

Biodiversity

5

5.1	Native fauna and threatened species	212
5.2	Native vegetation	224
5.3	Reserves and conservation	236
5.4	Invasive species	250
5.5	Fire	264
	References	273



5.1 Native fauna and threatened species

The overall diversity and richness of native species in New South Wales remain under threat of further decline. Thirty-five additional species have been listed as threatened under NSW legislation since 2009, including 11 terrestrial vertebrate species. The conservation status of 66% of terrestrial vertebrate species still remains non-threatened.

A general pattern of decline in biodiversity over the longer term is evident in changes to the extent and abundance of many native vertebrate species. At the same time, many species less susceptible to existing pressures have maintained their distributions, while a small number of adaptable species have flourished.

In terms of declines detected over historical time frames of around 200 years, birds have been more resistant to change than other vertebrate groups, whereas there have been substantial declines in mammals, especially small- to medium-sized ground-dwelling species.

Currently, 989 species of plants and animals, 49 populations and 107 ecological communities are listed as threatened in NSW legislation, and 45 key threatening processes have been identified. These numbers continue to rise.

Overall outcomes for native species represent the cumulative impact of many diverse pressures and threats. The main threats to native species are vegetation clearing, habitat degradation and invasive species, with vertebrate fauna in particular impacted by foxes and cats on the mainland and introduced rodents on islands.

NSW indicators

Indicator and status	Trend	Information availability
Terrestrial mammals: long-term (~200 year) loss of distribution	Stable	✓
Birds: long-term (~200 year) loss of distribution	Stable	✓
Proportion of vertebrate fauna species that is non-threatened	Decreasing	✓✓
Number of threatened species, communities and populations	Increasing	✓✓

Notes: Terms and symbols used above are defined in *About SoE 2012* at the front of the report.

Introduction

Biodiversity is the diversity of ecosystems, the species and populations they support and the genes they contain. It also encompasses the complex interactions between living organisms and the environment which provide the basis for a range of ecosystem services and maintain the health and productivity of the land.

NSW has a rich biodiversity, much of which is recognised as being internationally significant.

It is seldom possible to monitor or report on biodiversity across its breadth (Saunders et al. 1998). Because of the paucity of data for other groups, this section is largely restricted to dealing with the status of native fauna, particularly terrestrial vertebrates, and native plant and animal species listed as threatened under the *Threatened Species Conservation Act 1995* (TSC Act) and *Fisheries Management Act 1994* (FM Act).

A shrinking distribution is often the first and only evidence that a species is declining in numbers. Declines in many species have been under way for decades or longer, but have largely gone unrecorded. Heightened awareness of the plight of native flora and fauna over the past two decades has revealed the extent of many of these declines and the threats that cause them. For example, the eastern quoll once ranged over most of eastern NSW, but is now found only in Tasmania, representing a 100% decline in distribution in NSW which occurred before any estimates had been undertaken. In western NSW, 24 species of mammal became locally extinct between European settlement in 1841 and Federation in 1901 (Morton 1990; Lunney et al. 2000).

Much effort has gone into arresting declines that were largely incurred before the NSW Government recognised the need to formally protect native species. Growing knowledge about the extent of declines in species has the potential to mask recent achievements in stabilising declines and recovering some species.

Status and trends

Native fauna

The status of species under threat varies regionally and across Australia. Some species lost from NSW, such as the pig-footed bandicoot, are extinct throughout Australia, while others, such as the numbat, are still found elsewhere in Australia. A number of species no longer exist on the NSW mainland, but survive on predator-free islands. The brush-tailed rock-wallaby is listed under both the TSC Act and *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth), but is under greater threat in Victoria than NSW. Conversely, the koala is threatened in NSW but not in Victoria, where it is regarded as being over-abundant.

Declines in distribution and abundance

The lack of data makes it difficult to assess the distribution and abundance or conservation status of many species of native fauna, particularly those that are rare. The first comprehensive assessment of vertebrate fauna in NSW was undertaken in 1992 (Lunney et al. 2000) to determine which vertebrate species should be listed as threatened under the TSC Act and which did not require listing. *SoE 2009* (DECCW 2009a) provided clear evidence that the decline of NSW species was ongoing and concluded that the long-term sustainability of many species was poor.

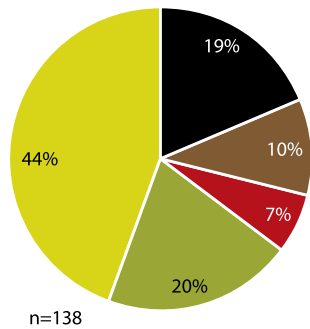
An estimated 897 species of native terrestrial vertebrates were found in NSW at the time of European settlement. Long-term changes in distribution since settlement have been estimated for all species for which there is adequate and reliable data (Mahon et al. 2011), using a methodology that relies on data collected at low intensity but rigorously and continuously over 200 years. The cumulative record can be used to build up and describe overall patterns of distribution over longer time frames.

The outcomes of this analysis were presented for mammals, birds, amphibians and reptiles in Figure 7.2 of *SoE 2009* (DECCW 2009a). As the outcomes described by this data are only expected to change slowly, over much longer time frames than the present reporting cycle of three years, the results of the 2009 analysis still apply.

