Criterion 1

Conservation of biological diversity

Biological diversity is the variety of life forms: the different plants, animals and microorganisms, the genes they contain, and the ecosystems they form. It is usually considered at three levels: genetic diversity, species diversity and ecosystem diversity. The ultimate objective of the conservation of biological diversity is the survival of species and the genetic variability within those species.

The nine indicators in this criterion are divided into three subcriteria: ecosystem diversity, species diversity and genetic diversity. Ecosystem diversity indicators describe the range, extent and growth stages of Australia's forest types, the tenure systems within which they are managed, the level of forest clearing and the extent to which such clearing has fragmented native forests. Species diversity indicators are concerned with the number and variety of forest-dependent animal and plant species; indicators in this subcriterion identify forest-dwelling species, the level of information to support conservation strategies, and the role of forest management in protecting threatened and vulnerable species. Genetic diversity indicators examine the risk of genetic diversity loss in forests and the measures in place to minimise that risk.

Melaleuca leucadendra forest.

Key findings

Ecosystem diversity

- Australia has 149 million hectares of forest. Of this, 147 million hectares is native forest, dominated by eucalypt (79%) and acacia (7%) forest types. There is 1.82 million hectares of plantations, mostly comprising 1.0 million hectares of pine (softwood) and 0.81 million hectares of eucalypt (hardwood), an increase of 12% over the 1.63 million hectares reported in 2003.
- Australia's ability to estimate its forest area continues to improve with the increasing availability of high-resolution remotely sensed data and improvements in forest typing methods. This largely explains the revision of estimated total forest area from 164 million hectares in 2003 to 149 million hectares reported here; little of the change is due to real forest loss.
- Since 2003, the area of native forest in formal nature conservation reserves has increased by about 1.5 million hectares to 23 million hectares, from 13% to 16% of Australia's forests. The area of multiple-use public forests (in which wood production is an objective) declined from 11.4 million hectares in 2000–01 to 9.4 million hectares in 2005–06.
- Seventy per cent of the total forest estate is privately managed, including private freehold, leasehold and Indigenous-managed lands.
- The net loss of woody vegetation (mostly forest) estimated by the Australian Greenhouse Office (AGO) was 260,000 hectares (0.25%) per year between 2000 and 2004, due mainly to clearing for agriculture and urban development. The rate of loss of woody vegetation is declining in response to changed land management practices and increased legislative controls.

- Of the 23 million hectares of forest assessed for old-growth values, 5.03 million hectares (22%) is classified as old-growth. This is about 200,000 hectares less than that reported in 2003 (5.23 million hectares), due mainly to the impact of severe fires, with younger forests replacing some old-growth forest, and also to some remapping. Over 70% of known old-growth forests is now in nature conservation reserves.
- The area of forests in formal nature conservation reserves increased for most forest types over the reporting period, with notable increases in some types, including rainforest (from 33% to 55%) and mangroves (from 13% to 18%).
- There has been an increase in the area of privately managed forest (including private freehold, leasehold and Indigenous-managed lands) managed for conservation objectives through a variety of national and jurisdictional programs, but the extent of this increase is not well documented.
- As much as one-third of Australia's native vegetation in the intensively managed agricultural and urban zones has been cleared or substantially modified over more than 200 years of European settlement. As a result, those areas exhibit a relatively high level of fragmentation.
- A review of fragmentation in two regions between 1972 and 2002 suggests that fragmentation can be dynamic, even in nature conservation reserves, with changing patch sizes and spatial arrangements of different forest types.
- The cessation of broadscale clearing in much of Australia and increased protection of forests have been critical in reducing forest fragmentation in recent times.

Species diversity

- The number of known forest-dwelling species increased from 1998 to 2006, reflecting improved information. Partial ecological information is available on around 60% of forest-dwelling vertebrate and vascular plant species and comprehensive ecological information is available on at least 10% of mammal, bird and amphibian species, but very limited information is available on forest-dwelling invertebrates, fungi, algae and lichens.
- A total of 1,287 forest-dwelling species are listed under the national *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act) as vulnerable, endangered or threatened. Thirty-nine species or subspecies were removed from the list during the reporting period, and 67 were added.
- Most additions of forest-dwelling species to the national list of threatened species were made based on inherently small population sizes and ongoing impacts on habitat extent and quality, including the impacts of introduced species and unsuitable fire regimes. Most removals of forest-dwelling species from the list were made as a result of improved information.
- Birds are the taxonomic group with the largest number of programs in place to track population trends. State and territory efforts are supplemented by a large-scale investment by non-government groups.
- The lack of comprehensive knowledge on the occurrence of representative species across land tenures and broad forest types limits the conclusions that can be drawn from available data.

Genetic diversity

- While the number of forest-associated species for which data on genetic variation are available is still very small, it has increased since SOFR 2003. Then, data were available for one faunal and two floral species; now, data are available for more than 10 faunal and 13 floral species.
- Several studies have documented genetic variation and distribution patterns within existing populations of a relatively small number of forest-associated species. Several institutions have programs to measure genetic diversity in forest fauna, but nationally conclusive results are available for only a few species.
- Conservation measures focus on increasing connectivity between isolated patches of native vegetation, increasing the area of forest contained in public and private nature conservation reserves, managing threats to native species, and assisting the recovery of threatened species.
- Genetic resource conservation plans exist for more than 40 native timber and oil-producing plant species, a 70% increase on the number reported in SOFR 2003. The increase includes species used in farm forestry in drier environments.
- Tree-breeding and genetic improvement programs are expanding the scope for conserving native forest genetic resources, including non-commercial endangered species.

Selective harvesting in multiple-use public forest.

Indicator 1.1a

Area of forest by forest type and tenure

Rationale

This indicator uses the area of each forest type over time as a broad measure of the extent to which forest ecosystems and their diversity are being maintained. Reporting on forest tenure aids our understanding of how different land management regimes may affect forest biodiversity.

Key points

- Australia has 149 million hectares of forest. Of this, 147 million hectares is native forest, dominated by eucalypt (79%) and acacia (7%) forest types. There are 1.82 million hectares of plantations, mostly comprising 1.0 million hectares of pine (softwood) and 0.81 million hectares of eucalypt (hardwood).
- Australia's ability to estimate its forest extent continues to improve with the increasing availability of high-resolution, remotely sensed data and improvements in forest typing methods. This largely explains the revision of estimated total forest area from 164 million hectares in 2003 to 149 million hectares reported here; little of the change is due to real forest loss.
- The area of native forest in formal nature conservation reserves increased by about 1.5 million hectares to 23 million hectares over the reporting period, from 13% to 16% of Australia's native forests. The area of multiple-use public native forests (in which wood production is an objective) declined from 11.4 million to 9.4 million hectares.
- Seventy per cent of the total forest estate is privately managed, including private freehold, leasehold and Indigenous-managed lands.
- The net loss of woody vegetation (mostly forest) estimated by the AGO was 260,000 hectares (0.25%) per year between 2000 and 2004, due mainly to clearing for agriculture and urban development. The rate of loss of woody vegetation is declining in response to changed land-management practices and increased legislative controls.
- Australia's plantation area increased to 1.82 million hectares over the period, up 12% from the 1.63 million hectares in 2003.

Australia has 149 million hectares of forest,[1] which is 19% of the total land area. Of this, 147 million hectares is native forest, which is dominated by eucalypt (79%) and acacia (7%) forest types. There are also 1.0 million hectares of pine plantations (softwood) and 0.81 million hectares of eucalypt plantations (hardwood). The total forest area reported here is significantly different from that reported in SOFR 2003, mainly due to improved data resolution and better forest typing.

Forest types

The vast majority of Australia's native forest area is evergreen broadleaf. In general, and with the notable exception of mallee, forest distribution today is confined mainly to regions where average rainfall exceeds 500 millimetres per year. Most forests are in the northern, eastern and southwestern coastal zones, although woodland forests extend into drier areas in several parts of the country. With an estimated 4% of the world's forests, Australia has the world's sixth-largest forest estate and the fourth-largest area of forest in nature conservation reserves.

The eucalypt forest type (comprising the genera *Eucalyptus*, *Corymbia* and *Angophora*) is dominant across most of the country's forest area. The second most important forest type is acacia. Despite the overwhelming dominance of these two types, Australia's forests are very diverse. There are more than 700 species of eucalypts and almost 1,000 *Acacia*

1 Using the definition of forest given in the introduction to this report.

Warm temperate rainforest.

species, as well as many other genera of trees, in a rich array of ecosystems that vary in their floristic composition, their structure and the fauna they support. Rainforests are particularly rich in floral and faunal biodiversity, even though they cover only 2% of the forest area.

For national reporting, forests are grouped into eight native forest types defined by dominant species and structure (Table 1). The first seven are eucalypt (divided into eleven subtypes), acacia, melaleuca, rainforest, casuarina, mangrove and callitris. The eighth group ('other') comprises forest types with relatively small total areas. Plantation forests are treated in two subcategories: hardwood and softwood. Figure 2 shows the distribution of these forest types across the continent and Table 2 shows it by jurisdiction.

Table 3 shows the percentage of total land area forested, by jurisdiction. Queensland has the largest area of forest (35% of the total), about half of which is classified as eucalypt medium woodland. The Northern Territory has about 20% of the forest estate, mostly low and medium eucalypt woodland and medium open eucalypt forest. Queensland and the Northern Territory also contain almost all (98%) of the melaleuca forest. About 18% of the total forest area is in New South Wales, including about 16 million hectares of tall and medium open forest. Tasmania has only 2% of Australia's forest estate.

Australia's plantation area expanded over the period. In 2006, it covered 1.82 million hectares, up 12% from 1.63 million hectares in 2003. Despite the increase, plantations account for only about 1% of the total forest area.

Further information describing Australia's forest types is provided in the Australian Forest Profile series.[2]

Table 1: Australia's forest area, by forest type

Forest type		Total ('000 ha)	% of total
Native forest	Acacia	10,365	7
	Callitris	2,597	2
	Casuarina	2,229	1
	Eucalypt	116,449	78
	Eucalypt low closed[a]	44	0.03
	Eucalypt low open	2,648	2
	Eucalypt low woodland	13,423	9
	Eucalypt mallee open	376	0.3
	Eucalypt mallee woodland	8,871	6
	Eucalypt medium closed[a]	254	0.2
	Eucalypt medium open	28,145	19
	Eucalypt medium woodland	56,187	38
	Eucalypt tall closed	123	0.1
	Eucalypt tall open	5,881	4
	Eucalypt tall woodland	497	0.3
	Mangrove	980	1
	Melaleuca	7,556	5
	Rainforest	3,280	2
	Other	3,942	3
Native forest total		*147,397*	*99*
Plantation[b]		1,818	1
Australian forest total		149,215	100

a New categories.

b Comprises both hardwood and softwood plantations. Plantation area as at 2006 from Parsons and Garvan (2007). May differ from state/territory estimates.

Note: Totals may not tally due to rounding.

Sources: NFI, National Plantation Inventory.

Young pine (*Pinus radiata*) (background) and bluegum (*Eucalyptus globulus*) plantations.

2 Compiled by the Bureau of Rural Sciences and available at www.daff.gov.au/forestsaustralia

Figure 2: Forest types and extent

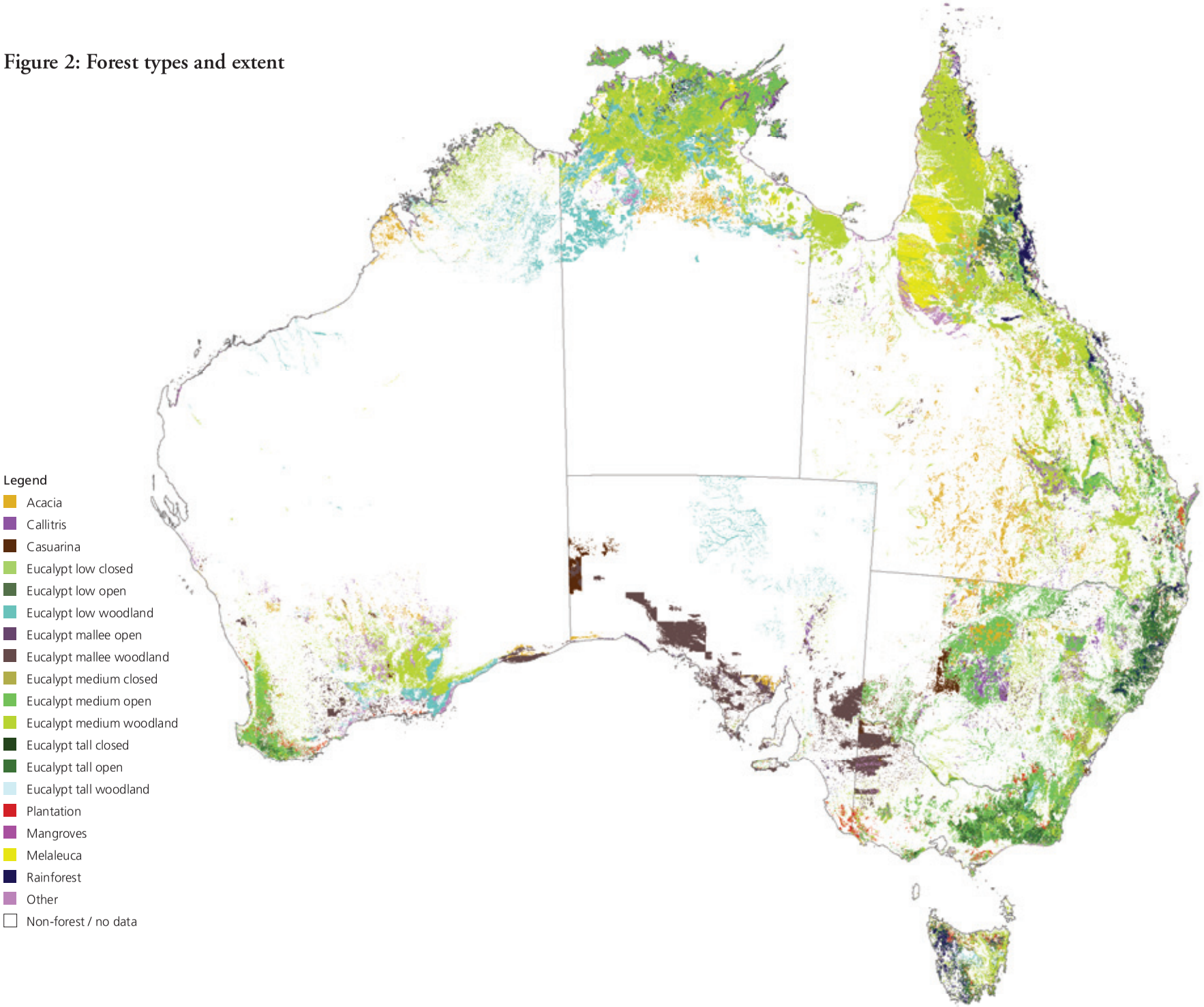
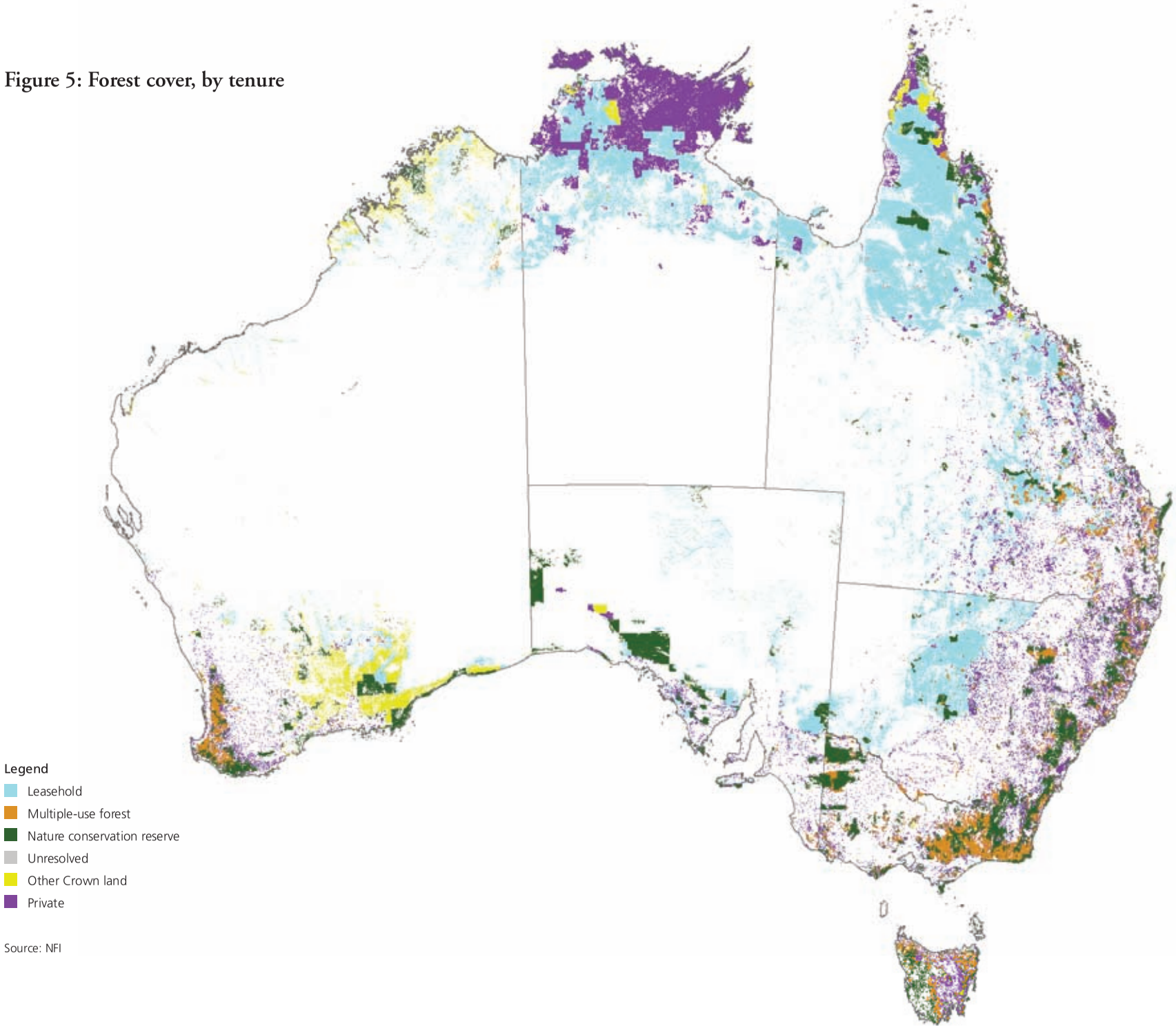


Figure 5: Forest cover, by tenure



Source: NFI

Table 2: Forest area, by forest type and jurisdiction ('000 hectares)

	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Australia
Acacia	–	1,333	1,496	6,060	239	72	41	1,123	10,365
Callitris	–	1,540	315	597	118	1	25	1	2,597
Casuarina	–	1,168	114	61	671	1	131	82	2,229
Eucalypt	116	21,147	26,389	36,466	7,792	2,430	7,281	14,827	116,449
Eucalypt low closed[a]	–	–	11	10	–	–	14	8	44
Eucalypt low open	4	31	592	1,739	8	–	70	204	2,648
Eucalypt low woodland	3	258	7,573	655	1,171	65	21	3,676	13,423
Eucalypt mallee open	–	53	–	–	318	–	–	5	376
Eucalypt mallee woodland	–	157	–	60	5,938	–	1,504	1,212	8,871
Eucalypt medium closed[a]	–	10	73	32	–	–	97	42	254
Eucalypt medium open	63	12,920	5,499	4,733	9	7	3,005	1,909	28,145
Eucalypt medium woodland	18	4,298	12,641	29,060	347	1,257	1,008	7,557	56,187
Eucalypt tall closed	–	–	–	–	–	–	117	6	123
Eucalypt tall open	28	3,319	–	156	–	814	1,372	193	5,881
Eucalypt tall woodland	–	102	–	21	–	287	73	14	497
Mangrove	–	5	359	436	14	–	2	164	980
Melaleuca	–	48	1,690	5,698	14	19	24	62	7,556
Rainforest	–	495	302	1,867	–	593	18	5	3,280
Other	7	473	344	1,397	7	–	314	1,400	3,942
Total native forest	*123*	*26,208*	*31,010*	*52,582*	*8,855*	*3,116*	*7,838*	*17,664*	*147,397*
Hardwood plantation	–	63	23	43	48	174	175	281	807
Softwood plantation	10	280	2	188	124	74	219	105	1,001
Mixed or unknown plantation	–	3	–	2	–	–	1	2	9
Total plantation[b]	*10*	*345*	*26*	*233*	*172*	*248*	*396*	*389*	*1,818*
Total forest 2007	132	26,554	31,035	52,815	9,027	3,364	8,234	18,053	149,215
% forested[c]	54	33	23	31	9	49	36	7	19

a New categories.

b Plantation areas as at 2006 from Parsons and Gavran (2007). May differ from state/territory estimates.

c Based on total land areas from ABS (2006a).

Note: Native forest data sourced from tables and forest type mapping provided by states and territories, nominally for data available as at June 2006. The date of mapping is earlier and may be different for some states or parts within a state (e.g. Queensland data are as at September 2003 and Tasmanian data are as at July 2005). Totals may not tally due to rounding.

Source: NFI

Table 3: Forest as a percentage of land area, by jurisdiction

	Native forest area[a] ('000 ha)	Plantation area[b] ('000 ha)	Total land area[c] ('000 ha)	Forest as % of jurisdiction	% of Australia's forest
ACT	123	10	243	54	<1
NSW	26,208	345	80,064	33	18
NT	31,010	26	134,913	23	21
Qld	52,582	233	173,065	31	35
SA	8,855	172	98,348	9	6
Tas.	3,116	248	6,840	49	2
Vic.	7,838	396	22,742	36	5
WA	17,664	389	252,988	7	12
Total	147,397	1,818	769,202	19	100

Sources:

a NFI

b Parsons and Gavran (2007)

c ABS (2006a)

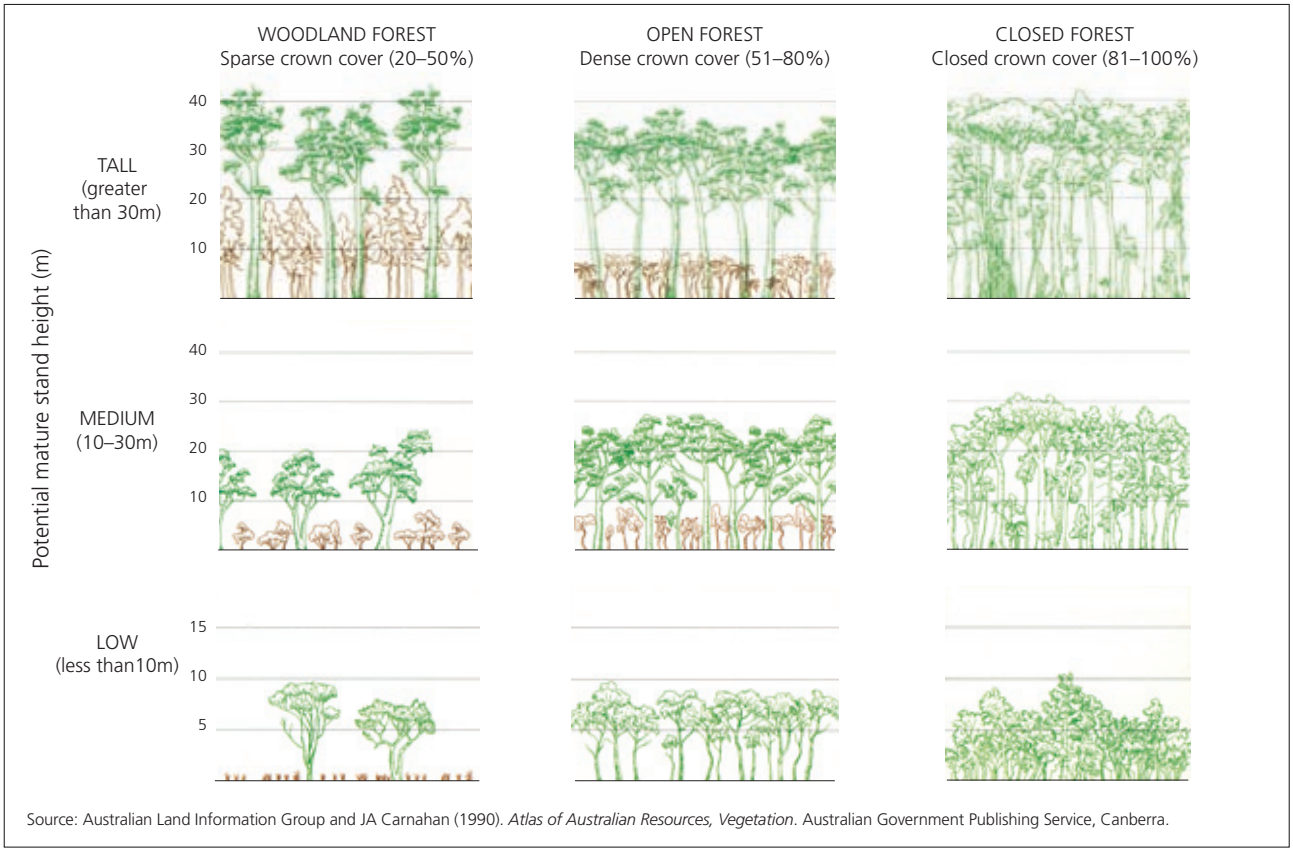
Note: Totals may not tally due to rounding.

