

What is biodiversity, and why is it important?

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Key messages

- * Biodiversity is the term used to encompass the variety of all living organisms on Earth, including their genetic diversity, species diversity and the diversity of marine, terrestrial and aquatic ecosystems, together with their associated evolutionary and ecological processes.
- * Biodiversity makes human life on Earth possible yet it goes beyond mere measurable scientific facts; understanding biodiversity highlights the benefits of the natural world, many of which are at risk due to the pressures of human resource-use.
- * Biodiversity is a human construct reflecting various values – economics, ecological life-support, recreation, culture and science – placed upon it according to perceived benefits and risks.
- * This book focuses on options for improving the management of Australia's biodiversity in response to such societal values.

WHAT IS BIODIVERSITY?

A writhing mass of Murray crays is revealed as the drum-net emerges pull by pull from the river, the greenish water draining in pulses from its mesh. The boy watches with keen anticipation as his father strains at a length of fencing wire attached to the net. There are such numbers of crayfish that they crawl in confusion over each other and around the sodden sheep's head that acts as bait. His father unlatches the door of the net and carefully extracts the animals, avoiding harm to his fingers by grasping the body behind the dangerous fore-claws. If eggs of deep crimson are found on the under-tail of a female, she is tossed back into the water, as are young individuals. The boy helps his father carry the wriggling hessian bag containing the catch a hundred metres or so to the homestead. They walk in the shade of the stately, heavy-limbed river red-gums that line the stream, the foliage glowing green and bronze in the late afternoon sun. The boy could hardly be happier.



The Murray River and its river red-gums, Eucalyptus camaldulensis. Photo: Matt Colloff, CSIRO.

In the laundry the copper is quickly lit and, as soon as its water is boiling, the crays are dropped in to cook. Only a short time is required before they can be lifted out, their original muddy green colours turned to a rosy blush. Father and son sit on the verandah while breaking up the crays and placing the chunky flesh from the fore-claws and tails into a bowl for the family's evening meal. They suck the juicy slivers of meat from the slim hind-claws and scoop out and eat the fatty deposits lining the carapaces. The flavours are deliciously sweet and subtle, a delicacy of taste never to be bettered in the boy's subsequent life. Now he is at a peak of delight, deeply at home in an Australian paradise.

