BIOMONITORING IN TWO CONTRASTING CATCHMENTS

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ABSTRACT

The introduction of instream biological monitoring to water resources management has been an increasing trend world-wide. This monitoring uses biological field assessments of instream biota such as macroinvertebrates, fish and riparian vegetation as an integrated and sensitive tool for diagnosing the condition of the ecosystems and assessing ecological impacts. Biomonitoring information has become an important component in the overall assessment of water resources and is used to drive and direct processes of decision-making and management of water resources. The River Health Programme (RHP) was initiated in South Africa to serve as a source of information regarding the ecological status of river systems, in order to support rational management of these natural resources.

In this study, biomonitoring indices (SASS5 and FAII) were used to assess the present ecological status of two rivers located in contrasting catchments of the Eastern Cape. The first river is the Buffalo River located in an urban and industrialized catchment. The second river is the Inxu River draining a rural and afforested catchment.

SASS5 was used successfully in both rivers and the results based on water quality and SASS5 indicated that most sites selected on the upper catchment of the Buffalo River have a fair water quality with most sites selected on the lower catchment having a poor water quality. The Inxu River sites (both upper and lower catchment) based on SASS5 and water quality results have a good to fair water quality. The majority of sites sampled on both rivers systems had very low FAII scores and fell within a critically modified water quality category. This result may be due to the fact that these rivers have low fish diversities (either low natural diversity or low diversity due to the presence of alien fish species), poor water quality or inadequate sampling methods. Observations from this study suggest that this index may not be suitable for rivers with low fish diversity. A fish index that is usable to all ecoregions of South Africa with minor adaptations to suit local conditions is still needed, as the present FAII index does not meet these requirements.

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GLOSSARY OF TERMS

The definitions have been summarized from Barbour *et al*. (1999), unless otherwise stated.

Biological assessment: an evaluation of the biological conditions of a waterbody that uses biological surveys and other direct measurements of the resident biota in surface waters.

Biological indicators: communities, whether plant or animal, with a narrow range of ecological tolerance that may be selected for emphasis and monitored because their presence and relative abundance serve as barometer of ecological conditions.

Biological integrity: the ability of an ecosystem to support and maintain a balanced and adaptive community of organisms, having species diversity, composition and functional organization comparable to that of the natural habitats of the region (Karr and Dudley, 1981).

Biological monitoring: the use of a biological entity as a detector and its response as a measure to determine environmental conditions. This is usually done through biological surveys and toxicity tests.

Biological survey: the process of collecting, processing and analyzing of representative portions of resident aquatic assemblages to determine the assemblage structure and function.

Biota: plants and animals and other living resources of a water body (Gerritsen *et al*., 1998).

Ecosystem: the interactions of the biological community and abiotic environment (Jamil, 2001).

Environment: the physical and biological aspects of a specific area including all living things, soil, air and water (Jamil, 2001).

Habitat: a place where physical and biological elements of an ecosystem provide a suitable environment including food, cover and space needed for plant and animal livelihood (Gerritsen *et al*., 1998).

Macroinvertebrates: animals that are retained by mesh size > 200μm inhabiting the bottom substrata (Rosenberg and Resh, 1993).

Monitoring sites: sites selected to assess the condition of available physical habitat, water quality and biological parameters for a river, relative to the expected unimpacted condition (Eekhout *et al*., 1996).

Reference sites: relatively unimpacted sites that can be used to define the best physical habitat, water quality and biological parameters for kind of a river (Eekhout *et al*., 1996).

Pollution: an undesirable change in the physico-chemical or biological status characteristics of air, water, and land that may or will having negative impact living species (Jamil, 2001).

Species: organisms forming a natural population or group of populations that transmit specific characteristics from a parent to an offspring.

ACRONYMS AND ABBREVIATIONS

ANOSIM	Analysis of similarity
ASPT	Average Score Per Taxon
CMA	Catchment Management Agency
DEAT	Depart of Environmental Affairs and Tourism
DWAF	Department of Water Affairs and Forestry
EMC	Ecological Management Class
FAII	Fish Assemblage Integrity Index
IHAS	Integrated Habitat Assessment System
IRVI	Integrated Riparian Vegetation Index
IWRM	Integrated Water Resource Management
NMMP	National Microbial Monitoring Programme
RHP	River Health Programme
NWA	National Water Act
NWRS	National Water Resource Strategy
PMT	Provincial Monitoring Team
PIT	Provincial Implementation Team
RDM	Resource-directed measures
RQO	Resource Quality Objectives
RQWO	Receiving Water Quality Objectives
RVI	Riparian Vegetation Index
SASS5	South African Scoring System version 5.0
SAIAB	South African Institute for Aquatic Biodiversity
SAWQG	South African Water Quality Guidelines
SDC	Source-directed controls

UES	Uniform Effluent Standards
WMA	Water Management Areas
WMI	Water Management Institution
WRC	Water Research Commission
WUA	Water User Association

CHAPTER 1

BIOMONITORING AND WATER RESOURCES MANAGEMENT IN SOUTH AFRICA

1.1 Introduction

South Africa's water resources are extremely limited and scarce in global terms (DWAF, 1997), due to the fact that the country's climate varies from desert to semi-desert in the west to sub-humid along the coastal area. The average rainfall of the country is approximately 450 mm per year, which is almost half of the world average rainfall, which is approximately 860 mm per year (NWRS, 2002). As a result, South Africa is categorised as a semi-arid country. Due to seasonal occurrence and variability of rainfall, surface water across the country is unevenly distributed (Zokufa *et al*., 2001). Although groundwater is extensively utilised, especially in more rural areas, it is also limited due to the geology of the country, which is mostly hard to rock (DWAF, 1997). As a result the country is dependent on surface water resources for most of the urban, industrial and irrigation water supplies. In addition, most of the urban and industrial growth centres and some highly populated catchments are situated in areas remote from river courses (DWAF, 1997). These shortages pose a need for management, monitoring and protection of South Africa’s water resources.

1.2 Water Resources Management in South Africa

As the custodian of the nation’s water resources the Department of Water Affairs and Forestry (DWAF) has been charged with ensuring that water resources are managed, allocated and developed in an equitable, sustainable and efficient manner (NWA, 1998). To achieve this, DWAF initiated the development of policies and legislation to guide protection, management and sustainable use of water resources.

1.2.1 The National Water Policy and the National Water Act

The government initiated a review process of water resource management since 1994, which resulted in the formulation of a National Water Policy (NWP), adopted by cabinet in 1997 and the National Water Act (NWA) (Act No. 36) in 1998. The main principles of the NWP are equal water availability for every citizen and for future generations. The NWP grants people a right to water needed for basic human needs and the environment a right to water required for its sustainable functioning. The policy is given legal substance through the National Water Act (NWA, 1998).

The National Water Act is founded on three principles, which are derived from Fundamental Principles and Objectives for a New South Africa Water Law and the NWP policy for managing water resources (NWRS, 2002). The principles are as follows:

- *Equitable access to water*: that is equal access to water irrespective of race, gender and age.
- *Sustainable use and protection of water resources*: humankind and ecosystems are interdependent and there should be a balance between water resources utilisation, development and their protection. People have to be conscious of the fact that their land-use activities may impact negatively on the quality and quantity of water in their catchments.
- *Efficient water use*: as South Africa is a water scarce country with evaporation higher than rainfall, water has to be used efficiently whilst ensuring social and economic development.

The National Water Act is the principal legal instrument relating to water resources management in South Africa and it contains comprehensive provisions for the protection, use, development, conservation and control of the country's water resources. The implementation of the NWP and the protection of water resources through the NWA are guided by two complementary approaches, namely: The resource-directed measures (RDM) and source-directed controls (SDC).

RDM are designed to protect the quality of water resources by managing water quality and quantity, the condition of instream and riparian habitats and the condition and distribution of the aquatic biota (NWRS, 2002). The RDM approach is composed of four components, which are:

1. A national system for classifying water resources.
2. Determination of Ecological Categories (EC), which are, Natural, Good, Fair and Poor.

3. Determination of the Reserve (which is the quality and quality of water needed to meet basic human needs and to protect aquatic ecosystems) (NWA, 1998).
4. Setting of Resource Quality Objectives (RQO) for the resource in accordance with its class (NWA, 1998; NWRS, 2002).

Source-Directed Controls (SDC) define limits and constraints that must be imposed on the use of water resources through tools like licences, registrations and authorisations issued to individual water users (NWRS, 2002). These measures can be categorised into three components:

1. Best management practices, which are measures, applied nationally with respect to water use.
2. Special measures that relate to source-related requirements derived from catchment management plans.
3. Site-specific measures related to measures stemming from authorisation processes taking into account of regional and national levels requirements.

The National Water Act is not the only instrument used to achieve the National Water Policy objectives. The Water Services Act (Act No.108 of 1997) and the National Environmental Management Act of 1998 are also used. Successful water resources management will therefore depend on co-operative governance amongst all government spheres and active involvement of water users and other stakeholders.

1.2.2 The National Water Resource Strategy

According to the NWA the Minister has to establish a NWRS and the terms of reference of this strategy are outlined in Chapter 2 of the Act (NWA, 1998). A draft of the first addition of the NWRS was completed in August 2002 and a full summary is available for comment in public places throughout the country. The purpose of this document is to set out strategies, objectives, plans, guidelines and procedures for the Minister as well as institutional arrangements relating to the protection, use, development, conservation, management and control of water resources within the framework of existing relevant government policies (NWRS, 2002). The strategy has four main objectives:

- to establish a national framework for managing water resources,

- to establish the framework for the preparation of catchment management strategies,
- to provide information for management and
- to identify resource development opportunities and constraints.

The strategy provides actions to be taken to meet projected future water needs. The strategy also allows for changes in emphasis and revision of action plans as growth and development progress and improved insights are gained, thereby ensuring its continued relevance. Implementation of the strategy has started and will continue in a step-by-step manner over the next twenty years (NWRS, 2002). The NWRS may be amended after mandatory consultations with stakeholders with reviews taking place at least every five years. The NWRS is the tool by which Integrated Water Resource Management (IWRM) can be achieved in South Africa (NWRS, 2002).

1.2.3 Integrated Water Resources Management

The three principles of equity, sustainability and efficiency in water resources management intersect in the field of Integrated Water Resources Management (IWRM). Pegram and Palmer (2001) describe IWRM as a process and implementation strategy to achieve equitable access and sustainable use of water resources. IWRM is achieved through co-ordinated involvement, participation planning, and management, of all stakeholders at catchment, regional and national levels. This participation of all stakeholders at all levels is required in the NWA and can be achieved through establishment of Water Management Institutions (WMIs), particularly Catchment Management Agencies (CMAs) and Water User Associations (WUAs). These organisations need to be viable technically, administratively and financially for the NWA to be implemented. Generally IWRM has the intention of satisfying human needs for water, jobs and economic growth in a manner that also enables maintenance, protection and rehabilitation of aquatic ecosystems (Pegram and Palmer, 2001). The NWRS sets out pathways by which IWRM can be achieved.

1.2.4 Water Quality Management in South Africa

Deteriorating water quality is one of freshwater resources major threats to South Africa's capability to provide sufficient water to meet the country's water needs and to ensure environmental sustainability (DWAF, 1997). Water quality management therefore forms a pivotal part of water resources management in South Africa. Water quality can be described as the physical, chemical and aesthetic properties of water to determine its fitness for a variety of uses and for the protection of health and integrity of aquatic ecosystems (DWAF, 1996a-g). Different management approaches for water quality management have been developed for the country over the decades. The first approach was the Uniform Effluent Standards (UES) approach, which requires compliance of effluents received by the natural aquatic environment with UES to control the input of pollutants. This approach is simple, more understandable and easy for regulators to enforce but fails to protect water quality when there are multiple point sources of a particular pollutant (DWAF, 1997). It is also not useful when there are high background levels of pollution from non- point sources (DWAF, 1997).

Van der Merwe and Grobler (1990) developed the Receiving Water Quality Objective (RWQO) approach. The objective of this approach is to maintain water quality in a water body fit for the use of its recognized users on a sustainable basis. This approach recognizes the natural environment as the resource base itself and not as a user. It is advantageous because it accounts for both point and non-point sources of pollution, cost effective as it considers the capacity of the water environment to assimilate pollutants, and enables an industry to locate in the least pollution- sensitive receiving environment. In 1996 DWAF developed the South African Water Quality Guidelines (SAWQG) for the protection of aquatic ecosystems (DWAF, 1996a-g). The aim of the guidelines was to develop criteria that are appropriate for ecological conditions in South Africa based on consensus amongst experts and water quality managers (Zokufa *et al*., 2001). Although the SAWQG are based on international literature, they have been adapted for South Africa's conditions (DWAF, 1996a-g).

DWAF has initiated several monitoring Programmes using different parameters to assess and monitor the quality of the nation's surface water resources. Once the quality of these resources is known, the need and priorities for management can be determined. The programmes that have been initiated to monitor surface water quality are:

- **Physico-chemical monitoring** – in South Africa a National Chemical Water Quality Monitoring Network has approximately 850 monitoring points linked to hydrological weirs in rivers and reservoirs. DWAF regional offices, water boards and private sector organisations undertake the monitoring. A national database of water quality information has been established.
- **Microbial monitoring –** the National Microbial Monitoring Programme (NMMP) is operational in some Water Management Areas (WMAs).
- **Eutrophication monitoring** – the National Eutrophication Programme that includes cyanobacterial surveys, is also operational in some reservoirs.
- **Radioactive monitoring –** the National Radioactivity Programme (NRP) is being tested in some catchments with mining activities taking place.
- **Biological monitoring** – the River Health Programme (RHP) initiated by DWAF in collaboration with Department of Environmental Affairs and Tourism (DEAT) and Water Research Commission (WRC), uses biological indicators to assess and monitor the ecological integrity of South Africa's river systems.
- **Toxicity monitoring –** the National Toxicity Monitoring Programme (NTMP) is currently under development.

1.2.4.1 The River Health Programme

The formal design and implementation of the RHP was initiated in 1994. The main purpose of this programme is to serve as a source of information regarding the overall ecological status of South Africa's river systems, in order to support their management (Roux, 1997; Roux *et al.*, 1999). This information is obtained through the use of in-stream and riparian biological information, for example fish, invertebrates and riparian vegetation, as indicators to characterize the response of the aquatic environment to disturbances. This activity where the ecological health of a system is determined through the use biota (e.g. macroinvertebrates, fish, and vegetation) and abiotic components (water quality and geomorphology) is called biomonitoring and is its use in water resource management an increasing worldwide trend. The rationale is that the biotic integrity or health of the biota inhabiting the river ecosystems provides a direct and integrated measure of the health of a river as a whole (Roux *et al*., 1999). Biotic integrity is defined as the ability of an ecosystem to support and maintain a balanced, integrated and adaptive community of organisms, having species diversity, composition and functional organisation comparable to that of the natural habitats of the region (Karr and Dudley, 1981). The biological indicators used in the RHP programme include aquatic invertebrates [South African Scoring System (SASS), Chutter, 1998], fish assemblages [Fish Assemblage Integrity Index (FAII), Kleynhans, 1999] and riparian vegetation [Riparian Vegetation Index (RVI), Kemper, 2001] and physical indicators which are habitat [Habitat Integrity Index (HII), Kleynhans, 1996], geomorphology [Geomophological Index (GI) Rowntree and Ziervogel, 1999] water quality [Water quality Index (WQI), Moore, 1990] and flow [Hydrological Index (HI) Hughes, 1996]. Physical indicators provide a framework for the interpretation of biological data. The objectives of the RHP are to: (i) measure, assess and report on the ecological state of aquatic ecosystems; (ii) detect and report on the spatial and temporal trends in the ecological state of aquatic ecosystems; (iii) identify and report on emerging problems regarding aquatic ecosystems; and (iv) ensure that all reports provide scientifically and managerially relevant information for the national aquatic ecosystem management.

1.2.4.2 Indicators and indices used in RHP

Macroinvertebrates and SASS5

Benthic macroinvertebrates are those organisms that inhabit the bottom substrates (sediments, logs, debris, macrophytes etc) of freshwater habitats for at least part of their life cycle and are retained by mesh sizes > 200 to 500µm (Rosenberg and Resh, 1993). Macroinvertebrates have been widely used as indicators of environmental health (Rosenberg and Resh, 1993). This is attributable to the fact that their sampling is very easy, requires few personnel, is relatively inexpensive and is not detrimental to the resident biota (Rosenberg and Resh, 1993). Macroinvertebrates are also widely distributed with diverse communities, which constitute a broad range of trophic levels and pollution tolerances (Rosenberg and Resh, 1993; Metcalfe-Smith, 1994; Barbour *et al*., 1999).

The South African Scoring System version 5 (SASS5) is a rapid biomonitoring index using macroinvertebrate families as indicators (Dickens and Graham, 2002). SASS has been tested and is widely used in South Africa as a tool for assessing water quality and river health (Dallas, 1997; Vos *et al*., 2002).

Fish and FAII

Fish are used as indicators of environmental health because their assemblages generally include a range of species representing a variety of trophic levels (herbivores, carnivores, insectivores, piscivores, planktivores and omnivores) with different tolerances to pollution (Karr and Dud1ey 1981; Barbour *et al*., 1999). According to Barbour *et al*. (1999), their assemblage structure is reflective of integrated environmental health. They are good indicators of long-term changes and broad habitat conditions because they are relatively long-lived and mobile (Barbour *et al*., 1999). Fish are relatively easy to collect and identify to species level, and most specimens can be sorted and identified in the field by fisheries specialists and subsequently released unharmed.

The Fish Assemblage Integrity Index (FAII) has been developed to assess the integrity of fish assemblages (Kleynhans, 1999). The index is based on expected fish assemblages under natural conditions and observed fish assemblages at the time of sampling. The FAII score calculated as the ratio of the observed conditions versus expected conditions in the absence of anthropogenic disturbances (Kleynhans, 1999). This index has been used successfully in rivers with high natural fish diversities (e.g. rivers in Mpumalanga), however there are difficulties in applying this index in rivers with low natural fish diversities (e.g. Eastern Cape and Western Cape river systems) (Bok A, Anton Bok & Associates, Port Elizabeth, pers. comm., 2003).

Riparian Vegetation and RVI

Riparian vegetation is the vegetation found in close proximity to rivers (Kemper, 2001). The riparian zone is therefore that area located next to a river, influenced by river processes such as flooding and alluvial deposition, and characterised by vegetation adapted to mesic conditions and occasional inundation (Kotze *et al*., 1997; RHP, 2004). Functional riparian vegetation stabilizes river channels, attenuate floods, maintain water temperature and quality and intercept and deposit nutrients and sediments (Kemper, 2001). Changes in stream flow, vegetation removal, grazing, construction, erosion and alien vegetation invasion within the riparian zone alter the structural and functional characteristics of the riparian vegetation thereby affecting the health of the river (RHP, 2004).

The riparian vegetation index was developed for the use in RHP to assess and monitor the degree of modification of riparian vegetation. This index was tested in Mpumalanga (Crocodile River) and was to be adapted for use in other provinces (Kemper NP, IWR Environmental, Pretoria, pers.comm.,2003).

Habitat and HII, IHAS

Habitat availability and diversity are major determinants of aquatic community structure (Uys *et al*., 1996), therefore the evaluation of habitat quality is critical to any assessment of ecological health. There are two indices used for habitat assessment in the RHP. The first index is Integrated Habitat Assessment System (IHAS) (McMillan, 1998). This index was specifically developed to be used with SASS, and can be used to modify SASS score based on habitat availability. It is used to assess the quality of habitat sampled for macroinvertebrates only. The Index of Habitat Integrity (IHI) on the other hand is used to assess the quality of both instream and riparian habitat at a sampling site. This index assesses the impact of disturbances such as water abstraction, flow regulation and channel modification at a sampling site.

Geomorphology and GI

Geomorphology is one of several important components used to assess the overall condition of a river. The geomorphological processes and flow determine the morphology of the channel, which in turn, provides the physical framework for the stream biota (Rowntree and Wadeson, 2000). Water and sediment therefore predominantly shape the river channel and also affect water quality with high sedimentation and silt loading contributing to water quality deterioration. Structural changes in the river channels influence the form, diversity and distribution of available physical habitat. This affects the composition and diversity of instream and riparian biological communities. Changes in stream biota in the absence of other disturbances can therefore be attributed to possible changes in channel morphology and channel condition whether this change is of natural or anthropogenic influence.

The geomorphological index (GI) is used in RHP implementation to assess the physical condition of river channels morphology. The development of this index is ongoing and its accuracy, applicability and reliability are dependent upon availability of data from various river systems across the country (RHP, 2004).

Flow and HI

Flow conditions and channel physical characteristics affect the distribution and abundance of the biota by creating dynamic habitat characterized by current speed, water depth and substratum characteristics (Hughes D, Institute for Water Research, Rhodes University, pers.comm., 2003). The collection of past and present flow data from gauging weirs is very important for tracing changes in flow that are likely to occur due to natural or anthropogenic impacts. Dams, inter-basin transfers, hydroelectric power generation and other anthropogenic impacts have altered most rivers flow regimes in South Africa. Flow conditions are also altered by natural processes such as large floods (temporarily inundating most habitats and resulting in sparse diversity), and droughts that result in low flow (loss of habitats) (Hughes D, Institute for Water Research, Rhodes University, pers.comm., 2003).

Although the prototype of the Hydrological Index (HI) has been developed the index is currently not being used in RHP implementation. Flow data for interpretation of biological data and to trace temporal changes in river flow are obtained and analyzed from DWAF gauging weirs.

Water quality and WQI

Water quality assessment is important in the overall assessment of ecological status of aquatic ecosystems. The term water quality describes the physical, chemical, and aesthetic properties of water, which determines its fitness for the protection of health and integrity of aquatic ecosystems (DWAF, 1996a-g). Aquatic organisms are therefore adapted to live within limited water quality ranges due to their evolutionary history. Changes in water quality condition can have detrimental effects on aquatic biota and thereby affect their ability to provide natural cleansing activities in aquatic ecosystems such as breaking down of organic matter. Water quality data gathering is therefore vital in assessment and monitoring of river health as water quality changes may affect the overall health of a river.

Although the Water Quality Index (WQI) has been developed it is not widely used in South Africa and is not currently used in RHP monitoring. For the RHP, water quality data are obtained from DWAF gauging weirs. Physical water quality variables (conductivity, temperature, dissolved oxygen and pH) are measured on site on each sampling occasion.

The RHP programme has undergone developmental phases starting in 1994 and the current phase now is the anchoring phase, which ensures that the RHP becomes part of the relevant water management institutions in terms of the required expertise, skills and budgets. The overall goal of this phase is to assist implementation agencies to go through the different steps of implementing the programme as well as to internalize the programme in their organizations. The implementation of this programme has also been adopted at provincial level with provinces such as Mpumalanga, Kwazulu-Natal, Western Cape and others having started the implementation of the RHP on selected river systems in their provinces.

1.2.4.3 Eastern Cape River Health Programme (EC RHP)

The EC RHP was launched in July 2002 under the leadership of Dr Patsy Scherman of Coastal & Environmental Services (CES), Grahamstown who was commissioned to lead the biomonitoring team to undertake River biomonitoring in the Eastern Cape. The Buffalo River was selected for the first phase of the EC RHP due to the fact that large quantity research has been conducted on this system (i.e. available historical data) and DWAF has been monitoring the water quality and flow data of this system for a number of years. The biomonitoring team undertook three surveys on this system and the Buffalo River Technical Report was produced in March 2004.

This thesis is based on the use of two biomonitoring indices, namely: SASS5 and FAII, to assess the ecological health of the Buffalo and Inxu Rivers. These indices have been developed, tested and applied in several river systems around South Africa. This research therefore contributes to information on use of these indices in the Eastern Cape. Although the SASS technique has been applied successfully in some river systems in the Eastern Cape, this study further assesses the replicability and representativeness of the SASS technique following its protocol (one sample taken at each biotope for a specified time at that particular time of sampling). This tested by taking three replicates per biotope at selected reference and monitoring sites on both the Inxu and Buffalo Rivers.

There have been uncertainties about the applicability of the FAII index to some river systems. This index was applied to the Inxu and Buffalo Rivers and problems encountered whilst using this index and recommendations for further development of this index have been documented.

Sampling on the Buffalo River was done in conjunction with the Eastern Cape biomonitoring team. The results of the riparian vegetation and geomorphological assessments conducted by respective specialists and are reported in Chapter 3.

1.3 Aims and objectives of the study

1.3.1 Overall aim

The overall aim of this study was to determine the present ecological health of the Buffalo and Inxu rivers based on macroinvertebrate and fish communities using SASS5 and FAII indices.

1.3.2 Objectives

The study identified four objectives:

- To describe the advantages and limitations of SASS5 and FAII in producing results that can be used to assess the ecological integrity of the Buffalo and Inxu rivers.
- To assess the ecological status of the sacred pools on the Inxu River using data of the water flowing through the sacred pools. This objective of the study is linked to the NRF funded programme on indigenous knowledge regarding natural water bodies, pools and rivers.
- To report on the use of these biomonitoring indices in rural and afforested and urban and industrialized catchments for water resources management.
- To provide data for the Eastern Cape and national River Health Programmes.

1.3.3 Thesis Structure

Chapter 1

In this chapter water resources management in South Africa and biomonitoring in general are briefly reviewed.

Chapter 2

In this chapter physical and biological indicators used during data gathering are described and critically reviewed. Procedures followed in selecting sites on both rivers are described. Data analysis methods are also described.

Chapter 3

This chapter focuses on the Buffalo River study starting from description of the study area, results and discussion of results gathered during the study.

Chapter 4

This chapter focuses on the Inxu River assessment starting from description of the study area, results and discussion of results gathered during the study.

Chapter 5

This is a concluding chapter based on results obtained during this study, with recommendations on further development of the indices used.

CHAPTER 2

MATERIALS AND METHODS

2.1 Introduction

When designing a biological monitoring programme attention should be given to aquatic community components that are representative of the larger ecosystem and are practical to measure (RHP, 2004). Decisions should be made as to which indicators to measure and which indices to select. Communities of fish, aquatic macroinvertebrates and riparian vegetation are the primary indicators used in the RHP (Roux *et al.*, 1999). Abiotic indicators such as geomorphology, habitat, flow and water quality are needed to provide a framework within which biological data could be interpreted. In this chapter the steps taken for the biological monitoring of the Buffalo and Inxu rivers are outlined. RHP indices (biotic and abiotic) used in this study are briefly discussed and statical analyses procedures undertaken are also explained.

2.2 The selected river catchments

The study was conducted on two rivers, namely the Buffalo and Inxu Rivers, located in two different catchments of the Eastern Cape. Fig 2.1 shows the location of these rivers relative to each other within the province. Although the underlying reasons for the assessment of the Buffalo and the Inxu Rivers were different, both rivers were suitable from a RHP perspective (Mangold, 2001), with perennial flow and a range of sites from least impacted to highly impacted. The Buffalo River drains an urban and industrialized catchment encompassing King William's Town, Zwelitsha, East London and Mdantsane. A detailed description of the Buffalo River catchment is presented in Chapter 3. The Inxu River is located in the northern Eastern Cape and drains a rural and afforested catchment with known sacred pools that are spiritually and culturally important. A detailed description of this catchment is presented in Chapter 4.

2.3 Site selection

Site selection is the first step in any bioassessment programme and there are two types of sites used in RHP assessment. These are reference and monitoring sites**.** The selection of monitoring sites depends on the objectives of the study to be undertaken.

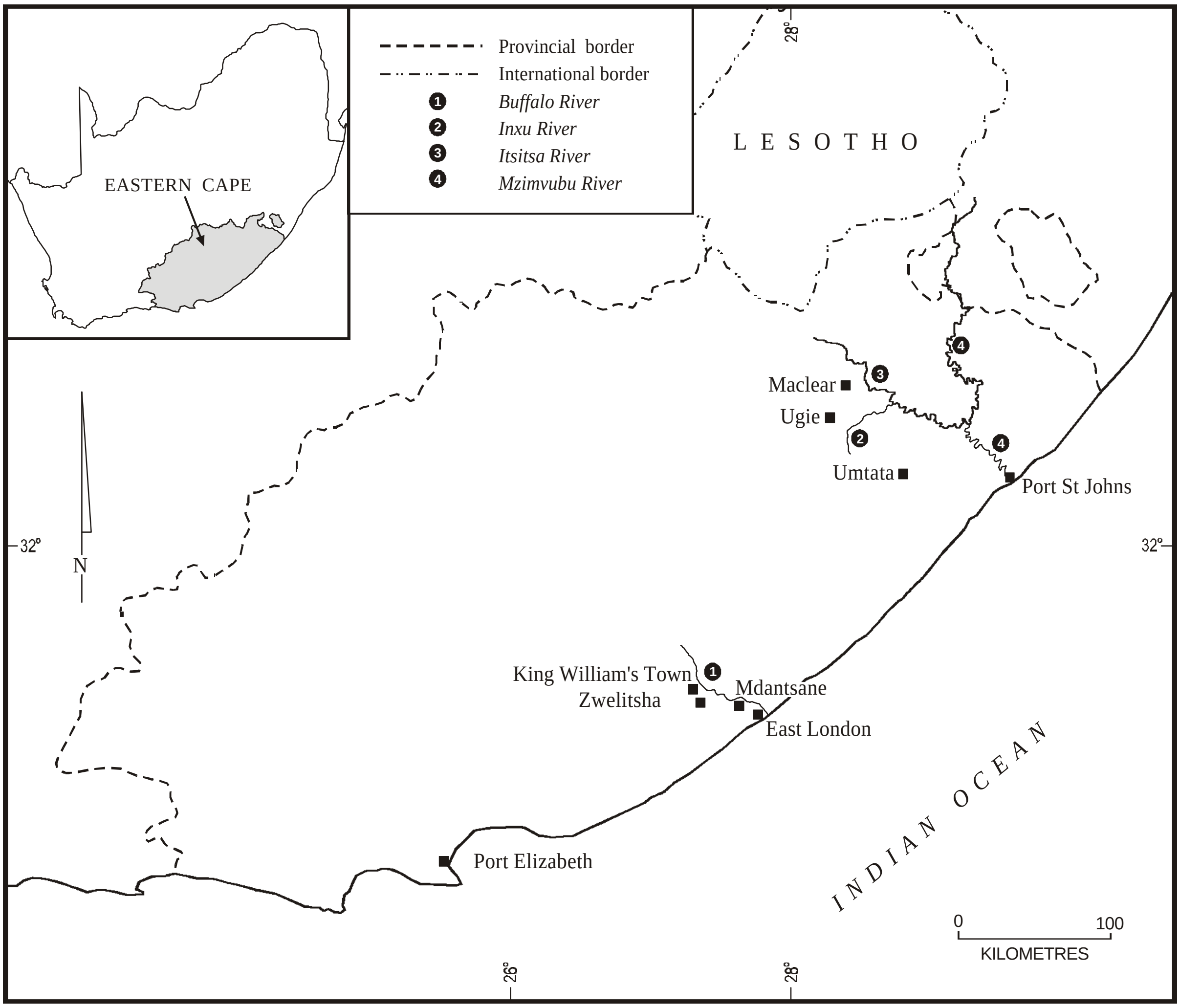

Fig 2.1 Location of the Buffalo and Inxu Rivers relative to each other within the Eastern Cape province.

Monitoring sites can be selected subjectively, e.g. below a particular point source to detect impact of the effluent to the ecosystem (Eekhout *et al.*, 1996). They can also be selected randomly for broad scale regional studies such as RHP programme assessments (Eekhout *et al.*, 1996). Reference sites are minimally disturbed sites that are representative of the natural condition of the river reach being monitored (Eekhout, *et al.*, 1996; Dallas, 2000). Selection of reference sites for a study can be conducted at either site-specific or regional level. Site-specific conditions are typically used in an upstream or downstream or both scenarios where a monitoring site is compared to a reference site (Dallas, 2000). Regional reference conditions are used due to absence of pristine and near pristine conditions. The site specific approach was used in selecting most sites for both rivers, and a regional approach was applied in selecting a reference site for the lower catchment on the Buffalo River.

A desktop study using 1: 50 000 topographical maps was conducted to select potential reference and monitoring sites for both the Inxu and Buffalo River catchments (Mangold, 2001). Potential sites were chosen from upstream to downstream on both rivers. Factors such as surrounding land-use activities and accessibility were considered when selecting potential sites. Sites previously sampled before on both rivers (available historical data) were also considered as potential sites. Proximity to DWAF gauging weirs (for water chemistry and biological data) was also considered in sites selected. Site selection surveys were conducted on both catchments to explore and evaluate whether the potential sites measured up to the criteria required for biomonitoring. The following criteria were used: accessibility, perennial flow and availability of suitable range of habitats. Twelve sites were selected on both rivers and photographic records were made during the site selection survey as well as subsequent biomonitoring surveys.

2.3.1 Buffalo River

The Buffalo River (Fig. 2.1) was divided into an upper and lower catchment. Accessible and least impacted sites that were above sources of impacts, identified as settlements, industries and agriculture, were selected as reference sites. Sites downstream of different land-uses in the catchment were selected as monitoring sites. Sites were also selected on selected Buffalo River tributaries (Mgqakwebe, Ngqokweni and Yellowwoods) to assess at the impacts of the inflow from these tributaries to the mainstem of the Buffalo River. Two reference sites were selected for the upper catchment. A potential reference site for the lower catchment was selected on the Nahoon River (this approach was considered acceptable as the Nahoon River is in the same ecoregion as the Buffalo River) due to unavailability of least impacted sites in the lower catchment. The assessment of the Buffalo River was done over three seasons (spring, winter and autumn). The Buffalo River catchment falls within a summer rainfall area and sampling during high flow is not recommended (Dickens and Graham, 2002). Detailed description of the sites selected is given in Chapter 3.

2.3.2 Inxu River

The Inxu River (Fig. 2.1) was also divided into an upper and lower catchment. Two sites (a reference and monitoring site) were selected on each of the three tributaries (Gatberg, Gqaqala and Umnga) of this river to assess the inflow from these tributaries and their possible influence on the Inxu River. One of the objectives of this research is to assess the present ecological status of the Inxu River around the sacred pools using biological and chemical information of water flowing through the sacred pools. A reference site above the sacred pools and a monitoring site below the sacred pools were selected. The sacred pools and their link with this research will be further discussed in Chapter 4. Apart from the reference and monitoring sites selected on each River and around the sacred pools, a reference site and monitoring sites were selected on the Inxu River mainstem in both the upper and lower catchment. Although three surveys were planned i.e. spring, winter and autumn for this catchment, only two surveys (spring and winter) were successfully undertaken. This was due to heavy rainfall in this catchment during autumn, which made sampling impossible. This was not expected, as the northern Eastern Cape is a summer rainfall area. A detailed description of the sites selected is provided in Chapter 4.

2.4 The River Health Programme (RHP) indices used

2.4.1 South African Scoring System version 5.0 (SASS5)

The South African Scoring System is a biotic index developed by Chutter (1998). It has been tested and refined over several years and the current version is SASS5 (Dickens and Graham, 2002). This technique is based on a British biotic index called Biological Monitoring Working Party (BMWP) scoring system (Chutter, 1994) and has been modified to suit South African fauna and conditions. SASS5 is a rapid biological assessment method developed to evaluate the impact of changes in water quality using aquatic macroinvertebrates as indicator organisms.

SASS is widely used as a bioassessment tool in South African because for the following reasons:

(i) It does not require sophisticated equipment, is rapid and relatively easy to apply.

(ii) This method is very cheap in comparison to chemical analysis of water samples, and analysis and interpretation of output data is simple.

(iii) Sampling is generally non-destructive (Davies and Day, 1998; Dickens and Graham, 2002), except where representative collections are required.

(iv) It provides some measure of the biological status of rivers (Chutter, 1998) in terms of water quality.

SASS is therefore a method for detection of water quality impairment and for monitoring long-term trends in water from an aquatic invertebrates perspective (Uys *et al*., 1996). Although SASS5 is user-friendly and cheap, it has some limitations. The method is dependent on sampling effort of the operator and the total SASS score is greatly affected by the number of biotopes sampled. SASS5 is not accurate for lentic conditions, rivers recently exposed to floods and should be used with caution in ephemeral rivers (Dickens and Graham, 2002). The resolution of SASS5 is at family level, therefore changes in species composition within the same family due to environmental changes cannot be detected (Roach *et al*., 2000). Although a SASS5 score acts as a warning ‘red flag’ for water quality deterioration, it cannot pinpoint the exact cause and quantity of a change. SASS5 does not cover all invertebrate taxa (some taxa that are known to be sensitive such as Cladocera are not included) (Barber-James H, Albany Museum, Grahamstown, pers.comm., 2003). SASS also cannot provide information about the degradation of habitat, so habitat assessment indices, e.g. Integrated Habitat Assessment System (IHAS) (McMillan, 1998), are routinely conducted with SASS5. Results from the IHAS assessment are used to aid interpretation of the final SASS scores.

The SASS protocol described by Chutter (1998), and refined by Dickens and Graham (2002), require collections of macroinvertebrates from a full range of biotopes available at each site. The biotopes sampled include vegetation both in and out of current (VG- aquatic and marginal), stones (S- both stones in current and out of current) and gravel, sand and mud (GSM). These biotopes and their sampling protocols are described in detail by Dickens and Graham (2002). The standardised sampling methods allow comparisons between studies and sites. Macroinvertebrate sampling is done using a standard SASS net (mesh size 1000 μm, and a frame of 30 cm × 30 cm).

