Climate Change and Biodiversity Landscape Scenario Assessment for the Resilient Hills and Coasts Region

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Contents

1. Introduction

Resilient Hills and Coasts is a climate vulnerability and adaptation planning project supported by a range of partners, including The Adelaide and Mount Lofty Ranges Natural Resources Management Board (the board) and covering the local government areas of Alexandrina Council, the City of Victor Harbor, Adelaide Hills Council, the District Council of Yankalilla, the District Council of Mt Barker and Kangaroo Island Council. The Resilient Hills and Coasts region is therefore largely (but not wholly) contained with the Adelaide and Mount Lofty Ranges NRM region.

The board and the Department of Environment, Water and Natural Resources have recently prepared a report on climate adaptation for biodiversity that encompasses the Resilient Hills and Coasts region (Rogers and West 2015). This report was based on a coarse-level assessment completed in 2013, which identifies broad adaptation scenarios and strategies for the Adelaide and Mount Lofty Ranges Natural Resources Management (AMLR NRM) region.

The board is currently working on a finer-scale assessment of climate change impacts on biodiversity, due to be completed later in 2016. To support the Resilient Hills and Coasts climate adaptation project, currently in its final stages, this brief report presents a précis of the coarse-scale work and includes some preliminary information that is emerging from the finer-scale assessment.

Biodiversity is a complex concept that encompasses the variety of life, its different levels of organisation and the associated ecological and evolutionary processes (Hunter 2002; Appendix 1).

At the global scale, there has been a very significant loss of biodiversity as more and more resources are sequestered for human use. This loss is predicted to accelerate in the future (Millennium Ecosystem Assessment 2005, Secretariat of the Convention of Biological Diversity 2014), with anthropogenic climate change being a significant contributor to predicted future loss (IPCC 2014).

Due to the complexity of biodiversity and the many factors that impact on its persistence, there is a risk that conservation actions can become haphazard and reactive in nature, following popular trends rather than being based on sound evidence (Benedict and McMahon 2002; Fazey et al. 2004). To address this issue, conservation planning typically adopts a nested (coarse and fine-filter) approach (Noss 1987; Hunter 2002; Appendix 2). This same approach can also be applied to address the inherent complexity of biodiversity climate change adaptation (Groves 2003).

2. Key guiding principles for a biodiversity climate adaptation framework

First principle - recognising the nested nature of biodiversity values

One of the challenges faced in any form of planning, is the identification of relevant values of concern, and ensuring a consistent logic in terms of the desired outcomes and the associated indicators (Wallace 2012; Barton et al. 2015). In biodiversity, the nested approach to the identification of values, outcomes and indicators ensures the development of a comprehensive portfolio of responses which is also efficient in its execution, as it inherently avoids the duplication of issues (Groves 2003; Appendix 2).

For the Resilient Hills and Coasts region, a broad-scale biodiversity adaptation assessment would need to encompass the landscape level (Gillson et al. 2013), while also addressing specific ecosystems known to have a different level of vulnerability than the broader landscapes within which they sit (Groves 2003; Prober et al. 2012), such as water-dependent ecosystems and 'soft' coastal systems.

Second principle – recognising synergies in climate change stressors

Apart from climate change, a wide range of threats impacting biodiversity already exists within the Resilient Hills and Coasts region (Adelaide and Mount Lofty Ranges Natural Resources Management Board, 2008).

Understanding the synergies between various aspects of climate change and the existing threats is critical to ensuring the implementation of effective responses (Brook et al. 2008).

It is therefore important to evaluate the combined implications for biodiversity arising from different components of climate change, as well as the interaction with existing, non-climatic threats. This is a case where the likely changes are more than just the sum of the parts.

Third principle – climatic scales, climate velocity and cross-sectoral implications
Climate is often recognised at three different scales of operation: macro-climate, meso-climate and micro-climate (Colls and Whittaker 1990; Bailey 1996; Sturman and Tapper 2006). The term 'macro-climate' refers to broad-scale climatic zones typically defined by latitude and continental position (James 1959) and driven by global circulations (Colls and Whittaker 1990; Sturman and Tapper 2006). While the macro-climate can generally describe the average climate over broad areas, there are significant variations from that average at finer geographic scales. These variations are a result of the interplay between the macro-climate and topographic irregularities (Bailey 1996), leading to smaller-scale climatic circulations (Colls and Whittaker 1990; Sturman and Tapper 2006) known as meso-climates. At the site scale, very local changes in elevation, slope, aspect, soils and vegetation result in very fine-scale variations in climate, thus creating so called micro-climates (Colls and Whittaker 1990; Bailey 1996).

The nature of future climate change will therefore not be uniform across the land-surface. Meso- and micro-climatic effects will continue to significantly influence the nature of the climate experienced at more local scales (IPCC 2014). In particular, climate velocity (the rate of change in climate over time) is comparatively low in topographically variable areas and is highest across flat landscapes (Loarie et al. 2009; Burrows et al. 2014). Just as current climates experienced across the Resilient Hills and Coasts region differ significantly (Bureau of Meteorology 1971; 1975), climate change will be experienced to varying degrees and in varying ways across the region's different landscapes.

