Increase in the knowledge of biodiversity

This section reports on the following environmental indicators, which are defined in Saunders et al. (1998).

Environmental Indicator	
BD 14	Proportion of bioregions covered by biological surveys
BD 24.1	Number of species described per reporting cycle
BD 24.2	Number of taxonomists involved per reporting cycle
BD 24.3	Amount of funding for taxonomy
BD 24.4	Number of research programs into surrogates
BD 24.5	Number of research programs into the role of biodiversity in ecological processes
BD 24.6	Number of long-term ecological monitoring sites

In order to sustainably manage Australian landscapes for both conservation and production purposes, there needs to be improvement in our understanding of the various elements of biodiversity. The previous sections illustrated how our understanding of even the most basic measure of biodiversity, the number of species, is poorly lacking.

Taxonomic endeavour in Australia

Number of taxonomists and species described [BD Indicators 24.1 and 24.2]

Results of the ABRS survey indicate that there were around 185 taxonomists working in Australia in June 2000 (Table 58; Figure 54). These figures capture roughly 75% of the taxonomic endeavour in Australia, due to non-respondents and private collectors from Australia and other countries not covered by the survey. All Australian institutions known to hold major collections were contacted, including museums, herbaria and universities. Taxonomists described about 2300 new species and 240 new genera between 1 July 1995 and 30 June 1999 (Table 58). Roughly two-thirds of the taxonomic effort was expended on animals and one-third on plants. There is currently no-one working on many of the taxa in Australia (some groups are being handled in other countries on a world basis).

Among the plants, vascular plants were the main focus. Fungi are expected to be far more numerous than vascular plants, but only about 6% of the total taxonomic effort was directed towards fungi, compared to about 75% of the effort on vascular plants. Among the animals, slightly more than one-half of the effort was directed towards the most numerous taxa (insects, arachnids and crustaceans). Just fewer than 20% of the effort was directed towards vertebrates, which make up less than 1% of all animal species.

The mismatch between effort and the amount of outstanding work is apparent in Figure 54. Fungi in particular are underresourced, relative to other taxa, when the total numbers of undescribed taxa are taken into account. Fungi are important in ecosystem services and biogeochemical cycles making them just as important as vascular plants from a utilitarian perspective. The ABRS lists them as a high priority. Part of the difficulty is the lack of taxonomists in these areas and lack of people willing to work in them. Similarly, taxonomic priorities among animals reflect to some extent social and immediate economic imperatives, rather than ecological ones.

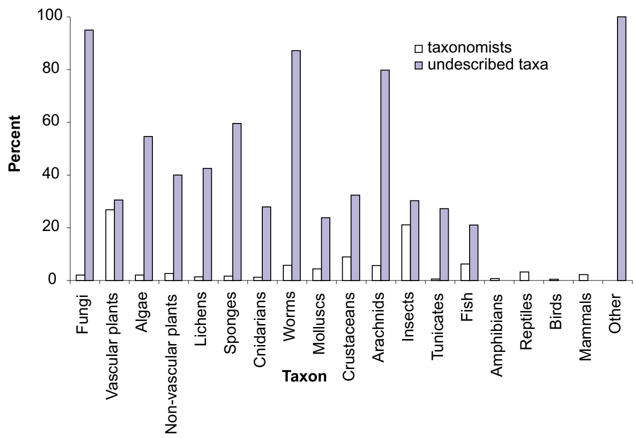

Figure 54: The percentage of taxonomists working on each taxon out of the total number of taxonomists and the percentage of undescribed taxa remaining in each taxon, in June 2000.

This figure demonstrates the paucity of information available for most native species in Australia. The category 'worms' includes annelid worms, flatworms, roundworms, velvet worms and thornyheaded worms.

Source: ABRS; see text for further details about the plant and animal survey that formed the basis of these figures.

Funding for taxonomy [BD Indicator 24.3]

Taxonomic work was undertaken by 57 different institutions in all states and territories (Table 59). The funding for this work comes from Commonwealth and state

Table 58: The number of taxonomists working in Australia (in full-time units) in June 2000, and the number of new Australian taxa described between 1 July 1995 and 30 June 2000