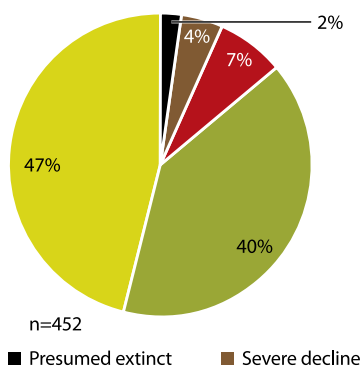


Figure 5.1: Long-term loss of distribution for native mammals and birds

Mammals (long-term)



Birds (long-term)



Source: Mahon et al. 2011; DECCW 2009a

Notes: Presumed extinct – 100% change (contraction) in distribution

Severe decline – 50–<100% change in distribution

Moderate decline – 25–<50% change in distribution

No significant decline – less than 25% change in distribution

n = the total number of species recorded as inhabiting NSW at the time of European settlement, but not including species regarded as 'vagrants' (occasional or accidental sightings of species well outside their normal range)

The results for birds and mammals shown in **Figure 5.1** illustrate the best and worst outcomes for the different vertebrate groups.

Over the longer term, outcomes for birds have been much better than for mammals, with only 2% of bird species (12 species of 452) becoming extinct compared with 19% of mammals (26 of 138 species). Losses of distribution of 50% or greater (including extinctions) involved only 6% of birds (31 species) compared with 29% of mammals (40 species).

The data reveals that, historically, birds have been significantly less susceptible to the pressures that have affected other terrestrial vertebrates, particularly mammals. Nine of the 12 bird extinctions occurred on Lord Howe Island which is a localised hotspot for bird extinctions. If these figures are disregarded, the persistence and survival of bird species on mainland NSW is even more pronounced.

However, shorter term data on bird populations produced over the past 10 years indicates that their numbers and range have recently declined significantly (Garnett et al. 2010; Mahon et al. 2011). This suggests that the relatively good outcomes for birds recorded over longer time frames may not be sustainable. Populations of woodland birds have declined the most (MacNally et al. 2009; Paton & O'Connor 2010), due to the extensive clearing of woodlands described in Biodiversity 5.2 and the effects of extended drought over much of the past decade.

Patterns of decline in vertebrate fauna groups

Most extinctions of native fauna in NSW have been in small- to medium-sized species of ground-dwelling mammals, including small wallabies, native mice, bandicoots and bettongs (Dickman et al. 1993; Lunney et al. 2000). Many of these species inhabited arid shrublands and grasslands in the west of the state and most of them had become extinct by the end of the nineteenth century. Predation by foxes and cats and overgrazing by stock have been attributed as the main causes. Other factors that may also have contributed to the decline include competition with invasive species, such as rabbits and goats, and the habitat degradation they cause, as well as changed fire regimes.

Historically, species that were habitat or dietary specialists have been the most vulnerable to extinction. Species that survived occupied a broader range of habitats and had broader dietary requirements. A similar pattern is also evident in surviving mammal species, with non-threatened species generally occupying a greater range of habitats than those under threat. Ground-dwelling mammals that occupy a broad range of habitats, such as woodlands and forests, as well as grasslands and shrublands, have better prospects for survival than those that occupy a narrower habitat range. The prospects for survival of arboreal or tree-dwelling species are significantly greater than those of ground-dwelling species (Lunney et al. 2000).

Regional patterns are also evident in the extinction or persistence of species. For example, nine of the 12 species of birds that are extinct in NSW were found only on Lord Howe Island, with human settlement and introduced rodents being the major pressures. The other three species were found in central or western NSW.

The largest number of mammal species, both threatened and non-threatened, are found in north-eastern NSW, where open forest habitats contain 38 non-threatened and 33 threatened mammal species. However, the habitat where the highest levels of mammal extinctions have occurred, by number and proportion, is the semi-arid shrubland in the west of the state, with 18 extinct species (Lunney et al. 2000).

An example of decline – koalas

As part of the process of preparing the approved Recovery Plan for the Koala (DECC 2008a), a major statewide survey of koalas was undertaken. This showed that koalas are concentrated along the north coast and in the north-east of the state within the eastern edge of the Murray–Darling Basin, particularly on the Liverpool Plains around Gunnedah. Comparison with a similar survey in 1986–87 showed that in contrast to general declines elsewhere in NSW, the koala population on the Liverpool Plains had expanded in the intervening two decades, where it was using trees planted in the 1990s to combat soil degradation and erosion as habitat (Lunney et al. 2009). However, intense heatwaves during the drought in 2009 killed about a quarter of this population, showing that short-term fluctuations in numbers also need to be considered when assessing the status of fauna populations.

Species with stable populations

Assessment of change in species distribution and abundance tends to focus on declines because this is the most common change. However, Figure 5.1 shows that the distributions of most bird species (for which there is sufficient data) have not declined over the long term. Disregarding the figures for extinctions, even in the case of terrestrial mammals, slightly more species have stable distributions than declining ones. Therefore, while many populations of species are declining in numbers and range due to human-caused habitat disturbance, many other species have been less susceptible to the effects of these pressures and maintained relatively stable populations.

Some species are more adaptable and can take advantage of human disturbances, even becoming nuisances which affect or interfere with human activities. The nuisance may be local – such as brush-tailed possums in the roofs of houses, ibises near airport runways or at waste disposal sites, and flying-foxes in orchards or near houses and schools – or regional – such as kangaroos on rural lands.