Crown cover

Australia's native forests are classified into three crown cover classes – woodland, open and closed – and three height classes – low, medium and tall (Figure 3). Table 4 shows the area of each native forest type by crown cover class, and Figure 4 shows the spatial distribution of the classes across the continent. Table 5 shows the area of native forest in each crown cover class by state and territory. Forest type and cover are reasonably well mapped, but forest height is not well measured outside forests in which timber is harvested.

The distribution of the three crown cover classes varies across the states and territories depending on climate, soil type and land use; it is often related to the soil moisture regime, declining with lower water availability. Almost 100 million hectares, or two-thirds of the native forest estate, is classified as woodland and almost one-third as open forest. Production forestry occurs almost exclusively in the tall, denser forest types within regional forest agreement (RFA)

Figure 3: Crown cover and height classes



Source: Australian Land Information Group and JA Carnahan (1990). *Atlas of Australian Resources, Vegetation*. Australian Government Publishing Service, Canberra.

areas; lower, more open forests are often used for livestock grazing. The crown cover map created for this report has been improved by using data from the National Vegetation Information System to fill in data gaps for almost 10 million hectares of forest in Queensland and New South Wales that were classed as unknown crown cover in SOFR 2003.

Tenure

Forest ownership is reported in six tenure classes summarising the wide range of classes used by various jurisdictions (see Introduction). About 70% of Australia's forests is effectively under private management, with 44% on leasehold land and another 26% on land either held under freehold private title or managed by Indigenous communities (Table 6, Figure 5 – fold out map on the back of Figure 2). Leasehold land accounts for 65.1 million hectares of forest, about half of which is in Queensland; the Northern Territory and New South Wales also have significant areas of leasehold forest. More than 80% of forest classified as private is in Queensland, New South Wales or the Northern Territory, which includes large areas managed by Indigenous people.

Sixteen per cent of Australia's forest is now formally protected in public nature conservation reserves, a significant increase over the area reported in SOFR 2003 (see Indicator 1.1c). Multiple-use public forests, where timber harvesting is generally permitted, cover 9.43 million hectares, or about 6% of Australia's total native forest estate, down from 11.4 million hectares in SOFR 2003.

Table 4: Area of forest type, by crown cover class ('000 hectares)

Forest type	Woodland	Open	Closed	Australia
Acacia	7,059	3,306	–	10,365
Callitris	803	1,793	–	2,597
Casuarina	2,082	191	–	2,274
Eucalypt	79,878	37,050	421	117,349
Eucalypt low closed	–	–	43	43
Eucalypt low open	–	2,641	–	2,641
Eucalypt low woodland	13,427	–	–	13,427
Eucalypt mallee open	–	376	–	376
Eucalypt mallee woodland	8,869	–	–	8,869
Eucalypt medium closed	–	–	251	251
Eucalypt medium open	–	28,107	–	28,107
Eucalypt medium woodland	56,279	–	–	56,279
Eucalypt tall closed	–	–	119	119
Eucalypt tall open	–	5,803	–	5,803
Eucalypt tall woodland	494	–	–	494
Mangrove	99	331	552	980
Melaleuca	6,654	878	26	7,556
Rainforest	–	–	3,280	3,280
Other	3,240	693	–	3,942
Total	99,007	44,120	4,270	147,397

Note: Totals may not tally due to rounding.

Source: NFI

Figure 4: Native forest, by crown cover class

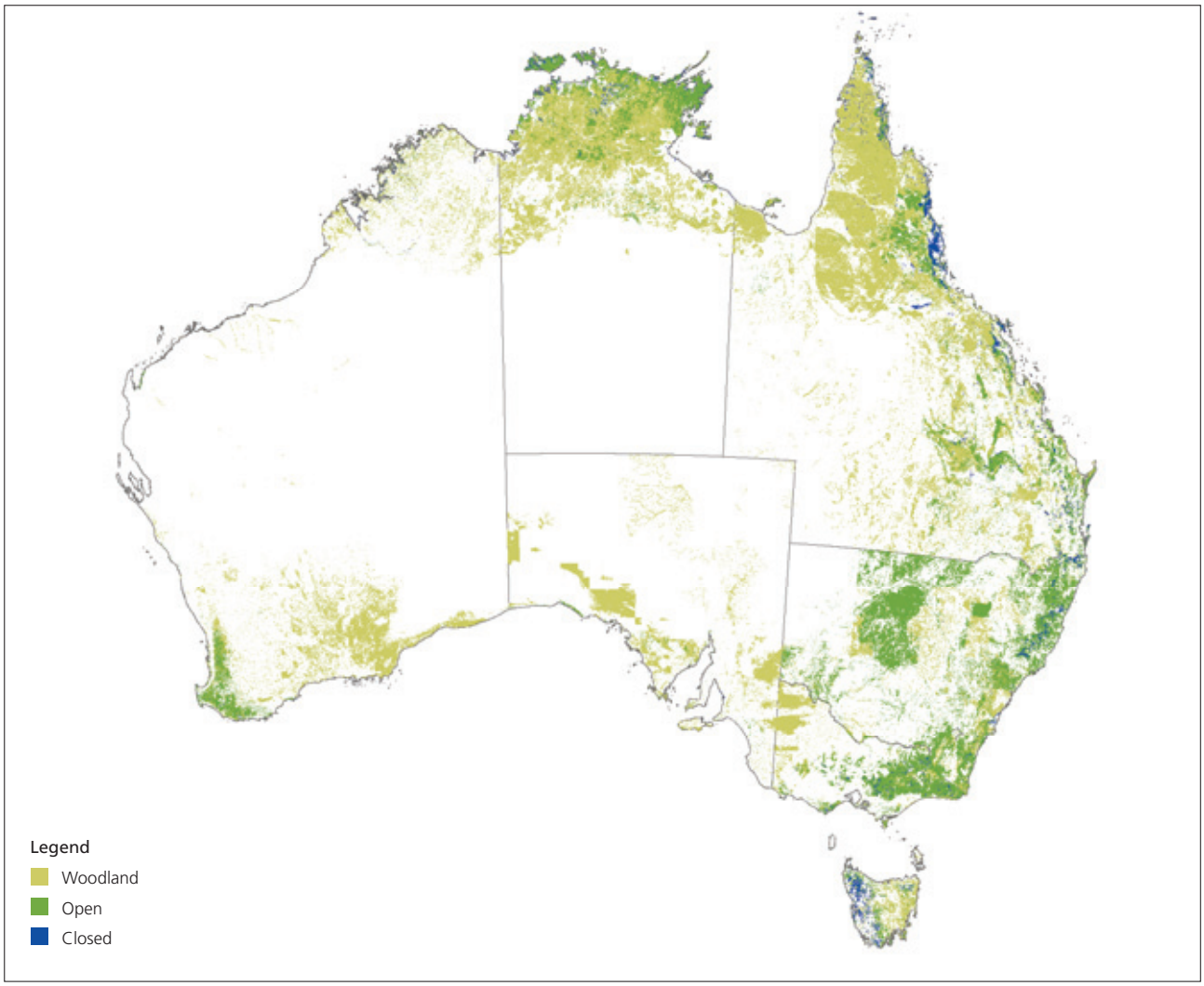


Table 5: Area of native forest, by crown cover class and state and territory ('000 hectares)

	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Australia	%
Woodland	37	6,480	22,905	41,172	8,494	1,610	3,177	15,130	99,007	67
Open	86	19,223	7,439	9,310	357	894	4,419	2,393	44,120	30
Closed	0	505	666	2,100	4	611	242	141	4,270	3
Total native forest	123	26,208	31,010	52,582	8,855	3,116	7,838	17,664	147,397	100

Note: Totals may not tally due to rounding.

Source: NFI

There are notable differences in the ownership of different forest types. The drier, sparse woodland forests make up almost 100 million hectares, half on leasehold land and another quarter on private land. The open forest types are distributed more or less evenly between public and private owners in most jurisdictions, while closed forests, comprising rainforest and mangroves, are mostly in public ownership.

Changes in forest mapping

The process used to collect data on forest extent for this and the previous two national reports (SOFR 1998 and SOFR 2003) involves the collation by Australia's National Forest Inventory (NFI) of forest-type maps produced by each state and territory. SOFR 2003 noted that imperfections in the process – such as the collection of data using different methods and at different scales – were the main reason for an apparent increase in forest area of about 7 million hectares between the 1998 and 2003 reports. Although the process used in compiling data for this 2008 report was similar to that used in 2003, the overall quality of the data

Table 6: Area of forest, by tenure and jurisdiction ('000 hectares)

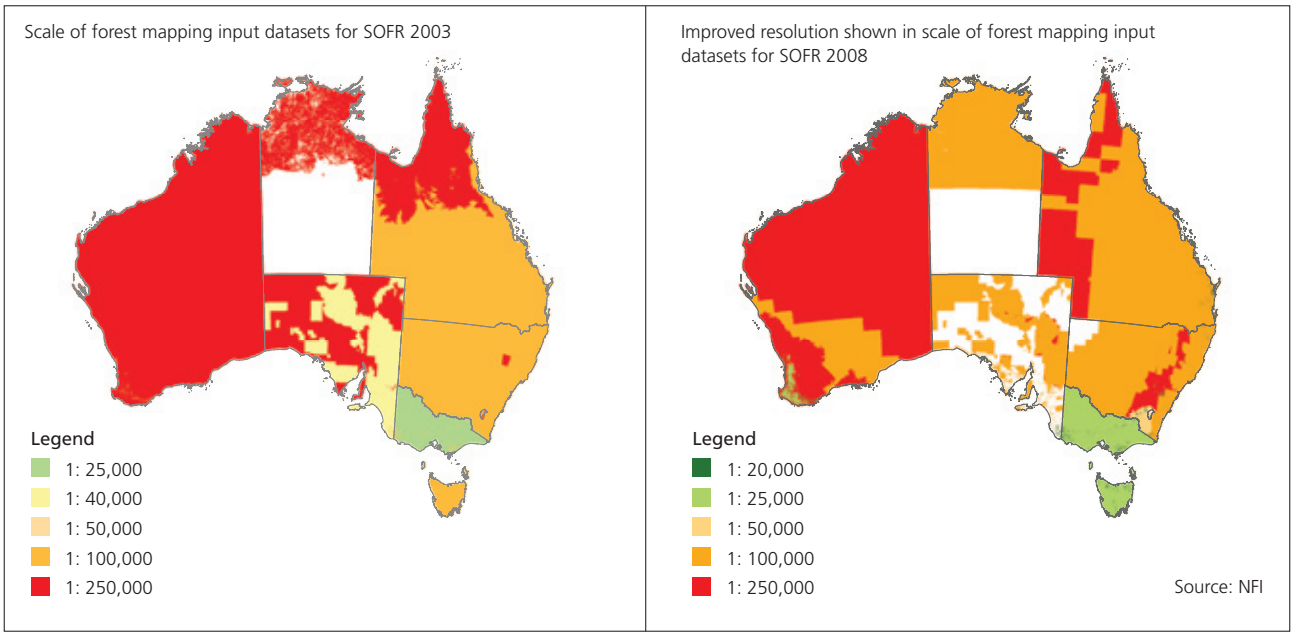
	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Australia	Tenure category as % of total native forest area
Leasehold forest	8	9,891	13,920	34,304	3,083	0	35	3,891	65,132	44
Multiple-use public forest	0	1,980	0	1,991	0	1,026	3,163	1,248	9,410	6
Nature conservation reserve	108	5,148	16	4,576	4,029	1,121	3,505	3,868	22,371	15
Other Crown land	7	943	674	1,598	277	85	109	7,169	10,862	7
Private land (including Indigenous)	0	8,076	16,317	8,908	1,399	885	1,025	1,489	38,099	26
Unresolved tenure	0	170	83	1,204	67	0	0	0	1,524	1
Total native forest	*123*	*26,208*	*31,010*	*52,581*	*8,855*	*3,116*	*7,837*	*17,665*	*147,397*	*99*
Plantations – all tenures[a]	10	345	26	233	172	248	396	389	1,818	1
Total forest	133	26,553	31,036	52,814	9,027	3,364	8,233	18,054	149,215	100

a The National Plantation Inventory classifies plantations by ownership classes that recognise land ownership, tree ownership and joint ownership. These cannot be aggregated into the tenure classes used for native forest.

Note: Totals may not tally due to rounding.

Sources: NFI, Parsons and Gavran (2007)

Figure 6: Improvements in national forest mapping 2003–08



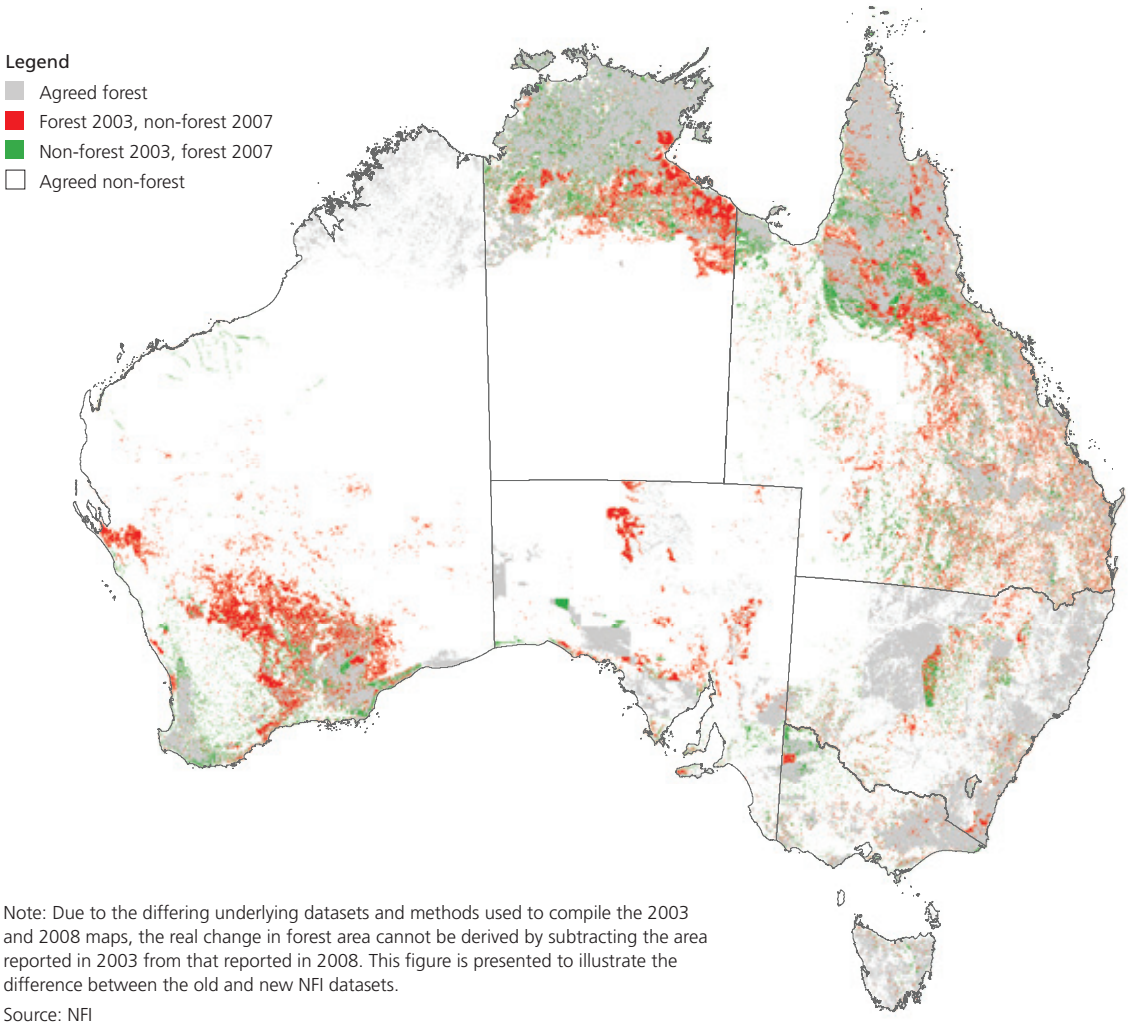
is much improved, due largely to increases in the resolution of remote sensing imagery. Figure 6 shows the distribution of the scale of data collection in SOFR 2003 and SOFR 2008.

One effect of improving data resolution is a reduction in the total apparent forest area, since it is now possible to detect small gaps in forest cover in areas that were previously treated as contiguous patches of forest. In contrast, some forest areas that were previously unknown have been detected using these high-resolution data (Figures 2, 5 and 6).

Many new or updated datasets – obtained mostly between 2004 and 2006 – were used in compiling SOFR 2008. The improvements in scale and currency of the data mean that the quality of mapping presented in this report is significantly improved from that in SOFR 2003. However, because of the different underlying datasets and methods used to compile the maps, the real change in forest area cannot be derived by subtracting the area reported in 2003 from that reported in 2008 (Figure 7). Most of the differences in forest cover between the two reports is due to new classifications of areas as shrublands or other non-forest vegetation.

The total native forest area is now considered to be more accurately estimated at slightly greater than 147 million hectares, compared to just less than 163 million hectares reported in SOFR 2003. Most of this change is due to changes in methodology and data resolution, rather than to a real change in forest cover. Data from other sources (see 'Changes in land cover') suggest that total native forest area is indeed declining, due largely to the clearing of open woodland forests for grazing and cropping, but by a much smaller amount.

Figure 7: Differences between national forest mapping in SOFR 2003 and SOFR 2008



Note: Due to the differing underlying datasets and methods used to compile the 2003 and 2008 maps, the real change in forest area cannot be derived by subtracting the area reported in 2003 from that reported in 2008. This figure is presented to illustrate the difference between the old and new NFI datasets.

Source: NFI

Almost half the national change in mapping is in Western Australia (mostly in the dry inland Goldfields region – Case study 1), which explains around 7.5 million hectares of the 15 million-hectare difference in forest extent between SOFR 2003 and SOFR 2008. Queensland accounts for another quarter of the change (some of which is due to land clearing – Case study 2). The Northern Territory and South Australia, combined, make up the remaining change, due mostly to changes in mapping rather than real forest conversion. New South Wales recorded little change in forest area; in its case, the underlying datasets have not been significantly updated. Victoria, Tasmania and the Australian Capital Territory have very stable mapped forest areas and together make up less than 1% of the total difference between 2003 and 2008.

Changes in land cover

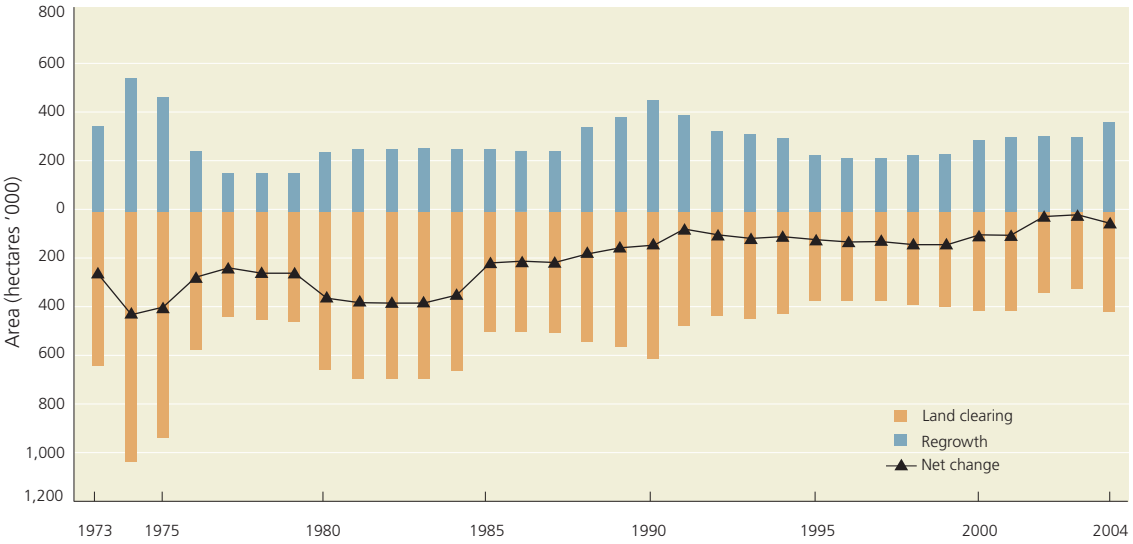
For various reasons (see earlier and box on page 14), the estimate of total forest extent presented here cannot be compared directly with those from SOFR 1998 and SOFR 2003 to determine the overall real change in forest cover over the periods covered by SOFRs. The 2006 Australian State of the Environment report discussed the net change in woody vegetation based on the AGO National Carbon Accounting System (NCAS – box on page 14 and Indicator 5.1a). The estimate of total woody vegetation cover derived by the NCAS methodology (108 million hectares) differs considerably from the estimate of total forest cover presented in this report. According to the NCAS, a net area of about 1 million hectares of woody vegetation (clearing minus regrowth) was cleared in Australia between 2000 and 2004, an average annual loss of about 260,000 hectares, or 0.25% of total woody vegetation.

A large part of this loss occurred in Queensland, due largely to the expansion of agriculture and urban development, although there is evidence that the rate of forest clearing is declining in that state (Case study 2). The net loss of woody vegetation (mostly forest) declined Australia-wide between 1973 and 2004 (Figure 8).

References and further reading

ABS (2006a), Accad et al (2006), AGO (2002), ASEC (2006), DNRM (2005), Kuhnell et al (1998), NFI (2007), Parsons and Gavran (2007) (list at the back of the report).