Group	No. of taxonomists working on each taxon in July 2000	No. of institutions working on each taxon	New genera	New Australian species
Protoctistae (Unicellular organisms)				
	6.9	7	—	12
Fungi				
Fungi (excluding lichens)	3.7	6	—	132
Lichens	2.5	3	—	29
Plantae (Plants)				
Vascular plants (flowering plants, cycads, conifers, ferns and fern allies)	50	18	3	500
Algae	3.8	4	1	6
Bryophyta (mosses and allies)	4.9	7		
Total Australian Flora (Plants and Fungi)	**65**	**—**	**4**	**667**
Animalia (Animals)				
Invertebrates				
Porifera (sponges)	3	2	—	70
Cnidaria (corals, anemones, jellyfish)	2.2	2	16	34
Platyhelminthes (flatworms, parasites)	2	1	9	52
Acanthocephala (thorny-headed worms)	0.2	1	1	1
Nematoda (roundworms, threadworms)	4.9	6	5	45
Mollusca (squid, octopus, mussels, clams, snails)	8.1	8	4	75
Annelida (ringed worms, earthworms)	3	2	4	37
Onychophora (velvet worms)	0.5	1		
Crustacea (crayfish, crabs, prawns etc.)	16.7	10	20	107
Arachnida (spiders, mites etc.)	10.5	10	31	242
Insecta (insects)	39.3	19	141	868
Chordates				
Tunicata (sea squirts, doliolids, salps)	1	1	2	2
Pisces (fish)	11.6	10	—	57
Amphibia (frogs)	1.2	2	—	1
Reptilia (snakes, lizards)	6	5	2	26
Aves (birds)	0.8	1	—	46
Mammalia (mammals)	4	4	—	1
Total Australian Fauna	**115**	**—**	**235**	**1 664**

Source: figures are derived from a survey of taxonomists in Australia, conducted by the ABRS (see text).

institutional support, and it occurs in museums and herbaria, state and Commonwealth regulatory agencies, and tertiary research and teaching institutions. Despite the significant gaps in taxonomic effort in Australia, the budget for the ABRS, which is producing the multivolumed *Flora of Australia* and *Fauna of Australia*, was cut by $400 000 in the 1999–2000 financial year. Fourteen Large Research Grants were awarded from the Australian Research Council (ARC) for taxonomic research between 1997 and 2000 (Table 60).

Table 59: **The number of institutions undertaking taxonomic work in each state and territory of Australia**

State/Territory	Flora	Fauna	Total
Antarctica	1	1	1
Australian Capital Territory	3	3	5
New South Wales	6	8	11
Northern Territory	1	3	4
Queensland	3	6	9
South Australia	2	5	7
Tasmania	2	2	5
Victoria	3	6	8
Western Australia	5	4	7
Total	**26**	**38**	**57**

Source: figures are derived from a survey of taxonomists in Australia, conducted by the ABRS (see text and Table 58).

Table 60: **Australian Research Council Large Research Grants funding for taxonomic projects between 1997 and 2000**

Year	Number of grants	Amount ($)	Groups
2000	2	297 500	*Davesia*, insects (ordinal relationships)
1999	1	140 000	Doryctine wasps
1998	6	1 238 000	Hymenoptera, crabs, insects, amphibians, reptiles, birds, mammals, Trematodes
1997	5	830 000	Caenogastropod molluscs, *Eucalyptus*, gall-forming thrips, *Styhelieae*, Cockroaches (*Paratemnopteryx*)

Biodiversity in ecological processes

Number of research programs into the role of biodiversity in ecological processes

[BD Indicator 24.5]

There have been no ARC Large Research Grants into the role of biodiversity in ecological processes in the last five years.

The use of surrogates for the management of biodiversity

Number of research programs into surrogates [BD Indicator 24.4]

In the context of State of Environment reporting, and for biodiversity management in general, 'surrogates' measure the spatial distribution of biodiversity. They are distinct from indicators that measure the response of ecosystems to disturbance, and from umbrella species and flagship species that provide de facto protection for species that occupy the same habitat.

The taxon-based biodiversity surrogates approach targets resource management or landscape restoration efforts at a group of species and assumes that the needs of other taxa will be met (see the *Taxon-based biodiversity surrogates* box on page 157).

A simple strategy is to conserve areas that incorporate a range of environmental factors (Faith & Walker 1993). Environmental domains are geographical regions that enclose a continuous range of physical environmental parameters that are expected to be important in determining the distributions of species.

Vegetation maps are perhaps the most frequently used biodiversity surrogates. Much of the vegetation of the Australian continent has been classified and mapped (Commonwealth of Australia 1990; Specht et al. 1995). It is assumed that protection of a proportion of each vegetation type will protect sufficient proportions of the populations of other organisms. Vegetation maps may fail as surrogates in cases where sets of species are dependent on particular successional stages within a vegetation community (e.g. the old growth stage of a particular type of forest), or when species respond to environmental variables to which the vascular flora are insensitive.