There is also some limited evidence that a few native species may be expanding in numbers or range, but such outcomes are rarely studied and difficult to demonstrate conclusively. However, some native species have become invasive after being translocated from their natural habitats, particularly native freshwater fish (see Table 5.12 and Table 5.17).

Threatened species

Species considered to be threatened can be listed as 'extinct', 'critically endangered', 'endangered' or 'vulnerable' in the schedules to the TSC Act or FM Act. Threatened populations and ecological communities are also listed in these Acts. Scientific committees established under both Acts evaluate all submissions for adding or removing species from the lists.

The conservation status of a species is based on its prospects for survival, its numbers and patterns of reproduction, and the pressures and risks that threaten it. This assessment is distinct from the analyses of species distributions and abundance described above, but population data would contribute to assessing a species' conservation status when it is available. Despite evidence of a decline in its abundance and range, a species may not be listed as threatened if its survival is not considered to be at risk.

Listed threatened species, populations and ecological communities

At 31 December 2011, 989 species in NSW were listed as threatened in the TSC and FM Acts. Over the past three years, 35 additional species have been added to the listings, including 11 terrestrial vertebrate species – an increase in listing of 3.7%. The number of extinct species has increased by three.



Table 5.1: Number of listed threatened species, populations and ecological communities in NSW

Taxa	No. of native NSW species	Extinct	Critically endangered	Endangered	Vulnerable	No. of threatened species listed	% of species listed	Endangered populations
Mammals	138	25	2	16	39	82	59%	10
Marine mammals	40	0	0	3	4	7	17%	0
Birds	452	12	11	23	90	136	30%	7
Amphibians	83	0	5	12	11	28	34%	1
Reptiles	230	1	0	18	23	42	18%	1
Plants	4,677	33	44	335	231	643	14%	25
Aquatic plants and algae	?	1	1	0	0	2	?	1
Freshwater fish	55	0	2	6	1	9	16%	3
Marine fish, sharks and rays	?	1	1	1	3	6	?	0
Terrestrial invertebrates	?	1	2	14	0	17	?	1
Aquatic invertebrates	?	2	1	3	2	8	?	0
Fungi	?	0	0	5	4	9	?	0
Total	?	76	69	436	408	989	?	49

Source: Office of Environment and Heritage (OEH) and Department of Primary Industries (DPI) data 2012

Notes: Based on listings at 31 December 2011

Table 5.1 displays numbers of listings for various plant and animal groups.

Terrestrial mammals are particularly at risk, with 59% of all species in NSW now identified as threatened. Other fauna groups to be severely affected include amphibians (34%), birds (30%), reptiles (18%), marine mammals (18%) and freshwater fish (16%). A total of 643 plants (14%) have also been identified as threatened.

The number of endangered populations is now 49, an increase of five (12%) since 2008, with populations of plants, mammals and birds being most represented. There are now 107 threatened ecological communities, an increase of 16 (18%) over the past three years.

Figure 5.2 shows the growth in the total number of listings of threatened species and ecological communities since 1995. Over the same period, the conservation status of some listed species and communities has continued to deteriorate, with many moving into higher risk categories and closer to the risk of extinction. There are now 505 endangered or

critically endangered species, compared with 471 in 2009 and 251 in 1995.

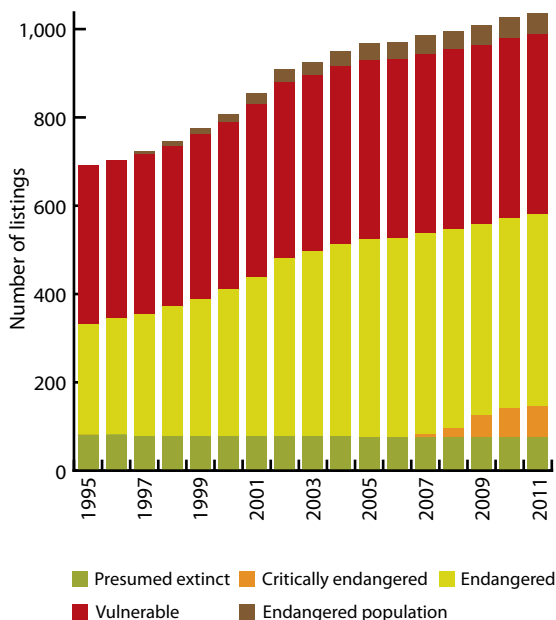
Interpretation of threatened species listings

The significance of changes in the number of listings of threatened species between reporting cycles and their interpretation is the subject of ongoing scientific investigation and debate. Some changes in conservation status may reflect improvements in the availability of information and knowledge rather than recent changes in species' prospects for survival (Keith & Burgman 2004). This is possible for most flora and fauna groups, such as invertebrates, where the full number of species is still not known with any certainty.