Figure 8: Net loss of woody vegetation (mostly forest), 1973 to 2004



Source: Adapted from ASEC (2006)

Case study 1: Changes in forest mapping in the Western Australian goldfields

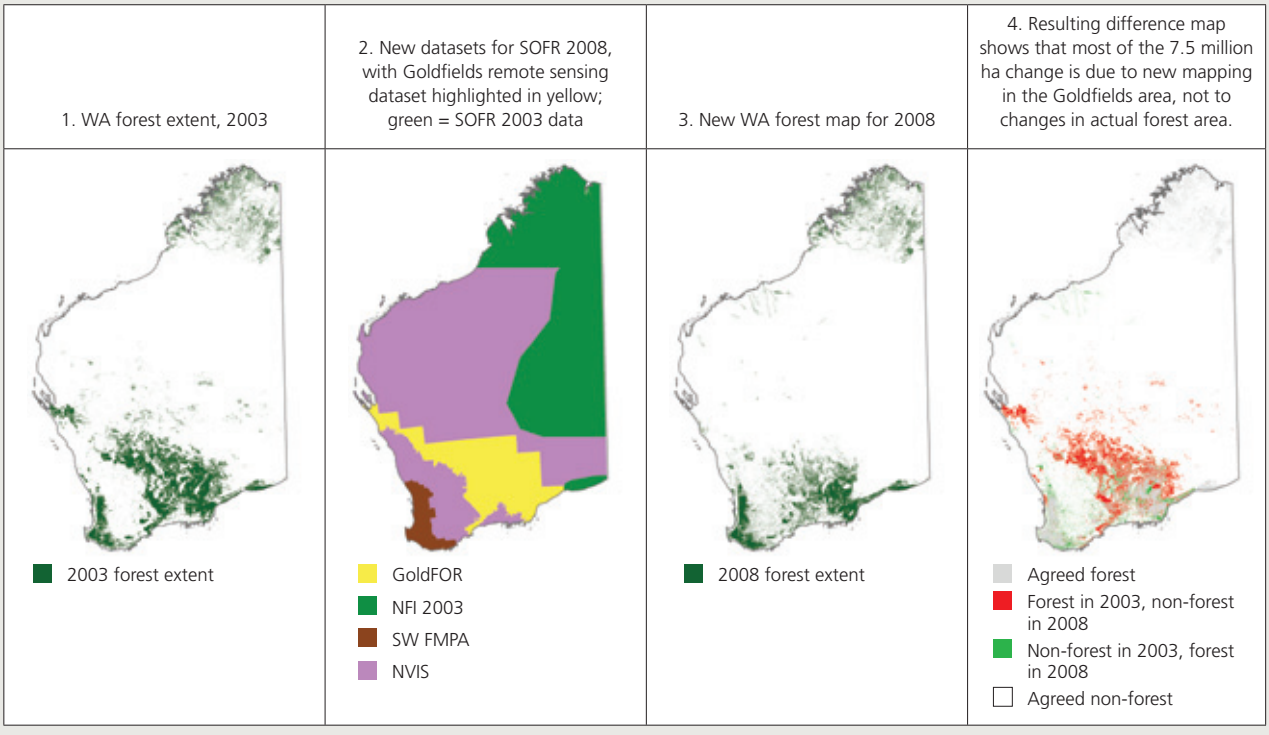
Approximately half of the 15 million-hectare difference in total forest extent between SOFR 2003 and SOFR 2008 can be attributed to changes in mapping across Western Australia, particularly in the Goldfields region.

Datasets used for SOFR 2008 are based on remote sensing data of higher resolution than previous spatial data available for the Southwest, Midwest, Goldfields and South Coast regions of Western Australia. This has enabled more accurate detection of forest cover in sparse woodland areas and resulted in the reclassification as shrublands of many areas that were previously recorded as forests.

Higher resolution data also improved the definition of forest boundaries and the identification of gaps in forest cover (Figure 9). As a consequence, the area mapped as forest in those regions, mostly the Goldfields region, has been reduced by 7.5 million hectares compared to the area reported in SOFR 2003.

Source: Department of Environment and Conservation (WA)

Figure 9: Differences in forest mapping for Western Australian goldfields, SOFR 2003 and SOFR 2008



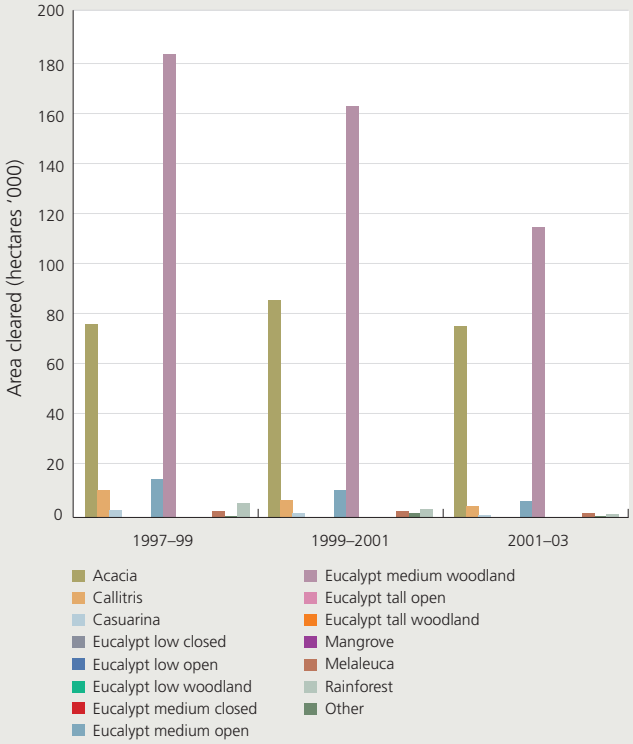
Case study 2: Forest clearing for agriculture in Queensland

The state of Queensland monitors the rate of change of woody vegetation cover and remnant native vegetation ecosystems. Figure 10 presents data from the regional ecosystem mapping program on the clearing of remnant vegetation over time in Queensland, by forest type. A total of just over 1.5 million hectares of forest was cleared over the period from 1999 to 2003, the rate declining from nearly 300,000 hectares per year in 1997–99 to around 200,000 hectares per year in 2001–03. Almost all (94%) of this clearing was in the drier open acacia and eucalypt medium woodland forest types (Figures 10 and 11), where forest was replaced by pasture for grazing or by other agricultural land uses. Clearing in most other forest types was much less or negligible.

The Queensland Government introduced a range of measures designed to phase out the broadscale clearing of remnant native vegetation in the state by the end of 2006 (Indicator 7.1a).

Sources: Accad et al (2006), DNRM (2005), Kuhnell et al (1998)

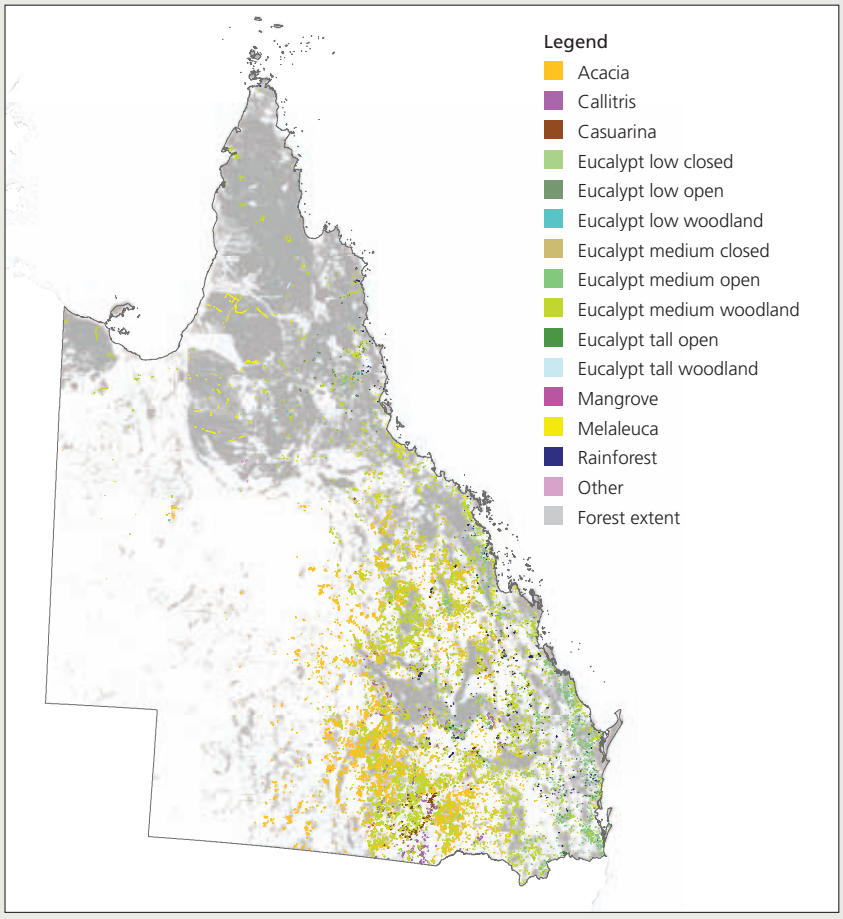
Figure 10: Forest clearing in Queensland, 1997–99 to 2001–03, by forest type



Note: Queensland regional ecosystem types have been converted to SOFR forest types.

Source: Data adapted from Accad et al (2006)

Figure 11: Extent and type of forest cleared in Queensland, 2003 to 2007



Differences between state and national forest mapping for SOFR 2008 and National Carbon Accounting System estimate of woody vegetation

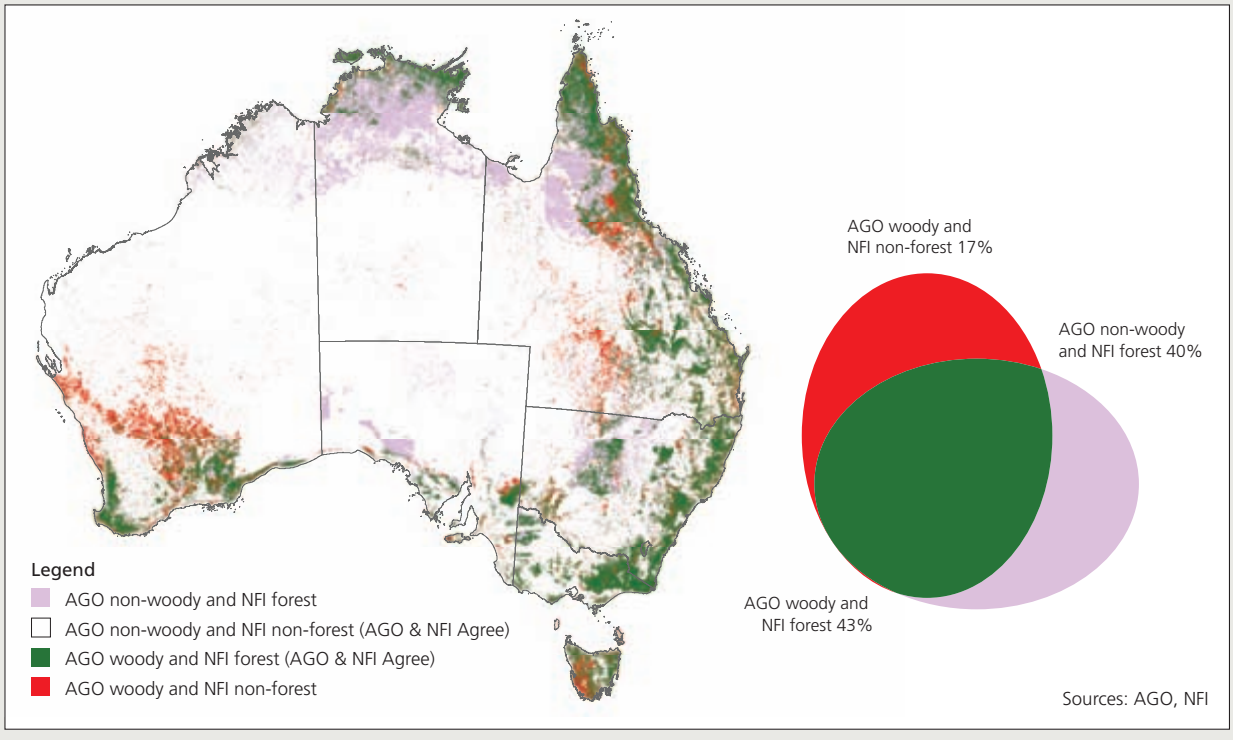
Each state and territory has its own method and sources of data for mapping and reporting on forest type and extent. The methods and data sources aim for a reliable, cost-effective estimate of forest type and cover appropriate to the needs of the jurisdiction. Historically, many jurisdictions have used aerial photography for developing forest-type maps combined with field validation, but satellite imagery of various time periods, scales and sources is increasingly used.

The NFI builds the national forest-cover map by compiling state and territory forest mapping information using eight agreed broad national forest types (including eucalypts with 11 subtypes). This map and its associated data are the accepted national data agreed by the Australian Government and the states and territories to be used for national and international reporting on Australia's forests. The NFI forest data incorporate the best available forest typing, floristic and structural information to make sure that vegetation counted as forest meets the national forest definition.

The AGO developed the National Carbon Accounting System (NCAS) for the purposes of reporting on Australia's carbon emissions. One part of the NCAS is a time-series of national woody-cover data layers based on Landsat satellite imagery from 1972 to the present; the primary end use of the final data is to determine vegetation cover change for the purpose of estimating net greenhouse gas emissions over time. The estimate of total woody vegetation cover derived by NCAS was 108 million hectares for 2005, which is considerably lower than the 149 million hectares total forest cover estimated in this report due to the different methodology used to compile the data. Neither dataset is right or wrong; both have been developed for and are best suited to specific purposes – the AGO dataset for tracking changes in woody cover and the NFI forest data, which include information on forest type, structure, height and extent, for reporting on a broader range of indicators for SOFR, including biodiversity and conservation values.

The NFI forest layer, which is used to report on total forest extent, overlaps the AGO NCAS woody-cover dataset on about half the NFI area (Figure 12). For dense forests, such as eucalypt tall open, eucalypt tall woodland and rainforest, there is a greater than 90% overlap; for softwood plantations there is a greater than 70% overlap. Some NFI forest types – particularly the open, drier forests across northern Australia, such as acacia, melaleuca, eucalypt medium woodland and eucalypt low woodland – are not well represented (<30% overlap) in the NCAS layer. The NCAS data also include dense woody vegetation that may have significant biomass but is not counted as forest in the NFI data. The AGO is currently developing a sparse woody vegetation layer that is expected to be larger in extent than the current NCAS dataset.

Figure 12: Differences between national forest mapping for SOFR 2008 and National Carbon Accounting System estimate of woody vegetation



Indicator 1.1b

Area of forest by growth stage

Rationale

This indicator measures the change in area of forest by growth stage to reflect how ecological processes and species associated with those processes change as forests grow. The age and size of trees are important in maintaining forest biodiversity.

Key points

- The growth stage of a forest provides an indication of its biodiversity and ecological values. Some growth stages, such as old-growth, provide specific habitat for particular species, wood products and a range of aesthetic and cultural values.
- Of the 23 million hectares of forest assessed for old-growth, 5.03 million hectares (22%) is classified as old-growth. This is about 200,000 hectares less than that reported in 2003 (5.23 million hectares); the difference is due mainly to the impact of severe fires, with younger forests replacing some areas of old-growth, and also to some remapping.
- Over 73% of known old-growth forests is now within formal or informal nature conservation reserves.
- Fire and disease represent the most significant threats to large areas of old-growth forests across all tenures. Logging is also a contentious issue, and several states have developed policies for the exclusion of harvesting from old-growth or for altered management prescriptions to reduce impacts.

Forests are dynamic ecosystems that go through stages of development following disturbances such as fire, storms and timber harvesting. Growth stage is an indicator of biodiversity in native forests[3] and also gives some indication of the balance of different age classes across the forest estate. The sustainable production of wood and the maintenance of values such as species diversity are often enhanced by a mix of areas in different age classes and a mosaic of growth stages.

The states and territories have developed various methods for describing forest growth stages or age classes. Four main growth stages in native forests can be identified: regeneration (less than 20 years since disturbance); regrowth (20–80 years); mature (80 or more years); and senescent (irregular crown form due to age) (Figure 13). These four categories work reasonably well for many eucalypt forests, which are often evenly aged. Substantial areas of forests are mixtures of one or more growth stages, especially forests dominated by other species.

Old-growth forests are of particular interest to the community for their habitat, conservation and aesthetic values, many of which are not found in forests in other stages of growth. However, old-growth is not a distinct growth stage; rather, it is a term that encompasses forest in the mature and senescent growth stages that has received minimal recent disturbance. The National Forest Policy Statement defines old-growth forest as:

> *… forest that is ecologically mature and has been subjected to negligible unnatural disturbance such as logging, roading and clearing. The definition focuses on forest in which the upper stratum or overstorey is in the late mature to over-mature growth phases.*[4]

The National Forest Policy Statement gives high priority to the protection of old-growth forests, with specific provisions to protect more than 60% of identified areas. This target was intended to be applied flexibly to include representative

3 Plantation growth stages are reported by Parsons et al (2007a).

4 Commonwealth of Australia (1992).

Figure 13: Classification of growth stages in native forests

Regeneration	Includes juvenile and sapling stages, when trees are very small and crowns exhibit apical dominance. (Apical dominance is where the main central stem of the tree is growing more strongly than the side branches).
Regrowth	Trees have well-developed stems with crowns of small branches but below mature stand height. Apical dominance apparent in vigorous trees.
Mature	Trees are at maximum height and crowns at full lateral development. Branch thickening can occur.
Senescent	Crowns are contracting and crown diameter and crown leaf area are decreasing.

examples of old-growth forest across the range, to ensure that high-quality habitat areas are included, and to take in the largest and least fragmented areas. To help achieve the National Forest Policy Statement target, national criteria were established for the conservation of old-growth forests in what is known as the JANIS report,[5] using a modified definition of old-growth:

> *Ecologically mature forest where the effects of disturbances are now negligible.*

Different jurisdictions use slight variations of this definition,[6] but all use the basic concept of identifying mature forest areas that have negligible disturbance. Old-growth forests generally have a layered structure, with large overstorey trees, a well-developed understorey of other tree species and shrubs, and ecological features such as dead standing trees and large logs on the forest floor. A number of wildlife species are reliant on these attributes because of the range of nesting hollows they provide and their greater structural complexity compared to forests in earlier stages of development. In addition, old-growth forests support a range of aesthetic and cultural values and provide tourism opportunities.

Mapping old-growth forests requires knowledge of both the growth stage and the disturbance history of the forest. The latter is often not well known and has to be interpreted from other information, such as the structure of the forest, and evidence of disturbance, such as tracks, stumps and fire scars. Some of these can be identified using aerial photographs, but in many cases expensive and labour-intensive on-the-ground inspection is required. Therefore, only a relatively small area of Australia's forests (mostly tall, wet forests) has been assessed for old-growth values. Old-growth forests are usually identified in patches larger than 2–3 hectares.

Other growth stages, such as regrowth (where the forest is younger and the trees are actively growing) are also important for habitat and conservation. Some wildlife species require more than one growth stage for their survival; for example, Leadbeater's possum (*Gymnobelideus leadbeateri*) requires one growth stage for nesting and another for feeding. Therefore, it is often important that a landscape includes a mosaic of growth stages.

The total area for which the growth stage of the forest is known is almost 15.4 million hectares, or 10% of Australia's 147 million-hectare native forest estate (Table 7). Growth stages are best known for multiple-use public forests used for wood production, as the mapping of growth stages in such forests is important for forest resource assessments. The largest gaps in the data are on private, leasehold and other Crown land tenures. Growth stage information is available for:

- 74% of forests in Tasmania
- 67% of forests in Victoria (mostly public land and some private)
- 21% of forests in New South Wales (comprising all public and private forests in the regional forest agreement regions)
- 11% of forests in Western Australia (all public forest land in the Southwest Forest Management Plan area)
- 1% of forests in Queensland.

5 Joint Australian and New Zealand Environment Conservation Council/ Ministerial Council on Forestry, Fisheries and Aquaculture National Forest Policy Statement Implementation Sub-committee (JANIS 1997).

6 See Keenan and Ryan (2004).

Table 7: Area of forest type, by growth stage (where known) and tenure ('000 hectares)

Growth stage[a]	Leasehold	Multiple-use public forest	Nature conservation reserve	Other Crown land	Private	Unresolved tenure	Total
Regeneration	53	752	520	13	215	26	1,580
Regrowth	17	717	422	20	443	21	1,639
Mature[b]	87	2,563	2,820	135	1,354	28	6,986
Senescent	236	258	1,714	69	789	27	3,092
Uneven-aged[c]	3	1,282	678	49	86	0	2,099
Total	396	5,572	6,154	285	2,888	102	15,396
% by tenure	3	36	40	2	19	1	100

a Growth-stage definitions vary among states and have been translated to closest national category.

b Mature forest reported here includes both mature and senescent forest in Tasmania.

c Uneven-aged forests exist in all states but were not reported in SOFR 2003 and are included here using new data from Victoria and Western Australia.

Note: Totals may not tally due to rounding.

Sources: NFI, state agencies

In Western Australia, growth-stage information has been collected for 1.9 million hectares of forests in the southwest RFA area and reported in the region's Forest Management Plan 2004–13. This information, which was not available for SOFR 2003, includes spatial data for 331,000 hectares of old-growth forest on public land and has been added to the national dataset for the first time (Figure 14). In Tasmania and Victoria, some old-growth mapping has been updated to take into account harvesting, minor permanent conversion to other land uses, and fire since 2003. In South Australia, the Australian Capital Territory and the Northern Territory, native forest mapping does not collect forest growth-stage information. A mix of growth stages is likely to be present in most forests in those jurisdictions as a result of previous disturbances.

Most known growth-stage information pertains to eucalypt forests, as they are more easily classified into growth stages than some other forest types. Most of the eucalypt forests for which growth stage is known are considered to be mature forests (Table 8). Non-eucalypt communities, such as rainforest or drier open acacia woodlands, cannot easily be classified by growth stage. Those forests often occur as mixtures of several growth stages, including old-growth.

Manna gum (*Eucalyptus viminalis*), even-aged regrowth stand.

Extent of old-growth forest

Old-growth forests have historically provided an important resource for the timber industry in some parts of Australia, especially for high-quality sawn timber and veneer. Old-growth forests generally contain higher timber volumes than younger forests. Thus, old-growth forests planned for harvesting contribute a higher proportion to regional native forest wood supplies for industry in the short term than indicated by their areas. Reliance on these forests is declining in all states. The Western Australian Government's policy, which took effect in 2001, ended timber harvesting in old-growth forests. This increased the total area of old-growth on public land set aside from timber harvesting to 331,000 hectares (Figure 14) and contributed to a reduction in supply of first and second-grade jarrah and karri sawlogs to the timber industry from 457,000 cubic metres per year to 185,000 cubic metres per year. Tasmania also recently announced a program to reduce the clearfelling of old-growth forest on public lands: by 2010, no more than 20% of the small area of old-growth harvested each year will be clearfelled.

The framework to protect old-growth forest set out in the National Forest Policy Statement has largely been implemented in those areas covered by RFAs. A total of 5.03 million hectares of old-growth forest has been identified in the RFA regions. This is around 200,000 hectares less than that reported in 2003 (5.233 million hectares), due mainly to the impact of severe fires, which converted some areas of old-growth forest into younger age classes, and some remapping. About 73% (3.7 million hectares) of these old-growth forests are now in formal or informal nature conservation reserves, with some of the remaining 27% available for timber production.

Almost half of Australia's total identified old-growth forest is in New South Wales, and most of it is on public land (Table 9). The proportion of the forest estate that is old-growth varies widely by state; Tasmania has the highest (almost 40%).