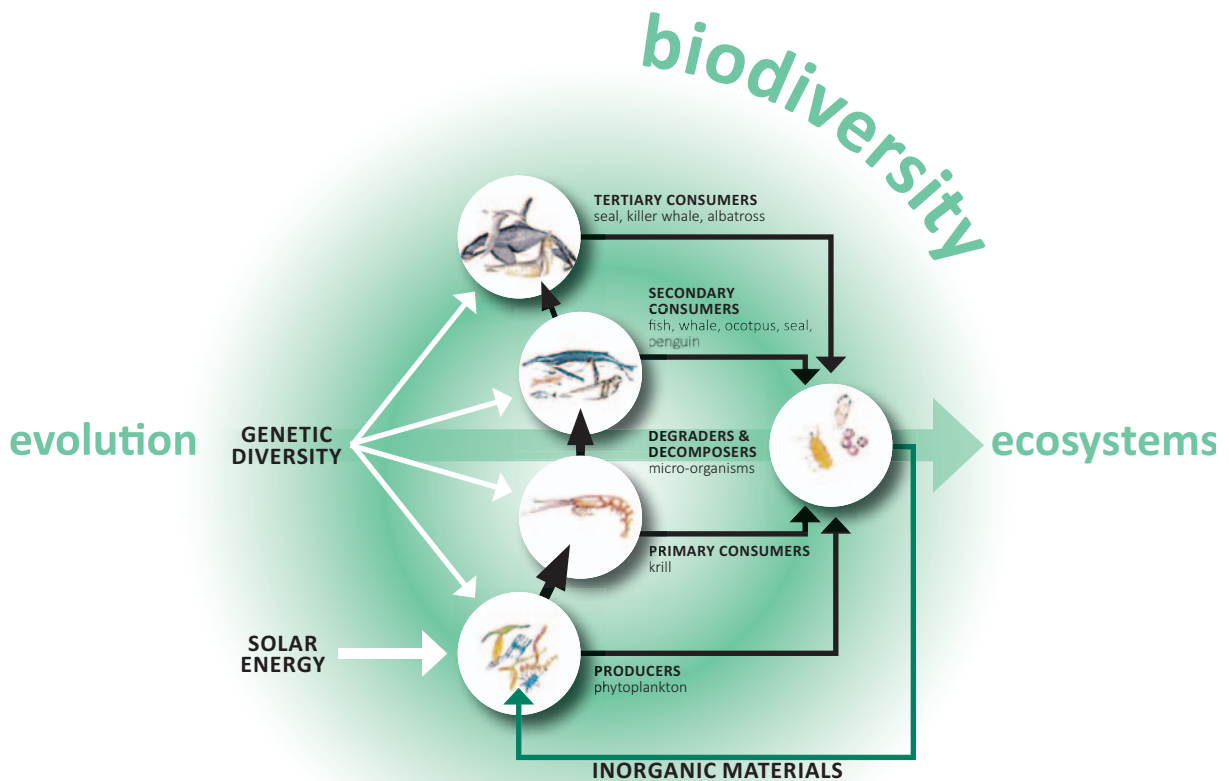


The Murray crayfish, Euastacus armatus. Photo: Rob McCormack.

Most of us hold on to some vision of an idyllic, productive or beautiful environment, often imbibed unconsciously in childhood and youth. The man grown from the boy – he is in fact one of the present authors – still admires most of all the Riverina plains country with its splendid river red-gums. Each of us has our own vision, though, not necessarily shared with others. We form a sense of the environmental values of our own particular place, not only as we come to maturity but throughout our lives. These values are at the heart of the concept of biodiversity, a notion that is only partly about science because it is based also in emotional experience and culture. First and foremost, appreciation of biodiversity springs directly from human interaction with the natural world. Often these experiences involve immediate use of the environment, such as working on the land or harvesting its bounty (especially its Murray crays!). Frequently, too, they stem from a simple enjoyment of the natural world through beach-going or bushwalking. Whatever the details of the individual human experience, the idea of biodiversity cannot be fully understood without the recognition of its roots in a perception of environmental values.

Biodiversity does encompass a significant component of scientific inquiry, of course. Scientists define biodiversity as the variety of all living organisms on Earth and at all levels of organisation (Figure 1.1). It incorporates living things from all parts of the globe, including land, sea and fresh waters. It constitutes *all* forms of life – bacteria, viruses, plants, fungi, invertebrate animals, animals with backbones – and not just the things we can see or prey upon. Biodiversity includes human beings too. Yet the scientific definition of biodiversity includes more than just organisms themselves. Its definition includes the diversity of the genetic material within each species and the diversity of ecosystems that those species make up, as well as the ecological and evolutionary processes that keep them functioning and adapting. Biodiversity is not simply a list of species, therefore. It includes the genetic and functional operations that keep the living world working, so emphasising inter-dependence of the elements of nature.

Scientists are striving to describe and measure the full variety of life, a massive undertaking when we consider the estimated nine million species on Earth, their genetic diversity, and the vast variety of ecosystems that they make up.¹ What is more, science aims not only to understand the evolution of this kaleidoscope of life but also the ebb and flow of biodiversity through time