Collected macroinvertebrates from each biotope are tipped into a SASS tray half filled with water and families are identified for not more than 15 minutes at the streamside. The invertebrates encountered from each biotope are recorded on a SASS5 sheet, with their abundance being noted on the sheet. Each taxon (usually a family) of invertebrates from South African rivers has been allocated a score ranging from 1 for those taxa that are most tolerant of pollutants, to 15 for those that are most sensitive to pollutants (Chutter, 1998). To complete the SASS exercise the scores for all the taxa are added together (total score). The ASPT (average score per taxon) is calculated by dividing the total score by the number of taxa. All three scores (SASS5, ASPT and number of families) are used in the interpretation of the status of the site or river being assessed. The default benchmark boundary values provided in the current water quality Ecological Water Requirements (Rivers) methods (Palmer *et al*., 2004) (Table 2.1) were used as a reference to which the average ASPT scores calculated per site were compared to provide an indication of the present water quality state based on SASS5. This data was used as part of suite of parameters to provide an overall present water quality state.

Table 2.1 Default benchmark category boundaries for SASS5 (Palmer *et al*., 2004).

CLASS BOUNDARY (RIVER CATEGORY)	**RANGE OF ASPT SCORES**
Natural	7
Good	6-6.9
Fair	5-5.9
Poor	<5

The sampling of macroinvertebrates from both rivers (Buffalo and Inxu) was done following the SASS5 protocol described by Dickens and Graham (2002). The SASS5 protocol requires one sample to be taken from each biotope. However, in this study replicate samples were taken from each biotope at selected sites to assess the representativeness of the single sample. Three replicates were taken at one reference site and one monitoring site for the upper catchment and lower catchment on both rivers. The replicate samples were taken to assess whether single samples taken at a particular biotope at a particular time are a true reflection of all the families present at that biotope at that particular time (for these catchments). Although SASS sampling is supposed to be non-destructive with organisms encountered during sampling being returned to the river this procedure was changed for the purposes of this study. Specimens from each biotope for each site were preserved in 80 % ethanol and taken to the laboratory for accurate identification and abundance counts after the SASS5 evaluation had been completed at the riverside. The replicate samples were also preserved.

2.4.2 Fish Assemblage Integrity Index (FAII)

This biological index uses attributes of fish to assess the biological integrity of a river (Kleynhans, 1999). It is based on fish communities expected to be present in biological (fish habitat) segments, which are sections of the river with relatively homogenous fish habitats (Kleynhans, 1999). Alien species (introduced indigenous and exotic species) are not included as metrics of FAII, but their presence is interpreted as one of the causal effects for the decline of the FAII score. This index takes into account three aspects of fish assemblages, namely the relative intolerance ratings of both expected and observed fish species, their frequency of occurrence and their health. The FAII score consists of the calculation of an expected value serving as a baseline reference, the calculation of the observed value and the comparison of these values providing a relative FAII score. The expected value is calculated using the following equation presented in Kleynhans (1999):

$$\text{FAII value (exp)} = \sum IT \times [(F+H)/2]$$

Where: exp = expected for a fish habitat segment;

IT = Intolerance rating for an individual species expected to be present in a fish habitat segment and in habitats that were sampled;

F= Expected frequency of occurrence rating for individual species expected to be present in a fish habitat segment and sites that were sampled;

H= Expected health rating for species expected to be present;

The observed situation is calculated using the equation:

$$\text{FAII value (obs)} = \sum IT \times [(F+H)/2]$$

The FAII scare is then calculated by FAII value (obs)/ FAII value (exp) x 100.

Kleynhans (1999) recommends the division of a river into fish habitat segments using topographical maps prior to sampling, with at least two sites sampled in each fish habitat segment. For this study, and as for most biomoniotoring surveys conducted across the country, sites on both catchments were selected from an RHP biomonitoring perspective (Mangold, 2001) and were not divided into fish segments. Each site therefore was regarded as a single fish habitat segment and the frequency of occurrence was not included in the calculation of the FAII score (Kleynhans CJ, Resource Quality Services, DWAF, pers.comm., 2003). The formula then used in the FAII calculation, as recommended by Kleynhans (1999), was therefore $\sum$ IT x H. FAII scores were calculated for each site for each season sampled on both rivers and compared to the FAII assessment classes adapted from Kleynhans (1999) (Table 2.2) to provide an indication of the present ecological state of a site based on FAII index.

Table 2.2 FAII assessment classes (Kleynhans 1999)

Class	**Description of generally expected condition**	**FAII score (Percent of total)**
A	Unmodified, or approximates natural conditions closely	90-100
B	Largely natural with few modifications. A change in community characteristics may have taken place but species richness and presence of intolerant species indicate little modification	80-89
C	Moderately modified. A lower than expected species richness and presence of most intolerant species. Some impairment of health may be evident at the lower end of this scale.	60-79
D	Largely modified. A clearly lower than expected species richness and general absence of intolerant and moderately intolerant species. Impairment of health may become very evident.	40-59
E	Seriously modified. A strikingly lower than expected species richness and general absence of intolerant and moderately intolerant species. Impairment of health may become very evident.	20-39
F	Critically modified. Extremely lowered species richness and an absence of intolerant and moderately intolerant species. Only tolerant species may be present with a complete loss of species at the lower end of the class. Impairment of health generally very evident.	0-19

Sampling was conducted using an electroshocker (DEKA 3000) and a seine net (5m length, 1.5 m depth, 0.5 cm mesh size). The electroshocker was mostly used in almost all available habitats, as the seine net was not suitable to sample substrate which was dominated by cobbles, boulders and bedrock. Two people were always involved in fish sampling. One person held the hand net and a bucket, to catch the shocked fish missed by the electroshocker net. Seining required two persons. All caught fish were identified on the streamside. Fish that could not be identified were preserved in 10% formalin and transported to the South African Institute for Aquatic Biodiversity (SAIAB) for identification by Mr Roger Bills (Fish Specialist, SAIAB, Grahamstown). Caught species were recorded on the FAII sheet and time spent in sampling each habitat was also recorded on the sheet.

The expected fish species for both rivers was established using historical data from SAIAB, Albany Museum and the *Freshwater Guide to Southern African Fishes* (Skelton, 2001) and in consultation with Mr Bills.

The FAII provides the indication of biological integrity of a river in terms of fish assemblages. However, in most cases it under estimates the biological integrity of a segment when not all the habitats could be sampled due to time, labour, and equipment limitations. This is important as the expected list of fish species is ascribed based on historical presence in all habitat types (Kleynhans, 1999). FAII is also considered to be suitable for the assessment of streams with naturally low fish species richness (Kleynhans, 1999). According to Kleynhans (1999), this index should not be regarded as the final answer to biological integrity.

2.4.3 Integrated Riparian Vegetation Index (IRVI)

IRVI is a biomonitoring index developed through the integration of some aspects of RIPARI-MAN (RIP) (Kotze *et al.*, 1997) and Riparian Vegetation Index (RVI) (Kemper, 2001), specifically for use during the Buffalo River monitoring surveys. The RIP index was developed for the purpose of management of riparian systems, chiefly near urban areas for improved social benefits and to increase awareness of environmental issues surrounding riparian zones (Kotze *et al.*, 1997). The RVI was developed as a biomonitoring tool to be used in the RHP for the qualitative assessment of the conservation status of riparian vegetation (Kemper, 2001). This index was developed in Mpumalanga and was adapted for other provinces. Both these indices have some flaws and criticisms and it was not certain whether they would be suitable to assess the riparian vegetation of the Eastern Cape rivers. An aim of Phase 1 of the Eastern Cape River Health Programme (EC RHP) was therefore to test these two indices and to provide refinement for their specific use in the Eastern Cape (RHP, 2004).

In April 2003 a field survey was conducted on selected sites (Site 1, 2 and 3) located in the upper catchment on the Buffalo River to test both the RIP and RVI indices. After this survey, a workshop was conducted to evaluate the results of the surveys and assess the use of the two indices. This evaluation was process attended by a number of vegetation specialists and resulted in the development of the Integrated Riparian Vegetation Index (IRVI).

The RVI formula

$$RVI = [(EVC) + (SI \times PCIRS) + (RIRS)]$$

Where: EVC = Extent of vegetation cover

SI = Structural intactness

PCIRS = Percentage cover of indigenous riparian species

RIRS = Recruitment of indigenous riparian species

has been retained in the new IRVI index. However, the recording of numbers of individuals of species size class has been excluded, as it is not required for the calculation of RVI. The RIP elements incorporated in this index are the physical characteristics that are not found in RVI (CES, 2004). The time spent in assessing a site using this new index is less than that spent using RVI and more than time spent using RIP. The index is still in its developmental stages and refinements will likely need to be done as it is applied on more Eastern Cape rivers.

In February 2004, the IRVI was tested on the sites where RVI and RIP indices were tested on the Buffalo River, under the leadership of Debbie Reynhardt (Down to Earth Consulting). Site 9 located in the lower catchment was also included in the survey to test the index at different vegetation types. The testing of this index on the Inxu River was not undertaken, as this river was not surveyed as part of the EC RHP. A critical evaluation of the method is not possible at this stage due to limited application, testing and data.

2.4.4 Water quality

Physical variables such as electrical conductivity (EC) using a Cyberscan 200 Conductivity Meter, dissolved oxygen (DO) using a WTW OXI 330i/SET, temperature using a thermometer, and pH using a Cyberscan 20 pH meter, were measured at each sampling on both rivers. This data was used to aid the interpretation of SASS scores.

Physico-chemical data from DWAF gauging weirs on both rivers was obtained from DWAF (Resource Quality Services) in Pretoria. The median concentrations were calculated for the nutrients and the 95th and 5th percentiles were calculated for other variables using STATISTICA according to the water quality methods listed in Palmer *et al*., in prep and were compared to default benchmark boundary values.

2.4.5 Integrated Habitat Assessment System (IHAS)

IHAS (McMillan, 1998) was specifically developed to be used in conjunction with SASS, and can be used to modify the SASS score based on habitat availability (McMillan 1998; Scherman and Muller, 2000). The scoring system is based on sampling habitat (i.e. availability of a range of habitats which could be utilized by instream invertebrates) and more general stream characteristics such as anthropogenic or natural impacts (McMillan, 1998). This habitat scoring system is based on 100 points (or percentage) and is divided into two sections reflecting the sampling habitat (50 points) and stream characteristics (50 points). The sampling habitat section is further broken down into three subsections: stones in current (20 points), vegetation (15 points) and other habitats (15 points) (McMillan, 1998). Very specific questions and answers score between 0 and 5. The higher the score the better the habitat for macroinvertebrates. The ideal condition is not based on the ultimate pristine stream, but rather on the representation of all habitats adequately and in reasonable conditions. The IHAS form must be completed for each site sampled during each sampling season on both rivers. This index is mostly subjective with the data collected dependent on the assessor's visual observation and level of expertise. IHAS data was to aid the interpretation of SASS data.

2.4.6 Geomorphological Index

Rowntree and Ziervogel (1999) developed a geomorphological index to be applied to South Africa's river systems to assess the geomorphological status. The development of this index is ongoing (Rowntree and Ziervogel, 1999) and was modified by Rowntree and Wadeson in 2000. The index is one of the biomonitoring tools used in

RHP. The assessment is done first as a desktop exercise and followed by a field exercise. The desktop exercise involves the collection of information relating to the location of a site, the geomorphological setting, and an audit of catchment condition. In the field the geomorphologist walks metres upstream and downstream along the river channel to obtain data to assess geormophological status of the stream channel (Rowntree and Wadeson, 2000). The field data sheet is then completed giving a rapid assessment of channel type and condition. Each data sheet is divided into 20 sections where the information on type of survey, desktop survey, condition of the channel, valley form, channel dimensions, riparian and channel vegetation, channel type, habitat and other geomorphological features are assessed and recorded.

The index is applied when biomonitoring sites are initially set up and should be repeated after major hydrological events such as major floods and should be applied every five years if the catchment conditions remained stable (Rowntree and Wadeson, 2000).

A geomorphological assessment was undertaken on the Buffalo and Inxu rivers as part of a Water Research Commission project under the leadership of Leanne du Preez, Geography Department at Rhodes University during the spring survey. The impact rating (between A-F) was assigned to each site after the effects of all the impacts noted at the site have been averaged. The definitions of the A-F values are presented in Table 2.3.

Table 2.3 Interpretation of the geomorphological impact class values (Rowntree, 2003)

CLASS	**GEOMORPHOLOGICAL CHANGE**	**ANTHROPOGENIC INDICATORS**
A: unmodified natural	no changes, erosion and deposition within reach are in balance	No human impacts identified in the catchment
B: largely natural	short term changes that can be reset within the frequency of the 'bankfull' flood.	Human impacts identified, but no clear evidence of channel response
C: moderately modified	slow trajectory of change, can be reset within five to ten 'bank full' events by restoring natural flow sediment regime and bank stability	Significant human impacts, changes to bed structure evident, localised bank erosion and channel widening, or deposition and narrowing. Changes reversible in the short term.
D: largely modified	well into the trajectory of change, may be difficult to restore natural conditions; river adjusting its form to the current sediment load and flow regime.	Major human impacts resulting in significant long term changes to channel geometry, pattern or reach type that may be irreversible.
E: seriously modified	engineering intervention required for rehabilitation	Channel structure largely engineered, but bed perimeter includes some natural materials that can be worked by fluvial processes (includes gabions, engineered bank stabilisation, channel straightening or re-alignment, bulldozing.
F: critically modified	major engineering intervention required for rehabilitation	Totally engineered channel, no natural material in the channel perimeter

The major advantage of the geomorphological index is that it does not require frequent application when the catchment conditions are stable, although annual assessments during low flows can be undertaken (Mangold, 2001). The limitation of this index as a rapid bioassessment tool is that it requires expertise in geomorphology and is time consuming. This index is mostly subjective with the data collected dependent on the assessor's visual observation skills and level of expertise.

2.5 Data Analysis

2.5.1 Biological data analysis

2.5.1.1 SASS5 and FAII

SASS5 and ASPT scores per biotope at each and total site scores were calculated for each site for each sampling season. These scores were also calculated for replicate samples taken within the same biotope. FAII scores were calculated for each site for each sampling season. These final scores were used in the assessment of the present ecological status of these rivers. From these scores however, it could not be established whether there were significant differences between: (i) replicates from the same biotope (ii) biotopes within a site and (iii) reference and a monitoring sites within the same reach, in terms of faunal composition. Multivariate statistical analyses were undertaken on macroinvertebrate data to answer these questions. Although the multivariate analyses were applied on fish data, no tangible conclusions could be drawn from the results due to minimal data records i.e. too few species or no fish species to perform an analysis. Hence the multivariate analyses performed on fish data are not presented.

The multivariate techniques used were chosen to analyse the invertebrate data due to the fact that they base their comparison of two or more samples on the extent to which these samples share particular families at comparable levels of abundance. Multivariate analysis was considered the most appropriate as the data were gathered from different sites within the same river and different replicate samples within the same biotope for both catchments. Multivariate methods used in this study consider each species or family to be a variable with its presence, absence and abundance being an attribute of a site or time, therefore allowing detection of spatial and temporal trends (Clarke and Warwick, 1994; 2001). Multivariate analysis for this study was undertaken using a computer Programme called PRIMER v5 (2001) (Plymouth Routines in Multivariate Ecological Research version 5) developed in Plymouth Marine Laboratory in the United Kingdom.

2.5.1.2 Data preparation

Macroinvertebrates were identified to family level and individual specimens of these families recorded from each biotope at each site were counted in the laboratory. This data was entered into a Microsoft Excel spreadsheet. The data was then imported from Excel to PRIMER.

2.5.1.3 Transformation and Similarity

Prior to analysis assessing similarity between data groups (e.g. replicates, biotopes, and site) were transformed using log (x+1) transformation. This transformation was chosen because it also takes into account rare species. Transformation is suggested prior to assessment of similarity (Clarke and Warwick, 2001) as similarities calculated on original abundance data values can be over dominated by a small number of highly abundant species or families thereby failing to reflect similarity of the overall community composition. The main purpose of data transformation in multivariate analyses is therefore to weight the contributions of different taxonomic groups (Clarke and Warwick, 2001). Transformation techniques range from no transformation (with only common taxa dominating the similarity matrix), square root transformation (with intermediate taxa dominating the transformation), fourth root transformation, log (x+1) (taking rarer species into account) and ultimately the presence/absence transformation (with rarer species dominating the similarity matrix).

Subsequent to transformation, Bray-Curtis similarity was performed to assess the following: (i) similarity between replicates taken within the same biotope at selected reference and monitoring sites, (ii) similarity between biotopes within the same site, (iii) similarity between seasons within the same site. Clarke and Warwick (1994; 2001) recommend Bray-Curtis similarity to assess similarity in ecological studies, as this similarity is not affected by absences and gives more weight to abundance in comparing species (Field *et al.*, 1982). The Bray Curtis measure leads to a triangular matrix, which is then be used in cluster and ordination analyses (Clarke and Warwick, 1994).

2.5.1.4 Cluster analysis

After computation of similarity, a cluster analysis was performed using the triangular matrix generated through Bray-Curtis similarity. A cluster analysis is usually performed, as it is difficult to detect similarity patterns within the Bray-Curtis triangular matrix, particularly in large data matrices. Cluster analysis forms a natural grouping of data based on similarity amongst separate samples (e.g. replicates, biotopes, seasons and sites); a level of 40 % similarity was selected for this study. Basically, samples within a group are more similar than samples from a different group. For this research project hierarchical agglomerative clustering, using complete linkages, was used to plot a dendrogram. A dendrogram is a graph plot with the x-axis representing the full set of samples and the y-axis defining the level of similarity at which samples are considered to have fused. The dendrogram was plotted as a graphic display to show similarity between samples.

2.5.1.5 Ordination

As dendrograms plotted from cluster analysis shows similarity in the form of a graph ordination shows similarity in the form of a map. Ordination is a map of samples, usually in two or three dimensions, in which the placement of samples reflects the similarity of their biological communities rather than representing their simple geographical location (Clarke and Warwick, 2001). For example, sites close together on a map have similar communities as opposed to sites further apart. There are several ordination methods available for use, e.g. Principal Component Analysis (PCA), Principal Co-ordinates Analysis (PCoA), Detrended Correspondence Analysis (DECORANA) and non-metric Multi-Dimensional Scaling (MDS) (Clarke and Warwick, 2001). The non-metric MDS was chosen over other ordination methods because of its ability to handle missing data, replicate data and data of non-uniform reliability (Field *et al*., 1982; Clarke and Warwick, 1994). MDS plots were drawn using Bray-Curtis similarities performed at different levels i.e. between replicates, sites and seasons to map their similarities. Ordination is considered to be useful in presenting a similarity relationship when stress levels of ordination are low. A stress value of < 0.05 gives excellent presentation with no prospect of misinterpretation. A stress value of < 0.1 provides good ordination and is unlikely to give misinterpretation. A stress value of < 0.2 gives a two dimensional picture although conclusions should not only be based on ordination, but should also be drawn from cluster analysis (Clarke and Warwick, 1994).

2.5.1.6 Analysis of similarity (ANOSIM)

The ANOSIM routine is analogous to the analysis of variance (ANOVA) and is designed for non-normally distributed data (Clarke and Warwick, 1994). This routine is part of the PRIMER programme and is based on the underlying cluster analysis and ordination results. A one-way ANOSIM allows a statistical test of the null hypothesis that there are no family or species differences between groups of samples sites (e.g. sites). A one-way ANOSIM was used to test whether there were any significant differences between biotopes within the same site and between sampling seasons within a site. A two way and nested layout allows the test of the null hypothesis that there are no differences between replicates. Two way nested ANOSIM was used to test whether there were any differences between replicate samples taken from the same biotope within a site.

Cluster analysis, ordination and ANOSIM for all replicated sites were undertaken at the site level (n=9) instead of per biotope (n=3) with replicate numbers being a factor. This was due to the fact that analyses could not be undertaken at biotope level due to insufficient sample size (few groups). By pooling the data for replicate sites, sufficient data was generated to perform the statistical analyses and to produce the dendrogram and ordination plots are presented for sites not biotopes. The statistical difference between replicates could therefore be tested in this way.

2.5.1.7 Similarity percentage (SIMPER)

SIMPER is a similarity percentage routine within PRIMER and is used to identify which families are responsible for similarities and dissimilarities between groups in a dendrogram. SIMPER was undertaken to assess which families were responsible for rejection or acceptance of the null hypothesis that there were no significant differences between replicates, biotopes, and seasons.

2.5.2 Physical data analysis

IHAS data was used in the interpretation of macroinvertebrate data for each site on both rivers. The data gathered using GI and IRVI was used as part of the present ecological state assessment of each site.

CHAPTER THREE

THE BUFFALO RIVER

3.1 Introduction

The Buffalo River catchment is mostly urban, industrialized and highly developed (O'Keeffe *et al.,* 1996). Although there are extensive data available for this river due to research that has previously been conducted, as well as DWAF flow and water quality data, the present ecological health status of this river has not been yet determined. This triggered the current research within the Buffalo River catchment. For the implementation of the RHP within the Eastern Cape, the Buffalo River catchment was selected as the first target catchment. The research on the Buffalo River was therefore conducted in conjunction with the Eastern Cape River Health team.

3.2 The Study Area

3.2.1 Topography

The Buffalo River rises in the Amatole Mountains (32^0 $02^{'}$ S, 27^0 $45^{'}$ E) between King William's Town and Stutterheim (Palmer and O'Keeffe, 1989). The river drains the catchment area of 1276 km^2 and flows for approximately 140 km (RHP, 2004), passing through the urban and industrial complex of King William's Town and Zwelitsha and entering the Indian Ocean at East London as a fourth-order stream. The river is regulated by four impoundments. The Maden and Rooikrantz dams are small dams situated in the relatively pristine forest at the foothills of the Amatole Mountains. Laing reservoir is a much larger dam situated in the middle reaches and the Bridle Drift Dam, which is the largest impoundment in the catchment, is situated in the lower reaches of the Buffalo River. Major tributaries of this river are the Mgqakwebe located in the upper reaches, and Ngqokweni and Yellowwoods rivers located in the middle reaches (RHP, 2004).

3.2.2 Climatology and rainfall

The region is characterized by a warm and temperate climate (Palmer and O'Keeffe, 1989). Summers (October to March) are warm with high rainfall almost twice that of winter rainfall (May to August). The overall mean annual precipitation over the whole catchment is about 738 mm. The Buffalo River can be divided into three climatic zones according to rainfall (O'Keeffe *et al*., 1996). Most of the rain, between 1500 mm and 2000 mm, falls on the mountainous-forested area in the northern part of the catchment. The middle reaches, from Rooikrantz Dam to Laing Dam, receive the lowest rainfall, i.e. between 500 and 650 mm. The lower reaches close to the Bridle Drift Dam and East London receives between 700 and 800 mm rainfall. Evaporation rates peaks in December and January at 160-170 mm per month, and are reduced from June to July (70 mm per month) (O'Keeffe *et al*., 1996).

3.2.3 Geology and soils

The catchment consists of mostly sedimentary rocks of the Lower Beaufort Series of the Karoo system, with few dolerite outcrops (Hart, 1982). The sandstone rocks weather to produce grey sandy loam soils with average clay content of 23 %, whilst the dolerite outcrops weathers to form red dolerite clay with clay content of 55 % and black clays with 38 % clay content. The red dolerite clays have high porosity and black clays have lower porosity (Stone, 1982). The geology and soils of the majority of the catchment, particularly in the middle and lower reaches, is derived from marine shales, which accounts for some of the high concentration of dissolved salts in the river (O'Keeffe *et al*., 1996).

3.2.4 Vegetation cover

In the past the vegetation of the Buffalo catchment consisted of five main types: small areas of False Macchia at the summit of the Amatole Mountains, Afromontane forest on the slopes of these mountains, False Thornveld dominated by grassland and *Acacia karoo* covering the middle reaches from below Rooikrantz to Bridle Drift dams, Valley Bushveld in the lower middle reaches and the Coastal Forest and Thornveld in the lower reaches (O'Keeffe *et al*., 1996; Zokufa *et al*., 2001). Currently downstream of the indigenous forest that is protected and managed by DWAF, most of the natural vegetation has been destroyed leaving only pockets of forests in the upper and lower parts of the catchment.

3.2.5 Land-use

The major part of the upper reaches is dominated by natural montane and commercial forestry (Fig. 3.1). This area generates 40 % of the runoff of the catchment (O'Keeffe *et.al*., 1996). Maden Dam is popular as a recreation area and the indigenous forest in this part of the catchment is a nature conservation zone. Rural settlements, agriculture and a trout fishery characterize the upper middle reaches. There are areas of intensive cultivation based on irrigation, although these have a minor impact on the overall land-use (O'Keeffe *et al*., 1996). However, increases in nitrate concentrate in the upper reaches can be attributable to fertilizers in the irrigation return flow and human sewage waste (O'Keeffe *et al*., 1996).

One of the greatest water quality problems in the middle reaches is the discharge of effluent from wastewater treatment works and industries around Zwelitsha, King William's Town, Mdantsane and East London (RHP, 2004). Urban runoff, squatter settlements, seepage from rubbish dumps, pollution from the Yellowwoods River and Bhisho Sewage Treatment Works all discharge into the reach above the Laing Dam situated in the upper region of the lower reaches. Large urban areas and settlements, including Needs Camp, Potsdam and Mdantsane, dominate the Bridle Drift Dam catchment. Two Sewage Treatment Works exist in this area and their combined effluents are discharged into the Buffalo River below Bridle Drift Dam.

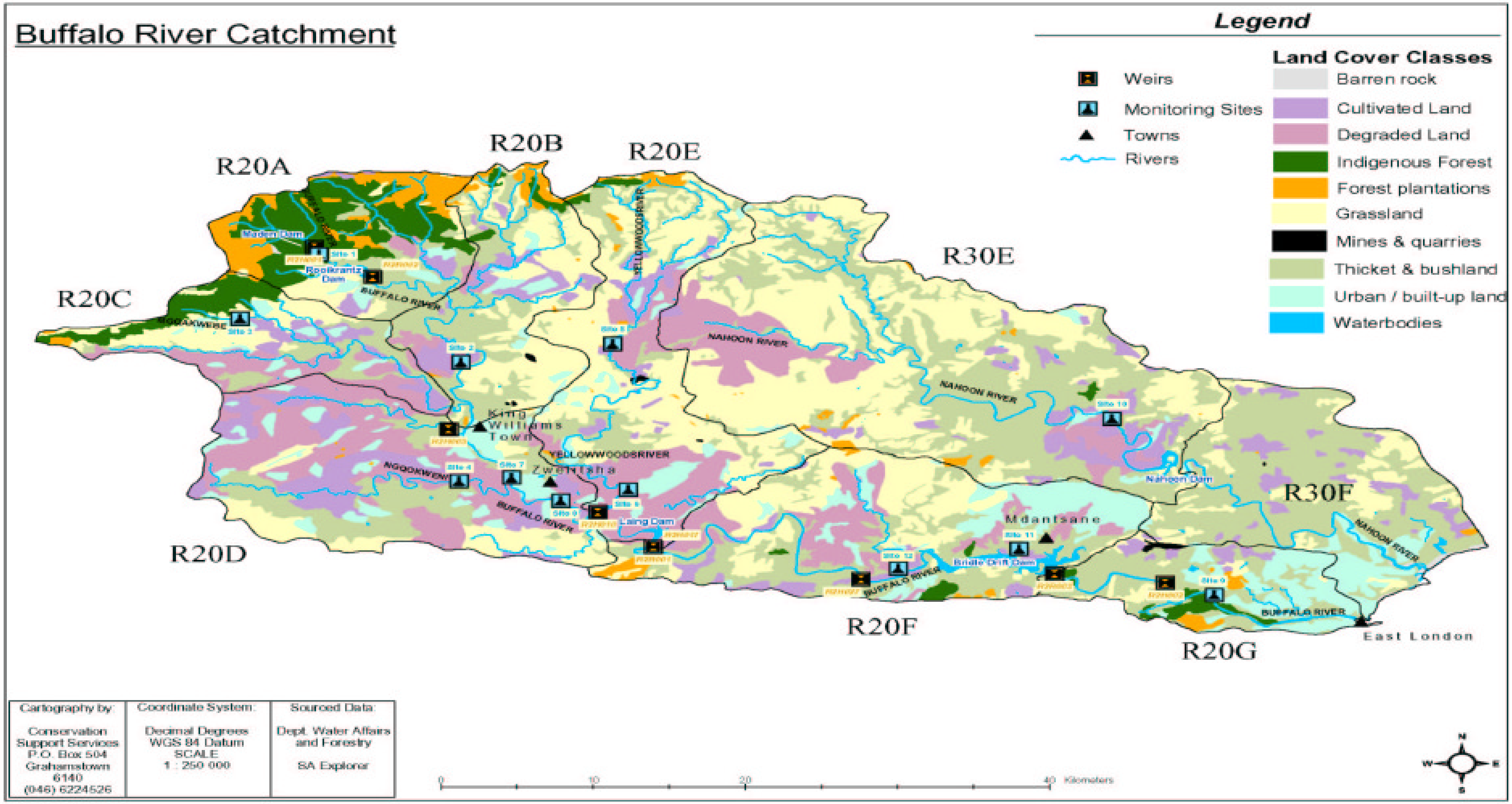

Fig. 3.1 A map of the Buffalo River, showing site locations and land-use activities within the catchment (adapted from RHP, 2004).

3.2.6 Impoundments

The water quality conditions and flow patterns of the Buffalo River are modified by four impoundments. The first impoundment is Maden Dam situated in the foothills of the Amatole Mountains. Maden Dam receives cool good quality water from a near pristine afro-montane closed canopy forest catchment (Palmer and O'Keeffe, 1989). The second impoundment, Rooikrantz Dam, is situated 5 km downstream of Maden Dam and receives overspill from Maden Dam. According to Selkirk and Hart (1984), Rooikrantz Dam also receives significant input via the Tyusha River, one of the Buffalo River tributaries. The third impoundment is Laing Dam, situated downstream of the urban industrial complex of King William's Town and Zwelitsha. Treated and untreated sewage, urban and agricultural runoff enters the river above this dam. According to O'Keeffe *et al*. (1996), Laing Dam acts as a significant sink for excess nutrients in the middle reaches of the Buffalo River, resulting in reduced nutrient concentrations reaching the downstream end of Bridle Drift Dam. Bridle Drift Dam is situated in the lower reaches and is the largest impoundment in the Buffalo River, supplying potable water to Mdantsane and East London.

3.3 The Study Sites

Twelve sampling sites (Fig. 3.1) were selected from the upper catchment to the lower catchment (Fig. 3.2 to Fig. 3.13) for an assessment of river health. The upper catchment was defined as the section from above Maden Dam to King William's Town and the area below King William's Town to below Bridle Drift Dam was defined as the lower catchment (Fig. 3.1). A summary table, Table 3.1, provides details about the selected sampling sites. Out of the twelve sites, four sites were selected on three major tributaries (Mgqakwebe, Ngqokweni and Yellowwoods) flowing into the Buffalo River (Table 3.1). Three reference sites were identified for the upper catchment and only one reference site could be identified for the lower catchment due to absence of least impacted sites in the lower catchment.

3.4 Materials and Methods

A detailed description of the materials and methods used for data collection and analysis is given in Chapter 2. Three sampling surveys were undertaken: October 2002 (spring survey), April (autumn survey) and August (winter survey) 2003. SASS sampling was replicated during the winter survey at Site 2 (monitoring site) and Site 3 (reference site) for the upper catchment and Site 10 (reference site) and Site 12 (monitoring site) for the lower catchment. SASS5 and FAII assessments were undertaken on all sampling sites during all three sampling seasons. A geomorphological assessment was undertaken at all sampling sites during the spring survey. A riparian vegetation assessment was undertaken on selected sites during spring and winter surveys. A water quality assessment was undertaken for sites with available water quality data. See Table 3.1 for a summary of sampling actvities.

SITE 1

Location: Buffalo River above Maden Dam	**Co-ordinates:** 32 ^{0}43' 21" S, 27 ^{0} 17' 46" E

This site was identified as a reference site for the upper catchment due to the fact that it is exposed to minimal land-use impacts and had a range of biotopes for macroinvertebrates and fish sampling. Exposure to human impacts is low, as access to this site is limited due to this site being located in an indigenous forest managed by DWAF. The average width of the river was between 12 and 14 metres. The banks were mostly vegetated by indigenous forest. Marginal vegetation was minimal. Fallen trees and logs provided extra habitat for macroinvertebrate colonization and fish refugia. Pebbles, cobbles and boulders characterized the substrate.

Fig. 3.2 Photograph of **Site 1** showing the diversity of biotopes and substrate.

SITE 2

Location: Buffalo River at Horseshoe Bend	**Co-ordinates:** 32 ^{0} 49' 21" S, 27 ^{0} 22' 49" E

This was selected as a monitoring site for the upper catchment as it is exposed to human impacts such as sand-mining, which have resulted in unstable riverbanks that are encroached with alien vegetation. This site is located below Maden and Rooikrantz dams (Fig. 3.1) and close to a school within a rural area. There is a low water bridge at this site that is used for human and cattle crossing. The average width was between 8 and 10 metres. The riffle substrate was predominantly cobbles. Marginal and fringing vegetation was approximately 2 metres. There is a small island that has been overgrown by reeds and grasses.

Fig. 3.3 Photograph of **Site 2** showing the diversity of biotopes and substrate.

SITE 3

Location: Mgqakwebe River near Pirie Mission Mission	**Co-ordinates:** 32 ^{0} 47' 17" S, 27 ^{0} 14' 59" E

This was selected as a reference site for the upper catchment. Although in a River, this site reflected good habitat for macroinvertebrates and fish and is similar to the upper catchment of the Buffalo River. Indigenous trees dominate the closed canopy. The major land-use is a cattle crossing area situated upstream of the site which has resulted in slight erosion of the riverbanks. This site is also adjacent to a rural residential area. The river channel was sinuous and meandering with an average width of approximately 4-5 metres. Cobbles and pebbles characterize the riffles. Pools were shallow. Marginal vegetation was very sparse and dominated by trees.

Fig. 3.4 Photograph of **Site 3** showing the diversity of biotopes and substrate.

SITE 4

Location: Ngqokweni River near Ginsberg Location	**Co-ordinates:** 32 ^{0} 54' 59" S, 27 ^{0} 22' 45" E

This was selected as a monitoring site for the upper catchment. It was selected as a monitoring site to assess the quality of water brought by this River into the Buffalo River. The substrate was mostly bedrock and boulders with riffles present in small patches. *Acacia* bushes that characterized the riverbanks were mostly chopped for firewood by surrounding communities. The average river width was between 10 and 15 metres. Pools were deep with cobble–boulder substrate upstream and downstream of the riffle area. Aquatic and marginal vegetation was present and mostly out of current.

Fig. 3.5 Photograph of **Site 4** showing the diversity of biotopes and substrate.

SITE 5

Location: Yellowwoods River at Lonsdale bridge	**Co-ordinates:** 32 ^{0} 48' 30 " S, 27 ^{0} 22' 45" E

This site was selected as a reference site on the Yellowwoods River to assess water quality upstream of the input from Bhisho area and as reference for the site located downstream of Bhisho so as to establish the quality of the inflow of the Yellowwoods River into the Buffalo River. Although this site receives transfer water from Wriggleswade Dam, this transfer is intermittent (Tshwete L, DWAF, Eastern Cape pers.comm., 2002). The average river width was between 8 and 10 metres with flowing area less than 5 metres in width. The substrate varied from cobbles to gravel and sand. Stones were mostly covered with sand and algae. Sedges and reeds dominated aquatic and marginal vegetation. Pools were shallow. Livestock impacts have eroded the riverbank, shifting the channel and forming gullies.

Fig. 3.6 Photograph of **Site 5** showing the diversity of biotopes and substrate.

SITE 6

Location: Yellowwoods River downstream of Bhisho	**Co-ordinates:** 32 ^{0} 55' 14 '' S, 27 ^{0} 29'18'' E

This was selected as a monitoring site on the Yellowwoods River. This site receives runoff from Bhisho and surrounding areas, including the Pakamisa settlement. Brick construction was evident along the riverbanks, and may have resulted in some erosion. The site is also located below Ndevana settlement. Macroinvertebrate habitat was limited as the substrate was mostly bedrock and boulders with small riffle areas. Marginal vegetation was minimal and found in pools. The average river width was between 8 and 10 metres. Small waterfalls were seen upstream.

Fig. 3.7 Photograph of **Site 6** showing the diversity of biotopes and substrate.

SITE 7

Location: Buffalo River below King William's Town	**Co-ordinates:** 32 ^{0} 54' 49'' S, 27 ^{0} 24' 37''E

This site was selected as a monitoring site for the lower catchment. This is due to the fact that this site is located below King William's Town and was also exposed to sources of impacts such as urban and industrial run- off, farmlands, cattle grazing area and a dumping site. Sand-mining and bulldozing were evident on the left bank. The river at this site is braided with suitable riffle areas for macroinvertebrates and pools for fish. The average river width was between 6 and 7 metres. Substrate was predominantly cobbles and boulders. Sedges, reeds and alien trees characterized the marginal vegetation.

Fig. 3.8 Photograph of **Site 7** showing the diversity of biotopes and substrate.

SITE 8

Location: Buffalo River below Zwelitsha	**Co-ordinates:** 32 ^{0} 55' 54'' S, 27 ^{0} 26' 22''E

This site is located above Zwelitsha Sewage Treatment Works and was selected as the monitoring site for the lower catchment as the site receives all the runoff from this urban settlement and the surrounding informal settlements. The water was green in colour due to algal growth, suggesting high levels of eutrophication during all the sampling surveys. The site is located immediately upstream of Laing Dam. The average river width was between 8 and 10 metres. The substrate varied from sand to cobbles and boulders. Marginal vegetation was predominatly sedges and grasses.