In assessing climatic biodiversity vulnerabilities, it is therefore clear that different parts of the region will vary significantly in their exposure to climatic risks. To some extent this variation will not just influence biodiversity, but will also be relevant for other sectors, especially those directly reliant on local natural resources.

3. Synthesising the evidence for a biodiversity climate adaptation framework

To enable the board's biodiversity climate adaptation planning work to be incorporated into the Resilient Hills and Coasts project, an attempt has been made to align it with the standard climate vulnerability and adaptation framework currently used across the state to assess and address climate vulnerabilities across a number of sectors (Local Government Association of South Australia 2012), using similar logic and terminology, as shown in Figure 1. The following sections explain the key terms used in this framework, and how they have been used in the AMLR regions biodiversity context.

Climate exposure
The term 'climate exposure' refers to the background climate conditions against which a system operates. The framework depicted in Figure 1 therefore takes into account the broad meso-climatic variations which different landscapes currently experience (Colls and Whittaker 1990; Bailey 1996; Bureau of Meteorology 1998; Gillson et al. 2013), and will continue to experience under future climate change. This essentially splits the Resilient Hills and Coasts region into four main landscape types (coastal, plains, flanks and uplands), based on physiological and meso-climatic parameters. Broadly, these landscapes are classified in the same manner across the whole of the AMLR region.

The broad meso-climatic (landscape) differentiation used here is not unique to biodiversity, but applies to other sectors. This is particularly the case for other natural resource sectors, such as forestry, fisheries and aquaculture, and agriculture, but may also apply to sectors such as community health and wellbeing, emergency management, infrastructure and urban areas, and tourism.

Climate sensitivity
Climate sensitivity refers to the responsiveness of a system to climatic influences (The Allen Consulting Group 2005). Based on consideration of the biological hierarchy (Appendix 2), as well as coverage across the broad landscape types (Gillson et al. 2013), additional impact areas at the ecosystem level have been added where these are known to have a different level of vulnerability (Prober et al. 2012). This has resulted in the addition of water-dependent terrestrial ecosystems (termed ‘wet ecosystems’ in Figure 1) and sedimentary coastal features, including samphire, beach-dune, and estuarine ecosystems (termed ‘soft coasts’ in Figure 1).

Following the approaches of Prober et al. (2012), Gillson et al. (2013) and Beever et al. (2015), the sensitivity of the different landscapes and ecosystems is assessed in terms of both their intrinsic sensitivity (i.e. disregarding other forms of human impact) as well as their realised sensitivity (i.e. incorporating the nature and degree of human modification).

Adaptive capacity and response
Adaptation reflects the ability of a system to change in a way that makes it better equipped to deal with external influences, reflecting both the inherent ability of the system to adapt, as well as its ability to adapt given human intervention (The Allen Consulting Group 2005). It is therefore useful to identify a system’s inherent adaptive capacity and its implications, as well the system’s adaptive capacity, given the implementation of potential response strategies (Figure 1).

In addition, there is also a need to ensure that response actions from various sectors are brought together to capitalise on synergies and to ensure that potential conflicts are identified and addressed. This is a task beyond the scope of the current assessment, but has been shown in Figure 1 in recognition of its importance.