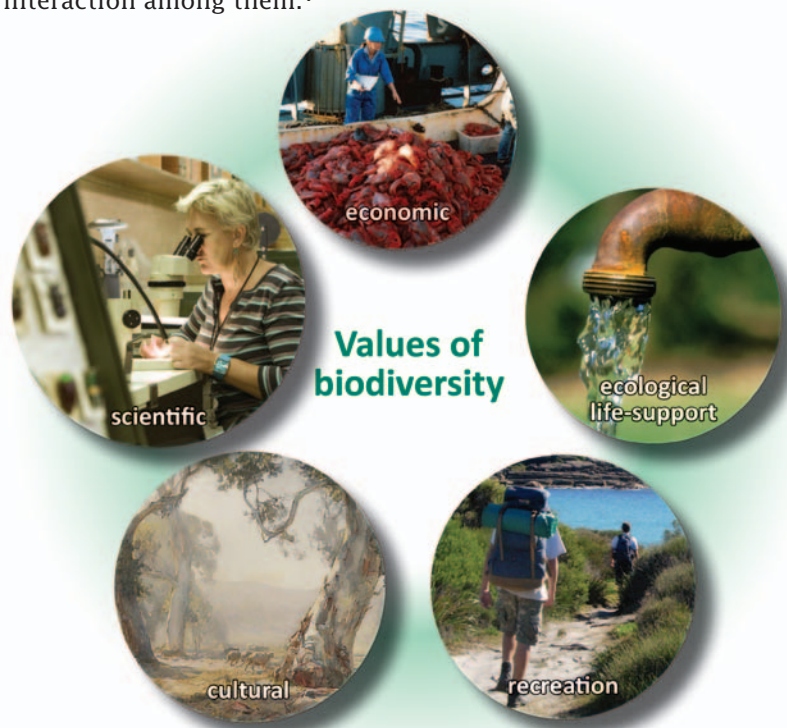
▲ **Figure 1.1:** Biodiversity is the web of life. This pictorial representation begins on the left with the evolutionary processes giving rise to the genetic diversity of living organisms, showing the organisation of the species carrying genetic diversity into food chains of producers (driven by energy from the sun), consumers and decomposers, and the ecosystems that the organisms make up. The diagram depicts a marine food chain. Redrawn from Biology: An Australian Focus.²

in response to the inevitable natural disturbances and human-induced disturbances.³ Science is charged with the responsibility of providing us with the knowledge and evidence needed to meet our diverse expectations for the use and conservation of biodiversity.

So it is that biodiversity is both a subject of scientific interest and a fascinating social construction. The term 'biodiversity' emerged in the 1980s from the conservation movement as a means of emphasising the values of the natural world under the pressure of human-induced environmental change and resource use. The concept underpinned the Convention on Biological Diversity in 1992, as well as considerable activity by governments to try to balance the benefits and risks associated with loss of biodiversity. Behind the term is a shared concern about the future of the planet and the accelerating expansion of humanity's effects upon the global environment. Further, the concept refers to more than measurable scientific facts or fears about risks associated with its loss. People throughout the world, many of whom may never use the term 'biodiversity', appreciate plants, animals, landscapes and seascapes for their usefulness and for qualities such as their spiritual significance – and it is because of these values also that biodiversity matters to us as human beings.

VALUES – WHY BIODIVERSITY MATTERS

Values are the lasting beliefs or ideals that will influence a person's attitude and which serve as broad guidelines for that person's behaviour. Values and value systems identifying what is good or bad, desirable or undesirable, are frequently shared by the members of a culture, even when not consciously expressed. Some values can be expressed in monetary terms so as to allow calculation of a common measure of worth. Yet, economic benefit provides only a partial measure of the full worth of things. Understanding biodiversity, and why it matters, is assisted by comprehending the range of distinctive values that individuals and societies may assign to the living world and the ecosystems that it comprises. It is an indication in itself of the complexity of views about biodiversity, and the variety of interactions with it, that at least five separate categories are necessary to cover all possibilities (Figure 1.2). They are described below, noting numerous possibilities for interaction among them.⁴



▲ **Figure 1.2:** The five primary values of biodiversity. Photos clockwise from top: CSIRO; Willem van Aken; Chris McKay; Hans Heysen (Germany; Australia; France, b.1877, d.1968), *Summer*, 1909, pencil, watercolour on ivory wove paper, 56.5 × 78.4 cm, Art Gallery of New South Wales (AGNSW), purchased 1909, Photo: AGNSW, © C Heysen; David McClenaghan.

