DWAF, 1996). Since macro-invertebrates form part of the food web and nutrient recycling an investigation of the effects of sediment is necessary for the maintenance of river biodiversity in the face of catchment development. Such knowledge would also contribute in water resource development / planning, biomonitoring (RHP) and management programmes.

4.2 MATERIALS AND METHODS

An artificial stream laboratory with 12-recirculating artificial streams was set up following the Palmer *et al.* (1996) method at the University of Transkei. Each stream was made up of one meter PVC guttering, delivery tube, (10 mm inside diameter) submersible water pump (little giant, PE-2F-WG) and a 25L bucket with perforated tube (to keep kaolin in suspension by bubbling from the bottom of a bucket) were set up in a temperature (10°C) controlled room (Fig.4.1 and Plate 2). A constant laboratory temperature of 10°C is capable of keeping stream water temperatures at an average of 17.5°C. Experiments were conducted during the winter and spring of 1998 and 1999.

The streams were calibrated in three ways. The first was hydraulic calibration involving running tap water in streams with pebble (river stones) substrates. This was to ensure that the hydraulic conditions such as flow, depth, and slopes were similar in all streams (Palmer *et al.* 1996). Simultaneously, water quality variables, such as the pH, oxygen, temperature, conductivity and nutrients (nitrogenous and phosphate compounds) were monitored, to provide water quality calibration. The third was biological or behavioural calibration (conducted in de-chlorinated tap water) involved observing the behaviour of test animals in streams with water and substrate but no test material.

The upper reaches of the Umtata River near the University of Transkei, were identified as a suitable collection site for test organisms (*Cheumatopsyche afra*:Hydropsychidae. In principle, these organisms are expected to be healthy and adapted to unimpacted or little-disturbed systems, (the collection site is within a protected area) (mean oxygen = 110%; pH 7.32; electrical conductivity = 36,7μS/cm; flow = 0.82m/s and temperature = 7.6°C in winter with slight changes during spring). *Hydropsyche longifurca*: (Hydropsychidae), were collected (once) from the middle reaches of the Tsitsa River, again an area of good water quality (oxygen = 84%; pH = 7.45; electrical conductivity = 123.2μS/cm; flow = 0.58m/s and temperature = 13.8°C).

Prior to collection of test organisms tap water was de-chlorinated by running in streams and aerating in containers for 48hrs (river water can also be used especially for chronic tests to avoid having to feed organisms). Organisms were carefully collected using nets, put into an aerated cooler box and transported back to the laboratory. In the laboratory, the condition of organisms was established and 25 healthy organisms (e.g. no damaged appendages) were transferred to each stream (with pre-cleaned river stones or mesh as substrate for organisms, see also discussion). In order to avoid exceeding the 10% limit on mortality (APHA, 1995), 25 organisms were used in 48 hrs of acclimation, so that the experiment can start with at least 20 organisms (Nikite pers.com). Selecting test organisms of the same size is critical, since response to test material can be influenced by life cycle stage (Rand *et al* 1995). The average size (length) of test organisms used in this study was 10mm. Handling was kept to a minimum throughout to avoid stress (Palmer *et al.* 1996). These preliminary experiments (Range-finding) were not replicated. Organisms were allowed to acclimate to test conditions for 48hrs prior to exposure to the test material (APHA, 1995). The non-toxic kaolin powder was used as a test material instead of using natural sediment, because natural sediment can have various adsorbed chemicals of unknown toxicity (Reynolds, 1987; Ingersol, 1991; Graney *et al.* 1993). Following acclimation, the water in streams was replaced with pre-mixed (water and kaolin) de-chlorinated tap water of various kaolin concentrations and turbidity, except in controls where only de-chlorinated water was used (Table 4.1). Turbidity concentrations were measured using a spectrophotometer (SQ 118). To minimize settling of kaolin, mainly at the bottom of a sump bucket, air was bubbled by using the perforated tube (Fig.4.1). Bubbling, coupled with slope and good flow, improved kaolin suspension by more than 85 % (Fig.4.2, 4.3 and 4.4). APHA (1995) requires that a test material should not be allowed to decrease below 15% of the original concentration. Except for nutrients, water quality variables (oxygen, temperature, pH and conductivity) were recorded daily during experiments. Nutrients (nitrogenous and phosphates) were measured (using spectrophotometer SQ 118) once at the beginning and again at the end of the experiments (96hrs) (Palmer *et al.* 1996). Specific equipment used in measuring other water quality variables is also described in Chapter 2. As kaolin is non-toxic, mortality was not a reliable response hence histological examination of gills was conducted according to Bruton (1988) and Goldes *et al.* (1988). Electron microscopy was used in this study to examine the condition of gills of organisms at the end of an experiment. The condition of the gills of exposed animals was compared to the gills of the controls or the unexposed animals.

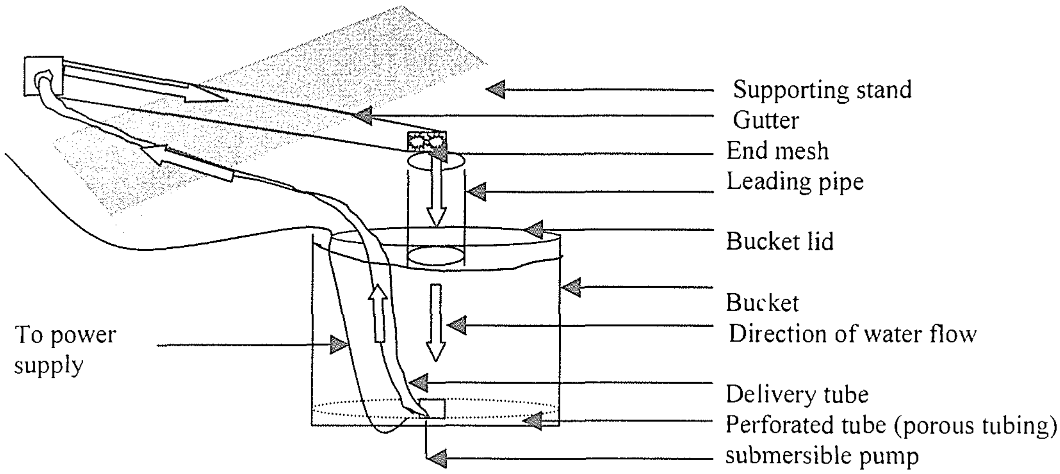

Fig.4.1 Diagrammatic representation of an artificial stream (Not drawn to scale). See also plate 2.

4.3 RESULTS

The preliminary results revealed no physical abrasion on gills (in both species) when examined under electron microscope. As a result of very low mortality (assumed not to be due to kaolin effect), randomly selected organisms from each concentration in the range (0 – 15g/l) were examined using electron microscope.

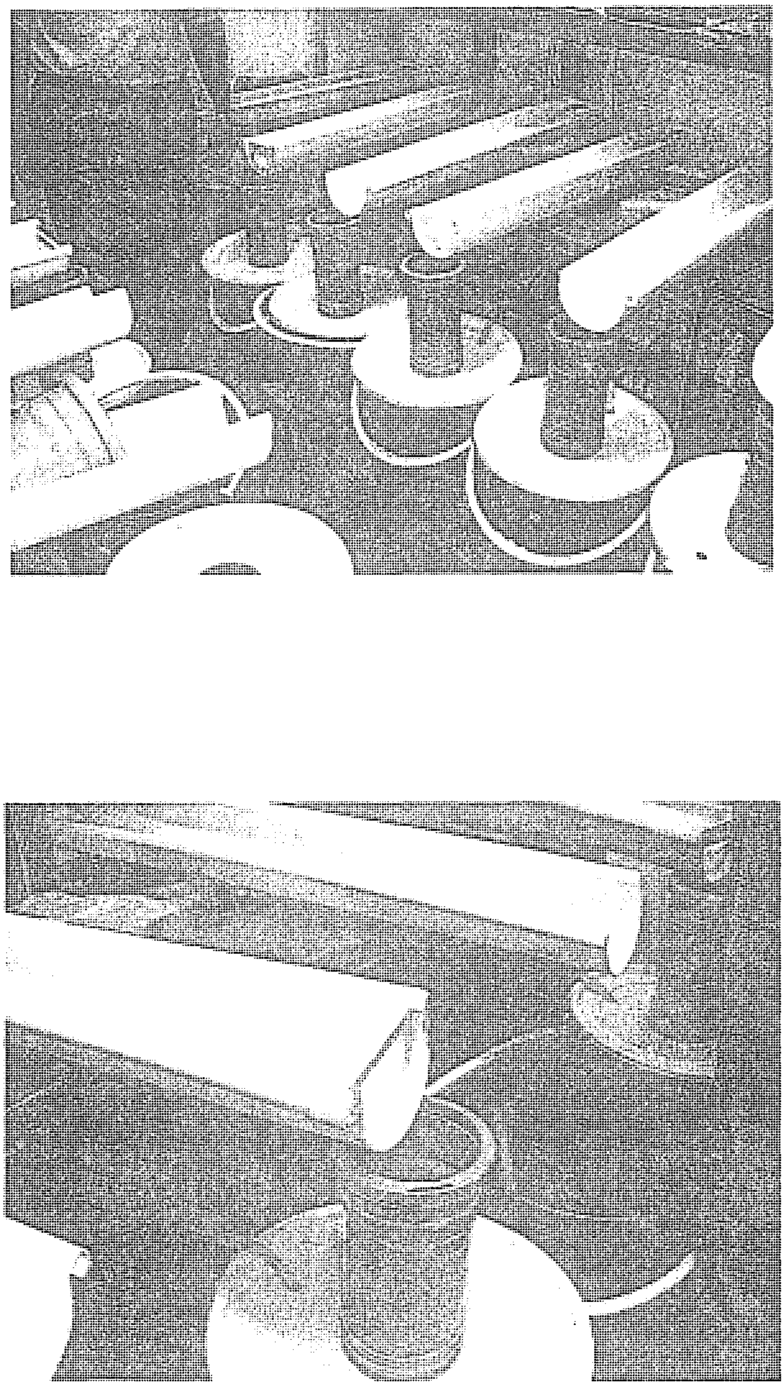

Plate 2. The digital photo of artificial streams used in sediment tolerance tests (see also Fig.4.1 for description).

Table 4.1 The range of kaolin concentrations used in range-finding tests during the first 96hr exposure of *C.afra*. Note: Though the sequence was sometimes different, similar kaolin concentrations were employed in all the experiments. (see Fig. 4.2 – 4.4).

Stream No.	1	2	3	4	5	6	7	8	9	10	11	12
Kaolin (g/l).	15	13.5	12	10.5	9	7.5	6	4.5	3	1.5	0.75	0
Turb (NTU)	7934	7912	7689	7466	6690	5346	4967	3579	2450	1199	392	1

Key: Turb = initial turbidity, i.e. on day zero.