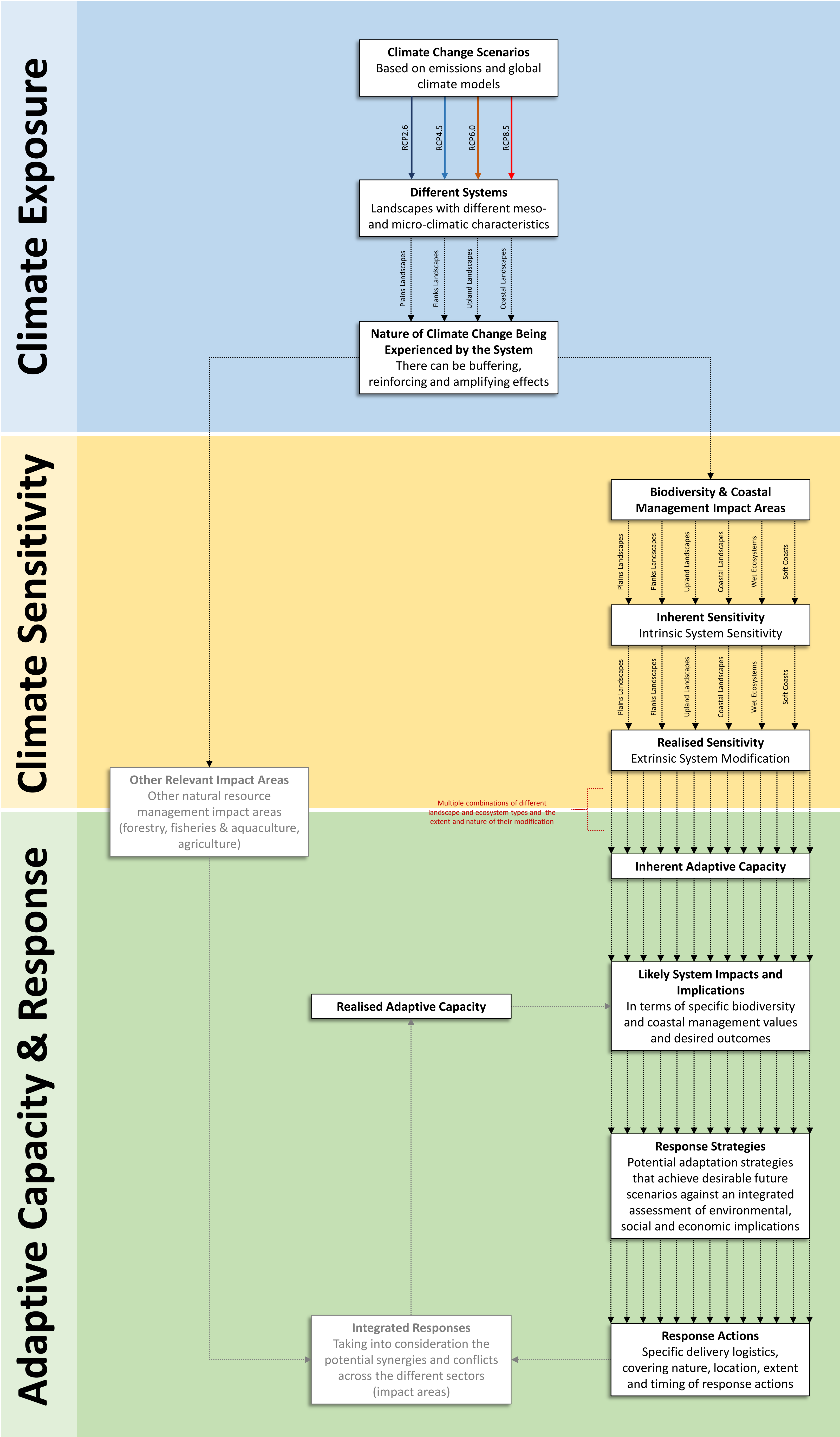


Figure 1: AMLR NRM Board Biodiversity Adaptation Framework

4. Assessment, implications and response

The broad biodiversity climate adaptation strategy types used by the board are explained in Figure 2.

A summary of the assessment and implications for biodiversity climate adaptation within the Resilient Hills and Coasts project area is presented in Figure 3, while Figure 4 provides an indicative map of the AMLR region's landscape types. Relevant sources of evidence are also cited, and broad response strategies are identified. These broad responses are currently being down-scaled by the board, incorporating more specific information on the nature and extent of landscape and ecosystem modification.

The downscaling process (to be completed later in 2016) will result in a higher resolution assessment, which will more specifically identify the timing, location and nature of proposed response actions.

The broad landscape types identified across the Resilient Hills and Coasts project area are as follows:

