4. MANAGEMENT OF AQUATIC ECOSYSTEMS

Sustainable resource management requires that the biosphere be viewed as an entity consisting of three integrated compartments, namely social, economic and environmental. No compartment can be sacrificed for any other without a decrease in the overall quality of human life. The guiding principle for integrating these compartments is *ecosystem health* - the health of human populations and their environments, jointly (Vallentyne and Munawar, 1993). In other words, healthy places result in healthy people and healthy people in healthy places.

4.1 Introduction

In the past, management of water quality was primarily based on the need to protect human health. Depending on the uses made of water - both direct and indirect - it's quality had to comply to norms acceptable to human health standards, typically established by microbiologists and health workers, and managed according to engineering methodologies.

Over time, as human activities intensified and spread, they have had an increasing impact on the quality of water, and on the ecological systems, or *ecosystems*, that the aquatic environment sustains. Recognition of these impacts has spurred increasing interest in describing the relationship between people and their environment. With this has come the realisation that water is the basis for **all** forms of life - not just human. Moreover, many of the uses and benefits that people obtain from water resources are dependant on healthy, functioning ecosystems. Furthermore, being able to provide the conditions for such ecosystems implies that the systems are in balance. Balanced systems are required to provide sustained use of water resources.

This development started in scientific circles, and is now shared by the wider community. This has lead governments to develop policies to protect aquatic ecosystems, and means that water quality managers, must adopt the broad philosophy of integrated ecosystems management, rather than the previous, narrower one of chemical water quality management.

The basis for aquatic ecosystems management is therefore more than just the protection of human health - it is the **protection of the water resource base.** To support this, ongoing, comprehensive monitoring, tied to effective management, of all aspects of aquatic ecosystems is needed.

4.2 Aquatic ecosystem concepts

A number of concepts, which are unique to aquatic ecosystems and of relevance in providing background information, are briefly described below. Most of these concepts originated in scientific research, but are of increasing importance for those who need to be able to assess and manage the health of aquatic ecosystems. Additional clarification and more detail of these terms will be found in the literature cited.

4.2.1 Biological diversity

The term *biological diversity*, or *biodiversity*, originated in the study of terrestrial ecosystems. One formal definition for biodiversity is "the variety and variability among living organisms and the ecological complexes in which they occur" and "encompasses different ecosystems, species, genes, and their relative abundance" (OTA, 1987, as quoted by Angermier and Karr, 1994). Such a definition means that biodiversity is broader than just species diversity. This means that the protection of biodiversity implies actions beyond species protection - the ecosystem forming the basis for those species also requires protection.

4.2.2 Biotic integrity

A formal definition for *biotic integrity*, or *biointegrity*, is "the capability of [an ecosystem for] supporting and maintaining a balanced, integrated and adaptive community of organisms, having a species diversity, composition and functional organisation comparable to that of the natural habitats of the region" (Karr and Dudley, 1981).

Biotic integrity can be viewed as a relative measure, typically by assessing the degree to which the biological condition of a system has been modified relative to its natural state. Biotic integrity offers a better basis than biodiversity for assessing ecosystem health because it:

- takes into account processes between biological components, and
- is associated with naturally evolved systems.

4.2.3 "Natural" aquatic ecosystems

One basis for determining the degree to which an ecosystem has retained its biointegrity is to examine equivalent ecosystems in their "natural" (or "pristine") state. However, because of the widespread and ongoing impact of human activities, very few systems can be said to be "natural". Such systems may exist in the older national parks or upland, mountain catchments, although even such areas can be impacted by atmospheric deposition. In

practice, the concept of "best attainable" ecosystems, representing areas which are minimally impacted, can be used as an equivalent measure.

4.2.4 Cause-effect relationships in ecosystems

In the assessment of water quality and ecosystem health, two differing, but equally valid, approaches can be used (Thorton *et al.*, 1994). One can measure variables which are assumed to be associated with a stress - the stress-oriented approach - or, in some way, to reflect the results or effects of changes - the effects-oriented approach.

The stress-oriented approach is the more well known one - it starts with the characterisation of the stressor (for example, a measured water quality constituent) and describes exposure pathways to the expected effects on the ecosystem. This approach is a predictive one and relies upon known cause-effect relationships between stressors and ecological effects.

The complementary approach is a retrospective one, which is usually more appropriate to the type of wide-scale ecosystem health monitoring required in this programme. In this approach, various biological indicators are measured and, from these measurements, an assessment can be made about the health of the aquatic ecosystem.