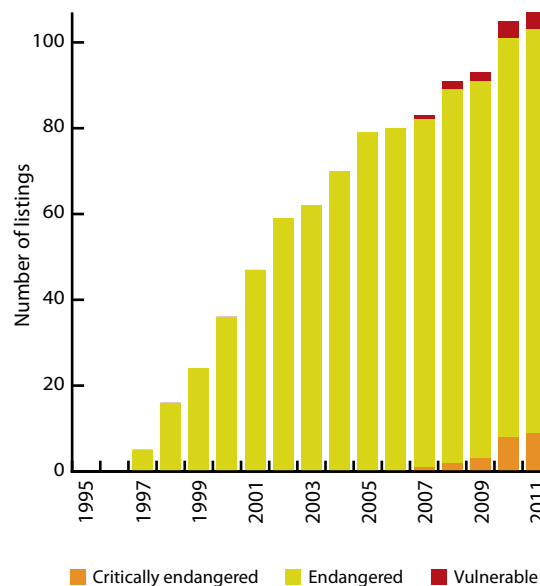
However, terrestrial vertebrates are relatively well-studied and the conservation status of all species in these groups was assessed soon after the TSC Act was introduced (Lunney et al. 2000). Any subsequent changes in status in these groups are more likely to reflect actual changes in their prospects for survival than recently filled gaps in information.

Figure 5.2: Changes in total listings of threatened species and ecological communities, 1995–2011

Threatened species



Threatened ecological communities



Source: OEH data 2012

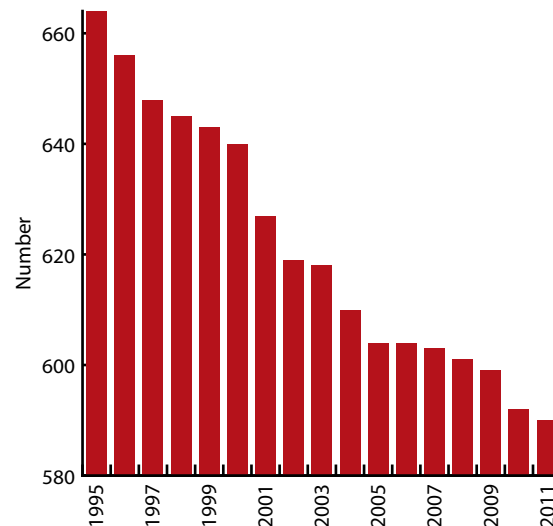
In the case of populations and ecological communities, their description or classification is open-ended so any changes reflect a pattern of new listings that had not previously been assessed. It is not possible to interpret these patterns as it is not clear when the actual declines that resulted in listing occurred.

Species that are not threatened

Where the total number of species in a group is known and there is sufficient information to systematically assess their conservation status, their overall prospects for survival can be described by looking at changes in the proportion of species that are listed as threatened over time. This information is available for terrestrial vertebrates (mammals, birds, reptiles and amphibians) and is shown in **Figure 5.3**.

Of the 903 terrestrial vertebrate species that inhabited NSW, 662 or 73% were not listed as threatened in the first assessment of conservation status, completed in 1995. This number has declined to 590 or 65% in 2011. Terrestrial vertebrates are the most well-known and best-studied group and the deteriorating conservation status of these species reflects the increasing number and intensity of pressures affecting the biodiversity of NSW. There is no reason to doubt that other, less well-studied groups are declining similarly.

Figure 5.3: Changes in the number of vertebrate species not listed as threatened under the TSC Act, 1995–2011



Source: OEH data 2012

Notes: For the purposes of this analysis, 'vertebrate species' refers to mammals, birds, reptiles and amphibians. It does not include fish, which are listed separately under the FM Act or marine mammals about which less is known due to their cryptic lifestyle and habits.

Pressures

The most important threats to ecosystems around the world have been identified (Millennium Ecosystem Assessment 2005) as:

- habitat change (land-use change, physical modification of rivers or withdrawal of water from rivers)
- over-exploitation
- invasive species
- pollution
- climate change.

The threats to biodiversity in NSW are varied and are described in greater detail in other sections of this report, including:

- clearing, fragmentation and disturbance of native vegetation (Biodiversity 5.2)
- land degradation (Land 3.1)
- the introduction of invasive species of pests, weeds and diseases and pathogens (Biodiversity 5.4)
- overgrazing by cattle, sheep and invasive herbivores (Biodiversity 5.2)
- changes to fire regimes (Biodiversity 5.5)
- changes to water flows (Water 4.1).

Over-exploitation and pollution are less substantial threats in the NSW context.

Main threats to threatened species

When a species, population or ecological community is listed as being threatened under the TSC Act or FM Act, the main pressures and threats affecting its conservation status are also described. These threats have been analysed for all threatened species listed in the TSC Act to identify the threats that have the greatest impact on biodiversity and the environment in NSW (Coutts-Smith & Downey 2006). The pressure affecting the largest number of threatened species in NSW (87%) is the clearing and disturbance of native vegetation, followed by invasive pest and weed species (70%).

Introduced pests are likely to have had the greatest impact on native fauna. In particular foxes and cats are considered to be responsible for the majority of fauna extinctions in NSW (Morton 1990; Dickman 1996a; Dickman 1996b). Based on the evidence above, the clearing of native vegetation and impacts of introduced species are therefore the most significant threats to biodiversity in NSW. However, many threats operate together to hasten the decline of species and communities and species often face multiple threats, requiring an integrated set of targeted actions to ensure their survival.