- **Coastal:** these are the landscapes that form the ecotone between the marine environment and terrestrial systems. These landscapes include low energy coastal ecosystems (i.e. samphire and estuaries), beach-dune ecosystems, and coastal cliff ecosystems (including softer calcareous and harder lithology cliffs).
- **Plains:** these are the landscapes that occur on both the western and eastern side of the spine of range, and are typified by their low elevation and topographic relief. These areas are dominated by mallee and shrub ecosystems.
- **Flanks:** these are the landscapes that form the transition zone between the plains and the upland landscapes and are typified by higher relief than the plains. This includes major physiographic features of the region such as Inman Valley. These landscapes are dominated by 'grassy' woodland and grassland ecosystems.
- **Upland:** these are the landscapes that form the spine of the Mount Lofty Ranges and are typified by both high relief and elevation. These landscapes are dominated by a diversity of both 'grassy' and 'shrubby' woodland ecosystems.

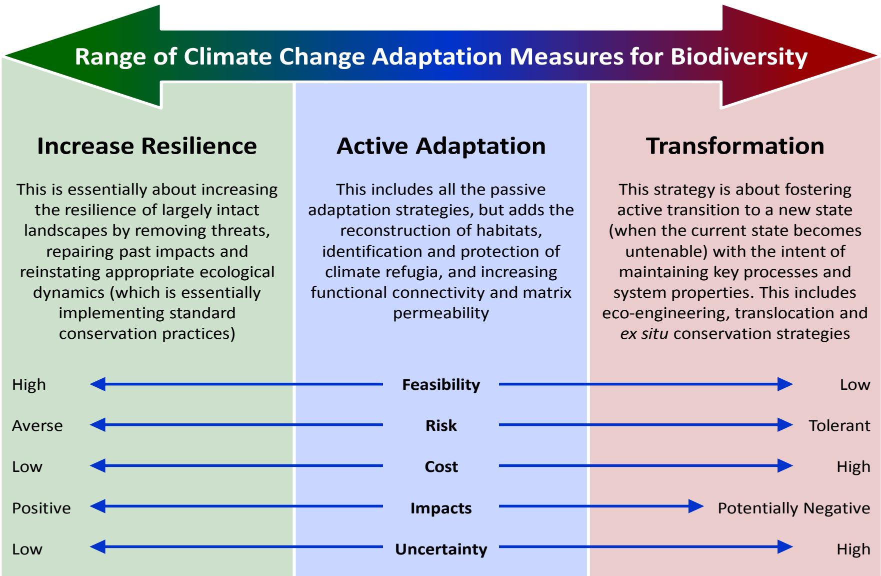
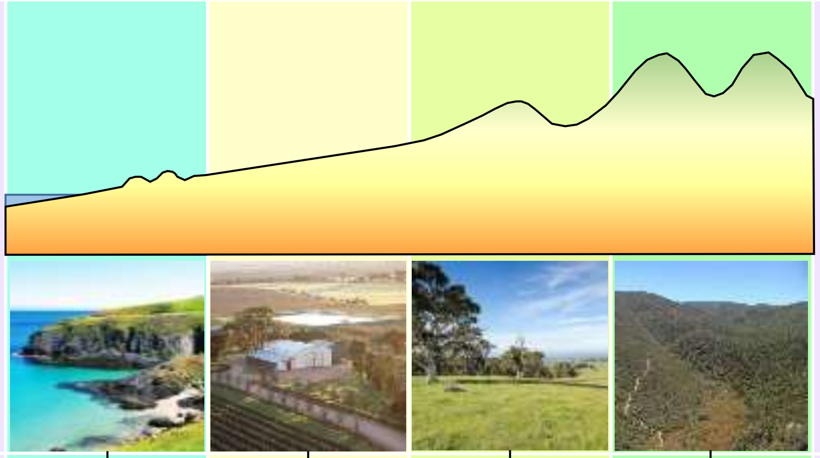


