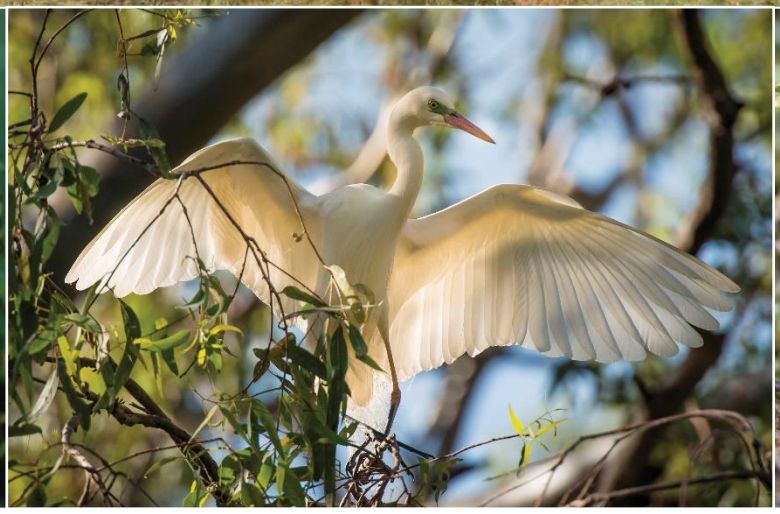
Measuring biodiversity and ecological integrity in NSW

Method summary



Published by:

Office of Environment and Heritage
59 Goulburn Street, Sydney NSW 2000
PO Box A290, Sydney South NSW 1232
Phone: +61 2 9995 5000 (switchboard)
Phone: 1300 361 967 (OEH and national parks enquiries)
TTY users: phone 133 677, then ask for 1300 361 967
Speak and listen users: phone 1300 555 727, then ask for 1300 361 967
Email: info@environment.nsw.gov.au
Website: www.environment.nsw.gov.au

Report pollution and environmental incidents
Environment Line: 131 555 (NSW only) or info@environment.nsw.gov.au
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Cover photos: Misty morning at Point Lookout, part of the Gondwana Rainforests World Heritage Area, M Van Ewijk/OEH; olearia cordata (*Olearia cordata)*, S Douglas; intermediate egret (*Ardea intermedia*), Macquarie Marshes, J Spencer/OEH; corroboree frog (*Pseudophryne corroboree)*, Kosciuszko National Park, J Spencer

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Photo: M Van Ewijk/OEH

New South Wales is home to an amazing array of plants, animals, insects, fungi and ecosystems. In 2017, the NSW Government introduced new legislation to manage land and conserve biodiversity. Biodiversity is complex and covers all the species and ecosystems in New South Wales. Many of these species and some of these ecosystems are not well known.

The Office of Environment and Heritage has collaborated with CSIRO and others to develop a method and suite of indicators to assess the status and trends in biodiversity in New South Wales now and in the future.

New South Wales is home to an amazing array of plants, animals and ecosystems. This biodiversity needs to be managed and protected to support the health of our environment and our communities.

Introduction

In 2017, the NSW Government introduced new measures to manage land and conserve biodiversity. These changes included the introduction of the Biodiversity Conservation Act 2016 (the Act). The purpose of the Act is 'to maintain a healthy, productive and resilient environment for the greatest well-being of the community, now and into the future, consistent with the principles of ecologically sustainable development'. This includes:

- conserving biodiversity at bioregional and state scales
- maintaining the diversity and quality of ecosystems and enhancing their capacity to adapt to change and provide for the needs of future generations.

It also requires the establishment of a program to collect, monitor and assess information on the **status** and **trends** in biodiversity in New South Wales. This information will be published in the first NSW biodiversity outlook report and will help inform the five-year review of the legislation in 2022.

Status means the condition or 'health' of a species, population, community, habitat or ecosystem.

Trends are directions of change in the environment, as shown by the changing values of measures (like indicators).