Listed key threatening processes

The biodiversity of NSW is subject to an increasing number and range of threats. The TSC Act and FM Act both list the key threatening processes (KTPs) that impact on native plants and animals. At 31 December 2011, there were 45 KTPs listed for NSW, an increase of five over the preceding three years. Thirty-seven were listed in the TSC Act and eight listed in the FM Act. There is, however, some overlap in the threats listed, with climate change, shark meshing and changes to river flow regimes listed in both Acts in some form.

Table 5.2 summarises the types of KTPs listed. Over 50% of all KTPs relate to invasive species, with 23 associated with pests and weeds and a further five pertaining to pathogens and diseases.

Table 5.2: Summary of the key threatening processes listed in NSW, 2011

Issue	Number of KTPs
Invasive species	23
Habitat change	10
Disease	5
Over-exploitation	3
Climate change	2
Altered fire regimes	1
Pollution	1
Total	45

Source: OEH and DPI data 2011
Notes: At 31 December 2011

Climate change

As many Australian species are adapted to highly variable climates, they are likely to have some capacity to cope with expected changes in climate. However, their resilience may have been eroded by existing pressures on biodiversity which have resulted in documented declines. Climate change is expected to exacerbate the effects of existing threats and introduce additional pressures (Steffen et al. 2009; DECCW 2010a; Hughes 2011).

Studies suggest that climate change could surpass habitat destruction as the greatest global threat to biodiversity over the next few decades (Leadley et al. 2010). Its likely effects include changes to species' distributions and the timing of their life cycles, and disruptions to food chains (Bellard et al. 2012). Species with broader geographic and habitat ranges, dietary requirements and environmental tolerances are expected to cope better and some will benefit from a warming climate (Chessman 2011).

The composition and function of ecosystems will be affected by changes in fire regimes and hydrological flows, as well as in the distribution and abundance of species. Many of the most vulnerable ecosystems in Australia are found in NSW and are sensitive to changes in climate. These include ecosystems that only exist at certain elevations, coastal floodplains and wetlands, the wetlands and floodplains of the Murray–Darling Basin, temperate eucalypt forests, and saltmarshes and mangroves. The main threats to these ecosystems are extreme weather events and changes in water balance and hydrology (Laurence et al. 2011).

There is evidence that recent climatic and atmospheric changes are already having wide-ranging effects on species (OEH 2011a). Long-term studies of 24 species of birds migrating to south-eastern Australia each year indicate that 12 species are arriving earlier by 3.5 days each decade and leaving earlier by 5.1 days each decade (Beaumont et al. 2006). Birds of the same species tend to have larger body sizes in cooler climates, so in NSW larger birds are usually found further south in their range. For eight species, birds with smaller body sizes are now being found further south in NSW, consistent with the effects of a warming climate (Gardner et al. 2009).

Rising temperatures have caused bold-striped cool skinks in south-eastern Australia to change the depth of their nests and the time at which they lay their eggs. Nest temperature affects the sex of their offspring, so more females are now being born (Telemeco et al. 2009).

A recent study found that the main factor affecting the distribution of the platypus had switched from being the availability of aquatic habitat to heat tolerance (estimated by annual maximum temperature). This switch is directly attributable to temperature changes in south-eastern Australia and raises concerns for the future of the species (Klamt et al. 2011).

Lack of Information

Knowledge of the conservation status of species has improved markedly over the past 20 years. There is now much more information available on the distribution and abundance of terrestrial vertebrates, but less is known about other groups. Patterns of decline likely to have been present for many years are still being discovered in the less well-studied groups of species, together with declines that have occurred more recently. For invertebrates, microorganisms and many plant groups, information is more likely to exist for only a few isolated species and this provides little insight into the broader status of, and prospects for, those groups.

It is unrealistic to expect that a full range of biodiversity could ever be monitored systematically with available resources. It is therefore an ongoing challenge to optimise the monitoring information that is collected so it can inform effective decision-making for managing biodiversity. Long-term monitoring projects are essential for detecting changes in patterns of distribution and abundance and the dynamics affecting them, so these can be managed appropriately while there is still scope for beneficial outcomes.

Responses


Established responses

NSW 2021

NSW 2021: A plan to make NSW number one (NSW Government 2011) is the Government's 10-year plan for NSW. Under Goal 22 – 'Protect our natural environment', the plan contains the following target: 'Protect and conserve land, biodiversity and native vegetation'. Strategies for achieving this target are:

- 'Identify and seek to acquire land of high conservation and strategic conservation value, for permanent conservation measures'
- 'Establish voluntary arrangements with landowners over the next decade to bring an average 20,000 hectares per year of private land under conservation management and an average 300,000 hectares per year of private land being improved for sustainable management'







NSW 2021 identifies actions to reduce 'red tape' (Goal 4), which includes reducing barriers associated with biodiversity controls. It specifically seeks to remove the need for dual approvals from the NSW and Australian governments for protecting threatened species and developing a common set of principles and practices to apply to offsetting disturbances to biodiversity.

Legislation


Legislation for protecting threatened species in NSW includes the:

- 
- *Threatened Species Conservation Act 1995* (TSC Act), which provides a range of strategies for protecting threatened species, populations, communities and their habitats, and addressing threats to their survival
 - *Fisheries Management Act 1994* (FM Act) which provides protection similar to the TSC Act for threatened fish, aquatic invertebrates and marine vegetation.



