CHAPTER 1. INTRODUCTION TO ECOLOGICAL REFERENCE CONDITIONS AND THE SPATIAL FRAMEWORK FOR DELINEATING HOMOGENEOUS REGIONS

Summary

This chapter provides an introduction to the River Health Programme (RHP) in South Africa. It describes the concept of reference conditions and the biotic components which may be used for deriving them. The advantages of using riverine macroinvertebrates in biomonitoring is discussed. The two key approaches for deriving ecological reference conditions, namely multimetric and multivariate approaches, are outlined and the advantages and assumptions of each approach are discussed. The South African approach is summarised and the spatial classification system used for delineating homogeneous regions is described.

1.1 INTRODUCTION

The implementation design phase of the National Aquatic Ecosystem Biomonitoring Programme (NAEBP) was initiated in August 1997. This programme, subsequently renamed the River Health Programme (RHP), consists of four portfolios, one of which is research and development. The overall objective of the RHP is to develop the procedures and infrastructures for implementation and ongoing maintenance of biomonitoring on a national scale. Within the research and development component, attention has focused on establishing a protocol for the derivation of ecological reference conditions for riverine macroinvertebrates. Macroinvertebrates form one of the main components of the RHP and are the basis for the rapid bioassessment (RBA) technique, SASS4 (South African Scoring System, Version 4), which is used extensively in South Africa for the biomonitoring of rivers. The need for an established benchmark or reference condition with which monitoring information can be compared, has been expressed on several occasions by organisations involved in biomonitoring. Interpretation of biomonitoring data in relation to reference conditions enable the degree of degradation or deviation from natural conditions to be ascertained.

This report focuses on the establishment of a protocol for the derivation of ecological reference conditions for riverine macroinvertebrates and is the last in a series of reports related to such reference conditions. Other reports emanating from this project include:

- Delineation of river types for rivers of Mpumalanga, South Africa: the establishment of a spatial framework for selection of reference sites (Dallas & Fowler 2000),
- Ecological Reference Condition Project: Field-manual. Volume 1: General Information, Catchment Condition, Invertebrates and Water Chemistry (Dallas 2000), and
- A Rivers Database and User Manual (Fowler, Dallas & Janssens 2000).

This chapter describes the "reference condition" in both the general context and in respect of riverine macroinvertebrates, discusses the two main approaches for deriving ecological reference conditions for

riverine macroinvertebrates, and describes the hierarchical spatial classification of rivers, henceforth termed the "spatial framework" developed to assist with the identification of homogeneous regions within which reference conditions can be established.

1.2 WHAT ARE ECOLOGICAL REFERENCE CONDITIONS?

An ecological reference condition is the condition that is representative of a group of "least-impacted" or minimally-disturbed sites organised by selected physical, chemical and biological characteristics (Reynoldson *et al*. 1997). Reference conditions enable the degree of degradation or deviation from natural conditions to be ascertained, and thereby serve as a foundation for developing biological criteria for the protection of aquatic ecosystems. In a regional landscape, this means identifying biotic patterns that vary with normal geomorphic variations of the landscape, as well as alterations caused by anthropogenic influences (Richards *et al*. 1997). In other words, when using biotic communities to detect the impact of one or more environmental stresses on a site, it is necessary to know the fauna expected at the site in the absence of environmental stress. Such an assemblage is referred to as a reference community, when applied to a single component of the biota such as riverine macroinvertebrates, fish or riparian vegetation, or a reference condition, in more general terms.

1.2.1 Types of reference conditions

There are two types of reference conditions. The first is site-specific and the second, regional. The former is typically used in an upstream/downstream or "paired" scenario where a monitoring site is compared to the condition at a single reference site. Regional reference conditions are more general applicability within the confines of established homogeneous groupings of sites. Regional reference conditions may be a relatively coarse level, such as ecoregions (Kleynhans *et al*. 1998) or bioregions (Brown *et al*. 1996), or be at a finer, and most likely more accurate level, which incorporates both subregions, based on geomorphological zonation, and river-types as outlined by Brown *et al*. (1996). The biological attributes of individual test or monitoring sites are compared with a group of reference sites (or reference condition) expected to be similar. Regional reference conditions are, therefore, not site-specific but are rather derived from a group of similar reference sites.

In significantly altered systems, suitable reference sites may not be available. In such cases, either the "best attainable" sites are selected or the reference condition is derived from historical data or ecological models. In some cases, for example the Fish Assemblage Integrity Index (FAII, Kleynhans 1999), the reference condition is actually based on historical data for spatially delineated river segments.

1.2.2 Biotic components for deriving reference conditions

One or several components of the biota may be used in the derivation of ecological reference conditions, including periphyton (Barbour *et al.* 1999), riverine macroinvertebrates (Reynoldson *et al*. 1997, Barbour *et al.* 1999, Dallas 2000), fish (Karr 1981, Kleynhans 1999), and riparian vegetation (Kemper 1999). The methodologies for establishing reference conditions for the different biotic components may vary and

include information from "least impacted" sites, in addition to historical data if available.

In South Africa, riverine macroinvertebrates are one of the most commonly used components of the biota and the RBA technique, SASS4 (Chutter 1995), is used as the routine monitoring tool to assess water quality and general river condition. It therefore forms one of the main components of the RHP and is hence an excellent candidate for aiding the derivation of ecological reference conditions for riverine macroinvertebrates.

SASS is a scoring system based on benthic macroinvertebrates, whereby each taxon is allocated a sensitivity/tolerance score according to the water quality conditions it is known to tolerate (Dallas *et al*. 1995, Dallas 1997). Interpretation of scores is based on two calculated values, namely SASS4 Score, which is the sum of the taxon scores for taxa present at a site, and average score per taxon (ASPT), which is SASS4 Score divided by number of taxa. Reference conditions designated for riverine macroinvertebrates in South African rivers will need to incorporate both Reference Condition SASS Scores and expected reference communities.

1.2.3 Why riverine macroinvertebrates?

There is general consensus that macroinvertebrates are amongst the most sensitive components of aquatic ecosystems, in addition to being relatively non-mobile and readily sampled, and are thus useful for assessing biological integrity (Metcalfe-Smith 1991). There are several advantages to using riverine macroinvertebrates for assessing water quality and these have been summarised by Rosenberg & Resh (1993).

- Macroinvertebrates are ubiquitous in rivers and can therefore be affected by environmental disturbances in many different types of aquatic systems and in most biotopes within these waters.
- Sensitivity to stress varies with species and the large number of species within a community offers a spectrum of responses to environmental stresses.
- In their aquatic phase macroinvertebrates are largely non-mobile and are thus representative of the location being sampled, which allows effective spatial analyses of disturbance and pollutants.
- Their life-span is long enough to allow elucidation of temporal changes caused by disturbances, whilst short enough to ensure observation of recolonisation patterns following such a disturbance.
- Macroinvertebrates are relatively easy to identify to family, and degraded conditions can often be detected by an experienced biologist or technician with only a cursory examination of the macroinvertebrate assemblage (Barbour *et al*. 1999).
- Sampling is relatively easy, requires few people and inexpensive equipment, and has very little detrimental effect on the resident biota.

As a result of these factors, benthic macroinvertebrates act as continuous monitors of the water they inhabit (Hawkes 1979), enabling long-term analysis of both regular and intermittent discharges, variable concentrations of pollutants, single and multiple pollutants, and synergistic or antagonistic effects.