Figure 2 – The broad types of biodiversity climate adaptation strategies used by the AMLR NRM Board

Broad Landscape Types Found Within the Resilient Hills and Coasts Region



Non-Nested Ecosystem Types

System Types	Soft Coastal Ecosystems	Coastal Landscapes	Plains Landscapes	Flanks Landscapes	Upland Landscapes	Wet Ecosystems
Human Modification Evidence: 1,2,3 & 4	Ranges from moderate to heavy modification, encompassing indirect changes resulting from broader landscape change through to direct replacement by intensive development (such as urban settlement)	Ranges from minimal to heavy modification, depending on the nature of the specific ecosystems and their location in relation to urban centres (and potential use for recreational purposes)	Mostly heavy modification, as these landscapes were immediately amenable to development – modification includes both agricultural production and densely settled (urban) areas	Ranges from moderate to heavy modification, as these landscapes were amenable to development. This has mostly taken the form of agricultural production, but there are some more densely settled areas	Ranges from minimal to heavy modification, as only parts of these landscapes were initially amenable to development. These landscapes retain a diversity of unique land uses due to their climate	Ranges from moderate to heavy modification, encompassing indirect changes resulting from broader landscape change through to direct replacement by intensive development (such as agricultural production)
Climate Exposure Evidence: 5,6,7,8,9,10,11, 12,13, 14, 15, 16	High exposure to climate change due to limited topographic variability and associated limitations in buffering climate velocity, coupled with the impact of sea level rise and coastal-migration implications	Ranges from low to high exposure to climate change, depending on the nature of the specific coastal ecosystems (sedimentary ecosystems have high exposure, while hard-rock cliff ecosystems have low exposure)	High exposure to climate change due to limited topographic variability and associated limitations in buffering climate velocity (the highest rates of climate velocity occur on flat landscapes)	Moderate exposure to climate change due to some topographic variability and associated buffering of climate velocity	Low to moderate exposure to climate change due to high topographic variability and associated buffering of climate velocity	Although exposure relates to landscape setting, water dependent ecosystems have an inherently high exposure to climate change due to the amplifying effect of rainfall reductions on water flows
Inherent Sensitivity Evidence: 17,18,19,20,21, 22 & 23	Low inherent sensitivity of biota to climate change as they are already adapted to comparatively extreme environmental conditions	Low inherent sensitivity of biota to climate change as they are already adapted to comparatively extreme environmental conditions	Low inherent sensitivity of biota to climate change as they are already well adapted to hot and dry conditions and persist across a broad bioclimatic envelope	High inherent sensitivity of biota to climate change due to the narrow bioclimatic envelope of the taxa that occur within this landscape and its limited spatial extent within the Mount Lofty Ranges	Low inherent sensitivity of biota to climate change (above a threshold of rainfall and temperature) as they occur across a broad bioclimatic envelope	High inherent sensitivity of biota to climate change due to their reliance on a specific water regime for their persistence
Realised Sensitivity Evidence: 1,2,3,4,8,9 & 24	High realised sensitivity of these ecosystems, as they retain significant conservation values and coastal migration is largely impeded by land tenure infrastructure barriers	Low to high realised sensitivity of these landscapes, as there are significant local differences in the degree, nature and timing of human modification and its impact on species trends	Low realised sensitivity of these landscapes, as they were extensively modified early in the modern development of SA and have now largely reached a new, biologically impoverished stable state	High realised sensitivity of these landscapes, as their inherent sensitivity is high and despite their extensive modification, they still retain significant conservation values that are declining	Low to moderate realised sensitivity of these landscapes, as there are significant local differences in the degree, nature and timing of human modification and its impacts on species trends	High realised sensitivity of these ecosystems, as their inherent sensitivity is high, and despite their variable modification, they retain significant conservation values that are often declining
Adaptive Capacity Evidence: 1,2,3,4,8,9 & 24	Little or no adaptive capacity due to the extensive land tenure and developmental barriers that impede coastal migration	Low to moderate adaptive capacity due to significant differences in coastal ecosystems, coupled with the significant local differences in human modification and associated resilience	Low adaptive capacity due to the early and extensive modification of these landscapes and existing level of biodiversity loss and associated loss of resilience	Low to moderate adaptive capacity, as these landscapes underwent early modification but still often retain significant components of biodiversity and associated resilience	Moderate to high adaptive capacity, as these landscapes contain significant local differences in the degree, nature and timing of human modification and associated resilience	Low adaptive capacity due to the reliance of these ecosystems on specific water regimes; changes in water regimes significantly impact the resilience of these systems
Global Emission Scenarios & Likely Implications Evidence: 1,2,3,4,5,14,15, 16,17,18,21,23,24,25,26, 27 & 28	**All RCP Scenarios:** Under all scenarios, these ecosystems would still remain dominant. **Implications:** Response is the likely loss of these ecosystems in areas where the indirect impact of climate change on sea level, combined with human development, impedes coastal migration.	**All RCP Scenarios:** Under all scenarios, these landscapes would essentially remain coastal dominated ecosystems. **Implications:** Response is most likely to reflect historic ecosystems already present in these landscapes. However, the indirect impact of climate change on sea level, combined with human modification, will likely result in the loss of sedimentary coastal ecosystems in some areas.	**All RCP Scenarios:** Under all scenarios, these landscapes would essentially remain mallee dominated ecosystems. Under RCP2.6-6.0, these systems would fall within their historic range of variability and so would be largely unaltered. Under RCP8.5, there would be some filtering of species to reflect the warmer and drier conditions. **Implications:** Response is most likely to reflect historic ecosystems already present in these landscapes, but may result in hybrid ecosystems under the most extreme scenario.	**RCP2.6:** These landscapes would still fall within their historic range of variability and so would essentially remain unaltered. **RCP4.5 & 6.0:** These landscapes would undergo some filtering of species to reflect the warmer and drier conditions. **RCP8.5:** These landscapes would experience climatic conditions outside the historic range of variability experienced in SA and would undergo fundamental re-assembly. **Implications:** Response is most likely to reflect historic ecosystems already present in these landscapes, or a hybrid of these ecosystems. Under the most extreme scenario, novel ecosystems would emerge with the closest analogues being box woodlands of the western slopes of the Great Diving Range in NSW. However, these systems would be functionally and structurally similar to the historic ecosystems.	**RCP2.6:** These landscapes would still fall within their historic range of variability and so would essentially remain unaltered. **RCP4.5 & 6.0:** These landscapes would undergo some filtering of species to reflect the warmer and drier conditions. **RCP8.5:** These landscapes would experience climatic conditions outside the historic range of variability experienced in SA and would undergo fundamental re-assembly. **Implications:** Response is most likely to reflect historic ecosystems already present in these landscapes, or a hybrid of these ecosystems. Under the most extreme scenario, novel ecosystems would emerge with the closest analogues being the forests and woodlands of southeastern NSW. However, these systems would be functionally and structurally similar to the historic ecosystems.	**All RCP Scenarios:** Under all scenarios, these ecosystems would experience water regimes outside their historic range of variability and so would undergo fundamental re-assembly. **Implications:** Response is the likely loss of these ecosystems and their replacement by a variety of novel ecosystems which may be structurally and functionally dissimilar.
Management Strategies Evidence: 26,27,29,30,31 & 32	**Transformation:** to pre-empt the likely loss of these ecosystems by supporting their replacement (to maintain stability and basic ecological functions), while artificially supporting coastal migration to minimise biodiversity loss.	**Increase Resilience to Transformation:** the range of response scenarios for this landscape is too broad to generalise. Down-scaled planning is required to inform specific response strategies.	**Increase Resilience:** these landscapes have already undergone significant modification and loss of biodiversity, so the focus would be on maintaining ecosystem services through the removal of threats and repair of basic ecological functions.	**Active Adaptation:** these landscapes have already undergone significant modification but still retain high biodiversity values. There is the potential to support adaptation through restoration, protection of refugia and maintenance of natural features.	**Increase Resilience:** these landscapes would be expected to retain significant biodiversity values under all scenarios, but this would be contingent on: removing existing threats, repairing past impacts and reinstating impaired ecological processes.	**Active Adaptation to Transformation:** re-assembly of these systems may need to be pre-empted (to maintain stability and ecological functions). However, monitoring should determine if/when such a drastic response would be required.