The Office of Environment and Heritage NSW (OEH) has collaborated with leading experts at the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the Australian Museum and Macquarie University to develop a method to assess status and trends in biodiversity and the ecological integrity of habitats that support biodiversity. This method is cutting-edge science using field data, environmental modelling and remote sensing to assess biodiversity for the whole of the State for the first time.

Monitoring and assessing all organisms and their habitats and ecosystems throughout an area as large and diverse as New South Wales is a substantial and complex task. To simplify the task and ensure it is cost-effective, we have developed a suite of indicators to measure biodiversity at regional and statewide scales. Indicators are described in more detail below. These indicators will be measured over time to track changes in biodiversity in New South Wales. OEH's Environmental Monitoring Assessment and Reporting Framework was used to guide the development of the indicators.

The method for measuring biodiversity is detailed in the technical report, Measuring biodiversity and ecological integrity in NSW: Method for the Biodiversity Indicator Program.

Biodiversity in New South Wales

Photo: S Douglas

What is biodiversity?

Biodiversity or 'biological diversity' is the variety of living animal and plant life from all sources. It includes diversity within and between species and diversity of ecosystems. It is the variety of life on Earth and applies to genetic, species and ecosystems diversity. Biodiversity includes all the different plants and animals, including fungi, lichen, invertebrates and microorganisms. Native plants and animals in New South Wales live and interact in complex ways, forming ecosystems. They depend on these natural ecosystems and habitats for their ongoing survival. Central to the maintenance of biodiversity is the idea of ecological integrity.

Ecological integrity is about maintaining the diversity and quality of ecosystems and enhancing their capacity to adapt to change and provide for the needs of future generations. It covers the extent, condition and connectivity of habitats; the effectiveness of on-ground conservation actions; and how well ecosystems respond to change, including climate change and other pressures.

Why is biodiversity important?

There are an estimated one million species of plants and animals in Australia, and many of them occur in New South Wales.

Maintaining the diversity of populations, species and ecosystems is crucial. Biodiversity has great value in itself; in the diverse range of forms and functions of plant and animal species, in the complex ecosystems those species create, and the important roles performed by microorganisms such as some types of fungi. Biodiversity also has direct value for human wellbeing because it:

- provides humans with food, construction materials, fresh water and medical resources
- regulates climate, air quality, carbon storage, erosion and pollination (including moderating extreme natural events such as floods)
- provides places for recreation and tourism
- has an intrinsic aesthetic and spiritual value
- maintains natural habitats that sustain species and ecosystems, which is especially important for Aboriginal people connecting to Country.

What is the status of biodiversity in New South Wales?

Photo: M Van Ewijk/OEH

New South Wales is blessed with a wealth of biodiversity. It is challenging to understand the status of biodiversity in New South Wales. The large variety of species and ecosystems reflects the diversity of landscapes in the State, including alpine mountains, arid deserts of the interior and coastal rainforests. Many of these plant and animal species are not found anywhere else and new species continue to be discovered.

In addition to tracking species and ecosystems, assessments of ecological integrity can tell us a lot about the status of biodiversity. This is because the survival of plants and animals depends on the condition and extent of habitats, as well as on the severity of pressures affecting biodiversity and how we manage our landscapes and protect natural areas.

Currently, some of the most significant pressures affecting biodiversity in New South Wales include:

- **habitat clearing**: through intensified agricultural activity and urban expansion
- **invasive species**: introduced predators (such as foxes and cats), invasive weeds and diseases
- **changes to natural cycles**: such as bushfires or flooding of wetlands occurring too frequently, or not frequently enough
- **a rapidly warming climate**: bringing warmer temperatures and altered rainfall patterns.

What is being done to conserve biodiversity in New South Wales?