In accordance with section 157 of the TSC Act, a review is being undertaken to determine whether its policy objectives remain valid and the terms of the legislation are still appropriate for securing those objectives. A similar review of the FM Act was completed and tabled in Parliament in 2011 with no changes to the objectives of the Act proposed. A number of recommendations relating to aquatic habitat protection and threatened species conservation were made, and public consultation papers are being developed outlining options to improve the legislation in these areas.

Strategic policy framework



Over the past 10 years, there has been a shift in focus from recovering individual threatened species, an approach which is largely reactive, to a more strategic focus on conservation across the whole landscape and the protection of communities and habitats. Consistent with this approach, there has been more emphasis on benefiting as many species as possible by addressing general threats to biodiversity and the processes that lead to decline. Nevertheless, for many threatened species, their prospects for survival can only be improved through undertaking a specific set of management actions at identified priority sites.

A biodiversity strategy is under development and the *Draft New South Wales Biodiversity Strategy 2010–2015* (DECCW 2010b) was released for public consultation from November 2010 to February 2011.

Priorities action statements

Priorities action statements (PAS) provide a strategic framework for coordinating conservation and management actions across the more than 1000 entities (threatened species, populations and communities) that are listed as threatened in NSW. One PAS is in place for entities listed in the TSC Act and one for entities listed in the FM Act.

With the implementation of the PAS for both Acts, NSW became one of the first jurisdictions in the world to formally document the management requirements of its threatened species, populations and communities. Following its first three years of operation (2007–10), the performance of the PAS for the TSC Act is being reviewed to revitalise threatened species management in NSW.

Threat abatement plans

Threat abatement plans (TAPs) have been developed to manage some listed key threatening processes (KTPs). These include TAPs for the red fox, bitou bush and boneseed, and gambusia under the TSC Act, and a TAP for the removal of woody debris from rivers and streams under the FM Act.

Each TAP:

- outlines actions to manage the relevant key threatening process
- provides a program and timetable for carrying out the actions
- explains how the success of these actions will be measured.

BioBanking

The Biodiversity Banking and Offsets Scheme (BioBanking) is a market-based scheme designed to reduce the impacts of development on biodiversity, particularly threatened species and ecological communities. BioBanking enables developers to offset the impacts of development on biodiversity at one site by improving its management at other sites, provided that overall biodiversity values are improved or maintained. Offset (biobank) sites are expected to contain the same threatened species or ecological communities as those affected by the development and must be managed for conservation in perpetuity.

BioBanking is currently being reviewed to identify its strengths and challenges, ensure it achieves effective environmental outcomes and is practical to use.

Planning and biocertification

The *Biodiversity Certification Assessment Methodology* (DECCW 2011) was introduced in February 2011. Biodiversity certification provides a streamlined process for assessing the biodiversity of areas proposed for development during strategic planning and a range of enduring options for offsetting impacts on biodiversity. After biodiversity certification is conferred on an area, development may proceed without the usual requirement for site-by-site assessments of threatened species listed in the TSC Act.

On-ground programs and management

The strategic framework described above provides direction for a range of conservation programs and activities that are delivered locally and regionally. These programs protect native species, reduce threatening processes and provide effective conservation outcomes.

Reservation

A dedicated system of national parks and reserves is the cornerstone of conservation efforts to preserve and protect biodiversity and ecosystems in NSW. Approximately 8.8% of land and 34% of NSW marine waters have been incorporated into the terrestrial and marine reserve systems. Conservation in reserves is being supplemented by conservation measures on other public and private lands, which are described in Biodiversity 5.3. Under *NSW 2021*, the NSW Government has committed to establishing more national parks, including the new Dharawal National Park.

Recovery plans for threatened species

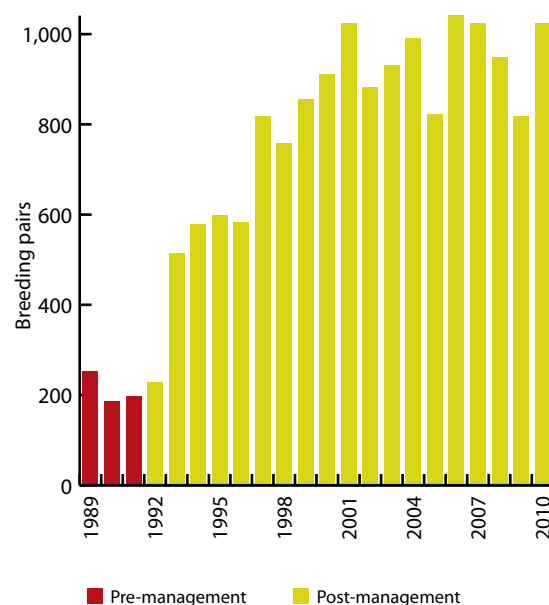
Both the TSC and FM Acts provide for the development of recovery plans for threatened species. Targeted recovery plans set out management actions to ensure the survival of high-profile, complex or critically endangered species. However, around 90% of species listed as threatened under the TSC Act are not covered by a recovery plan and are managed under the PAS system. Nineteen per cent of species listed under the FM Act have recovery plans in place, with recovery and threat abatement strategies for the remainder incorporated into the PAS for the FM Act.