Taxon-based biodiversity surrogates

Taxon-based biodiversity surrogates schemes have been used widely in conservation management efforts in many parts of the world. The search for indicators of biodiversity has tended to focus on biological entities (e.g. gene frequencies, populations, species, species assemblages and communities) that might function as surrogates or proxies for other forms of biodiversity and/or reflect changes in ecosystem patterns or processes (Burgman & Lindenmayer 1998). Many types of biodiversity surrogate schemes have been proposed. Some of these include: indicator species, management indicator species, keystone species, umbrella species, and the focal species approach (Lindenmayer et al. 2000). The biodiversity surrogate scheme that has received greatest attention has been 'indicator species'.

The term indicator species has been used to mean many different things. Some examples of types of indicator species include:

1. a species whose presence indicates the presence of a set of other species and whose absence indicates the lack of that entire set of species
2. a keystone species, *sensu* Terborgh (1986), which is a species whose addition to, or loss from, an ecosystem leads to major changes in abundance or occurrence of at least one other species (e.g. Mills et al. 1993)
3. a species whose presence indicates human-created abiotic conditions such as air or water pollution (often termed a pollution indicator species, Spellerberg 1994)
4. a dominant species in the sense that it provides much of the biomass or number of individuals in an area
5. a species that indicates particular environmental conditions like certain soil or rock types (Klinka et al. 1989)
6. a species thought likely to be sensitive to, and to therefore serve as an early warning indicator of, environmental changes like global warming (Parsons 1991) or modified fire regimes (Wolseley & Aguirre-Hudson 1991) (sometimes termed a bioindicator species)
7. a management indicator species, which is a species believed to reflect the effects of a disturbance regime or the efficacy of efforts to mitigate disturbance effects (Milledge et al. 1991).

Types 1, 2 and 4 have been proposed as indicators of biodiversity and types 3, 5, 6 and 7 as indicators of abiotic conditions and/or changes in ecological processes.

Taxon-based biodiversity surrogate schemes have wide appeal because it is simply impossible to measure, monitor and manage all of biodiversity (Burgman & Lindenmayer 1998). The fundamental assumption of all taxon-based surrogate schemes is that if resource management or landscape restoration efforts are targeted at a group of species, the needs of other taxa will be provided. However, as early as the 1980s, several workers raised concerns about the conceptual, theoretical and practical basis for taxon-based surrogate schemes (e.g. Landres et al. 1988). None of these concerns have been adequately answered in the intervening years (Lindenmayer et al. 2000). Some of the many problems which afflict taxon-based surrogate schemes are outlined below.

The effects of human perturbation such as landscape change and habitat fragmentation varies for each species and also between groups of species. Hence, the response of a given species or suite of species to landscape modification may reveal very little about the response of many other species in the same or different assemblage or group.

Any species that is the specific target for conservation by particular management actions can no longer be an independent yardstick of those actions and, in turn, be regarded as a suitable surrogate for other taxa.

There are problems stemming simply from choosing the wrong biodiversity surrogate that can arise from a lack of understanding of the causal relationship between the response of that species and the ecosystem conditions for which it is supposed to be indicate. There are also problems stemming simply from choosing the wrong indicator species. The case of the Bivalve Mollusc (*Velesunio ambiguus*) in Australian river systems is a classic example. Early research suggested that the species was an indicator of the presence of heavy metals (Walker 1981). Subsequent work found that the uptake of heavy metals by *Velesunio ambiguus* did not reflect the extent of pollution in the surrounding riverine system, making the mollusc an unreliable, and thus entirely unsuitable, indicator species (Millington & Walker 1983). Robust causal relationships between surrogates and other elements of biodiversity have never been demonstrated (Lindenmayer et al. 2000).

A recent study of surrogate schemes by Andelman and Fagan (2000) examined the efficacy of an array of types of taxon-based surrogate schemes including indicator species, flagship species and umbrella species. Andelman and Fagan (2000) found that none of the surrogate schemes captured more species or better protected habitat than a given species selected at random from the large databases they assembled to conduct their tests.

Thus, a key problem with taxon-based surrogate schemes is that when a landscape is managed or restored in an attempt to meet the requirements of a given suite of species such as birds (e.g. through the focal species approach) it may be inappropriate to automatically assume that the food, shelter and breeding requirements of other plants and animals in the landscape have also been met.