The first category has already been mentioned – *economic*. The natural world provides humans with raw materials for direct consumption and production, and from which to make money. We harvest fish and timber, for example, and make from them food and goods with utilitarian value in the marketplace. This category expresses the material use of nature by humans for direct benefit. These benefits – and the economic value system that lies behind them – are held especially dear by many whose livelihoods bring them close to the natural world, such as farmers, fishers, timber workers, bee-keepers, and so on.

A second value system comprises *ecological life-support*. Biodiversity provides humans with the healthy, functioning ecosystems that make up the Earth, without which our societies could not exist. Nature delivers to us a supply of oxygen, clean water, pollination of plants, pest control, and so on. As understanding and evidence about the interconnectedness of the natural and human worlds has grown over the past century, many have come to believe that protection of the web of life is vital to our own interests, and biodiversity is a convenient expression of that value system. In fact, the concept of ‘ecosystem services’ – the multitude of resources and processes that are supplied by biodiversity to human beings – grows out of this value. Such a value system is shared by almost all human beings in at least some degree.

The natural world’s opportunities for human *recreation* comprise the third set of values. The benefits of rejuvenation for those who hold to these values may be obtained from a tough bushwalk in Tasmania, a relaxed experience of bird-watching in the back paddock, or jogging beside a river in an urban setting. Tourism frequently gains commercial benefit from biodiversity as a result of international perceptions that in Australia these values are unusually prominent. Many Australians from all walks of life respond to them.

Next, biodiversity provides *cultural values* via the expression of identity or through spirituality or an aesthetic appreciation. The celebration in our National Anthem that ‘our land abounds in nature’s gifts of beauty rich and rare’ reflects an attachment to biodiversity that is a widely shared aspect of Australian culture. Virtually every Australian who returns from overseas has



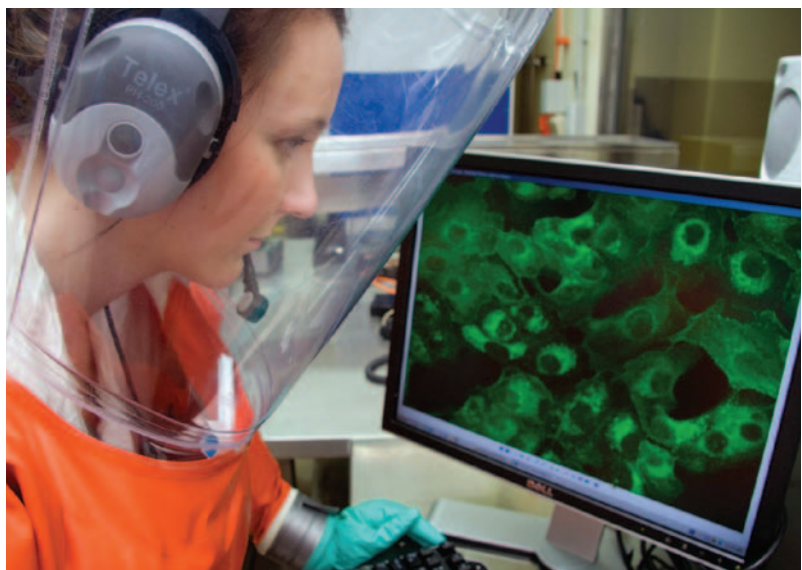
Using reworked high resolution 3D scans of insects to create an eye-catching mosaic, this artwork is an example of the cultural value of biodiversity. Image: Artwork by Eleanor Gates-Stuart, CSIRO; original insect scans by Dr Chuong Nguyen, CSIRO; original insect illustrations by F. Nanninga, CSIRO.

experienced a satisfying re-exposure to the odour of gum leaves. Indigenous peoples in Australia express cultural values especially strongly and in an unusually intimate fashion, through totemic connections to animals and plants that are believed also to be ancestral beings. Spiritual values are a subset of such connections, an opportunity to explore questions about the meaning of the universe through contemplation of biodiversity. The splendour of nature also provides aesthetic values simply through the appreciation of the non-human world. Obviously enough, artists are frequently the major bearers of this value system and, like most nations, we have a long tradition of exhilarating practitioners, such as Hans Heysen, Fred Williams and Emily Kame Kngwarreye. Yet aesthetic values are also appreciated more broadly across society, and often by direct individual absorption in a natural context as well as by reflection in art galleries or in the words of poems and songs. Finally, education makes up another aspect of cultural values, providing the basis for discussion about how to live sustainably on planet Earth.

