5.0 Introduction

5.0.1 Background

Does it make any difference to the functioning of an ecological system if there are many species or only a few? Are species that perform similar functions within an ecosystem interchangeable, or do they differ in ways that matter to the workings of the system? Does the genetic diversity of species affect the sustainability of ecosystem-level functions? How does diversity among ecosystems affect the flow of energy, water or chemicals across the landscape? What are the ecosystem-level ramifications of human-driven changes in biodiversity?

Addressing these questions requires an understanding of the relationships between biological diversity and ecosystem functioning, and thus the functional consequences of changes in biological diversity. The importance of this topic is underscored by the realization that the provision of marketable goods and free ecological services are essential features of humankind's interest in and benefit from the biosphere's diversity. The explosive growth of the human population and its use of resources, energy and land are resulting in massive changes in diversity at a variety of levels throughout the world. Some of these changes, such as extinction of species, are truly irreversible; while others are not, but the challenge of managing natural resources in a sustainable manner has clearly increased. Increases in our understanding of the relationships between changes in biological diversity and the functioning of ecosystems can help improve a wide range of policies involving agriculture, forestry, fisheries and land use, transcending traditional conservation-based policies. Assessing our knowledge of the general principles of the relationships between diversity and the functioning of ecological systems is the focus of this Section.

Understanding the functional implications of biodiversity requires that issues addressed in population and community ecology be merged with those in ecosystems ecology. Each of these areas of ecology has developed research traditions largely without interaction with the other. However, in the past decade, there have been a number of attempts to bridge these two approaches (Vitousek *et al.* 1987; Vitousek 1990; Schulze and Mooney 1993; Naeem *et al.* 1994; Tilman and Downing 1994; Jones and Lawton 1995). International scientific reviews by SCOPE (Mooney *et al.* 1995) aimed at understanding the relationship between biodiversity and ecosystem functioning, and the broader approach by the Diversitas programme of IUBS and UNESCO (Solbrig 1991) designed to also analyse the origins, maintenance and monitoring of diversity, have played a critical role in the preparation of Sections 5 and 6 of the GBA.

5.0.2 Important concepts

The term biodiversity has frequently been equated with diversity of species. The strength of the term is its simplicity. However, understanding the functional significance of biodiversity necessitates teasing apart the rich and multiple dimensions of the concepts underlying the term (see Section 1). There are four key concepts to consider: (1) the levels of biological and ecological organization and their interactions, (2) the numbers of different biological units within each level, (3) the influence and degree of similarity in the traits or roles that biological and ecological units within each level play, and (4) the spatial configuration of the units within any level. For example, at the species level we need to consider whether there are functional consequences of the total numbers of different species, whether the degree of similarity in their functional roles or traits has ecosystem-level consequences, and whether the spatial configuration of the species influences ecosystem functioning.

Ecological systems can be viewed at increasing levels of organization: genetic, population, species, community, ecosystem and landscape. Patterns and processes at any particular level affect not only the target level, but also the levels above and below. Because ecosystems provide ecological goods and services to humanity, the assessment in the following chapters is focused generally on the ecosystem level, but includes relevant functioning at lower and higher levels.

We use the term 'ecosystem' to refer to all the individuals, species and populations in a spatially defined area, the interactions among them, and those between the organisms and the abiotic environment (Likens 1993; see Section 2.3). 'Ecosystem functioning' denotes the sum total of processes operating at the ecosystem level, such as the cycling of matter, energy and nutrients, as well as those processes operating at lower ecological levels which impact on patterns or processes at the ecosystem level. Interactions among species or the transfer of genetic material are examples of some of the lower level processes that are immediately relevant to the ecosystem consequences of biodiversity. Thus, in the following sections, patterns of diversity at the genetic, species, community and ecosystem levels are related to key functional properties of ecosystems.

Following other syntheses (Lubchenco *et al.* 1991), we use the term 'ecological system' to refer to the characteristics or functioning of organisms, populations, communities or ecosystems at a level that is appropriate to the particular questions being asked. Thus, it is analogous to the use of the word 'taxon' by systematists.

The roles of different species and the extent to which they overlap in function have been a common theme in community ecology. The concepts of 'keystone species', 'redundancy', 'compensation', 'functional groups' and 'rivets' all deal with the extent to which individuals or species overlap in function, and the consequences of this overlap to the system. An understanding of unique species' traits, overlap among species, and the possible functional significance of low or high numbers of species, apart from how they differ in traits, is clearly immediately relevant to understanding the conditions under which 'species matter'. Historically less attention has been paid to the equivalent questions dealing with functional overlap among genes or ecosystems. Nonetheless, comparable information is now recognized as immediately relevant to conservation and management.

The third important topic of interest to the relation between diversity and the functioning of ecological systems is that of the spatial configuration of the units within the system. For example, knowing the consequences of different habitat or ecosystem configurations to the functional properties of landscapes would enhance the design of reserves as well as the management of resources. Knowing how the populations within an ecosystem are distributed in space would enhance our ability to predict its functional resilience to stress from pathogens and environmental variability.

5.0.3 Section organization

Chapter 5.1 begins with an exploration of the social and political context within which the study of biodiversity and ecosystem functioning occurs. Why should society care? In particular, it considers the notion that one of the very important aspects of ecosystem functioning that depends on diversity is the provision of goods and services, and the provision of insurance against adverse changes due to stress or environmental variability.

Chapter 5.2 then considers how the diversity of the natural world is organized, and how diversity at each level of organization affects ecosystem functioning. Subsection 5.2.1 addresses the question of the extent to which intraspecific genetic variation is important in understanding the relationship between biodiversity and ecosystem functioning; 5.2.2 addresses the degree to which we can predict the ecosystem-level consequences of species additions, deletions and replacements, and synthesizes the state of knowledge with respect to the processes that determine the importance of species and communities in ecosystem-level functioning; 5.2.3 addresses the spatial structure of populations, its effect on abundance, species interactions and life-history characteristics, and the subsequent consequences for ecosystem functioning and 5.2.4 analyses the larger spatial scales of landscapes and regions, in which human activities exert large influences, and considers how the relationships of diversity and functioning at these scales are similar to, or different from the relationships at other levels of organization.

Chapter 5.3 considers the drivers and dynamics of changes in biodiversity, and their subsequent consequences for ecosystem functioning. Subsection 5.3.1 assesses our knowledge of disturbance as a factor that strongly affects the structure and function of ecological systems, and examines closely the role that different intensities and frequencies of disturbance have in determining species diversity within ecosystems, while 5.3.2 reviews the influence of human-driven changes in diversity due to changes in land use and resource use, atmospheric composition and climate change, and the potential or realized consequences for ecosystem and landscape/regional-scale functioning.

The Conclusion to Section 5 summarizes key findings and provides a synthesis of the general patterns and principles relating biodiversity and ecosystem functioning.

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5.1 Context: biodiversity and ecosystem services

The conditions and processes characterizing natural ecosystems supply humanity with an array of free services upon which society depends. These include: maintenance of the gaseous quality of the atmosphere (which in turn helps to regulate climate); amelioration of the weather;