CHAPTER 6. CONCLUSIONS, RECOMMENDATIONS AND THE WAY FORWARD

Summary

This chapter summarises the concepts discussed in this report. It provides a protocol for deriving ecological reference conditions for riverine macroinvertebrates. Each step in the procedure is described and reference is made to the appropriate details in the document. Recommendations regarding biomonitoring within the RHP in general and issue specific to SASS and/or reference conditions are provided.

6.1 CONCLUSIONS

Ecological reference conditions for riverine macroinvertebrates are a useful tool for facilitating the interpretation of data from monitoring sites. It is possible to interpret trends in biomonitoring data at one site over time, using the same site as the reference site, or to use the classic "above" and "below" approach in which a monitoring site below an impact is compared to a control or reference site above the same impact. For both these scenarios, it is not critical to have a derived reference condition. In order to compare biomonitoring data from sites which do not conform to the "above/below" scenario, or for extrapolation from one site to another, spatial and temporal considerations come into play. In such instances reference conditions provide a means of comparison.

Riverine macroinvertebrates have proved to be useful components of the biota for biomonitoring. The widely used SASS biomonitoring technique provides a relatively quick and reliable means of assessing the water quality and general river health at a site. Data interpretation is based on the three derived SASS Scores, namely SASS4 Score (the sum of the individual taxon sensitivity/tolerance scores), number of taxa and the Average Score per Taxon (ASPT = SASS4 Score divided by the number of taxa). A site is considered impacted if the SASS Scores are lower than those expected at a site which is minimally or least impacted, i.e. a reference site. The problem arises in determining what such an expected SASS Score, and indeed, invertebrate community might be. Biota vary spatially in response to regional differences in factors such as geology, climate, geomorphology etc. For this reason, regional reference conditions have been adopted in South Africa, whereby spatial differences in invertebrate communities, as reflected in SASS Scores have been taken into account.

The spatial framework within which biomonitoring is undertaken has been developed for use within the RHP. The testing of this framework in the study region, Mpumalanga, by multivariate analysis of invertebrate communities at selected reference sites, has shown that Reference Groups are generally comparable to Level 1 Ecoregions, with Level 2 Sub-regions and Level 3 River types varying in their level of importance depending on the particular Reference Group. Three Reference and two sub-groups were derived from the reference sites located within the Central Highlands, Great Escarpment Mountains and Lowveld ecoregions. These Reference or sub-groups were based on the invertebrate fauna combined from three seasons and from all available biotopes.

Environmental variables were identified which best discriminated between Reference Groups. These variables were used to characterise each of the Reference Groups in terms of catchment, site, habitat and water chemistry variables. Enormous potential exists for developing predictive modelling systems which enable the prediction of invertebrate taxa on the basis of selected environmental variables.

An examination of the influence of biotope availability and seasonal variation indicated that both factors needed to be considered when interpreting biomonitoring data and deriving reference conditions. Biotope availability, in particular, significantly affected SASS Scores which varied amongst biotope-groups, and certain taxa were more commonly recorded in one or another biotope-group. Similarly, SASS4 Scores and number of taxa differed significantly between seasons. Of the three indices, ASPT proved to be the most robust and least variable with respect to both biotope availability and season. It is therefore important that ASPT be used in data interpretation. Comparing SASS Scores or invertebrate communities from sites, with different biotopes available or sampled in different seasons, may lead to erroneous interpretation with respect to water quality or river health. The influence of both factors have been examined at the reference sites assessed in this study and the extent of the variation measured.

Discussions with biomonitoring practitioners invariably raise questions related to the interpretation of data and what conditions one would expect at the monitoring site under natural conditions. Accepting that "natural" conditions rarely exist, "least impacted"' conditions serve as the best available surrogate. Through these discussions, together with the understanding gained through the course of the project, it has become clear that for biomonitoring to be effectively implemented within a national context, attention needs to be paid to deriving reference conditions on a regional basis. The methods developed in this report should serve as an adequate guideline for establishing reference conditions in other regions. The protocol followed is easily transferable to other regions and methods for taking factors such as biotope availability and sampling season into account have been detailed (Figure 5.1). Even so, the complexity related to spatial and temporal variability of invertebrate communities in riverine ecosystems, makes data interpretation complex and the risk of misinterpretation relatively high. There is a clear need to consider the development of a predictive modelling system which factors in the aspects creating uncertainty. This is discussed further under recommendations.

6.2 A PROTOCOL FOR DERIVING ECOLOGICAL REFERENCE CONDITIONS FOR RIVERINE MACROINVERTEBRATES

The procedures and analyses undertaken during this project and which are documented in this report have been summarised in the form of a protocol. It is hoped that this protocol will guide biomonitoring practitioners in their endeavours to derive ecological reference conditions for riverine macroinvertebrates. The flow diagram (Figure 5.1) provides an overview of the protocol.