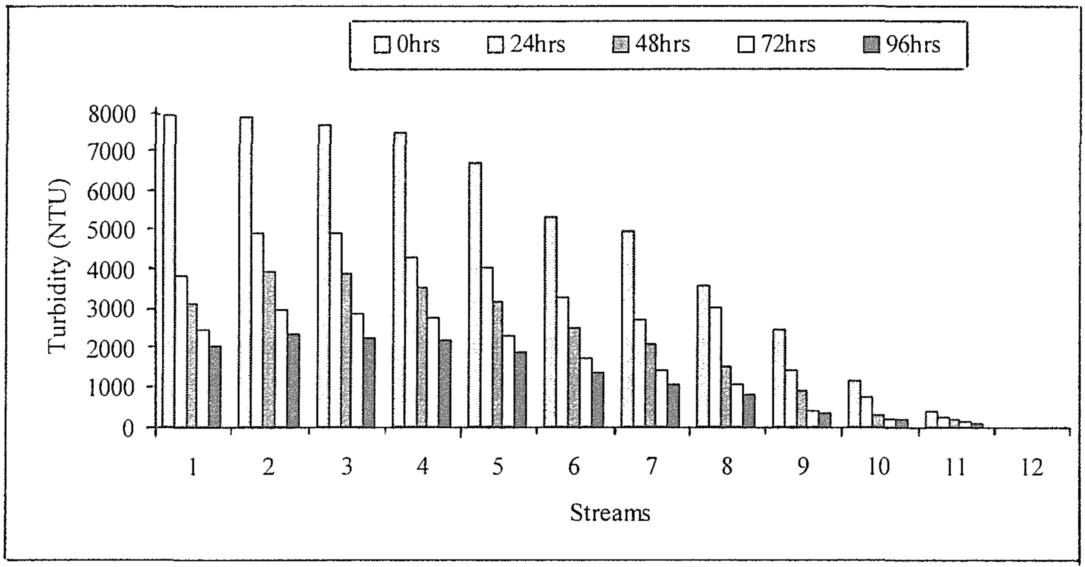

Fig.4.2 The drop in the kaolin concentration per stream over a period of 96hrs during the first *C. afra* range finding test without bubbling. Stream No.12 was the control (see also Table 4.1).

The drastic drop in the concentration of kaolin (turbidity) during the first 96hr exposure (Fig.4.2) of *C.afra* necessitated the repetition of the experiment (Fig.4.3). The experiment was only resumed when more than 85% of kaolin was successfully kept in suspension through bubbling and circulation (Fig.4.1, 4.3 and 4.4). The sudden decrease in kaolin concentration during the last two days (72 and 96 hrs) of the experiment was due to a fault in the compressor. The severe drop in kaolin concentration in stream number 9 was due to a faulty submersible pump (Fig.4.1)

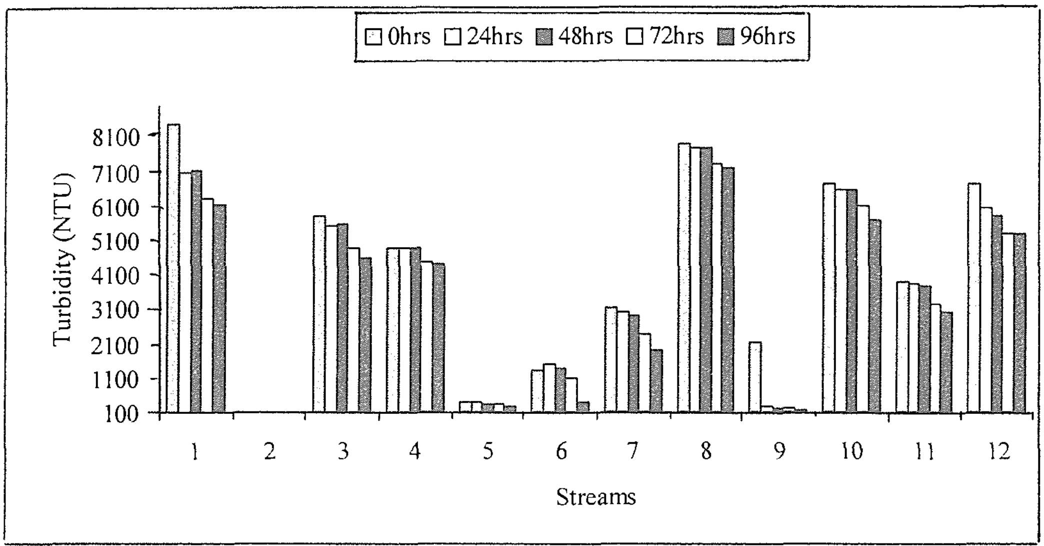

Fig.4.3 Kaolin concentration during the second 96hr exposure of *C.afra* with bubbling. More than 85 % kaolin was kept in suspension and circulation (except in stream No.9 with faulty pump) through bubbling. Stream No. 2 was the control (no kaolin).

The gills of *C.afra* examined by electron microscope revealed no measurable effects of kaolin between treatments and control. The only observable "effects" were the kaolin deposition on the surfaces, collapsing of gills and some fusion of gill filaments (Plate 3-b). A similar experiment was run using *H. longifurca*. In this case, stones were removed and substituted with mesh in order to remove "refugia". The results were not different from those of *C. afra* (Plate 3-c). Both species spun nets (though not all individuals) during the acclimation time in which they would stay till death or to the end of an experiment. The nets were either built between two stones or stone and the gutter, but never on the stone surfaces. The role of nets as indicators of a response to kaolin was not clear in this study. On average four organisms died during the exposure in all treatments.

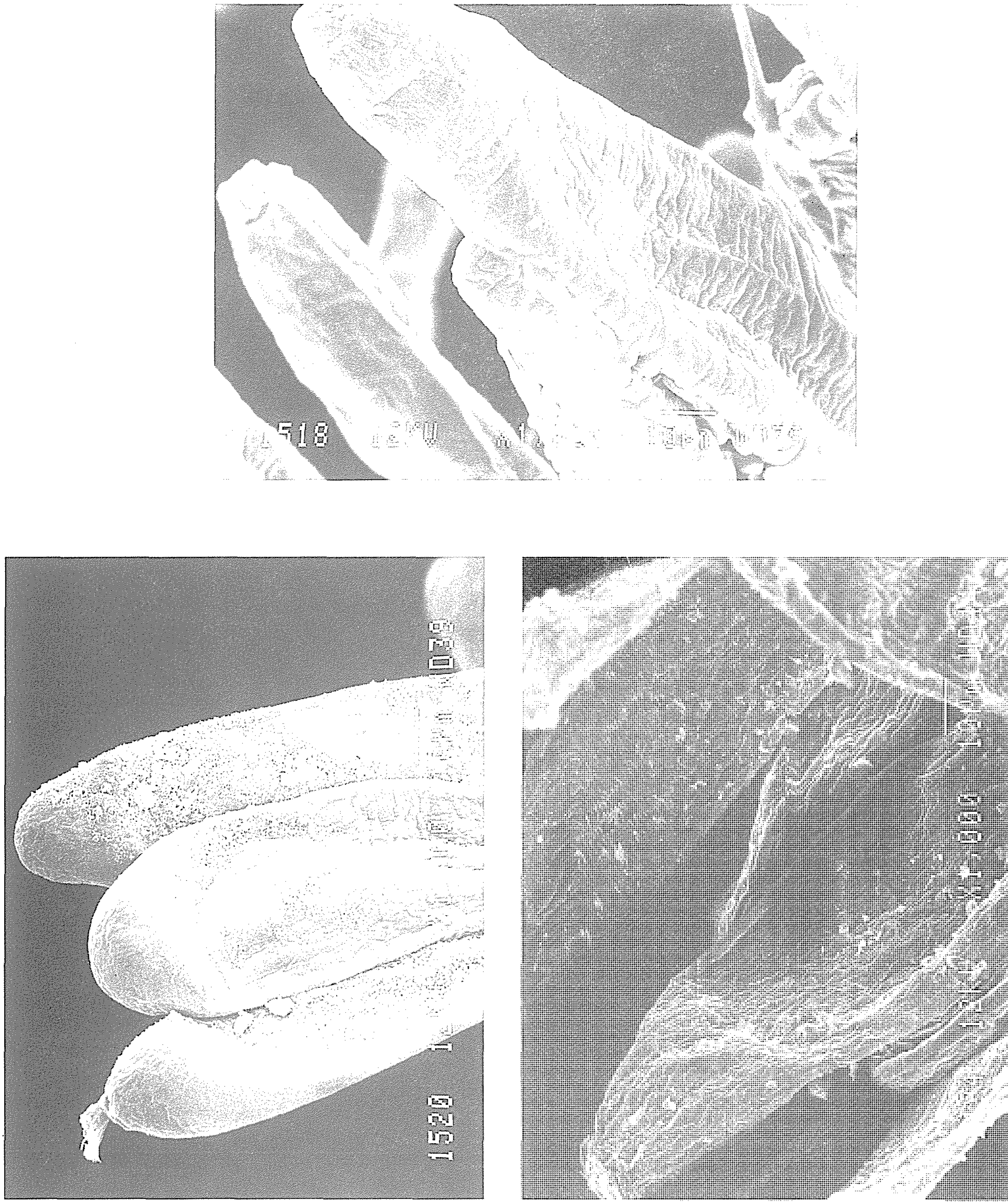

Plate 3. The appearance of *C. afra* and *H. longifurca* gill micrographs (using electron microscopy). The top picture represent a control while the bottom left represent *C. afra* and bottom right represent *H. longifurca* gills. Micrographs were based on the highest kaolin concentration 15 g/l).

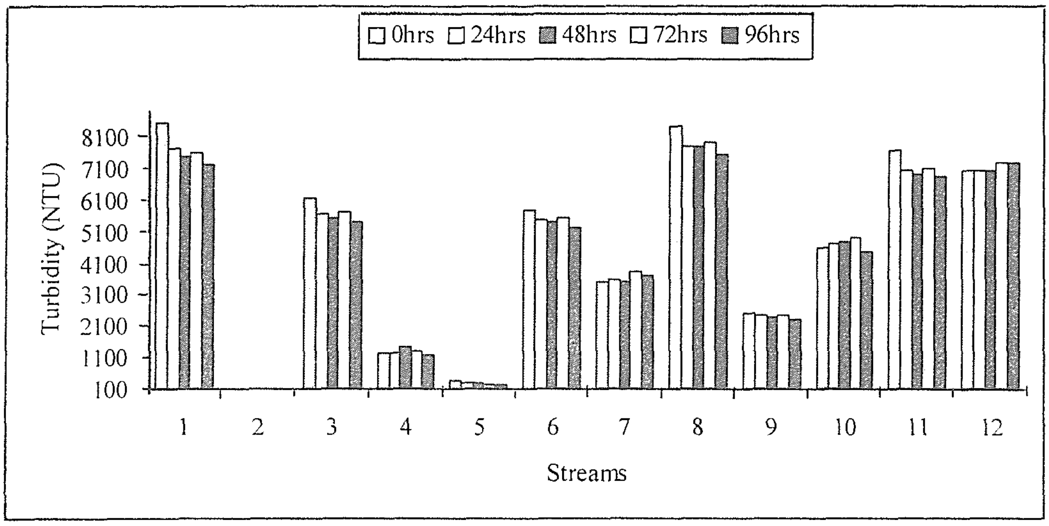

Fig.4.4 Kaolin concentration during the 96hr exposure of *H.longifurca* with bubbling. Note the consistency in kaolin concentration over time per stream. (Stream No. 2 was the control)

Water quality began to deteriorate (Fig.4.5 – 4.8) towards the end of the experiment, although that did not seem to affect results (lack of mortality) Though water quality parameters presented below were those recorded during *C.afra* experiment, the data were "similar" during the *H.longifurca* test.