Photo: D Croft/OEH

The NSW Government has committed to conserving our biodiversity through:

- **protected areas**: expanding and appropriately managing the protected area network across New South Wales
- **threatened species and ecological community conservation**: programs such as *Saving our Species* are focusing conservation actions aimed at conserving populations of listed threatened species and ecological communities
- **managing pressures**: programs to reduce key pressures on biodiversity include appropriately managing vegetation, controlling feral animal populations and reducing the impacts of weeds
- **habitat restoration**: substantial investment has been made in restoring natural vegetation, including improving the connectivity between patches of habitat.

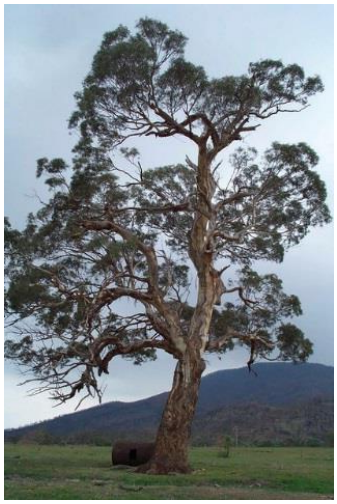

Photo: S Douglas

How do we know if these measures are working?

It is important to accurately assess the status of biodiversity, now and into the future, so that we can understand whether current biodiversity management and conservation measures are working. This type of long-term assessment can then be used to improve the way we manage biodiversity. Assessing changes in biodiversity status is particularly important for New South Wales in the current context of biodiversity legislation and to support land management programs.

Some methods to assess the effectiveness of individual conservation efforts, or for a particular species or a particular area, are already known. For example, changes in the population of a threatened mammal species can be tracked following a fox control program within its habitat.

However, assessing the overall success of biodiversity management across all of New South Wales presents a much greater challenge. This is due to the size of New South Wales, the vast array of species living in different parts of the State, the variety of human activities influencing the natural environment at local scales, and limitations in the number of places where scientists or the community can directly monitor changes in populations of species, ecosystems and their habitats.

Comparing assessments of biodiversity and ecological integrity now and in the future will help track changes in biodiversity, and tell us if our conservation efforts have been successful.

Measuring biodiversity

What are our indicators?

Biodiversity indicators are specific, measurable characteristics that show trends or changes in the status of biodiversity and ecological integrity.

No single indicator can satisfactorily report on all aspects of biodiversity because biodiversity is complex. We have identified an array of indicators to assess the status and trends of different aspects of biodiversity and ecological integrity in New South Wales. Indicators sit within a nested framework of classes, themes and indicator families (see Figure 1). The indicators (see Figure 2) have been designed to detect change, specifically the rate of loss of biodiversity, as well as the effectiveness of conservation actions. They allow for innovation in measurement methods over time. They reflect the requirements of biodiversity legislation, and include a mix of commonly used and novel (i.e. new) measures.

The indicators assess biodiversity at regional and statewide scales, and in some cases can be applied locally. Importantly, these indicators have a sound theoretical basis, are scientifically rigorous, and are based on internationally agreed approaches to biodiversity monitoring. They enable comparisons between biodiversity status in different regions at different times. They use information from other data collection, monitoring and evaluation programs already underway in New South Wales.

The indicators developed so far mainly apply to terrestrial (i.e. land-based) biodiversity to determine current status and to track changes. OEH is also developing equivalent indicators to measure freshwater, coastal and marine biodiversity and their habitats. All indicators, as they are developed, have a common place within the nested framework of classes, themes and families.

The indicators are reported under five main themes (summarised in Figure 1). The **expected survival of biodiversity** indicators assess threatened species and ecosystems in New South Wales (including those that are likely to be threatened but have not been formally assessed and listed by the Scientific Committee). The **state of biodiversity** indicators take a much broader view on biodiversity and include using models to measure the status of biodiversity as a whole, including species that are yet to be described. The **ecosystem quality** indicators assess the condition of ecosystems and the habitats that plants and animals depend on, and the pressures that threaten biodiversity. The **ecosystem management** indicators assess our management responses and how effective they are at conserving biodiversity. The final indicator theme, **ecosystem integrity**, integrates across the other indicators to measure the ability of ecosystems to adapt to change (including climate change), and retain their biological diversity and functions into the future.