Fig. 3.9 Photograph of **Site 8** showing the diversity of biotopes and substrate.

SITE 9

Location: Buffalo River at Buffalo Pass	**Co-ordinates:** 33 ^{0} 00' 31'' S, 27 ^{0} 29' 32''E

This site was selected as the monitoring site for the lower catchment and is located within the Umtiza Nature Reserve. This site is the most downstream monitoring site immediately upstream of the harbour and the estuary and was selected to assess whether there was evidence of recovery downstream of the impacts from King William's Town, Zwelitsha and Mdantsane. The substrate was predominantly bedrock and boulders. The average river width was between 40 and 50 metres. Reeds, sedges and alien trees characterized marginal vegetation.

Fig. 3.10 Photograph of **Site 9** showing the diversity of biotopes and substrate.

SITE 10

Location: Nahoon River upstream of Nahoon Dam	**Co-ordinates:** 32 ^{0} 52’ 01’’ S, 27 ^{0} 45’ 55’’E

This site was selected as a potential reference site for the lower catchment due to the perceived absence of least impacted sites on the Buffalo River. The Nahoon River is in the same ecoregion as the Buffalo River and this site was similar to sites in the lower Buffalo River. This site had natural vegetation characterizing the riverbanks and there was good availability of a wide range of fish and macroinvertebrate habitats. The average river width was between 10 and 15 metres. Boulders and bedrock dominated the substrate although cobbles and gravel were present. The stream was braided, with backwaters present at the site.

Fig. 3.11 Photograph of **Site 10** showing diversity of biotope and substrate.

SITE 11

Location: Shangani River draining Mdantsane	**Co-ordinates:** 32 ^{0} 58’ 11’’ S, 27 ^{0} 42’ 37’’E

This site was selected as a monitoring site for the lower catchment to assess the potential impacts to the Buffalo River from the urban settlement of Mdantsane. Although there are several streams draining this area, this site was selected due to the fact that it is exposed to sources of anthropogenic impacts such as Potsdam Sewage Treament Works, which suffers intermittent, pump failure, with resultant overflows into this stream. In addition, urban runoff from Mdantsane settlement flows into this stream. The average river width was between 3 and 5 metres. The substrate was predominantly bedrock and boulders. A good riffle was found upstream of the bridge and sand road. Reeds and alien trees characterized marginal vegetation.

Fig. 3.12 Photograph of **Site 11** showing the diversity of biotops and substrate.

SITE 12

Location: KwaNxamkwane River draining Potsdam	**Co-ordinates:** 32 ^{0} 59' 06 '' S, 27 ^{0} 38' 19''E

This site was selected as a monitoring site for the lower catchment. KwaNxamkwane River is perceived to contribute significantly to the water quality of the Buffalo River as it receives run-off from the large settlement of Potsdam. Anthropogenic impacts such as cattle grazing and chopping of the indigenous riparian vegetation were the major landuse activities and have destabilised the riverbanks. The average river width was between 4 and 6 metres. There was a long riffle area characterized by cobbles that were mostly in current. Grass and sedges dominated marginal vegetation. The riparian zone was mostly indigenous.

Fig. 3.13 Photograph of **Site 12** showing diversity of biotope and substrate.

Table 3.1 Summary table indicating the location of each river site, whether a site was a reference or monitoring site, whether replicated sampling was done and which indices were used. SASS5= South African Scoring System version 5, FAII= Fish Assemblage Integrity Index, IRVI= Integrated Riparian Vegetation Index and WQA= Water Quality Assessment.

Site	**River**	**Catchment position**	**Reference or Monitoring site**	**Replicated (Yes or No)**	**Indices used**
1	Buffalo	Upper	Reference	No	SASS5, FAII, GI IRVI and WQA
2	Buffalo	Upper	Monitoring	Yes	SASS5, FAII, GI IRVI, and WQA
3	Mgqakwebe	Upper	Reference	Yes	SASS5, FAII, GI IRVI and WQA
4	Ngqokweni	Upper	Monitoring	No	SASS5, FAII and GI
5	Yellowwoods	Upper	Reference	No	SASS5, FAII and GI
6	Yellowwoods	Upper	Monitoring	No	SASS5, FAII, GI and WQA
7	Buffalo	Lower	Monitoring	No	SASS5, FAII and GI
8	Buffalo	Lower	Monitoring	No	SASS5, FAII, GI and WQA
9	Buffalo	Lower	Monitoring	No	SASS5, FAII, GI and IRVI
10	Nahoon	Lower	Reference	Yes	SASS5, FAII and GI
11	Shangani	Lower	Monitoring	No	SASS5, FAII and GI
12	KwaNxamkwane	Lower	Monitoring	Yes	SASS5, FAII, GI and WQA

3.5 Results

3.5.1 Macroinvertebrate assessment

3.5.1.1 Assessment of similarity or differences between replicates

Table 3.2 shows how the number of taxa, SASS5 and ASPT scores varied between replicates from the same biotope for each site where replicate sampling was undertaken. SASS5 scores were highly variable while the number of taxa and ASPT scores were less variable between replicates. ANOSIM performed to assess whether there were differences between replicates from the same biotope in terms of faunal composition revealed that there were no significant differences between replicates despite the differences observed in scores. The dendrogram plots based on hierarchical cluster analyses performed to group replicates from each site on the basis of their similarities are presented in Fig. 3.14, 3.16, 3.18 and 3.20 respectively. MDS ordination plots based on similarities between replicates from these sites are presented in Fig. 3.15, 3.17, 3.19 and 3.21 respectively.

Although replicate samples from sites 2 (Fig. 3.14), 10 (Fig. 3.18) and 12 (Fig. 3.20) grouped randomly (i.e. groups were characterized by replicates from different biotopes) replicates for stones (A), vegetation (B) and GSM (C) from Site 3 grouped according to their biotopes indicating high similarity between replicates taken from the same biotope (Fig. 3.16) at this site. This high similarity was also revealed by a significance level of 98% when the analysis of similarity between replicate numbers at this site was performed.

Table 3.2 SASS5, ASPT scores and number of taxa for each replicate sample taken from each biotope from all replicated sites on the Buffalo River.

Site	**Biotope**	**Replicate no.**	**SASS**	**No. of taxa**	**ASPT**
2	Stones	1	94	17	5.5
2	Stones	2	89	15	5.9
2	Stones	3	80	14	5.7
2	Vegetation	1	77	13	5.9
2	Vegetation	2	51	9	5.6
2	Vegetation	3	47	9	5.2
2	Gravel Sand and Mud	1	84	14	6.0
2	Gravel Sand and Mud	2	53	7	7.5
2	Gravel Sand and Mud	3	67	13	5.2
3	Stones	1	92	13	7.0
3	Stones	2	104	13	8.0
3	Stones	3	77	10	7.7
3	Vegetation	1	66	12	5.5
3	Vegetation	2	72	12	6.0
3	Vegetation	3	61	13	4.7
3	Gravel Sand and Mud	1	9	3	3.0
3	Gravel Sand and Mud	2	15	4	3.8
3	Gravel Sand and Mud	3	17	3	5.7
10	Stones	1	65	12	5.4
10	Stones	2	55	12	4.6
10	Stones	3	86	15	5.7
10	Vegetation	1	54	12	4.5
10	Vegetation	2	79	16	4.9
10	Vegetation	3	51	10	5.1
10	Gravel Sand and Mud	1	40	10	4.0
10	Gravel Sand and Mud	2	44	10	4.4
10	Gravel Sand and Mud	3	48	10	4.8

Site	**Biotope**	**Replicate no.**	**SASS**	**No. of taxa**	**ASPT**
12	Stones	1	54	12	4.5
12	Stones	2	53	12	4.4
12	Stones	3	51	10	5.1
12	Vegetation	1	61	14	4.4
12	Vegetation	2	59	12	4.9
12	Vegetation	3	81	16	5.1
12	Gravel Sand and Mud	1	50	11	4.5
12	Gravel Sand and Mud	2	49	10	4.9
12	Gravel Sand and Mud	3	51	10	5.1

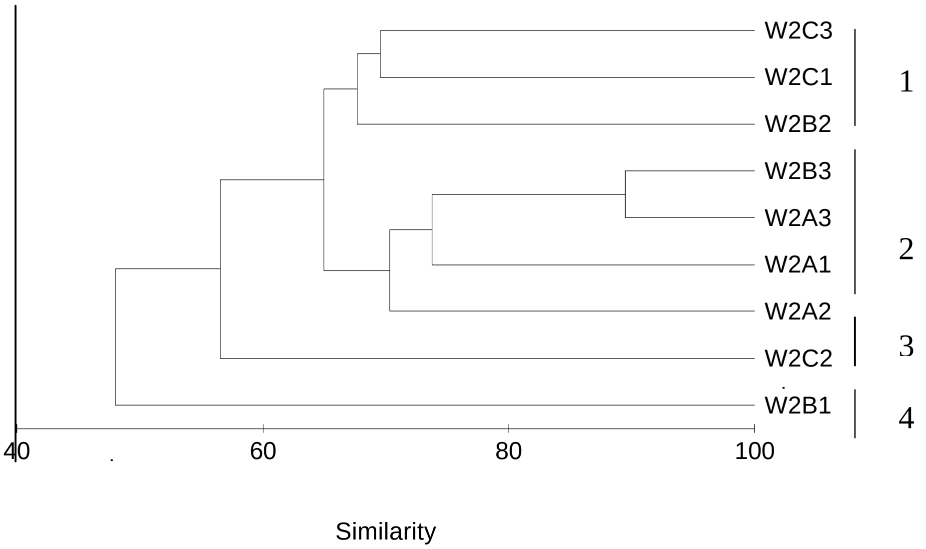

Fig. 3.14 Dendrogram for the hierarchical cluster analysis of macroinvertebrate replicate samples taken from Site 2 (monitoring site) on the Buffalo River in winter. Abbreviation format: season (W=winter), site no. (2 = site 2), biotope (A= stones B = vegetation C= GSM), replicate no. (1= replicate 1, 2 = replicate 2, 3 = replicate3).

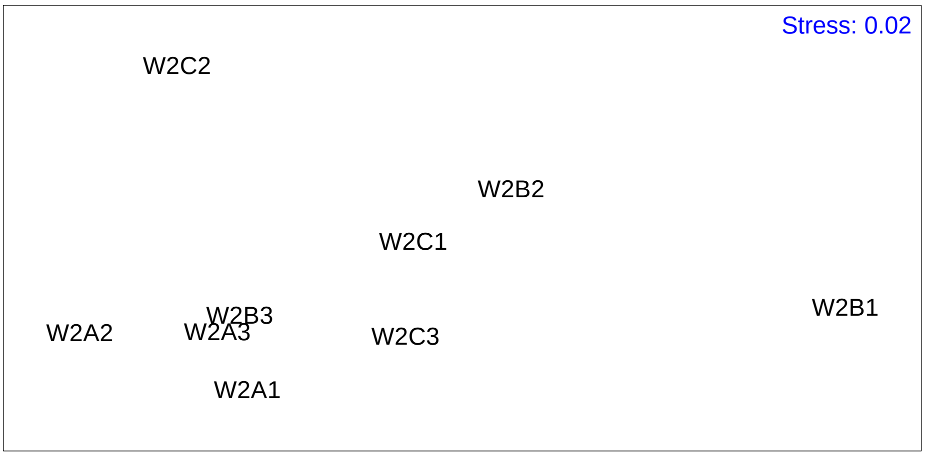

Fig. 3.15 MDS ordination plot based on Bray Curtis similarities of macroinvertebrate replicate samples taken from Site 2 on the Buffalo River in winter. Abbreviation format: season (W=winter), site no. (2 = site 2), biotope (A stones B= vegetation C= GSM), replicate no. (1= replicate 1, 2 =replicate 2, 3 = replicate 3). A stress value of 0.02 indicates an excellent ordination.

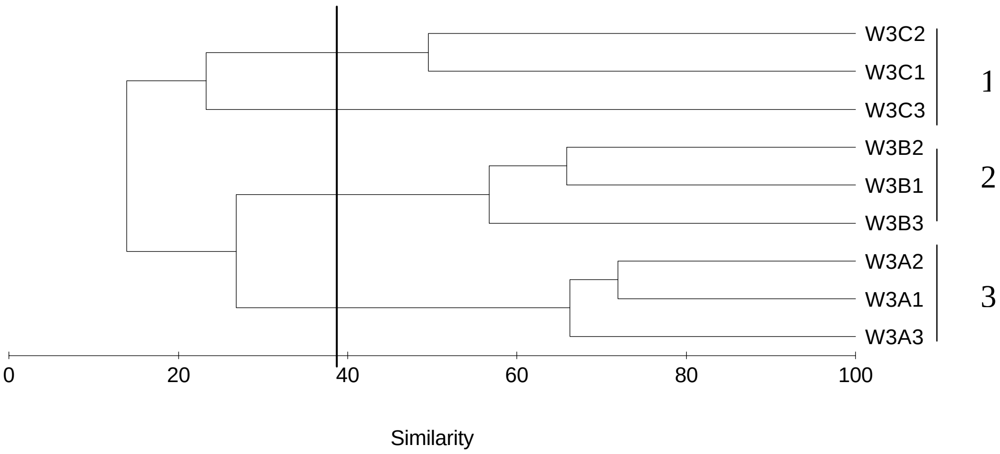

Fig. 3.16 Dendrogram for the hierachical cluster analysis of macroinvertebrate replicate samples taken from Site 3 (reference site) on the Buffalo River in winter. Abbreviation format: season (W= winter), site no. (2 = site 2), biotope (A= stones B= vegetation C= GSM), replicate no. (1= replicate 1, 2 = replicate 2, 3 = replicate 3).

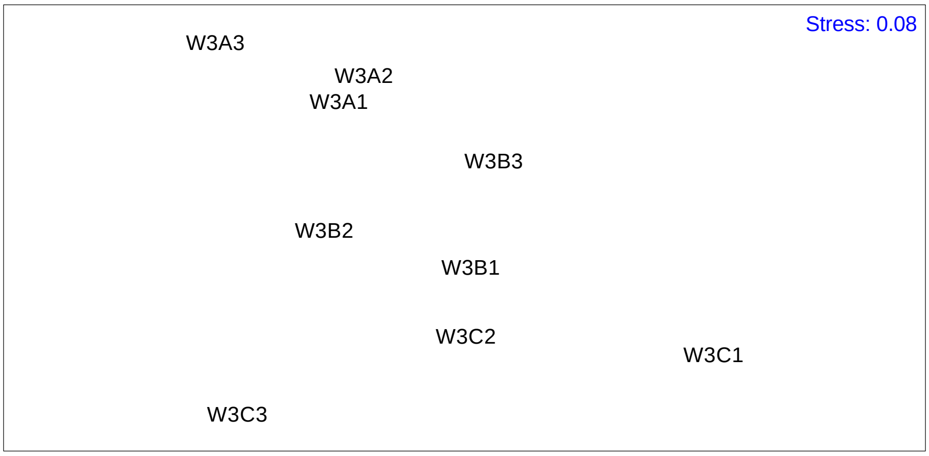

Fig. 3.17 MDS ordination plot based on Bray Curtis similarities of macroinvertebrate replicate samples taken from site 3 on the Buffalo River in winter. Abbreviation format: season (W= winter), site no. (2 = site 2), biotope (A= stones B= vegetation C= GSM), replicate no. (1= replicate 1, 2 = replicate 2, 3 = replicate 3). A stress value of 0.08 indicates good ordination.

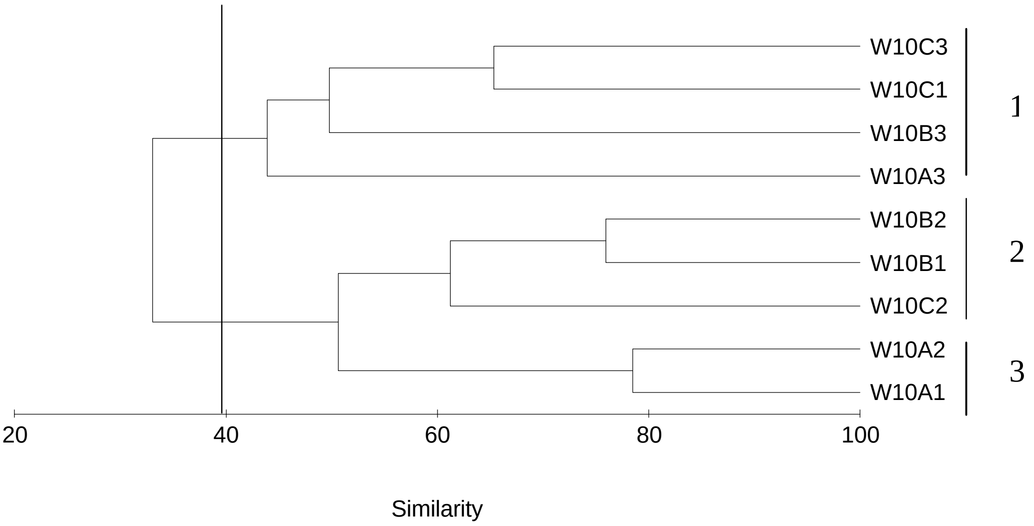

Fig. 3.18 Dendrogram for the hierachical cluster analysis of macroinvertebrate replicate samples taken from Site 10 (reference site) on the Buffalo River in winter. Abbreviation format: season (W= winter), site no. (2 = site 2), biotope (A= stones, B= vegetation C= GSM), replicate no. (1= replicate 1, 2 = replicate 2, 3 = replicate 3).

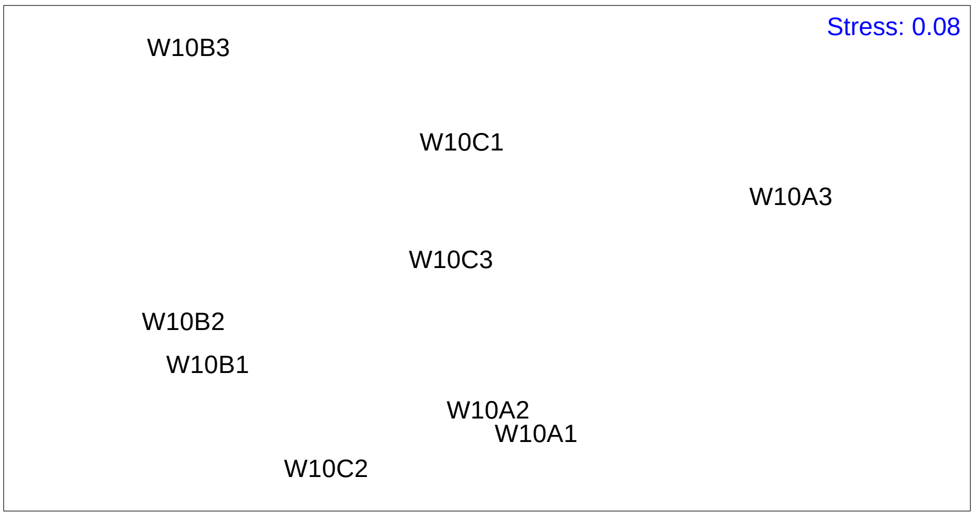

Fig. 3.19 MDS ordination plot based on Bray Curtis similarities of macroinvertebrate replicate samples taken from Site 10 on the Buffalo River in winter. Abbreviation format: season (W= winter), site no. (2 = site 2), biotope (A= stones, B= vegetation C= GSM), replicate no. (1= replicate 1, 2 = replicate 2, 3 = replicate 3). A stress value of 0.08 indicates good ordination.

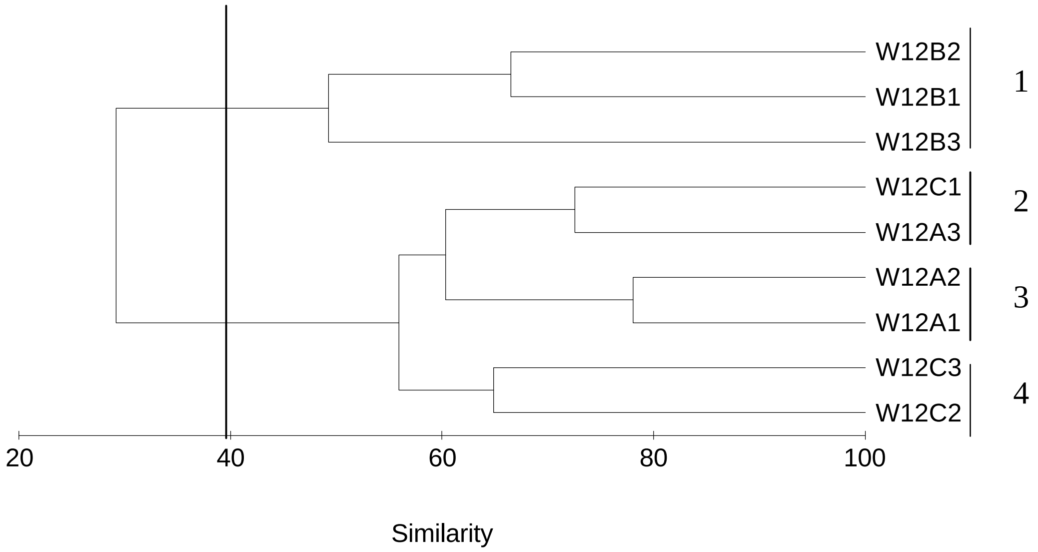

Fig. 3.20 Dendrogram for hierachical cluster analysis of macroinvertebrate replicate samples taken from Site 12 (monitoring site) on the Buffalo River in winter. Abbreviation format: season (W= winter), site no. (12= site 12), biotope (A= stones B= vegetation C= GSM), replicate no (1 = replicate 1, 2 = replicate 2, 3 = replicate 3).

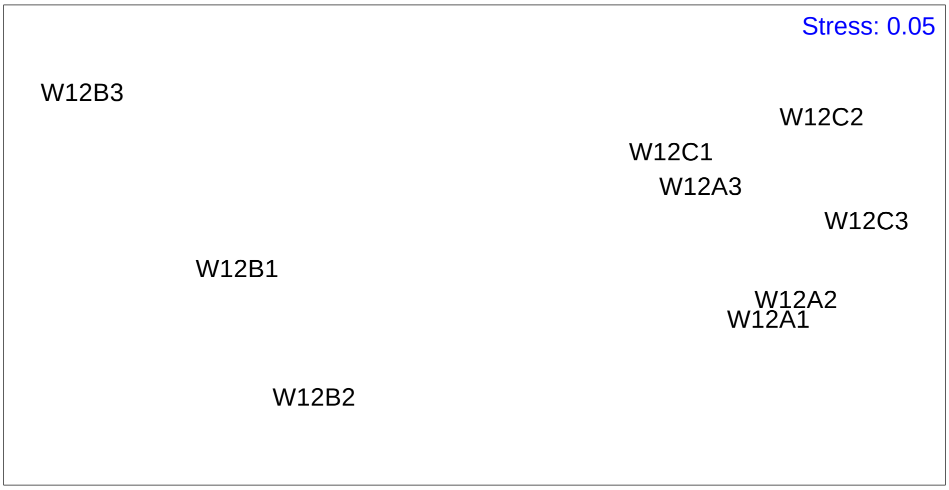

Fig. 3.19 MDS ordination plot based Bray Curtis similarities of macroinvertebrate replicate samples taken from Site 12 on the Buffalo River in winter. Abbreviation format: season (W= winter), site no. (12= site 12), biotope (A= stones B= vegetation C= GSM), replicate no. (1 = replicate 1, 2 = replicate 2, 3 = replicate 3). A stress value of 0.05 indicates good ordination.

3.5.1.2 Assessment of similarities and differences between sampling sites

Introduction

SASS5, ASPT, IHAS scores and number of taxa per site and per sampling season on the Buffalo River are presented in Table 3.3. Table 3.3 also shows scores per individual biotope. ANOSIM analyses (Table 3.4) were undertaken for each site to assess whether there were significant differences in terms of faunal composition between biotopes and seasons sampled. SIMPER analysis was undertaken to indicate family contribution to dissimilarity between biotopes and seasons. ANOSIM results are shown in Table 3.4, with Tables 3.5 and 3.6 relating to water quality. Measurements of the water quality variables (electrical conductivity, pH, temperature and dissolved oxygen) recorded during the three biomonitoring surveys are presented in Table 3.6. A trend that was observed is that electrical conductivity and pH were higher in winter compared to other seasons at most sites (Table 3.5). Dissolved oxygen was lower in autumn at most sites. As expected due to cold conditions in winter the temperature was lower (Table 3.5). A summary of taxa recorded at each sampling site for each survey is presented in Appendix 2. An overall ASPT score was calculated for each site and used as part of the present overall water quality state assessment (Palmer *et al*., 2004) documented in Table 3.6. These overall ASPT scores were compared to the default benchmark boundary values (Table 2.1) and used to derive a category for a biotic response variable, which could then be incorporated in an overall site water quality assessment.

Site 1

Although this site was selected as a reference site for the upper catchment due to its location within the catchment and its surrounding land-use activities (Fig. 3.1), reduced macroinvertebrate (Table 3.3) scores when compared to the monitoring sites in the upper catchment (e.g. Site 2) suggested that this site was not an appropriate reference site. Results indicated reduced habitat quality (reflected by low IHAS scores in most seasons), which may have contributed to reduced macroinvertebrate diversity (also reflected by low SASS scores and total number of taxa recorded) and dominance of tolerant organisms scores (Appendix 2), reflected by SASS and ASPT (Table 3.3). Absence of some biotopes during some sampling seasons (Table 3.3) also contributed to reduced habitat quality and availability and possibly contributed to reduced macroinvertebrate scores. A closed canopy that reduces the amount of light penetration and reduces autochthonous activities characterizes this site. This might reduce food availability and result in reduced macroinvertebrate diversity (Davies and Day, 1998). ANOSIM analysis performed to assess whether there were significant differences between sampling seasons at this site in terms of macroinvertebrate faunal composition, revealed that there were no significant differences (Table 3.4). However, this analysis indicated significant differences in terms of macroinvertebrate fauna between biotopes. SIMPER analysis revealed that abundance of families such as athericids, simulids, and baetids in the stone biotopes and caenids, gomphids, oligochaetes and naucorids in the gravel, sand and mud biotope resulted in significant differences observed between these two biotopes. Significant differences between vegetation and gravel, sand and mud biotope can be ascribed to baetids, gerrids and culicids recorded in the vegetation biotope and not in the gravel, sand and mud biotope while caenids, gomphids, ceratopogonids and naucorids were recorded in the gravel, sand and mud biotope and not encountered in the vegetation biotope. The water quality category for this site based on the overall ASPT score was Fair (Table 3.6).

Site 2

The macroinvertebrate scores recorded at this site were higher than Site 1 scores although this site is located below two dams and exposed to anthropogenic impacts (Fig 3.1). This site however had lower macroinvertebrate and habitat scores compared to Site 3, which selected as a reference site for the upper catchment. Absence of some biotopes may have attributed to low IHAS scores. SASS scores were high indicating high macroinvertebrate diversity although the ASPT scores were reduced (Table 3.3) Reduced ASPT scores can be attributed to dominance of tolerant and low-scoring families such as oligochaetes, baetids, caenids, simulids, chironomids and others although sensitive families such as athericids were recorded (Appendix 2). ANOSIM indicated no significant differences between macroinvertebrate biotopes in terms of macroinvertebrate faunal composition at this site (Table 3.4). This pattern is contrary to what was observed on most sites on the Buffalo River. Significant differences however, existed between sampling seasons. Abundance of baetids, corbiculids, and heptagenids encountered during the autumn survey as compared to abundance of chironomids, simulids, caenids and ceratopogonids during the spring survey contributed to dissimilarity between these two seasons (Appendix 2). Corbiculids, leptophlebids, heptagenids and baetids abundance in autumn and abundance of caenids, culicids, and chironomids in winter contributed to the dissimilarity between these two seasons. The water quality category for this site based on overall ASPT score index was Fair (Table 3.6).

Site 3

This site, located on the Mgqakwebe River as the second reference site for the upper catchment, was considered an appropriate reference site for the upper catchment of the Buffalo River as it had the highest macroinvertebrate and habitat scores during all sampling seasons (Table 3.3). Both macroinvertebrate and habitat scores were highest in spring but were reduced in autumn and winter (Table 3.3). This can possibly be attributed to the observed reduced flow, which might have affected habitat quality and availability. ANOSIM analysis based on macroinvertebrate faunal composition indicated no significant differences between seasons at this site. However, this analysis showed that significant differences existed between macroinvertebrate biotopes (Table 3.4). SIMPER revealed that differences between the stone biotope and vegetation biotope could be attributed to the abundance of epheropteran families such as heptagenids, tricorythids, baetids and leptophlebids within the stone biotope as opposed to abundance of coenagrionids, gerrids and leptocerids within the vegetation biotope. Differences between vegetation and gravel, sand and mud biotopes can be attributed to the presence of families such as coenagrionids, leptocerids and culicids which were not encountered within the gravel, sand and mud biotope and dominance of families such as leptophlebids and caenids within the gravel, sand and mud biotope. The water quality category for this site based on overall ASPT score was Good (Table 3.6).

Site 4

This site located on the Ngqokweni River was selected as a monitoring site for the upper catchment to assess the possible contribution from this River to the water quality of the Buffalo River. This site had lower macroinvertebrate and habitat scores compared to Site 3, which was a reference sites for the upper catchment. Highest scores were recorded in spring and were reduced in autumn and slightly improved in winter (Table 3.3). Reduced habitat quality as reflected by IHAS scores in autumn might have contributed lower SASS5 and ASPT scores recorded at this site during this season. Improvement in habitat quality for the winter survey might have contributed to the slight improvent in both SASS and ASPT scores. Despite the differences observed in scores between the sampled seasons, ANOSIM analysis indicated that there were no significant differences between the three seasons in terms of faunal composition (Table 3.4). ANOSIM indicated that significant differences existed between the vegetation and the gravel, sand and mud biotopes. According to SIMPER these differences can be ascribed to families such as ceratopogonids, hydrometrids, baetids, oligochaetes and caenids which dominated the gravel, sand and mud biotope as opposed to psychodids and sphaerids that dominated the vegetation biotope. The water quality category for this site based on overall ASPT score was Fair (Table 3.6).

Site 5

This site was selected as a reference site on the Yellowwoods River to assess the status of Yellowwoods River upstream of Bhisho settlement. Sand-mining was evident along the riverbanks, which may have resulted in the sedimentation observed at this site during all sampling seasons. Although the SASS scores (Table 3.3) for all the seasons were higher than the monitoring site (Site 6), indicating macroinvertebrate diversity, the ASPT scores were reduced due dominance of relatively tolerant families such as oligochaetes, leeches, baetids, caenids, naucorids, simulids, chironomids and others (Appendix 2) during all the sampling seasons. These tolerant families are indicative of water quality deterioration, which may be attributed to sedimentation and other surrounding land-use activities such as cattle grazing and sand mining. Reduction in habitat quality, shown by IHAS scores, in winter can be attributed to the observed reduced flow. ANOSIM (Table 3.4) analysis based on macroinvertebrate faunal composition and abundance indicated that there were no significant differences between the sampling seasons at this site. However, this analysis indicated that significant differences existed between the stone and the vegetation biotopes. SIMPER showed that these differences could be ascribed to families such as baetids, hydropyschids, simulids, and turbellaria that dominated the stone biotope as opposed to families such as coenagrionids and dystiscids that dominated the vegetation biotope. The water quality category for this site based on overall ASPT score was Fair (Table 3.6).

Site 6

This site was selected as a monitoring site on the Yellowwoods River. Reduced habitat and macroinvertebrates scores (Table 3.3) compared to Site 5 suggest downstream deterioration in both water and habitat quality. There is a large settlement immediately upstream of this site, with runoff from this settlement probably impacting on the site. This site also receives urban runoff from the Bhisho settlement area. ANOSIM analysis indicated no significant differences between the sampling seasons at this site in terms of faunal composition and abundance. Significant faunal differences existed between the stone and the vegetation biotopes (Table 3.4). SIMPER analysis indicated that the differences between these biotopes at this site could be ascribed to families such as simulids, baetids, caenids, and leptophlebids, which recorded at high abundances within the stone biotopes as opposed to notonectids, dystiscids and coenagrionids which dominated the vegetation biotope. The water quality category for this site based on overall ASPT score was Good (Table 3.6).

Site 7

This site, located in the Buffalo River below King William's Town and its Sewage Treatment Works had the lowest scores of all the sites in all sampling seasons (Table 3.3). Low macroinvertebrate diversity, green coloured water with a pungent odour and dominance of low-scoring and tolerant dipterans (Appendix 2) were signs of possible water quality impairment. Although the IHAS scores were fairly similar between the sampling seasons, SASS scores and ASPT scores were highly reduced in winter and this can be attributable to water quality impairment exacerbated by the observed reduced flow. ANOSIM analysis indicated that faunal differences existed between seasons sampled at this site (Table 3.4). This analysis further revealed that winter was significantly different to both spring and autumn. SIMPER analysis indicated that significant differences between the spring and winter surveys could be ascribed to families such as hydropsychids, simulids, turbellaria, baetids, elmids and tricorythids which were recorded during the spring survey but not encountered during the winter survey (Appendix 2). Significant differences between the autumn and the winter survey can be ascribed to abundances of families such as leeches, chironomids, potamonautids, naucorids, and oligochaetes with the autumn survey having higher abundances than winter survey. ANOSIM analysis indicated that there were no significant differences between biotopes sampled at this site in terms of faunal composition, in contrast to apparent trend at most sites on the Buffalo River. The water quality category for this site based on overall ASPT scores was Poor (Table 3.6).

Site 8

This site located on the Buffalo River and below Zwelitsha Township followed the same trend as Site 7 with reduced SASS and ASPT scores (Table 3.3) compared to most sites in the lower catchment. This site was dominated by tolerant and low-scoring taxa such as oligochaetes, leeches, chironomids and culicids (Appendix 2). Macroinvertebrate scores and habitat scores were similar in spring and autumn and were lower in winter (Table 3.3). This suggested that observed reduced flow in winter possibly reduced both habitat and water quality. ANOSIM analysis indicated that faunal differences existed between the spring and winter surveys (Table 3.4). SIMPER analysis indicated that these differences could be ascribed to families such as baetids, simulids, hydropsychids, leeches, ancylids and caenids, which were recorded in high abundances during the spring survey but not during the winter survey. ANOSIM indicated that there were no significant differences between biotopes sampled at this site in terms of faunal composition. The water quality category for this site based on average ASPT score was Poor (Table 3.6).

Site 9

This site is the furthest downstream site on the Buffalo River and is located within a nature conservation area, which has reduced anthropogenic impacts. The habitat and macroinvertebrate scores recorded at this site were the highest (Table 3.3) of all lower catchment sites and this suggested possible downstream recovery within the Buffalo River as this site is located below sources of impacts such dams and settlements. IHAS and SASS scores were similar during the spring and winter surveys, although the ASPT scores were the highest recorded in this study in winter indicating increased diversity of sensitive families (Appendix 2). Reduced flow observed at this site during the autumn survey possibly resulted in unavailability of GSM biotope for sampling and this may have contributed to the reduction of both macroinvertebrate and habitat scores during this season (Table 3.3). ANOSIM analysis indicated that there were significant differences in faunal composition between the seasons and biotopes sampled at this site (Table 3.4). SIMPER analysis indicated that the significant differences between spring and autumn surveys were due to familes such as baetids, hydropyschids and caenids which were more abundant in spring than in autumn and abundances of families such as vellids, coenagrionids, libellulids and heptagenids which were higher in autumn than in spring. Differences between the spring and the winter surveys could be ascribed to the abundance of families such as baetids, simulids, heptagenids and leptophlebids during the winter survey as opposed to the abundance of families such as caenids, oligochaetes, hydropschids and turbellaria during the spring survey. Differences between the autumn and winter survey can ascribed to presence of families such as libelluids, ancylids, hydropyschids and vellids during the autumn survey; these families were not encountered during the winter survey. Differences between the stone and the vegetation biotopes could be ascribed to families such as leptophlebiids, psephenids, heptagenids and hydropychids that dominated the stones biotope and families such leptocerids, vellids, ceratopogonids and naucorids that dominated the vegetation biotope. Differences between the stone biotope and the GSM biotope can be ascribed to families such as baetids, leptophlebids, psephenids and heptagenids that dominated the stones biotope as opposed to families such as caenids, naucorids and ceratopogonids that dominated the GSM biotope. Differences between the vegetation and GSM biotopes can be ascribed to families such as leptocerids, vellids and coenagrionids that dominated the vegetation biotope as opposed to caenids, naucorids and chironomids that dominated the GSM biotope. The water quality category for this site based on overall ASPT was Good (Table 3.6).

Site 10

Although this site located on the Nahoon River, was selected as a possible reference site for the lower catchment, it was not considered an appropriate reference site. This site had lower macroinvertebrate and IHAS scores than monitoring sites of which it was expected to act as a reference (Table 3.3). This suggested that although this site is located above sources of impacts like dams there was an impact affecting the instream biotopes, resulting in reduced macroinvertebrate diversity and sensitivity. Absence of the vegetation biotope due to the observed low flow necessary to inundate the vegetation, contributed to very low IHAS scores recorded during the autumn survey.

ANOSIM analysis (Table 3.4) indicated that there were significant differences between sampling seasons with winter and spring being the seasons significantly different in terms of fauna. SIMPER analysis indicated that the observed differences between these seasons could be ascribed to families such as baetids, chironomids and simulids that dominated the spring survey, as opposed to families such as vellids, caenids, libellulids and naucorids that dominated the winter survey (Appendix 2). There were no significant differences between biotopes in terms of faunal composition. The water quality category for this site based on overall ASPT score was Poor (Table 3.6).