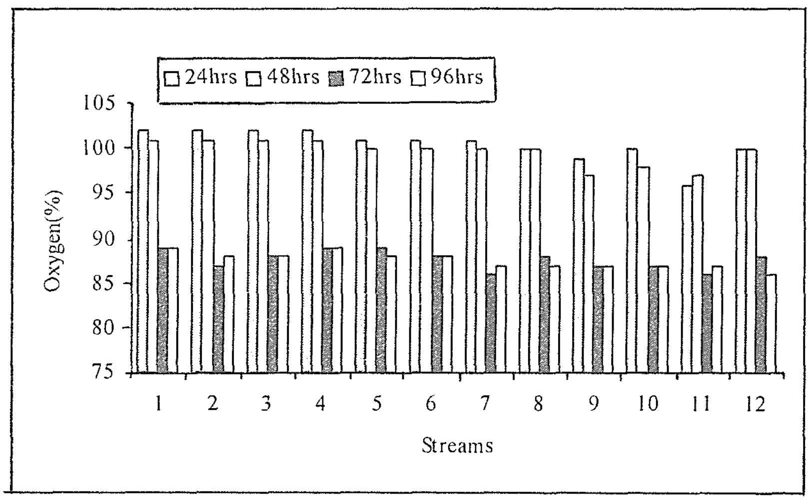

Fig.4.5 Variation in oxygen concentrations during the 96hr range finding experiment using *C. afra.* Note: Faulty air-conditioner caused sudden drop in oxygen concentration in the last two days, though not detrimental (DWAF, 1996).

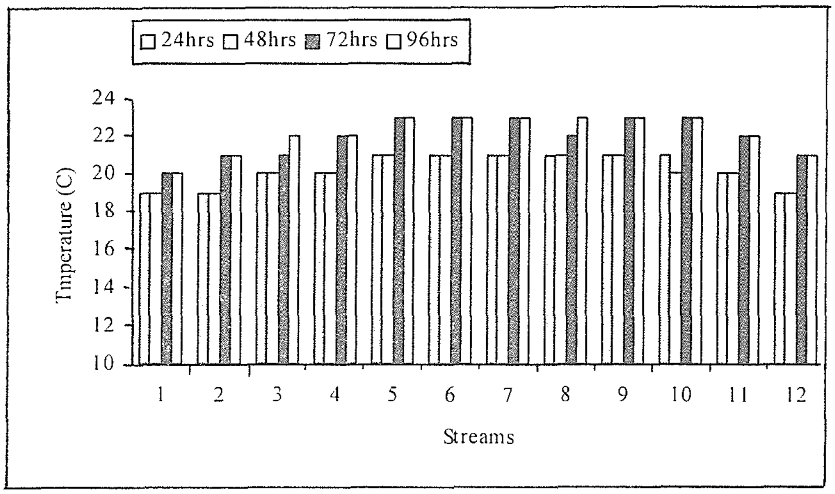

Fig.4.6 Temperature variation during the 96hr range-finding experiment using *C.afra.* Note that temperature increased on the last two days, due to failure of an air-conditioner in the laboratory.

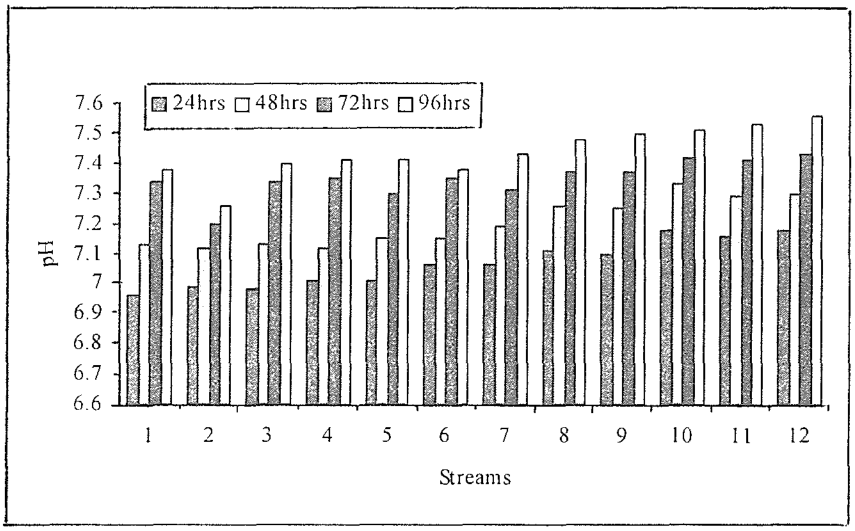

Fig.4.7 Variation in pH during the 96hr range- finding experiment using *C.afra.* Note, the rapid increase in pH on the last two days was due to changes in the laboratory temperatures (see Fig.4.6)

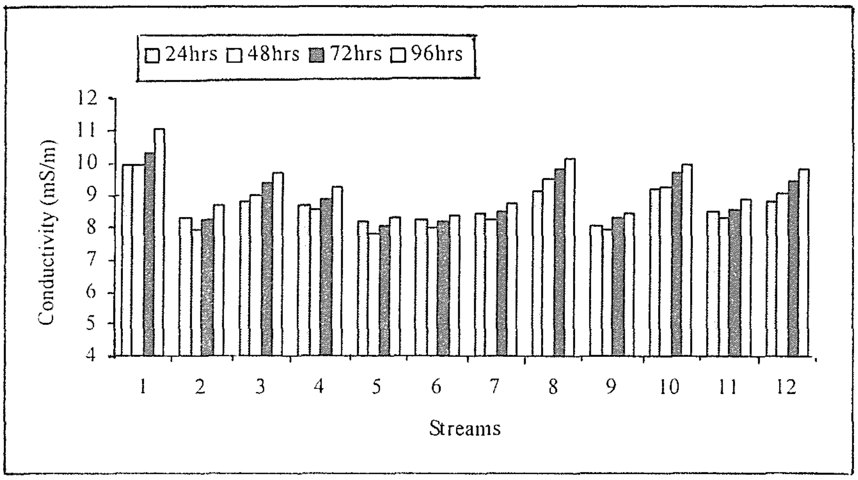

Fig.4.8 Conductivity variation during the 96hr range – finding experiment using *C.afra.*

The concentration of oxygen dropped during the last two days to just below 90%, still within the requirements of the experiment (APHA 1995), i.e. oxygen concentration should not be allowed to drop below 60% saturation. Besides, the measured concentrations of dissolved oxygen were above 80%, which is within the Target Water Quality Range (TWQR) of 80 – 120%. Similarly temperature, pH and electrical conductivity started to deteriorate in the last two days of the experiment. The average stream temperature (17.5°C) increased by ± 4°C (Fig. 4.6).

4.4 DISCUSSION

The results of the tolerance tests (Plate 3a-c) revealed no histological damage or lesions on gills of either *C.afra* or *H. longifurca*. Though water quality status started to deteriorate by the third and fourth days (Fig. 4.5 – 4.8), few animals died (avg. 4 % per stream) and this mortality could not be attributed to water quality deterioration. Only the water quality changes during the *C. afra* test were shown in the results because those recorded during *H. longifurca* were fairly comparable. The kaolin deposition on gills, their collapse and fusion would be expected to reduce the surface area available for respiration, resulting in impaired respiration. Chutter (1968) reported on the variable occurrence of *C. afra*, *C. thomasseti,* ancylids and others in relation to sedimentation, though this was not quantified. The variable response by macro-invertebrates to sedimentation is a common view upheld by many researchers. Amongst them is de Moor (1992) who believes that trichopterans are very sensitive macro-invertebrates that can be used to protect aquatic biodiversity when used as indicators. Increased river turbidity from 8.2 to 154 NTU lowered the invertebrate diversity downstream of a gold mine in a stream in New Zealand (Quin *et al.* 1992). Reduction in invertebrate densities was ascribed to drifting as a common invertebrate avoidance response to threats. Avoidance responses (drifting) were observed mainly in *C. afra* during preliminary tolerance tests, though organisms were held back by the end mesh (at the end of a stream). Such behaviour exposed them even better to kaolin, i.e. away from stones or mesh as substrate.

Goldes *et al.* (1988) studying the histological effect of kaolin on juvenile rainbow trout, *Salmo gairdneri*, reported some gill abrasion by the 16th day of exposure. However the gills had recovered by the 64th day of exposure to 4 887mg/l kaolin. They suggested that large amounts of mucus released helped restore the immune system hence the gills adapted to their new environment. Du Preez *et al.* (1996) recorded a similar gill response in adult *Oreochromis mossambicus,* fish exposed to sub-lethal natural silt at 20g/l. While no mortality was recorded, increased oxygen consumption was clearly observed. Though the response to silt concentration was sub-lethal, a long time exposure would lead to lower growth, poor production and even mortality.

It is difficult to explain lack of damage on macro-invertebrate gills of caddis flies exposed to kaolin levels 3-fold (15g/l) higher than 4 887g/l used with trout juveniles (see Table 4.1). A lengthy (chronic) exposure to slightly higher kaolin concentrations may result in some observable responses (Palmer, pers.com). Though *C.afra* were collected from the upper reaches of the Umtata River, they were also recorded in the middle and lower reaches of the Umzimvubu River catchment (see Appendix 2). *H.longifurca* was collected from the middle reaches of the Tsitsa River at site 14 (see Fig. 1.1 and 1.6, Chapter 1). With the Eastern Cape experience of high seasonal TSS (see Chapter 2), these two caddis flies are most likely to have adapted to survive such sediment pulses (Bruton, 1988).

The National Water Act (Act No.36, DWAF, 1998) requires that the reserve be determined in order to prioritise the protection of water resources for sustainable use. In order to protect river integrity in the light of catchment development the Department of Water Affairs and Forestry, has established South African water quality guidelines for the protection of aquatic environment (DWAF, 1996). Before any reserve can be determined, however, comprehensive data about the resource and the demands are required. Due to the urgency with which such determination must be made, the fundamental step of acquiring enough data is often not feasible (King *et al.* 1998).

The aim of this chapter was to contribute to the establishment of the limits (TWQR) for TSS in aquatic systems in accordance with the South African Water quality guidelines for protection of aquatic ecosystems (DWAF, 1996). TWQR is not a criterion itself, but the range within which the concentration of a substance (being tested) has no significant or measurable adverse effects on the health of aquatic ecosystems hence their protection must be ensured by the range (DWAF, 1996).

The preliminary results indicate that the candidate species (*C. afra* and *H. longifurca*) did not show any physical damage to gills as expected over a 96hr acute test period. More sensitive candidates will have to be evaluated for testing or chronic exposure at the higher kaolin concentrations conducted. Alternatively, as Jarvis (1989), Snell (1991), and

Ingersoll (1991) suggested, more sensitive growth stages (early life stages) may be preferable for tolerance tests.