Table 8: Area of forest type, by growth stage

	Area by growth stage ('000 ha)[a]						
Forest type	Regeneration	Regrowth	Mature	Senescent	Uneven-aged	Total	% of total known growth stage
Acacia[b]	1	0	15	0	2	20	0
Callitris[b]	7	0	19	22	1	48	0
Casuarina[b]	1	1	2	4	0	8	0
Eucalypt	1,478	5,569	6,830	2,966	2,085	14,929	97
Eucalypt low closed	3	5	5	0	1	14	0
Eucalypt low open	19	15	35	9	4	83	1
Eucalypt low woodland	2	35	77	75	2	192	1
Eucalypt mallee open	0	1	1	6	0	8	0
Eucalypt mallee woodland	3	0	35	1	1	40	0
Eucalypt medium closed	13	22	47	1	21	105	1
Eucalypt medium open	736	428	2,643	1,224	1,268	6,299	41
Eucalypt medium woodland	234	234	1,489	91	519	2,567	17
Eucalypt tall closed	24	29	48	1	22	123	1
Eucalypt tall open	414	744	2,187	1,538	231	5,114	33
Eucalypt tall woodland	29	56	264	21	15	385	3
Mangrove[b]	0	0	0	0	0	0	0
Melaleuca[b]	2	1	4	3	0	11	0
Rainforest[b]	68	55	35	59	2	219	1
Other[b]	23	13	81	36	8	161	1
Total	1,580	1,639	6,986	3,092	2,099	15,396	100
% of known growth-stage areas	10	11	45	20	14	100	

a Growth-stage class definitions vary between jurisdiction; national growth-stage classes are applied here.

b Non-eucalypt communities cannot readily be mapped by growth stage.

Note: Data for RFA regions in New South Wales, Queensland, Tasmania, Victoria and Western Australia only. Totals may not tally due to rounding.

Sources: NFI, state agencies

Table 9: Area of old-growth forest in areas surveyed for regional forest agreements

	Native forest area in region ('000 ha)	Area of old-growth identified ('000 ha)	Area of old-growth as % of forest in region	Area of old-growth on public land ('000 ha)	Area of old-growth on private land ('000 ha)	Area of old-growth in formal and informal reserves[a] ('000 ha)	% old-growth in reserves
NSW[b]	8,989	2,536	28	1,892	644	1,742	69
Qld[b]	3,230	270	8	196	71	196	73
Tas.[c]	3,116	1,228	39	1,118	110	973[c]	79
Vic.	5,774	673	12	673	1	460	68
WA[d]	1,909	331	17	331	n/a	331	100
Total	23,018	5,039	22	4,209	826	3,702	73

a Includes nature conservation reserves and informal reserves on other tenures.

b Old-growth data for Queensland and New South Wales have not been updated since SOFR 2003. They do not include reserves established since 2003 and therefore 'area of old-growth in formal and informal reserves' is an underestimate.

c Includes new reserves established under the Tasmanian Community Forest Agreement on public land and 9,000 hectares of old-growth reserved on private land.

d Based on old-growth mapping for the RFA.

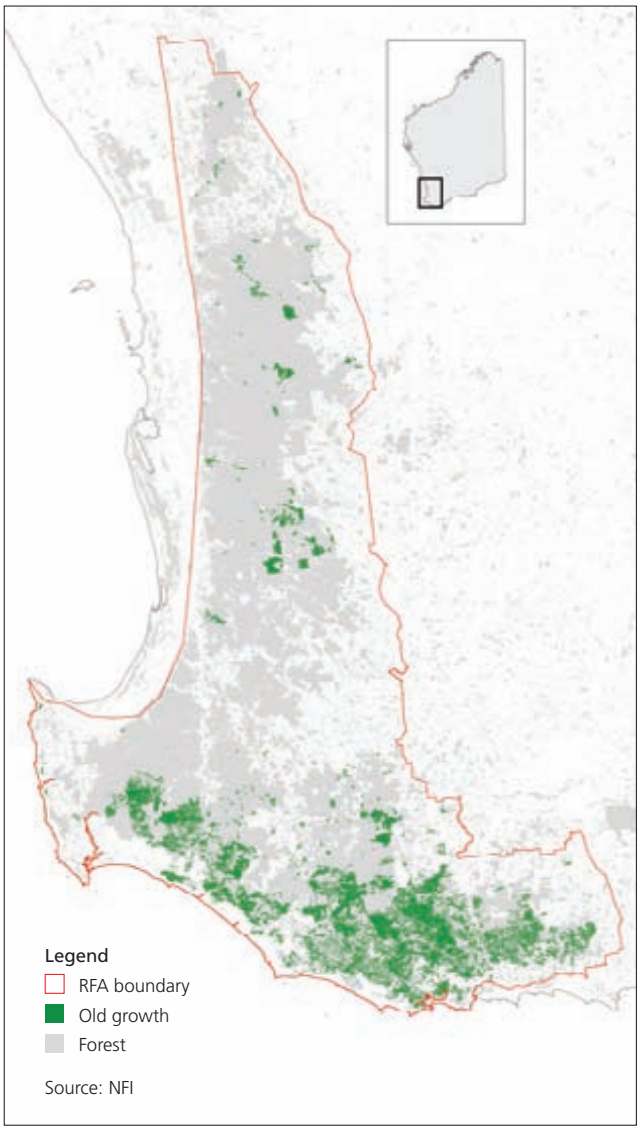
Note: Old-growth definitions vary among states. Old-growth forest has not been assessed in the Australian Capital Territory, Northern Territory or South Australia. Totals may not tally due to rounding.

Sources: NFI, state agencies

Old-growth forest also occurs outside RFA regions, but its extent is not well known. The classification of forests to a growth stage is difficult in areas where the age class is either mixed or not known or where the disturbance history is not known, which is often the case for drier, more remote forests. In Victoria, surveys have been conducted of old trees in red gum (*Eucalyptus camaldulensis*) forests, but those forests often do not meet the formal definition of old-growth forest.

Fire and disease are significant threats to old-growth forests across all tenures. In Victoria and New South Wales, large areas of old-growth have been burned and converted to regeneration and earlier growth stages since the completion of the RFA surveys, mostly in the 2003 fires, but the impact on the extent of old-growth areas has not been fully investigated. For jarrah forests to be classified as old-growth in Western Australia, they must be free of the *Phytophthora* root-rot disease, which is considered a form of disturbance.

Figure 14: Old-growth forest in southwest Western Australia's regional forest agreement area



References

Commonwealth of Australia (1992), JANIS (1997), Keenan and Ryan (2004), Parsons et al (2007a) (list at the back of the report).

Eastern jarrah (*Eucalyptus marginata*) mature growth stage near Dinningup, southwestern Western Australia.

Senescent (large tree, left foreground), mature and regenerating growth phases in eucalypt open forest.

Indicator 1.1c

Area of forest in protected area categories

Rationale

This indicator uses the area and proportion of forest ecosystems reserved through formal and informal processes as a measure of the emphasis placed by society on the preservation of representative ecosystems as a strategy to conserve biodiversity.

Key points

- 23 million hectares of Australia's native forest is in formal nature conservation reserves, an increase of about 1.5 million hectares since SOFR 2003. There have also been significant increases to the informal reserve system on both public and private land.
- The representation of forests in Australia's forest reserve system is substantial, with most of the broad forest types protected above the targets recommended by the World Conservation Union.
- Representation in formal nature conservation reserves increased for most forest types over the reporting period, with notable increases in some types, including rainforest (from 33% to 55%) and mangroves (from 13% to 18%).
- Almost all of the increase in forest in nature conservation reserves has been achieved by reducing the area of multiple-use public forest (in which wood production is an objective) through the regional forest agreement (RFA) process and separate state processes.
- There has been an increase in the area of privately managed forest (including private freehold, leasehold and Indigenous-managed lands) managed for conservation objectives through a variety of national and jurisdictional programs, but the extent of that increase is not well documented.
- About 4.6 million hectares of Australia's native forests are within World Heritage-listed areas, a small increase over the area reported in SOFR 2003.

The National Forest Policy Statement[7] sets out Australia's approach to forest conservation:

> *The nature conservation objectives are being pursued in three ways. First, parts of the public native forest estate will continue to be set aside in dedicated nature conservation reserve systems to protect native forest communities, based on the principles of* comprehensiveness, adequacy *and* representativeness *(CAR reserves). The reserve system will safeguard endangered and vulnerable species and communities. The terms 'reserves' and the 'reservation system' mean National Parks and all other areas that have been specifically dedicated by government for the protection of conservation values. Other areas of forest will also be protected to safeguard special areas and to provide links where possible between reserves or other protected areas. Second, there will be complementary management outside reserves, in public native forests that are available for wood production and other commercial uses and in forests on unallocated or leased Crown land. Third, the management of private forests in sympathy with nature conservation goals will be promoted.*

The RFAs followed this approach in the allocation of areas to the reserve system or to multiple-use public forests where wood production is also a management objective. Within the RFA areas, the reserve system comprises formal and informal reserves on both public and private land:

- **Formal reserves** are publicly managed land-tenures that cannot be revoked without parliamentary approval. Of these, *dedicated formal reserves* exclude mining.
- **Informal reserves** on public land are protected through administrative instruments by public authorities.
- **Private CAR reserves** are areas of private land that are managed in the long term for the protection of CAR values under secure arrangements, including proclamation under legislation, contractual agreements

7 Commonwealth of Australia (1992).

such as management agreements and covenants, and reserves set aside under independently certified forest management systems.

- In some areas, some *forest values may be managed by prescription* in a code of practice or management plan. These areas outside other reserves are not recorded as reserves for the purposes of this indicator.

The proportion of native forest formally protected in public nature conservation reserves has increased significantly over the past decade, from 11% (17.6 million hectares) reported in SOFR 1998, to 13% (21.5 million hectares) reported in 2003, to 16% (23 million hectares) reported in 2008 (Table 10). There have also been significant increases in the informal reserve system on both public and private land. There is a notable trend of increasing reservation on private property by a variety of secure legal mechanisms, such as covenants, but the full extent of that trend is not well documented.

A large part of the increase between the 1998 and 2003 reports arose from the RFA process and subsequent decisions taken by relevant states and territories. One of the key objectives of the RFA process was to use a set of nationally agreed criteria for the establishment of a CAR reserve system in Australia based on the JANIS[8] criteria to protect, in nature conservation reserves:

- 15% of the pre-1750 distribution of each forest type
- 60% of the existing distribution of each forest type, if vulnerable
- 60% of the existing old-growth forest
- 90% or more of high-quality wilderness forests
- all remaining occurrences of rare and endangered forest ecosystems (including rare, old-growth forests).

The process resulted in the transfer of more than 2 million hectares of forest from the broad tenure category of multiple-use public forest to nature conservation reserves; much of that change (1.7 million hectares) was reported in SOFR 2003 (page 42) and is not repeated here.

The 2005 Tasmanian Community Forest Agreement resulted in further increases in the area of forest in formal and informal nature conservation areas in Tasmania. Other states have made changes in forest tenure through departmental arrangements or passed legislation providing further protection to additional areas of forests. For example, New South Wales enacted the *Brigalow and Nandewar Community Conservation Area Act 2005*, which added 352,000 hectares of forest to nature conservation reserves stretching from Dubbo to the Queensland border. Western Australia developed a forest management plan for the southwest of the state covering the period from 2004 to 2013, which resulted in significant increases in the area of forest in nature conservation reserves; outcomes included placing all identified old-growth forest in reserves and altered management prescriptions in many other areas. In large part, the increase in nature conservation reserves has been at the expense of the multiple-use public forest estate (Figure 15).

Informal forest reserves and reserves on private land

Informal reserves are an integral part of the national forest reserve system. All states that undertook comprehensive regional assessments as part of the RFA process (New South Wales, Tasmania, Victoria, Queensland and Western Australia) have developed approaches to forest protection and conservation that include informal reserves, as reported in SOFR 2003.

Figure 15: Change in percentage of forest in formal nature conservation reserves on public land and multiple-use public forest available for wood production, 1997 to 2007

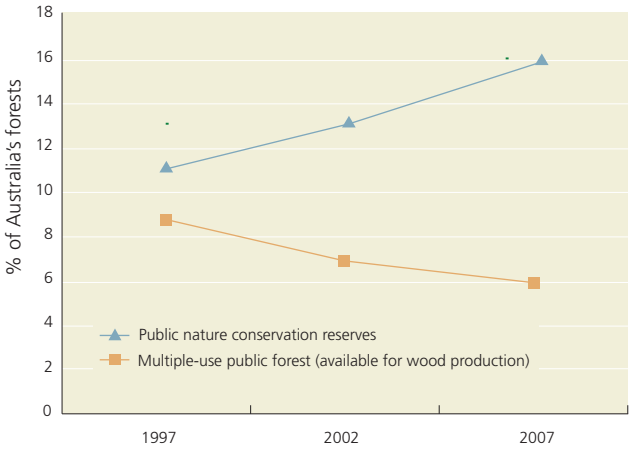


Table 10: Forest area reserved on public land as a percentage of total forest area, as reported in 1998, 2003 and 2008

	Forest area reported in SOFR 1998 (million ha)	% of total native forest area 1998	Forest area reported in SOFR 2003 (million ha)	% of total native forest area 2003	Forest area reported in SOFR 2008 (million ha)	% of total native forest area 2008
Forest in public nature conservation reserves[a]	17.6	11	21.5	13	23	16
All forest[b]	156	100	164	100	149	100

a Does not include informal reserves or private land.

b 'All forest' includes all forest types (native and plantation) on all tenures; it includes multiple-use public forest on public land where wood production is permitted, and forest on private, leasehold and other Crown land. Only relatively small proportions of those areas are used for wood production.

Note: Figures may differ from those reported in state and territory or regional RFA reports due to different forest-type mapping or more recent data.

8 JANIS (1997).

Although private CAR reserves are relatively small, they are important because they are most often selected to protect rare or endangered species or other important forest values that cannot be fully catered for by reservation on public land. There has been an increase in the area of privately managed forest (including private freehold, leasehold and Indigenous-managed lands) being managed for conservation objectives through a variety of national and jurisdictional programs. However, data on conservation areas on private land are not consistently reported and may not be complete.

Tasmania completed its second five-year review of the implementation of its RFA in 2007 and added areas both to the formal reserve system and to the informal system; it is the only state that is able to report comprehensively across both public and private land. Table 11 shows that 47% of the state's total forest area is in either formal or informal nature conservation reserves. It also demonstrates how informal (10% of total forest) and private (2%) reserves add about 350,000 hectares to the total area of forest in nature conservation reserves. Other states are at varying stages of their RFA reviews, and updated data from those states are not yet available.

The area of public land protected in three CAR reserve categories in Victoria is shown in Table 12. Data on CAR reserves on private land in the state are insufficient for reporting here, but it is known that the area of such reserves has increased. For example, in Victoria the Trust for Nature currently has in place more than 800 conservation covenants that offer legally binding protection to more than 35,000 hectares of native vegetation on private land, including a significant number on forested land. There are also conservation management agreements over 200,000 hectares of private land in Victoria, most of it forested. These management agreements, which are not binding on land titles, are associated with formal government programs including BushTender, the National Action Plan for Salinity and Water Quality, the Natural Heritage Trust and Land for Wildlife, which have been integrated into a new government program, Caring for our Country.

IUCN protected areas

The International Union for Conservation of Nature (IUCN) defines a protected area as:

> *… an area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means.*[9]

The IUCN classifies protected areas into the following protected area management categories as a basis for international comparison:

- **Ia Strict nature reserve**: protected area managed mainly for science
- **Ib Wilderness area**: protected area managed mainly for wilderness protection
- **II National park**: protected area managed mainly for ecosystem conservation and recreation
- **III Natural monument**: protected area managed for the conservation of specific natural features
- **IV Habitat/species management area**: protected area managed mainly for conservation through management intervention
- **V Protected landscape/seascape**: protected area managed mainly for landscape/seascape conservation and recreation
- **VI Managed resource protected area**: protected area managed mainly for the sustainable use of natural ecosystems.

In 1982, the IUCN recommended that at least 10% of each biome should be in reserve categories I–VI. Of Australia's 18 broad national forest types, 13 have reservation levels exceeding this; only acacia, callitris and eucalypt medium woodland forest types are represented below this level. In the RFA areas, the IUCN target has been significantly exceeded. The area of forest in IUCN categories I–VI is shown by jurisdiction in Table 13 and by type in Table 14. Nationally,

Table 11: Area of protected native forest in Tasmania, by CAR reserve type

	Dedicated formal reserves	Other formal reserves	Informal CAR reserves	Private CAR reserves	Total forest reserved
Forest area[a] ('000 ha)	635	479[b]	303	48	1,465
% total native forest[c]	20	15	10	2	47

a Forest areas in each reserve class are as at 30 June 2006.

b Subject to the *Mineral Resources Development Act 1995* (Tas.).

c Total forest area in Tasmania as of first quarter 2005 was 3.12 million hectares.

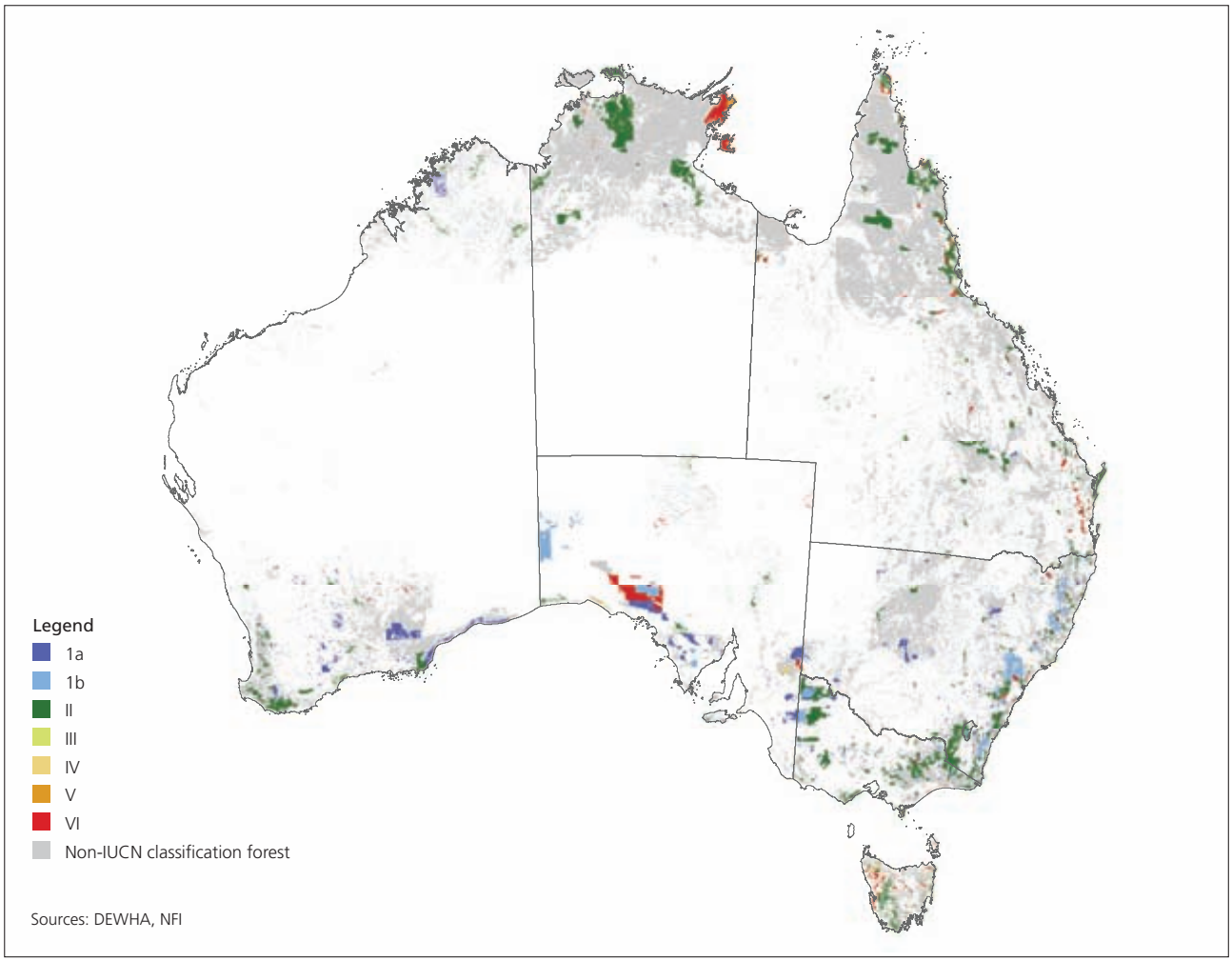
Table 12: Area of protected native forest on public land in Victoria, by CAR reserve type ('000 hectares)

	Dedicated formal reserves	Informal CAR reserves	Values protected by prescription	Private CAR reserves	Total forest reserved
Forest area[a] ('000 ha)	3,546	740	494	n/a	4,780
% total native forest[a]	45	10	6	–	61

a Total native forest area in Victoria of 7.84 million hectares.

9 www.iucn.org/themes/wcpa

Figure 16: Forest cover, by IUCN classification



18% of native forests are in IUCN protected area categories I–VI. In the main, categories Ia, Ib and II are equivalent to the nature conservation reserves reported elsewhere in this indicator; little forest area is contained in categories III, IV and V. Figure 16 illustrates the distribution of forest, by IUCN category.

National Estate

The Register of the National Estate is a national list of places of natural, historic and Indigenous significance. It was compiled and maintained by the Australian Heritage Commission from 1975 to 2003 and after that by the Australian Heritage Council. However, since February 2007 the council can no longer add places to the register or remove them from it. As a result of amendments to the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), two new lists were created on 1 January 2004: the National Heritage List and the Commonwealth Heritage List.

In the past, a place may have been added to the Register of the National Estate if the statutory criteria were met to the appropriate degree, including if the place contained aspects of, or contributed to a greater understanding of, Australia's natural or cultural history, if it was aesthetically valued by the community, or if it was highly valued for social, cultural or spiritual reasons. The register lists sites under three broad categories of historic, Indigenous and natural values.

The register is now frozen but will continue to have statutory status until February 2012. This means that the Minister for the Environment, Heritage and the Arts is required to consider the register when making certain decisions under the EPBC Act. References to the register will remain in the *Australian Heritage Council Act 2003* (Cwlth) during this time, and it will continue to be available online.

Sites listed on the Register of the National Estate cover 66 million hectares in total, of which 22 million hectares is estimated to be forested (Table 15 and Figure 17). The vast majority (21 million hectares) of forest areas are listed for their natural values, and smaller but still significant areas (1.5 million hectares) are listed for Indigenous values and historical values (0.5 million hectares). The total area listed has not changed significantly since 2003, and any differences are most likely due to changes in forest mapping.

Table 13: Area of native forest in IUCN protected area categories, by jurisdiction ('000 hectares)

	IUCN protected area category										
	Ia	Ib	II	III	IV	V	VI[a]	Forest in IUCN categories I–IV	Forest in IUCN categories I–VI	Total native forest	% of forest in IUCN categories I–VI
ACT	–	28	84	–	–	–	–	112	112	123	91
NSW	672	1,636	2,184	–	16	7	215	4,506	4,730	26,208	18
NT	13	–	3,477	1	–	148	896	3,492	4,536	30,927	15
Qld	36	–	4,114	45	9	–	657	4,204	4,861	52,582	9
SA	1,194	1,306	340	111	103	41	1,059	3,054	4,155	8,855	47
Tas.	14	–	604	12	23	46	292	653	991	3,116	32
Vic.	387	781	2,187	49	30	30	66	3,434	3,531	7,838	45
WA	1,913	–	1,636	–	1	2	46	3,550	3,598	17,664	20
Total	4,229	3,752	14,626	218	182	274	3,232	23,005	26,514	147,311	18
IUCN areas as % of total forest	3	3	10	0.1	0.1	0.2	2	16	18		

a Multiple-use public forest could be classified under IUCN category VI; however, the Collaborative Australian Protected Areas Database, which provides estimates of forest areas in IUCN categories, does not do so if the multiple-use public forest is not principally managed for the conservation of biodiversity (see Dudley and Phillips 2006). Areas of forest in IUCN categories were calculated using the Collaborative Protected Area Database for IUCN data, except for Tasmania and Victoria, where state-supplied data were used for Table 13. This leads to slight differences in totals between Table 13 and Table 14.

Note: Totals may not tally due to rounding.