Site 11

This site located at Shangani River, which drains the area around the Mdantsane settlement, had low macroinvertebrate scores (Table 3.3) and was dominated by low-scoring and tolerant families such as oligochaetes, potamonautids, chironomids and others (Appendix 2). This suggested water quality impairment as the IHAS scores were above 60 and similar to other sites on the Buffalo River. Possible water quality impairment can be attributable to the fact that this site is located below sources of anthropogenic impacts such as Potsdam Sewage Treatment Works, which suffers intermittent pump failure and also receives urban runoff from Mdantsane settlement. ANOSIM analysis indicated that there were no significant differences in terms of faunal composition and abundance between both sampling seasons and biotopes sampled at this site (Table 3.4). The water quality category for this site based on overall ASPT score index was Poor (Table 3.6).

Site 12

This site, located in the KwaNxamkwane River draining runoff from the Potsdam settlement, had reduced macroinvertebrate and habitat scores (Table 3.3.). Although the scores recorded at this site were slightly higher than Site 11, it was evident that input from these tributaries contributes to the perceived water quality deterioration on the lower catchment of the Buffalo River. Lower IHAS scores recorded during the autumn survey can be attributable to the observed low flow, which resulted in unavailability of the GSM biotope. ANOSIM analysis (Table 3.4) indicated that there were no significant differences between sampling seasons in terms of faunal composition and abundance. Significant differences existed between stone and vegetation biotopes and between vegetation and GSM biotopes. SIMPER analysis indicated that differences between the stones and vegetation biotope could be ascribed to families such caenids, baetids, and simulids dominating the stones biotope as opposed to families such as coenagrionids, naucorids and ceratopogonids which dominated the vegetation biotope. Differences between vegetation and GSM could be ascribed to families such as ceratopogonids, coenagrionids, and vellids that dominated the vegetation biotope as opposed to families such as caenids and naucorids that dominated the GSM biotope. The water quality category for this site based on overall ASPT score was Poor (Table 3.6).

Table 3.3 Total site, as well as individual biotope, SASS scores, number of taxa and ASPT scores recorded at each site for each sampling season conducted on the Buffalo River. IHAS scores for each site during each sampling season have been included. Blank cells indicate that a biotope was not available for sampling. (S=stones, VG= vegetation and GSM= gravel, sand and mud).

	Spring			**Autumn**			**Winter**		
	SASS	**No. of taxa**	**ASPT**	**SASS**	**No. of taxa**	**ASPT**	**SASS**	**No. of taxa**	**ASPT**
Site 1									
S	31	6	5.2	24	4	6	42	6	7
VG				19	5	3.8			
GSM				40	8	5	38	9	4.2
Total	31	6	5.2	73	15	4.9	71	13	5.5
IHAS	45			70			52		
Site 2									
S	120	19	6.3	94	14	6.7	98	17	5.8
VG	95	16	5.9	44	7	6.3	77	13	5.9
GSM							84	14	6
Total	154	27	5.7	101	16	6.3	146	26	5.6
IHAS	61			50			62		
Site 3									
S	158	22	7.2	134	19	7.1	92	13	7.1
VG	77	12	6.4	84	17	4.9	66	12	5.5
GSM	74	10	7.4	86	14	6.1	9	3	3
Total	188	26	7.2	181	30	6.0	119	19	6.3
IHAS	80			71			72		

	Spring			Autumn			Winter		
	SASS	**No. of taxa**	**ASPT**	**SASS**	**No. of taxa**	**ASPT**	**SASS**	**No. of taxa**	**ASPT**
Site 4									
S	63	10	6.3	54	10	5.4	71	12	5.9
VG	61	11	5.6	28	7	4	50	10	5
GSM	53	11	4.8	34	9	3.8	28	7	4
Total	120	20	6	77	17	4.5	97	18	5.4
IHAS	68			64			70		
Site 5									
S	71	13	5.5	81	16	5.1	74	15	4.9
VG	73	13	5.6	80	18	4.4	79	15	5.3
GSM	53	10	5.3	44	10	4.4	34	8	4.3
Total	116	21	5.5	127	26	4.9	114	23	5
IHAS	73			75			56		
Site 6									
S	59	12	4.9	74	13	5.7	55	10	5.5
VG	60	11	5.5	41	9	4.6	36	8	4.5
GSM	23	6	3.8	39	9	4.3	44	10	4.4
Total	99	18	5.5	97	18	5.4	84	18	4.7
IHAS	58			63			67		
Site 7									
Site 7									
S	64	14	4.6	13	5	2.6	15	5	3
VG	43	9	4.8	36	9	4	13	5	2.6
GSM	28	8	3.5	33	9	3.7	10	3	3.3
Total	78	17	4.6	47	12	3.9	16	6	2.7
IHAS	67			62			60		

	Spring			Autumn			Winter		
	SASS	**No. of taxa**	**ASPT**	**SASS**	**No. of taxa**	**ASPT**	**SASS**	**No. of taxa**	**ASPT**
Site 8									
S	64	13	4.9	49	11	4.5	26	7	3.7
VG	44	10	4.4	35	9	3.9	29	8	3.6
GSM	38	10	3.8						
Total	69	16	4.4	57	13	4.4	46	12	3.8
IHAS	63			64			51		
Site 9									
S	104	17	6.1	86	15	5.7	61	8	76
VG	51	11	4.6	62	12	5.2	101	16	6.3
GSM	61	10	6.1				45	7	6.4
Total	140	24	5.8	120	21	5.7	141	20	7.1
IHAS	70			58			71		
Site 10									
S	38	9	4.2	52	11	4.7	65	12	5.4
VG	34	8	4.3				54	12	4.5
GSM	20	5	4	37	9	4.1	39	10	3.9
Total	52	13	4	66	14	4.7	90	19	4.7
IHAS	77			43			60		
Site 11									
S	38	9	4.2	33	9	3.7	15	5	3
VG	22	7	3.1	47	10	4.7	12	4	3
GSM	20	6	3.3	41	8	5.1	7	3	2.3
Total	64	14	4.6	83	17	4.9	15	5	3
IHAS	62			60			65		

	Spring			**Autumn**			**Winter**		
	SASS	**No. of taxa**	**ASPT**	**SASS**	**No. of taxa**	**ASPT**	**SASS**	**No. of taxa**	**ASPT**
Site 12									
S	54	12	4.5	71	13	5.5	54	12	4.5
VG	82	16	5.1	31	7	4.4	61	14	4.6
GSM	21	5	4.2				50	11	4.6
Total	110	24	4.6	94	18	5.2	100	21	4.8
IHAS	68			52			62		

Table 3.4 Analysis of similarities between biotopes and seasons for each site sampled on the Buffalo River. (S = stones, VG = vegetation and GSM = gravel, sand and mud. Sp = spring, Au = autumn and Wi = winter).

Site 1					
Biotopes			**Seasons**		
Significant difference	**Biotopes different**	**Average dissimilarity**	**Significant difference**	**Seasons different**	**Average dissimilarity**
Yes	S and GSM	82.90	No		
	VG and GSM	85.78			
Site 2					
No			Yes	Sp and Au	72.56
				Au and Wi	61.36
Site 3					
Yes	S and VG	64.14	No		
	VG and GSM	66.28			
Site 4					
Yes	VG and GSM	62.65	No		
Site 5					
Yes	S and VG	62.44	No		
Site 6					
Yes	S and VG	67.95	No		
Site 7					
No			Yes	Sp and Wi	79.32
				Au and Wi	69.28
Site 8					
No			Yes	Sp and Wi	61.91
Site 9					
Yes	S and VG	71.11	Yes	Sp and Au	67.61
	S and GSM	70.26		Sp and Wi	68.96
	VG and GSM	65.90		Au and Wi	72.22

Site 10					
Biotopes			**Seasons**		
Significant difference	**Biotopes different**	**Average dissimilarity**	**Significant difference**	**Seasons different**	**Average dissimilarity**
No			Yes	Sp and Wi	64.7
Site 11					
No			No		
Site 12					
Yes	S and VG	64.21	No		
	VG and GSM	67.29			

Table 3.5 Measurements of water quality variables recorded during three biomonitoring surveys conducted on the Buffalo River and its tributaries. S: Spring, A: Autumn, W: Winter EC: electrical conductivity (mS/m), Temp: temperature (^{o}C), DO: dissolved oxygen (mg/l) unless indicated as % saturation. Blank cells indicate that no measurements were recorded

Site	**1**			**2**			**3**			**4**			**5**			**6**		
Season	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**
EC	8.1	7.5	12	52	40	107	93	98	161	116	143	153	103	59	57		167	234
pH	6.5	7.5	7.5	7.5	7.5	8.3	7.9	7.9	7.6	8.1	8.4	8.9	7.8	7.5	8.7		8.2	8.4
Temp	15	18	10	22	22	16	16	19	11	28	23	14	21	18	17		20	19
DO	115%	8.02	11.1	105%	6.5	6.9		7.5	7.4	114%	8.5	10.8	122%	6.04	12.9		7.5	11.2
Site	**7**			**8**			**9**			**10**			**11**			**12**		
Season	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**
EC	81	58	79	89	68	79	46	53	48	135	173	291	93	82	68	124	91	62
pH	7.4	7.4	7.8	8.3	7.4	8.3	7.1	7.9	8.3	7.4	8.1	8.2	6.7	7.8	7.5	7.5	8.7	9.4
Temp	22	22	16	23	22	15	19	24	16	22	26	17	20	22	13	22	28	13
DO	68%	4.7	8.2	114%	4.3	11	90%	7.6	10.3	86%	8.7	10	86%	6.7	7.5	104%	9.8	7.8

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Table 3.6 Seasonal and overall water quality categories based on the Reserve water quality present state assessment method (Palmer *et al*., 2004)

Site	**Ref/Mon**	**Spring**	**Autumn**	**Winter**	**Site average**
1	Reference site	Fair	Poor	Fair	Fair
2	Monitoring site	Fair	Good	Fair	Fair
3	Reference site	Natural	Good	Good	Good
4	Monitoring site	Good	Poor	Fair	Fair
5	Monitoring site	Fair	Poor	Fair	Fair
6	Monitoring site	Fair	Fair	Poor	Fair
7	Monitoring site	Poor	Poor	Poor	Poor
8	Monitoring site	Poor	Poor	Poor	Poor
9	Monitoring site	Fair	Fair	Natural	Good
10	Reference site	Poor	Poor	Poor	Poor
11	Monitoring site	Poor	Poor	Poor	Poor
12	Monitoring site	Poor	Poor	Fair	Poor

3.5.2 Fish assessment

Introduction

Out of 22 fish species previously recorded the Buffalo River and its tributaries (Terry S, SAIAB, Grahamstown, pers.comm., 2003) 17 fish species were caught during this study (Table 3.7). Eleven of these fish species are indigenous and six were alien species. One species, *Barbus pallidus,* had not previously been recorded in the Buffalo River (Terry S, SAIAB, Grahamstown, pers.comm., 2003), and was added to the species list for this river. There were only two sites (5 and 6) where fish species were caught during each of the surveys. Low fish diversity, and therefore low FAII scores at all sites, can be attributed to both alien species that tend to outcompete indigenous species for food and space (Skelton, 2001). The low efficiency of the sampling methods cannot be excluded in contributing to low scores.

Site 1

During this study there were three fish species caught at this site located on the Buffalo River (Appendix 3). The species caught were the indigenous species *Barbus anoplus*, and two alien species *Labeo umbratus* and *Tilapia sparrmanii*. The alien species are not included in the FAII calculation and this accounted for the low FAII scores at this site. No fish species were recorded at this site during the spring survey even though both the seine net and the electroshocker were used to sample pools and fast flowing and rocky habitats respectively. Overall, this site fell within a critically modified class based of FAII assessment classes (Table 3.8).

Site 2

This site located on the Buffalo River followed the same trend as Site 1 with no fish species recorded during the spring survey with only three species encountered at this site during this study. The fish species caught were indigenous species *Barbus anoplus* and two alien species *Labeo umbratus and Tilapia sparrmanii* (Appendix 3). This site is located below two dams, which may have contributed to low diversity of fish species as dams restrict the mobility of fish species. Dominance by alien species and the possible inefficiency of the sampling gear cannot be excluded as contributing factors to low diversity and the resultant FAII scores (Table 3.8) observed at this site. Overall, this site fell within a critically modified class based of FAII assessment classes (Table 3.8).

Site 3

Four fish species were recorded at this site located on the Mgqakwebe River during this study. The species were two indigenous species *Barbus anoplus and Barbus trevelyani* and two alien species *Labeo umbratus* and *Tilapia sparrmanii* (Appendix 3). *Barbus trevelyani* is one of the critically endangered fish species in Southern Africa (Skelton, 2001). No fish species were caught during the winter survey and this can possibly be attributed less adequate conditions for fish survival due to the observed reduced flow. Overall this site was the only site of all upper catchment sites that fell within a largely modified class based of FAII assessment classes (Table 3.8).

Site 4

There were three fish species recorded at this site located in the Ngqokweni River (Appendix 3). The species were the indigenous species *Barbus anoplus*, and two alien species *Labeo umbratus* and *Tilapia sparrmanii,* which are not included in the FAII calculation and this resulted in low FAII scores for this site (Table 3.8). Fish species were recorded at this site during all three sampling seasons. The substrate at this site was mostly boulder and bedrock and and the seine net could not be used as it was snagged by rocks. This may have have contributed to few species encountered. Overall this site fell within a critically modified class based of FAII assessment classes (Table 3.8).

Site 5

The indigenous *Barbus anoplus* was the only species recorded at this site located on the Yellowwoods River during all sampling seasons (Appendix 3). No alien species were recorded at this site even though both the seine net and the electroshocker were used to sample this site. Overall this site fell within a critically modified class based of FAII assessment classes (Table 3.8).

Site 6

Two fish species were caught at this most downstream site on the Yellowwods River. The species were the indigenous species *Barbus anoplus* and the alien species *Clarias gariepinus* (Appendix 3). The *Clarias gariepinus* had not been previously recorded on the Buffalo River and was added to the species list. This species tends to outcompete indigenous species and is tolerant of poor water quality (Skelton, 2001). Overall this site fell within a critically modified class based of FAII assessment classes (Table 3.8).

Site 7

In autumn three alien species were recorded at this site located on the Buffalo River below King William's Town, i.e. *Clarias gariepinus, Cyprinus carpio* and *Labeo umbratus* (Appendix 3). There were no fish species recorded at this site during both the spring and the winter surveys. This can possibly be attributed to water quality impairment at this site, inefficiency of the sampling equipment and presence of alien species. The water at this site was (greenish in colour with a pungent odour) indicating nutrient enrichment and water pollution. The FAII score for this site for all the sampling seasons was zero (Table 3.8) due to no fish species recorded during winter and spring surveys and due to the fact that only alien species were recorded during the autumn survey. Overall this site fell within a critically modified class based of FAII assessment classes (Table 3.8).

Site 8

Four species were recorded at this site located on the Buffalo River below Zwelitsha. In spring three fish species were recorded: the indigenous species *Barbus pallidus*, and the two alien species *Cyprinus carpio* and *Labeo umbratus (*Appendix 3). The indigenous species *Barbus pallidus* had not been previously recorded on the Buffalo River and was added to the species list for the Buffalo River. Two fish species were encountered during the autumn survey, i.e. *Tilapia sparrmanii* and *Labeo umbratus*. Both species are alien species and were therefore not included in the FAII score calculation. No fish species were recorded in winter at this site resulting in FAII scores of zero for this season. Overall this site fell within a critically modified class based of FAII assessment classes (Table 3.8).

Site 9

This site located on the Buffalo River at Buffalo Pass was the most diverse site in terms of fish species, with seven indigenous fish recorded at this site and one alien species (Appendix 3). In autumn six fish species were caught at this site. Five of these species were the indigenous species *Anguilla mossambica*, *Awaous aeneofuscus*, *Glossogobius callidus, Mugil cephalus and Oreochromis mossambicus* with *Tilapia sparrmanii* being the only alien species caught. In spring three indigenous species *Glossogobius callidus, Monodactylus falciformis* and *Myxus capensis* were the only species caught. There were no fish species caught during the winter survey. Fish diversity observed at this site can be attributable to a wide range fish of habitats available such fast flowing runs to deep pools. Overall this site fell within a seriously modified class based of FAII assessment classes (Table 3.8).

Site 10

During this study six species were caught at this site located on the Nahoon River (Appendix 3). In spring one indigenous species *Glossogobius callidus* and two alien species *Cyprinus carpio* and *Labeo umbratus* were caught. In autumn one indigenous species *Anguilla mossambica* and two alien species *Lepomis macrochirus* and *Micropterus punctulatus* were caught. There were no fish species caught during the winter survey. Overall this site fell within a critically modified class based of FAII assessment classes (Table 3.8).

Site 11

No fish species were recorded during the spring and winter surveys at this site located on the Shangani River. In autumn, three indigenous species *Barbus anoplus*, *Orechromis mossambicus* and *Glossogobius callidus* were recorded coexisting with the alien species *Tilapia sparrmanii*. Overall this site fell within a critically modified class based of FAII assessment classes (Table 3.8).

Site 12

During this study four species were caught at this site located on the KwaNxamkwane River (Appendix 3). In spring one indigenous species, *Glossogobius callidus* and the alien species *Tilapia sparrmanii*, were caught. In autumn three indigenous species *Barbus anoplus, Glossogobius callidus, Orechromis mossambicus* and one alien species *Tilapia sparrmanii* were caught. No fish species were recorded at this site during the winter survey. Overall this site fell within a critically modified class based of FAII assessment classes (Table 3.8).

Table 3.7 Fish species previously recorded in the Buffalo River and its tributaries versus fish species recorded during the 2002 -2003 sampling surveys.

Fish species	**Indigenous (I) or Alien (A)**	**Previously recorded in the Buffalo River**	**Recorded during 2002-2003 survey**
Anguilla marmorata	I	Yes	Yes
Anguilla mossambica	I	Yes	Yes
Awaous aeneofuscus	I	Yes	Yes
Barbus anoplus	I	Yes	Yes
Barbus pallidus	I	No	Yes
Barbus trevelyani	I	Yes	Yes
Clarias gariepinus	A	Yes	Yes
Cyprinus carpio	A	Yes	Yes
Gilchristella aesturaria	I	Yes	No
Glossogobius callidus	I	Yes	Yes
Labeo umbratus	A	Yes	Yes
Lepomis macrochirus	A	Yes	Yes
Micropterus dolomieu	A	Yes	No
Micropterus punctulatus	A	Yes	Yes
Micropterus salmoides	A	Yes	Yes
Monodactylus falciformis	I	Yes	Yes
Mugil cephalus	I	Yes	Yes
Myxus capensis	I	Yes	Yes
Oncorhynchus mykiss	A	Yes	No
Oreochromis mossambicus	I	Yes	Yes
Tilapia sparrmanii	A	Yes	Yes
Salmo trutta	A	Yes	No
Sandelia bainsii	I	Yes	No

Table 3.8 Seasonal FAII scores per site, class categories and overall site assessment based on FAII scores.

Site	Seasons	FAII Scores	Seasonal Categories	Overall Category	Corresponding RHP Class
1	SPRING	0	F	F	POOR
	AUTUMN	19	F		
	WINTER	12	F		
2	SPRING	0	F	F	POOR
	AUTUMN	32	E		
	WINTER	12	F		
3	SPRING	67	C	E	POOR
	AUTUMN	76	C		
	WINTER	0	F		
4	SPRING	19	F	F	POOR
	AUTUMN	12	F		
	WINTER	12	F		
5	SPRING	19	F	F	POOR
	AUTUMN	12	F		
	WINTER	15	F		
6	SPRING	19	F	F	POOR
	AUTUMN	19	F		
	WINTER	0	F		
7	SPRING	0	F	F	POOR
	AUTUMN	0	F		
	WINTER	0	F		

Site	Seasons	FAII Scores	Seasonal Categories	Overall Category	Corresponding RHP Class
8	SPRING	30	E	F	POOR
	AUTUMN	0	F		
	WINTER	0	F		
9	SPRING	34	E	C	GOOD
	AUTUMN	50	D		
	WINTER	10	F		
10	SPRING	11	F	F	POOR
	AUTUMN	11	F		
	WINTER	0	F		
11	SPRING	0	F	F	POOR
	AUTUMN	29	E		
	WINTER	0	F		
12	SPRING	11	F	F	POOR
	AUTUMN	21	E		
	WINTER	12	F		

3.5.3 Geomorphological assessment

Introduction

A description of the impact classess on which sites were categorised is detailed in Table 2.3. This assessment was done under the leadership of Leanne Du Preez of the Geography Department, Rhodes University. The results of this assessment are reported in Buffalo River Technical Report for the Eastern Cape River Health Programme (RHP, 2004). No major differences in geomorphological impacts in the upper and lower catchments. Certain impacts like grazing and erosion are prevalent throughout the catchment.

Site 1

Both the left and the right riverbanks were stable although there was slight fluvial and sub-aerial erosion on both banks. A gauging weir, infrequent causeways and sources of sediments due to anthropogenic impacts were the geomorphological impacts noted around this site. The indigenous forest provides a good canopy cover and also stabilizes both riverbanks (RHP, 2004). Channel straightening and incision, together with relict cut-off meanders, are prevalent features within this region of the Buffalo River. This site is within a B impact class.

Site 2

Bank stability was low on the left bank and moderately stable on the right bank. This can be attributed to the fact that this site is located on a sharp river bend with alien vegetation also contributing to undercutting and slumping. A dam upstream, infrequent causeways, alien vegetation, and sediment extractions were the geomorphological impacts noted around this site. This site is within a C impact class.

Site 3

Both riverbanks were stable although undercutting due to fluvial action was evident. Impacts noted were alien vegetation and moderate sediment sources due to anthropogenic impacts (RHP, 2004). A notable feature near this site is a wetland that has formed a natural depression on the right bank. This site is within a B impact class.

Site 4

Both riverbanks were moderately stable due to bedrock cliffs that alternate with less stable bank sections consisting of a layer of sand over bedrock. Riparian zone indigenous vegetation clearance (for firewood), a gauging weir, infrequent causeways and sediment sources related to anthropogenic activity, were the impacts noted around this site. This site is within a C impact class.

Site 5

Extensive gully formations together with undercutting and slumping have resulted in a low to moderate stability of both riverbanks. Sand-mining, a bridge, invasive alien vegetation and sediment sources related to anthropogenic activities were the impacts noted around this site. This site is within a C to D impact class.

Site 6

The left riverbank was predominantly bedrock with high stability. However the right bank was moderately stable due to erosion occuring on the left bank. Storage weirs, invasive alien vegetation and sediment sources due anthropogenic impacts were the impacts noted around this site. This site is within a C to D impact class.

Site 7

Bank stability on both riverbanks was moderate. Vegetation clearance from the riparian zone, upstream dam, sand-mining and invasive aliens were the impacts noted around this site. This site is within a C to D impact class.

Site 8

Bank stability was high on both banks. An upstream dam, in- channel supports, invasive aliens and moderate sediment sources due to anthropogenic impacts were the impacts noted around this site. This site is within a C to D impact class.

Site 9

Bank stability was high on both riverbanks. A low water bridge at this site has been partially washed away and this has resulted in the formation of a deep pool behind the remnants of the bridge. Other impacts noted around this site were invasive aliens, upstream dams, infrequent causeways and in-channel supports. This site is within a C impact class.

Site 10

The stability of both banks was low due to gully formation. A bridge with in-channel supports, localized gabions, infrequent causeways and riparian vegetation clearance were the impacts noted around this site. This site is within a C impact class.

Site 11

The stability of both riverbanks was high although there was severe localized erosion at one point on the left bank due to a previous waste disposal at this site. Overgrazing, sand-mining and infrequent causeways were the impacts noted around this site. This site is within a C to D impact class.

Site 12

Bank stability was high on the right bank, which was dominated by bedrock, and moderate on the leftbank. Impacts noted around this site were invasive aliens, indigenous vegetation clearance from the riparian zone and sediment sources related to human activitities. This site is within a B impact class.

3.5.4 Riparian vegetation assessment

The Riparian vegetation assessment was done under the leadership of Debbie Reynhardt of Down-to- Earth Landscape and Design Consultation in East London. The results of this assessment were reported on Buffalo River Technical Report for the Eastern Cape River Health Programme (CES, 2004). The assessment was undertaken at three sites (Sites 1, 2 and 3) in the upper catchment and one site (Site 9) in lower catchment during method development of the index.

Site 1

This site falls within an indigenous forest area managed by the Department of Water Affairs and Forestry and is dominated by a climax afromontane forest which is in a near pristine state similar to what could be considered as a perceived reference state (CES, 2004). The high percentage cover of indigenous riparian species such as Yellowoods characterizes the site and recruitment of these species is evident. Alien and exotic invasive species such as *Quercis palustris* and *Acacia mearnsii* are present although they have a low disturbance impact at this site and their presence is attributable to previous harvesting of the indigenous species for firewood. Forest management and ecotourism are the only human impacts this site is exposed to. The IRVI category for this site is B.

Site 2

This site is located in a rural area and is characterized by remnant woody riparian vegetation, indicative of Eastern Thorn Bushveld and transitional Valley Thicket (CES, 2004). The riverbanks are highly eroded and the riparian vegetation is highly disturbed with approximately 25 % of the area showing bare soil. Alien vegetation encroachment is high covering more than 35 % of the site, with the most common species being *Sesbania punicea* and Black Wattle. The human impacts around this site include sand-mining, substistence agriculture and farming (cattle grazing). The IRVI index score for this site is an E category, indicating extensive loss of habitat and ecosystem functions.

Site 3

Different stages of riparian forest predominantly characterize this site with some parts being in the intact stage and some in the secondary stages of succession. The forest is mixed with open grass areas that appear to have been previously cleared for agriculture. Understorey terrestrial vegetation species such as *Gymnosporia buxfolia* and *Coddia ruddis cover*, alongside with riparian species, account for approximately 60% of the vegetation cover and recruitment of indigenous species is evident. The extent of vegetation cover has been altered and this can be attributable to clearing of riparian trees on both riverbanks for cattle crossing and for previous agricultural purposes. However the extent of vegetation cover is still high and IRVI index score for this site is a C category, indicating that the riparian vegetation has been moderately modified although the basic functions of the ecosystem have been unchanged.

Site 9

A mix between valley and coastal forest thicket characterize the vegetation of this site. The intactness of this mix, which is the perceived state of this site under natural conditions, has been disturbed by bridge construction and the previous use of the northern section of the Umtiza Reserve as a picnic area. This has resulted in substantial encroachment of invasive exotic weed species, although the intactness and recruitment of indigenous species is evident in areas where this encroachment is less severe. Generally, the vegetation cover at this site is high, covering approximately 100 % although dominated by invasive species such as *Celtis africana*, *Harpephyllum caffra* and *Ficus sur*. The IRVI index score is a D category, indicating loss of habitat and some basic ecosystem functions.

3.5.5 Water quality assessment

Introduction

O'Keeffe *et al*. (1996), identified salinization and nutrient enrichment as variables of concern within the Buffalo River catchment, particularly in the middle reaches. Electrical conductivity (EC), Total Inorganic Nitrogen (TIN) and Soluble Reactive Phosphate (SRP) data records from 1996 onwards were therefore selected and compared to the default benchmark boundary values provided in the methods used for Ecological Water Requirements (Rivers) assessments (Palmer *et al.*, 2004), to assess the present ecological state for water quality in the Buffalo River. Aluminium was also assessed as high concentrations were observed from a monitoring point located around Site 2 (DWAF monitoring point R2H005). pH and flouride were also assessed. Only physico-chemical data from weirs in rivers were used with data from dams excluded. Data were obtained from R2H001 (Site 1), R2H005 (Site 2), R2H010 (Site 8), R2H011 (Site 6), R2H012 (Site 3) and R2H027 (Site 12). The results obtained from assessments of physico-chemical data together with data obtained using SASS index (ASPT score) were used to provide an overall water quality assessment. For sites with no available physico-chemical data, only the SASS data (ASPT score), were used and compared with the default benchmark boundary values provided in the methods used for Ecological Water Requirements (Rivers) assessments, to indicate the overall present water quality state. Note that this approach is low confidence.

Site 1

The physico-chemical parameters assessed at Site 1 (DWAF monitoring point R2H001) indicated unimpacted conditions relative to the default benchmarks except for SRP, which had very high concentrations and fell within in a Poor category (Table 3.9). The overall water quality status for this site can be classified as good due to the fact that ASPT score fell within a fair category. The physico–chemical parameters assessed indicated downstream water quality impairment from Site 1 within the Buffalo River mainstream.

Site 2

At Site 2 (DWAF monitoring point R2H005), conductivity and total inorganic nitrogen fell within a “ fair” category with phosphates and aluminium falling within a Poor category (Table 3.9). This can be possibly attributed to the fact that this site is exposed to sources of impacts such as cattle grazing and agriculture. The fact that this site is located below two dams cannot be excluded as a contributing factor to this water quality deterioration. The ASPT score for this site fell within a Fair category and the overall present water quality status of the site can be classified as Fair.

Site 8

At Site 8 (DWAF monitoring point R2H010) the physico-chemical parameters EC, SRP and Al fell within a “poor category” and TIN fell within a fair category (Table 3.9). This site is located downstream of King William’s Town and Zwelitsha and receives urban runoff from these settlements. Green water-colour (indicating possible eutrophication) and pungent odour were other signs of water quality impairment observed at this site during the sampling surveys. The ASPT scores fell within a Poor category. The overall water quality state of this site can be classified as being fair to poor.

Site 3

Site 3 (DWAF monitoring point R2H012) located in the Mgqakwebe River, had a Natural pH, EC and flouride levels. The total inorganic nitrogen at this site was in a Fair category and the phosphates were in a Poor category; and this can be possibly attributed to organic enrichment from subsistence farming activities such as a cattle crossing area and drinking points around this site. The ASPT scores fell within a Good category and the overall present water quality status of this site can be classified as being Good (Table 3.9).

Site 6

Site 6 (DWAF monitoring point R2H011) located on the Yellowwoods River had Poor categories for conductivity and phosphates, and Fair total inorganic nitrogen whilst pH and flourine fell within a Natural category. This site is located downstream of Bhisho and Pakamisa settlement areas and water quality impairment can be attributable to the inflow from this area. The ASPT score fell within a Fair category. The overall present water quality state of this site can be classified as Fair (Table 3.9).

Site 12

At Site 12 (DWAF monitoring point R2H027) located at KwaNxamkwane River, EC and SRP fell within a Fair category and TIN fell within a Good category (Table 3.9). Aluminium and ASPT scores however were in a Poor category and the overall present water quality state of this site can be classified as Fair.

Table 3.9 Summary of the present ecological assessment for each site sampled on the Buffalo River. ND indicates that data for that particular variable was not available.

Variables	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**	**Site 7**	**Site 8**	**Site 9**	**Site 10**	**Site 11**	**Site 12**
pH	Natural	Natural to Good	Natural	ND	ND	Natural to Good	ND	Natural to Good	ND	ND	ND	Natural to Good
EC	Natural	Fair	Natural	ND	ND	Poor	ND	Poor	ND	ND	ND	Fair
TIN	Natural	Fair	Fair	ND	ND	Fair	ND	Fair	ND	ND	ND	Good
SRP	Poor	Poor	Poor	ND	ND	Poor	ND	Poor	ND	ND	ND	Fair
Al	ND	Poor	ND	ND	ND	ND	ND	Poor	ND	ND	ND	Poor
F	Natural	Natural	Natural	ND	ND	Natural	ND	Natural	ND	ND	ND	Natural
ASPT score	Fair	Fair	Good	Fair	Fair	Fair	Poor	Poor	Good	Poor	Poor	Poor
Overall water quality assessment	Good	Fair	Good	Fair	Fair	Fair	Poor	Fair to Poor	Good	Poor	Poor	Fair
FAII category	F (Poor)	F (Poor)	E (Poor)	F (Poor)	F (Poor)	F (Poor)	F (Poor)	F (Poor)	C (Good)	F (Poor)	F (Poor)	F (Poor)
GI impact class	B (Good)	C (Good)	B (Good)	C (Good)	C/D (Fair)	C/D (Fair)	C/D (Fair)	C/D (Fair)	C (Good)	C (Fair)	C/D (Fair)	B (Good)
IRVI category	B (Natural to Good)	E (Poor)	C (Good)	ND	ND	ND	ND	ND	D (Fair)	ND	ND	ND
Overall health of a site	Good to Fair	Fair	Good	Fair	Fair to Poor	Fair to Poor	Poor	Fair to Poor	Good	Poor	Poor	Fair

3.5.6 Overall health

The overall health for Site 1, the uppermost site selected on the Buffalo River mainstem and located within an area of indigenous forest managed by DWAF, can be classified as Good to Fair (Table 3.9). This is due to the fact that although the assessment of the riparian vegetation, geomorphology and physico-chemical paratemers indicated the least impacted conditions, the macroinvertebrate assessment indicated fair health and fish assemblages were in a poor health. As a result of the reduced macroinvertebrate, fish and habitat scores, this site was not considered a suitable reference site as it scored lower than impacted monitoring sites further downstream in the catchment. The overall health of Site 2, downstream of Site 1, can be classified as Fair (Table 3.9). Site 2 is exposed to sources of impacts such agriculture, sand-mining, a large rural population and alien vegetation which possibly have negative impacts on water quality and on the biological and physical indicators. The overall health of Site 3 located on the Mgqakwebe River can be classified as Good. This site was selected as a reference site and performed as an appropriate reference site for macroinvertebrate assessment. The intergrity of the fish assemblage is the only indicator that fell within poor health state at this site (Table 3.9). The overall health of Site 4 located on the Ngqokweni River can be classified as fair (Table 3.9). This site is exposed to impacts such vegetation clearance that affect the stability of riverbanks and its substrate is predominatly bedrock with reduced habitat for macroinvertebrates.

The overall health of Site 5 selected on the upper reaches of the Yellowwoods River can be classified as Fair to Poor (Table 3.9). This site is exposed to sources of impacts such as cattle grazing and sand-mining and these negatively impact on both biological and physical status of this site. Site 6 located further downstream on the Yellowwoods River can also be classified as having a Fair to Poor overall health. This site is located below Bhisho and Pakamisa settlements area with this site receiving runoff from this settlement. The overall health of Site 7 located below King William's Town can be classified as Poor. This site receives urban runoff from the King William's Town and is also exposed to sources of impacts such vegetation clearance, sand-mining and alien vegetation which negatively impact on biological, physical and chemical status of this site. Site 8 located downstream of Site 7 and below Zwelitsha township, can also be classified as being in a Poor state. This site receives urban runoff from the township and is also located below the Sewage Treatment Works. It is also exposed to sources of impacts such as alien vegetation, small bridge construction and gully formation. The overall health of Site 9, the most downstream site selected on the Buffalo River can be classified as Good. Macroinvertebrate, fish and geomorphological assessment fell within a Good health status, with only the riparian vegetation assessment falling within a Fair health state due the dominance of alien and exotic vegetation. These results suggest possible downstream recovery further downstream on the Buffalo River.

The overall health of Site 10 selected as a reference site for macroinvertebrate assessment on the Nahoon River can be classified as Poor (Table 3.9). This site did not perform as an appropriate reference for macroinvertebrate assessment due to the fact that it had lower macroinvertebrate scores and habitat scores compared to the monitoring sites of which it was expected to provide a reference. This site is exposed to sources of impacts such as gabions, indigenous vegetation clearance and erosion. These impacts negatively affect the biological and the physical status of this site. The bridge has a noteworthy impact on the geomorphological status of the site (RHP, 2004). The overall status of Site 11 located on the Shangani stream below Mdantsane settlement can be classified as Poor (Table 3.9). This site receives urban runoff from Mdantsane settlement and is also exposed to sources of impacts such as overgrazing, sand-mining and a bridge, which possibly negatively impact on the biological, physical and chemical status of this site. The overall health of Site 12 located at KwaNxamkwane River can be classified as Fair.

3.6 DISCUSSION

3.6.1 Macroinvertebrate assessment

Replication

Replication of macroinvertebrate sampling using the SASS protocol was conducted to ascertain whether one sample taken per site per biotope at a particular time of sampling is a true representation of macroinvertebrate taxa occurring at that particular site. Different taxa at different abundances were recorded amongst replicates taken within the same biotope (Appendix 1). This resulted in varying SASS5, ASPT scores and number of taxa between these replicates (Table 3.2). Although variability was observed in faunal composition, which resulted in different scores between replicates, multivariate analyses (ANOSIM) undertaken to assess whether there were any significant differences between replicates from the same biotope (in terms of faunal composition and abundance), indicated that the differences between replicates were not significant.

Although replicate samples within a site grouped randomly on the dendrogram plots (Fig. 3.14, 3.16, 3.18 and 3.20) the trend that was observed was that replicates taken from the stones biotope fell within the same groups for all replicated sites. This indicates a high level of homogeneity within this biotope. This was further indicated by the fact that replicate samples from this biotope did not differ by more than three families (Appendix 1).

Generally, the SASS5 scores were the most variable between replicates from the same biotope while ASPT scores and number of taxa remained relatively consistent. This is comparable with findings by Dallas (2000), and Dickens Graham (2002), and Palmer and Taylor (2004), which regarded the ASPT score as the least variable and more conservative score, providing a reliable indication of the ecological condition of a river.

Macroinvertebrate biotopes

Differences in macroinvertebrate scores recorded between biotopes within a site (Table 3.3) were not unexpected as there are natural differences between biotopes in terms of substrate, flow and other aspects (Dickens and Graham, 2002). The stones biotope had the highest scores of all sampled biotopes. This can be attributed to the wide range of taxa recorded in this biotope, ranging from the presence of high scoring and sensitive families such as ephemeropterans to low-scoring and tolerant families such as dipterans. This biotope was also the most available biotope in all seasons, further indicating its importance in SASS sampling (Table 3.3).