CHAPTER 5

5.1 CONCLUDING REMARKS AND RECOMMENDATIONS FOR FURTHER RESEARCH

The Umzimvubu River catchment has a good water quality. The ASPT scores were generally above five (5.3 – 8.9) in all sites longitudinally down the stream and between rivers. The ASPT scores were generally constant throughout regardless of SASS4 and habitat scores. Despite the low number of taxa (Fig. 3.9), this relationship was also observed at the Umzimvubu River site 2 and the Tsitsa River site 13, where SASS4 scores were to some extent influenced by homogeneity of biotopes (only 2 biotopes occurred, i.e. sand and MV) (Fig. 3.10 – 3.13). SASS4 clearly fluctuated depending on the habitat status or value, while ASPT seemed to be more independent of habitat value. Linking recorded ASPT, SASS4 and habitat values using Table 3.3 revealed that water quality in the Umzimvubu and its selected tributaries is good. The rural nature of the study area and lack of catchment development (such as industrialization) has minimized human impacts so far. The only threat to water quality at present is TSS. The results of automatic sediment sampling (Tsitsa River site 14) warrant further investigation and results from four other sites (rivers) will be reported early in the year 2000.

The catchment has few small municipal areas (Fig.1.1 – 1.6) considered to be "insignificant in terms of effluent discharge". There are also isolated patches of commercial farming and afforested land. Because of occasional floods and good summer rainfalls, rivers easily clean themselves (self-purification). The key to solving the sedimentation problem lies with source-directed catchment management, through catchment management agencies and including all stakeholders, particularly the rural people. The main causes of soil erosion in the study catchment include overstocking resulting in overgrazing, sparse vegetation cover, ploughing on valleys and sometimes down to the river bank, without a riparian zone. It is therefore imperative that the rural communities are made aware of their catchment activities and consequences in order to minimize further catchment degradation (erosion). Other developers can use the collected database (prior to serious development) to support their decisions in catchment development and resource management. The data can be incorporate into provincial and national RHP in the biomonitoring network of the rivers. Tolerance tests using more sensitive species, chronic tests need to be considered. The main focus of the future research study in the Umzimvubu River catchment must be on the effects of sediment on selected indigenous macro-invertebrates. Baseline data so established can be used as a background against which future impacts of catchment development can be compared. The future of the Umzimvubu River estuary in the light of possible upstream river regulation needs urgent attention. Impoundment could lead to possible outbreaks of bilharzia, and proliferation of black fly, a stock pest. Further research is suggested into these possibilities, and the need to establish their biological controls.

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Appendix 1

Table 5 Spring 1996 water quality parameters from the Umzimvubu River and its selected tributaries.

Variables	Umzimvubu						Umzintlava		Kinira		Tina		Tsitsa	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Temp.(°C)	17	21	18	22	19	23	16	22	12	20	23	17	19	18
O_2 (% sat.)	119	116	118	108	106	105	101	104	121	113	106	104	113	100
pH	7.6	7.4	8.1	8.26	8.17	8.23	7.74	7.46	8.85	8.83	7.89	8.24	8.83	8.2
EC (μS/cm)	44	66	115.5	132	137.5	140	79.8	110	101	162	66	118.3	162	117.6
Turb.(NTU)	21	34.3±	48.3±0.	129±0.	39.67±	9.3±0.47	10±0.8	334±33	29.67	185.3±	34.67±	14.3±0.	16.3±1.	7±0.94
		0.94	49	82	1.25		2	.2	±1.25	1.25	0.47	47	89	
TSS(mg/l)	130	130	216.7	346.7±	1309±9	190.67	173.3	1083±2	216.6	1179±	303.3	216.67	216.8	160.3
			±61.3	6.1(FR)	(FR)	±50.2	±61.3	3 (FR)	7±61	37FR	±61.3	±31	±60.3	±34.1
Flow (m^3/s)	0.383	0.603	0.821	2.224	7.222	14.97	1.08	2.77	1.065	1.11	0.23	0.5	0.47	1.58
PO_4-P (mg/l)	0.01	0.02	0.01	0.02	0.01	0.00	0.01	0.02	0.02	0.01	0.02	0.02	0.01	0.03
NO_3-N (mg/l)	0.06	0.003	0.00	0.6	0.23	0.21	0.37	0.03	0.1	0.19	0.42	0.1	0.00	0.47
NO_2-N (mg/l)	0.01	0.01	0.00	0.00	0.02	0.01	0.02	0.03	0.00	0.04	0.00	0.05	0.00	0.01
NH_4-N (mg/l)	0.00	0.47	0.00	0.04	0.01	0.04	0.02	0.06	0.06	0.01	0.03	0.13	0.05	0.19
River width	12:W	10:W	22:W	48:W	44:W	64:W	12:W	22:W	15:W	22:W	11:W	15:W	8:W	34:W
(m)	0:D	0D	0:D	5:D	70:D	87:D	8:D	6:D	3:D	9:D	9:D	18:D	0:D	18:D
TDS(mg/l)#	29.92	44.88	78.54	89.76	93.5	95.5	54.26	74.8	68.68	110.16	44.88	80.44	40.39	79.97

Key: W & D = wet and dry parts of the river
%sat. = percent saturation
FR = Following rainfall
TDS (mg/l)# = EC (mS/m) x 6.8, (Hoffman, 1995)

Table 6 Winter 1997 water quality parameters from the Umzimvubu River and its selected tributaries.

Variables	Umzimvubu						Umzintlava		Kinira		Tina		Tsitsa	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Temp.(°C)	14	16	14	14	18	20	15	16	9	14	12	11	12	16
O_2(% sat.)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	7.26	7.09	7.65	7.89	7.47	7.08	7.06	7.98	7.45	8.05	7.35	7.47	6.89	7.76
EC (μS/cm)	63.4	120.2	62	186	239.4	275	124	212.8	118	248	65	69.2	66.3	119
Turb (NTU)	7.7±	8.3	20.3±	11.7±0.	8.3±0.4	8.4±0.47	3	8.3±0	27	27.67	10	3.67	11	3.67±0.
	0.47	±2.1	0.47	94	7			.5		±0.47				47
TSS (mg/l)	118.7	160	365±	331.3±	211.3±	331.7±5.	220±8.	229.7	149.7±	226±3.	97.5±5.	113.8	58.67±	32.67±
	±1.2	±6.4	3.63	12.6	20.4	3	7	±6.9	10.6	19	31	±2.66	5.31	0.12
Flow (m^3/s)	0.25	0.75	1.92	7.17	7.86	19.9	1.55	3.73	8.28	2.73	0.85	3.36	4.32	7.68
PO_4-P(mg/l)	0.02	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.08	0.00	0.11	0.15	0.01	0.01
NO_3-N (mg/l)	0.00	0.00	0.00	5.7	1.57	2.5	0.00	0.00	0.54	0.00	1.1	0.6	2.2	0.00
NO_2-N(mg/l)	0.01	0.18	0.02	0.02	0.00	0.02	0.00	0.02	0.01	0.00	0.03	0.03	0.27	0.00
NH_4-N(mg/l)	0.06	0.01	0.31	0.03	0.02	0.03	0.00	0.17	0.02	0.00	0.02	0.03	0.00	0.00
River width	8:W	6:W	22:W	48:W	64:W	151:W	20:W	18:W	15:W	17:W	8:W	15:W	13:W	49:W
(m)	0:D	4:D	0:D	3:D	50:D	20:D	2.5:D	18:D	10:D	59:D	11:D	18:D	0:D	35:D
TDS(mg/l)[#]	43.11	42.16	81.74	126.48	162.79	187	84.32	144.7	80.24	168.64	44.2	47.05	45.08	80.92

Key: W & D = wet and dry parts of the river

%sat. = percent saturation

TDS (mg/l)[#] = EC(mS/m) x 6.8 (Hoffman, 1995)

Table 7 Autumn 1997 water quality parameters from the Umzimvubu River and its selected tributaries.

Variables	Umzimvubu						Umzintlava		Kinira		Tina		Tsitsa	
	1	2	3	4	5	6*	7	8	9	10	11	12	13	14
Temp.(°C)	4	9	7	11	13		11	13	13	17	16	12	11	15
O_2(% sat.)	-	-	-	-	-		-	-	-	-	-	-	-	-
pH	7.3	7.17	7.5	7.89	8.04		7.15	7.81	7.52	7.89	7.82	7.56	7.3	7.6
EC(μS/cm)	79	115	120.5	109.7	114.3		40	52	40	143	83.3	130	109	99.8
Turb(NTU)	6±1.4	5±0.82	10	10.67±0.47	8.33±0.47		7.7±0.47	23.7±0.9	31.7±1.7	138.7	5.7±0.47	303.7	12	27±0.47
TSS(mg/l)	113.8±7.69	139.8±18.6	156±21.2	211.3±13.5	201.5±15.9		130	260	390.3	338.67	243.3	416	130	260
Flow(m^3/s)	0.58	1.18	3.31	8.52	>flow		1.77	4.12	2.8	4.4	0.86	3.5	1.09	8.77
PO_4-P(mg/l)	0.08	0.00	0.13	0.00	0.00		0.01	0.01	0.1	0.01	0.03	0.01	0.07	0.02
NO_3-N(mg/l)	0.00	0.00	0.00	0.13	0.00		0.00	0.054	0.01	0.06	0.00	0.07	0.43	0.00
NO_2-N(mg/l)	0.00	0.01	0.00	0.07	0.09		0.00	0.02	0.01	0.01	0.00	0.04	0.07	0.03
NH_4-N(mg/l)	0.05	0.01	0.01	0.04	0.04		0.00	0.00	0.01	0.003	0.00	0.05	0.06	0.24
River width	9:W	7:W	21:W	38:W	-		20:W	19:W	17:W	18:W	9:W	25:W	15:W	54:W
(m)	0:D	3:D	0:D	10:D	-		3:D	16:D	4.5:D	62:D	12:D	44:D	0:	47:D
TDS(mg/l)[#]	53.72	78.2	81.94	74.59	77.72		27.2	35.36	27.2	97.24	56.64	88.4	74.12	86.67

Key: W & D = wet and dry parts of the river
% sat. = percent saturation
TDS (mg/l)[#] = EC (mS/m) x 6.8 (Hoffman, 1995)
6* = site six was not sampled.

Table 8 The summer 1998 water quality parameters from the Umzimvubu River and its selected tributaries.

Variables	Umzimvubu						Umzintlava		Kinira		Tina		Tsitsa	
	1	2	3	4	5	6*	7	8	9	10	11	12	13	14
Temp.(°C)	18	21	24	26	28		23	27	21	28	21	25	22	23
O_2(% sat.)	98	76	62	80	67		83	82	98	62	95	78	70	75
pH	7.12	7.19	7.49	7.57	7.9		7.59	8.06	7.25	7.75	7.08	8.59	7.56	7.39
EC(μS/cm)	29	33	61.2	115.6	95		83	164.9	54	106.7	44	130	95.4	31.2
Turb(NTU)	123.7±1.7	1097±8.73	402.3±0.47	1760±2.7	413.67±0.47		27.7±0.5	51	966±19.6	1967±10	1521±12.08	1960±2.7	64.3±1.3	436±0.8
TSS(mg/l)	315±29.2	1849±18.8	546.17±0.24	1449.7±64.5	562.1±7.07		51.3±2.1	146	1365±5.3	3301.9±23.7	2564.2±55.7	2827±5.3	168.8	692±19
Flow(m^3/s)	>flow	>flow	>flow	>flow	>flow		2.55	4.03	>flow	>flow	>flow	>flow	2.06	>flow
PO_4-P(mg/l)	0.23	0.02	0.08	0.14	0.04		0.04	0.03	0.02	0.07	0.02	0.05	0.07	0.04
NO_3-N(mg/l)	0.03	1.43	2.3	2.4	0.7		1.93	0.83	0.7	3.8	0.1	0.01	0.57	0.25
NO_2-N(mg/l)	0.1	0.02	0.01	0.05	0.01		0.02	0.01	0.03	0.05	0.04	0.01	0.01	0.05
NH_4-N(mg/l)	0.07	0.1	0.09	0.24	0.01		0.02	0.03	0.07	0.09	0.1	0.15	0.00	0.11
River width (meters)	-	-	-	-	-		22:W 1.5:D	17:W 15:D	-	-	-	-	13:W 0:D	-
TDS(mg/l)[#]	19.72	22.44	41.48	78.2	64.6		56.58	112.13	36.72	72.56	29.92	88.4	64.87	21.22

Key: W & D = wet and dry parts of the river

% sat. = percent saturation

TDS (mg/l)[#] = EC(mS/m)x 6.8. (Hoffman, 1995)

>flow = very high flows. 6* = site 6 was not sampled.