Sources: Collaborative Australian Protected Areas Database, Forestry Tasmania, Department of Sustainability and Environment (Vic.)

Table 14: Area of forest in each IUCN protected area category, by forest type ('000 hectares)

	IUCN protected area category									
Forest type	IA	IB	II	III	IV	V	VI[a]	Total protected	Total forest by type	% protected of type total
Acacia	67	4	388	9	13	2	26	510	10,364	5
Callitris	41	5	76	1	–	2	92	216	2,596	8
Casuarina	51	644	153	2	4	4	17	874	2,229	39
Eucalypt	3,751	2,526	11,601	190	284	235	2,672	21,261	116,413	79
Eucalypt low closed	–	–	11	1	–	–	–	12	44	27
Eucalypt low open	9	3	194	2	–	1	67	276	2,647	10
Eucalypt low woodland	334	7	1,309	7	3	7	91	1,758	13,416	13
Eucalypt mallee open	51	5	29	22	–	30	–	137	376	36
Eucalypt mallee woodland	1,634	1,003	849	66	105	8	1,014	4,681	8,871	53
Eucalypt medium closed	7	6	47	1	–	6	10	77	254	30
Eucalypt medium open	618	855	3,430	39	15	102	827	5,887	28,135	21
Eucalypt medium woodland	1,021	261	4,778	45	103	57	498	6,762	56,169	12
Eucalypt tall closed	1	–	18	–	–	–	1	21	123	17
Eucalypt tall open	75	383	879	6	49	20	140	1,552	5,881	26
Eucalypt tall woodland	1	3	57	1	9	4	24	98	497	20
Mangrove	30	1	102	7	–	8	23	172	936	18
Melaleuca	10	5	764	8	2	3	39	832	7,555	11
Rainforest	24	167	1,197	5	68	28	312	1,802	3,277	55
Other	202	99	593	1	1	–	58	956	3,942	24
Total	4,179	3,451	14,875	223	372	282	3,239	26,621	147,397	18

a Multiple-use public forest could be classified under IUCN category VI; however, the Collaborative Australian Protected Areas Database, which provides estimates of forest areas in IUCN categories, does not generally do so if the multiple-use public forest is not principally managed for conservation of biodiversity (see Dudley and Phillips 2006). Totals may not tally due to rounding. See also note under Table 13.

Sources: DEWHA Collaborative Australian Protected Areas Database for IUCN data, NFI for forest areas

Table 15: Area of forest on Australia's Register of the National Estate, by forest type (hectares)

	Historical	Indigenous	Natural	All values
Acacia	604	33,678	374,206	388,038
Callitris	99	101,467	99,655	175,734
Casuarina	318	17,566	835,887	849,536
Eucalypt	479,525	1,198,553	15,847,056	16,754,997
Eucalypt low closed	29	1,251	21,156	21,188
Eucalypt low open	1,543	61,811	282,483	337,426
Eucalypt low woodland	135,959	56,084	1,764,369	1,815,064
Eucalypt mallee open	69	1,046	56,689	57,666
Eucalypt mallee woodland	4,488	16,087	3,018,609	3,033,618
Eucalypt medium closed	64	1,164	52,077	52,585
Eucalypt medium open	205,513	389,349	4,259,079	4,542,238
Eucalypt medium woodland	49,103	657,568	5,242,951	5,724,927
Eucalypt tall closed	46	54	18,137	18,260
Eucalypt tall open	81,912	13,687	1,027,756	1,047,972
Eucalypt tall woodland	799	452	103,750	104,053
Hardwood plantation	1,225	155	7,542	8,906
Mangrove	199	7,551	339,793	352,613
Melaleuca	2,890	141,955	1,127,234	1,158,016
Other	492	34,607	816,584	828,924
Rainforest	1,062	38,321	1,811,317	1,824,064
Softwood plantation	811	66	9,481	10,956
Unknown plantation	2	–	313	313
Subtotal of forest areas	*487,227*	*1,573,919*	*21,269,068*	*22,352,097*
Non-forest or no data	*375,157*	*1,024,598*	*42,756,017*	*43,774,541*
Total[a]	862,384	2,598,517	64,025,085	66,126,638

a Areas registered as natural, historical and Indigenous overlap in some areas (e.g. Indigenous sites may be recorded in a national park that is also listed for its natural values). Therefore there is a difference between the total forest listed individually under each classification and the total forest listed under all values.

World Heritage

The World Heritage Convention establishes a list of places that have natural and/or cultural values of outstanding global significance. Inclusion of a place on the World Heritage List does not affect ownership rights, and state and local laws still apply. However, as a signatory to the Convention, Australia has an obligation to identify, protect and conserve places on the list. Australia's 17 recognised World Heritage areas cover a total of 7.3 million hectares, of which about 4.6 million hectares is forested (Table 16, Figure 18). This is a small increase over the area reported in SOFR 2003, with a new listing for the sparsely forested areas in the Purnululu National Park in Western Australia. Other examples of forested World Heritage areas include Kakadu National Park (Northern Territory), the Wet Tropics of Queensland, Shark Bay (Western Australia), Fraser Island (Queensland), Gondwana Rainforests (New South Wales) and the Tasmanian Wilderness. A place may be included on both the Register of the National Estate and the World Heritage List, although the two use different criteria and therefore the boundaries of the two listings might not coincide.

Tropical rainforest, World Heritage Area, far north Queensland.

Figure 17: Area of forest listed on the Register of the National Estate

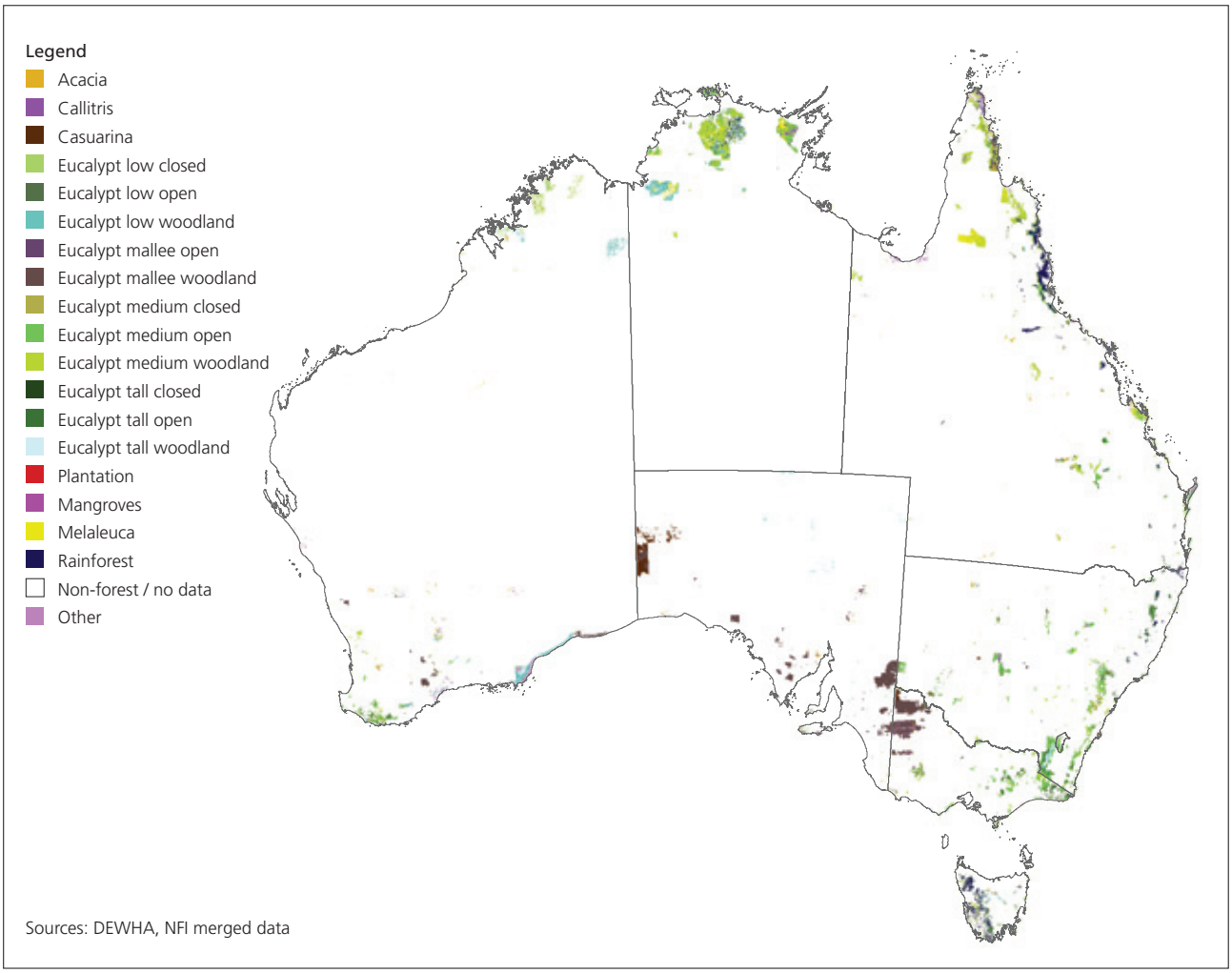
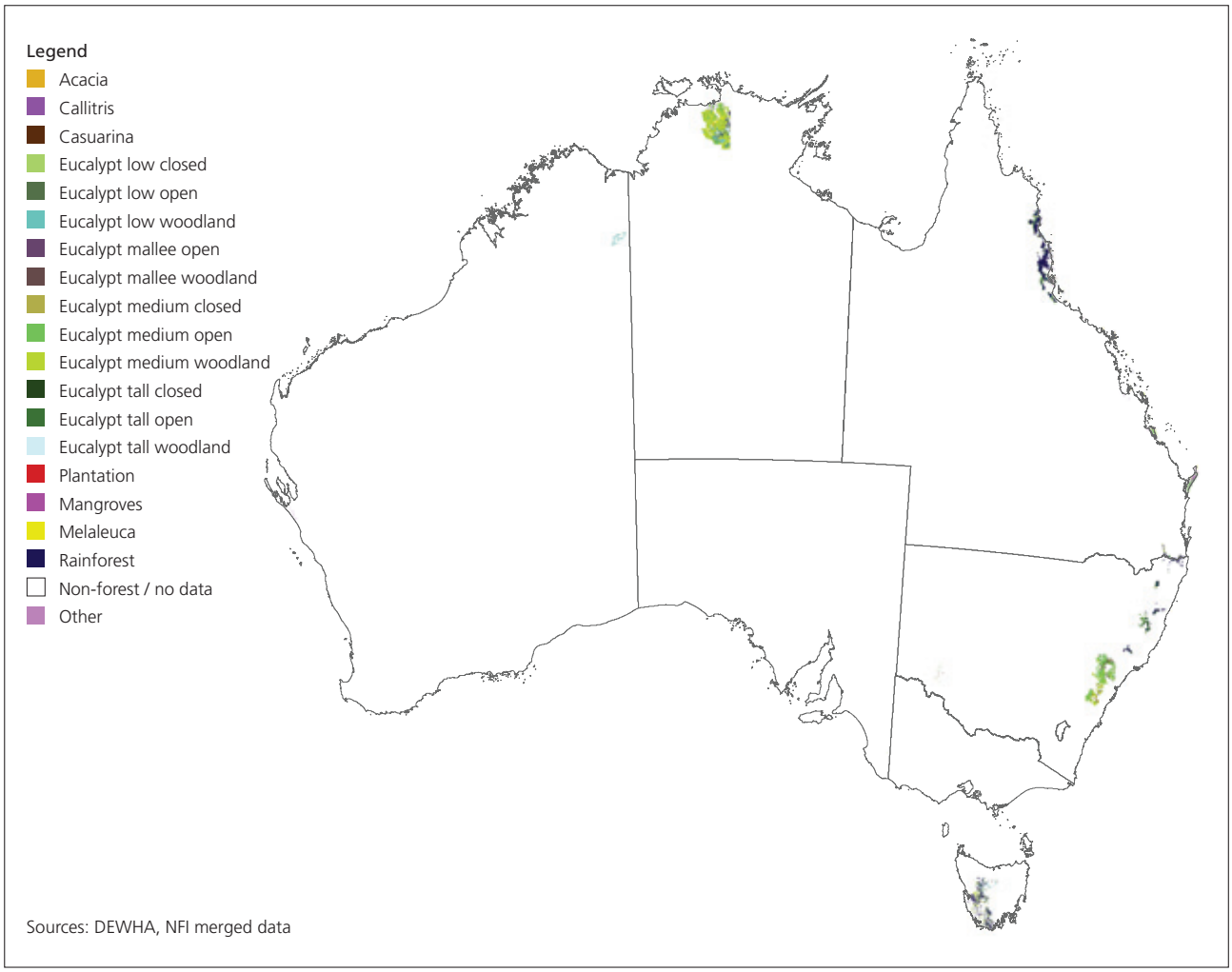


Table 16: Area of native forest in World Heritage areas ('000 hectares)

Forest type	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Australia
Acacia	–	–	–	11	–	2	–	–	13
Callitris	–	4	–	–	–	–	–	–	4
Casuarina	–	32	8	2	–	–	–	–	42
Eucalypt	–	1,003	1,433	396	–	278	–	59	3,170
Eucalypt low closed	–	–	1	–	–	–	–	–	1
Eucalypt low open	–	2	53	1	–	–	–	1	56
Eucalypt low woodland	–	–	137	1	–	34	–	58	230
Eucalypt mallee open	–	2	–	–	–	–	–	–	2
Eucalypt mallee woodland	–	7	–	–	–	–	–	–	7
Eucalypt medium closed	–	–	2	8	–	–	–	–	11
Eucalypt medium open	–	551	325	254	–	–	–	–	1,129
Eucalypt medium woodland	–	315	915	93	–	100	–	–	1,423
Eucalypt tall closed	–	–	–	–	–	–	–	–	–
Eucalypt tall open	–	126	–	40	–	114	–	–	279
Eucalypt tall woodland	–	1	–	–	–	31	–	–	32
Mangrove	–	–	11	52	–	–	–	1	64
Melaleuca	–	–	109	16	–	7	–	–	132
Rainforest	–	135	50	654	–	202	–	–	1,041
Other	–	68	–	64	–	–	–	8	140
Total	–	1,244	1,611	1,195	–	489	–	68	4,607

Figure 18: Forest areas with World Heritage status



References and further reading

ASEC (2006), Collaborative Australian Protected Area Database, Commonwealth of Australia (1992, 1997), Department of Natural Resources and Environment (Vic.) (2002), DEW (2007), Dudley and Phillips (2006), Government of Tasmania and Government of Australia (2007ab) (list at the back of the report).

Arve River, messmate (*Eucalyptus obliqua*) reserved forest, Tahune, Tasmania.

Indicator 1.1d

Fragmentation of forest cover

Rationale

This indicator describes the loss of forest cover and the spatial configuration of that loss. Fragmentation can impact on forest-dwelling species and gene pools through changes in the connectivity of populations and the loss of species genetic variability.

Key points

- As much as one-third of Australia's native vegetation in the intensively managed agricultural and urban zones has been cleared or substantially modified over more than 200 years of European settlement. As a result, those areas exhibit relatively high levels of fragmentation.
- The cessation of broadscale clearing in much of Australia and increased protection of forests have been critical in reducing forest fragmentation in recent times.
- A review of fragmentation in two regions between 1972 and 2002 suggests that recent fragmentation can be dynamic, even in nature conservation reserves, with changing patch sizes and spatial arrangements of different forest types, or stable, particularly in regions where broadscale clearing has been limited.
- Where broadscale clearing is still occurring, the level of fragmentation is significant and may have increased between 1972 and 2002.

This indicator measures the level of fragmentation. It can be measured over a long time period (centuries) to take into account land clearing and land use change. It can also record and contrast change within forested areas in conservation reserves, multiple-use public forests and private forests in the shorter term (decades).

Fragmentation involving permanent clearing of land can cause a decline in habitat quality for many plant, mammal, reptile, bird and amphibian species found in Australian forests, although the impact varies considerably by species and community. An increase in forest fragmentation increases edge effects, reducing habitat quality for interior-adapted species and possibly improving it for edge and open-field species. When forests are divided into smaller patches, the capacity to provide habitat is reduced and the threat from non-native species, including weeds and predators, generally increases. Other ecosystem services may also be adversely affected.

Fragmentation caused by rock outcrops, lakes, streams, rivers and successional changes within forest boundaries or driven by climate change and fire has always been a feature of Australian forests. However, the main cause of forest fragmentation over the past 200 years has been land-use change, primarily for agriculture. As much as one-third of Australia's native vegetation in the intensively used areas, mainly the agricultural and urban zones, has been cleared or substantially modified over that time. As a result, some ecological communities now occupy less than 1% of their original extent and others have become highly fragmented. The cessation of broadscale clearing in much of southern Australia (Indicator 1.1a) and increased protection of forests (Indicator 1.1c) have been critical in reducing further forest fragmentation. An exception is occurring in the Northern Territory, where forest land is being cleared for new agricultural settlement (Case study 3). Clearing north–south in a linear fashion in the territory is resulting in reduced east–west connectivity between areas of formerly contiguous forest.

In some localities, native trees and shrubs have been planted in corridors to re-establish connectivity in landscapes (Case study 4).

Measuring fragmentation

The measurement of fragmentation involves analyses of the configuration, connectivity and composition of native forest patches, where configuration addresses patch size and shape, connectivity addresses the dispersion pattern of patches within the landscape, and composition addresses the variation of disturbance within patches.

Increasingly sophisticated software is available for analysing fragmentation using satellite imagery. Satellite-based remote sensing data obtained from the Australian Greenhouse Office and the FRAGSTATS computer program supported fragmentation analyses, by tenure, in a study area of two regions over a 31-year period (1972–2002). The study area comprised those parts of the landscape in which tenure did not change over the period. Seven parameters of fragmentation were examined for the entire study area (Table 17). The results of the analyses for Tasmania, where there has been little broadscale clearing in recent decades (Figure 19), and southeastern Queensland (Figure 20), where land clearing is known to have occurred in recent decades, demonstrate key changes in forest fragmentation (Appendix B). Analyses were conducted using subregions as categorised in the Interim Biogeographic Regionalisation of Australia (IBRA), which divides the Australian continent into 85 bioregions and 404 subregions.[10]

Tasmania

The representation of forest types in the fragmentation analyses varies by tenure (Table 18). Rainforests are prominent in nature conservation reserves, eucalypt tall open forests in multiple-use public forests and eucalypt medium woodlands in private forests.

Nature conservation reserves

In nature conservation reserves, fragmentation decreased in the period from 1972 to 1992 (i.e. the mean number of patches decreased, mean patch size increased, and distance

Figure 19: Sub-IBRA regions analysed for trends in forest fragmentation in Tasmania

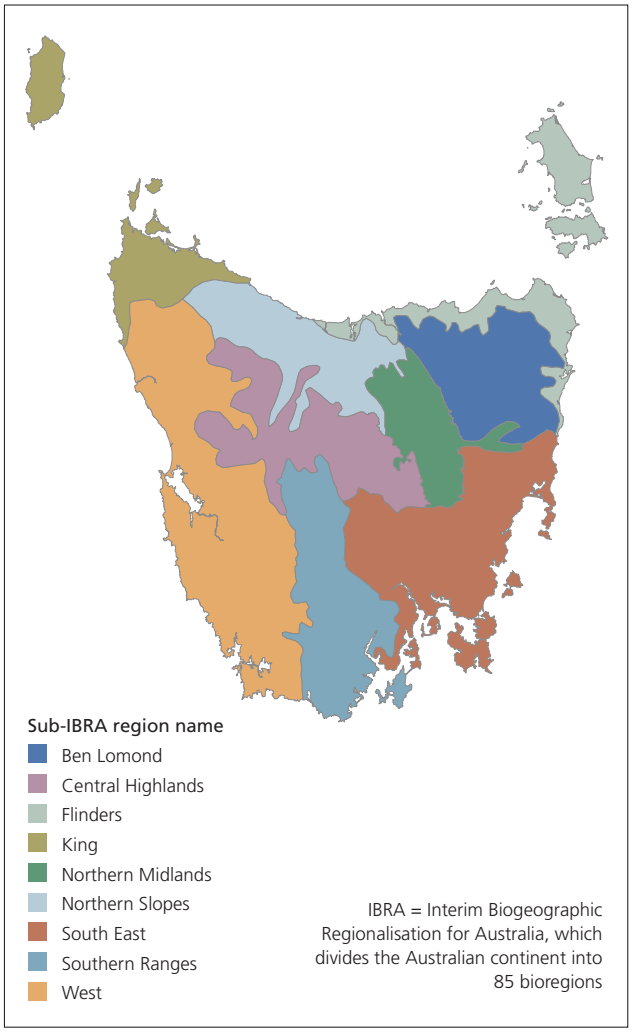


Table 17: Parameters of landscape fragmentation examined, SOFR 2008

Term	Definition and interpretive value
Forest type area	The area sum (hectares) of all patches in a forest type. A measure of the abundance of each forest type in the landscape.
Percent of landscape	The percentage of the landscape area composed of a particular forest type or class. A measure of landscape composition, as it quantifies the proportional abundance of each forest type in the landscape.
Number of patches	The number of patches of each particular forest type or class in a landscape.
Mean patch size	The sum of areas (hectares) of all patches divided by the number of patches comprising that sum. An indicator of the 'grain' of the landscape. (Coarse 'grain' is a mosaic of large patches, fine 'grain' is a mosaic of small patches.)
Mean nearest neighbour	The average distance, in metres, between nearest neighbouring patches based on patch edge-to-edge distance. A measure of isolation where small values indicate that patches of similar type are close or clustered together, and large values indicate otherwise.
Patch density	Number of patches per unit area. A measure of spatial configuration that facilitates comparison among landscapes of varying sizes.
Edge density	The total length of edge of patches divided by the area of the patches (metres per unit area). Measures landscape configuration.