The protocol developed for use in South Africa adopts a regional reference condition approach which also

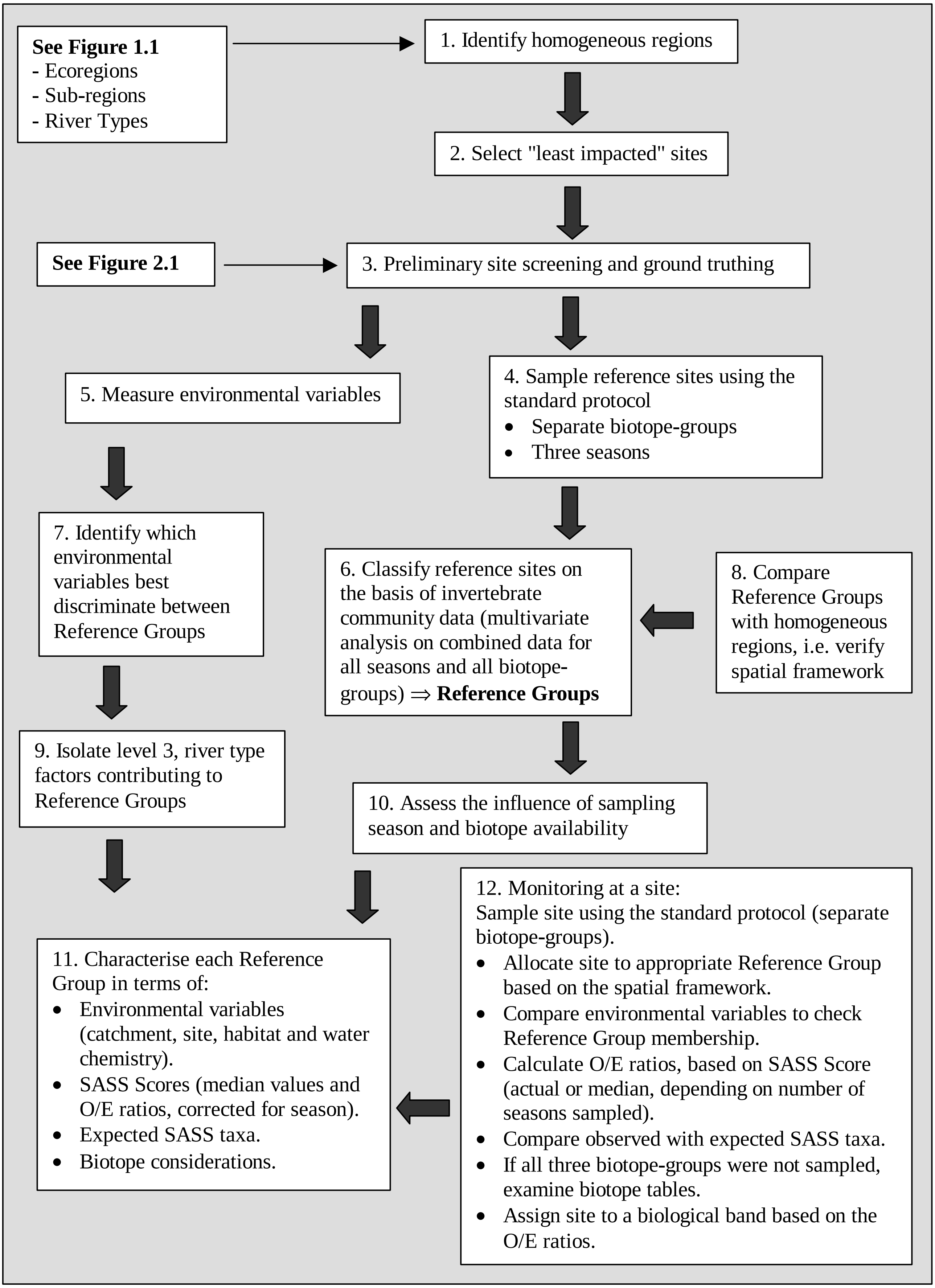

Figure 5.1 Suggested protocol for deriving ecological reference conditions for riverine macroinvertebrates and its use within the RHP.

incorporates separate analyses of invertebrate communities in an attempt to verify the spatial framework and to factor in potential variability resulting from physical, seasonal and habitat/biotope factors. A short explanation of each process is given below, together with the relevant chapter and section details.