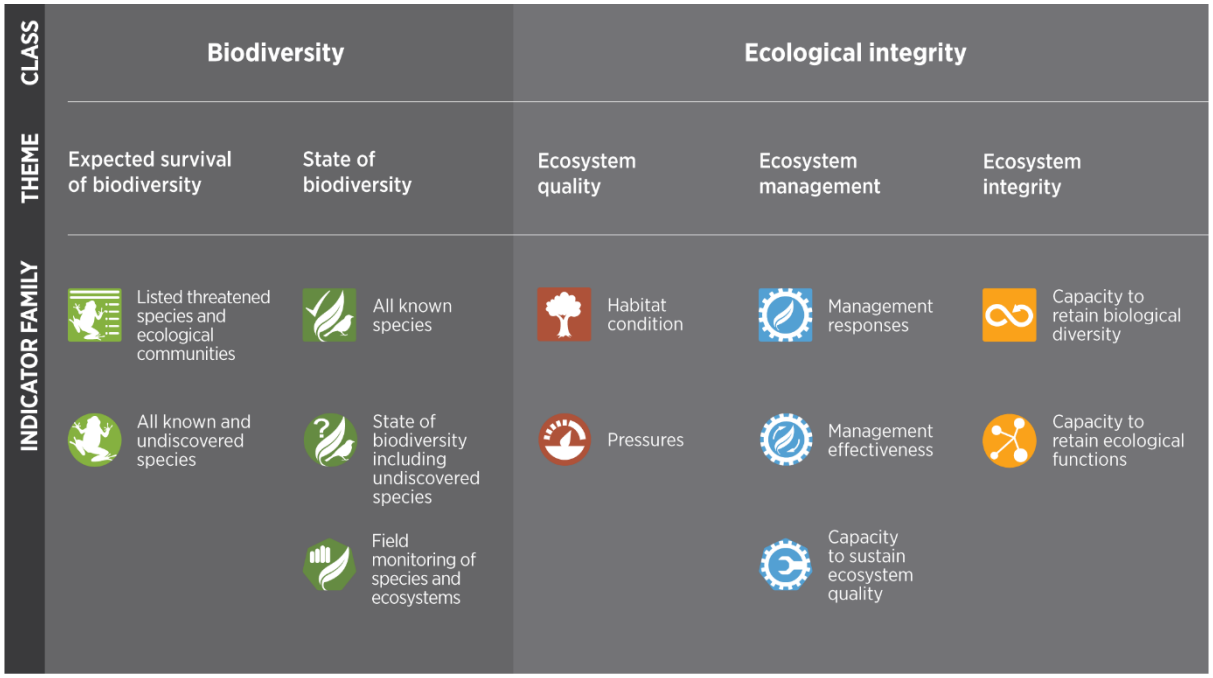

Figure 1 **Nested structure used to describe indicators for measuring biodiversity and ecological integrity in New South Wales.**