10 www.environment.gov.au/parks/nrs/ibra/index.html, accessed February 2008

Figure 20: Sub-IBRA regions analysed for trends in forest fragmentation in Queensland

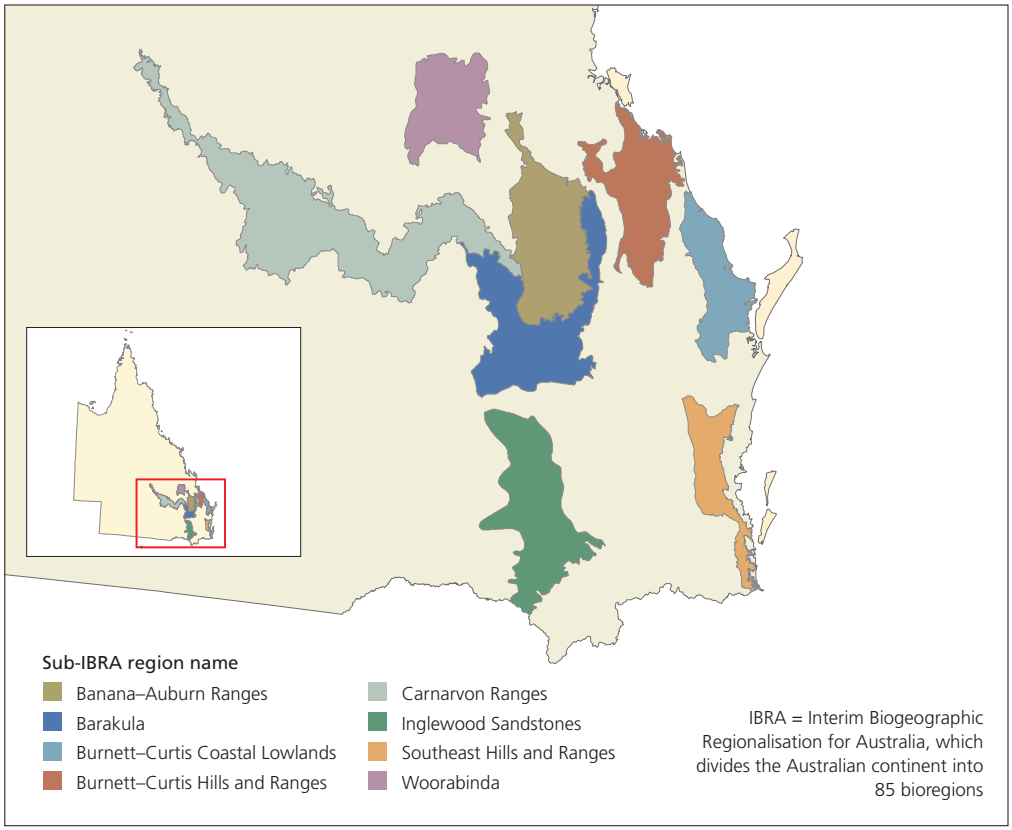


Table 18: Principal forest types examined in fragmentation analyses, Tasmania

	Forest type classes (% of all types)					
Tenure	Acacia	Eucalypt low woodlands	Eucalypt medium woodlands	Eucalypt tall open forests	Eucalypt tall woodlands	Rainforests
Nature conservation reserves	0.3	6.0	26.1	23.2	6.7	35.9
Multiple-use public forests	3.3	0.8	22.1	45.5	10.2	9.1
Private forests	2.1	0.7	60.9	12.4	10.6	2.2

Source: BRS

Table 19: Principal forest types examined in fragmentation analyses, Queensland

	Forest type classes (% of all types)				
Tenure	Acacia	Eucalypt medium open forests	Eucalypt medium woodlands	Callitris	Rainforests
Nature conservation reserves	3.9	11.4	63.4	1.2	4.2
Multiple-use public forests	1.8	9.6	71.7	7.4	2.5
Private forests	3.1	35.0	51.8	0.5	4.6

Source: BRS

to nearest neighbour decreased), then increased to 2002 in the Central Highlands, King and West regions. The early decrease was particularly large in King. Fragmentation decreased between 1972 and about 1998 and then increased to 2002 in the Northern Slopes, South East and Southern Ranges regions. The early decrease was particularly large in the last two regions. The reasons for the reversal in trend around the middle of the study period are unknown, but possibilities include the impacts of fire and drought.

Multiple-use public forests

In multiple-use public forests, fragmentation decreased in six of the nine regions over the period from 1972 to 2002, most markedly in the South East region. Fragmentation increased in the Southern Ranges region to about the mid 1990s and then decreased. In the West region, fragmentation increased between 1972 and 1980 but decreased significantly thereafter. One region, Northern Midlands, experienced increasing fragmentation throughout the entire period.

Private forests

Fragmentation in private forests fluctuated within fairly narrow limits across all regions, with no apparent trend over the period from 1972 to 2002.

Southeast Queensland

For southeast Queensland, the representation of forest types in the fragmentation analyses varies among tenures (Table 19). Eucalypt medium woodlands are prominent in nature conservation reserves and multiple-use public forests. Eucalypt medium woodlands and eucalypt medium open forests are well represented on private land.

Nature conservation reserves

Fragmentation in nature conservation reserves decreased significantly between 1972 and 2002 in the Banana–Auburn Ranges, Burnett–Curtis Hills and Ranges, Inglewood Sandstones and Woorabinda regions; the number of patches decreased and patch size increased (but connectivity was lower). The Barakula and Southeast Hills and Ranges regions also showed decreased fragmentation, but the magnitude was smaller. Fragmentation fluctuated over the period from 1972 to 2002 in the Carnarvon Ranges region.

Multiple-use public forests

In multiple-use public forests, fragmentation decreased in the Baracula, Burnett–Curtis Coastal Lowlands and Burnett–Curtis Hills and Ranges regions, but usually also with lower connectivity. A particularly large decrease was observed in the Carnarvon Ranges region. Fragmentation fluctuated in the Banana–Auburn Ranges, Southeast Hills and Ranges and Woorabinda regions.

Private forests

Fragmentation in private forests decreased in the Burnett–Curtis Hills region, increased in Woorabinda and fluctuated in all other regions.

References and further reading

Governments of Tasmania and Australia (2007ab), NLWRA (2001), Rankmore and Price (2004), Thackway and Lesslie (2006) (list at the back of the report).

Clearing for cropping and grazing has led to fragmentation in many Australian landscapes.

Case study 3: Land clearing in the Northern Territory

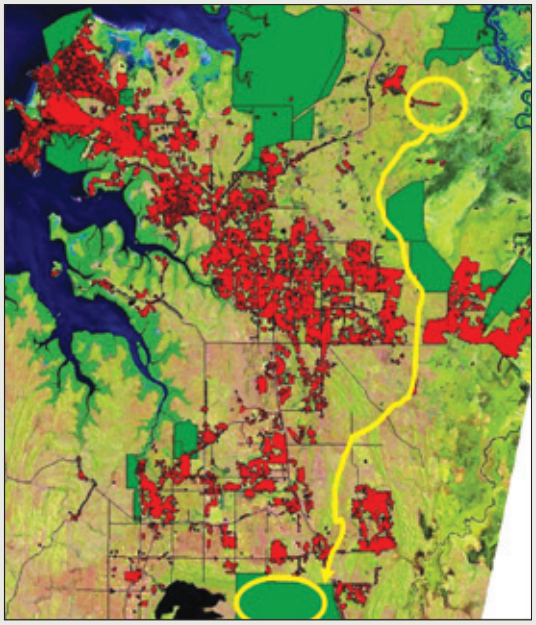
The extent of land clearing is generally lower in the Northern Territory than in southern parts of Australia: 35,000 hectares (6%) of the greater Darwin region; 202,000 hectares (10%) of the Daly Basin.

In both the greater Darwin region and the Daly Basin, clearing is concentrated in certain areas and is carried out in a linear fashion, north–south along the main drainage lines. The biggest problem is to ensure east–west connectivity through cleared areas between significant areas of contiguous forest (see Figures 21 and 22). Research in these regions has shown that biodiversity responds to the extent of clearing of forest habitat in the landscape, the size of patches retained and the degree of connectivity among patches. Of 75 bird, mammal, frog or reptile species, only a small proportion (25%) used modified land, but most (69%) were recorded in corridors. No species could confidently be classified as an edge specialist (i.e. preferring the interface between woodland and modified land).

Three variables were found to have a strong positive influence on animals occurring in a fragment: the size of the fragment; the total amount of woodland within a 4-kilometre radius of the fragment; and connectivity, or the extent of corridors linking the fragment to other large woodland tracts. The fire regime and the density of trees were identified as having important effects in determining the animals present in fragments.

Source: Rankmore and Price (2004)

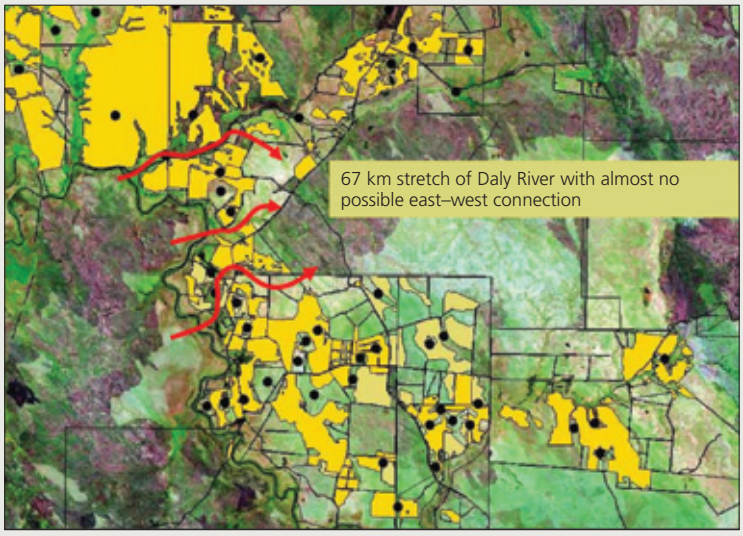
Figure 21: Land clearing and remaining connectivity options in the greater Darwin region



Red = land clearing; yellow = remaining connectivity options

Note: Solid green areas are nature conservation reserves.

Figure 22: Land clearing and remaining connectivity options in the Daly Basin



Yellow = land clearing; red = remaining connectivity options

Case study 4: Biodiversity corridors in the Green Triangle

ForestrySA manages a total of 13,500 hectares of native vegetation in the Green Triangle in the state's southeast, as well as significant areas of forest plantations, particularly radiata pine (*Pinus radiata*). It has set aside more than 70 hectares of productive plantation land for the development of biodiversity corridors that link native vegetation remnants. Some native species are able to move from one remnant to another through plantations and grazing land, but many others cannot. The fragmentation of native vegetation is considered a key threat to such species.

ForestrySA and the Department of Primary Industries and Resources South Australia (PIRSA) Forestry have undertaken modelling to determine priority locations for corridors. As ForestrySA radiata pine plantations are harvested, strategic strips of land are being direct-seeded with local understorey species and a canopy is established by the hand-planting of native tree species.

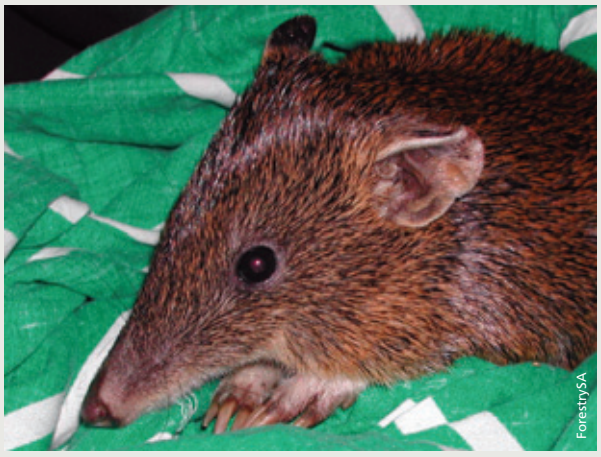
Each corridor is designed to create specific resources for target species. Elements such as a diverse and thick understorey for predator protection, a linked tree canopy, hollows and nesting boxes, logs, rocks and leaf litter are all incorporated in corridors to cater for species such as the southern brown bandicoot, sugar gliders, crested shrike tits, painted button quails and splendid ochre butterflies.

Seed collection, hand-planting and ongoing monitoring of flora and fauna provide opportunities for community involvement by individuals and groups such as schools, environmental interest groups and ForestrySA's Friends of the Forests volunteers.

Other owners of land identified in the project's modelling are being approached to set aside land, to undertake fauna surveys, and to prepare sites and select species for revegetating their own biodiversity corridors. PIRSA Forestry, South Australia's Department of Environment and Heritage and ForestrySA have also begun a program of bird monitoring to look at changes in diversity in corridors compared to adjacent land.

Source: ForestrySA

Planting in a biodiversity corridor after harvest of a pine plantation.



Southern brown bandicoot (*Isoodon obesulus*).

Indicator 1.2a

Forest dwelling species for which ecological information is available

Rationale

This indicator examines the level of information available to manage forest dwelling species and tracks changes in this knowledge over time. The amount of habitat, disturbance and life history information available to make management decisions indicates the capacity to assess risk to species and to implement conservation strategies.

Key points

- All states and the Northern Territory have developed lists of forest-dwelling vertebrates and vascular plant species. The lists show that the number of forest-dwelling species generally increased over the period from 1998 to 2006, reflecting improved information.
- Partial ecological information is available on around 60% of forest-dwelling vertebrate and vascular plant species, and comprehensive ecological information is available on at least 10% of mammal, bird and amphibian species.
- Significantly better information is available for species in regions subject to formal assessment processes, such as comprehensive regional assessments.
- Information is very limited on forest-dwelling invertebrates, fungi, algae and lichens.

Echidna (*Tachyglossus aculeatus*).

Knowledge of the species present in a forest, and increases or decreases in their number, can provide an indication of the extent and condition of forest habitat and ecosystem health. This is particularly important in Australia, where knowledge of species diversity remains a precondition for the effective management of forest ecosystems. Nevertheless, the changes in numbers reported in this indicator reflect improvements in the data on which the lists are based and not actual changes in forest ecosystem diversity.

Australia is home to between 600,000 and 700,000 species, many of which are found nowhere else in the world. About 84% of plants, 83% of mammals and 45% of birds are endemic – that is, they are found only in Australia.[11] An important indicator of forest ecosystem diversity is the number of forest-dwelling species, which are species that use forest habitat for all or part of their lifecycles. This is a broader set of species than forest-dependent species, which are those species that are dependent on forest habitat for all or part of their lifecycles.

All states and territories except the Australian Capital Territory have developed lists of forest-dwelling plant and animal species (Table 20). In New South Wales, the Northern Territory, South Australia, Tasmania and Victoria the number of species reported increased from those in SOFR 2003 because of improved information. However, Western Australia reported a significant decrease in forest-dwelling species in its southwest forest region. The decrease reflects a change in the methodology for identifying forest-dwelling species in Western Australia; the methodology now includes a more focused subset of data, derived in part from a new forest monitoring process called ForestCheck (Indicator 1.2c).

11 Chapman (2006).

Table 20: Number of forest-dwelling vertebrate species, by taxon and jurisdiction

	NSW	NT	SA	Tas.	Vic.	WA[a]
Fish	75	–	–	11	–	10
Amphibians	74	38	22	9	37	20
Reptiles	191	232	182	15	117	53
Birds	317	87	311	69	272	112
Mammals	103	83	59	33	87	31
Total	760	440	574	137	513	226

a Southwest Western Australia only.

Note: No data available for the Australian Capital Territory or Queensland.

Source: State and territory agencies

Grey-headed flying foxes (*Pteropus poliocephalus*).

Table 21 shows the number of known forest-dwelling vascular plant species, by jurisdiction. Compared to SOFR 2003, the number of species reported increased by 109 (about 10%) in Tasmania, increased marginally in New South Wales, and decreased slightly in South Australia. In the Northern Territory, the number reported decreased by 72 (about 2%). All changes reflect improved information, rather than real changes in forest composition.

Table 21: Number of forest-dwelling vascular plant species, by jurisdiction

	NSW	NT	SA	Tas.	Vic.	WA[a]
Species	7,461	3,970	2,306	1,017	2,853	3,000

a Southwest Western Australia only.

Note: No data available for the Australian Capital Territory or Queensland.

Sources: SOFR 2003, state and territory agencies

The comprehensive regional assessments carried out as part of the regional forest agreement process (Indicator 7.1a) and specific species surveys of rare, threatened or endangered species have been important in increasing knowledge of forest-dwelling species. The number of species considered to be adequately known is also increasing as a result of scientific studies and regional planning exercises, especially for species that are considered under threat (Case study 5). As more surveys are undertaken, it is likely that species will be found in areas where they were previously unknown and, in rare cases, species previously unknown to science might be discovered.

There are no comprehensive lists of the invertebrate fauna, fungi, lichens and algae that occur in forests, and the overall level of knowledge about them is low. There are probably well over 100,000 terrestrial invertebrate species, of which only a small fraction has been described. Non-vascular plants

Table 22: Assessed level of ecological knowledge on forest-dwelling species, by taxonomic group

	Assessed knowledge level[a] (% of species)		
Taxonomic group	Minimal or inadequate information is available to inform management decisions	Partial information is available but some crucial information may be absent or limited	Information is comprehensive or adequate to inform management decisions
Arthropods: insects[b]	85.0	11.0	4.0
Arthropods: other[b]	90.0	7.5	2.5
Non-arthropods[b]	89.5	8.0	2.5
Fish[b]	0.0	32	68.0
Amphibians	34.0	51.2	14.8
Reptiles	39.5	50.5	10.0
Birds	35.0	39.2	25.8
Mammals	30.3	55.7	14.0
Vascular plants	37.3	52.2	10.5
Non-vascular plants[b]	85.0	15.0	0.0

a Comprehensive/adequate = knowledge of life history parameters, habitat requirements and distribution and population status and trends; Partial = knowledge of at least broad habitat requirements and population trends; Minimal/inadequate = information limited to species taxonomic identification, with no or very limited knowledge of past and present distribution and population trends. Each jurisdiction was asked to assess the level of knowledge available for species by taxonomic group according to these descriptions. A score of 100 would mean that the knowledge level applies to 100% of species in that taxonomic group. The figures presented in the table are the mean of all responses received and are indicative only.

b Information based on only two or three jurisdictions. Non-arthropods are invertebrates without jointed limbs, segmented body and exoskeleton. Non-vascular plants are plants without tissues that transport sugars, water and salts: algae, lichens, fungi and mosses.

Note: No data available for the Australian Capital Territory and Queensland.

Sources: State and territory forest agencies, analysis by BRS

are also poorly known; for example, only 5,000 of an estimated 250,000 species of fungi have been formally described. Western Australia is collecting comprehensive information on lesser studied fauna and flora groups through ForestCheck; over time, this should result in the development of a more comprehensive list of forest-dwelling invertebrates and non-vascular plants in the southwest of the state.

Table 22 illustrates the level of ecological knowledge about forest-dwelling animal and plant species. Such knowledge varies markedly across taxa. At least partial (limited to adequate) information is available for the majority of vertebrate and vascular plant species; confidence in the level of information was greatest for species occurring in areas where comprehensive regional assessments have been undertaken. All jurisdictions reported that their confidence in the level of knowledge for invertebrates and non-vascular plants was low. In contrast, the level of knowledge on amphibians increased as a result of heightened concerns about declines in the populations of several frog species.

For all taxa for which ecological information is inadequate, risk assessments are necessarily based on information about better studied, closely related taxa in similar ecological niches. Management strategies are reliant on general conservation measures, such as additions to the reserve system, additional environmental protection measures and the maintenance of ecosystem processes.

Reference

Chapman (2006) (list at the back of the report).

Brush-tailed rock wallaby (*Petrogale penicillata*). The species is vulnerable at the national level and critically endangered in Victoria.

Case study 5: Changes to the list of forest species in Tasmania

In Tasmania, improved information has brought about significant changes in the list of threatened forest-dwelling vascular plant species. For example, between 2002 and 2006 the number of new listings increased by 10, with 42 species added and 32 removed. These changes were based on new information gathered largely during the preparation of *Threatened Flora of Tasmania*, a database on threatened flora listed on the schedules of the Tasmanian *Threatened Species Protection Act 1995* and the national *Environment Protection and Biodiversity Conservation Act 1999*.

In 2004, a forest-dwelling fauna species, the Miena jewel beetle (*Castiarina insculpta*), was rediscovered in Tasmania. The beetle was previously known only from two specimens, one collected in 1934 and the other in 1965; both were collected in the Great Lake district of the state's Central Plateau.

Indicator 1.2b

The status of forest dwelling species at risk of not maintaining viable breeding populations, as determined by legislation or scientific assessment

Rationale

This indicator measures the conservation status of nationally listed threatened forest dwelling species. Documentation of this information over time allows analysis of changes to species' conservation status, indicating the extent to which forest species biodiversity is being maintained.

Key points

- In total, 1,287 forest-dwelling species are listed as vulnerable, endangered or critically endangered under the national *Environment Protection and Biodiversity Conservation Act 1999 (*EPBC Act).
- Thirty-nine species or subspecies were removed from the national list of threatened species during the reporting period, and 71 were added.
- Most additions of forest-dwelling species to the national list were made based on inherently small population sizes and ongoing impacts on habitat extent and quality, including the impacts of introduced species and unsuitable fire regimes.
- Most removals of forest-dwelling species from the national list were made as a result of improved information.

The EPBC Act, with subsequent amendments, is the Australian Government's principal piece of environment legislation. It is designed to protect Australia's native species and ecological communities by providing for:

- the identification and listing of species and ecological communities as threatened
- the development of conservation advice and recovery plans for listed species and ecological communities
- the development of a register of critical habitat
- recognition of key threatening processes
- where appropriate, threat abatement plans to reduce the impacts of those processes.

The Act requires the establishment of a national list of threatened species. As of December 2006, 1,287 extant forest-dwelling species were listed under the Act as critically endangered, endangered or vulnerable, and 50 species (including subspecies) were listed as having become extinct (Table 23).

Table 23: Number of forest-dwelling species listed as extinct, critically endangered, endangered or vulnerable under the EPBC Act, by taxon

	Extinct	Critically endangered	Endangered	Vulnerable	Total
Mammals	8	1	16	18	43
Birds	4	3	18	13	38
Reptiles			6	14	20
Amphibians	4	1	10	9	24
Fish		1	5	9	15
Invertebrates		3	2	5	10
Flora (higher plants)	34	49	474	630	1,187
Total	50	58	531	698	1,337

Note: Species were determined to be forest-dwelling if they were known to or likely to occur, or might possibly occur, in vegetation types designated as being forest communities in the National Vegetation Information System.

Source: Environmental Resources Information Network Species of National Environmental Significance Database

Changes in conservation status

An addition to the list of threatened species or the movement of a species to a higher risk category (e.g. from vulnerable to endangered) may indicate that additional steps need to be taken to ensure the survival of the species, such as improvements in the management regime or the protection of additional habitat. However, because many listings (or non-listings) reflect information deficiencies, changes in this indicator need to be assessed with caution.

Since SOFR 2003, a number of changes in the national listing of threatened forest-dwelling species has occurred, including both additions (Table 24, Case study 6) and removals (Table 25, Case study 7). Fewer species were removed from the list (Table 26) than were added (Table 27), reflecting better information on the conservation status of many species as well as taxonomic revisions. Most newly listed species were added because of their small population size and/or restricted range and because of threats caused by land clearing, habitat degradation and unsuitable fire regimes (Case study 6). Overgrazing (for plants) and predation by introduced species (for animals) were often factors. A total of 16 forest-dwelling fauna species and 34 vascular plant species are known to have become extinct since European settlement, but none are known to have become extinct during the reporting period.

Bird-eating spider (*Selenocosmia* sp.) found in rainforest, Kimberley, Western Australia.

Table 24: Forest-dwelling species added to the national list of threatened species during the reporting period

	Extinct	Critically endangered	Endangered	Vulnerable	Total
Vertebrate fauna	–	5	6	6	17
Invertebrate fauna	–	3	1	–	4
Vascular plants	–	19	17	14	50

Note: Species were determined to be forest-dwelling if they were known to or likely to occur, or might possibly occur, in vegetation types designated as being forest communities in the National Vegetation Information System.

Source: www.environment.gov.au/biodiversity/threatened/index.html

Table 25: Forest-dwelling species removed from the national list of threatened species during the reporting period

	Extinct	Critically endangered	Endangered	Vulnerable	Total
Vertebrate fauna	1	–	–	3	4
Vascular plants	2	–	10	23	35

Note: Species were determined to be forest-dwelling if they were known to or likely to occur, or might possibly occur, in vegetation types designated as being forest communities in the National Vegetation Information System.

Source: www.environment.gov.au/biodiversity/threatened/index.html

Table 26: Reasons for the removal of forest-dwelling species from the national list of threatened species during the reporting period

Reason	Number	%
Revised taxonomy/no longer considered valid species	12	31
Lack of data to justify original listing	8	20
No longer considered to be in decline	9	23
No identified threat	10	26
Total	39	100

Note: Species were determined to be forest-dwelling if they were known to or likely to occur, or might possibly occur, in vegetation types designated as being forest communities in the National Vegetation Information System.