1. Identification of homogeneous regions (See Chapter 1, Section 1.3, Figure 1.1)

A three-tiered hierarchical spatial framework (see figure 1.1) has been developed in an attempt to identify homogeneous regions within which biomonitoring can be undertaken.

- *Level 1: Bioregions or ecoregions:* Bioregions (Brown *et al*. 1996) represent broad historical distribution patterns of riverine macroinvertebrates, fish and riparian vegetation (Eekhout *et al*. 1997), and which have been modified using local knowledge. Ecoregions are based on factors such physiography, climate, geology, soils and potential natural vegetation. At present, both level 1's are used since the suitability of one or the other with respect to biomonitoring and the RHP has not yet been established.
- *Level 2: Sub-regions or geomorphological zones* reflect broad geomorphological characteristics and distribution patterns of components of the biota. Rivers are longitudinally divided into the following zones: Source zone, Mountain headwater stream, Mountain stream, Foothills (cobble bed), Foothills (gravel bed) (previously termed Transitional) and Lowland sand bed or Lowland floodplain (Wadeson 1999). Three other geomorphological zones associated with a rejuvenated profile, namely Upland Flood Plain, Rejuvenated bedrock fall/cascade and Rejuvenated foothills, were also proposed.
- *Level 3: River types* are identified using factors such as river size (e.g. stream width, stream order etc.), hydrological type (ephemeral, seasonal or perennial), geomorphological characteristics (channel pattern, substratum composition) and other chemical and biological factors.

Differentiation into Levels 1 and 2, i.e. ecoregions and sub-regions, is a map-based desktop exercise, whilst Level 3, i.e. river types, is undertaken at the ground truthing and data analysis stage.

2. Selection of "least-impacted" sites (See Chapter 2, Section 2.2)

"Least-impacted" or potential reference sites, i.e. sites exposed to minimal anthropogenic influences, are identified using local knowledge, land-use maps and existing biomonitoring information.

3. Preliminary site screening and ground truthing (See Chapter 2, Sections 2.3 and 2.4, Figure 2.1)

This phase involves assessing each site in the field. The geomorphological zones are confirmed and anthropogenic influences are checked by examining the surrounding land-use, channel, bed and bank modifications, and present status. A ground-truthing data-sheet designed for this phase is appended (Appendix A). Potential Level 3 River Type factors are identified.

4. Sampling invertebrates using SASS4 (See Chapter 3)

SASS4 sampling is undertaken using the appropriate SASS protocol (Chutter 1998). For the purposes of deriving reference conditions, it is recommended that sampling be conducted in three seasons and that biotope-groups are sampled separately (i.e. stones-in-current/stones-out-of-current;

marginal and aquatic vegetation; gravel/sand/mud). An assessment of the habitat is undertaken simultaneously (e.g. IHAS).

5. **Measurement of environmental variables (See Chapter 3, Section 3.3.6, Chapter 4, Section 4.3.4)**
   Selected environmental variables are measured, including catchment (e.g. longitude, latitude, altitude, distance from source and stream order), site (channel pattern, stream width, habitat depths, geological type, vegetation type and canopy cover), habitat (substratum richness, composition and dominance, the percentage of each substratum type, percentage embeddedness, the number and combination of biotopes, the percentage of each biotope present, and the percentage cover of algae and macrophytes), and water chemistry variables (pH, temperature, conductivity, turbidity, dissolved oxygen and nutrients).

6. **Classification of reference sites (See Chapter 4, Section 4.3.2 and 4.3.3)**
   Reference sites are classified into Reference Groups on the basis of the similarity of their invertebrate communities. Invertebrate data from each of three seasons and all three biotope-groups are combined for the analysis. If predictive models such as AusRivAs or RIVPACS are adopted in the future, season and biotope-groups will be analysed separately.

7. **Identification of environmental variables which best discriminate between Reference Groups (See Chapter 4, Section 4.2, 4.3.4 and 4.4.2, Chapter 5, Section 5.3.1.1)**
   Environmental variables are identified which best discriminated between Reference Groups. These variables are used to characterise each of the Reference Groups in terms of catchment, site, habitat and water chemistry variables.

8. **Verification of homogeneous regions (See Chapter 4, Section 4.3.3 and 4.4.1.1)**
   The validity of the spatial framework is examined by comparing the Reference Groups with the identified homogenous regions.

9. **Isolation of river type factors contributing to Reference Group classification (See Chapter 4, Section 4.4.1 and 4.4.2)**
   Specific river type factors such as substratum type, which were considered significant in differentiating between Reference Groups, were identified.