The inherent problems associated with the use of indicator species and other biodiversity surrogate schemes means that other approaches may be needed to conserve biodiversity as part of ecologically sustainable natural resource management. In the case of forest landscapes,

Taxon-based biodiversity surrogates

Lindenmayer et al. (2000) recommended the adoption of what they termed 'structure-based' indicators. These included stand and landscape (spatial) level features of forests such as stand structural complexity and plant species composition, connectivity and heterogeneity. In addition to these structure-based indicators, Lindenmayer et al. (2000) advocated the following four key approaches to enhance biodiversity conservation in forests:

- the establishment of biodiversity priority areas (e.g. reserves) managed primarily for the conservation of biodiversity
- within production forests, the application of structure-based indicators, including structural complexity, connectivity and heterogeneity
- the deployment of a risk-spreading approach in wood production forests using multiple conservation strategies at multiple spatial scales
- the adoption of an adaptive management approach to test the validity of structure-based indices of biodiversity by treating management practices as experiments.

Source: David Lindenmayer, Australian National University.

No ARC Large Research Grants have been awarded on the subject of surrogates between 1995 and 2000.

The use of bioregions

Proportion of bioregions covered by biological surveys

[BD Indicator 14]

The data on this indicator are not readily available at a national or regional level, even for areas with relatively comprehensive survey records such as north-east New South Wales.

Long-term monitoring

Long-term monitoring and research sites

[BD Indicator 24.6]

Long-term monitoring sites are permanent sample locations set up to record trends in a range of ecological and biological characteristics. In Australia, there are numerous agencies and programs responsible for the upkeep and continued measurement of long-term monitoring sites. The first long-term monitoring site was a CSIRO site established at Gilruth Plains, Qld, in 1944. The 20 ha grazing exclosure is located within the Warrego floodplain and includes a mix of Mitchell Grass downs, Gidgee drainage line and Spinifex sandhill vegetation. A total of 14 photopoints were established in 1944 and have been rephotographed and interpreted at irregular intervals since. Several studies into the ecology and demography of Mitchell Grass (*Astrebla* spp.) have been conducted using these data, and the understanding from this study informs the management and resource use of the plains.

There is a broad range of motivations for the establishment of long-term monitoring sites. Many of the early sites were established to monitor production systems such as forests and fisheries. Most of the ecological monitoring sites with a non-production focus were established in the 1980s and 1990s, with some notable exceptions. There are also many community monitoring programs which are covered in following sections. Over 80 biodiversity or monitoring programs, covering 1995 to 2001, are also recorded for the AAT (http://www.aad.gov.au).

Global scientific interest in developing a Long-Term Ecological Research (LTER) program is expanding very rapidly, reflecting the increased appreciation of their importance in assessing and resolving complex environmental issues. In 1993,

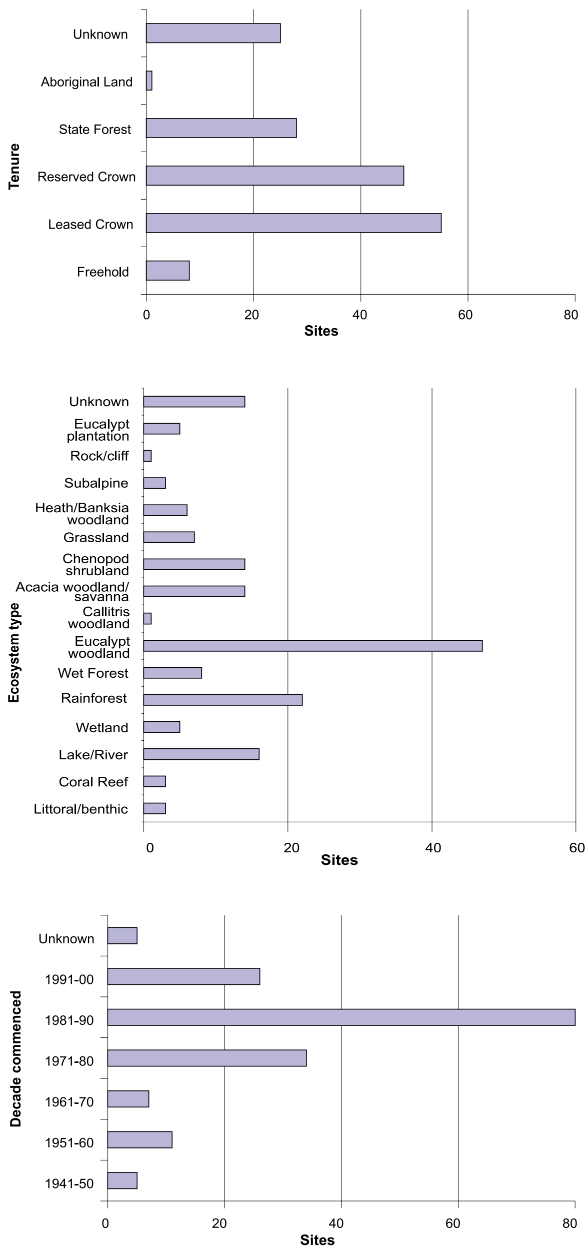

Figure 55: The number of long-term research and monitoring sites by tenure, ecosystem type and decade commenced.