Fifth is a *scientific value* system, which calls attention to the worth of systematic ecological data in helping us to understand the natural world, its origins, and the place of the human species within it. Scientists are likely to highlight the excitement of uncovering genetic diversity, for example, or cataloguing the strange creatures of the deep-sea trenches, or understanding how vegetation patterns are influenced by fire. While economic benefit may well accrue from scientific understanding, the motivation of the scientific value system is primarily intellectual. All of the authors of the present book share this value system.

Lastly, for completeness there is a *negative value* system, a stance towards biodiversity characterised by fear or hostility. Settler Australians were prone to the expression of such anti-values, which persist today in relation to some animals (an understandable fear of crocodiles or of influenza viruses). Negative views are not confined to Australia, of course, because apprehension about spiders and snakes, for example, is common to many cultures. And it is also true that virtually no one feels compelled to defend the right of the malarial parasite to continued existence, or argues in favour of the Hendra viruses, even though biodiversity encompasses life in *all* of its variety. Negative values are likely to be held in some small part by many people, therefore, although their significance in Australia declined throughout the 20th century and narrowed to specific targets.

This CSIRO scientist studies a fluorescently stained image of cells infected with Hendra virus. Her encapsulated suit reminds us of the deadly nature of some life-forms: not every biodiversity value is regarded as positive.
Photo: Frank Filippi, CSIRO.



VALUES – WHY WE WORRY ABOUT BIODIVERSITY

Humans are presently concerned about biodiversity because there is undeniable evidence of significant global and Australian declines. The problem is real, as shown in Chapter 3 of this book. Decline in biodiversity may compromise each of the values outlined above, even though it may not be immediately evident how to measure an impact on any one of them. Scientific progress is being made, though, in understanding likely consequences of declining ecological life-support. We now know the following general principles:⁵

- * Biodiversity loss can reduce the efficiency with which ecosystems acquire resources, produce biomass, and decompose it to recycle nutrients.
- * Maintenance of biodiversity allows ecosystems both to keep working in the face of ongoing change and to recover functions more readily after a shock.
- * The impact of a decline in biodiversity on the ecosystem accelerates as the loss increases.
- * Diverse communities may be more productive because species differ in the way they capture energy and nutrients, so leading to a potentially greater collective uptake.
- * Loss of diversity at multiple levels within a food chain (e.g. from grasses through grazing animals to their predators) can influence ecosystems more than loss within just one level.
- * Effects of extinction range from undetectable (for species having small roles in ecosystem functions) to profound (for those that dominate the working of the ecosystem).

These six findings represent important advances in our understanding of the value of ecological life-support. Nevertheless, science is struggling to translate this growing knowledge into thresholds of concern: at what point in biodiversity decline should humans become worried to the point of taking corrective action, and what aspects of the challenge of managing biodiversity should be addressed first? This book cannot answer all those deep questions, yet it will provide important pointers.

BIODIVERSITY AND HUMAN SOCIETIES

Discussion of value concepts highlights the fact that the linkages between biodiversity and human societies may be as multifaceted as are those within ecosystems. The Millennium Ecosystem Assessment in 2005 was the first global effort to examine links between human wellbeing and biodiversity.³ The Assessment found benefits to societies from biodiversity in material welfare, security of communities, resilience of local economies, relations among groups in communities, and human health. It also emphasised the term ‘ecosystem services’ under four broad categories: *provisioning*, the production of food, fibre and water; *regulating*, the control of climate and diseases; *supporting*, nutrient cycling and crop pollination; and *cultural*, such as spiritual and recreational benefits (Figure 1.3).