	INDICATOR FAMILY	STAGE	INDICATORS
BIODIVERSITY	Listed threatened species and ecological communities	1	Expected survival of listed threatened species
		1	Expected existence of listed threatened ecological communities
		1	Expected survival of phylogenetic diversity for listed threatened species
	All known and undiscovered species	1	Expected survival of all known species
		2	Expected survival of all known and undiscovered species
	All known species	2	Within-species genetic diversity (for all known species)
		2	Extant area occupied (for all known species)
	State of biodiversity including undiscovered species	3	Within-species genetic diversity (including undiscovered species)
		2	Persistence of all species (including undiscovered species)
		1	Persistence of ecosystems (including undiscovered species)
	Field monitoring of species and ecosystems	1	Species trends
		1	Ecosystem trends
ECOLOGICAL INTEGRITY	Habitat condition	1	Ecological condition of terrestrial vegetation
		2	Ecological connectivity of terrestrial vegetation
		1	Ecological carrying capacity of terrestrial vegetation
		3	Ecosystem function of terrestrial vegetation
	Pressures	2	Land-use and management practices
		2	Native vegetation extent
		3	Inappropriate fire regimes
		3	Inappropriate hydrological regimes
		3	Invasive species (pests, weeds, disease)
		3	Altered climatic regimes, variability and extremes
	Management responses	2	Areas managed for conservation in perpetuity
		3	Areas managed for conservation under formal or informal agreements
		3	Community appreciation of biodiversity
	Management effectiveness	3	Effectiveness of on-ground biodiversity conservation programs
		3	Community-based maintenance of biodiversity values
		3	Implemented climate-adapted conservation planning and management
	Capacity to sustain ecosystem quality	3	Capacity to maintain or enhance ecosystem quality (local resilience)
	Capacity to retain biological diversity	3	Ecosystem capacity to adapt to change and retain biological diversity under climate change
		3	Ecosystem capacity to adapt to change and retain biological diversity under land-use change
	Capacity to retain ecological functions	3	Ecosystem capacity to adapt to change and maintain ecological functions under climate change
		3	Ecosystem capacity to adapt to change and maintain ecological functions under land-use change

Figure 2 **List of indicators that will be used to measure biodiversity and ecological integrity in New South Wales at bioregional and statewide scales. Indicators are categorised into five themes and assigned to indicator families.**

Our first assessment of the status of biodiversity will be presented in the first NSW Biodiversity Outlook Report, which is scheduled to be published in 2019. This assessment will use 2017–18 data, or data from as close to this time as possible. Where historical data is available, it will be used to estimate a trend. To begin with, only a few of the indicators will be able to be measured, but more will be completed as the data and methods advance. Remeasurement of indicators in the future will be used to show changes from the initial 2017–18 assessment. Figure 3 shows how the indicators will be able to reveal trends in relation to the initial assessment.

The technical report provides more detail about the indicators and how they were developed.

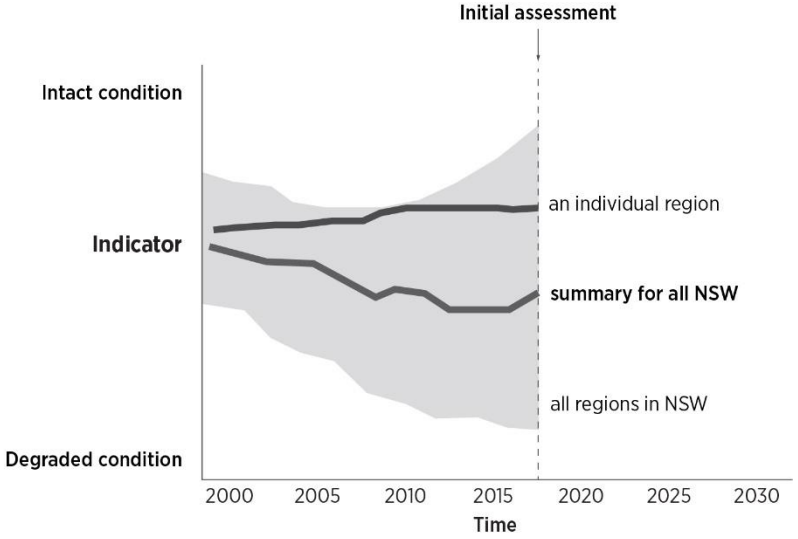

Figure 3 **An example of how indicators will help to report on the changes in the status of biodiversity.** For a given biodiversity indicator, it may be possible to track change for an individual region, for all New South Wales and as a summary statistic for all New South Wales. The dotted vertical line indicates the initial assessment, which future changes will be assessed against.