About 130 sites are recorded in the ESA database, which while incomplete, provides a base-line for documenting long-term sites around Australia.

Source: ESA.

Table 61: The eight sites recorded in the Ecological Society of Australia's database on long-term ecological research and monitoring sites that sample vertebrates, invertebrates and plants

Ecosystem	No. of sites	Location	Project commenced
Coral reef/lagoon	1	One Tree Island Reef, Qld	1974
Eucalypt forest	1	Barren Grounds, NSW	1983
Eucalypt woodland	1	Gladstone Block, Qld	1988
Savanna	1	Manbullo, Katherine, NT	1975
Savanna	1	Lake Mere, NSW	1985
Wet forest	3	Central Plateau, Tarraleah, Tas.	1992

Source: ESA database (see Figure 55).

the International Long Term Ecological Research (ILTER) network was formed to develop a worldwide program, and the infrastructure necessary to facilitate communication and to manage distributed databases. Australia is a member of this international network and has four sites registered—three of these focus on production forests (two in Queensland and one in Tasmania) and the fourth, which began operations in 1998, is centred around rainforest canopy research at Cape Tribulation, north Queensland.

The only national register of long-term research and monitoring sites is maintained by the Ecological Society of Australia (ESA) (Figures 55 and 56). The database mainly contains sites contributed by members of the Society, and would benefit from a more systematic approach to collecting information. However, with over 130 sites listed, this database represents a very useful starting point to develop a national strategy. The database has site location details for roughly 90% of the study sites listed.

Of the more than 130 long-term monitoring and research sites in the ESA database, only eight are comprehensive in the sense that they sample vertebrates, invertebrates and plants (Table 61). Most sites are dedicated to sampling just one, or more rarely two, taxonomic groups. There is a distinct bias towards monitoring vascular plants, and there is a very uneven distribution of effort across taxa and among ecosystems (Figure 57).

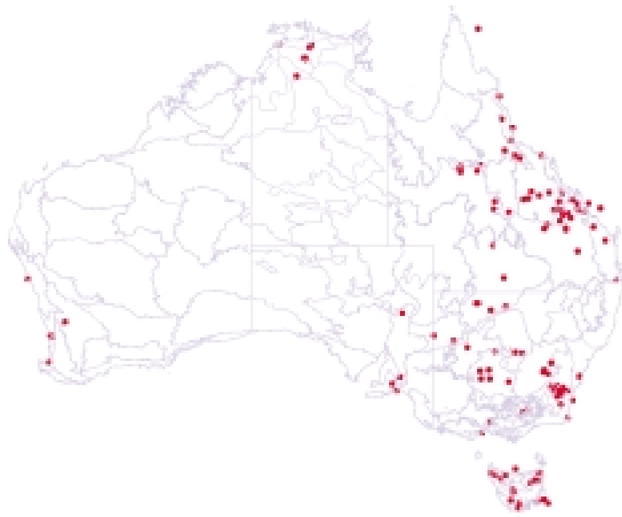

Figure 56: Distribution of long-term ecological research and monitoring sites across Australia.

Offshore points are located on islands. Large-scale monitoring programs with many study sites are not mapped. For example, the Rangelands Assessment Program in South Australia, and the Great Barrier Reef long-term change monitoring sites for the Reef CRC in Queensland are not included.

Source: ESA database.

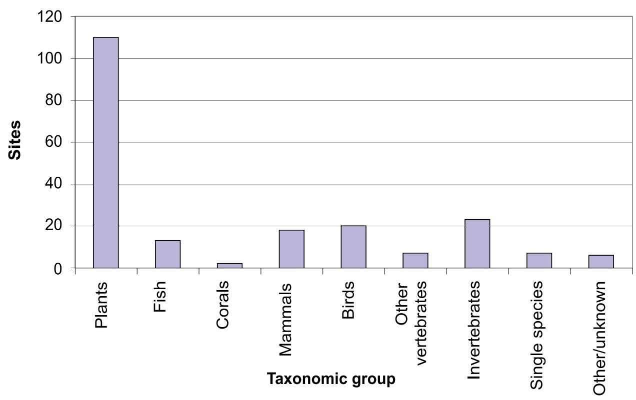

Figure 57: The number of long-term research and monitoring sites in Australia devoted to sampling various taxa.

See also Figures 55 and 56.

Source: ESA database.