Table 9 The spring 1998 ad-hoc water quality parameters analyzed by IWQS (DWAF) from the Umzimvubu River and its selected tributaries. All were measured in mg/l, except pH and electrical conductivity.

Variables	Detection limits	Umzimvubu						Umzintlava		Kinira		Tina		Tsitsa	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Al.	0.02	0.134	0.352	0.408	0.738	1.086	0.473	0.153	0.473	0.21	0.735	0.162	0.252	0.224	1.076
Ti.	0.003	<0.003	<0.003	<0.003	0.01	0.01	<0.003	<0.003	0.007	<0.003	<0.003	<0.003	<0.003	<0.003	0.02
Mn.	0.001	<0.001	<0.001	0.046	0.03	0.002	0.004	<0.001	0.012	0.007	<0.001	<0.001	<0.001	<0.001	0.001
Fe.	0.005	0.088	0.739	0.563	0.71	<0.005	0.329	0.141	0.441	0.21	0.625	0.044	0.140	0.417	<0.002
Co.	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ni	0.007	0.022	0.029	0.032	0.025	0.036	0.028	0.03	0.034	0.025	0.021	0.034	0.023	0.031	0.037
Cu	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Zn	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Hg	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Pb	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
PH	2	7.9	7.9	8	8.3	8.4	8.4	8	8.4	8.2	8.5	8.1	8.1	7.8	8.1
NH_4-N	0.04	<0.04	<0.04	<0.04	0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
NO_3/NO_2-N	0.04	<0.04	<0.05	<0.04	0.14	0.19	0.16	0.24	0.68	<0.04	0.11	<0.04	0.08	<0.04	0.09
F.	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1
Alkalinity*	0.4	42	62	82	103	119	136	58	102	120	122	66	81	41	60
Na	2	3	6	8	10	13	25	7	10	9	13	4	8	2	8
Mg	1	3	4	6	11	11	14	5	12	9	11	4	7	2	5
Si	0.4	7.8	6.3	3.6	7.3	8	8	6.4	8	8.4	7	7.2	7.1	6.3	5.5
PO_4-P	0.005	0.008	0.006	0.007	0.008	0.009	0.009	<0.005	0.008	<0.005	<0.005	0.006	0.007	0.013	<0.005
SO_4	4	<4	<4	<4	<4	4	9	<4	<4	<0.4	<4	<4	<4	<4	<4
Cl	10	<10	<10	<10	<10	<10	19	<10	<10	<10	<10	<10	<10	<10	<10
K	0.3	0.23	0.23	0.8	0.9	0.8	1.3	1.4	1	0.7	0.9	0.4	0.8	0.3	0.5
Ca	1	8	12	15	16	19	22	10	14	22	20	15	13	9	10
EC(mS/m)	1	10	12.1	16.2	20.9	24.5	33	13.5	19	22.6	21.4	12.8	16.5	7.8	13.6
TDS	1	99	103	136	172	201	256	105	175	193	201	108	135	67	106

Key: Alkalinity* as calcium cabonate (Ca_2Co_3).

APPENDIX 2

Table 10 Summer 1998 macro-invertebrate community composition in the Umzimvubu River and its tributaries.

	Umzimvubu						Umzintlava		Kinira		Tina		Tsitsa	
Taxonomic level	1	2	3	4	5	6	7	8	9	10	11	12	13	14
COLEOPTERA														
Dytiscidae	-	-	-	-	-		5	-	-	-	-	1	-	-
Elmidae	1	-	1	-	4		1	-	-	1	-	-	1	1
Gyrinidae	2	14	1	2	-		15	-	-	1	-	3	1	10
Hydraenidae	1	-	-	-	-		-	-	-	-	-	=	-	-
Hydrophilidae	-	-	-	-	-		-	-	-	-	-	=	-	-
Psephnidae	-	-	-	-	2		-	1	-	-	-	1	-	1
Torrindincolidae	-	3	-	-	-		-	-	-	-	-	-	-	5
DIPTERA														
Athericidae	-	-	-	-	-		-	-	-	-	-	-	-	-
Blepharoceridae	-	-	-	-	-		-	-	-	-	-	-	-	-
Ceratopogonidae	-	-	-	-	-		-	-	-	-	-	-	-	-
Chironomidae														
*Chironominae+	-	-	-	-	-		-	-	1	1	-	-	-	1
*Chironomini	1	-	-	9	1		17	18	10	4	-	-	-	6
*Orthocladinae	-	-	-	2	5		21	17	36	12	-	1	-	1
*Tanypodinae	-	-	-	2	-		3	-	1	1	-	-	-	-
Empididae	1	1	-	-	-		-	-	-	-	-	-	-	-
Sciomyzidae	-	-	-	-	-		-	-	-	-	-	-	-	-
Simuliidae														
Simulium chutteri	-	-	-	-	-		-	-	1	91	-	5	-	28
S.damnosum	-	-	-	-	-		2	-	-	-	-	-	-	1
S.dentulosum	-	-	-	1	-		-	-	-	-	-	-	-	-
S.impukani/alcocki?	-	-	-	-	-		5	-	-	-	-	2	-	-
S.medusaeforme	-	-	-	261	2010		115	70	2	-	1	5	-	15
S.rotundum	-	-	-	-	-		2	-	4	-	-	-	-	-
S.ruficorne	-	-	-	-	-		-	-	-	-	-	-	-	1
Tipulidae	-	-	-	1	-		-	-	-	-	-	-	-	-

Table 10 (continues)

	Umzimvubu						Umzintlava		Kinira		Tina		Tsitsa	
Taxonomic level	1	2	3	4	5	6	7	8	9	10	11	12	13	14
EPHEMEROPTERA														
Baetidae														
Afroptilium sp.	58	-	-	-	-		346	2	1	3	10	4	-	8
Baetis sp.	-	-	-	-	-		-	-	-	1	-	-	-	-
B.glaucus	-	-	-	-	-		-	-	-	-	2	-	2	5
B.harrisoni	4	-	-	11	-		270	16	2	1	10	28	-	2
Cloen sp.	-	-	-	-	-		-	-	-	1	-	-	-	-
Centroptiloides sp.	1	-	-	3	-		1	-	-	7	-	-	-	1
C.excisum	20	-	-	-	-		2	3	4	6	48	3	-	2
Demoreptus sp.	1	-	-	-	-		6	-	-	-	-	1	-	-
Labiobaetis sp.	-	-	-	24	-		67	31	187	35	29	94	146	45
Small Baetids	-	-	-	-	-		-	25	-	-	-	-	-	-
Caenidae														
Afrocaenis sp.	1	-	-	-	1		3	2	-	-	3	3	-	1
Caenis sp.	-	-	-	-	-		-	-	-	1	-	-	-	-
C.umgeni	-	-	-	-	-		-	-	-	-	-	-	-	-
Polymitarcyidae	-	-	-	-	-		-	-	-	-	-	-	-	-
Heptageniidae														
A.barnardi	-	-	-	19	3		4	-	1	-	-	3	-	-
Oligoneuridae	-	1	-	24	2		84	-	-	3	2	88	1	1
Leptophlebidae														
A.peringueyella	2	-	-	-	-		1	-	-	1	4	1	-	-
Castanophlebia sp.	-	-	-	-	-		-	-	-	-	-	-	-	1
E.elegans	-	-	-	2	-		17	5	1	1	-	1	-	2
Prosopistomatidae														
P.crassi	-	-	-	-	-		-	-	-	-	-	1	-	-
Trichorythidae														
T.discolor	2	-	-	14	15		95	5	-	-	13	4	-	7

Table 10 (continues)

	Umzimvubu						Umzintlava		Kinira		Tina		Tsitsa	
Taxonomic level	1	2	3	4	5	6	7	8	9	10	11	12	13	14
HEMIPTERA														
Corixidae	-	-	-	-	-		1	68	-	2	-	-	-	-
Gerridae	-	-	-	-	-		3	-	-	-	-	-	-	-
Naucoridae	-	4	-	-	-		-	-	-	-	-	-	-	-
Notonectidae	1	-	-	-	-		35	-	1	1	-	-	-	3
Pleidae	-	-	-	-	-		-	-	-	-	-	9	-	-
Vellidae	-	-	2	-	-		10	-	-	-	-	-	4	3
Nepidae	-	1	1	-	-		-	-	-	-	-	-	1	-
ODONATA														
Aeshnidae	1	-	-	-	-		6	-	-	-	-	-	-	-
Cordullidae	-	-	-	-	-		-	-	-	-	-	1	57	-
Gomphidae	1	1	-	-	-		-	-	1	-	-	-	-	-
Libellulidae	-	-	-	-	-		42	-	-	2	-	1	-	-
Platycnemididae														
PLECOPTERA														
N.spio	-	-	-	9	1		-	-	-	21	-	5	-	-
PULMONATA														
Ancylidae														
Burnupia sp.	-	-	-	12	25		25	25	-	-	-	2	-	123
Ferrisia sp.	-	-	-	4	3		12	7	-	-	-	2	-	11
Planorbidae														
Physidae	-	-	-	-	-		-	5	-	-	-	-	-	-
TRICHOPTERA														
C.afra														
C.thomasseti	-	-	-	-	-		135	2	-	-	-	-	-	2
Cheumatopsyche sp.	-	-	-	5	-		2	138	-	5	-	2	-	13
H.longifurca	-	-	-	22	10		-	12	-	8	-	3	-	20
Hydropsyche sp.	-	-	-	13	54		-	34	-	58	-	15	-	59
M.capense	-	-	-	-	-		-	-	-	-	-	-	-	-
Leptoceridae	-	-	-	-	-		9	-	-	-	-	-	-	-
	-	-	-	-	-		-	-	-	-	-	-	-	-

Table 10 (continues)

	Umzimvubu						Umzintlava		Kinira		Tina		Tsitsa	
Taxonomic level	1	2	3	4	5	6	7	8	9	10	11	12	13	14
MISCELLANEOUS														
Annelida														
Arachnida	1	1	1	-	2		-	-	-	1	-	2	-	4
Coleoptera larvae	3	-	-	-	-		12	-	-	-	-	-	3	-
Collembola	-	-	-	-	-		1	-	-	-	-	-	-	-
Crab	-	-	-	-	-		-	-	-	-	-	-	2	-
Diptera pupae	4	-	-	-	-		11	-	-	-	23	-	-	-
Hemiptera (immature)	-	-	-	-	-		1	-	-	-	-	-	-	-
Hydracarina	-	-	-	-	-		-	-	-	-	-	-	-	-
Insect (immature)	-	-	-	-	-		-	-	-	-	-	-	-	-
Lepidotera larvae	1	-	-	-	-		12	-	-	-	1	1	3	-
Nematoda	-	-	-	-	-		3	-	1	5	-	-	-	-
Nematormorpha	-	-	-	-	-		-	-	-	-	-	-	-	-
Ostracoda	-	-	-	-	-		-	-	-	-	-	-	-	-
Turbellaria	-	-	-	-	-		-	-	-	-	-	-	-	-
Trichoptera pupae	-	-	-	-	-		-	2	-	-	-	-	-	4
	-	-	-	-	-		1	1	-	-	-	-	-	-
Number of taxa.	20	8	5	20	15	N/a	40	22	16	27	12	41	11	31

Note:The Umzimvubu River site six was no sampled in summer.