The vegetation biotope was sparse at most sites and it was highly affected by reduced flow and subsequent reduction in inundation of the biotope. This was reflected in low scores recorded from this biotope at most sites, but particulary during winter (Table 3.3) when the flow in the Buffalo River catchment is reduced as this is the summer rainfall area (Palmer and O'Keeffe, 1989).

The GSM (gravel sand and mud) biotope was the least diverse in terms of macroinvertebrate diversity, with lowest scores being recorded at this biotope during all sampling seasons (Table 3.3). Although this biotope is a combination of gravel, sand and mud, gravel was not available at most Buffalo River sites and this possibly contributed to the reduced macroinvertebrate diversity (SASS5 scores) and sensitivity (ASPT scores) (Table 3.3) observed for this biotope. GSM was also affected by flow with low flows resulting in a reduction of GSM habitat availability and resultant fewer families recorded. Literature considers sandy habitats to be poor and shifting habitats affected by flow (Madikizela *et al*., 2001).

Analysis of similarity (ANOSIM) performed at each site to assess whether the differences observed between biotopes were significant, indicated there were significant differences between biotopes in terms of faunal composition at most sites (Table 3.4). These analyses also further revealed that in most sites the stones biotope differed significantly from both the vegetation and GSM biotopes. This emphasizes the importance of sampling all available biotopes at a site during biomonitoring surveys in order to obtain an accurate assessment of that particular site. Availability of all sampling biotopes should also be noted when comparisons between sites are conducted. For instance, the fact that not all biotopes are available at a monitoring site should be taken into consideration when that particular monitoring site is being compared to a reference site with all the three biotopes available. Comparison should be based on the diversity and sensivity of macroinvertebrates found within available biotopes on both sites being compared.

Seasonal differences

Changes in physico-chemical parameters (Table 3.6) and in habitat availability between the three seasons resulted in variability in macroinvertebrate diversity within sites (Table 3.3; Appendix 3). The major contributing factor to this trend is likely to be the observed reduced flow and temperature in winter. Dallas (2004) also attributes seasonal differences in macroinvertebrate diversity to seasonal variations in discharge, which leads to differences in wetted perimeter, hydraulic conditions and biotope availability. The highest macroinvertebrate diversity was observed in spring and the lowest in winter (Table 3.3; Appendix 3). This is contradictory to what was observed by Dallas (2004) who observed highest macroinvertebrate diversity in winter than in spring in Mpumalanga sites located in a summer rainfall area like the Buffalo River catchment. Conductivity was high and dissolved oxygen levels were reduced at most sites in winter (Table 3.6). Habitat quality and availability was also reduced, as reflected by IHAS scores (Table 3.3). Reduced SASS scores also suggested reduction in macroinvertebrate diversity in winter although this pattern was not as evident for ASPT as it was for SASS scores. The ASPT scores were similar between seasons and this confirms the report by Chutter (1998) that ASPT is less affected by habitat availability as compared to SASS scores. Dickens and Graham (2002) also reported the consistency of ASPT as opposed to SASS scores.

Analysis of similarity indicated that there were no significant differences between seasons in terms of faunal composition at most sites (Table 3.4). This is similar to what has been reported by Madikizela *et al*. (2001), who reported 70% similarity between spring, winter and autumn in terms of faunal similarity for the UMzimvubu River in the Eastern Cape. At those sites where significant differences were observed between seasons, winter was different with either spring or autumn. From this study it is recommended that biomonitoring surveys in this catchment be conducted in winter and spring, as the autumn sampling results did not differ significantly from either spring nor winter results.

3.6.2 Fish assessment

The calculation of FAII is largely dependent on knowledge of the expected (under natural conditions) fish species for a particular system (Kleynhans, 1999). This is usually established through historical data. As historical data is not usually available (as most systems in the Eastern Cape have not been intensively sampled for fish), expert knowledge and judgement of species expected to occur is essential (Kleynhans, pers. comm., 2003). However, the use of expert knowledge might result in underestimating or overestimating the number of fish species expected in an area and this will significantly affect the FAII scores (RHP, 2004). The greater the number of species expected and not encountered, the lower the FAII score, and vice versa.

Although the Eastern Cape rivers naturally have low diversity of indigenous fish species (Bok, pers.comm., 2003), this condition is exacerbated in the Buffalo River by the presence of alien species. Some species e.g. *Clarias gariepinus,* are predacious and have the ability to outcompete indigenous species for habitat and food (Skelton, 2001). Alien species were recorded at almost every site except at sites 3 and 5 (Appendix 4). Eleven sites on the Buffalo River catchment were classified as Poor due to the fact that the expected indigenous species were not encountered (Table 3.8). Site 9 is the only site that was classified as being in good health in terms of fish assemblages.

Sampling effort and efficiency is one of the major contributors to low fish diversity and the resultant low FAII scores observed on most Buffalo River sites. The FAII sampling method has prescribed the electroshocker as a tool to sample fast habitats and seine nets as a tool to sample slow habitats (Kleynhans, 1999). Most Buffalo River catchment sites are characterized by boulder- bedrock substrate. It was difficult to use the seine on this substrate as it snagged on boulders and the electroshocker therefore was used to sample most available habitats. Some fish species, such as *Anguilla mossambica* were seen but could not be caught as they darted away from the electroshocker suggesting that this tool was not effective in catching this species. The effectiveness of the electroshocker is affected by low conductivity (RHP, 2004) and this reduces the confidence of data captured using this tool in site with low conductivity such as Site 1. The use of other sampling techniques e.g. gill nets for slow habitats and fyke nets for rocky bottoms in order to ensure representative and effective sampling, need consideration so as to improve confidence in results obtained. These methods however require more time and effort and this might affect the objectives of a rapid assessment. A compromise between rapid assessment and sampling efficiency should be taken into consideration, as fish are highly mobile and move to utilize different habitats on a daily and seasonal basis (RHP, 2004).

3.6.3 Water quality

The selected physico-chemical parameters assessed indicated that water quality at R2H001 (Site 1) is least impacted relative to the default benchmark boundary values, with SRP being the only variable higher than the natural concentrations according to the boundary values (Table 3.9). There was evidence of water quality impairment at monitoring points R2H005 (Site 2) and R2H10 (Site 8) located downstream of Site 1. O'Keeffe *et al*. (1996), identified salinization and nutrient enrichment as variables of concern particularly in the middle to lower catchment of the Buffalo River. This pattern is still prevalent as the data records for Sites 2 and 8 for SRP, TIN and EC from 1996 onwards fell within Fair and Poor categories relative to the benchmarks provided in Palmer *et al*. (2004). At Site 2 the observed nutrient enrichment can be attributed to the fact that this site is exposed to sources of impacts such agriculture and run off from the surrounding settlements. Aluminium is present at high concentrations at this site suggesting that there is a source of aluminium in the area and a detailed investigation is recommended. Water quality impairment observed at monitoring point R2H010 (Site 8) can be attributed to the fact that this site is located downstream of Zwelitsha and King William's Town with urban run off and industrial discharges possible sources of impacts.

3.6.4 Geomorphological assessment

Most sites on the Buffalo River catchment fell within an impact classes C and C/D despite their position within the catchment. Anthropogenic impacts that were prevalent at most sites were riparian vegetation clearance, erosion and bridges. These impacts have affected the stability of the riverbanks, changed the bed structure and have resulted in channel widening or narrowing (RHP, 2004). Alien vegetation encroachment is also one of the results of riparian vegetation clearance, although this has a negligible impact on the geomorphology. Impoundments are considered major contributors to alterations of the natural geomorphological regime of the Buffalo River.

3.6.5 Riparian vegetation assessment

The disturbance of the riparian vegetation at Site 1 is low and is attributable to DWAF management of the forestry area. However presence of alien vegetation in this protected area poses a threat to the indigenous vegetation and indicates the extent of the problem throughout the entire length of the Buffalo catchment (RHP, 2004). High infestation of alien plants around Site 2 is attributable to vegetation clearance, agricultural practices and sand-mining, all of which have contributed to the eroded riverbanks. Interventions through programmes such as land care are needed to rehabilitate this area. Dense infestation of exotic and invasive species is one a major concern at Site 9, although the structural composition of the vegetation is still intact.

3.6.6 Overall health

Sites 1 and 10 were selected as reference sites for the macroinvertebrates assessment for the upper and lower catchments respectively. However results revealed that these sites were a poor indication of reference condition. This suggests the absence of reference sites for the Buffalo River as a result of highly developed nature of this catchment. It is imperative that reference conditions be generated for the Buffalo River (Dallas, 2000) and that future assessments can be undertaken relative to these assessments.

Macroinvertebrate assessment revealed that most sites in the upper catchment are in a Fair category except for Site 3, which indicated good health. Lower catchment sites however fell within a Poor category except for Site 9, which is the most downstream site on the Buffalo River (Table 3.5) suggesting possible downstream recovery in this catchment. Sites located below King William's Town are exposed to sources of impacts such industrial effluents, urban inflow, untreated sewage and other impacts that negatively impact on the water quality. Local anthropogenic impacts such as erosion resulted in alteration of vegetation structure contributed to the reduced habitat quality at most sites. The low scores of Yellowwoods, Ngqokweni, Shangani and KwaNxamkwane rivers suggest that they have possible negative inflow into the Buffalo River.

Fish assessment indicated that fish assemblages on the Buffalo River are in a poor health except for Site 9 (Table 3.8; 3.9). Although factors such as presence of alien species which tend to outcompete indigenous species (Skelton, 2001), habitat availability and water quality impairement cannot be excluded, sampling efficiency may be the major contributing factor to low FAII scores observed amongst sites. Physico- chemical assessment indicates that there is downstream deterioration in water quality from upstream to downstream and this can be attributable to catchments activities along the longitudinal stretch of the Buffalo River, with some recovery by Site 9.

A geomorphological assessment indicated that present geomorphological status of most sites on the Buffalo River is in a C impact class. This indicates significant human impact, evident changes in bed structure, localised bank erosion and channel widening. This can be attributable to human impacts such sand-mining, construction of bridges, agricultural practices, weirs and many other activities that alter the geomorphological regime of a site. Riparian vegetation scores indicated that alien vegetation infestation due to riparian vegetation clearance is the major threat to the riparian vegetation health within the catchment. The present overall health of most sites can be classified as being Fair to Poor, which indicate degradation. Management intervention is needed on this catchment is needed to prevent further degradation.

CHAPTER FOUR
THE INXU RIVER

4.1 Introduction

Research on the Inxu River emanates from a National Research Foundation (NRF) programme that focusses on the protection of knowledge, nature and resource rights. The key focus of this programme is the area of indigenous knowledge regarding rivers, pools and natural water bodies and their riparian zones (Bernard P, Department of Anthropology, Rhodes University, pers. comm., 2003). The focus of the programme is on the role these natural resources may hold in the training of spiritual healers like *izangoma* and *amagqirha* throughout southern Africa. It is believed that river systems and their riparian zones have a profound significance in linking with the spiritual world.

A number of sacred sites have been identified across South Africa. Sacred pools located within the Inxu River are one of the sites identified as sites of spiritual and cultural importance (Bernard P, Department of Anthropology, Rhodes University, pers. comm., 2003). Although this river is very important culturally and spiritually, its present ecological state is not known. This study was therefore undertaken to assess its overall ecological health to aid in its protection and management. The Inxu River catchment is further important as the Gatberg wetlands, nominated as a RAMSAR site worthy of protection, form part of this catchment (Bernard P, Department of Anthropology, Rhodes University, pers. comm., 2003). In addition, research previously conducted within this catchment focussed mainly on the upper catchment (Rowntree, 1993; Forsyth *et.al*., 1997), with little or no information being available for the lower catchment.

4.2 Study Area

4.2.1 Topography

The Inxu River catchment lies between latitudes 31^{0} $9^{'}$ and 31^{0} $11^{'}$ S and longitudes 28 ^{0} $9^{'}$ and 28 ^{0} $9^{'}$ E in the rural areas of Maclear and Ugie, North Eastern Cape. It flows for approximately 700 km before it joins the Tsitsa River, which is a River of the Umzimvubu River. A land-use map (Fig. 4.1) shows that the river is impacted by afforestation, particularly in the upper catchment, and by subsistence agriculture and farming in the lower catchment. The channel patterns along the river alternates between sinuous and meandering, depending on the width of the valley floor (Forsyth *et al*., 1997).

4.2.2 Climatology and rainfall

The North Eastern Cape is characterized by a warm temperate climate. Summers are warm with regular thunderstorms bringing most of the high annual rainfall (Forsyth *et al*., 1997). The catchment receives between 600 and 1200 mm mean annual rainfall (Midgley *et al*., 1994). The frequency of annual droughts is approximately 7.4%, which means once in 13.5 years on average (Schulze, 1974). According to Schulze (1974), frequent occurrence of frost and occasional snow characterize the region in cold and dry winters.

4.2.3 Geological formations and soils

The region is characterized by a series of horizontal sedimentary layers of Karoo Sequence (Decker, 1981). Features include the Molteno formation, which consists of coarse, pebbly, felspathic sandstone, mudstone and shale. The Molteno formation is followed by the Elliot formation consisting of red and purple mudstones. The impressive cliffs above the Elliot formation are the Clarens formation. Clarens formation consists of pale-orange to cream-coloured varying felspathic sandstone, with minor mudstone intercalations. Due to extensive basaltic lava the Drakensberg formations occur at the highest altitudes. Sills and dykes of dolerite are present in the underlying sedimentary rocks. The soils are predominantly deep-red well-drained soils. They have high clay content with concentrations higher in sub-soils than top-soils. The soils have a very low pH (Forsyth *et al*., 1997).

4.2.4 Vegetation cover

The North Eastern Cape region is predominantly covered with grasslands with *Protea* savanna occuring on the rocky slopes of the Clarens formations (Forsyth *et al*., 1997). There are patches of afro-montane forest in the sheltered kloofs. South–eastern mountain grassland and moist upland grassland, as recognized by Low and Rebelo (1998), are the two predominant grassland types (Forsyth *et al*., 1997). A substantial amount of invasive and indigenous vegetation has been cleared by North Eastern Cape Forest (NECF) and replaced by commercial forestry (pine plantations), covering most parts of the upper catchment. In the lower catchment, Black and Silver Wattle, Grey Poplar, *Salix babylonica* and *Robinia pseudoacacia* dominate exotic trees.

4.2.5 Land-use

Presently afforestation is the major land-use in the upper catchment. The lower catchment is dominated by subsistence agriculture and farming. The northern Eastern Cape is an isolated agricultural district, traditionally dependent on rangeland stock farming together with some winter pastures limited to cropping (maize and potatoes) and to dairy products (Forsyth *et al*., 1997). Maize and potato cropping has traditionally been practised under dryland conditions, with irrigation taking place on a very limited scale. Sheep and cattle characterize stock farming. Although remote, the area is serviced by tertiary roads between Ugie and Maclear towns, and secondary roads between the rural settlements in the lower catchment around Ugie and Maclear. NECF has also engaged in an extensive road construction programme to provide access to all their plantations in the upper catchment (Forsyth *et al*., 1997).

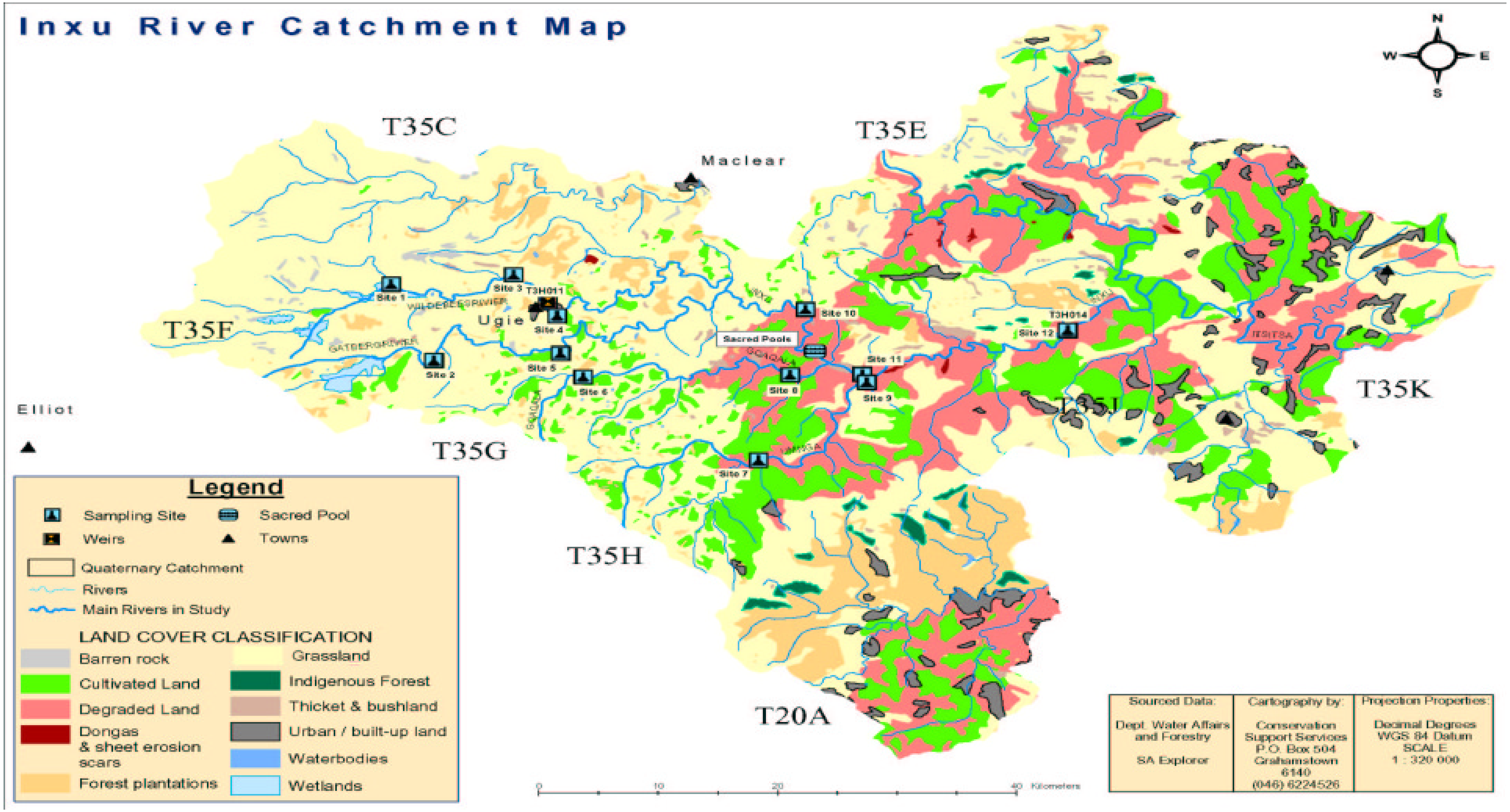

Fig 4.1 A map of the Inxu River, showing site locations and land-use activities within the catchment.

4.3 The Study Sites

Twelve sampling sites (Fig. 4.1) were selected on the Inxu River mainstem and on its tributaries (Fig. 4.2 to Fig. 4.13). Two reference sites were selected on the Inxu River mainstream for the upper and lower catchment and a reference site was selected on each of the tributaries (Gatberg, Gqaqala and Umnga). The upper catchment was defined as the section from Mt Challenger to the upper reaches of the Gqaqala River and the lower catchment was defined as the area from the upper reaches of the Umnga River to the area around Site 12 (i.e before Inxu joins the Tsitsa River) (Fig. 4.1). Two sampling surveys were undertaken in June and October 2003. Descriptive information of the sampling sites is given below.

4.4 Materials and Methods

A detailed description of the materials and methods applied is given in Chapter 2. Two sampling surveys were undertaken in June 2003 (winter survey) and October 2003 (spring survey). Replicated sampling for macroinvertebrates, using SASS, was undertaken during the winter survey at Site 1 (reference site), Site 10 (reference site) and Site 11 (monitoring site). During the spring survey replication was undertaken at Site 1 (reference site) and Site 4 (monitoring site) for the upper catchment and Site 10 (reference site) and Site 11 (monitoring site) for the lower catchment (Table 4.1). SASS5 and FAII assessments were undertaken at all sampling sites during both seasons. A geomorphological assessment was undertaken on all sampling sites during the spring survey. Water quality assessment was undertaken on sites with available water quality data (Table 4.1).

SITE 1

Location: Inxu River at Mt Challenger	**Co-ordinates:** 31^0 10’ 28 ’’ S, 28 ^{0}07’18’’ E

This site was selected as a reference site for the upper catchment of the Inxu River. Although this site is located within the NECF area (Fig. 4.1) it was selected as a reference site due to its least impacted conditions and habitat availability compared to other upstream sites on the Inxu River, and its open canopy that was similar to downstream sites on the Inxu River. The stream width was between 6 and 8 metres within a wetland area. The riverbanks were stable and characterized by grassland with some overhanging vegetation. The substrate was mostly cobbles, and pools were present for fish sampling. Reeds and sedges characterized marginal vegetation. There were fallen logs (probably chopped pine trees) which were dumped downstream of this site, which provided additional refugia for biota.

Fig. 4.2 Photograph of **Site 1** showing the diversity of biotopes and substrate.

SITE 2

Location: Gatberg River, around Serengia	**Co-ordinates:** $31^{0}14^{'}59^{''}$S, $28^{0}09^{'}14^{''}$E

The site is located in the upper reaches of the Gatberg River and was selected as a reference site for this system. The site is located within the NECF area and approximately 20 metres from the wetland area. This wetland area separates the forestry area from the river, possibly minimizing the direct impact of pine plantations on the river. The upper region of the Gatberg River catchment is within the NECF area and this site was selected as a reference site as it was the least impacted site upstream on the Gatberg River. Extensive mature pine plantations surrounded the site. The average stream width was between 4 and 5 metres. Banks were partly eroded and vegetated by grassland. Marginal vegetation was present, although reduced and was characterized by grasses. Substrate was mostly cobbles, and pools for fish sampling were present further downstream.

Fig. 4.3 Photograph of **Site 2** showing the diversity of biotopes and substrate.

SITE 3

Location: Inxu River at Lanark farm	**Co-ordinates:** 31^{0} $09^{'}$ 58 ’’S, 28 ^{0} 12’$^{'}$23 ’’E

This site was selected as the first monitoring site in the upper reaches of the Inxu River due to the fact that it is located downstream of extensive pine plantations (Fig. 4.1) within the NECF area. It was therefore selected as a monitoring site to assess the impact of extensive pine plantations on the upper catchment of the Inxu. The average stream width was between 6 and 8 metres. The banks were mostly grassland although there were small pine trees around the site. The substrate was mostly cobbles and pools were present. Reeds and sedges characterized marginal vegetation.

Fig. 4.4 Photograph of **Site 3** showing the diversity of biotopes and substrate.

SITE 4

Location: Inxu River, below Ugie town	**Co-ordinates:** $31^0$12'09''S, 28^0 14' 40''E

This site located below Ugie town (Fig. 4.1), was selected as a second monitoring site on the Inxu River to assess the impacts of activities from Ugie and the adjacent township. The average stream width was between 8 and 10 metres. Riverbanks were partly eroded and vegetated by few alien trees and grassland. Substrate varied from cobbles to gravel and sand. This was a crossing area for both people and cattle, and has widened the channel. Grasses and few alien trees characterized marginal vegetation.

Fig. 4.5 Photograph of **Site 4** showing the diversity of biotopes and substrate.

SITE 5

Location: Gatberg River, lower reaches	**Co-ordinates:** $31^0$14'34 ''S, 28 ^{0}14'57 ''E

The site is situated on the lower reaches of the Gatberg River and was selected as a monitoring site due to the fact that it is located downstream from sources of impacts such as afforestation and agriculture. It was used to assess the quality of water entering the Inxu River from the Gatberg River. The average stream width was between 4 and 5 metres. Bedrock dominated the substrate although cobbles were present. The riverbanks were stable and characterized by grassland. The stream was meandering within a wetland area.

Fig. 4.6 Photograph of **Site 5** showing the diversity of biotopes and substrate.

SITE 6

Location: Ggaqala River, upper reaches	**Co-ordinates:** 31^0 15’57 ’’S, 28 ^{0} 15’58 ’’E

This site is located on the upper reaches of the Gqalala River and was selected as a reference site against which the lower reaches site could be compared. This site was similar to the downstream site in terms of open canopy and rocky substrate. The stream width was between 4 and 5 metres upstream of the bridge, and widens to between 7 and 8 metres downstream of the bridge. The substrate is bedrock dominated, although few kickable stones were present. Rocks and grassland characterized the riverbanks.

Fig. 4.7 Photograph of **Site 6** showing the diversity of biotopes and substrate.

SITE 7

Location: Umnga River, upper reaches	**Co-ordinates:** 31^{0} 22'43 ''S, 28 ^{0} 22'17''E

This site was selected as a reference site for the Umnga River against which the downstream site could be compared. The average stream width was between 7 and 8 metres and the substrate was predominantly bedrock. The rightbank was rocky and the leftbank was grassy with few *Acacia* trees. Grasses characterized marginal vegetation.

Fig. 4.8 Photograph of **Site 7** showing the diversity of biotopes and substrate.

SITE 8

Location: Gqaqala River, lower reaches	**Co-ordinates:** $31^{0}15'51''S$, $28^{0}25'18''E$

This site was selected as a monitoring site on the Gqaqala River due to the fact it is located at the lower end of the catchment and is therefore able to provide an overall assessment of the catchment land-use impacts the effect on water quality conditions of the Inxu River. The average stream width is between 10 and 12 metres. The substrate is predominantly bedrock with few boulders available. Small alien trees and grasses characterized the marginal vegetation.

Fig. 4.9 Photograph of **Site 8** showing the diversity of biotopes and substrate.

SITE 9

Location: Umnga River, lower reaches	**Co-ordinates:** 31^{0}16'17''S, 28 ^{0}46'.8''E

The site was selected as a monitoring site on the Umnga stream before its confluence with the Inxu River. This site was selected as it is located downstream on the Umnga stream in an extensively eroded area and was also selected to assess the quality of water entering the Inxu River from Umnga stream. The average stream width stream was between 15 and 17 metres. The riverbanks were eroded and unstable. Sand dominated the substrate although cobbles were present. Reeds and sedges characterized marginal vegetation. There was extensive erosion around the site that resulted in the formation of dongas. Sand-mining was evident along the riverbanks.

Fig. 4.10 Photograph of **Site 9** showing the diversity of biotopes and substrate.

SITE 10

Location: Inxu River in Mbindlana area	**Co-ordinates:** 31^{0} 11$^{'}$ 57'' S, 28 ^{0} 26'$^{'}$0''E

This site was selected as a reference site for the Inxu system as it is situated upstream of the sacred pools and is situated in a remote area which is sparsely populated. It was also selected as a reference site to assess the condition of the Inxu River upstream of the sacred pools to which the site located below the sacred pools could be compared so as to establish the ecological condition of the Inxu River around the sacred pools. This selection of sites was necessary, as monitoring within the sacred pools was not allowed. The approximate stream width was between 10 and 12 metres. The riverbanks were quite stable and characterized by grassland and rocks. Instream substrate was mostly bedrock and boulders although cobbles were also present. Reeds and sedges characterized marginal vegetation. The major land-use around the site was subsistence cattle grazing.

Fig. 4.11 Photograph of **Site 10** showing the diversity of biotopes and substrate.

SITE 11

Location: Inxu River below the confluences with both Gqaqala and Umnga rivers	**Co-ordinates:** 31^{0} 14’52’’S, 28 ^{0}31’50’’E

The site located on the Inxu River was selected as a monitoring site below the sacred pools to assess the ecological health of the Inxu River below the sacred pools. It was selected as a monitoring site as it was below sources of impacts such as extensive erosion and also due to the fact that it is below the confluences with both the Umnga and Gqaqala streams. The banks are unstable and the erodible resulted in extensive dongas around the site. The average stream width was between 20 and 25 metres. Sand and boulders that were difficult to kick during macroinvertebrate sampling dominated the instream substrate. Reeds and sedges characterized marginal vegetation.

Fig. 4.12 Photograph of **Site 11** showing the diversity of biotopes and substrate.

SITE 12

Location: Inxu River, lower reaches before it joins Tsitsa River	**Co-ordinates:** $31^0$13'11''S, 28 ^{0}37'50''E

This site was selected as a monitoring site in the lower reaches to assess the Inxu River at its most downstream readily accessible point before it joins the Tsitsa River. The Inxu River is very wide at this point with average stream width between 25 and 30 metres. The banks are unstable stable due to erosion that has resulted in the formation of dongas. The instream substrate was dominated by sand although some riffles were present upstream of the roadbridge. Reeds and sedges characterized marginal vegetation.

Fig. 4.12 Photograph of **Site 12** showing the diversity of biotopes and substrate.

Table 4.1 Summary table indicating in which river each site was located, whether it was a reference or a monitoring site, whether replicated sampling was conducted and which indices were used. SASS5= South African Scoring System version 5, FAII= Fish Assemblage Integrity Index, IRVI= Integrated Riparian Vegetation Index and WQA= Water Quality Assessment.

Site	**River**	**Catchment position**	**Reference or monitoring site**	**Replicated (Yes or No)**	**Indices used**
1	Inxu	Upper	Reference	Yes	SASS5, FAII and GI
2	Gatberg	Upper	Reference	No	SASS5, FAII and GI
3	Inxu	Upper	Monitoring	No	SASS5, FAII and GI
4	Inxu	Upper	Monitoring	Yes	SASS5, FAII WQA and GI
5	Gatberg	Upper	Monitoring	No	SASS5, FAII and GI
6	Gqaqala	Upper	Reference	No	SASS5, FAII and GI
7	Umnga	Lower	Reference	No	SASS5, FAII and GI
8	Gqaqala	Lower	Monitoring	No	SASS5, FAII and GI
9	Umnga	Lower	Monitoring	No	SASS5, FAII and GI
10	Inxu	Lower	Reference	Yes	SASS5, FAII and GI
11	Inxu	Lower	Monitoring	Yes	SASS5, FAII and GI
12	Inxu	Lower	Monitoring	No	SASS5, FAII, WQA and GI

4.5 Results

4.5.1 Macroinvertebrate assessment

4.5.1.1 Replication

During the winter survey replicate samples were only taken from the stones biotope. Table 4.2 shows how SASS5, ASPT scores and number of taxa varied between replicate samples taken at each site where replicate sampling took place. Table 4.3 shows the results of the replicate sampling undertaken in spring. Tables 4.4 and 4.5 show all macroinvertebrate scores and ANOSIM results respectively. Amongst the SASS5 sub- indices the total SASS score was the most variable while the ASPT score was the least variable. Cluster analysis, MDS and ANOSIM were performed jointly for all three replicated sites due to the fact that analysis was not possible at site level due to insufficient groups. Replicates taken from Site 1 clustered together on a dendrogram plot (Fig. 4.14) based on hierarchical cluster analysis of replicate samples taken from sites 1, 10, and 11.This was also revealed in an MDS plot (Fig. 4.15). ANOSIM (Table 4.5) performed to assess whether there were any significant differences between replicates in terms of faunal composition indicated no significant differences despite the variation in SASS5 scores.

During the spring survey replicates were taken from sites 1, 4, 10 and 11 for all macroinvertebrate biotopes i.e. stones, vegetation and gravel, sand and mud (GSM). A similar trend whereby total SASS5 scores were the most variable and number of taxa the least variable sub-index, was also observed amongst the spring replicates (Table 4.3). Analyses amongst replicates from each biotope per site were not possible due to few groups so they were undertaken at site level. Dendrogram plots based on hierachical cluster analysis of replicates from sites 1, 4, 10 and 11 are presented in Fig. 4.16, 4.18, 4.20 and 4. 22 respectively. MDS ordination plots, based on these plots, are presented in Fig. 4.17, 4.19, 4.21 and 4.23 respectively. Although replicates for each biotope plotted randomly within a site it was observed that replicates from the stones biotopes tende to cluster per site. ANOSIM results revealed that there were no significant differences between replicate numbers from each site.

Table 4.2 SASS5, ASPT scores and number of taxa for each replicate sample taken from stones biotope from all replicated sites on the Inxu River during the winter survey.

Site	**Replicate no.**	**SASS**	**No. of taxa**	**ASPT**
1	1	99	13	7.6
	2	114	16	7.1
	3	108	15	7.2
10	1	102	14	7.3
	2	68	12	5.8
	3	111	16	6.9
11	1	93	13	7.2
	2	48	6	6
	3	93	13	7.2

Table 4.3 SASS5, ASPT scores and number of taxa for each replicate sample taken from each biotope from all replicated sites on the Inxu River during the spring survey.

Site	Biotope	Replicate no.	SASS	No. of taxa	ASPT
1	Stones	1	123	20	6.2
1	Stones	2	95	14	6.8
1	Stones	3	81	14	5.9
1	Vegetation	1	73	13	5.6
1	Vegetation	2	53	12	4.4
1	Vegetation	3	45	8	5.6
1	Gravel Sand and Mud	1	93	14	6.6
1	Gravel Sand and Mud	2	86	13	6.6
1	Gravel Sand and Mud	3	56	10	5.6
4	Stones	1	83	13	6.4
4	Stones	2	91	13	7.0
4	Stones	3	60	11	5.5
4	Vegetation	1	74	14	5.3
4	Vegetation	2	63	11	5.7
4	Vegetation	3	67	14	4.9
4	Gravel Sand and Mud	1	51	10	5.1
4	Gravel Sand and Mud	2	56	9	5.9
4	Gravel Sand and Mud	3	67	14	4.8
10	Stones	1	93	15	6.2
10	Stones	2	75	11	6.8
10	Stones	3	82	12	6.8
10	Vegetation	1	87	15	5.8
10	Vegetation	2	67	12	5.6
10	Vegetation	3	70	12	5.8
10	Gravel Sand and Mud	1	47	10	4.7
10	Gravel Sand and Mud	2	78	13	6.0
10	Gravel Sand and Mud	3	70	14	6.0

Site	Biotope	Replicate no.	SASS	No. of taxa	ASPT
11	Stones	1	68	12	5.7
11	Stones	2	69	10	6.9
11	Stones	3	97	14	6.9
11	Vegetation	1	56	12	4.7
11	Vegetation	2	89	15	5.9
11	Vegetation	3	55	12	4.6
11	Gravel Sand and Mud	1	26	5	5.2
11	Gravel Sand and Mud	2	47	10	4.7
11	Gravel Sand and Mud	3	39	17	5.5

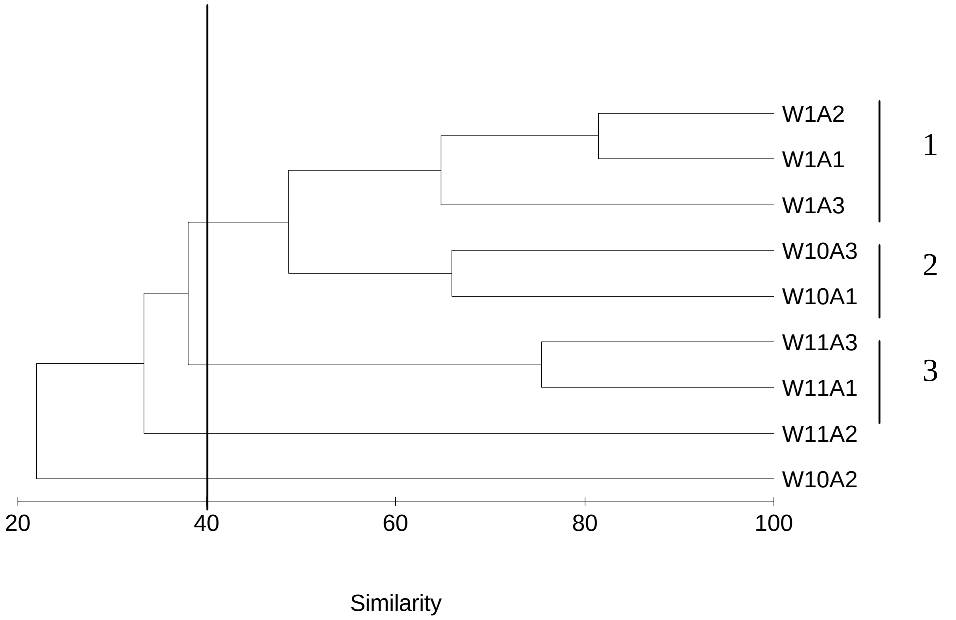

Fig. 4.14 Dendrogram for hierarchical cluster analysis of macroinvertebrate replicate samples taken from the stones biotope from sites 1, 10, and 11 in winter 2003. Abbreviation format: season (W= winter), site no. (1=site 1), biotope (A= stones), replicate no. (1= replicate 1, 2= replicate 2 and 3= replicate 3).