10. **Assessment of the influence of sampling season and biotope availability (See Chapter 3, Section 3.3.1 and 3.3.2, Chapter 4, Sections 4.3.5, 4.3.6, 4.4.3 and 4.4.4)**
    Comparing SASS Scores or invertebrate communities from sites, with different biotopes available or which have been sampled in different seasons, may lead to misinterpretations. For this reason it is advised that the potential effect of both biotope availability and sampling season on invertebrate communities and SASS Scores, be examined. Separate- versus combined-biotope sampling and single- versus multiple-season sampling is examined so that erroneous interpretation with respect to water quality or river health can be avoided.

11. Characterisation of Reference Groups (Chapter 5)

Each identified Reference Group is characterised in terms of environmental variables, SASS Scores, expected SASS taxa and biotope considerations.

12. Comparison of monitoring site with reference condition (Chapter 5)

Following the standard sampling protocol, monitoring site data is compared with the appropriate reference condition. *Observed* (monitoring site) to *Expected* (reference condition) ratios are calculated and site is assigned to a biological band based on the *O/E* ratio.

6.2 RECOMMENDATIONS

During the course of this project and following discussions with biomonitoring practitioners, certain issues have surfaced which clearly need addressing. The following are recommendations regarding biomonitoring within the RHP in general and issues specific to SASS and/or reference conditions:

1. The biomonitoring protocol needs to be standardised and adhered to by all SASS practitioners. It is recommended that the Reference Condition manual is used (Dallas 2000). A second version of this manual is planned which takes into account comments from biomonitoring practitioners and knowledge gained as a result of this report. This modified version will be available via the River Health Programme web-site (www.csir.co.za/rhp).

2. Biomonitoring practitioners need to be informed of the importance of correctly assessing a site and ensuring that all peripheral information is assessed. Quality is important.

3. Biomonitoring practitioners need to be made aware of the limitations of SASS and when and where it is not suitable for use, e.g. in canalised rivers with few, if any, biotopes, and in non-perennial systems or wetlands.

4. The issue of sampling biotopes separately needs to be discussed, and standardised. The results of this study clearly show the importance of sampling biotopes separately and the misinterpretation of data that may result through differences in the availability of biotopes. It is recommended that the three biotope-groups discussed in this document are sampled separately. Data should be examined to assess the effect of biotope availability on invertebrate communities and SASS Scores.

5. The Invertebrate Habitat Assessment System (IHAS) needs to be thoroughly tested so that its usefulness as an interpretative tool for SASS may be assessed.

6. During the initial establishment and monitoring of reference sites, it is recommended that sampling is conducted in at least three seasons and that site classification is based on the combined data.

7. The development of a prediction-based modelling system, similar to that of AusRivAs, is strongly recommended. The complexity of invertebrate communities and the uncertainty related to the

measurement of them, make deriving sound reference conditions, in the absence of modelling, difficult. By ensuring that all biomonitoring practitioners adhere to the standard sampling protocol, which includes the collection of a subset of environmental variables and separate biotope-group sampling, we will be ensured of an extensive and useful data-set in the future. The vehicle for data storage has already been developed (Rivers Database, Fowler *et al*. 2000). In the long term, it should be possible to develop a series of models based on the RHP data which will automate the allocation of a monitoring site to its appropriate Reference Group, calculate the expected probabilities of each taxon occurring at the monitoring site, calculate the Observed/Expected ratios and thereby generate information on the extent to which the monitoring site has deviated from the expected reference condition. This will greatly simplify data interpretation and reporting on the river health of a monitoring site or series of monitoring.

8. Biomonitoring practitioners, researchers, consultants and all individuals and organisations likely to participate in the RHP, should be encouraged to develop reference conditions for their region, and to validate components of the RHP such as the spatial framework and the IHAS.

9. Once reference sites have been identified within a region, and reference conditions based on these sites have been derived, annual assessments of the reference sites need to be conducted. In the case of Mpumalanga, it seems that routine monitoring of all reference sites would best be undertaken in spring. In this way changes in the condition of the reference site can be picked up, and the site excluded from future monitoring if it has become impacted. An understanding of the "natural" or expected annual variability in the various components will also be measured.

10. At least one (preferably more) reference site of each type should be included in some formally conserved area or at least afforded some protection. This task could fall to the Catchment Management Agencies.

11. Lastly, whilst SASS has proved to be a useful tool for monitoring water quality and general river health, it should not be a stagnant technique. As our biomonitoring database increases, so does our potential to test and validate the sensitivity/tolerance scores. Other aspects, such as incorporating an abundance rating in the score calculations, are often raised by biomonitoring practitioners. These need to be addressed. SASS is fundamental to the RHP and it also forms one of the key tools used in generating aquatic invertebrate information for the Rapid, Intermediate and Comprehensive Ecological Reserve for Rivers. For this reason, it needs to maintain a solid scientific basis.