Recovery of species

The status of some threatened species such as the Lord Howe woodhen, little tern and Gould's petrel has improved through direct conservation action. Recovery actions for Gould's petrel have increased numbers from fewer than 250 breeding pairs in the early 1990s to about 1000 pairs, as shown in **Figure 5.4** (Priddel & Carlile 2009). In addition, a second colony of this island-nesting seabird has now been established through the translocation of nestlings (Priddel et al. 2006). Accordingly, the listing of this species has changed from endangered to vulnerable. To date, this is the only instance of a threatened species in NSW having improved its conservation status as a direct result of such actions.

Management actions have significantly reduced the impact of invasive species on some NSW offshore islands. Exotic rodents and rabbits have been eradicated from several islands (Priddel et al. 2011), which has reduced predation on, and competition with, seabirds and other native species, and facilitated the return of some species previously eliminated by these pests, such as the white-faced storm-petrel. The removal of the highly invasive weed Kikuyu grass from Montague Island has stopped little penguins becoming entangled in the grass, improving their survival rate.

Figure 5.4: Number of breeding pairs of Gould's petrel, 1989–2010



Source: OEH data 2012

Table 5.3: Combined performance outputs of programs delivered regionally for natural resource management in NSW during 2010

Natural resource management actions	Area (ha)
Total area of native vegetation protected and actively managed under new conservation covenants on public and private land, including:	859,500
– Area of land added to the national parks system	378,600
– Area of native vegetation protected by property vegetation plans on public or private land	3,000
Total area of native vegetation where vegetation condition was improved, including:	1,360,000
– Area of terrestrial vegetation where vegetation condition was improved	730,000
– Area of riparian vegetation where vegetation condition was improved	20,400
– Area of wetland and aquatic vegetation where vegetation condition was improved	127,000
Total area of land managed to control or eradicate new, widespread or invasive weeds	3,500,000
Total area of land managed to reduce the impact of feral pest animals, including:	5,300,000
– Area where specific pest control activities were carried out (baiting, trapping, shooting)	984,000

Source: OEH data 2011

The critically endangered Lord Howe phasmid (or giant stick insect) has been successfully bred in captivity, for reintroduction to Lord Howe Island once rats and mice have been eradicated. The phasmid was once common on Lord Howe Island, but disappeared soon after rats arrived in 1918 after a cargo ship ran aground. It was thought to be extinct until a tiny population was rediscovered in 2001 (Priddel et al. 2003).

Natural resource management

NSW natural resource management programs are primarily delivered regionally through the state's 13 catchment management authorities (CMAs). The CMAs reflect regional priorities and sensitivities in their catchment action plans. These plans provide the direction and framework for delivering programs regionally while incorporating statewide targets and objectives. CMAs engage with their local communities, and support private and public land managers and community volunteers in maintaining and restoring the natural environment.

For the first time, the collective actions of the CMAs and government agencies can now be compiled and reported on in a common framework for describing program performance, and this reporting will be improved and refined in the future. It is recognised

that in natural resource management it can take a long time for the outputs of programs to be fully effective, and reach the critical levels needed to translate into measurable outcomes and environmental change. Actions benefiting biodiversity throughout 2010 are summarised in **Table 5.3**.

Under the *NSW 2021* target to protect and conserve land, biodiversity and native vegetation, the NSW Government is committed to working with CMAs and local community groups to deliver programs that will:

- regenerate degraded natural bushland, including riverbanks and degraded waterways, through a \$10-million fund
- purchase and protect strategic areas of high conservation value and ensure more green spaces across Sydney and NSW through the \$40-million Green Corridors Program
- increase Aboriginal participation in natural resource management by supporting Aboriginal Green Teams and other Aboriginal groups working to protect and conserve natural environments
- better protect threatened and iconic species, such as koalas, and review the PAS for the TSC Act to enable community groups and businesses to get involved in threatened species conservation.

Regulation of clearing

The clearing of native vegetation and harvesting of non-plantation native forest timber on rural lands are regulated under the *Native Vegetation Act 2003* and enhanced systems for enforcing and monitoring compliance are now in place. Approvals to clear native vegetation have fallen significantly since the introduction of the Act. At the same time, measures to promote revegetation and improve the condition and management of native vegetation are being delivered regionally through property vegetation plans established by the CMAs and implemented by landowners (Biodiversity 5.2). Corridors and buffers are being established through urban planning processes.

Management and control of invasive species

Eradication of widespread invasive species is seldom feasible. Therefore, control of some high-priority invasive species, such as foxes and bitou bush, is specifically targeted at sites of high conservation value. Control is delivered through TAPs which facilitate whole-of-government coordination across agencies and local authorities. Broadscale rabbit control is being provided through the release of rabbit haemorrhagic disease, while rats, mice and rabbits have been eradicated from some NSW islands. CMAs are responsible for identifying priority weeds regionally and developing programs to manage them (Biodiversity 5.4).

Management of native species

Plans are needed for the management of some native fauna in NSW. Licences have been issued to manage 50 species of native fauna in NSW at least once in recent decades. Licensing is also required to conduct research to better understand and conserve native fauna and to look after animals that are taken into care for rehabilitation and subsequent release. Up to 70,000 native animals are taken into care each year.

The Kangaroo Management Program monitors numbers of the four large kangaroo species in NSW to ensure that populations do not expand at the expense of other native fauna. Changes to benefit stock, such as clearing of woodlands, removing dingos and providing watering points, have all contributed to increasing the populations of kangaroos, which are regarded as pests and culled on agricultural and pastoral lands.