Provisioning Services	
	Food: Ecosystems provide the conditions for growing food such as fish in wild habitats.
	Raw materials: Ecosystems provide materials for construction such as fine timbers.
	Fresh water: Ecosystems provide surface and groundwater.
	Medicinal resources: Many plants are used as traditional medicines and as input for the pharmaceutical industry.
Regulating Services	
	Local climate and air quality regulation: Water and vegetation reduce temperature extremes.
	Carbon sequestration and storage: As trees and plants grow, they remove carbon dioxide from the atmosphere and effectively lock it away in their tissues.
	Moderation of extreme events: Ecosystems can create buffers against natural hazards such as floods.
	Waste-water treatment: Micro-organisms in soil and in wetlands decompose human and animal waste, as well as pollutants.
	Erosion prevention: Vegetation prevents river and foreshore erosion.
	Pollination: Some 87 out of the 115 leading global food crops depend upon animal pollination including important cash crops such as cocoa and coffee.
	Biological control: Ecosystems are important for regulating pests and vector-borne diseases.
Habitat or Supporting Services	
	Habitats for species: Habitats provide everything that an individual plant or animal needs to survive. Migratory species need habitats along their migration routes.
	Maintenance of genetic diversity: Genetic diversity distinguishes different breeds or races, providing the basis for locally well-adapted cultivars and a gene pool for further developing commercial species.
Cultural Services	
	Recreation and mental and physical health: The roles of natural landscapes and green space for maintaining mental and physical health are increasingly being recognised.
	Tourism: Nature tourism provides considerable economic benefits and is a vital source of income for some regions.
	Aesthetic appreciation and inspiration for culture, art and design: Language, knowledge and appreciation of the natural environment have been intimately related throughout human history.
	Spiritual experience and sense of place: Nature is a common element of all major religions; natural landscapes also form local identity and sense of belonging.

▲ **Figure 1.3:** The range of services that biodiversity may provide for people, under four broad categories.⁶ Icons designed by Jan Sasse.

The Assessment also noted that many people have benefited from the conversion of natural ecosystems to human-dominated farms, towns and cities. It confirmed that the concept of biodiversity stems from dynamic interactions between people and their environment, rather than being something separated from humanity. It is now recognised that every ecosystem on Earth is influenced by such interactions, and there is a growing scientific effort to study biodiversity as a social–ecological system. New models are attempting to integrate human behaviours with ecosystem functions, to incorporate the feedbacks among them, and thereby to explore more effective policies for conservation and utilisation of resources.⁷

A new term has been mooted – ‘biocultural diversity’ – to highlight the fact that the full diversity of life includes human cultures. Biodiversity and human cultural diversity possess a fascinating overlap, because global ‘biodiversity hotspots’ (only 2% of land area) also include 70% of the languages on Earth. Environmental complexity and abundance of resources are some of the ideas currently being tested as explanations for the links between high biological and high cultural diversity.⁸ In Australia’s case, Indigenous Australians see plants and animals as possessing dual ecological and social identities, their systems of law and management aiming at the protection of both cultural and biological diversity.⁹ For this reason this book includes a section in Chapter 6 dedicated to Indigenous views of biodiversity. The roles of Indigenous Australians are emphasised also for practical reasons: Indigenous rights and management responsibilities are recognised to varying extents in over half of Australia’s landmass through grant or purchase of title, determination of Native Title, Indigenous Land Use Agreements and Indigenous Protected Areas, which now make up 40% of the National Reserve System.¹⁰