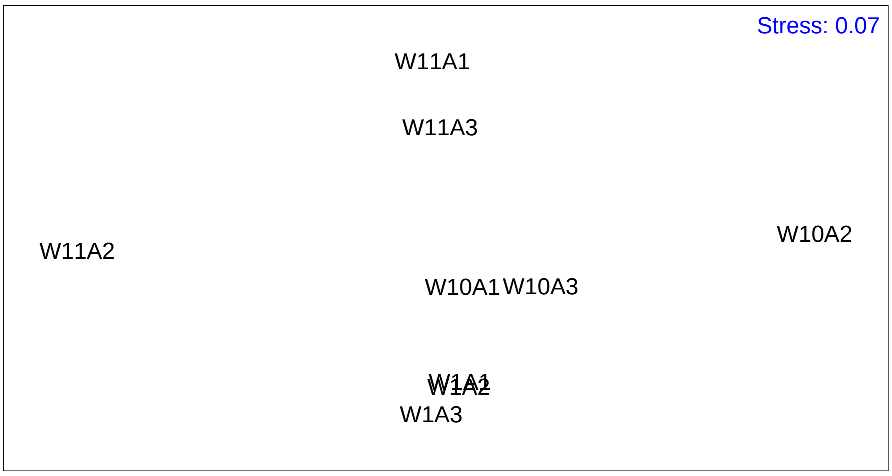

Fig. 4.15 MDS ordination plot based on Bray Curtis similarities of macroinvertebrate replicate samples taken from the stones biotope from sites 1, 10, and 11 in winter 2003. Abbreviation format: season (W= winter), site no. (1=site 1), biotope (A= stones), replicate no. (1= replicate 1, 2= replicate 2 and 3= replicate 3). A stress value of 0.07 indicates good ordination.

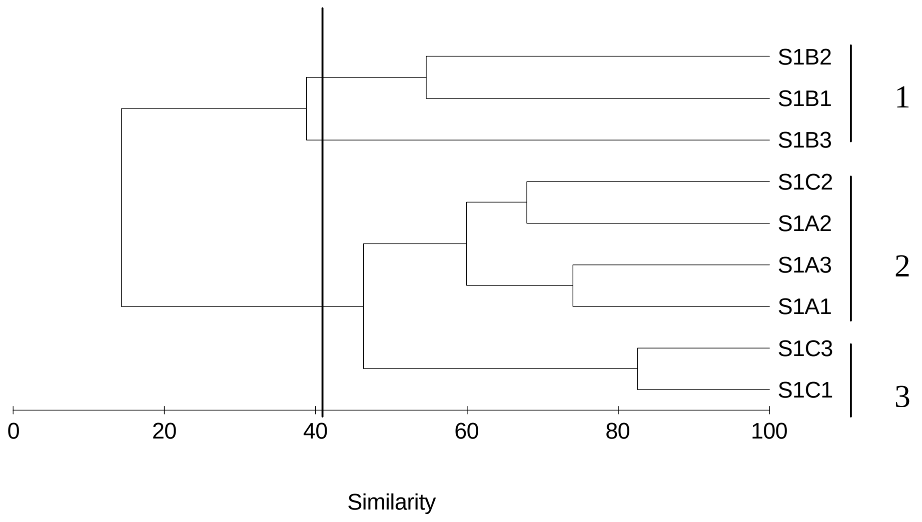

Fig. 4.16 Dendrogram for hierarchical cluster analysis of macroinvertebrate replicate samples taken from Site 1 (reference site) on the Inxu River spring in 2003. Abbreviation format: season (S= spring), site no. (1=site 1), biotope (A= stones, B= vegetation, C= GSM), replicate no. (1= replicate 1, 2= replicate 2 and 3= replicate 3).

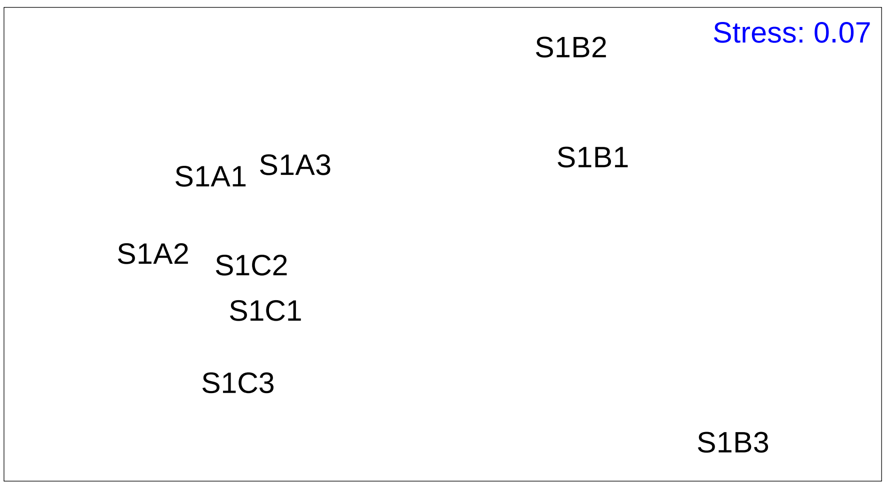

Fig. 4.17 MDS ordination plot based on Bray Curtis similarities of macroinvertebrate replicate samples taken from Site 1 (reference site) on the Inxu River in spring 2003. Abbreviation format: season (S= spring), site no. (1=site 1), biotope (A= stones, B= vegetation, C= GSM), replicate no. (1= replicate 1, 2= replicate 2 and 3= replicate 3). A stress value of 0.07 indicates good ordination.

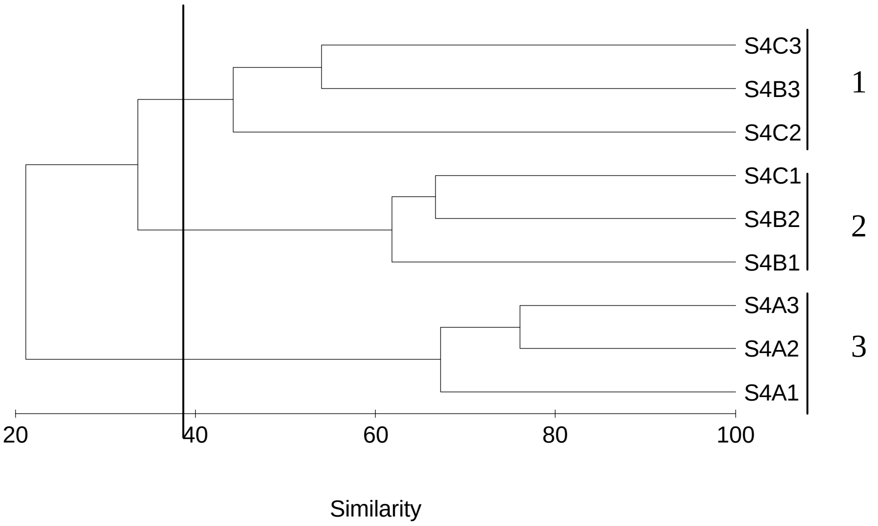

Fig. 4.18 Dendrogram for hierachical cluster analysis of macroinvertebrate replicate samples taken from Site 4 (monitoring site) on the Inxu River in spring 2003. Abbreviation format: season (S= spring), site no. (4=site 4), biotope (A= stones, B= vegetation, C= GSM), replicate no. (1= replicate 1, 2= replicate 2 and 3= replicate 3).

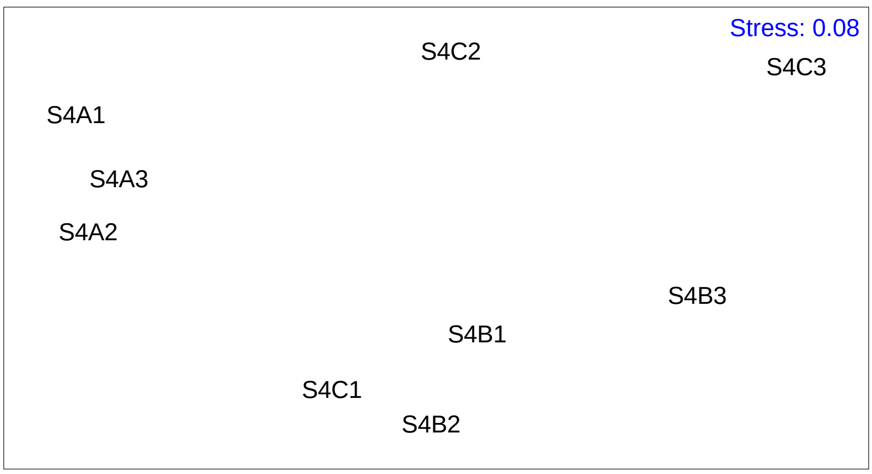

Fig. 4.19 MDS ordination plot based on Bray Curtis similarities of macroinvertebrate replicate samples taken from Site 4 (monitoring site) on the Inxu River in spring 2003. Abbreviation format: season (S= spring), site no. (4=site 4), biotope (A= stones, B= vegetation, C= GSM), replicate no. (1= replicate 1, 2= replicate 2 and 3= replicate 3). A stress value of 0.06 indicates good ordination.

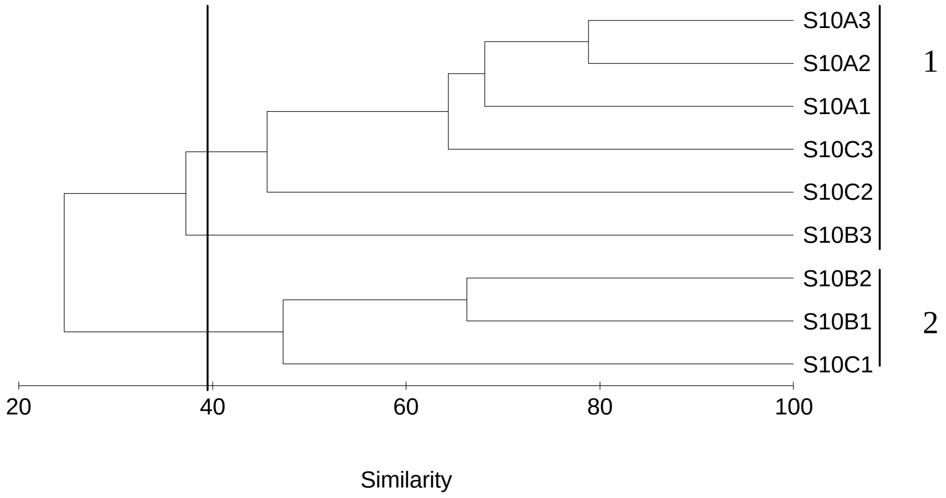

Fig. 4.20 Dendrogram for hierachical cluster analysis of macroinvertebrate replicate samples taken from Site 10 (reference site) on the Inxu River in spring 2003. Abbreviation format: season (S= spring), site no. (10=site 10), biotope (A= stones, B= vegetation, C= GSM), replicate no. (1= replicate 1, 2= replicate 2 and 3= replicate 3).

Fig. 4.21 MDS ordination plot based on Bray Curtis similarities of macroinvertebrate replicate samples taken from Site 10 (reference site) on the Inxu River in spring 2003. Abbreviation format: season (S= spring), site no. (10=site 10), biotope (A= stones, B= vegetation, C= GSM), replicate no. (1= replicate 1, 2= replicate 2 and 3= replicate 3). A stress value of 0.06 indicates good ordination.

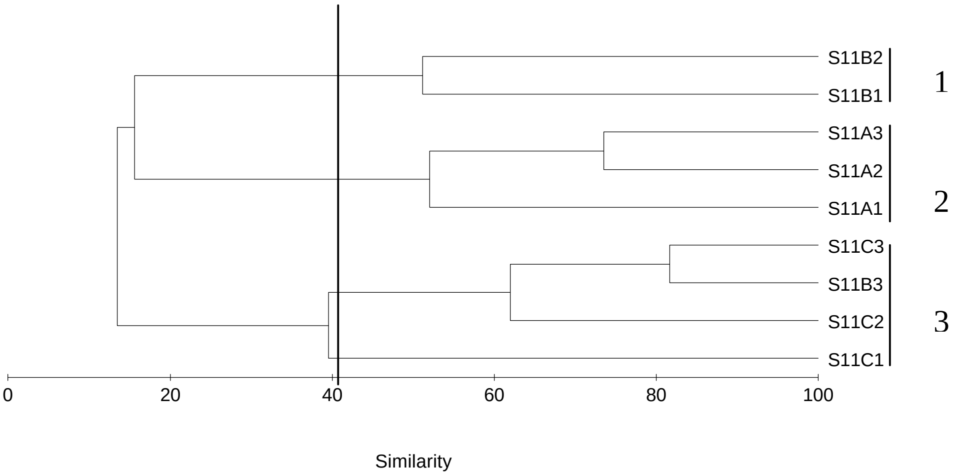

Fig. 4.22 Dendrogram for hierachical cluster analysis of macroinvertebrate replicate samples taken from Site 11 (monitoring site) on the Inxu River in spring 2003. Abbreviation format: season (S= spring), site no. (11=site 11), biotope (A= stones, B= vegetation, C= GSM), replicate no. (1= replicate 1, 2= replicate 2 and 3= replicate 3).

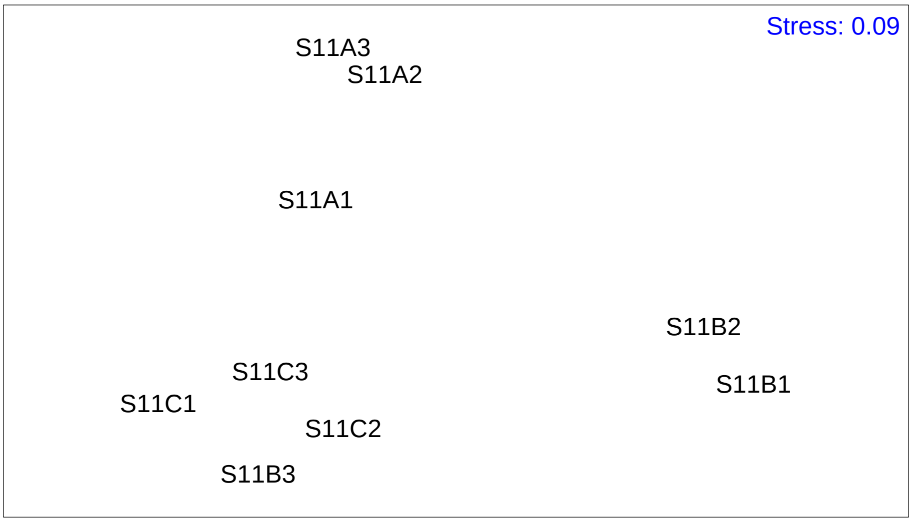

Fig. 4.23 MDS ordination plot based on Bray Curtis similarities of macroinvertebrate replicate samples taken from Site 11 (monitoring site) on the Inxu River in spring 2003. Abbreviation format: season (S= spring), site no. (11=site 11), biotope (A= stones, B= vegetation, C= GSM), replicate no. (1= replicate 1, 2= replicate 2 and 3= replicate 3). A stress value of 0.09 indicates good ordination.

4.5.1.2 Assessment of similarities and differences between sampling sites

Introduction

SASS5, ASPT, IHAS scores and number of taxa per biotope and per site for samples taken during each of the sampling seasons on the Inxu River are presented in Table 4.4. A summary of taxa recorded at each sampling site for each survey is presented in Appendix 6. An average ASPT score was calculated for each site and used as part of the overall water quality present state assessment (Palmer *et al*., 2004). These average ASPT scores were compared to the default benchmark boundary values (Table 2.1) and used to derive a category for a biotic response, which was then incorporated into an overall water quality assessment for each site. ANOSIM (Table 4.5) was undertaken for each site to assess whether there were significant differences in terms of faunal composition between biotopes and seasons sampled. SIMPER was undertaken to indicate family contribution to dissimilarity between biotopes and seasons.

Inxu River upper catchment
Site 1

This site is considered an appropriate reference site for the Inxu River upper catchment as it had the highest habitat (IHAS) and macroinvertebrate (total SASS5 and ASPT) scores, particularly in winter, when compared to the monitoring sites 3 and 4 (Table 4.4). Reduced macroinvertebrate diversity and sensitivity scores (reflected by SASS and ASPT scores during the spring survey) can be attributed to the observed reduced flow which possibly resulted in poorer habitat quality as reflected the by IHAS score. In addition, there was reduction in water quality, reflected by increased pH and conductivity and a decrease in dissolved oxygen levels during the spring survey (Table 4.6). ANOSIM undertaken to assess whether there were any significant differences between the two seasons sampled at this site in terms of macroinvertebrate faunal composition and abundance, revealed no significant difference despite the reduced scores during the spring survey (Table 4.5). ANOSIM indicated that significant macroinvertebrate differences existed at this site between the stones and vegetation biotopes and between the vegetation and GSM biotopes. SIMPER indicated that differences between the stones and vegetation biotopes could be ascribed to families such as turbellarians, ancylids, hydropsychids, aeshinids, tricorythids, heptageniids and leptophlebids which were encountered on the stones biotope but were absent in the vegetation biotope. Families such as vellids and leptocerids were encountered in the vegetation biotope but were not in the stones biotope. The water quality category for this site based on average ASPT score was Good (Table 4.7).

Site 3

This site, selected as the first monitoring site for the Inxu River upper catchment, had lower macroinvertebrate (SASS and ASPT) and IHAS scores (Table 4.4) in winter compared to the upstream reference site. This downstream deterioration can possibly be attributed to the fact that this site is downstream of extensive afforestation when compared to the reference site. However, this pattern was not evident during the spring survey as both macroinvertebrate and habitat results were similar between these two sites. SASS and ASPT scores at this site were reduced during the spring survey when compared to the winter survey, although the IHAS score improved (Table 4.4). This suggests the observed reduced flow during the spring survey may have resulted in poorer water quality conditions, which resulted in the reduction of macroinvertebrate diversity and sensivity (Appendix 6). This was indicated by higher temperatures, pH and conductivity and lower dissolved oxygen levels during the spring survey (Table 4.6). ANOSIM undertaken to assess whether there were any significant differences between the two seasons sampled at this site in terms of macroinvertebrate faunal composition, revealed that there were significant differences between the sampling seasons (Table 4.5). SIMPER revealed that significant differences between the two seasons could be ascribed to families such as naucorids, hydrophilids, planorbids, aeshinids, tricorythids, coenagrionids, hydropsychids and dytiscids which were encountered during the winter survey, but not encountered during the spring survey, and families such as corixids and vellids which were only encountered during the spring survey at this site (Appendix 6). ANOSIM also indicated no significant differences in terms of faunal composition and abundance between biotopes sampled at this site. The water quality category for this site based on average ASPT score was Good (Table 4.7).

Site 4

This site selected as the second monitoring site for the Inxu River upper catchment, had lower macroinvertebrate (SASS and ASPT) and IHAS scores (Table 4.4) in winter as compared to the reference site. This downstream deterioration can possibly be attributed to the fact that this site is located below Ugie town and receiving urban runoff. However this pattern was not evident during the spring survey as both the macroinvertebrate and habitat results were similar between these two sites. Macroinvertebrate diversity (reflected by SASS scores) and sensitivity (reflected by ASPT scores) was lower during the spring survey as compared to the winter survey. This can be attributed to a reduction in habitat quality (reflected by IHAS scores) (Table 4.4) and water quality reflected by physical variables measured at this site (Table 4.6). ANOSIM undertaken to assess whether there were any significant differences between the two seasons sampled at this site in terms of macroinvertebrate faunal composition, revealed that there were significant differences between the sampling seasons (Table 4.5). SIMPER revealed that significant differences between the two seasons could be ascribed to families such as simuliids, heptageniids, gyrinids, naucorids, dixids and aeshinids, which were encountered during the winter survey but not encountered during the spring surveys, and families such as culicids, hydracarinas and planorbids which were only encountered during the spring survey at this site (Appendix 6). ANOSIM also indicated no significant differences in terms of faunal composition between biotopes sampled at this site. The water quality category for this site based on average ASPT score was Good (Table 4.7).

Gatberg River

Site 2

This site, selected as a reference site for the Gatberg River had higher SASS and ASPT scores in winter compared to Site 5, the monitoring for this river, even though the IHAS scores at this site were lower than those recorded at Site 5 (Table 4.4). In spring the SASS and ASPT scores were similar at the two sites although the IHAS scores remained higher at Site 5. These results suggest that Site 5 has better habitat quality than Site 2. The physical variables measured at the site suggest the downstream reduction observed in macroinvertebrate scores during winter is likely to be attributable to reduction in water quality further downstream on the Gatberg River (Table 4.6). Site 2 had higher SASS and ASPT scores in winter than in spring although the habitat scores were higher in spring (Table 4.4). Water quality variables such as temperature, pH and electrical conductivity were higher and dissolved oxygen level lower in spring than in winter. This suggests possible water quality deterioration in spring, which can be attributed to the observed reduction in flow and is reflected in the lower in macroinvertebrate diversity and sensitivity (Appendix 6). ANOSIM undertaken to assess whether there were any significant differences between the two seasons sampled at this site in terms of macroinvertebrate faunal composition, revealed no significant differences despite the reduced scores during the spring survey (Table 4.5). ANOSIM indicated that the stones biotope was significantly different to both vegetation and GSM biotopes. SIMPER revealed that significant differences between the stones and the vegetation biotopes could be ascribed to families such as potamonautids, hydropsychids, tricorythids, leptophlebids, ancylids and hydracarinas, which were recorded from stones biotope but absent from the vegetation biotope, and families such as coenagrionids, dytiscids, hydrophilids, leptocerids and notonectids which were recorded from the vegetation biotope but absent from the stones biotope. SIMPER revealed that significant differences between the stones and GSM biotopes could be ascribed to hydropsychids, elmids, tricorythids, leptophlebids, and aeshinids which were recorded from the stones biotope but absent from the GSM biotpe, and families such as gomphids and oligochaetes recorded from the GSM biotope but absent from the stones biotope. The water quality category for this site based on average ASPT score was Fair (Table 4.7).

Site 5

This monitoring site on the Gatberg River had lower SASS and IHAS scores in spring than in winter, although the ASPT score remained the same (Table 4.4). Physical variables measured also suggested water quality deterioration in spring (Table 4.6). This suggests that although the observed reduced flow in spring may have resulted in the reduction of both habitat and water quality, the sensitivity of organisms was not affected despite the overall reduction in macroinvertebrate diversity. ANOSIM undertaken to assess whether there were any significant differences between the two seasons sampled at this site in terms of macroinvertebrate faunal composition, revealed no significant difference (Table 4.5). ANOSIM indicated that significant differences existed between all three macroinvertebrate biotopes sampled at this site. SIMPER revealed that signicant differences between the stones and vegetation biotopes could be ascribed to families such as leptophlebiids, hydropsychids, turbellarians, potamonautids and dytiscids recorded from the stones biotope but absent from the vegetation biotope and families such as coenagrionids, hydrophilids, gyrinids and ceratopogonids which were recorded from the vegetation biotope, and absent from the stones biotope. Significant differences between the stones and the GSM biotope could be ascribed to families such as tricorythids, hydropsychids, potamonautids, dytiscids, elmids and simuliids recorded from the stones biotope but absent from the GSM biotope and families such as hydrophilids, gomphids, corixids, tipulids and pleids recorded from the GSM biotope, and absent from the stones biotope. Significant differences between the vegetation and GSM biotopes could be ascribed to families such as simuliids, coenagrionids, gyrinids, ancylids, ceratopogonids, elmids and vellids recorded from the vegetation biotope and absent from the GSM biotope, and families such as leptophlebiids, gomphids, tipulids, pleids and oligochaetes recorded from the GSM biotope and absent from the vegetation biotope. The water quality state for this site based on average ASPT score was fair (Table 4.7).

Gqaqala River

Site 6

This site, selected as a reference site on the Gqaqala River did not perform as an appropriate reference for comparison with Site 8, a monitoring site on the river. Site 6 had lower habitat quality (IHAS scores) and reduced macroinvertebrate diversity (SASS) and sensivity (ASPT) than Site 8 during both sampling seasons (Table 4.4). The measured water quality variables (Table 4.6) however, suggested better water quality at Site 6 than Site 8 and this suggests that habitat quality is the major contributing factor to lower macroinvertebrate scores observed at Site 6. IHAS and ASPT scores were reduced at Site 6 during the spring survey, although the SASS scores improved as compared to winter. Water quality (Table 4.6) was also reduced in spring compared to winter at this site. This suggests that the observed reduced flow in spring negatively affected both habitat and water quality and resulted in lower macroinvertebrate diversity dominated by tolerant families such as ceratopogonids, culicids, chironomids, tipulids, oligochaetes and others (Appendix 6). ANOSIM indicated that significant differences in terms of faunal composition and abundance existed between seasons sampled and macroinvertebrate biotopes sampled at this site

(Table 4.5). SIMPER revealed that significant differences between seasons could be ascribed to families such as notonectids, hydrophilids, pleids, hydropyschids, dytiscids, corixids and nepids encountered during the winter survey, but absent during the spring survey and families such as elmids, gyrinids and coenagrionids encountered only during the spring survey (Appendix 6). Significant differences between the stones and the vegetation biotope could be ascribed to families such as vellids, potamounautids, ancylids, gerrids and nepids recorded from the vegetation biotope but absent from the stones biotope. Significant differences between the stones biotope and GSM biotope could be ascribed to families such as vellids, pleids, hydropsychids, dytiscids and coenagrionids which were recorded from the GSM biotope, but absent from the stones biotope and families such as corixids, oligochaetes, leptophlebiids, caenids and elmids which were recorded from the stones biotope, but absent from the GSM biotope. Significant differences between vegetation and GSM biotopes could be ascribed to families such as hydropsychids, nepids, elmids, caenids, and leptophlebiids which were recorded from the vegetation biotope, but absent from the GSM biotope, and families such as naucorids and simuliids which were recorded from the GSM biotope, but absent from the vegetation biotope. The water quality category for this site based on average ASPT score was Fair (Table 4.7).

Site 8

This site selected as a monitoring site on the Gqaqala River, had reduced SASS, ASPT and IHAS scores in spring as compared to the winter survey (Table 4.4). Water quality variables measured at the site indicated poor in water quality parameters during spring, compared to the winter survey results (Table 4.6). The reduction in both habitat and water quality, which resulted in reduced macroinvertebrate diversity and sensitivity, can be attributed to the observed reduced flow during the spring survey. ANOSIM indicated that significant differences in terms of faunal composition and abundance existed between seasons sampled and macroinvertebrate biotopes sampled at this site (Table 4.5). SIMPER revealed that significant differences between seasons could be ascribed to families such as aeshnids, hydropyschids, gyrinids, planorbids and hydrophilids encountered during the winter survey but absent during the spring survey and families such as pleids, corixids and oligochaetes encountered only during the spring survey (Appendix 6). Significant differences between the stones and the vegetation biotope could be ascribed to families such as dytiscids, coenagrionids, notonectids, lestids, corixids and hydrophilids recorded from the vegetation biotope but absent from the stones biotope, and families such as gomphids, turbellarias, planorbids, and hydropsychids recorded from the stones biotope but absent from the vegetation biotope. Significant differences between vegetation and GSM biotopes could be ascribed to families such as dytiscids, coenagrionids, hydrophilids, notonectids, aeshnids, platycnemids, lestids, elmids and potamonautids recorded from the vegetation biotope but absent from the GSM biotope, and families such as gomphids and turbellarias recorded from the GSM biotope but absent from the vegetation biotope. The water quality category for this site based on average ASPT score was Fair (Table 4.7).

Umnga River

Site 7

This site, selected as a reference site on the Umnga River, performed as an appropriate reference site in winter with higher macroinvertebrate scores (SASS5 and ASPT) and habitat (IHAS) scores compared to a monitoring site selected on this river, i.e. Site 9 (Table 4.4). During the spring survey when the flow was lower, this site had lower macroinvertebrate scores (SASS and ASPT) than Site 9 although the habitat scores were similar to the winter survey. The measured water quality variables indicated downstream deterioration in water quality from Site 7 to 9 during both sampling seasons. These variables also indicated that there was water quality reduction during the spring survey as compared to the winter survey and this is possibly related to the observed reduced flow (Table 4.6). ANOSIM indicated that significant differences in terms of faunal composition and abundance existed between the two seasons sampled at this site. SIMPER revealed that significant differences between seasons could be ascribed to families such as naucorids, hydropsychids, tabanids, aeshnids, gyrinids and leptophlebiids encountered during the winter survey but absent during the spring survey, and families such as corixids, culicids, pleids, notonectids and muscids encountered only during the spring survey (Appendix 6). ANOSIM indicated no significant differences between biotopes sampled at this site in terms of faunal composition. The water quality category for this site based on average ASPT score was Fair (Table 4.7).

Site 9

This site, selected as a monitoring site on the Umnga River, had higher IHAS and ASPT scores in winter than during the spring survey but higher SASS scores in spring than in winter. Physical water quality variables such as temperature, pH and electrical conductivity were higher in spring than in winter and the dissolved oxygen levels was lower in spring than in winter (Table 4.4). This suggests possible water quality deterioration during the spring survey. Reduction in water quality in spring may be linked to the observed reduced flow, which may have resulted in the reduction in both habitat and water quality that resulted in an increased diversity of tolerant families. ANOSIM indicated that significant differences in terms of faunal composition and abundance existed between seasons sampled and macroinvertebrate biotopes sampled at this site (Table 4.5). SIMPER revealed that significant differences between seasons could be ascribed to families such as poriferas and gyrinids encountered during the winter survey but absent during the spring survey, and families such as coenagrionids, pleids, hydropsychids and hydracarinas encountered only during the spring survey (Appendix 6). Significant differences between the stones and the vegetation biotope could be ascribed to families such as planorbids, notonectids, hydrophilids, ancylids and leptocerids recorded from the vegetation biotope but absent from the stones biotope, and families such as chironomids, hydropsychids and naucorids recorded from the stones biotope but absent from the vegetation biotope. Significant differences between the stones and the GSM biotope could be ascribed to families such as caenids, poriferas, simuliids, libellulids and gyrinids recorded from the stones biotope but absent from the GSM biotope. Significant differences between vegetation and GSM biotopes could be ascribed to families such as vellids, dytiscids, gyrinids, notonectids, hydrophilids, libellulids, leptophlebiids, simuliids and pleids which were recorded from the vegetation biotope but absent from the GSM biotope. The water quality state for this site based on average ASPT score was Fair (Table 4.7).

Inxu River lower catchment

Site 10

This site, selected as a reference site for the Inxu River in the lower catchment to which Site 11 and 12 could be compared and a reference site above the sacred pools, performed as an appropriate reference site particularly in winter with the highest ASPT scores relative to all the sampling sites. SASS and ASPT scores were lower in spring than during the winter survey although the IHAS scores improved slightly (Table 4.4). The measured water quality variables indicated water quality reduction during the spring survey to which the reduction in macroinvertebrate scores could be attributed (Table 4.6). ANOSIM indicated no significant differences between sampled seasons and macroinvertebrate biotopes sampled at this site. The water quality category for this site based on average ASPT score was Good (Table 4.7).

Site 11

Reduction in SASS and ASPT scores at this site selected as a monitoring site on the Inxu River for the lower catchment and below the sacred pools, can be attributed to the fact that this site is exposed to sources of impacts such as extensive erosion and agriculture in the area. Inflow from the tributaries cannot be excluded, as this site is located below the confluences with the Gatberg, Gqaqala and Umnga rivers. The observed reduced flow during the spring survey possibly exacerbated the conditions resulting in lower habitat and macroinvertebrate scores (Table 4.4) as compared to Site 10. The measured water quality variables suggested poor water quality in spring (Table 4.6) and this suggests that the reduction in flow negatively impacted on both water and habitat quality. ANOSIM indicated that significant differences in terms of faunal composition and abundance existed between seasons sampled and macroinvertebrate biotopes sampled at this site (Table 4.5). SIMPER revealed that significant differences between seasons could be ascribed to families such as oligochaetes, hydrophilids, hydropsychids, simuliids, prosopistomatids, aeshnids, and gyrinids encountered during the winter survey but absent during the spring survey, and families such as planorbids, notonectids, coeonagrionids, vellids and corixids encountered only during the spring survey (Appendix 6). Significant differences between the stones and the vegetation biotope could be ascribed to families such as simuliids, prosopistomatids, aeshnids, gomphids, tricorythids, leptophlebiids and gomphids recorded from the stones biotope but absent from the vegetation biotope and families such as planorbids, notonectids, coenagrionids, leptocerids, dytiscids and hydracarinas recorded from the vegetation biotope but absent from the stones biotope. Significant differences between the stones and the GSM biotope could be ascribed to families such as tricorythids, prosopistomatids, aeshnids, simuliids, vellids, elmids, pleids, gyrinids and leptophlebiids recorded from the stones biotope but absent from the GSM biotope. Significant differences between vegetation and GSM biotopes could be ascribed to families such as planorbids, notonectids, coenagrionids, leptocerids, dytiscids, hydracarinas, vellids, pleids and chironomids which were recorded from the vegetation biotope but absent from the GSM biotope. The water quality category for this site based on average ASPT score was Fair (Table 4.7).

Site 12

This site located as the second monitoring site in the lower Inxu River catchment, had reduced macroinvertebrate and habitat scores as compared to the reference site, Site 10. This can possibly be attributed to longitudinal influence, as this site is located further downstream on the Inxu River. SASS and IHAS scores at this site were lower in spring than in winter, although the ASPT scores were higher in spring (Table 4.4). This improvement in ASPT scores could be attributable to sensitive families such prosopistomatids, heptageniids and chlorocyphids recorded during the spring survey (Appendix 6) that were not encountered during the winter survey. The physical water quality variables indicated water quality deterioration during the spring survey as compared to winter and this is possibly due to the observed reduced flow (Table 4.6). Reduced macroinvertebrate diversity observed in spring is due to both reductions in habitat and water quality. ANOSIM indicated that significant differences in terms of faunal composition existed between seasons sampled and macroinvertebrate biotopes sampled at this site (Table 4.5). SIMPER revealed that significant differences between seasons could be ascribed to families such as oligochaetes, hydropsychids, simuliids, platycnemids dytiscids and turbellarias encountered during the winter survey but absent during the spring survey and families such as chlorocyphids only encountered during the spring survey (Appendix 6). Significant differences between the stones and the vegetation biotopes could be ascribed to families such as coenagrionids, vellids, leptocerids, caenids, hydrophilids, chlorocyphids, corixids and perlids recorded from the vegetation biotope but absent from the stones biotope and families such chironomids, prosopistomatids and leptophlebiids recorded from the stones biotope but absent from the vegetation biotope. Significant differences between the stones and the GSM biotope could be ascribed to families such as tricorythids, prosopistomatids, aeshnids, hydropsychids, vellids, elmids, pleids, corixids, leptophlebiids and libellulids recorded from the stones biotope but absent from the GSM biotope. Significant differences between vegetation and GSM biotopes could be ascribed to such as tricorythids, libellulids, aeshnids, simuliids, vellids, elmids, gyrinids and leptocerids, naucorids and coenagrionids recorded from the vegetation biotope but absent from the GSM biotope. The water quality category for this site based on average ASPT score was Good (Table 4.7).

Table 4.4 Total site, as well as individual biotope, SASS scores, number of taxa and ASPT scores recorded at each site for each sampling season conducted on the Inxu River and its tributaries are shown. IHAS score for each site during each sampling season has been included. Blank cells indicate a biotope was not available for sampling. S=stones, VG= vegetation and GSM= gravel, sand and mud.

	Winter			**Spring**		
	SASS	**No. of taxa**	**ASPT**	**SASS**	**No. of taxa**	**ASPT**
Site 1						
Stones	99	13	7.6	123	20	6.2
Vegetation	88	15	5.9	73	13	5.6
GSM	82	14	5.9	93	14	6.6
Total Site Score	159	24	6.6	131	23	5.7
IHAS	80			60		
Site 3						
Stones	103	16	6.4	94	14	6.2
Vegetation	97	16	6.1	48	8	6
GSM	78	14	5.6	38	8	4.9
Total Site Score	168	28	6	107	18	5.9
IHAS	59			67		
Site 4						
Stones	75	12	6.3	83	13	6.4
Vegetation	87	15	5.8	74	14	5.3
GSM	88	14	6.3	51	10	5.1
Total Site Score	117	19	6.2	108	18	6
IHAS	73			62		
Site 2						
Stones	60	10	6.2	74	12	6.2
Vegetation	94	18	5.2	42	9	4.7
GSM	29	6	4.8	41	8	5.1
Total Site Score	125	22	5.7	80	15	5.3
IHAS	53			60		

	Winter			Spring		
	SASS	No. of taxa	ASPT	SASS	No. of taxa	ASPT
Site 5						
Stones	57	9	6.3	69	11	6.3
Vegetation	48	9	5.3	61	12	5.1
GSM	49	10	4.9	47	10	4.9
Total Site Score	105	18	5.3	85	16	5.3
IHAS	74			69		
Site 6						
Stones	42	7	6	78	15	5.2
Vegetation	40	9	5	70	15	4.7
GSM	23	5	4.6	35	10	3.5
Total Site Score	77	12	6.4	86	19	4.5
IHAS	58			52		
Site 8						
Stones	84	15	5.6	74	13	5.7
Vegetation	83	14	5.9	72	14	5.1
GSM	57	9	6.3	47	10	4.7
Total Site Score	134	22	6.1	112	20	5.6
IHAS	66			60		
Site 7						
Stones	96	15	6.4	63	13	4.2
Vegetation	62	13	4.8	54	13	4.2
GSM	64	11	5.8	29	8	3.6
Total Site Score	140	20	7	79	19	4.2
IHAS	69			64		

	Winter			Spring		
	SASS	No. of taxa	ASPT	SASS	No. of taxa	ASPT
Site 9						
Stones	58	9	6.4	85	16	5.3
Vegetation	67	14	4.9	72	15	4.8
GSM	25	5	5	24	6	4
Total Site Score	103	17	6.1	110	21	5.2
IHAS	61			59		
Site 10						
Stones	102	14	7.3	93	15	6.2
Vegetation	69	12	5.8	87	15	5.8
GSM	77	14	5.5	45	10	4.5
Total Site Score	146	20	7.3	136	24	5.7
IHAS	64			68		
Site 11						
Stones	93	13	7.2	68	12	5.7
Vegetation				56	12	4.7
GSM	28	6	4.7	26	5	5.2
Total Site Score	109	16	6.8	90	18	5
IHAS	60			55		
Site 12						
Stones	98	14	7	81	12	6.8
Vegetation	90	15	6	59	10	5.9
GSM	38	8	4.8	10	2	5
Total Site Score	145	23	6.3	99	14	7.1
IHAS	63			54		

Table 4.5 Analysis of similarities between biotopes and seasons for each site sampled on the Inxu River.