Figure 3: Biodiversity adaptation assessment, implications and response

Climate Change and Biodiversity Landscape Scenario Assessment for the Resilient Hills and Coasts Region

Evidence cited in Figure 3

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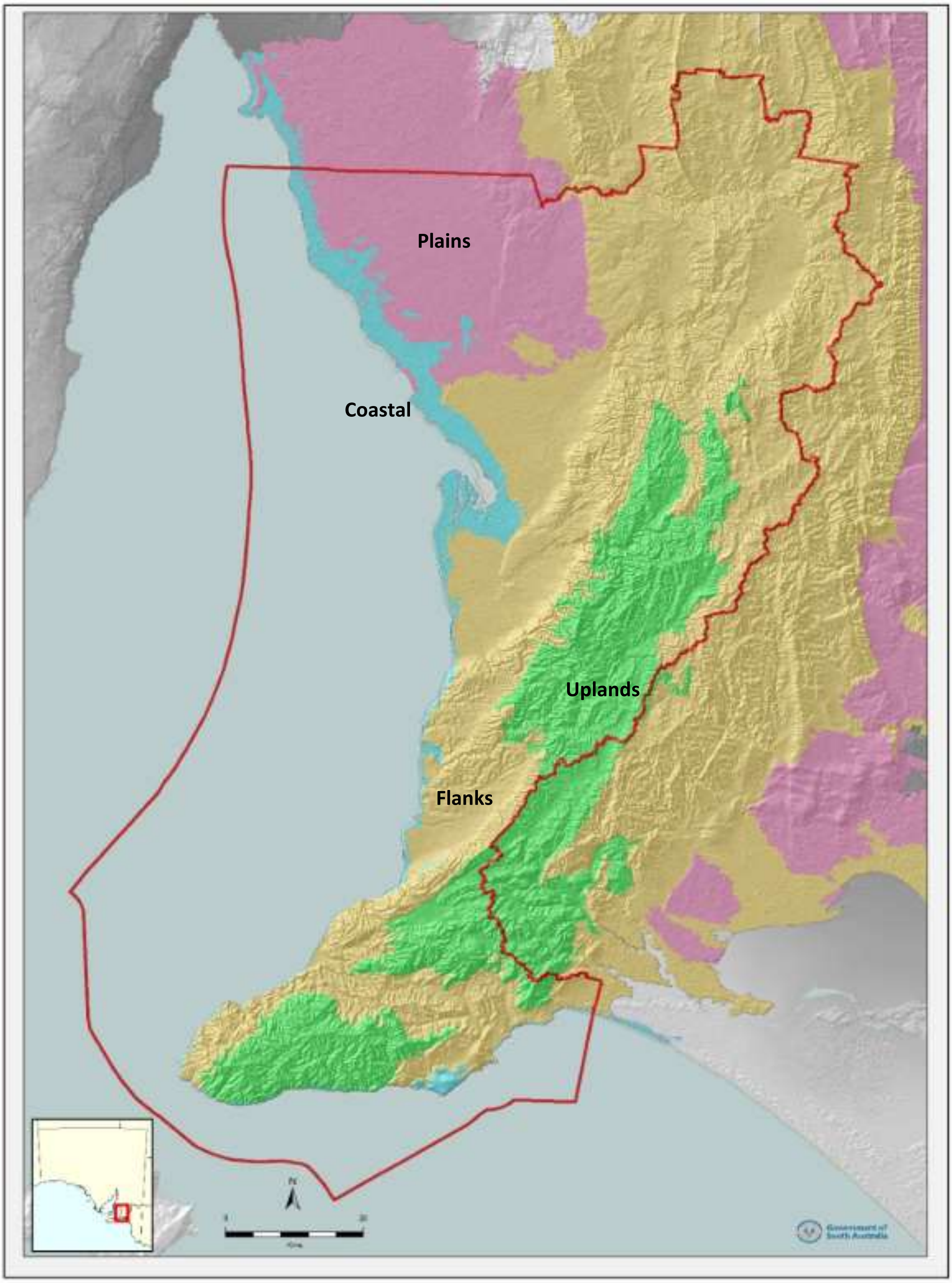

Figure 4: Indicative distribution of the AMLR NRM region's landscape types

Appendix 1 – What does the biodiversity concept encompass?

Biodiversity is an abbreviation of biological-diversity and is a concept that encompasses the variety of life, its different levels of organisation and the associated ecological and evolutionary processes (Hunter, 2002).

The variety of life

The variety of life refers to all the different forms of life, including plants, invertebrate animals, fungi, bacteria and other micro-organisms, as well as vertebrate animals. Vertebrate animals and vascular plants are the most studied and described types of life. However, the most diverse in terms of numbers of different species are the arthropods, insects and spiders (May 1992; Wilson 1992; Figure 1.1).