Table 11 Spring 1997 macro-invertebrate community composition in the Umzimvubub River and its selected tributaries.

	Umzimvubu						Umzintlava		Kinira		Tina		Tsitsa	
Taxonomic level	1	2	3	4	5	6	7	8	9	10	11	12	13	14
COLEOPTERA														
Dytiscidae	1	-	-	-	-	-	-	-	1	-	2	-	-	-
Elmidae	1	-	14	8	2	17	7	-	9	1	3	2	1	22
Gyrinidae	1	1	71	-	-	-	9	9	4	-	5	3	-	6
Hydrophilidae	-	-	34	-	-	2	-	3	15	-	1	-	-	7
Hydraenidae	-	-	6	-	-	-	-	-	-	-	-	-	-	-
Psephnidae	-	-	-	-	-	-	-	-	-	-	-	-	-	1
DIPTERA														
Blepharoceridae	3	-	-	-	-	-	-	-	-	4	-	-	-	-
Ceratopogonidae	1	3	27	14	-	1	-	3	5	-	-	-	-	1
Athericidae	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Chironomidae														
*Chironominae+	212	65	768	47	24	49	414	238	1214	28	55	15	13	665
*Chironomini	17	178	124	65	124	124	243	79	19	154	8	5	65	288
*Orthocladinae	65	27	236	297	49	49	655	124	184	34	24	9	2	1865
*Tanypodinae	32	10	139	86	64	64	74	8	158	4	43	25	1	16
Empididae	-	-	-	-	-	2	2	-	1	-	-	-	-	1
Simulidae														
S.bequaerti	5	-	-	-	-	-	-	-	-	-	-	-	-	-
S.dentulosum	-	-	-	-	-	-	2	-	-	-	-	-	-	-
S.medusaeforme	59	-	55	-	-	-	389	-	174	-	30	-	-	-
S.nigritarse	1	-	-	-	-	-	37	-	69	-	28	-	-	-
S.unicornotum	1	-	-	-	-	-	2	-	-	-	-	-	-	-
S.vorax	-	-	18	411	2	16	193	529	67	40	-	-	-	192
Small Simuliids#	699	-	13	1233	1	-	436	-	295	109	-	-	-	612
Tipulidae	1	-	-	1	-	-	-	-	-	-	52	4	-	-

Table 11 (continues)

	Umzimvubu						Umzintlava		Kinira		Tina		Tsitsa	
Taxonomic level	1	2	3	4	5	6	7	8	9	10	11	12	13	14
EPHEMEROPTERA														
Baetidae														
Afroptilium sp.	102	11	120	33	-	-	19	-	-	-	7	3	-	17
B.glaucus	-	2	5	26	-	-	-	-	-	-	-	-	1	-
B.harrisoni	-	3	177	350	23	3	91	42	10	-	36	2	-	143
C.excisum	16	21	271	130	12	47	2	34	105	309	185	30	7	24
Centroptiloides sp.	-	-	-	1	2	2	-	-	-	10	-	10	-	74
Demoreptus sp.	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Labiobaetis sp.	1	58	80	-	-	-	1	7	83	3	-	12	-	35
Small Baetids#	699	40	730	347	124	41	522	121	246	93	-	762	12	323
Caenidae														
Afrocaenis sp.	2	13	171	174	2	2	19	18	37	23	103	94	-	5
Caenis sp.	-	-	31	10	3	-	-	3	-	-	2	-	-	-
C.umgeni	-	-	-	30	2	5	-	-	-	-	-	-	-	-
Heptagenidae														
A.barnardi	10	-	13	5	21	150	-	-	-	-	4	-	-	10
Leptophlebidae														
A.peringueyella	-	-	-	-	-	-	-	-	-	-	9	-	-	-
E.elegans	3	-	114	238	83	144	58	2	14	52	122	98	-	173
Castanophlebia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trichorythidae														
T.discolor	-	1	88	1	-	-	13	1	8	-	35	278	-	1
Prosopistomatidae														
P.crassi	-	-	1	16	13	15	-	-	-	-	-	-	-	6
HEMIPTERA														
Corixidae	10	-	6	3	-	-	1	-	-	-	28	1	-	-
Hebridae	-	-	-	1	-	-	-	1	2	-	-	1	-	2

Table 11 (continues)

	Umzimvubu						Umzintlava		Kinira		Tina		Tsitsa	
Taxonomic level	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Naucoridae	-	-	-	-	-	-	-	-	2	-	-	-	-	-
Notonectidae	-	-	1	4	1	1	2	1	1	-	-	-	-	-
Vellide	-	-	-	-	-	-	-	-	2	-	-	2	-	-
ODONATA														
Aeshnidae	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Cordullidae	2	2	-	-	-	-	-	-	-	-	-	-	-	21
Gomphidae	1	6	-	-	-	-	-	-	-	-	1	1	-	1
Lestidae	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Libellulidae	-	-	-	7	1	8	-	-	-	-	-	-	-	-
Platycnemididae	-	19	6	-	-	-	-	-	-	-	-	-	-	2
PLECOPTERA														
Neorpela spio	-	-	2	126	12	28	-	1	-	14	-	1	-	-
PULMONATA														
Ancylidae														
Burnupia sp.	-	-	188	49	-	-	32	14	15	-	-	2	-	28
Ferrisia sp.	-	-	402	18	-	-	-	3	-	-	-	-	-	-
Small Ancylids#	2	-	-	-	-	-	-	-	-	-	-	-	-	4
Lymnaedae	-	-	3	-	-	-	-	2	-	-	-	-	-	-
Unionidae	-	-	12	-	-	-	-	12	-	-	-	-	-	-
Planorbidae														
Gyraulus sp.	-	-	17	-	-	-	-	-	-	-	-	-	-	-
TRICHOPTERA														
Hydropsychidae														
C.afra	11	-	39	1	-	13	94	-	5	85	19	-	-	16
C.thomasseti	21	-	126	201	28	-	4	91	21	75	5	-	-	169
H.longifurca	-	-	21	114	61	4	-	29	-	-	-	-	-	56

Table 11 (continues)

	Umzimvubu						Umzintlava		Kinira		Tina		Tsitsa	
Taxonomic level	1	2	3	4	5	6	7	8	9	10	11	12	13	14
M.capense	-	-	-	-	-	-	5	1	-	-	-	-	-	-
Cheumatopsyche sp.	38	-	13	177	106	-	2	1	-	43	2	10	-	23
Hydropsych sp.	-	-	1	67	1	-	-	-	-	6	-	-	-	56
Leptoceridae	-	-	5	-	-	-	-	-	-	33	-	-	-	-
Small Hydropsychidae#	6	-	3	165	-	1	-	-	-	-	-	-	-	-
MISCELLANEOUS.														
Cladocera	-	-	42	-	-	-	-	42	-	-	-	-	-	-
Coleoptera larvae	-	-	-	-	-	-	-	1	-	1	-	-	-	-
Collembola	-	1	-	-	-	-	3	-	-	-	-	-	-	-
Crab	-	-	2	-	-	-	1	-	-	-	1	-	-	-
Diptera pupae	5	3	40	8	15	4	69	36	138	5	15	2	-	141
Hirudinae	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hemiptera larvae	-	-	1	-	-	-	-	-	-	-	3	-	-	-
Insect(immature)	2	-	4	3	19	4	17	5	79	3	5	2	-	25
Lepidoptera larvae	-	-	-	6	-	-	-	1	-	1	-	-	-	-
Nematoda	-	-	8	24	-	1	1	15	-	2	-	-	-	4
Nematomorpha	-	-	13	3	-	-	-	-	-	-	-	-	-	1
Ostracoda	33	-	50	-	-	-	-	-	-	-	-	-	-	-
Number of taxa	34	19	48	41	26	27	34	33	30	25	29	26	9	38

Table 12 Winter 1997 Macro-invertebrate community composition in the Umzimvubu River and its selected tributaries.

Taxonomic Level.	Umzimvubu						Umzintlava		Kinira		Tina		Tsitsa	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
COLEOPTERA.														
Dytiscidae.	2	-	-	-	-	-	1	-	1	-	-	-	-	-
Elmidae	1	-	-	1	6	20	-	-	-	-	1	2	-	1
Gyrinidae	4	12	11	-	1	1	1	-	3	-	-	4	-	18
Hydrophilidae	8	-	-	-	-	-	24	-	-	-	-	-	-	-
DIPTERA.														
Blepharoceridae	3	-	-	-	-	-	-	-	-	-	-	-	-	-
Cerotopogonidae	1	-	-	-	-	-	-	-	2	-	-	-	-	-
*Chironominae+	91	-	16	10	4	53	14	-	62	1	40	10	4	7
*Chironomini	20	-	15	20	1	24	66	1	8	2	16	24	6	2
*Orthocladinae	132	26	191	109	226	366	110	267	977	55	265	24	277	51
*Tanypodinae	58	1	4	3	1	60	10	-	30	1	6	19	-	1
Empididae	-	-	-	-	-	-	-	-	3	1	-	-	-	-
Simuliidae														
Simulium.bequarti	36	-	3	-	-	-	-	1	22	-	12	4	-	-
S.chutteri	-	-	-	-	-	-	-	-	1	6	-	-	-	-
S.damnosum	-	-	-	1	-	-	-	1	-	-	-	-	-	1
S.dentulosum	19	-	-	2	-	-	11	-	52	1	48	7	-	-
S.impukane/alcocki ?	-	2	1	-	-	-	14	-	-	1	-	5	-	1
S.medusaeforme	910	20	287	469	358	3	820	138	132	385	647	727	6	965
S.nigritarse	15	35	50	-	-	4	15	2	167	1	8	26	1	-
S.rotundum	-	2	6	1	-	1	1	-	3	-	-	-	-	3
S.rutherfoordi	5	-	1	-	-	-	-	-	-	-	-	-	-	-
S.ruficorne	-	-	-	-	-	2	-	-	-	-	-	-	-	-
S.unicornutum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S.vorax	-	-	-	-	-	-	-	-	-	-	-	-	-	903
Small simuliids#	125	-	-	-	-	3	-	-	-	-	-	-	-	-
Tabanidae	-	-	-	-	-	-	-	-	-	-	1	-	-	-

Table 12 (continues).