Site 1					
Biotopes			**Seasons**		
*** Different**	**Biotopes different**	**Average dissimilarity**	*** Different**	**Seasons different**	**Average dissimilarity**
Yes	S and VG	59.72	No		
	VG and GSM	62.13			
Site 3					
No			No		
Site 4					
No			Yes	Wi and Sp	62.16
Site 2					
Yes	S and VG	63.03	No		
	VG and GSM	62.10			
Site 5					
Yes	S and VG	66.61	No		
	S and GSM	67.50			
	VG and GSM	65.21			
Site 6					
Yes	S and VG	65.53	Yes	Wi and Sp	71.39
	S and GSM	61.35			
	VG and GSM	69.79			
Site 8					
Yes	S and VG	58.55	Yes	Wi and Sp	59.25
	VG and GSM	62.66			
Site 7					
No			Yes	Wi and Sp	58.30

Site 9					
Biotopes			**Seasons**		
*** Different**	**Biotopes different**	**Average dissimilarity**	*** Different**	**Seasons different**	**Average dissimilarity**
Yes	S and VG	66.85	Yes	Wi and Sp	77.55
	S and GSM	84.85			
	VG and GSM	88.03			
Site 10					
No			No		
Site 11					
Yes	S and VG	71.63	Yes	Wi and Sp	75.81
	S and GSM	75.32			
	VG and GSM	89.93			
Site 12					
Yes	S and VG	65.89	Yes	Wi and Sp	64.63
	S and GSM	63.78			
	VG and GSM	75.00			

Table 4.6 Measurements of water quality variables recorded during two biomonitoring surveys conducted on the Inxu River. S: Spring, W: Winter EC: electrical conductivity (mS/m), Temp: temperature (^{o}C), DO: dissolved oxygen (mg/l).

Site	**1**		**2**		**3**		**4**		**5**		**6**		**7**		**8**		**9**		**10**		**11**		**12**	
Season	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S
EC	7.07	7.76	6.02	5.38	6.28	6.81	6.53	7.56	3.86	5.59	5.77	17.4	13.5	16.6	13.5	30.2	12.9	22.8	5.41	6.79	8.88	13.5	10.5	18.3
pH	6.31	8.16	6.3	7.29	6.49	8.58	6.41	9.93	6.22	8.26	6.21	7.4	6.73	8.52	7.36	8.86	6.85	8.7	6.45	8.64	7.02	7.8	7.04	8.44
Temp	8	21	10	20	10	22	7	21	11	22	7	23	8	22	11	27	12	29	11	21	13	25	10	27
DO	11.8	8.05	9.9	8.85	12.6	8.43	11.1	12.8	12	8.42	11.2	6.17	9.97	9.96	14.2	8.64	11.1	8.64	9.68	9.85	12.9	6.91	11.9	9.88

Table 4.7 Seasonal and overall water quality categories based on the Reserve water quality present state assessment method (Palmer *et al*., 2004).

Site	**Reference/Monitoring**	**Winter**	**Spring**	**Site average**
1	Reference site	Good	Fair	Good
2	Reference site	Fair	Fair	Fair
3	Monitoring site	Good	Fair	Good
4	Monitoring site	Good	Good	Good
5	Monitoring site	Fair	Fair	Fair
6	Reference site	Good	Poor	Good
7	Reference site	Natural	Poor	Fair
8	Monitoring site	Good	Fair	Fair
9	Monitoring site	Good	Fair	Fair
10	Reference site	Natural	Fair	Good
11	Monitoring site	Good	Fair	Fair
12	Monitoring site	Good	Natural	Good

4.5.2 Fish assessment

Introduction

Historical data obtained from South African Institute of Aquatic Biodiversity (SAIAB) indicated that there was four fish species previously recorded in the Inxu River catchment of which only one species (*Barbus anoplus*) is indigenous (Table 4.8). During this study one more alien species (*Micropterus salmoides*) was added to the species list (Table 4.8). No fish species were recorded at most sites and a trend that was observed was that for sites where alien species were recorded, the indigenous *Barbus anoplus* was not encountered (Appendix 7). Low fish diversity, and therefore low FAII scores at all sites can be attributed to both alien species that tend to outcompete indigenous for food and space (Skelton, 2001), as well as low efficiency of the sampling methods.

Inxu River upper catchment (Sites 1, 3 and 4)

The alien trout species *Oncorhynchus mykiss* was the only fish species encountered in the Inxu River upper catchment sites (1, 3 and 4) in both sampling seasons (Appendix 7). The indigenous *Barbus anoplus* was expected as it is widely distributed within this catchment under natural conditions (Bok P, Anton Bok & Associates, Port Elizabeth, pers.comm., 2003). One of the contributors to its absence at all these three sites could be the presence of the alien trout species, which not only prey on the *Barbus* species but also outcompete indigenous fish for available food and habitat (Skelton, 2001). The assessments for all three sites were a critically modified assessment class (F category) with an FAII score being zero as the alien species are not included in the FAII calculation (Table 4.9).

Gatberg River (Sites 2 and 5)

There were no fish species recorded at either site (2 and 5) selected on the Gatberg River during both sampling seasons (Appendix 7). Records from SAIAB indicate that the indigenous *Barbus anoplus* has been previously encountered in the Gatberg River. These sites fell within a critically modified assessment class (F category) (Table 4.9).

Gqaqala River (Sites 6 and 8)

The indigenous *Barbus anoplus* was encountered at both sites (6 and 8) selected on the Gqaqala River during both sampling surveys (Appendix 7). The substrate in this river was mostly bedrock and boulders, which possibly provided a good habitat for *Barbus anoplus*. Highest number of fish individuals caught for both sampling seasons was recorded at Site 6. Juveniles were among the individuals caught and there were some juveniles indicating some recruitment at both sites. Site 6 fell within a natural assessment class (A category) and site 8 fell within a largely modified assessment class (D category) (Table 4.9).

Umnga River (Sites 7 and 9)

The indigenous *Barbus anoplus* was encountered during both surveys at Site 7 located in the upper reaches of Umnga River (Appendix 7). The alien bass species, *Micropterus salmoides,* was the only species recorded during the winter survey at Site 9, and the alien trout species *Oncorhynchus mykiss* was the only species recorded at this site during the spring survey (Appendix 7). Site 7 fell within a natural assessment class (A category) and Site 9 fell within a critically modified assessment class (F category) (Table 4.9).

Inxu River lower catchment (Sites 10, 11 and 12)

The bass species *Micropterus punctulatus* was the only fish species recorded at sites 10 and 11 during the spring survey, and *Micropterus salmoides* was the only species recorded at these sites during the winter survey (Appendix 7). There were no fish species recorded at Site 12 during either sampling surveys. The indigenous *Barbus anoplus* and *Anguilla mossambica* were two species expected in the Inxu River lower catchment (Bok P, Anton Bok & Associates, Port Elizabeth, pers.comm., 2003). Absence of these species may be attributed to presence of alien species and the limited efficiency of sampling equipment. For example, *Anguilla mossambica* was spotted in between rocks at Site 11 whilst sampling during the spring survey. This fish could not be caught as it disappeared in the turbid water. All three sites selected in the lower catchment fell within the critically modified category (F category) (Table 4.9).

Table 4.8 Comparison between fish species previously recorded on the Inxu River and its tributaries, and fish species recorded during the 2003 survey.

Species name	**Indigenous or Alien**	**2003 survey**	**River where recorded**	**Previously**	**River where recorded**
Barbus anoplus	I	P	Gqaqala, Umnga	P	Gatberg
Micropterus punctulatus	A	P	Inxu	P	Inxu
Micropterus salmoides	A	P	Umnga	-	-
Oncorhynchus mykiss	A	P	Inxu	P	Inxu

Table 4.9 Seasonal FAII scores, class categories and overall site assessment based on FAII scores per site.

Site	**Seasons**	**FAII Scores**	**Seasonal Categories**	**Overall Category**	**Corresponding RHP Class**
1	Winter	0	F	F	POOR
	Spring	0	F		
2	Winter	0	F	F	POOR
	Spring	0	F		
3	Winter	0	F	F	POOR
	Spring	0	F		
4	Winter	0	F	F	POOR
	Spring	0	F		
5	Winter	0	F	F	POOR
	Spring	0	F		
6	Winter	100	A	A	NATURAL
	Spring	100	A		
7	Winter	100	A	A	NATURAL
	Spring	100	A		
8	Winter	48	D	D	FAIR
	Spring	48	D		
9	Winter	0	F	F	POOR
	Spring	0	F		
10	Winter	0	F	F	POOR
	Spring	0	F		
11	Winter	0	F	F	POOR
	Spring	0	F		
12	Winter	0	F	F	POOR
	Spring	0	F		

4.5.3 Water quality

The available water quality data from DWAF for the Inxu River catchment was from two gauging weirs: T3H011, a monitoring point below Ugie Town (Site 4); and T3H014, a monitoring point above Site 12. Data records from T3h011 are from 1980 to 1982 and data records from T3H014 are from 1995 and 2001. In 2003 when the water quality data from these weirs were requested from DWAF, these weirs were both dysfunctional. The method used to analyse the selected water quality data is that used for Ecological Water Requirements (Rivers) assessments (Palmer *et al*., 2004). The variables assessed included pH, Total Inorganic Nitrogen (TIN), Soluble Reactive Phosphate (SRP), Electrical conductivity (EC) and fluoride (F). T3H011 data indicated an unimpacted assessment relative to default benchmark boundary tables with pH, TIN, EC and F falling within a Natural category and SRP falling within a Good category (Table 4.10). The water quality might have changed as this assessment is based on data from 1980-1982, before activities such as afforestation in the area. It may be possible that the present water quality conditions below Ugie Town would have changed. This assessment is therefore of low confidence. T3H014 data also showed least impacted conditions relative to the benchmarks with pH, F and EC falling within a Natural category and SRP and TIN falling within a Good category (Table 4.10). The data records from this monitoring point are from 1995 to 2001. Institution of the monitoring points on the Inxu River tributaries (Gatberg, Gqaqala and Umnga) and the initiation of regular monitoring at T3h011 and T3H014 is recommended.

4.5.4 Geomorphological assessment

Introduction

A description of the impact classess on which sites were categorised is detailed in Table 2.3. This assessment was done under the leadership of Leanne Du Preez of the Geography Department, Rhodes University.

Inxu River upper catchment

Site 1

Both riverbanks can be classified as moderately stable although slumping has occurred on both banks. Localised gabions, a bridge with in-channel supports, alien vegetation (pine plantations) and few sediment sources related to human activity were the impacts noted at this site. This site is probably susceptible to floods due to willow trees on both banks. This site fell within a C impact class.

Site 3

Both riverbanks can be classified as highly stable and this can be attributed to pine plantantions along the riverbanks. Extensive pine plantations and a bridge with in-channel supports were the impacts noted around this site. This site fell within a C impact class.

Site 4

Both riverbanks can be classified as moderately stable although the banks have slumped due to grazing impacts. Other impacts noted around this site were infrequent causeways, a road, recent riparian vegetation clearance, extensive grazing, erosion the presence and alien vegetation. This site fell within a C to D impact class.

Gatberg River

Site 2

Both riverbanks can be classified as highly stable. A bridge with side supports, extensive pine plantations and few sediment sources related to human impacts were the impacts noted around this site. This site fell within a B - C impact class.

Site 5

Both riverbanks can be classified as highly stable. This site was least impacted of all sites geomorphologically, with a small bridge with in-channel support the only impacted noted. This site fell within a B impact class.

Gqaqala River

Site 6

Both riverbanks can be classified as highly stable and this can be attributed to the bedrock substrate, which dominated the reach. There were no obvious geormorphological impacts observed at this site. This site fell within a B impact class.

Site 8

Similarly to Site 6 both riverbanks can be classified as highly stable due to bedrock substrate. A small bridge was the only geomorphological impact noted at this site. This site fell within a B impact class.

Umnga River

Site 7

Both riverbanks can be classified as moderately stable. A strong bedrock influence has stabilised the leftbank, which should be very unstable due to gully formation. Impacts noted around this site were overgrazing, a bridge with in-channel supports, and extensive sediment sources related to human impacts. This site fell within a C - D impact class.

Site 9

Stability on both riverbanks can be classified as moderate to low. This is due to extensive erosion and gully formation. Impacts noted around this site include extensive gully formation and erosion, a bridge with in-channel supports, overgrazing and extensive sediment sources related to human impacts. This site fell within a C to D impact class.

Inxu River lower catchment

Site 10

Stability on both riverbanks can be classified as moderate. Impacts noted around this site include recent riparian vegetation clearance, bridges with in-channel supports, gully formation and extensive sediment sources related to human activities. This site fell within a C -D impact class.

Site 11

The left bank was not stable and the right bank was unstable due to extensive erosion along this site that has led to the formation of extensive gullies. Overgrazing and extensive sediment sources related to human impacts are noted impacts. This site fell within a D impact class.

Site 12

Bank stability on both banks can be classified as low due to the presence of gullies and slumps along both riverbanks. Impacts noted included extensive erosion, a bridge with in-channel supports and extensive sediment sources related to human impacts. This site fell within a D impact class.

Table 4.10 Summary of the present ecological state assessment for each site sampled on the Inxu River and its tributaries. (TIN= Total Inorganic Nitrogen; SRP= Soluble Reactive Phosphate; EC = Electrical Conductivity. ND indicates that the data for that particular variable was not available.

Variables	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12
pH	ND	ND	ND	Natural	ND	ND	ND	ND	ND	ND	ND	Natural to Good
EC	ND	ND	ND	Natural	ND	ND	ND	ND	ND	ND	ND	Good
TIN	ND	ND	ND	Natural	ND	ND	ND	ND	ND	ND	ND	Natural
SRP	ND	ND	ND	Good	ND	ND	ND	ND	ND	ND	ND	Good
F	ND	ND	ND	Natural	ND	ND	ND	ND	ND	ND	ND	Natural
ASPT score	Good	Fair	Good	Good	Fair	Good	Fair	Fair	Fair	Good	Fair	Good
Overall water quality assessment	Good	Fair	Good	Good	Fair	Good	Fair	Fair	Fair	Good	Fair	Good
FAII category	F (Poor)	F (Poor)	F (Poor)	F (Poor)	F (Poor)	A (Natural)	A (Natural)	D (Fair)	E (Poor)	F (Poor)	F (Poor)	F (Poor)
GI impact class	C (Good)	B/C (Good)	C (Good)	C/D (Fair)	B (Good)	B (Good)	C (Good)	B(Good)	C/D (Fair)	C/D (Fair)	D (Fair)	D (Fair
Overall site health	Good to Fair	Fair	Good to fair	Fair	Fair	Good	Good	Fair	Fair to Poor	Fair	Fair to Poor	Fair

4.5.5 Overall health

Introduction

The overall water quality assessment for sites with no available physico-chemical was based on average macroinvertebrate ASPT scores, one of the biotic response indicators used for the present state assessment of water quality assessment in Ecological Water Requirements (Rivers) assessments (Palmer *et al*., 2004).

Inxu River upper catchment (Sites 1, 3 and 4)

The overall ecological health of sites 1 and 3 can be classified as Good to Fair. The fish assessments at both these sites indicated that fish assemblages were in poor health, although geomorphologically and based on macroinvertebrate communities, these sites were in good health (Table 4.10). However, Site 4 located below Ugie Town can be classified as a Fair. Although this site indicated good water quality based on its macroinvertebrate assessment, its fish assemblages were in a poor state and the geomorphology was Fair (Table 4.10).

Gatberg River (Sites 2 and 5)

Both sites 2 and 5 located on the Gatberg River can be classified as being in a Fair ecological state. These sites were in good health geomorphologically but the state of macroinvertebrate communities was Fair health and the fish assemblages Poor (Table 4.10).

Gqaqala River (Sites 6 and 8)

Site 6 located on the upper reaches of the Umnga River, can be classified as being in Good health. This is due to the fact that fish assemblages at this site were in a Natural state with macroinvertebrate communities and geomorphology being in Good health. However, Site 8 located in the lower reaches of this river, was in a Fair ecological state. This is due to the fact that the state of macroinvertebrate communities and fish assemblages was Fair while the geomorphological assessment was in a good category (Table 4.10).

Umnga River (Sites 7 and 9)

Site 7 located on the upper reaches of the Umnga River can be classified as being in good ecological health. This is due to the fact that fish assemblages at this site were in a Natural state with macroinvertebrate communities indicating fair health and the site being geomorphologically intact (Good state). However, Site 9 located in the lower reaches of this river and just above the confluence with the Inxu River was in a Fair to Poor ecological state. This site had macroinvertebrate communities in a Fair category a Fair geormophological status and Poor fish assemblages (Table 4.10).

Inxu River lower catchment (Sites 10, 11 and 12)

The overall ecological health of sites 10 and 12 can be classified as Fair. Although these sites had macroinvertebrate communities that were in a Good state their fish assemblages were in a Poor state and the geomorphological status was Fair health. Site 11 can be classified as being in a Fair to Poor ecological state. This site is located below the sacred pools and below the confluences with Umnga and Gqaqala rivers. The geomorphological and macroinvertebrate status of this site was Fair health and the fish assemblages being Poor.

4.6 DISCUSSION

4.6.1 Macroinvertebrate assessment

Replication

Three macroinvertebrate replicates were taken per biotope on selected reference and monitoring sites for both the upper and lower catchments. This was conducted to assess the representativeness of the SASS5 technique. During the winter survey replicates were taken only from the stones biotope and for the spring surveys replicate samples were taken from all three macroinvertebrate biotopes. Differences in SASS5 scores for replicate samples taken during spring and winter surveys are presented in Tables 4.2 and 4.3 respectively. Different SASS5 scores between replicates taken during spring and winter are the results of different taxa recorded between these replicates; taxa recorded are shown in Appendices 4 and 5 respectively. For replicate samples taken during the winter survey multivariate analyses were undertaken for all the replicates samples taken from all the replicated sites combined due to the fact that it was not possible to undertake analyses per site due to a small sample size. ANOSIM undertaken for winter replicates indicated that there were no significant differences between replicates taken from the stones biotope from selected sites (1, 10 and 11) in terms of faunal composition.

For replicates taken during the spring survey multivariate analyses was undertaken at site level with all biotopes combined as analyses were not possible at biotope level due to a small sample size. ANOSIM undertaken to assess whether there were any significant differences between replicates taken from the same biotope indicated that there were no significant differences between replicates in terms of faunal composition. Variability in SASS5 and ASPT scores between replicates is attributed to the fact that these scores are based on macroinvertebrate sensitivity scores. The presence of high or low-ranking families therefore has a large impact on total scores. As multivariate analyses assessed the faunal composition, the presence or absence of one or two families would not result in significant differences between replicates. These results then indicate that one sample per biotope per site, as prescribed by the SASS method, is representative of macroinvertebrate families present at that particular biotope at that time of sampling.

Biotopes

SASS5 scores presented in Table 4.4 indicate that there were differences between macroinvertebrates biotopes sampled within sampling sites. ANOSIM (Table 4.5) undertaken to assess whether these observed differences were significant in terms of faunal composition, revealed that these differences were significant. This was not unexpected as the macroinvertebrate biotopes differ in habitat conditions such as substrate, water velocity and inundation.

Seasonal differences

Assessment of the Inxu River catchment was conducted over two seasons, namely winter and spring. Three surveys were planned for this catchment, but an autumn survey could not be undertaken due to heavy rainfall, which made sampling impossible. ANOSIM performed to assess whether there were any significant differences between seasons sampled in terms of faunal composition, indicated that significant differences between seasons existed for the majority of sites existed (Table 4.5). Macroinvertebrate diversity (reflected in SASS5 scores) and sensitivity (reflected in ASPT scores) were lower during the spring survey (Table 4.4; Appendix 6). Habitat quality as reflected by the IHAS scores at most sites, was also poorer in spring (Table 4.4). Physico-chemical parameters measured at each sampling site for both sampling seasons also suggested possible reduction in water quality during the spring survey (Table 4.6). During the spring survey at most sites temperature, pH and electrical conductivity increased while dissolved oxygen levels were reduced (Table 4.6).

The observed reduction in SASS5 and ASPT scores (Table 4.4) can be attributed to reduction in both water and habitat quality during the spring survey. Water quality and habitat reduction can be ascribed to the observed reduced flows in spring. Afforestation, primarily pine plantations, is the major land-use, particularly in the upper catchment. Forsyth *et al*. (1997), commented that planted forests use proportionately more water during dry conditions than during moist conditions. Pine plantations may therefore have contributed to the reduced flow and hence water and habitat quality deterioration particularly during the dry spring conditions.

4.6.2 Fish assessment

Only four fish species were recorded during this study (Table 4.8; Appendix 7). A comparative summary of fish species previously recorded on the Inxu River and its tributaries (mainly the Gatberg) is presented in Table 4.8. The fish species that were previously recoreded were all encountered during this study with the addition of another bass species, *Micropterus salmoides.* The Inxu River system is naturally low in fish species (Bok A, Anton Bok & Associates, Port Elizabeth, pers comm., 2003) with only two fish species *Barbus anoplus* and *Anguilla mossambica* being indigenous to the system.

Low fish species diversity and abundances in this system are exacerbated by the presence of predacious and alien bass and trout species, which do not only prey on *Barbus anoplus* but also outcompete indigenous species for available food and habitat (Skelton, 2001). The maximum number of indigenous *Barbus anoplus* caught at a single site (Site 6) during the study was 19 individuals. According to Bok A of Anton Bok & Associates, Port Elizabeth, (pers. comm., 2003), under natural conditions the abundance of this species is more than a hundred individuals per site. Most sites fell within an F category (which is a critically modified impact class) (Table 4.9) according to Kleynhans's (1999) fish assessment classes. This is due to the fact that no fish were recorded at most sites and in some sites only alien were encountered (Appendix 7). The calculation of FAII is also dependent on the knowledge of expected (under natural conditions) fish species for that particular system. This is usually established through historical data. As historical data is often not available, expert judgement of species expected to occur in that particular system is often used (Kleynhans CJ, Resource Quality Services, DWAF, pers.comm., 2003). This might however underestimate or overestimate the number of fish species expected in a system.

Another contributing factor to low fish diversity is the efficiency of the fish sampling equipment. The seine net, which is used for slow flowing deeper habitats in could not be used, particularly in the lower catchment sites, as the substrate was predominatly boulders which snagged the seine net. The electroshocker that is prescribed to sample fast habitats was used to sample almost all available habitats. These resulted in species such as the indigenous eel *Anguilla mossambica,* not being caught although they were observed darting away from the electroshocker and were therefore not included in the FAII calculation assessment.

Site 10 located in the lower catchment on the Inxu River fell within a C/D modified class due to impacts such as erosion and bridge construction that has led to channel widening. Sites 11 and 12 located further downstream on the Inxu River fell into a D impact class indicating large modification. Both these sites are exposed to extensive erosion, which has led to gully formation, channel widening, and instability of riverbanks.

4.6.3 Water quality

Assessment of the selected physico-chemical variables from T3H011 and T3H014 indicated relatively unimpacted conditions relative to the benchmark boundary values provided in Palmer *et al*., 2004. Both these monitoring points are presently dysfunctional and these assessments therefore have to be interpreted with caution particularly for the present water quality assessment as it is based on early data. Reinstitution of monitoring at these points and institution of monitoring on the Inxu River tributaries is vital.

4.6.4 Geomorphological assessment

The Inxu River upper catchment sites (1 and 3) fell into a C impact class indicating moderate modification of the natural geomorphological state. This modification is primarily due to bridges with in - channel supports at these two sites. Site 4 fell within a C/D impact class due to overgrazing, riparian vegetation clearance and a path through the site that may have resulted in channel widening and instability of both riverbanks.

The Gatberg River sites (2 and 5) fell within a B/C and a B impact class respectively, indicating that although human impacts around them were noted they have no significant impact on the river channel and subsequent ecological health of the system. The Gqaqala River sites (6 and 8) fell within a B impact class. These sites are dominated by a bedrock substrate, which stabilizes the riverbanks.

Geomorphologically there were no significant human impacts noted at both these sites.

The Umnga River can be classified as moderately modified in the upper reaches (Site 9) due to impacts such as recent riparian vegetation clearance and a bridge that have resulted in channel widening. Site 11 located further downstream on this river is largely modified (impact class C/D) due to impacts such as extensive erosion and overgrazing that has led gully formation. This has led to channel widening and instability of the riverbanks.

4.6.5 Overall health

Sites 1 and 3 located on the Inxu River upper catchment can be classified as being in a Good to Fair overall ecological health. Site 4 located below Ugie Town is in a Fair state of health. Reduction in the overall ecological health at Site 4 can be ascribed to the fact that this site is located below the town and it receives urban runoff, which results in poorer water quality and thereby a lower diversity of biological communities. There is a path through this site that has resulted to unstable riverbanks and a poorer geomorphological assessment.

Both sites selected on the Gatberg River (Sites 2 and 5) can be classified as being in a Fair overall ecological state. These results suggest that the inflow from this River into the Inxu River is of poorer quality.

Results from Gqaqala River sites (6 and 8) suggest that even though this river is in good health in the upper reaches its condition deteriorates downstream before the confluence with the Inxu River. The Inxu River therefore receives the inflow of poorer quality at the confluence.

The results from the Umnga River sites (7 and 9) are similar to those of Gqaqala River sites whereby the upstream site in good ecological health and there is deterioration in the integrity of the river downstream towards the confluence with the Inxu River. These results also suggest that the Inxu River receives inflow of poorer water quality form Umnga River.

Results for the lower Inxu River catchment sites (10, 11 and 12) suggest that the overall ecological health of the Inxu River is reduced around Site 11 from Site 10 and improves slightly further downstream at Site 12. At Site 11 the Inxu River is exposed to sources of impacts such as erosion and settlement area. Inflows of reduced water quality from contribute to poorer river health at this site.

4.6.6 Sacred pools

One of the objectives of the study was to assess the condition of the Inxu River around the sacred pools. Firstly, the SASS technique is not designed to sample pools (Dickens and Graham, 2002) and secondly, as only people who are called to be healers are allowed access to the pools (Bernard P, Department of Anthropology, Rhodes University, pers.comm., 2003), this objective could only be achieved by using physical and biological data of water flowing through the pools. Site 10 was selected as a reference site upstream of the sacred pools to assess the ecological conditions above the sacred pools and Site 11 was selected as the site downstream of the sacred pools below the confluences with both Gqaqala and Umnga streams (Fig 4.1). Although the access to the pools is limited there was evidence of ploughing on the rightbank approximately 500m below the sacred pools. Site 10 was classified as being in a Fair ecological state. Site 11 is in a Fair to Poor overall ecological state. as compared to the reference site upstream of the pools.

The sacred pools are situated in an area with limited exposure to anthopogenic impacts. It is envisaged that macroinvertebrate and fish health and water quality around the sacred pools are similar to those observed at Site 10 upstream. The geomorphological status however should be better as the sacred pools are not exposed to the same anthropogenic impacts as sites 10 and 11 such as overgrazing and bridge construction

CHAPTER FIVE

GENERAL DISCUSSION AND CONCLUSIONS

5.1 Introduction

In this study, selected biomonitoring indices recommended for use in the implementation of the River Health Programme (RHP) were used to assess the ecological health of two rivers located in two contrasting catchments of the Eastern Cape. These indices have been developed and tested in some river systems around South Africa and this study contributes to an assessment of the suitability of the selected biomonitoring indices for use in Eastern Cape rivers. The research in the Inxu River catchment did not encompass the actual implementation of the RHP, but rather consisted of a baseline data-gathering and initiation process, which could aid in the implementation of the RHP in this catchment. Research on the Buffalo River system was conducted as part of the EC RHP. The data presented in this thesis also contributes to the objectives of the quality assurance component of the National RHP, as it presents data on the representativeness of SASS sampling at biomonitoring sites. The assessment design for both these catchments was based on the RHP protocols (Mangold, 2001). In this chapter findings on the suitability of these protocols for monitoring the Buffalo and Inxu rivers, the present ecological health of these rivers and the issues observed and lessons learned whilst undertaking biomonitoring in these two catchments using the selected RHP indices, are briefly discussed.

Provincial monitoring

The Provincial River Health champion usually coordinates provincial implementation of the RHP (Mangold, 2001). The champion conducts this job together with the Provincial Implementation Team (PIT), which is a team representing all the stakeholders involved in water management in that particular province e.g. representatives from DWAF, water boards, local communities, staff and students from surrounding universities and other interested parties. The team is responsible for implementation of the RHP according to provincial requirements and identification of rivers important for river health monitoring (Mangold, 2001). The Provincial Monitoring Team (PMT) does the actual biomonitoring sampling on selected rivers and is the core of the provincial RHP implementation. Trained staff from organisations participating in the provincial RHP perform the tasks.

The Buffalo River was the first target catchment for the implementation of the RHP in the Eastern Cape, and sampling, for this river was done in conjunction with the PMT. The PMT was not involved in the Inxu River sampling and the RHP implementation in this catchment will be conducted at a later stage. The Inxu River study therefore provides baseline data in preparation for the RHP implementation in this catchment.

One of the problems observed whilst working in conjunction with the PMT was the lack of continuity amongst representatives from participating organisations e.g. inability to be part of all the three surveys conducted on the Buffalo River. As some of the members have never undertaken biomonitoring before, it was important for them to be part of at least all three surveys conducted so as to broaden their understanding of how the biomonitoring indices work and to develop their capacity to conduct the surveys. These indices are designed to be rapid and not to require a high level of expertise, however, being part of only one survey would not grant one clear and complete understanding of their application.

5.2 The selected river catchments

Selection of the catchment is the first step involved in the RHP biomonitoring sampling. The selected river should be suitable for biomonitoring from a RHP perspective (Mangold, 2001), i.e. with perennial flow and a range of sites from least impacted to highly impacted sites. Although both the Buffalo and Inxu rivers met these criteria, the underlying reasons for undertaking assessments were different.

5.2.1 The Buffalo River

The Buffalo River was selected for assessment due to the fact that it is an important river in the Eastern Cape province as a population of more than 40 000 people utilizes it and drains an urban and industrialized catchment. Although there is extensive historical data available for this catchment due to research and DWAF monitoring flow and water quality status at various gauging weirs, the present ecological health status of this river has not previously assessed. These provided the motivation for undertaking the assessment in this catchment as well as its selection as the pilot catchment for ECRHP implementation.

Macroinvertebrate assessments and water quality data indicated that the water quality category is in a Fair status for the upper catchment (Table 3.9). The conditions deteriorate to Poor water quality category in the lower catchment from below King Williams to Mdantsane due to urban run off and untreated sewage effluent reaching the river. High population numbers exacerbates these conditions with inadequate sanitation facilities. Management intervention is critical to avoid further deterioration and to improve water quality conditions. Data from this study does indicate some recovery of the system downstream towards Umtiza Nature Reserve.

Fish assessments revealed that the health of this river in terms of fish assemblages is in a critically modified state at most sites. However, the accuracy of the assessment may be open for interpretation as there were a number of issues concerning the index and the sampling methods used for this assessment. These issues are discussed in section 5.4.2.

Although the index used for the riparian vegetation assessment of this river is in its developmental stages, it indicated that riparian vegetation health changes amongst sites with no specific defined upper catchment to lower catchment trend. Surrounding impacts included the presence of exotics, erosion and many other aspects.

The geomorphological assessment indicated that anthropogenic actvities such as impoundments have resulted in changes in bed structure, localised bank erosion and channel widening at most sites.

5.2.2 The Inxu River

The Inxu River drains a rural and afforested catchment, and was therefore chosen for the assessment. In addition, sacred pools, which are very important culturally and spiritually to the surrounding communities in the training of *izangoma* and *amagqirha*, exist in the catchment. Furthermore, the Gatberg Wetlands nominated as one of RAMSAR sites worthy of protection, form an integral part of this catchment. Research previously conducted has mainly focussed on the upper catchment

(Rowntree, 1993; Forsyth *et al*., 1997), while the overall integrated ecological health of this river remains unknown.

The results based on macroinvertebrate assessments indicated that this river is generally in a Good water quality state in the upper catchment, however the input from the tributaries changes the quality to Fair state in the lower catchment below the confluences with Gqaqala and Umnga rivers. Conditions improve with downstream recovery around Site 12. Macroinvertebrate diversity and water quality deteriorated in spring due to reduced flow. Pine plantations, which are the major land-use in the upper catchment, exacerbated low flow conditions as they absorb more water during dry conditions than moist conditions (Forsyth *et al*., 1997).

Fish assessments indicated that the fish assemblages are in a critically modified state at most sites. The Inxu River and its tributaries has a natural low fish diversity with less than five species expected under natural conditions (Bok A, Anton Bok & Associates, Port Elizabeth, pers.comm.,2003). The presence of exotic and predacious trout species like *Oncorhynchus mykiss* excludes the presence of indigenous species such as *Barbus anoplus* in most northern Eastern Cape rivers (Bok A, Anton Bok & Associates, Port Elizabeth, pers comm., 2003). This trend was evident for the Inxu River catchment, as at sites where trout species were recorded expected indigenous fish species like *Barbus anoplus* were not encountered. However, the efficiency of the sampling methods (section 5.4.2) may have contributed to low fish scores.

5.3 Selection of sites

The RHP requires selection of two categories of sites, namely reference and monitoring sites (Mangold, 2001). The description of reference and monitoring sites and how sites were selected for each river is provided in Chapter 2. Reference sites are usually selected as the least impacted sites in terms of anthropogenic impacts, with suitable habitat diversity and availability. They are expected to represent and reflect conditions for that particular reach under natural conditions and to act as a template to which monitoring sites can be compared. Not all the sites selected as reference sites performed as appropriate reference sites in terms of species diversity (either macroinvertebrates or fish), resulting in low scores for these sites.

Site 1 situated upstream on the Buffalo River and located within a fairly protected area with limited access, had the lowest macroinvertebrate and fish species diversity as compared to other sites located at the upper reaches. Dallas (1995) commented on reduced species diversity on sites located in mountainous zone. These sites are usually characterised by closed a canopy and are mostly shaded with reduced sunlight penetration and photosynthesis. Biota therefore derives their food source from allochthnous inputs. Although this site is not strictly situated in the mountainous zone, mountain stream conditions might have an influence on the site as its riparian zone is characterised by tall trees providing a shady canopy. A detailed look at the chemical water quality and the upstream anthropogenic activities would be important to establish the impacts on this site.

A reference site was selected on the Nahoon River, located in the same ecoregion as the lower Buffalo River, due to the absence of suitable reference sites within the lower Buffalo catchment. This site also did not perform as an appropriate reference site as it showed the lowest fish and invertebrate scores. For continuous RHP assessment of the Buffalo River it would not be worth sampling, as this site did not fulfil the purpose it was selected for. The results indicate the absence of reference sites on the mainstem Buffalo River and this is likely due to the highly developed nature of this catchment. Development of a reference condition (Dallas, 2000) for the Buffalo River is recommended.

Out of the twelve sites selected for monitoring on the Inxu River, six were selected on its tributaries (Refer to Chapter 2). The run-off in this catchment is mostly from non-point sources such as agriculture and afforestation, so it was important to assess the inflow into the Inxu River from its tributaries. Reference and monitoring sites were selected upstream and downstream of the sacred pools respectively, so as to assess the conditions around these pools. It is very important to note the presence of such pools in catchments where the RHP is implemented. The local communities respect the pools and access to them is limited. It is therefore important to consult local leaders such as chiefs, headmen or councillors when initiating the RHP, particularly in rural catchments where these beliefs are more prevalent. This liaison will assist the PMT in knowing when and where not to sample, so as not to ignore the community beliefs and not to offend local communities.

No information was available about the sacred pools on the Buffalo River catchment. Local people met whilst sampling, particularly at sites close to rural communities, indicated that there were no sacred pools within these reaches. This maybe due to the fact that this catchment is highly urbanized and strong cultural beliefs are disappearing due to urban influences. The possible presence of sacred pools within this catchment needs verification.

The absence of appropriate reference sites for the upper reaches of the Gatberg River was observed. Beamish (2001) reported a similar observation. This can be attributable to the fact that extensive agroforestry is concentrated around this area in the Gatberg catchment. Roads constructed within the NECF area for transportation of harvested pine trees might negatively impact on the conditions of the river. It is also possible that the river is naturally depaupaurate.

Reference sites selected on the Gqaqala and Umnga rivers appeared adequate in winter. However these sites deteriorated in spring due to reduced flows. Lower scores as compared to the reference sites were recorded on the monitoring sites located downstream end of both tributaries. Input from these tributaries negatively impact on the Inxu River mainstem as water quality deteriorated on the Inxu River below the confluences with both Gqaqala and Umnga rivers. Continuous monitoring of these tributaries would therefore be necessary to monitor their impact on the Inxu River.

5.4 Biomonitoring indices used

5.4.1 SASS5 and IHAS

The SASS5 technique is widely used and accepted nationally as a rapid biomonitoring method used for RHP assessments and monitoring. Uys *et al.* (1996), regarded SASS as the backbone of the National RHP. Efficiency of SASS as a rapid biological assessment technique has been evaluated and tested (Dallas, 1995; 1997; Vos *et al.*, 2002) on different river systems in the country. The SASS technique has undergone iterations of refinements and the current version is the fifth version (SASS5). SASS is designed such that one sample per biotope per site is taken.