Source: www.environment.gov.au/biodiversity/threatened/index.html

Table 27: Reasons for the addition of species to the national list of threatened species during the reporting period

Reason	Extinct	Critically endangered	Endangered	Vulnerable	Total
Fauna					
Very small population	–	8	6	–	14
Competition from introduced fauna	–	3	2	3	8
Disease/pathogens	–	3	2	1	6
Land-use change/habitat loss	–	7	7	4	18
Predation by introduced fauna	–	4	1	2	7
Unsuitable fire regime	–	5	5	–	10
Overexploitation/mortality agents	–	1	1	3	5
Flora					
Very small population	–	4	4	4	12
Weeds	–	–	1	1	2
Pathogens	–	1	–	–	1
Land-use change/mechanical disturbance	–	1	4	1	6
Overgrazing/overbrowsing	–	1	2	1	4
Unsuitable fire regime	–	1	1	2	4
Over-harvest	–	–	1	–	1
Moved from higher threat category – better data	–	–	–	1	1

Note: Multiple reasons may be given for individual species. Assessment of flora based on a random sample of five species in each threat category (excluding 'extinct', which had no occurrences).

Source: www.environment.gov.au/biodiversity/threatened/index.html

Protecting listed threatened species

Once a species is listed under the EPBC Act, its recovery is promoted using conservation advice, recovery plans, and the Act's assessment and approval provisions. Recovery plans set out the research and management actions necessary to stop the decline and support the recovery of listed threatened species or threatened ecological communities. The aim of a recovery plan is to maximise the long-term survival in the wild of the species or ecological community. The regional forest agreement process has also provided specific protections in relation to forest-dwelling species.

All states and territories maintain legislation to protect native species of flora and fauna, including forest species. Recent changes in forest-related legislation, including those related to the protection of threatened species, are reported in Indicator 7.1a.

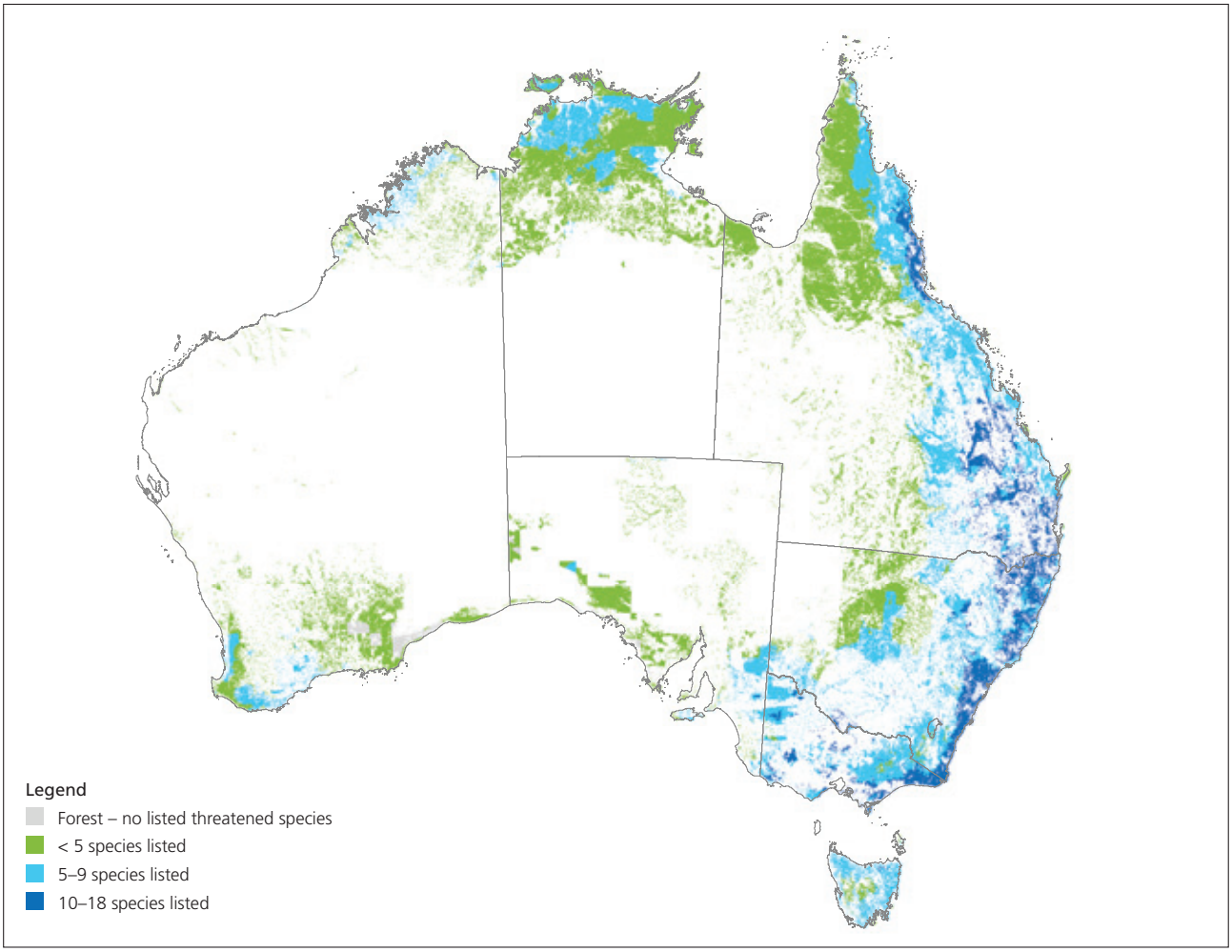
The central north burrowing crayfish. General body length is usually under 10 cm. It is believed to eat rotting wood, detritis, root material and occasionally animal matter.

Case study 6: The central north burrowing crayfish

The central north burrowing crayfish (*Engaeus granulatus*), a small crustacean, is listed as endangered under the Tasmanian *Threatened Species Protection Act 1995*. It occurs in a triangular area in central north Tasmania (southwest from Port Sorell to the Railton area and north to Quoiba, near Devonport) and inhabits seeps, wetlands and stream banks. The species is confined to seven geographically isolated areas, with a minimum of 5 kilometres separating each area. Precise population figures for an invertebrate species such as this are difficult to determine, and estimates vary considerably.

To date, the crayfish has not been recorded in any secure nature conservation reserve, and it may be subject to a number of ongoing threats, including activities that alter water quality or quantity, such as clearing of riparian and seepage-way vegetation, ploughing, dam construction, unrestricted stock grazing, and competition from an introduced species. No specific assessments have been conducted of potential threats, and it is difficult to determine the extent to which such threats are jeopardising the species' survival in the wild. Nevertheless, its geographical distribution is so restricted as to make its survival precarious. For this and other reasons, the species was considered to be eligible for listing as endangered under the EPBC Act, and it was added to the list in November 2005.

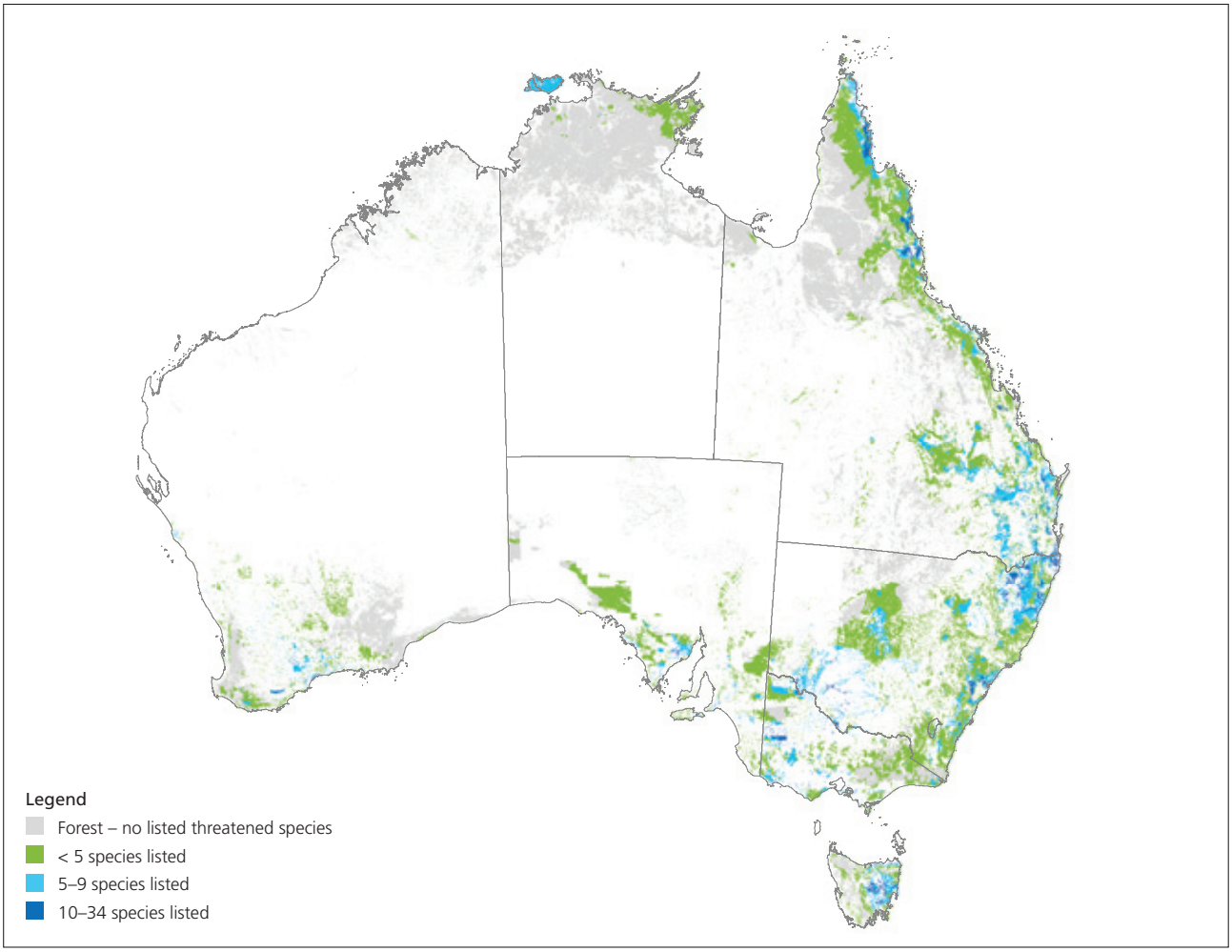
Figure 23: Distribution of rare and threatened forest-dwelling fauna species



Distribution of threatened forest-dwelling species

Figures 23 and 24 show the distribution of threatened forest-dwelling fauna and flora species. The number of listed species per forest area is highest in the wet coastal areas, where species diversity is also high. The mallee and Grampian regions in Victoria are also 'biodiversity hotspots'.

Figure 24: Distribution of rare and threatened forest-dwelling flora species



Case study 7: The Eprapah wattle

The Eprapah wattle was previously considered to be a species (*Acacia perangusta*) in its own right but is now considered to be an extreme form of the Brisbane golden wattle (*A. fimbriata*). The Brisbane golden wattle is a small tree or rounded shrub that grows up to 7 metres high and 6 metres across. It has profuse yellow, ball-shaped flowers in spring.

In 1980, *A. perangusta* was recognised as a separate species that was restricted to the banks of small streams in an area south and southeast of Brisbane and on the Burrum River north of Maryborough; it was listed as vulnerable under the EPBC Act. However, collections of plants since then have indicated that *A. perangusta* represents natural variation within *A. fimbriata* and is therefore part of that species. *A. fimbriata* is a widespread plant in eastern Australia, occurring between Rockhampton in Queensland and Nowra in New South Wales, and is not listed as threatened under Australian legislation. *A. perangusta* was removed from the list of threatened species under the EPBC Act in November 2005.

The Eprapah wattle.

Indicator 1.2c

Representative species from a range of habitats monitored at scales relevant to regional forest management

Rationale

This indicator provides broad habitat, population, and range information for representative forest dwelling flora and fauna. Evidence of changing ranges or densities of forest-dwelling species can be used to guide forest management activities so that they are consistent with the maintenance of forest biodiversity.

Key points

- Efforts to monitor forest-dwelling species vary across jurisdictions.
- Birds are the taxonomic group with the largest number of programs in place to track population trends. State and territory agency efforts are supplemented by a large-scale investment by non-government groups.
- The lack of comprehensive knowledge on the occurrence of representative species across land tenures and broad forest types limits the conclusions that can be drawn from the data.
- States and territories undertake separate monitoring for their own requirements, and their priorities may differ from national priorities.

Forest-dwelling species are monitored under programs implemented by a range of different bodies, including state forest management and conservation agencies, universities, non-government organisations and private individuals. Such programs have been established for a variety of reasons and at various scales; for example, university programs are often designed to address particular research questions, usually at a localised scale. Individual jurisdictions monitor forest-dwelling species to meet requirements specified by legislation; therefore, priorities at the state and territory level may differ from those set at the national level.

Table 28 indicates the extent to which monitoring programs are in place for representative species in various taxonomic groups, by state and territory. The table is based on reporting by individual state agencies and therefore might not include all existing programs.

At the national level, the most comprehensive monitoring is in place for bird fauna, driven by a national volunteer program coordinated by Birds Australia and supplemented by agency-specific programs. While birds are usually reasonably visible and hence amenable to direct monitoring, that is not the case for all species, so innovative monitoring approaches are also needed (for example, Case study 11). A similar community-partnership program has been developed for amphibians through FrogWatch, which is now active in most states and territories. In both the bird and frog-monitoring approaches, a non-government organisation is working in collaboration with government agencies to develop comprehensive monitoring programs using public participation.

Frogs are often considered good environmental indicators because they use both land and water and because their permeable skin makes them more susceptible to changes in the environment. Monitoring frog populations, therefore, offers an opportunity to test the impacts of habitat change using an organism that should be quite sensitive to such change. Long-term trends are essential to understanding population processes and threats. For example, in New South Wales, frog populations have been monitored at the Watagan Mountains and around Dorrigo over the past 5–10 years to determine whether populations of pond frogs are stable within a general forestry environment (including roading, logging and fire). The data show no change in populations overall and no obvious signs that any activities in these areas have affected the frogs significantly. Importantly, a few species appear to be increasing in numbers again, possibly recovering from outbreaks of the chytrid fungus in the 1980s.

Recognising the value of a structured, broad-based monitoring program in assisting long-term management, Western Australia recently established ForestCheck, a comprehensive approach to the monitoring of species in the

state's southwestern forests. ForestCheck is one of only a few programs in the world collecting regional-scale information on mosses, lichens, fungi and invertebrates as well as the more well-known components of forest biodiversity (vertebrates and vascular plants). Sustainable forest management requires an understanding of ecological trends over long timescales; long-term monitoring programs such as ForestCheck will deliver some of that information and thereby contribute to the continuous improvement of the forest management regime. Other such programs include projects to monitor fire in Eden, New South Wales (Case study 8), the swift parrot in Tasmania (Case study 9), barking owls in New South Wales (Case study 10), Tasmanian devils (Case study 11), and wildlife in mountain ash forest in Victoria (Case study 12).

Table 28: Taxonomic groups for which representative species are being monitored, by jurisdiction

	Mammals	Birds	Reptiles	Amphibians	Invertebrates	Vascular plants	Non-vascular plants
NSW	✓	✓		✓		✓	
NT	✓	✓				✓	
SA	✓	✓					
Tas.[a]	✓	✓			✓	✓	
Vic.	✓	✓		✓		✓	
WA[b]	✓	✓	✓	✓	✓	✓	✓
National[c]		✓		✓			

a Government of Tasmania and Government of Australia (2007a), www.warra.com/warra

b www.naturebase.net/content/view/2388/482

c www.birdata.com.au; frogs.org.au/frogwatch

Note: No data are available for the Australian Capital Territory and Queensland. A tick indicates that at least one species of the taxonomic group is being monitored to detect changes in population size at a scale relevant to forest management.

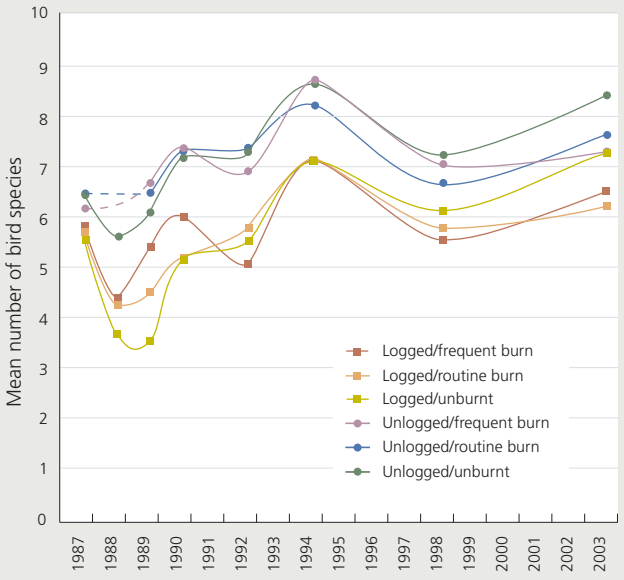
Sources: As noted, and state and territory agencies

Case study 8: Eden, NSW, burning study

Biological data have been collected in the Eden Burning Study Area in southeastern New South Wales over two decades. In one study, bird populations in six logging and prescribed burning treatments (three replicates of six treatments = 18 coupes) have been surveyed using the same sampling methods for the past 20 years. In 1987, all sites were unlogged and not recently burned. Logging occurred in 1988 within coupes scheduled for that treatment. Prescribed burning (depending on treatment) occurred in 1988, 1990, 1992, 1996, 2001 and 2003. Figure 25 shows that the number of bird species fluctuated in treated and untreated coupes over time but was generally lowest at sites that were logged and burned frequently and higher in unlogged sites.

The study also collected data on the effects of fire and logging on understorey and overstorey vegetation. The prescribed burns were found to be extremely patchy, and are likely to have significantly lower ecological impacts than homogeneous burns because refuges are provided for fire-sensitive species and newly burned areas for colonising species. Logging (but not fire) was associated with higher species richness in the shrub understorey. In contrast, fire (but not logging) had a significant impact on ground vegetation diversity and richness. The results of this study will allow the identification of species or groups of species that are more susceptible to logging and fire disturbances.

Figure 25: Bird species observed in surveys in the Eden Burning Study Area under various treatments, 1986 to 2003



Source: Forests NSW

Case study 9: Swift parrot

The swift parrot (*Lathamus discolor*) breeds only in Tasmania and migrates to the Australian mainland in autumn to spend the winter foraging for lerps and nectar in flowering eucalypts, mainly in Victoria and New South Wales. In Tasmania, the bird's breeding range is mostly restricted to the east coast within the range of the Tasmanian blue gum (*Eucalyptus globulus*). The breeding season coincides with the blue gum's flowering, when the tree's nectar provides the parrot with its main food source.

Populations of the swift parrot were monitored annually in Tasmania from 1999 to 2005 during the bird's breeding season. Results were strongly affected by the blue-gum flowering event. In years of poor flowering (2000 and 2002), both the number of swift parrots observed and the number of sites at which they were observed were very low. In years of moderate-to-heavy flowering (1999, 2001, 2003, 2004 and 2005), swift parrots were recorded at 25–30% of sites. Excluding the poor flowering years of 2000 and 2002, the swift parrot population appears to have been reasonably steady over the period. These results are inconclusive, however, because they cover a relatively short period and were influenced by the temporal and spatial variability in blue-gum flowering patterns.

Surveys conducted during the 2004–05 and 2005–06 breeding seasons found 134 swift parrot nests; previously, only 40 had been recorded throughout Tasmania. Many of the nests were in breeding aggregations of up to 50 nests covering about 100 hectares.

The information collected from known nest sites and from additional surveys targeting both nesting and foraging habitat is being integrated into the management of breeding habitat and used to identify potential nesting habitat.

The forest practices system provides protection to two of the swift parrot's key habitats in Tasmania – grassy *E. globulus* forest and shrubby *E. ovata* forest – from clearing and conversion on both public and private land. Prescriptions for the management of swift parrot nesting and foraging habitat are currently under review, with the aim of improving the management of nesting habitat (particularly as the species tends to exhibit aggregated nesting behaviour) and foraging habitat in wet forest types, especially near coastal *E. globulus* forest.

Source: Swift Parrot Recovery Team (2000)

Case study 10: Ecology of barking owls in managed forests

Many vertebrate species occur so rarely in the wild that it is not possible to assess their sensitivity to logging using standard fauna survey techniques. Instead, species-specific research programs are needed to obtain information useful for those species' conservation and management. Scientists working for the New South Wales Department of Primary Industries conducted a radio-tracking study of nine barking owls (*Ninox connivens*), a vulnerable species, in the state's Pilliga forests to determine key elements of habitat required by the species and to provide appropriate guidelines for forest managers.

The owls were trapped, released and radio-tracked for one year. The study identified important aspects of the ecology of the species, enabling the development of guidelines for conserving it in timber-producing forests. The research showed that barking owl pairs in the Pilliga forests live year-round in non-overlapping home ranges of about 2,000 hectares. The owls used most of the forest vegetation types available in their home ranges, but preferred particular subsets of tree species associations for hunting, nesting and roosting.

A feature of the owls in the Pilliga is their diet of native prey species, including sugar gliders, bats, birds and insects; in some other locations, European rabbits form the main component of their diet. Perhaps for this reason, forest edges were not as important an element of habitat for barking owls in the Pilliga as they appear to be elsewhere. The Pilliga forests have a long history of selective logging, but there appeared to be no evidence of owls avoiding logged areas within their home ranges. Most pairs of owls attempted to breed during the study but only half were successful, each producing two or three young. Nest predation by goannas appeared to be a significant cause of nest failure for the other pairs.

Management guidelines arising from this study are being incorporated in the negotiated outcomes of recent land-use decisions for the Brigalow and Nandewar regions.

Source: Forests NSW

Barking owl (*Ninox connivens*).

Case study 11: Tasmanian devil

In recent years, the Tasmanian devil (*Sarcophilus harrisii*) has been severely affected by devil facial tumour disease (DFTD). Long-term monitoring of the species indicates that, while its population has fluctuated, numbers were relatively stable until about five years ago (Figure 26).

DFTD has now been confirmed in Tasmanian devils across more than half of the Tasmanian mainland (Figure 27) and has been demonstrably linked to a 41% decline in the population over the past 10 years. This cancerous disease takes the form of tumours on the head of the devil; the tumours may spread to other parts of the body. Death occurs within months of the first signs. DFTD appears to be a new, infectious disease, typically affecting only adults. The cancerous cells are thought to be the agent of infection; no viruses or other disease agents have been identified, despite extensive investigation. While wildlife diseases rarely cause extinction, there is so far no evidence to suggest that DFTD will not continue to spread across Tasmania, or that populations can recover once infected. No local extinctions have been detected to date, and Tasmanian devils still exist in all rural habitats throughout the mainland of the state. However, the population has declined by 89% in the region where DFTD signs were first reported.

The first clear indications of the impact and wide distribution of the disease emerged in 2003, and in response the DFTD Program was established in 2004. The program's key focal areas are:

- **population monitoring**: gathering data in the field to clarify disease distribution and impacts, and using those data to help determine conservation strategies
- **disease diagnostics**: a laboratory-based investigation of the disease, which includes defining the disease and exploring its transmission and possible causes
- **wild management**: establishing methods for managing the impact of the disease in the wild
- **captive management**: assembling captive breeding populations using devils from disease-free areas.