	Umzimvubu						Umzintava		Kinira		Tina		Tsitsa sites	
Taxonomic level.	1.	2.	3.	4.	5.	6.	7	8	9	10	11	12	13	14
Tipulidae	-	1	1	1	-	-	-	-	-	2	1	-	-	-
EPHEMEROPTERA														
Baetidae														
Afroptilium sp.	402	13	70	1	-	7	816	-	8	5	15	89	1	-
B.harrisoni	42	21	306	228	29	302	200	16	93	303	169	135	15	215
Centroptiloides sp.	-	-	-	6	7	-	-	-	-	4	-	4	-	-
C.excisum	58	7	8	-	8	18	8	-	2	39	12	39	-	5
Demoreptus sp.	15	-	-	-	-	-	13	-	-	-	-	6	-	1
Labiobaetis sp	107	34	48	-	-	19	96	-	1	1	3	59	7	108
Small Baetids#	217	32	28	2	-	239	83	-	23	23	45	83	8	62
Caenidae														
Afrocaenis sp.	1	1	-	6	-	2	1	-	9	-	-	-	-	-
Caenis sp.	-	-	-	1	-	1	-	-	-	-	5	3	9	-
C.umgeni	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Heptageniidae														
A.barnardi	30	-	1	7	1	12	-	-	-	-	1	2	-	-
Leptophlebidae														
A.peringueyella	248	2	-	-	-	-	-	-	5	-	77	25	-	-
E. elegans	6	-	10	6	3	2	23	4	1	6	13	18	1	2
Castanophlebia sp	11	-	-	-	-	-	-	-	-	-	19	1	-	-
Trichorythidae														
T.discolor	102	1	175	3	-	-	39	6	2	-	750	55	1	-
HEMIPTERA.														
Notonectidae														9
Pleidae	-	-	-	-	-	-	1	-	-	-	-	-	-	-
ODONATA.	-	-	-	-	-	-	2	-	-	-	-	-	-	-
Aeshnidae														
Gomphidae	3	-	-	-	-	-	1	-	-	-	-	2	-	-
Libellulidae	10	2	3	-	-	-	-	-	-	-	8	5	-	-
	-	-	-	1	2	3	-	-	1	2	-	-	1	2

Table 12 (Continues)

	Umzimvubu						Umzintava		Kinira		Tina sites		Tsitsa sites	
Taxanomic level	1.	2.	3.	4.	5.	6.	7	8	9	10	11	12	13	14
Platycnemididae	10	5	-	-	-	-	3	12	-	-	-	-	-	-
PLECOPTERA														
Neorpela spio	-	-	-	2	2	4	-	-	-	-	-	1	-	-
PULMONATA														
Ancylidae														
Burnupia sp.	8	-	21	-	-	1	78	-	5	-	-	-	-	57
Ferrissia sp.	7	-	27	-	-	-	73	-	-	-	-	-	-	19
Gyraulus sp.	-	-	-	-	-	-	3	-	-	-	-	-	-	-
TRICHOPTERA														
Hydropsychidae														
C. afra.	27	8	13	4	-	-	27	4	10	-	70	5	-	1
C. thomasseti	13	-	9	19	-	1	13	6	64	33	23	9	-	6
H.longifurca.	-	-	33	44	11	-	-	20	-	63	6	42	-	1
M.capense.	-	-	-	-	-	-	15	-	-	-	-	-	-	-
Cheumatopsyche sp	30	3	43	61	2	4	4	-	3	15	34	19	-	1
Hydropsyche sp.	2	-	6	19	-	1	-	-	-	2	-	6	-	-
MISCELLANEOUS.														
Annelida														
Arachnida	-	-	-	1	-	-	1	-	-	-	-	-	-	1
Cladocera	-	-	-	-	-	-	-	-	-	-	2	-	-	-
Coleoptera lavae	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Crab	-	-	-	-	1	-	-	-	-	-	6	-	-	-
Diptera pupae	3	1	-	-	-	1	-	-	1	8	-	-	1	5
Hirudinae	5	-	-	-	-	10	-	-	20	1	-	-	-	1
Hydracarina	-	-	-	-	-	-	-	-	-	-	-	-	2	5
Insect(Immature)	-	-	4	-	-	-	-	-	-	1	-	-	-	-
Lepidoptera lavae	-	2	-	-	24	1	-	1	-	1	-	1	-	-
Nematoda	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 12 (Continues)

	Umzimvubu						Umzintlava sites		Kinira		Tina sites		Tsitsa sites	
Taxanomic level	1.	2.	3.	4.	5.	6.	7	8	9	10	11	12	13	14
Nematomorpha	-	-	-	-	-	2	-	-	-	-	-	-	-	-
Trichoptera pupa	-	-	-	-	-	-	1	-	-	-	-	1	-	-
Turbellaria	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Number of taxa	38	22	30	26	18	30	34	14	29	27	30	34	15	29

Key:
S.chutteri = *Simulium.chutteri*
B.harrisoni = *Baetis horrisoni*
C.excisum = *Cheleocleon excisum*
C.umgeni = *Clypeocaenis umgeni*
A.barnardi = *Afronurus barnardi*
A.pringueyella = *Adenophlebia peringueyella*
T.discolor = *Trichorythus discolor*
E.elegans = *Euthraulus elegans*
P.crassi = *Prosopistoma crassi*
C.afra = Cheumatopsyche afra
C.thomasseti = *Cheumatopsyche thomasseti*
H.longifrca = *Hydropsyche longifurca*
M.capense = *Macrostema capense*
Chironominae^{+} = chironominae and tanytarsini
= Unidentifiable small macro-invertebrates
* = subfamily

Table 13 Autumn 1997 macro-invertebrate community composition in the Umzimvubu River and its selected tributaries.

	Umzimvubu						Umzintlavaa		Kinira		Tina		Tsitsa	
Taxonomic level.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Coleoptera.														
Dytiscidae	-	-	-	-	-		4	1	1	-	-	-	4	-
Elmidae	2	-	4	4	1		12	19	26	8	39	15	13	5
Gyrinidae	1	-	5	1	-		16	17	4	-	-	3	-	1
Hydraenidae	1	1	-	-	-		15	13	3	-	-	-	9	-
Hydrophilidae	15	2	-	-	-		2	4	1	-	13	1	1	-
Psephnidae	-	-	-	-	-		-	2	-	-	-	-	-	1
Diptera.														
Athericidae	-	-	-	-	-		-	-	3	-	-	1	-	-
Blepharoceridae	14	-	-	-	-		-	-	-	4	-	-	-	-
Ceratopogonidae	-	1	-	-	-		2	-	1	-	-	1	-	-
Chironomidae														
*Chironominae+	24	-	3	9	-		331	45	56	10	131	205	2	30
*Chironomini	23	8	1	2	6		84	97	37	14	45	65	49	29
*Orthocladinae	379	-	882	65	2		933	280	2833	60	555	904	56	561
*Tanypodinae	16	-	-	-	-		14	8	17	-	53	25	7	3
Empididae	-	-	-	-	-		-	-		-	3	-	-	-
Simuliidae									27					
Simulium bequaerti	2	-	-	-	-		9	-	12	5	4	-	-	-
S.chutteri	-	-	-	-	-		-	-	-	92	-	44	-	21
S.damnosum	-	-	-	1	-		-	1	-	1	-	1	-	48
S.dentulosum	21	-	1	-	1		-	-	-	-	-	-	-	-
S.impukane/alcocki?	-	-	-	-	-		2	1	75	1	1	1	-	-
S.medusaeforme	430	-	96	832	2010		1453	18	93	54	800	785	6	2894
S.nigritarse	1	1	4	-	-		1	-	78	46	1	-	-	1
S.rotundum	-	-	15	1	-		20	4	-	10	-	-	1	17
S.rutherfordi	-	-	-	-	-		-	-	-	-	-	-	-	-
S.ruficorne	-	-	-	-	-		-	-	-	-	-	17	-	-
S.unicornutum	-	-	1	-	-		-	-	-	-	-	-	-	-

Table 13 (Continues).

	Umzimvubu sites						Umzintlava		Kinira		Tina		Tsitsa	
Taxonomic level	1	2	3	4	5	6	7	8	9	10	11	11	13	14
S.vorax	99	-	313	-	-		2	-	167	2	-	7	-	2402
Small Simuliids#	142	-	-	-	-		336	-	1	232	5	-	-	107
Tipulidae	13	-	-	-	-		-	-	-	-	-	-	-	-
EPHEMEROPTERA														
Baetidae	376	1	104	1	-		361	9	4	2	8	7	23	-
Afroptilium sp	-	-	7	-	-		-	-	-	-	-	-	-	-
B.glaucus	216	4	67	-	-		167	180	99	24	270	101	24	74
B.horrisoni	-	-	-	23	-		-	-	1	-	-	-	-	-
Baetis sp.	-	-	-	-	1		-	-	1	-	1	23	-	4
Centroptiloides sp.	217	1	5	144	-		7	7	6	5	4	16	-	4
C.excisum	39	-	-	-	-		9	1	-	-	-	-	-	-
Demoreptus sp.	67	4	110	10	-		51	267	55	17	-	32	3	48
Labiobaetis sp.	213	-	30	47	-		618	218	84	26	331	191	11	104
Small Baetids	-	-	-	1	-		85	7	20	4	248	40	38	1
Caenidae														
Afrocaenis sp.	8	1	18	36	-		-	3	-	1	64	16	-	-
Caenis sp.	-	-	3	38	-		-	2	-	1	-	-	-	-
C.umgeni	-	3	-	2	-		-	-	1	-	-	-	-	
Polymitarcyidae	-	-	9	1	-		-	1	1	-	415	-	-	-
Heptageniidae														
A.barnardi	19	-	11	9	9		1	10	-	2	213	12	-	-
Leptophlebidae														
A.peringueyella	190	-	-	22	-		33	1	-	-	-	-	27	-
Castanophlebia sp.	179	-	-	-	-		-	2	1	1	90	5	1	-
E.elegans.	7	-	50	29	8		108	128	-	-	90	90	-	28
Oligoneuridae	-	3	-	-	-		-	-	-	-	-	1	-	-
Prosopistomatidae														
P.crassi	-	1	-	-	-		-	-	-	-	1	-	1	3
Trichorythidae														
T.discolor	154	2	266	5	-		35	62	6	5	1089	56	1	-

Table 13 (Continues).