4.3 Factors affecting aquatic ecosystem health

A wide range of human activities can impact on aquatic ecosystems, such as:

- point source discharges (for example, from factories or sewage treatment works)
- non-point source runoff from agriculture, urban or mining areas
- alteration of channel characteristics via sedimentation or siltation
- changes in the stream flow regime through dams or diversions
- removal of riparian zone vegetation
- introduction of exotic or alien species

Human activities can thus impact on both instream organisms and the habitats in which they occur. Ecosystem management must therefore encompass the effects of many changes; for example, impacts of discharges on water quality, creation of barriers reducing stream flow, to land use changes affecting habitat, etc.

4.4 Approaches to management of aquatic ecosystems

The behaviour of water quality constituents and their interactions, while complex, has been well studied in the past and can be monitored and predicted with some degree of confidence. In contrast, management of aquatic ecosystems is less well developed.

Because aquatic ecosystems are highly complex and variable, many differences in response to different stressors are possible under different circumstances. Most predictions relating to ecosystem behaviour carry a high degree of uncertainty. For this reason, management of aquatic ecosystems needs to be adaptive and flexible (ANZECC, 1992). In particular, managers need to be able to make effective decisions without access to detailed knowledge. Thus, ecosystem management presents demanding challenges.

4.4.1 Barriers to effective management

A number of actual or potential barriers exist when implementing ecosystem management on a national scale (GAO, 1994):

- Noncomparable and insufficient data, generally resulting from uncoordinated and incomplete data collection programmes
- Scientific uncertainty relating to understanding of ecosystem behaviour
- Difficulties in "trading off" ecological and socioeconomic considerations
- Disparate missions and planning activities across different responsible organisations (on national, regional and local levels).

Clearly these types of barriers cannot be dealt with in the short term, and it should be borne in mind that the data collection and reporting activities of a biomonitoring programme are one small part of a much broader framework.

4.4.2 Overseas approaches

In Australia, the national government has adopted a policy of ecologically sustainable development which aims at maintaining sustainable ecosystems and preserving genetic diversity. In terms of water quality management, the goal is to protect biological diversity and maintain ecological processes and systems (ANZECC, 1992). In practice, it is realised that all development is likely to cause the loss of some genetic component of biodiversity, to reduce overall population of some species and to interfere to some extent with ecosystem function. Therefore, protecting biodiversity means ensuring that these impacts associated with development do not threaten ecosystem integrity.

In the United States of America, there are a number of federal agencies who play a role in ecosystem management. For various reasons, each has developed its own approach to, and priorities for, ecosystem management. In a report to Congress on the subject, the GAO (1994) has clearly spelt out the need to adopt a single goal. The current working definition

that it reports on is the goal of "preserving, restoring, or, where those are not possible, simulating ecosystem integrity as defined by the composition, structure and function that also maintains the possibility of sustainable societies and economies."

The GAO also recommends a four step approach of (1) delineating the boundaries of ecosystems, at several different scales, (2) understanding the ecologies of these ecosystems, including conditions, impacts and trends, (3) making management choices about desired conditions and types of activities on a coordinated basis, and (4) adapting management to new information received from research and monitoring.

In the United Kingdom, efforts around ecosystem management have been based on the development of the RIVPACS system. This system allows for the assessment of actual data gathered from test sites, against a baseline established at reference sites, thereby providing an assessment of the biological condition of a river.

4.4.3 Aquatic ecosystems management in South Africa

In South Africa, the recent change in government has brought with it many changes in approach and legislation in all spheres of life and consequent changes in approaches to management of social, economic and environmental sectors. The Department of Water Affairs and Forestry has published a White Paper outlining its fundamental policy on the environment (DWAF, 1994) as part of its approach to managing water supply and sanitation. Parts of this policy are quoted fully in **Appendix A**, and its key principles are summarized below:

- Protection and conservation of the natural resource base is imperative
- The environment should not be regarded as a "user" of water in competition with other users, but as the base from which the resource is derived and without which no development is sustainable
- The concept of water as having economic value should be extended to it also having intrinsic environmental value

It is realised that application of these principles will involve the following actions:

- Developing an understanding of the resource characteristics
- Monitoring of the resource
- Implementing protection measures, where necessary
- Applying simple environmental impact assessment procedures
- Auditing of development projects to ensure that the guidelines are being applied

Water monitoring and, in particular, biomonitoring, has a key role to play in providing information to support the above actions.

Although the DWAF's policy on aquatic ecosystems does not view it as a competing water use, protection of aquatic ecosystems must nonetheless consider the direct and indirect uses of the services derived from it. Therefore, the health of aquatic ecosystems must be maintained at levels that will also protect the uses.

The goal of aquatic ecosystem management that has been adopted by the DWAF is:

> "to **protect** the health of aquatic ecosystems. Therefore the DWAF will seek both to **maintain** existing, healthy ecosystems, as well as to **improve** those ecosystems, which are, in some way, impaired, in order to restore their biological integrity."

Implementation of appropriate management actions may require the setting of short-term management objectives in order to reach this goal in a practical and cost-effective manner.