This study evaluated the representativeness of one sample taken per biotope per site by taking three replicates per biotope per site on selected reference and monitoring sites for both catchments. Although the SASS score, ASPT, and the total number of taxa were calculated and varied between replicates (Table 3.2, 4.2 and 4.3) , it could not be ascertained whether these differences were significant. Statistical analyses using the ANOSIM procedure (PRIMER statistical package) were undertaken based on macroinvertebrate data for each set of replicates with the null hypothesis being that there are no significant differences between replicate samples taken from a single biotope at a particular site. ANOSIM at $p \geq 0.05$ revealed that the null hypothesis could not be rejected indicating that there were no significant differences between replicate samples taken from a single biotope for macroinvertebrate taxa composition for both rivers. From these results it could be concluded that one sample per biotope taken at each site is representative of macroinvertebrate composition at a particular biotope at a particular time of sampling. The results also indicated that the stones biotope is highly replicable as compared to the vegetation and GSM biotopes with replicates from the stones biotope clustering together in most dendrogram plots for both rivers.

IHAS assessments were conducted at every site where SASS5 sampling was done. IHAS is a habitat assessment system that poses specific questions about habitats sampled as well as the general stream characteristics, to provide an overall habitat assessment of the site sampled. However, this method is subjective and mostly based on visual observations of the assessor.

5.4.2 FAII

The FAII is based on the comparison of the expected and observed condition of fish assemblages to establish the deviation from natural conditions (Kleynhans, 1999). Expected conditions are therefore established from the historical data and/or based on expert knowledge and judgement. Establishment of expected conditions was not an easy exercise, especially on the Inxu River and its tributaries. Although experts were approached they were not eager to provide information about rivers they had not previously worked on, making it difficult to establish expected conditions. From this study it was observed that establishment of expected conditions can be subjective if not based on sampling, but rather on expert judgement. This might lead to over or under estimation of fish assemblage integrity. Kleynhans (1999) also commentes on the over-estimation of fish integrity when the expected conditions are derived from expert judgement.

The FAII calculation does not include alien or introduced species. The fish species were regarded as alien species if they were found outside of their natural or home range (Kleynhans CJ, Resource Quality Services, DWAF, 2003). From this study it was observed that both river systems sampled were dominated by alien fish species. This resulted in low FAII scores for the majority of sites on both rivers, with most sites falling within a critically modified category (Table 3.8 and 4.9). The presence of predaceous species like rainbow trout may have excluded the indigenous species (Skelton, 2001; Bok A, Anton Bok & Associates, Port Elizabeth, pers. comm., 2003).

The sampling equipment used for FAII sampling such as an electroshocker to sample fast- flowing habitats (runs and rapids) and a seine net to sample slow habitats (pools and backwaters) were not efficient in catching all the species that might be present. The middle to lower reaches of both systems were turbid with substrate predominantly boulders. The seine nets are suitable for sandy bottoms but snagged on rocks, therefore possibly missing some species that might be present. The effectiveness of the electroshocker is affected by low conductivities (CES, 2004) resulting in some species not being sampled at sites with low conductivities (e.g. Site 1 on the Buffalo River). Although the sampling equipment used in FAII sampling (seine net and electroshocker) fit within the scope of RHP due the fact that they are easy to use and not time and labour intensive, sampling may not be effective. The use of more labour-intensive equipment such as fyke and gill nets for Eastern Cape rivers with natural low fish diversities is recommended. These nets however require more time and intensity of sampling and might not fit in the scope of rapid assessments. A compromise between rapid assessments and a need for effective sampling should be reached.

One of the objectives of the FAII, as required by the RHP for any rapid biological assessment index, is to be usable within the limits of available information, labour, expertise and financial resources (Kleynhans, 1999). The observations from this study confirmed (a comment previously highlighted by Kleynhans (1999)) that the FAII is not suitable for rivers with low fish species diversity. The index needs to be developed further for the assessment of rivers with low fish diversity and rivers with no or little available historical data. Assessment of fish assemblage in rivers with low fish diversities could look at factors such as the existence of fish species with different age structures (recruitment) and the abundances and the health status of fish species recorded.

5.4.3 IRVI

Due to problems associated with the of the applicability of the Riparian Vegetation Index in some ecoregions, the riparian vegetation status of selected sites on the Buffalo River was assessed using a modified index called the Integrated Riparian Vegetation Index (IRVI) (RHP, 2004) developed during the Buffalo River monitoring programme. It is the integration of an index called RIPARIMAN (Kotze *et al.*, 1997) and the Riparian Vegetation Index (Kemper, 2001). This index is under development in the Eastern Cape and the Buffalo catchment was the test catchment for this index. Although this index provides more information regarding the riparian zone it still needs testing and development.

5.4.4 Geomorphological index

This index was used to assess the physical condition of the channel morphology of the Buffalo and Inxu rivers under the leadership the of the geomorphology specialist, Leanne du Preez of the Geography Department at Rhodes University. An overview of the geomorphological state for each catchment is given in Chapter 3 and Chapter 4. This index is time-consuming and requires detailed geomorphological knowledge.

5.5 Sampling frequency

Three SASS5 and FAII surveys were planned for both rivers i.e one in winter, spring and autumn. Geomorphological and RVI surveys were to be conducted on one sampling survey as required by the RHP (Mangold, 2001). Sampling on the Buffalo River was conducted as planned. However, in the Inxu River the autumn survey could not be undertaken due to heavy rainfall in this catchment during this season. This was unexpected as this is normally the low flow season. Mangold (2001) and Dickens and Graham (2002) discouraged sampling during wet conditions as major floods modify the habitat as well as macroinvertebrate communities. Sampling in autumn under normal flow conditions would have provided a more complete picture of the health of the Inxu River and is recommended for future monitoring. For future monitoring on the Buffalo River spring and winter sampling are recommended.

5.6 Data management and storage

Information management and storage is an important component of the RHP (Mangold, 2001). The data sheets for all the surveys on both rivers information will be curated as part of the provincial and national RHP Rivers Database.

5.7 Lessons learnt from biomonitoring on both catchments

Biomonitoring was undertaken in two contrasting catchments using selected RHP indices. Lessons learnt from this study are listed below:

- **Communication with stakeholders**: The issue of public participation has been emphasized in RHP implementation. It was observed during this study that it is very important to consult with key people within a selected catchment. Communication creates awareness about general activities within a selected catchment. In this way the community feel involved and taking part in the programme. This procedure would also assist with identifying waterbodies, e.g sacred pools and wetlands, and accessing useful information e.g. on historical fish species previously present in a river reach.
- **Safety and security in the field**: It has been suggested that the RHP monitoring personnel should work in pairs as a minimum requirement. It was observed during this study that two people might not be sufficient, especially whilst working on rivers within urbanised catchments or around townships such as Mdantsane. It was noted that being vaccinated against diseases such as hepatitis and typhoid is an important requirement for working in urban rivers, particularly in impacted catchmets such as Buffalo River.
- **Working as a part of team:** Organisational ability, discipline and understanding were identified as crucial skills needed when working as part of a team such as the PMT.

5.8 Conclusions

This study provided useful data for assessing the present ecological health of the selected catchments using the SASS5 index. The representativeness of the SASS5 technique was also assessed and based on the results it could be concluded that one sample taken per biotope per site at a particular time of sampling, as prescribed by the SASS protocol, gives an accurate assessment of the macroinvertebrate taxa present at that particular biotope. Problems associated with the FAII index have been documented and recommendations for further development of this index have been suggested. The data gathered during this study will contribute to successful implementation and continuous RHP monitoring on both catchments.

CHAPTER SIX

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Appendix 1 Variations in number of families and abundances between replicate samples taken from the same biotope from all replicated sites on the Buffalo River.

SITE 2			
STONES BIOTOPE			
FAMILIES RECORDED	**REPLICATE 1**	**REPLICATE 2**	**REPLICATE 3**
Turbellaria	15	15	4
Oligochaeta	6	4	5
Potamonautidae	-	2	-
Perlidae	-	-	1
Baetidae	30	20	40
Caenidae	40		20
Heptageniidae	15	12	17
Leptophlebiidae	12	11	19
Tricorythidae	7	11	4
Aeshnidae	-	4	-
Gomphidae		1	
Hydropsychidae	7	5	25
Gyrinidae	2	-	-
Helodidae	1	-	-
Ceratopogonidae	12	6	6
Chironomidae	60	20	90
Culicidae	5	-	-
Simuliidae	5	5	-
Tabanidae	-	7	1
Tipulidae	-	7	-
Ancyliidae	5	-	-
Sphaeriidae	6	16	8
SITE 2			
VEGETATION BIOTOPE			
FAMILIES RECORDED	**REPLICATE 1**	**REPLICATE 2**	**REPLICATE 3**
Baetidae	40	40	15
Caenidae	15	9	25
Heptageniidae	-	13	27
Leptophlebiidae	3	9	-
Tricorythidae	1	-	5
Coenagrionidae	2	5	-
Platycnemidae	2	-	-
Naucoridae	13	7	-
Notonectidae	-	7	
Dytiscidae	1	-	-
Leptoceridae	-	-	8
Athericidae	1	-	-
Ceratopogonidae	2	-	-

Chironomidae	4	9	
Culidae	35	5	
Muscidae	-	-	4
Planorbinae	1	-	
SITE 2			
GRAVEL SAND AND MUD BIOTOPE			
FAMILIES RECORDED	**REPLICATE 1**	**REPLICATE 2**	**REPLICATE 3**
Turbellaria	-	-	7
Oligochaeta	2	-	1
Potamonautidae	1	1	-
Baetidae	20	-	25
Caenidae	20	-	17
Heptageniidae	12	11	11
Leptophlebiidae	8	15	12
Tricorythidae	5	9	-
Coenagrionidae	1	-	-
Chlorocyphidae	-	1	-
Gomphidae	-	-	8
Naucoridae	8	1	9
Dytiscidae	-	-	5
Athericidae	1	-	
Ceratopogonidae	-	-	5
Chironomidae	10	15	9
Ancylidae	5	-	7
Corbiculidae	1	-	-
Sphaeriidae	1	-	-
SITE 3			
STONES BIOTOPE			
FAMILIES RECORDED	**REPLICATE 1**	**REPLICATE 2**	**REPLICATE 3**
Turbellaria	-	5	-
Oligochaeta	-	-	-
Potamonautidae	1	-	1
Hydracarina	-	4	-
Baetidae	90	50	-
Caenidae	8	-	7
Heptageniidae	15	15	12
Leptophlebiidae	25	20	20
Tricorythidae	17	7	1
Platycnemidae	1	5	7
Naucoridae	-	4	-
Hydropsychidae	7	-	-
Philopotamidae	5	9	3
Helodidae	-	7	-
Athericidae	4	1	1

Chironomidae	30	70	20
Simuliidae	20	30	25
Tipulidae	1	-	-
SITE 3			
VEGETATION BIOTOPE			
FAMILIES RECORDED	**REPLICATE 1**	**REPLICATE 2**	**REPLICATE 3**
Turbellaria	-	-	4
Oligochaeta	-	-	1
Potamonautidae	1	-	3
Baetidae	20	40	50
Caenidae	3	7	6
Leptophlebiidae	3	17	1
Chlorocyphidae	1	1	-
Chlorolestidae	-	1	-
Platycnemidae	2	16	2
Naucoridae	-	5	-
Notonectidae	-	1	-
Hydropsychidae	7	-	-
Leptoceridae	4	14	22
Ceratopogonidae	-	-	4
Chironomidae	5	9	3
Culicidae	3	30	19
Simuliidae	-	-	9
SITE 3			
GRAVEL SAND AND MUD BIOTOPE			
FAMILIES RECORDED	**REPLICATE 1**	**REPLICATE 2**	**REPLICATE 3**
Oligochaeta	3	-	-
Baetidae	4	30	-
Caenidae	-	8	5
Leptophlebiidae	-	-	6
Chironomidae	4	7	2
Culicidae	-	1	-
SITE 10			
STONES BIOTOPE			
FAMILIES RECORDED	**REPLICATE 1**	**REPLICATE 2**	**REPLICATE 3**
Turbellaria	5	1	2
Oligochaeta	-	10	-
Baetidae	40	30	12
Caenidae	37	40	40
Leptophlebiidae	14	12	12
Coenagrionidae	-	5	-

Aeshinidae	1	5	-
Gomphidae	2	3	-
Libellulidae	1	1	-
Naucoridae	15	12	2
Hydropsychidae	-	4	5
Leptoceridae	-	-	3
Dytiscidae	-	-	6
Elmidae	1	-	-
Psephenidae	-	-	1
Athericidae	-	-	2
Ceratopogonidae	5	7	4
Chironomidae	8	8	30
Culicidae	-	-	1
Muscidae	1	-	-
Tabanidae	-	-	1
Ancylidae	-	-	4
SITE 10			
VEGETATION BIOTOPE			
FAMILIES RECORDED	**REPLICATE 1**	**REPLICATE 2**	**REPLICATE 3**
Oligochaeta	2	1	-
Baetidae	6	16	7
Caenidae	50	11	5
Chlorolestidae	-	4	-
Coenagrionidae	7	8	5
Platycnemidae	-	2	-
Aeshnidae	-	1	1
Libellulidae	7	4	5
Naucoridae	12	4	4
Notonectidae	3	2	-
Veliidae	1	-	-
Leptoceridae	15	3	1
Dytiscidae	15	9	2
Hydrophilidae	-	-	1
Ceratopogonidae	15	15	-
Chironomidae	2	10	3
Culicidae	-	1	-
Lymnaeidae	-	1	-
SITE 10			
GRAVEL SAND AND MUD BIOTOPE			
FAMILIES RECORDED	**REPLICATE 1**	**REPLICATE 2**	**REPLICATE 3**
Oligochaeta	4	40	24
Leeches	-	5	-
Baetidae	6	40	18
Caenidae	5	20	20

Leptophlebiidae	-	-	6
Coenagrionidae	-	-	1
Gomphidae	4	-	2
Libellulidae	1	3	4
Naucoridae	5	12	6
Notonectidae	4	-	-
Dytiscidae	-	5	-
Ceratopogonidae	3	7	15
Chironomidae	25	5	4
Culicidae	1	-	-
SITE 12			
STONES BIOTOPE			
FAMILIES RECORDED	**REPLICATE 1**	**REPLICATE 2**	**REPLICATE 3**
Turbellaria	3	3	-
Baetidae	130	130	30
Caenidae	40	15	13
Leptophlebiidae	-	4	3
Aeshnidae	4	3	-
Gomphidae	1	-	-
Libellulidae	1	-	2
Naucoridae	-	-	6
Hydroptilidae	-	4	-
Elmidae	-	1	-
Gyrinidae	4	2	3
Ceratopogonidae	4	5	18
Chironomidae	40	24	22
Culicidae	2	-	-
Muscidae	30	24	19
Simuliidae	40	5	-
Tabanidae	-	1	-
Ancylidae	2	-	-
SITE 12			
VEGETATION BIOTOPE			
FAMILIES RECORDED	**REPLICATE 1**	**REPLICATE 2**	**REPLICATE 3**
Oligochaeta	-	1	-
Baetidae	12	17	8
Caenidae	7	10	6
Leptophlebiidae	-	-	7
Coenagrionidae	4	-	2
Platycnemidae	1	7	2
Aeshnidae	-	1	1
Gomphidae	-	-	-
Libellulidae	2	2	2
Hydrometridae	-	-	1

Naucoridae	-	1	12
Notonectidae	1	-	3
Vellidae	-	-	1
Hydropsychidae	1	-	-
Leptoceridae	-	-	8
Hydroptilidae	-	2	-
Dytiscidae	1	-	6
Gyrinidae	7	3	-
Chironomidae	55	26	7
Culicidae	3	-	4
Muscidae	3	8	8
Simuliidae	12	5	-
SITE 12			
GRAVEL SAND AND MUD BIOTOPE			
FAMILIES RECORDED	**REPLICATE 1**	**REPLICATE 2**	**REPLICATE 3**
Potamonautidae	-	1	-
Baetidae	8	70	130
Caenidae	8	8	5
Leptophlebiidae	2	-	-
Aeshnidae	-	-	1
Libellulidae	-	8	-
Naucoridae	4	1	-
Dytiscidae	-	-	1
Elmidae	-	-	1
Gyrinidae	1	1	4
Ceratopogonidae	7	9	6
Chironomidae	53	30	20
Culicidae	2	1	-
Muscidae	3	-	4
Simuliidae	2	-	7

Appendix 2 Summary of macroinvertebrate families recorded on the Buffalo River for all seasons sampled with all biotopes combined.

	SITES																																			
	1			2			3			4			5			6			7			8			9			10			11			12		
FAMILIES	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**
Turbellaria				P		P	P	P			P		P	P	P			P	P	P		P		P	P	P				P				P		
Annelida																																				
Oligochaeta		P	P	P	P			P	P			P	P	P	P	P	P	P	P	P	P	P	P	P	P			P	P	P	P	P	P		P	
Leeches															P				P	P	P	P	P				P		P			P				
Crustacea																																				
Potamonautidae	P	P	P		P	P	P	P	P		P	P		P	P	P	P	P	P	P			P	P	P	P		P			P	P	P	P		
Hydracarina													P		P																					
Plecoptera																																				
Perlidae							P	P																P		P										
Ephemeroptera																																				
Baetidae	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
Caenidae		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P			P	P		P	P	P	P	P					P	P	P
Heptageniidae				P	P		P	P	P																P	P	P									
Tricorythidae				P	P	P	P	P	P	P		P			P				P			P			P											
Odonata																																				
Chlorocyphidae				P			P																			P										
Chlorolestidae									P																											
Coenagrionidae			P	P		P	P	P	P	P		P	P	P	P	P	P	P			P				P	P	P	P	P		P	P	P		P	

	SITES																																			
	1			**2**			**3**			**4**			**5**			**6**			**7**			**8**			**9**			**10**			**11**			**12**		
FAMILIES	S	A	W	S	A	W	S	A	W	S	A	W	S	A	W	S	A	W	S	A	W	S	A	W	S	A	W	S	A	W	S	A	W	S	A	W
Odonata																																				
Lestidae			P											P	P	P																		P		
Platycnemidae						P	P	P	P																		P				P					P
Aeshinidae					P		P	P				P	P	P	P															P					P	P
Gomphidae		P	P	P			P	P					P	P					P									P	P							P
Libellulidae		P	P	P						P			P		P		P								P			P	P			P		P		
Hemiptera																																				
Belostomatidae									P					P									P		P			P							P	
Corixidae																																				
Gerridae		P				P	P			P																										
Naucoridae			P	P	P	P			P			P	P	P	P	P	P	P		P					P		P	P	P	P	P	P		P	P	P
Nepidae																																		P		
Notonectidae							P		P	P			P	P				P																		P
Vellidae				P				P		P									P					P		P				P	P			P	P	
Trichoptera																																				
Hydropyschidae					P	P	P	P	P	P			P	P	P	P	P	P													P	P		P	P	P
Philopotamidae							P	P											P	P		P	P	P	P	P	P	P								
Leptoceridae				P			P	P	P	P			P													P										
Coleptera																																				
Dystiscidae				P		P		P	P	P	P	P	P	P	P	P	P	P													P	P		P	P	P
Elmidae				P	P	P	P			P	P		P	P		P	P										P		P	P				P	P	P

	SITES																																			
	1			**2**			**3**			**4**			**5**			**6**			**7**			**8**			**9**			**10**			**11**			**12**		
FAMILIES	S	A	W	S	A	W	S	A	W	S	A	W	S	A	W	S	A	W	S	A	W	S	A	W	S	A	W	S	A	W	S	A	W	S	A	W
Coleptera																																				
Gyrinidae				P			P			P		P	P	P	P		P		P			P	P		P			P	P						P	P
Hydrophilidae				P						P			P			P		P																		
Psephenidae				P			P			P	P	P					P													P	P					
Diptera																																				
Athericidae	P	P	P		P	P	P	P	P																P		P									
Ceratopogonidae			P	P		P	P				P		P	P	P		P	P																P		P
Chironomidae	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P				P		P		P	P			P	P	P	P	P	P	P
Culicidae						P	P		P				P	P	P				P	P	P	P	P	P	P	P	P	P	P	P	P			P		P
Muscidae																					P							P						P		P
Simuliidae	P		P	P		P	P	P	P	P	P	P	P	P	P	P	P	P												P	P	P	P	P	P	
Tabanidae				P	P		P												P	P		P	P	P			P	P	P			P				
Tipulidae	P			P			P	P	P								P									P									P	
Gastropoda																																				
Ancylidae		P	P	P	P	P	P					P	P	P	P																P	P		P		P
Lymnaeidae												P							P		P	P	P	P	P	P			P							
Planorbinae			P		P																				P											
Thiaridae																									P											
Pelecypoda																																				
Corbiculidae		P			P	P								P			P									P									**P**	
Sphaeriidae						P				P		P	P	P				P	P			P														

Appendix 3 Summary of fish species recorded on the Buffalo River for all seasons sampled with all biotopes combined.

	SITES																																		
	1			2			3			4			5			6			7			8			9			10			11			12		
FISH SPECIES	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**
A. mossambica																										P			P							
A.aeriofuscus																										P										
B. anoplus		P	P			P	P	P		P	P	P	P	P		P	P															P			P	
B.pallidus																						P														
B.trevelyani							P			P																										
C.gariepinus																	P			P																
C. carpio																				P		P						P								
G. callidus																									P	P		P				P		P	P	
L. umbratus			P		P			P			P									P		P	P					P				P		P	P	
L. macrochirus																													P							
M. punctulatus																													P							
M. falciformis																									P											
M. cephalus																																				
M. capensis																									P	P										
O. mossambicus																										P						P			P	
T. sparrmanii																							P			P						P		P	P	

Appendix 4 Variations in number of families and abundances between replicate samples taken from the stones biotope from all replicated sites on the Inxu River in Winter 2003.

STONES BIOTOPE			
SITE 1			
FAMILIES RECORDED	**REPLICATE 1**	**REPLICATE 2**	**REPLICATE 3**
Turbellaria	5	5	-
Potamonautidae	1	3	4
Hydracarina	-	2	1
Baetidae	100	20	50
Caenidae	8	-	-
Heptageniidae	8	10	8
Leptophlebiidae	40	9	5
Tricorythidae	120	40	20
Aeshinidae	4	7	4
Gomphidae	-	-	3
Hydropsychidae	50	30	5
Philopotamidae	-	1	-
Leptoceridae	-	-	1
Gyrinidae	-	2	-
Psephenidae	-	-	1
Athericidae	6	5	4
Chironomidae	20	20	9
Muscidae	-	-	1
Simuliidae	12	12	4
Tipulidae	-	3	-
Ancylidae	7	10	7
SITE 10			
FAMILIES RECORDED	**REPLICATE 1**	**REPLICATE 2**	**REPLICATE 3**
Turbellaria	1	-	-
Oligochaeta	-	1	-
Leeches	-	2	-
Potamonautidae	3	6	2
Baetidae	15	24	30
Caenidae	12	4	6
Heptageniidae	3	-	1
Leptophlebiidae	9	12	24
Polymitarcyidae	-	-	1
Prosopistomatidae	6	-	2
Tricorythidae	21	8	12
Chlorocyphidae	-	1	1
Aeshinidae	1	-	2
Gomphidae	-	7	-
Libellulidae	-	-	1

Naucoridae	2	20	5
Hydropsychidae	6	8	12
Elmidae	1	-	-
Gyrinidae	-	1	12
Athericidae	-	-	1
Chironomidae	-	40	9
Simuliidae	4	-	7
Tipulidae	-	2	1
SITE 11			
FAMILIES RECORDED	**REPLICATE 1**	**REPLICATE 2**	**REPLICATE 3**
Turbellaria	3	2	2
Baetidae	36	36	55
Caenidae	1	-	-
Leptophlebiidae	2	2	12
Prosopistomatidae	2	-	15
Tricorythidae	6	-	26
Aeshinidae	2	-	6
Libellulidae	-	12	5
Naucoridae	4		8
Vellidae	-	2	-
Hydropsychidae	3	-	4
Elmidae	-	-	1
Gyrinidae	1	2	1
Chironomidae	1	-	4
Simuliidae	3	2	6
Ancylidae	6	2	6

Appendix 5 Variations in number of families and abundances between replicate samples taken from the same biotope from all replicated sites on the Inxu River in Spring 2003.

SITE 1			
STONES BIOTOPE			
FAMILIES RECORDED	**REPLICATE 1**	**REPLICATE 2**	**REPLICATE 3**
Turbellaria	12	11	5
Potamonautidae	13	7	3
Hydracarina	15	10	12
Baetidae	26	-	20
Caenidae	6	-	6
Heptageniidae	1	-	-
Leptophlebiidae	40	60	25
Prosopistomatidae	-	1	-
Tricorythidae	12	12	19
Aeshinidae	5	2	4
Gomphidae	2	3	6
Pleidae	5	-	-
Hydropsychidae	6	8	-
Elmidae	3	-	-
Hydrophilidae	4	-	2
Athericidae	6	8	2
Ceratopogonidae	-	12	3
Chironomidae	30	30	30
Culicidae	-	-	1
Muscidae	1	-	-
Simuliidae	12	12	20
Tipulidae	1	-	-
Ancylidae	7	3	-
SITE 1			
VEGETATION BIOTOPE			
FAMILIES RECORDED	**REPLICATE 1**	**REPLICATE 2**	**REPLICATE 3**
Turbellaria	-	-	4
Leeches	-	1	-
Hydracarina	2		-
Baetidae	16	4	6
Caenidae	24	4	12
Leptophlebiidae	2	6	-
Tricorythidae	2	-	-
Aeshinidae	-	-	-
Gomphidae	-	-	1
Libellulidae	-	-	1
Naucoridae	1	-	15
Nepidae	-	1	-

Pleidae	-	-	1
Vellidae	1	-	-
Hydropsychidae	2	-	-
Leptoceridae	1	1	3
Elmidae	-	2	-
Ceratopogonidae	3	-	2
Chironomidae	6	8	3
Culicidae	-	-	1
Simuliidae	13	6	-
Planorbinae	9	-	-
SITE 1			
GRAVEL SAND AND MUD BIOTOPE			
FAMILIES RECORDED	**REPLICATE 1**	**REPLICATE 2**	**REPLICATE 3**
Turbellaria	2	1	2
Potamonautidae	1	1	1
Hydracarina	4	7	2
Baetidae	6	36	14
Caenidae	16	7	12
Leptophlebiidae	9	28	20
Tricorythidae	-	5	-
Gomphidae	6	10	2
Elmidae	1	3	-
Athericidae	6	7	-
Ceratopogonidae	9	2	8
Chironomidae	40	30	6
Simuliidae	3	8	70
Tipulidae	1	-	-
Ancylidae	1	-	-

SITE 4			
STONES BIOTOPE			
FAMILIES RECORDED	**REPLICATE 1**	**REPLICATE 2**	**REPLICATE 3**
Turbellaria	19	10	14
Potamonautidae	1	1	-
Hydracarina	-	5	-
Baetidae	22	25	17
Caenidae	12	40	26
Leptophlebiidae	9	4	12
Prostopistomatidae	-	1	-
Tricorythidae	46	48	29
Gomphidae	-	-	2
Hydropsychidae	5	2	1
Leptoceridae	1	-	-
Elmidae	5	5	1

Hydrophilidae	-	-	-
Athericidae	2	1	3
Ceratopogonidae	4	4	2
Chironomidae	28	22	16
Muscidae	-	1	-
Ancylidae	4	-	-
SITE 4			
VEGETATION BIOTOPE			
FAMILIES RECORDED	**REPLICATE 1**	**REPLICATE 2**	**REPLICATE 3**
Turbellaria	-	-	1
Hydracarina	-	14	-
Baetidae	12	12	9
Caenidae	6	13	8
Leptophlebiidae	1	-	-
Tricorythidae	-	1	-
Coenagrionidae	-	-	1
Aeshinidae	-	-	1
Corixidae	2	15	4
Hydrometridae	-	1	-
Vellidae	2	3	12
Hydropsychidae	1	-	-
Leptoceridae	2	-	2
Dytiscidae	2	2	3
Elmidae	1	4	3
Hydrophilidae	1	-	1
Ceratopogonidae	1	2	2
Chironomidae	9	8	9
Culicidae	1	-	-
Ancylidae	1	-	-
Planorbinae	-	-	1
SITE 4			
GRAVEL SAND AND MUD BIOTOPE			
FAMILIES RECORDED	**REPLICATE 1**	**REPLICATE 2**	**REPLICATE 3**
Turbellaria	1	1	1
Hydracarina	5	4	-
Baetidae	10	12	9
Caenidae	6	2	8
Tricorythidae	1	-	-
Gomphidae	-	2	3
Corixidae	-	2	4
Hydropsychidae	-	-	1
Dytiscidae	5	-	1
Elmidae	-	2	-
Ceratopogonidae	2	1	-

Chironomidae	33	10	-
Culicidae	2	-	-
Ancylidae	1	-	-
SITE 10			
STONES BIOTOPE			
FAMILIES RECORDED	**REPLICATE 1**	**REPLICATE 2**	**REPLICATE 3**
Turbellaria	16	-	-
Potamonautidae	5	-	-
Hydracarina	10	4	2
Baetidae	50	40	20
Caenidae	16	8	2
Leptophlebiidae	60	16	14
Prosopistomatidae	5	6	4
Tricorythidae	80	80	60
Corixidae	-	1	1
Naucoridae	2	-	-
Hydropsychidae	9	20	6
Elmidae	1	4	5
Ceratopogonidae	8	-	5
Chironomidae	35	8	15
Culicidae	1	-	-
Simuliidae	6	6	8
Ancylidae	-	-	-
SITE 10			
VEGETATION BIOTOPE			
FAMILIES RECORDED	**REPLICATE 1**	**REPLICATE 2**	**REPLICATE 3**
Turbellaria	1	1	-
Hydracarina	10	-	2
Baetidae	-	28	4
Caenidae	18	15	7
Leptophlebiidae	-	-	2
Prosopistomatidae	1	-	-
Tricorythidae	1	-	6
Coenagrionidae	-	1	1
Lestidae	-	-	-
Gomphidae	1	-	-
Libellulidae	-	1	-
Corixidae	12	12	12
Naucoridae	3	2	-
Pleidae	1	2	4
Vellidae	1	-	-
Dytiscidae	2	-	1
Elmidae	1	1	1
Ceratopogonidae	3	2	-

Chironomidae	4	4	-
Simuliidae	-	-	2
Ancylidae	1	-	-
Planorbinae	-	-	3
SITE 10			
GRAVEL SAND AND MUD BIOTOPE			
FAMILIES RECORDED	**REPLICATE 1**	**REPLICATE 2**	**REPLICATE 3**
Turbellaria	-	2	1
Oligochaeta	-	2	-
Leeches	1	-	-
Potamonautidae	-	-	1
Hydracarina	1	2	1
Baetidae	4	2	26
Caenidae	12	18	12
Leptophlebiidae	-	6	15
Prosopistomatidae	-	-	3
Tricorythidae	-	-	24
Chlorocyphidae	-	1	-
Gomphidae	-	12	11
Corixidae	6	2	15
Notonectidae	1	-	-
Leptoceridae	1	-	-
Dytiscidae	3	-	-
Elmidae	-	4	8
Ceratopogonidae	2	4	12
Chironomidae	24	12	12
Culicidae	-	-	1
Tipulidae	-	1	-

SITE 11			
STONES BIOTOPE			
FAMILIES RECORDED	**REPLICATE 1**	**REPLICATE 2**	**REPLICATE 3**
Turbellaria	4	4	7
Hydracarina	-	-	4
Baetidae	21	30	2
Caenidae	-	-	5
Leptophlebiidae	2	13	4
Prosopistomatidae	-	11	8
Tricorythidae	3	2	4
Gomphidae	6	2	2
Libellulidae	-	2	3
Corixidae	3	-	-
Naucoridae	2	2	4
Pleidae	5	2	2

Vellidae	4	-	-
Elmidae	1	-	-
Athericidae	-	-	1
Ceratopogonidae	-	-	2
Chironomidae	6	-	-
Ancylidae	5	4	-
SITE 11			
VEGETATION BIOTOPE			
FAMILIES RECORDED	**REPLICATE 1**	**REPLICATE 2**	**REPLICATE 3**
Turbellaria	7	-	1
Hydracarina	1	1	-
Baetidae	-	9	4
Caenidae	-	6	-
Leptophlebiidae	-	1	-
Prosopistomatidae	-	28	-
Coenagrionidae	6	9	5
Platycnemidae	-	1	-
Libellulidae	-	2	4
Corixidae	15	16	-
Naucoridae	-	1	2
Nepidae	-	-	4
Notonectidae	6	7	5
Pleidae	14	-	5
Vellidae	2	4	12
Leptoceridae	1	1	1
Dytiscidae	3	-	-
Elmidae	-	-	1
Hydrophilidae	-	-	3
Ceratopogonidae	-	1	-
Ancylidae	-	-	-
Lymnaeidae	-	-	-
Planorbinae	-	12	-
SITE 11			
GRAVEL SAND AND MUD BIOTOPE			
FAMILIES RECORDED	**REPLICATE 1**	**REPLICATE 2**	**REPLICATE 3**
Oligochaeta	-	-	1
Baetidae	1	-	-
Caenidae	-	1	-
Leptophlebiidae	-	2	-
Gomphidae	2	1	1
Libellulidae	-	-	1
Corixidae	4	9	50
Naucoridae	2	4	-
Dytiscidae	-	-	1

Elmidae	-	-	1
Ceratopogonidae	-	-	7
Chironomidae	-	35	45
Ancylidae	1	-	2

Appendix 6. Summary of macroinvertebrate families recorded on the Inxu River for both seasons sampled with all biotopes combined.

	SITES																							
	1		**2**		**3**		**4**		**5**		**6**		**7**		**8**		**9**		**10**		**11**		**12**	
FAMILIES	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S
Porifera																	P				P			
Turbellaria	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P		P	P		P	P	
Annelida																								
Oligochaeta			P		P							P	P								P		P	
Leeches		P																		P				
Crustacea																								
Potamonautidae	P		P	P	P	P	P	P	P	P	P	P		P	P	P			P					
Hydracarina	P	P		P	P			P					P							P				
Plecoptera																								
Perlidae																							P	
Ephemeroptera																								
Baetidae	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P		P	P	P	P	P	P
Caenidae	P		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P		P	P	P		P	
Heptageniidae	P				P	P	P			P									P					
Leptophlebiidae	P	P		P	P	P	P	P	P		P	P	P			P	P		P		P	P	P	P
Polymitarcyidae																								
Prosopistomatidae						P							P	P	P	P			P	P	P	P	P	P

	SITES																							
	1		**2**		**3**		**4**		**5**		**6**		**7**		**8**		**9**		**10**		**11**		**12**	
FAMILIES	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S
Tricorythidae	P	P	P		P		P	P	P	P			P	P	P	P			P	P	P	P	P	P
Odonata																								P
Chlorocyphidae																								
Coenagrionidae			P	P	P				P	P		P				P						P	P	P
Lestidae																P								
Platycnemidae																P						P	P	
Aeshinidae	P	P	P		P		P						P		P				P		P			
Gomphidae	P	P	P	P	P	P			P						P	P			P	P	P	P	P	P
Libellulidae			P		P	P							P				P						P	P
Hemiptera																								
Corixidae						P		P		P		P		P		P				P		P	P	
Gerridae									P															
Naucoridae	P		P	P	P		P		P	P	P	P	P			P		P	P	P	P	P	P	P
Nepidae		P			P		P					P												
Notonectidae			P						P					P		P	P			P		P		
Pleidae		P								P		P		P		P				P				
Vellidae	P	P	P	P		P		P		P	P	P					P			P		P	P	P
Trichoptera																								
Hydropyschidae	P	P	P		P		P	P	P		P		P						P	P	P			P

	SITES																							
	1		**2**		**3**		**4**		**5**		**6**		**7**		**8**		**9**		**10**		**11**		**12**	
FAMILIES	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S
Trichoptera																								
Philopotamidae	P																							
Hydroptilidae																								
Leptoceridae	P	P	P		P	P	P	P		P					P				P	P				P
Coleptera																								
Dytiscidae				P				P		P	P				P	P	P		P	P		P	P	
Elmidae		P	P	P	P	P	P	P	P			P			P	P				P		P	P	P
Gyrinidae			P	P			P		P			P	P		P		P		P		P		P	
Hydrophilidae		P	P		P			P		P		P			P		P		P	P	P			
Psephenidae	P																							
Diptera																								
Athericidae	P	P	P	P	P	P		P					P		P									
Ceratopogonidae	P	P				P	P	P	P		P	P	P	P	P	P	P		P	P	P		P	P
Chironomidae	P	P	P	P	P	P	P	P	P	P	P	P	P	P		P	P		P	P	P	P	P	P
Culicidae	P	P				P		P				P		P						P				
Dixidae	P			P																				
Muscidae	P	P						P						P										
Simuliidae	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P		P	P	P		P	
Tabanidae																								
Tipulidae	P	P			P	P				P		P		P	P				P	P				
Gastropoda																								
Ancylidae	P	P		P	P	P	P	P	P	P	P		P	P			P		P	P	P	P		
Lymnaeidae																						P		
Planorbidae	P	P			P		P						P		P		P			P		P		

Appendix 7. Summary of fish species recorded on the Inxu River for both seasons sampled with all biotopes combined

	SITES																							
Fish species	**1**		**2**		**3**		**4**		**5**		**6**		**7**		**8**		**9**		**10**		**11**		**12**	
	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S
Barbus anoplus											P	P	P	P	P	P								
Micropterus punctulatus																								
Micropterus salmoides																	P		P	P		P		
Oncorhynchus mykiss	P	P				P	P	P										P			P			