Source: Forest Practices Authority (Tasmania) (2007)

Figure 26: Changes in population of the Tasmanian devil, 1985 to 2005

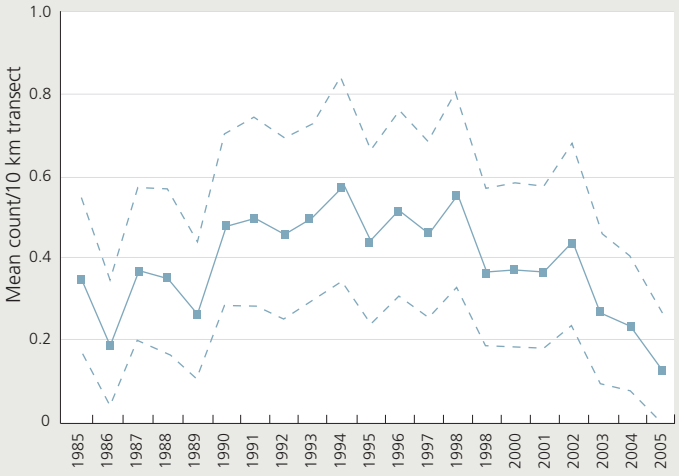
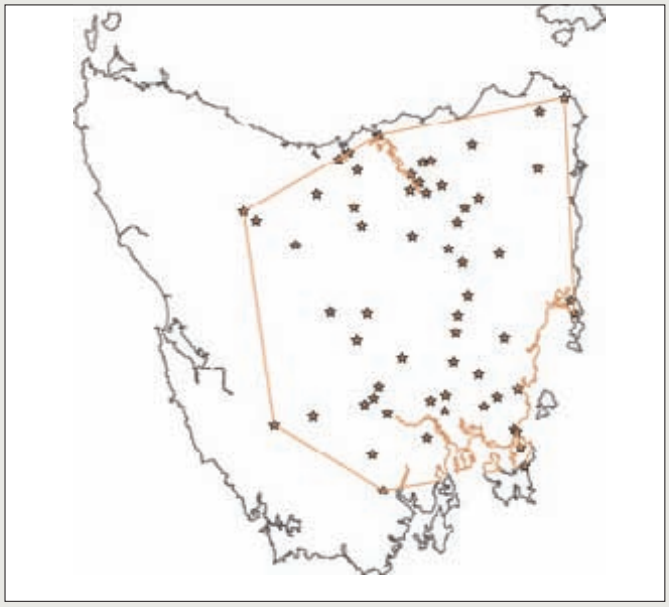


Figure 27: Locations at which the presence of devil facial tumour disease had been confirmed by November 2006



The Tasmanian devil (*Sarcophilus harrisii*) now found in the wild only in Tasmania, is the largest carnivorous mammal in the world. It is vicious when feeding and is known to hunt prey and scavenge carion. Although usually solitary, devils sometimes eat together.

Case study 12: Long-term species monitoring and research program in the Victorian mountain ash forests

Since 1983, the Victorian Department of Sustainability and Environment has supported a long-term monitoring and allied research program in the mountain ash (*Eucalyptus regnans*) forests of the Central Highlands of Victoria (Figure 28). To date, over 50 major projects have been completed, 6 books and 130 scientific articles have been published, and many field workshops and other extension activities have been conducted.

This is one of the most significant and longest running forest monitoring and research programs of its type in the world. The value of the data, the new insights gained and the relevance and importance of the work to indicators of sustainability strengthen with each additional year of work.

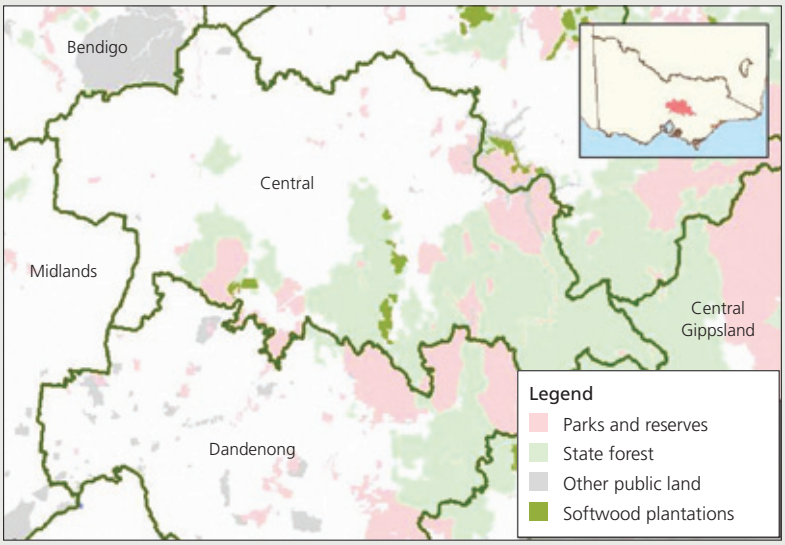
A suite of projects is ongoing, and several key strategically important new projects have been established. The primary focus is the long-term monitoring of arboreal marsupials, such as Leadbeater's possum (*Gymnobelideus leadbeateri*) and the mountain brushtail possum (*Trichosurus cunninghami*). The study is considering the effectiveness of various forest management prescriptions.

The monitoring program currently comprises:

- long-term ecological monitoring of landscape cover and composition (logged/unlogged mosaic) effects on arboreal marsupials, forest owls and diurnal birds
- monitoring falls of large hollow trees
- nest-box use and occupancy patterns of hollow-dependent fauna
- fauna surveys (mammals, birds and reptiles) of dry and mixed-species forest patches in the Upper Yarra catchment (32 sites in the Yarra Ranges National Park)
- a variable retention harvest system experiment
- small-mammal population dynamics – relationships between forest floor architecture (logs, ground cover, etc.) and populations of three species of small mammals
- long-term population dynamics of the mountain brushtail possum.

Source: DSE, Victoria

Figure 28: Victorian Central Highlands study area



Leadbeater's possum (*Gymnobelideus leadbeateri*).

Indicator 1.3a

Forest associated species at risk from isolation and the loss of genetic variation, and conservation efforts for those species

Rationale

This indicator assesses the risks to loss of forest genetic variation and describes the formal measures designed to mitigate this risk. A loss of genetic diversity in species can result in decreased ability to adapt to future environmental change, and thus a higher risk of extinction.

Key points

- While the number of forest-associated species for which data on genetic variation are available is still low, it has increased since SOFR 2003. Then, data were available for one faunal and two floral species; now, data are available for more than 10 faunal and 13 floral species.
- Several studies have documented genetic variation and distribution patterns within existing populations of a relatively small number of forest-associated species. Several institutions have programs to measure genetic diversity in forest fauna, but nationally conclusive results are available for only a few species.
- Conservation measures therefore focus on increasing connectivity between isolated patches of native vegetation, increasing the area of forest contained in public and private nature conservation reserves, managing threats to native species, and assisting the recovery of threatened species.

Spider orchid (*Caladenia behrii*).

The distributions of Australian species before European settlement are needed for definitive assessments of genetic variation. Evidence of major changes in the past few decades can assist. Historical records, expert opinion and analysis and incidental observations have been used to compile maps or to model the former distributions of species. For example, the regional forest agreements provided pre-1750 estimates of the extent of forest ecosystems within the main production forest estate.

Species with low genetic variation are widely held to be less able to withstand unexpected threats and so face a higher risk of extinction. In practice, it is difficult to demonstrate the level of genetic variation that has been lost in a species. However, it is possible to identify whether certain threatened species are becoming endangered by the increased isolation of populations arising from habitat loss, fragmentation and threatening biotic factors such as predators and disease.

Efforts are being made to improve long-term conservation outcomes, for example by increasing connectivity among patches of native vegetation. In South Australia, ForestrySA is implementing biodiversity corridor programs across its (mostly pine plantation) land in the southeast of the state and in the Mount Lofty Ranges to link areas of isolated native forest with strips of revegetation (Case study 4 in Indicator 1.1d). Most jurisdictions have threat abatement plans in place to reduce the impacts of predators and diseases on threatened species.

Several institutions have programs to measure genetic diversity in forest fauna, but nationally conclusive results are available for only a few species. Changes in the genetic diversity of forest-associated flora have also been little measured, although several studies have documented genetic variations and distribution patterns within existing populations. Those studies suggest that a reduction in range is less likely to cause a significant loss of genetic variation in species with a high level of diversity within populations and

a low level of diversity between populations. A reduction in range is more likely to reduce genetic variation in species that exhibit low genetic diversity within populations and high variability among populations. The former applies to most of the limited number of tree species that have been surveyed, but the latter applies to species with naturally restricted ranges – such as the narrow-leaved mallee (*Eucalyptus angustissima*). Knowledge of genetic variation in Australia's native species and conservation measures to maintain that variation are greatest in non-threatened species of economic importance, such as the blue gum (*E. globulus*).

The number of species for which data on genetic variation are available has increased since SOFR 2003, when data were available for one faunal and two floral species. Data are now available for more than 10 faunal and 13 floral species (Appendix C).

Threatened species

The states and territories and the Australian Government maintain lists of threatened species, the Australian Government at the national level (Indicator 1.2a). For example, Table 29 shows threatened forest-associated species in New South Wales by broad taxonomic group and the reasons for their listing. Many taxa in Table 29 are the subject of priority action statements prepared by the New South Wales Department of Environment and Climate Change, which describe the actions required for the conservation and recovery of the species.

Table 30 shows the number of forest-associated species potentially at risk in Tasmania from isolation and the loss of genetic variation. Measures in place to address the risk of loss of genetic variation in the state's threatened species include recovery plans, habitat restoration, seed-collecting programs and the management of habitat and populations under the forest practices system.

Table 30: Tasmanian forest-associated species potentially at risk from isolation and the loss of genetic variation as a result of past human-induced or natural events, by taxon

Group	Potential high and moderate risk	Potential low risk	Unknown risk	Total
Fish	3	3	–	6
Amphibians	1	1	–	2
Reptiles	–	1	1	2
Birds	6	5	–	11
Mammals	3	2	1	5
Plants[a]	104	116	50	270
Total	117	128	52	296

a Includes dicotyledons, monocotyledons, pteridophytes and gymnosperms.

Source: Forest Practices Authority (Tasmania) (2007)

Fragmentation

Forest fragmentation (Indicator 1.1d) caused principally by land clearing and loss of habitat can contribute to a loss of genetic variation. Native populations at greatest risk and of greatest concern are those that are small or fragmented and at the same time have high conservation value. For example, the rare species swamp peppermint (*Eucalyptus rodwayi*) may be at risk where outlying populations exist near shining gum (*E. nitens*) plantations in southern Tasmania because of the possibility of hybridisation between them. Case studies 13 and 14 examine several species with highly restricted distributions.

Climate change

A change in climate, such as that being predicted due to the enhanced greenhouse effect (see Indicator 3.1a), may contribute to a loss of forest genetic variation. For example, a reduction in rainfall is believed to be the cause of widespread mortality over the past decade in some Gunns white gum (*E. gunnii*) populations on Tasmania's Central Plateau. *E. gunnii* is one of the most frost resistant of all

Table 29: Threatened forest-associated species in New South Wales with conservation and recovery plans in place, by taxon

	Reasons for listing species as threatened			
Group	Low population	Hybridisation	Low genetic diversity	Other[a]
Plants[b]	265	2	8	20
Reptiles	11	–	–	–
Birds	17	1	–	–
Mammals	4	–	1	2
Amphibians	3	–	–	–
Invertebrates	–	–	–	1

a Includes too-frequent fire, grazing pressure, weed competition, low seed viability, germination difficulties and stochastic events.

b Includes dicotyledons, monocotyledons, pteridophytes and gymnosperms.

Source: Department of Environment and Climate Change (Parks and Wildlife Group) (NSW)

eucalypts. The greatest mortality has been in some of its most frost-resistant populations, so an important part of the species' gene pool is being lost (see Case study 18 in Indicator 1.3b for information on efforts to conserve this species). Another possible example of the effects of climate change is the mortality occurring in the small population of Tasmania's rarest eucalypt species, Morrisby's gum (*E. morrisbyi*), in the East Risdon Flora Reserve as a result of drought.

Increases in nature conservation reserves

There has been an increase in the area of public and private forests in formal and informal nature conservation reserves (Indicator 1.1c). These reserves are being managed for nature conservation objectives under a variety of national and jurisdictional programs, helping to address the risk to biodiversity caused by isolation and the loss of genetic variation. In private forests, forest purchases by governments and non-government organisations and management covenants are being used to help conserve threatened species and habitats.

References and further reading

Butcher et al (2005), Forest Practices Authority (2007), Lindenmayer et al (2003ab) (list at the back of the report).

Web resources

Case study 13: Recovery plans in South Australia

Case study 14: *Eucalyptus benthamii*

Southern Emu-wren (*Stipiturus malachurus intermedius*) Mount Lofty Ranges, South Australia.

Indicator 1.3b

Native forest and plantations of indigenous timber species which have genetic resource conservation mechanisms in place

Rationale

This indicator uses the coverage and implementation of formal genetic resource conservation mechanisms as a measure of the degree to which timber species genetic resources are managed and conserved.

Key points

- Most states and territories have guidelines and management plans for the conservation of the genetic diversity of forest timber species of commercial significance.
- Genetic resource conservation plans exist for more than 40 native timber and oil-producing species, a 70% increase on the number reported in SOFR 2003. The increase includes species used in farm forestry in drier environments.
- Tree-breeding and genetic improvement programs are expanding the scope for conserving native forest genetic resources, including non-commercial endangered species.

There are significant ongoing activities for the conservation of native forest species and communities. For forests covered by regional forest agreements (RFAs), governments have developed a set of criteria that includes broad benchmarks for the in-situ conservation of forest biodiversity (Indicator 1.1c). In the RFA regions, significant additional areas of forest were included in nature conservation reserves and in reserves in multiple-use public forests to meet those criteria. There were relatively high reservations of rainforests (35% of the pre-1750 distribution), mangroves (32%), eucalypt tall open forests (29%) and eucalypt low open forests (29%).

In addition to these reservations, ex-situ seed orchards and conservation plantings have been made for several rare and endangered species, including Miena cider gum (*Eucalyptus gunnii* subsp. *divaricata* – Case study 18 on the SOFR website), Camden white gum (*E. benthamii*), Brooker's gum (*E. brookeriana*), Risdon peppermint (*E. risdonii*), varnished gum (*E. vernicosa*), spinning gum (*E. perriniana*) and Morrisby's gum (*E. morrisbyi*) in Tasmania.

Most states and territories have guidelines and management plans for conserving the genetic diversity of native forest timber species of commercial significance. In the regeneration of native production forests, the aim is to maintain local gene pools and the approximate composition and spatial distribution of the species (including non-timber and understorey species) that were present before harvesting. Plans include specifications for seed collection and the selection of seed trees of good form and health.

Codes of forest practice, such as those in Victoria and Tasmania, require native forests to be sown with species that approximate the natural mix of a site's canopy trees, while allowing for those species that will regenerate naturally. Seed to be sown should be collected either from the stand to be felled or from the nearest similar ecological zone. In Western Australia, silvicultural guidelines specify the seed sources to be used in the rehabilitation of cleared areas in jarrah forest (Case study 15).

The Australian Tree Seed Centre in Canberra, ACT, maintains a national collection of more than 900 species in some 75 mainly Australian genera, including over 240 species of *Acacia*, 19 *Allocasuarina*, 11 *Casuarina*, 25 *Corymbia*, 330 *Eucalyptus* and 38 *Melaleuca*. This seed bank provides a high-quality, representative, ex-situ sample of Australia's tree and shrub genetic diversity. Originally, the centre collected and stored seed mostly on a population or provenance basis, but the emphasis has increasingly shifted to individual parent trees. These genetically distinct acquisitions are important for ex-situ genetic resource conservation. In addition to the national collection, various tree-growing communities and forest and research agencies maintain their own forest seed collections. Several of these organisations are listed in Table 31, which shows that tree-breeding and genetic conservation and/or improvement programs are in place for more than 25 native species, most of which are commercially important.

Australia is a partner in the Millennium Seed Bank Project run by the United Kingdom's Royal Botanic Gardens at Kew, the largest ex-situ conservation project ever conceived. By 2010, project partners will have banked seed from 10% of the world's wild plant species, including many of the rarest, most threatened and most useful plant species known.

Base populations for breeding

While breeding populations are maintained mainly for improving commercial wood production, they have an important spinoff in conserving genetic resources. Plant-breeding strategies require a base population with wide-ranging genetic diversity. Normally, seeds are collected from natural forests whenever new genetic material is needed. However, several of the best seed-source provenances of some eucalypts are no longer available in-situ because the original populations no longer exist. A part of this genetic material for blue gum (*E. globulus*) and shining gum (*E. nitens*) is held in existing Australian plantations and special-purpose field trials, many of which are approaching harvest age and some of which have already been felled. Plans are urgently required to collect seed from these mature stands to provide the basis for the next generation of ex-situ plantation genetic resources.

The Southern Tree Breeding Association, formed in 1983, runs cooperative national tree improvement programs for *E. globulus* (Case study 17 on the SOFR website) and *E. nitens*. The program for *E. globulus* has been running since the 1994 amalgamation of genetic material and data from eight selection and breeding programs previously managed by individual organisations. Grafted trees of *E. globulus* have been planted in the National Genetic Resource Centre at Mount Gambier, South Australia, which was launched in August 2005. Control-pollinated *E. globulus* seed is collected and stored in refrigerators, and diversity is maintained in 32 field trials spread across temperate Australia. The TREEPLAN® genetic evaluation system is being used to update genetic values in *E. globulus* and *E. nitens*.

Forests NSW manages its 40-year-old hardwood tree improvement and breeding program from the Grafton Forest Technology Centre, which opened in August 2005. Specialised clonal propagation and breeding facilities have been constructed. Clonal seed orchards of key species – *E. dunnii*, *E. nitens*, *E. pilularis* and *Corymbia citriodora* subsp. *variegata* – have been established. Clonal propagation of eucalypts by cuttings commenced in 2004 and should reach full commercial production by 2010. Hybrid eucalypts are being produced in a pot-based arboretum; these involve

Table 31: Principal native genera and species in genetic resource conservation and improvement programs in Australia

Organisation	Principal native genera and species
CSIRO Australian Tree Seed Centre (Canberra)	*Acacia, Casuarina, Corymbia, Eucalyptus*
Southern Tree Breeding Association and National Genetic Resource Centre (Mount Gambier, South Australia)	Blue gum (*Eucalyptus globulus*), shining gum (*E. nitens*)
Cooperative Research Centre for Forestry (Hobart, Tasmania)	Blue gum (*E. globulus*), shining gum (*E. nitens*), mountain ash (*E. regnans*), messmate stringybark (*E. obliqua*)
Forestry Tasmania	Blue gum (*E. globulus*), shining gum (*E. nitens*), blackwood (*Acacia melanoxylon*), mountain ash (*E. regnans*), messmate stringybark (*E. obliqua*), alpine ash (*E. delegatensis*), Brooker's gum (*E. brookeriana*), red tingle (*E. johnstonii*)
University of Tasmania	Blackwood (*Acacia melanoxylon*), myrtle beech (*Nothofagus cunninghamii*), manna gum (*E. viminalis*), swamp gum (*E. ovata*)
Department of Primary Industries and Fisheries (Queensland)	Spotted gum (*Corymbia citriodora* subsp. *variegata*), Gympie messmate (*E. cloeziana*), blackbutt (*E. pilularis*), western (Chinchilla) white gum (*E. argophloia*), large-fruited (broad-leaved) red mahogany (*E. pellita*), flooded gum (*E. grandis*), mangium (*Acacia mangium*), red cedar (*Toona ciliata*), silky oak (*Grevillea robusta*), hoop pine (*Araucaria cunninghamii*), Wollemi pine (*Wollemia nobilis*)
Forests NSW Grafton Forest Technology Centre (New South Wales)	Dunn's white gum (*E. dunnii*), shining gum (*E. nitens*), blackbutt (*E. pilularis*), spotted gums (*C. citriodora* subsp. *variegata, C. citriodora* subsp. *citriodora, C. henryi* and *C. maculata*), cadaga (*C. torelliana*), large-fruited (broad-leaved) red mahogany (*E. pellita*), flooded gum (*E. grandis*), Gympie messmate (*E. cloeziana*), Sydney blue gum (*E. saligna*), flooded gum (*E. grandis*), grey gum (*E. longirostrata*)
Collaborative programs, some from the former Australian Low Rainfall Tree Improvement Group	Blue-leaved mallee (*E. polybractea*), mulga (*E. sideroxylon*), red ironbark (*E. tricarpa*), river red gum (*E. camaldulensis*), spotted gums (*C. citriodora* subsp. *variegata* and *C. maculata*), sugar gum (*E. cladocalyx*), swamp yate (*E. occidentalis*), oil mallees (*E. kochii* and *E. horistes*)
Department of Environment and Conservation (Western Australia)	Jarrah (*E. marginata*), karri (*E. diversicolor*), WA flooded gum (*E. rudis*), York gum (*E. loxophleba*), coojong (*Acacia saligna)*

many of the main commercial species and also species that are more suited to marginal sites, tolerant of frost and/or able to grow on heavier soils (e.g. blackbutt (*E. pilularis*) with stringybark (*E. macroryncha*)) or that combine useful wood properties with rapid growth (e.g. red mahogany (*E. pellita*) with flooded gum (*E. grandis*)).

The Department of Environment and Conservation in Western Australia runs provenance trials of karri (*E. diversicolor*) and associated timber species used for site-restocking after timber harvesting. Range-wide collections of west-Australian flooded gum (*E. rudis*) are under way, and limited trials are testing the heritability of the species' natural resistance to disease.

Gene flow from plantations

Gene flow from rapidly expanding native-tree plantations (see Indicator 2.1b) into surrounding native forests (a phenomenon sometimes called 'introgression') is a potential risk, diminishing the full range of variation within local native tree populations. Breeding strategies and genetic resource management plans aim to maintain the genetic diversity of commercially utilised native species and avoid gene flow that could damage the overall genetic resource. Strategies include the careful selection of species and provenances, the genetic manipulation of flowering times and flower abundance, and silvicultural practices such as isolation distances, the use of buffer zones of non-interbreeding species, and closer planting to reduce the area of crowns able to produce flowers (see Case study 16 on the SOFR website).

Shining gum (*E. nitens*) was introduced to Tasmania from Victoria and New South Wales, and about 100,000 hectares of plantations have been established. Spontaneous hybridisation between *E. nitens* plantations and native swamp gum (*E. ovata*) and manna gum (*E. viminalis*) populations has been documented. The results of research by the University of Tasmania and the Cooperative Research Centre for Forestry are influencing guidelines for plantation establishment.

Further reading

Dieters et al (2007), Harwood et al (2007), Henson and Smith (2007), Lee (2007), Pilbeam and McRae (2007), Potts et al (2001), Smith and Henson (2007) (list at the back of the report).

Web resources

Case study 16: Gene flow studies for *Acacia saligna* and *Eucalyptus loxophleba*

Case study 17: Breeding *Eucalyptus globulus* in the Southern Tree Breeding Association

Case study 18: *Eucalyptus gunnii* subsp. *divaricata* ex-situ seed orchard and conservation plantings in Tasmania

Case study 15: In-situ and ex-situ genetic resource conservation of jarrah in Western Australia

In Western Australia, the Department of Environment and Conservation (formerly the Department of Conservation and Land Management) provides the Forest Products Commission with guidelines on seed collection zones for the rehabilitation of cleared areas and for the species mix to be used in the regeneration of native forests.

The ecologically sustainable rehabilitation and regeneration of timber-harvesting areas requires plants that are adapted to local site conditions. Provenance trials are being conducted for jarrah (*Eucalyptus marginata*) and associated understorey species to identify seed collection zones for genetic material that suits the rehabilitation requirements of particular sites. Under the silvicultural guidelines, seedlings for planting should be grown from seed sourced from a seed zone appropriate to the species' genetic management.

Genetically based resistance to the fungal pathogen *Phytophthora cinnamomi* (also called 'dieback') has been demonstrated in jarrah. Under a long-term selection and screening program, inoculation trials have been carried out and field validation trials have been established to prove the selections. Individuals showing the highest resistance have been propagated and multiplied by tissue culture. The resulting clonal lines have been used in further validation trials, in field plantings, and to establish seed orchards for the production of dieback-resistant jarrah for future operational forest rehabilitation planting.

The department's Sustainable Forest Management Guideline No. 1 (*Silvicultural Practice in the Jarrah Forest, 2004*) describes measures that must be taken to retain jarrah trees that show resistance to *P. cinnamomi*; such trees form an important genetic resource and are a potential source of seed.

Ex-situ conservation stand of cider gum (*Eucalyptus gunnii*), Tasmania.