Indicators are based on the best available data and information

What data is used in the indicators?

Measurements for the indicators require data on biodiversity, habitats, pressures (i.e. threats) and management actions across New South Wales. Data has been obtained from a variety of sources including field surveys, museum collections, genetic samples, maps of environmental features and remote sensing using satellite imagery. To obtain a statewide snapshot of biodiversity, some indicators have combined data from different sources using advanced spatial or temporal analytical techniques and computer-based

modelling approaches to create new data. Other indicators have used data from repeated field surveys for specific ecosystems or species. Indicators will also assess the effectiveness of conservation efforts and management actions. Some indicators are still under development.

What methods are used to measure the indicators?

We are using four complementary methods to measure the status of biodiversity and ecological integrity:

1. direct measures of biodiversity status, such as direct field surveys and long-term monitoring across a representative sample of locations
2. indirect measures of biodiversity status, such as remote sensing and modelling of habitat extent and condition, from which biodiversity status can be inferred
3. direct measures of ecological integrity, from field observations and using remote sensing of habitat extent and condition; or by monitoring pressures (such as habitat loss) and mitigations (such as conservation actions and their effectiveness)
4. indirect measures of ecological integrity, such as forecasting the capacity of ecosystems to adapt to change based on current and future projections of climate change, including management objectives and models of ecosystem resilience.

Photo: S Cohen/OEH

How will field surveys be used?

The NSW Government invests in collecting high-quality, long-term data on biodiversity and habitats. These datasets are very valuable but cannot cover every location, species or ecosystem across the State. As a result, we use existing data strategically to inform statewide assessments of biodiversity. In addition to indicators that use measures of biodiversity directly to show trends in populations or habitats, field data is used to calibrate and correct interpretations of satellite imagery. It is also used to generate ecological computer models that allow us to get a snapshot of biodiversity across New South Wales.

How will remote sensing be used?

Remote sensing is the interpretation of images of the landscape taken from a satellite or an aircraft. Satellite images (similar to that in Figure 4) can be used to inform us where there are changes in vegetation.

OEH has a long history of using remote sensing to manage vegetation and identify changes in vegetation. While remotely sensed data cannot measure biodiversity directly in the way that on-ground field surveys can, it is of great benefit because it provides a picture of the State at regular intervals. For statewide biodiversity assessment, remote sensing is crucial in measuring indicators related to habitat extent and condition. Methods that allow habitat condition to be reliably interpreted from remote sensing are rapidly evolving and new approaches will be applied to indicators as they are developed and proven.

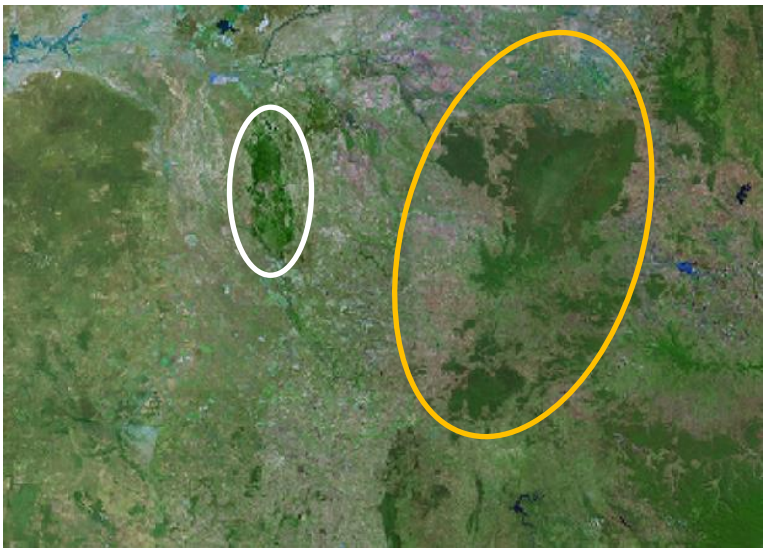

Figure 4 **Satellite image of NSW Central West, showing the Pilliga (large green area within the yellow oval) and Macquarie Marshes (smaller green area within the white oval), captured by SPOT 5 satellite in 2011.**

How will spatial modelling be used?