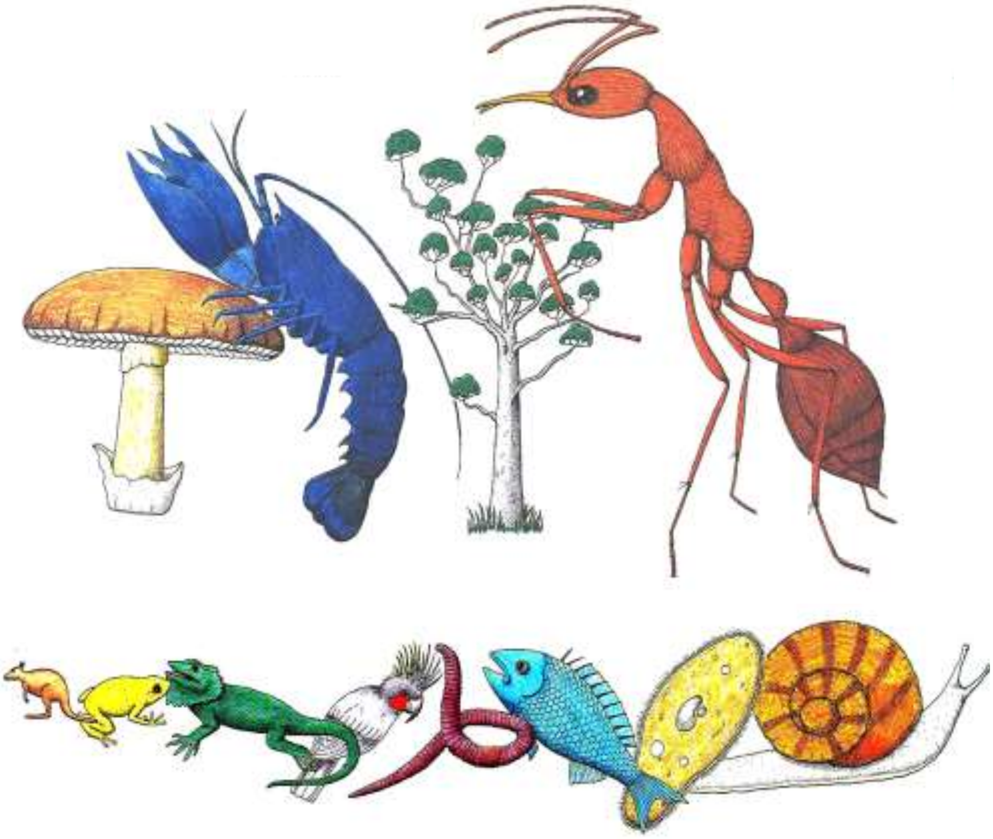

Figure 1.1: Diversity in proportion
Relative numbers of species found within different forms of life represented by size. Vertebrates are symbolised here by a kangaroo (mammals), frog (amphibians), lizard (reptiles), cockatoo (birds) and fish. The vertebrates show relatively little species diversity compared to worms, single-celled animals, fungi and molluscs (shown by the snail). Plants are diverse, but are dwarfed by the arthropods (represented by both a lobster and an ant).
Source: Beattie (1995). Biodiversity: Australia's Living Wealth, p.104-105.

The organisation of life

Life is organised at a number of different levels (Figure 1.2). The most tangible and familiar is the species level. However, genes shape the form and function of each individual organism, providing the basis through which species adapt to different environments and change through time (Hunter, 2002). So genetic diversity is also fundamentally important.

At the higher levels of organisation are ecosystems and landscapes. Ecosystems are a dynamic complex of interacting species and their physical environment, while landscapes are a mosaic of ecosystems (Calow, 1999; Hunter, 2002). At these levels, multiple species and associated processes may be conserved, including species that may be unknown to science (such as soil biota).

Genes Species Ecosystems Landscapes

Figure 1.2: Levels of organisation
Biodiversity is organised at a number of different levels: genetic, species, ecosystems and landscapes.

Ecological and evolutionary processes

Fundamental to the adaptation and maintenance of biodiversity are a series of ecological processes through which species interact with each-other, such as competition, predation, parasitism and mutualism (Morin, 1999). Species also interact with their physical environment through processes such as photosynthesis, respiration and biogeochemical cycling (Hunter, 2002). Through time, these ecological processes contribute to natural selection, which shapes each species' genetic diversity and drives evolution (Dobson, 1998).

Figure 1.3 presents a summary of biodiversity in terms of the variety of life, the levels in which it is organised, and the processes critical to its maintenance (Noss 1990; Groves 2003).

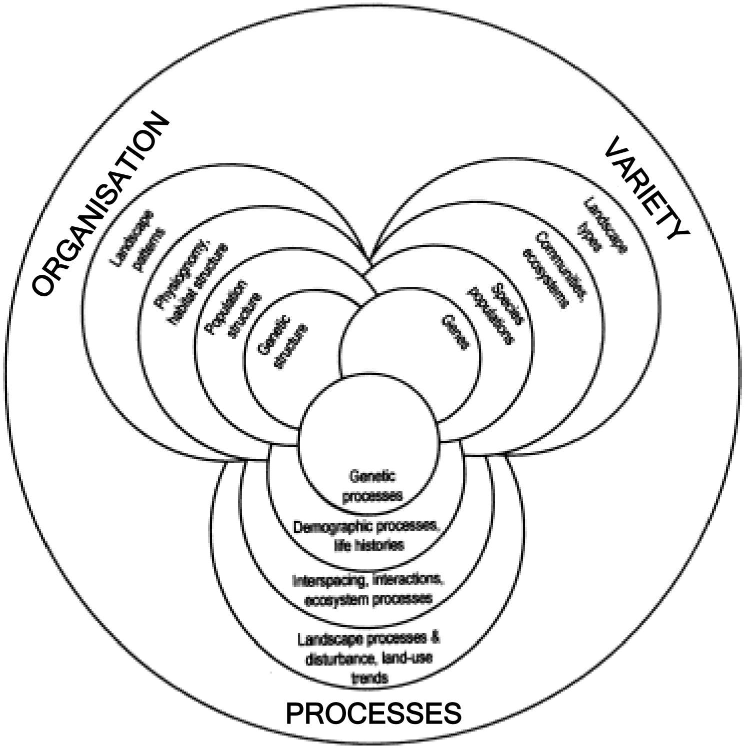

Figure 1.3: Biodiversity – variety, organisation and processes
Biodiversity encompasses different forms of life, organised at different levels and maintained through ecological and evolutionary processes.
Modified from: Groves, C. (2003). Drafting a Conservation Blueprint, p.8.