So we return to the way individual members of society discern values in biodiversity and appreciate their interaction with the natural world. Because that world is changing more rapidly and to a greater extent than ever in human history, individuals may experience great changes in their interactions with nature and so perceive their values as under assault. The boy we saw delighting in the drum-net of Murray crays has become an adult concerned about their fate, for they are now worryingly uncommon. Did he contribute towards their decline through over-fishing? Or is it due to the vast numbers of European carp that have swept down the Murray River system, or to altered temperatures of stored waters when released into the rivers, or to modified water chemistry resulting from diversion of water to irrigation? Whatever the cause, to one observer the quality of his interaction with the place has changed and the cultural value of biodiversity no longer matches his childhood memories. The focus of each individual’s concern is likely to be different, of course; furthermore, the activities that are causing change are often bringing benefit to someone else. Balancing the risks against the benefits elsewhere is essential if the results of our decisions are to meet the needs of society at large – and understanding the inter-linkages between biodiversity and human societies is a first step in such assessment.

BIODIVERSITY: SCIENCE AND SOLUTIONS FOR AUSTRALIA

Is it curious to find a scientific account of biodiversity opening with a discussion of values? It should not be seen so, because science is a human activity after all, drawing from many wellsprings of human inspiration. More particularly, biodiversity is such a broad-ranging concept that it simply cannot be understood – or, more importantly, made useful – if these background motivations for caring about it are left unstated. Given that the concept has its roots in the conservation movement, with the express objective of influencing the manner in which society reaches decisions on the use of natural resources, then the use of the notion of biodiversity quickly ramifies into political consequences. When we add to this the fact that biodiversity as a scientific concept remains broad, the need for frankness about our values becomes even more pronounced.

As a member of CSIRO, each contributor to this book recognises her or his obligation to be an impartial and respected source of information and advice on science for the community and government. Our authors aim to assist society in finding solutions to the challenges represented in biodiversity management, and in identifying means by which new opportunities might be seized. In short, this book is about options for Australia, underpinned by our best efforts to produce impartial science that can help guide the nation towards decisions on ‘preferred’ or ‘best’ solutions to any specific aspect of the challenge.



CSIRO biodiversity scientists at work in a rainforest stream. Photo: David Westcott, CSIRO.

While our authors write from the perspective of science we are also human beings, with deeply held values affecting our activities. Unsurprisingly, each of the authors reflects a commitment to scientific values in the very choice of a career. Most contributors, as scientists, also share a personal belief in the significance of growing evidence that biodiversity is linked to life-support; the importance we assign to the rapid decline in biodiversity reflects a human concern for the living planet. We have written this book to provide a bridge from the scientific literature on biodiversity to the wider community and because the value of biodiversity to life support is important to us. However, the book offers impartial information achieved through the established scientific methods: of testing ideas against critical data, and subsequent peer review and scrutiny of the results to remove gaps and mistakes. We do our best to present trustworthy advice about options for Australia in managing its natural resources.

Hence this book focuses on science and its application in response to change in the Australian landscape. A brief summary only is given of the nature and status of the continent's biodiversity, for many other texts already provide such information. Instead, our spotlight is on options for responding to the variety of values placed by members of society upon the natural diversity of Australia, and thereby for managing it better. The book does not shy away from the problems inherent in translating such a broad canvas of values into pragmatic actions. Indeed, it is written in the firm belief that a dialogue between science and society is necessary to bring clarity to our shared objectives for improved management. Such a conversation is needed not only on behalf of those wonderful creatures with which we share our continent, but also in recognition of a responsibility to hand on a healthy place for future generations.

FURTHER READING

Australian Government Department of the Environment, Water, Heritage and the Arts (2008) *Assessment of Australia's Terrestrial Biodiversity*. Department of the Environment, Water, Heritage and the Arts, Canberra. <<http://www.environment.gov.au/biodiversity/publications/terrestrial-assessment/index.html>>.

State of the Environment Committee (2011) *Australia State of the Environment 2011: Independent Report to the Australian Government Minister for Sustainability, Environment, Water, Population and Communities*. Australian Government Department of Sustainability, Environment, Water, Population and Communities, Canberra. <<http://www.environment.gov.au/topics/science-and-research/state-environment-reporting/soe-2011>>.