Spatial modelling is a computer-based analysis used, for example, to estimate the potential distribution of species and ecosystems and the condition of habitat.

Spatial modelling is used to help fill gaps where we do not have sufficient data of biodiversity patterns from field surveys. Known relationships between environmental features that are mapped across New South Wales (such as annual rainfall, soils and the occurrence of species and ecosystems) are used to predict potential distributions. Potential distributions are combined with habitat condition data to provide the best possible picture of the biodiversity we would expect to find at any location.

Next steps

Photo: J Spencer/OEH

The indicators will be measured in a staged approach.

We are measuring and reporting some indicators now because we have the necessary data and analysis techniques. For other indicators, such as those related to management effectiveness, we need to collect additional data and use advanced statistical methods to produce reliable results. Further scientific assessment is required for groups of indicators to identify the most robust way to implement them. This work is underway.

The process of developing and measuring indicators is also useful in identifying crucial data gaps. These can be prioritised for specific research or data collection.

The method detailed in the technical report sets out a program to further develop and refine indicators for future reporting. In the future, the method will be repeated with new and historical data to help us track our progress in managing biodiversity in New South Wales.

Glossary

Animal: any animal, whether vertebrate or invertebrate and in any stage of biological development. Note that under NSW biodiversity legislation, 'animal' does not include fish or humans.

Biodiversity (biological diversity): is defined by the *Biodiversity Conservation Act 2016* as the 'variety of living animal and plant life from all sources, and includes diversity within and between species and diversity of ecosystems'. It encompasses all the variability among living organisms from all sources, including genetic, species and ecosystem diversity across terrestrial and land-based aquatic realms and certain coastal and marine species. Biodiversity includes both species and ecosystems that are currently known, as well as those that are yet to be discovered.

Habitat: an area or areas occupied, or periodically or occasionally occupied, by a species, population or ecological community, including any biotic or abiotic component.

Habitat condition: the capacity of an area to provide the structures and functions necessary for the persistence of all species naturally expected to occur there in an intact state.

Ecological community: an assemblage of species occupying a particular area at a particular time.

Ecological integrity: is about maintaining the diversity and quality of ecosystems and enhancing their capacity to adapt to change and provide for the needs of future generations.

Ecosystem: a dynamic complex of plant, animal and microorganism communities and their nonliving environment that interact as a functional unit. Ecosystems may be small and simple, like an isolated pond, or large and complex, like a specific tropical rainforest or a coral reef.

Fungi: a diverse group of microorganisms in the taxonomic kingdom of Fungi, including mushrooms, moulds, mildews, smuts, rusts and yeasts.

Genetic diversity: the range of intrinsic differences in genes among individual organisms within a species, or among different species within a taxonomic group.

Indicator: something that shows what a situation is like, or measures the status or level of something.

Listed threatened species and ecological communities: species or ecological communities listed as threatened in the Biodiversity Conservation Act.

Modelling: computational simulation of a process, concept or the operation of a system.

Plant: any plant, whether vascular or non-vascular and in any stage of biological development in the taxonomic kingdom of Plantae. Note that under NSW biodiversity

legislation, ‘plant’ includes fungi and lichens but not marine vegetation.

Remote sensing: a means of acquiring information using airborne or satellite equipment and techniques to determine the characteristics of an area, most commonly using imagery from aircraft and images from satellites.

Status: the condition or ‘health’ of a species, population, community, habitat or ecosystem.

Trends: directions of significant change in the environment, as shown by the changing values of measures (like essential variables, indicators or indices).