5. BIOMONITORING CONCEPTS

5.1 The role and purpose of biomonitoring

Traditionally, water quality monitoring actions have focused on physical and chemical measurements. It is widely recognised that the use of other indicators, in addition and complimentary to traditional chemical and physical water quality monitoring techniques, can greatly enhance the assessment and management of aquatic ecosystems. Consequently, biological monitoring, or *biomonitoring*, is an important tool in assessing the condition of aquatic ecosystems.

Information on and understanding of environmental change is necessary to allow for the protection and remediation of ecosystems. With current knowledge however, normal limits of variation in South African ecosystems are virtually unknown. This lack of historical and current environmental data makes it difficult to define clearly the nature and extent of environmental change.

It is clear that sufficient and appropriate information is necessary to allow managers to make rational and equitable decisions with respect to water resource management. This information can only be derived from statistically and scientifically defensible monitoring designs. The best way to identify measurement parameters that can serve as vital signs of ecosystems, and define the limits of their variation, is through long term biomonitoring. The resulting data sets will be analysed to provide the basis for defining normal limits of variation or diagnosing ecosystem impairment.

5.2 Definition of biomonitoring

In the operational context, the term *aquatic biomonitoring* is used to refer to the gathering of biological data in both the laboratory and the field for the purposes of making some sort of assessment, or in determining whether regulatory standards and criteria are being met in aquatic ecosystems.

Biomonitoring of aquatic communities can be subdivided into a number categories, as follows (Roux *et al*, 1993):

- *Bioassessments* are based on ecological surveys of the functional and/or structural aspects of biological communities.
- *Toxicity bioassays* are a laboratory-based methodology for investigating and predicting the effect of compounds on test organisms.
- *Behavioral bioassays* explore sub-lethal effects of fish or other species when exposed to contaminated water; usually as on-site, early warning systems.
- *Bioaccumulation* studies monitor the uptake and retention of chemicals in the body of an organism and the consequent effects higher up the food chain.
- *Fish health* studies deal with causes, processes and effects of diseases; and can form a complementary indication of overall ecosystem health.

Apart from information derived from monitoring of in-stream biotic communities, the evaluation of the health aquatic ecosystems must also include other system descriptors. The assessment of the available *habitat* is crucial when comparing biomonitoring results from different sites. The characterisation of geomorphological characteristics, hydrological and hydraulic regimes, chemical and physical water quality and riparian vegetation all form essential components in aquatic ecosystem health assessment.

5.3 The use of ecosystem indicators

The overall condition, or health, of aquatic ecosystems is determined by the interaction of all its physical, chemical and biological components. Because of the lack of resources, it is usually impossible to monitor all these components, and therefore indicators are used instead. Indicators can be defined as "characteristics of the environment that provide quantitative information on the condition of ecological resources, the magnitude of stress, or the exposure of a biological component to stress" (Thorton *et al.*, quoting Olsen, 1992).

Indicators are usually selected on the basis of their ability to:

- represent the overall status of the environment
- permit the detection of trends, through their sensitivity to a range of stresses
- be measured and interpreted relatively easily.

5.4 The use of ecosystem indices

One of the challenges of biomonitoring is to simplify various ecological data to the point where they are useful to resource managers, conservationists, politicians and the general public. This has resulted in the development of a number of relatively simple and rapid assessment techniques by which biological and other data can be presented numerically. These techniques are generally referred to as "indices", and are used to quantify the status of aquatic ecosystems by summarising data on the ecological health status of aquatic communities and their environment.

Ecosystem indices do not attempt to explain the reason for changes to ecosystems, nor do they account for the complexity of interactions between physical, chemical and biological components. They are simply a tool for organising and abstracting ecological data so that these can be understood by non-specialists.

5.5 Assessment of aquatic ecosystem health

5.5.1 The concept of assessment

Aquatic ecosystem health, like human health, cannot be measured directly. Instead, only indicators of health can be measured and, in turn, used to assess the "health" status. Therefore, for the purpose of designing a monitoring programme, it is important to distinguish between measurement end-points and assessment end-points.

A *measurement end-point* is the result of an actual measurement of some characteristic or component of the aquatic ecosystem - for example, the numbers of mayfly at a particular location - via a bioindicator. It usually does not provide any information on what the implications of such measurements are for the aquatic ecosystem health.

An *assessment end-point* is usually the result of an interpretation (assessment) of measured data, often in conjunction with other related information, to arrive at an end-point which can be related to aquatic ecosystem health. Any number of assessment end-points can be arrived at, for example: creation of health "categories" by grouping sets of biological data; comparison between measured and desired aquatic communities; estimates of costs associated with managing ecosystems from measured to desired states, etc.

These concepts have important implications for a monitoring programme, which must:

- Reflect and describe the relationship between measurement and assessment end-points;
- Describe in sufficient detail the assessment process so that different people using the same measured information will consistently arrive at the same assessment;
- Recognise that for the purpose of management decision-taking the information has to be reported in the form of assessment rather than measuring end-points.

5.5.2 Assessment relative to a reference point

Arriving at an assessment usually requires two different type of data: first, a "baseline", or reference point, which is usually associated with some desired or ideal state; and, second, measurements of the actual condition that needs to be assessed.

Unlike water quality, where the reference point is pre-determined standard (or guideline), usually based on the use which is made of the water (see **Appendix C**), the assessment of aquatic ecosystem health requires a different type of reference.

The ideal approach to assessing the health of aquatic ecosystems would be to compare the measured values, or indicators, against similar measurements taken at an equivalent, but "pristine" site i.e. a habitat whose physical and chemical characteristics are unaffected by any human activities. However, as mentioned earlier (see 4.2.3), because of the widespread and ongoing impact of human activities, very few - if any - systems are "pristine". The best compromise is the use of minimally impacted sites to define a "best attainable" reference condition. Such sites are typically linked to a specific region with similar physical and biological characteristics.

The assessment of measured data against a "best attainable" reference condition allows the "health status" to be derived, and can also provide the basis for assessing trends. Both of these assessment end-points would be important in a monitoring programme to assess aquatic ecosystem health.

5.5.3 Reference site selection

In South Africa, there are currently two initiatives to determine regions which could form the basis for reference site selection.

- *Physiogeographic regions* represent relatively homogeneous regions of similar climate, soil, geology, natural vegetation, land form and land use (Omernik, 1987, as quoted by Peterson, 1989).
- *Biogeographic regions* represent regions of similar conditions in terms of large-scale patterns of riverine flora and fauna. These regions can be further divided into sub-regions, thereby grouping mountain-stream or lower-river zones of many rivers (Eekhout *et al.*, in prep.).

Once suitable regions (and, if needed, sub-regions) have been delineated, the next step is to establish reference sites within each that represent the best attainable condition for that type of region. Measurements at these sites do not necessarily represent pristine, or totally undisturbed, conditions (see 4.2.3), but do represent a point or area with minimal impact from human activities (Peterson, 1989).