	Umzimvubu sites						Umzintlava		Kinira		Tina		Tsitsa	
Taxonomic level	1.	2.	3.	4.	5	6	7	8	9	10	11	12	13	14
HEMIPTERA														
Corixidae	-	-	-	-	-		47	35	-	-	-	-	1	-
Gerridae	-	-	-	-	-		-	2	-	-	-	-	-	-
Naucoridae	-	-	-	-	-		-	-	-	-	-	-	-	1
Notonectidae	-	-	-	-	-		3	1	-	-	-	-	-	-
Pleidae	-	-	-	-	-		1	-	-	-	-	-	-	-
Vellidae	-	-	-	-	-		3	7	-	-	-	-	-	9
ODONATA														
Aeshnidae	1	-	-	-	-		2	1	-	-	3	-	1	-
Gomphidae	7	1	7	7	-		-	-	2	1	12	3	9	1
Libellulidae	-	-	-	-	1		-	5	-	2	-	5	-	27
Platycnemididae	-	-	-	-	-		15	16	-	-	-	1	-	-
PLECOPTERA.														
Neoperla spio	4	-	1	1	2		-	-	2	7	43	11	-	-
PULMONATA.														
Ancylidae														
Burnupia sp.	-	-	31	31	-		164	255	7	-	-	16	-	188
Ferrisia sp.	-	-	-	-	-		127	256	-	-	-	2	-	105
Planorbidae														
Gyraulus sp.	-	-	-	-	-		5	-	-	-	-	-	-	-

Table 13 (continues)

Taxonomic level	Umzimvubu						Umzintlava		Kinira		Tina		Tsitsa	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
TRICHOPTERA.														
C.afra	114	-	197	-	-		137	5	28	1	126	7	2	1
C.thomasseti	9	-	109	7	-		2	34	162	111	44	14	-	3
Cheumatopsyche sp.	54	-	212	22	5		115	28	46	83	246	93	8	1
H.longifurca	1	-	9	64	32		-	488	1	194	2	115	-	13
Hydropsyche sp.	1	-	2	6	2		-	70	-	-	-	5	1	-
M.capense	-	-	-	-	-		10	-	-	-	-	-	-	-
Leptoceridae	-	-	-	-	-		6	8	-	-	-	-	-	-
MISCELLANEOUS														
Arachnida	2	1	-	1	-		20	2	-	4	-	-	3	2
Collembola	-	-	-	-	-		-	-	2	-	2	-	1	6
Crab	5	-	-	-	-		1	1	2	-	4	-	-	-
Diptera. P.	-	-	-	-	-		8	-	77	2	12	39	5	8
Hemiptera.L	1	-	-	-	-		2	16	1	1	1	-	2	1
Hydracarina	-	-	-	-	-		13	1	1	1	82	2	-	2
Insect (immature)	3	-	1	-	-		24	12	12	8	2	2	5	4
Lepidoptera. L.	-	-	-	3	3		2	6	6	2	-	1	-	1
Nematoda	-	-	-	6	-		1	-	-	-	10	5	-	149
Nematormorpha	-	-	-	-	-		-	3	3	1	8	-	-	-
Ostracoda	-	-	-	-	-		1	2	2	-	-	-	-	-
Turbellaria	1	-	-	-	-		-	-	-	-	-	1	-	-
Number of taxa	42	14	31	33	14	N/A	48	52	46	38	36	44	31	38

Appendix 3

Table 14 Qualitative analysis of macro-invertebrate data from the Umzimvubu River and its selected tributaries based on Chutter's (1998) SASS4 score sheet and sensitivity levels (1 – 15).

Taxa	Sensitivi-ty scores	Umzimvubu						Umzintlava		Kinira		Tina		Tsitsa	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Coleoptera		ssaw	ssaw	ssaw	ssaw	ssaw	ssaw	ssaw	ssaw	ssaw	ssaw	ssaw	ssaw	ssaw	ssaw
Dytiscidae	5	-P-P	----	----	----	----	----	P-PP	--P-	-PPP	----	-P--	P-P-	--P--	----
Elmidae	8	PPPP	-P--	PPP-	-PPP	PPPP	-P-P	PPP-	--P-	-PP-	PPP-	-PPP	-PPP	PPP-	PPPP
Gyrinidae	5	PPPP	PP-P	PPPP	P-P-	---P	---P	PPPP	--P-	-PPP	P---	-P--	PP-P	P---	PPPP
Hydraenidae	8	P-P-	-PP-	-P--	----	----	----	--P-	-PP-	--P-	----	----	--P-	--P-	----
Hydrophilidae	5	--PP	--P-	-P--	----	----	P---	--PP	-PP-	-PP-	----	-PP-	--P-	--P-	-P--
Psephnidae	10	----	----	----	----	P---	----	---P	P-P-	----	----	----	P---	----	PPP-
Diptera															
Athericidae	13	----	----	----	-P--	----	----	----	----	--P-	----	----	--P-	----	----
Blephariceridae	15	-PPP	----	----	----	----	----	----	----	----	-PP-	----	----	----	----
Ceratopogonidae	5	-P-P	-PP-	-P--	-P--	----	-P--	--P-	-P--	-PPP	----	----	--P-	----	-P--
Chironomidae	2	PPPP	-PPP	-PPP	PPPP	PPPP	-P-P	PPPP	PPPP	PPPP	PPPP	-PPP	PPPP	-PPP	PPPP
Empididae	6	P---	P---	----	----	-P--	-P--	-P--	----	-PPP	---P	--P-	----	----	-P--
Simuliidae	5	-PPP	--PP	-PPP	PPPP	PPPP	-P-P	PPPP	PPPP	PPPP	-PPP	PPPP	P-PP	--PP	PPPP
Tipulidae	5	-PP-	---P	---P	PPP-	----	----	----	----	--P-	---P	-P-P	-P--	---	----
Ephemeroptera															
Baetidae 1spp.	4	PPPP	-PPP	-PPP	PPPP	-P-P	-P-P	PPPP	PPPP	PPPP	PPPP	PPPP	PPPP	PPPP	PPPP
2 spp.	6	PPPP	-PPP	-PPP	PPPP	-P-P	-P-P	PPPP	PPP-	PPPP	PPPP	PPPP	PPPP	PPPP	PPPP
>2 spp.	12	PPPP	-PPP	-PPP	PPPP	-P-P	-P-P	PPPP	PPP-	PPPP	PPPP	PPPP	PPPP	--PP	PPPP
Caenidae	6	PPPP	-P-P	-PP-	-PPP	PP--	-P-P	PPPP	PPP-	-PPP	PPP-	PPPP	PPPP	--PP	PPP-
Polymitarcyidae	10	----	----	--P-	----	----	----	----	--P-	--P-	----	----	----	----	----
Heptageniidae	10	--PP	----	-PPP	PPPP	PPPP	-P-P	P-P-	--P-	P-P-	----	-PPP	P-PP	----	-P--

Table 14 (continues)

Taxa	Scores*	Umzimvubu						Umzintlava		Kinira		Tina		Tsitsa	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
		ssaw	ssaw	ssaw	ssaw	ssaw	ssaw	ssaw	ssaw	ssaw	ssaw	ssaw	ssaw	ssaw	ssaw
Oligoneuridae	15	----	P---	----	P---	P---	----	P---	----	----	P---	P---	P-P-	P---	P---
Leptophlebiidae	13	PPPP	--PP	-PPP	PPPP	-PPP	-P-P	PPPP	PPPP	PPPP	PPP	PPP	PPP	--P	PPP
Prosopistomatidae	15	----	----	-P--	-P--	-P--	-P--	----	----	---	----	--P-	P---	--P-	-PP-
Trichorythidae	9	PP-P	-PPP	-PPP	PPPP	P---	----	PPPP	PPPP	-PPP	--P-	P-PP	PPPP	--PP	PP--
Hemiptera															
Corixidae	3	-P--	----	-P--	-P--	----	----	PPP-	P-P-	----	----	-P--	-PP-	----	----
Gerridae	5	----	----	----	----	----	----	P---	--P-	----	----	----	----	----	----
Naucoridae	7	----	P---	----	----	----	----	----	--P-	-P--	----	----	----	--P-	----
Notonectidae	3	P---	----	-P--	-P--	-P--	-P--	PPPP	-PP-	PP--	P---	----	----	----	P--P
Pleidae	4	----	----	----	----	----	----	--PP	----	----	----	----	P---	----	----
Vellidae	5	----	----	P---	----	----	----	P-P-	--P-	-P--	----	----	-P--	P-P-	P---
Nepidae	3	----	P---	P---	----	----	----	----	----	----	----	----	----	P---	----
Odonata															
Aeshnidae	8	P-P-	----	----	----	----	----	PPPP	--P-	----	----	--P-	---P	--P-	----
Cordullidae	8	-P--	-P--	----	----	----	----	----	----	----	---	----	P--P	P---	-P--
Gomphidae	6	PPPP	PPPP	--PP	--P-	----	----	----	----	--P-	--P	-PPP	-PPP	--P-	-PP-
Lestidae	8	-P--	----	--P-	----	----	----	----	----	----	--P	---	---	--P	---
Libellulidae	4	----	----	--P-	-P-P	-PPP	-P-P	P---	--P-	P--P	---P	----	--P-	--PP	--PP
Platycnemididae	10	---P	-P-P	-PP-	----	----	----	--PP	--PP	---P	P---	----	P-P-	--P-	-P--
Plecoptera															
Perlidae	12	--P-	----	-PP-	PPPP	PPPP	P--P	----	-P--	--P-	PPP-	--P-	PPPP	--P-	----

Table 14 (continues)

Taxa	Scores*	Umzimvubu						Umzintlava		Kinira		Tina		Tsitsa	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Pulmonata		ssaw	ssaw	ssaw	ssaw	ssaw	ssaw	ssaw	ssaw	ssaw	ssaw	ssaw	ssaw	ssaw	ssaw
Ancylidae	6	-P--	----	-PPP	PPP-	P---	---P	PPPP	PPP-	-PPP	----	----	PPP-	----	PPPP
Lymnaeidae	3	----	----	-P--	-P--	----	----	----	-P--	----	----	----	----	----	---
Planorbidae	3	----	----	-P--	-P--	----	----	--PP	-P--	----	----	----	----	----	---
Physidae	3	----	----	----	-P--	----	----	----	P---	----	----	----	----	----	---
Unionidae	6	----	----	-P--	----	----	----	----	-P--	----	----	----	----	----	---
Trichoptera															
Hydropsychidae															
1 spp	4	-PPP	---P	-PPP	PPPP	PPPP	-P-P	PPPP	PPPP	-PPP	PPPP	-PPP	P-PP	--P-	PPPP
2spp	6	-PPP	----	-PPP	PPPP	PPP-	-P--	PPPP	PPPP	-PPP	PPPP	-PPP	P-PP	--P-	PPPP
>2spp	12	--P-	----	-PPP	PP-P	----	----	PPPP	PPPP	--P-	--P-	--PP	--PP	----	PPPP
Leptoceridae - case larva.	8	----	----	----	-P-P	---P-	----	--PP	--P-	----	----	----	---P	----	----
Miscellaneous															
Crab	3	P-P-	----	-P--	----	---P	----	PPP-	--P-	--P	---	P-P-	----	----	---P
Hydracarina	8	----	----	----	----	---P	----	--P-	--P-	--p	--P	--P-	--P-	----	--P-
Hirudinea	3	---P	----	----	----	----	---P	----	----	---P	-P-PP	----	----	----	----
Nymphulidae	15	----	----	----	-PP-	--P-	----	P-P-	-PP-	P-P	P--	----	--P-	----	--P-
Oligochaeta	1	P---	P---	P---	---P	----	----	---P	----	----	P--	----	P---	----	P---
Turbellaria	5	--P-	----	---P	----	----	----	----	----	----	----	---	--P-	----	p---
Number of taxa		34	23	36	31	25	21	36	38	34	27	26	39	27	32

Key: scores* = sensitivity range (1 – 15) or pollution tolerant to pollution sensitive families.
SSAW (seasons) = summer, spring, autumn and winter.
Note : Umzimvubu River site six was not sampled in summer and autumn