Appendix 2 – The nested approach to conservation planning

Biodiversity encompasses a range of different levels, including genes, species, ecosystems and landscapes. This requires planning that potentially encompasses all these different levels, which often causes confusion, as the different levels are partially nested (Figure 2.1).

Higher levels, such as landscapes and ecosystems capture a greater range of biodiversity, including both known and unknown species and a myriad of associated processes. However, a focus on conserving a representative sample of landscapes and ecosystems will not encompass all species and processes. Those missed will require specific management.

This split has been explained through the metaphor of coarse and fine filters (Noss 1987; Hunter 2002). Conservation focussed on obtaining representative samples of landscapes and ecosystems is termed the 'coarse filter', as it acts as a surrogate for broader biodiversity, picking up a multitude of species, levels of organisation and processes. However, some species and processes are not picked up through such an approach and require individually focussed efforts; this is termed the 'fine filter'. Reserve acquisition is typically based on 'coarse-filter' approaches, while threatened species recovery is more a 'fine-filter' approach (Groves 2003).

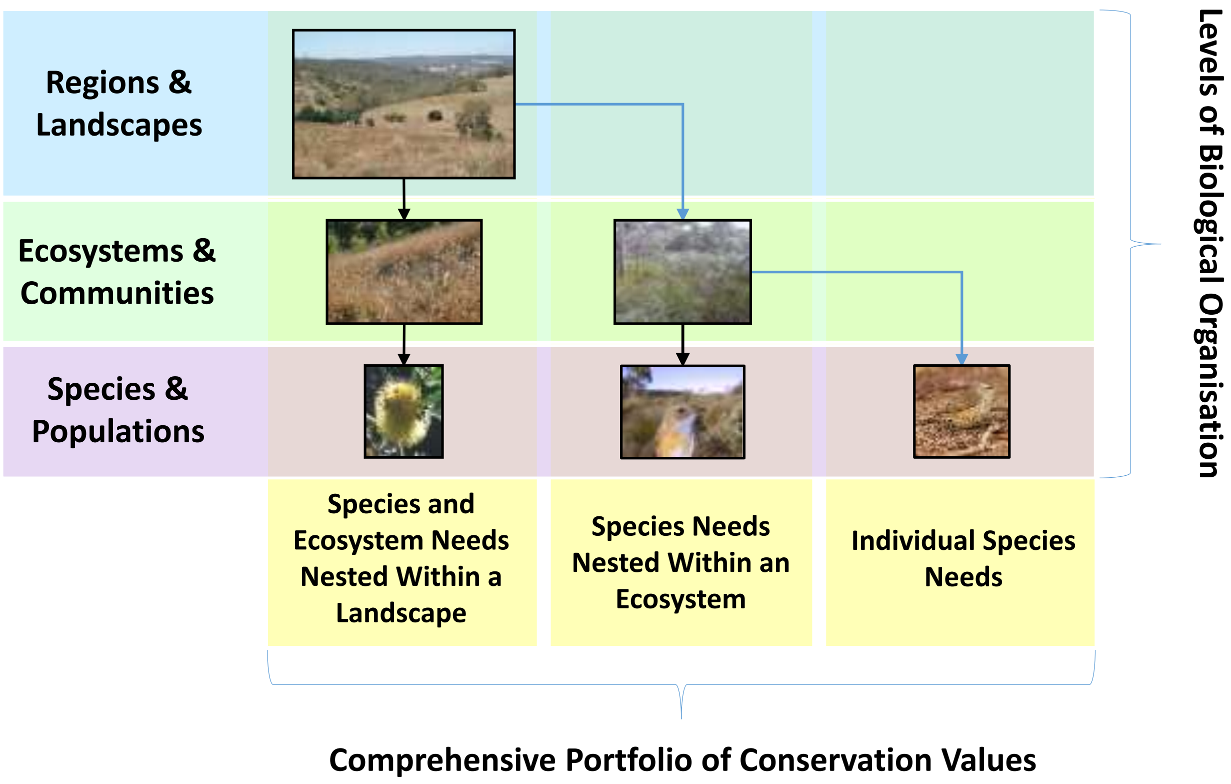

Figure 2.1: The partially nested nature of biodiversity and conservation planning logic. Biodiversity is organised at a number of different levels. As a result, it is often possible to implement management actions required at the highest level (such as landscapes) and automatically address the needs of the subordinate ecosystems and species (if these needs are nested). However, there will always be some components of biodiversity that have idiosyncratic management needs that are not shared with the higher levels of organisation (these are not nested). A comprehensive but efficient portfolio of conservation values and management responses can be developed by ensuring coverage across the higher levels of the biological hierarchy, and extending to the lower levels just for those values and issues that are not nested.

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