Adaptation to climate change

Priorities for Biodiversity Adaptation to Climate Change (DECCW 2010c) was produced in response to the listing of anthropogenic climate change as a key threatening process under the TSC Act.

The report outlines priority measures for dealing with the effects of climate change over the next five years, which focus on four key areas:

- enhancing understanding of the likely responses of biodiversity to climate change and readjusting management programs where necessary
- protecting a diverse range of habitats by building a comprehensive, adequate and representative public reserve system in NSW, with a focus on under-represented bioregions
- increasing opportunities for species to move across the landscape by working with partners and the community to protect habitat and increase connectivity by consolidating areas of vegetation in good condition
- assessing adaptation options for ecosystems most at risk from climate change in NSW.

Management of other threats

The extraction and use of water from rivers and groundwater sources is now largely regulated and specific allocations are made for environmental flows (see Water 4.1 and Water 4.2).

Management of fire has focused mostly on reducing risks to people. However, research on the relationships between fire and the population dynamics of a range of Australian flora and fauna is now enabling fire regimes to be developed that maintain biodiversity and can be incorporated into fire management practices (Biodiversity 5.5).

Future opportunities

A combination of integrated conservation management across landscapes and actions targeted to specific species will be needed to prevent further biodiversity declines. Programs that deliver targeted on-ground actions regionally within a strategic framework are likely to achieve the most effective outcomes.

Measures to improve connectivity across landscapes and build the health and resilience of the land will enhance the capacity of species and ecosystems to adapt to, and cope with, disturbance.

More information about the factors contributing to the resilience or success of some native species and processes, in contrast to the declines of many others, may assist in efforts to maintain sustainable populations of flora and fauna species.



5.2 Native vegetation

Sixty-one per cent of New South Wales is covered by native vegetation. Of this, only 9% of NSW has vegetation considered to be in close to natural condition, whereas condition has deteriorated in the remaining 52%. Land use and land management have had an impact on the condition and function of native vegetation. Levels of vegetation clearing have stabilised over the past six years.

Land clearing has been recognised as the main threat to the extent and condition of native vegetation in NSW. While some vegetation classes, particularly woodlands and grasslands, have been substantially depleted since European settlement, others remain largely intact.

The clearing of native vegetation has been greatest in areas preferred for urban development (the coastal plain) or agricultural development (the wheat–sheep belt of central NSW).

Over the past nine years, the overall area of woody vegetation has remained relatively stable, but in the longer term positive gains in the overall extent and condition of native vegetation are expected as current programs take effect.

Vegetation condition largely reflects the primary land use and is being addressed through better land management practices. However, pressures on condition are likely to remain for the foreseeable future, due to the long-term effects of fragmentation following clearing, coupled with increasing pressures from invasive species and climate change.

NSW indicators

Indicator and status	Trend	Information availability
Extent of native vegetation	Stable	✓✓✓
Condition of native vegetation	Stable	✓
Levels of pressures on native vegetation condition	Stable	✓
Clearing rate for woody native vegetation	Decreasing	✓✓✓

Notes: Terms and symbols used above are defined in *About SoE 2012* at the front of the report.

Introduction

NSW contains a great variety of native vegetation, with outstanding examples of rainforests, eucalypt forests and woodlands, grasslands, wetlands, coastal heaths, alpine habitats and arid shrublands. Native vegetation provides essential habitat for plant and animal species, and is an integral component of healthy, functioning ecosystems.

Native vegetation extent and condition are indicators of ecosystem health and diversity (Saunders et al.

1998). While generalised mapping based only on vegetation structure and growth form provides a useful overview for reporting on the statewide status and extent of native vegetation, it is less descriptive of ecosystems. More detailed vegetation mapping based on information about species composition provides a better practical indicator of the location and status of ecosystems. However, the description in this section is largely based on generalised mapping as more detailed mapping is not consistently available across the state.

Status and trends

Vegetation extent

A dataset on the extent of NSW native vegetation was prepared under the NSW Natural Resources Monitoring Evaluation and Reporting Strategy 2010–2015 (DECCW 2010d) using a compilation of vegetation mapping and remote sensing analysis (Dillon et al. 2011). This described the extent of native vegetation in four 'extent modification categories' which represented various levels or degrees of modification and was presented as Map 7.1 in *SoE 2009* (DECCW 2009a). The four extent modification categories shown were:

- **native – intact:** native vegetation in which the structure has not been substantially altered
- **native – derived:** vegetation that is predominantly native but is no longer structurally intact as it has been substantially altered and is missing important structural components or layers

- **native/non-native mosaic:** vegetation that cannot be classified as native or non-native using current remote sensing technologies
- **non-native/other vegetation types:** non-native vegetation (crops, plantations, pasture) or other non-vegetative land cover.

This earlier map has now been combined with the latest map of change in woody vegetation. 'Woody' vegetation is vegetation that is over two metres tall with a canopy cover of more than 20%. All other vegetation is described as 'non-woody'. Whether native vegetation is woody or non-woody affects how it is monitored and hence the quality of the information available on vegetation clearing in different areas and the change in its extent (see 'Pressures'). Information is generally more reliable for woody vegetation as it is easier to monitor by satellite.

Map 5.1 depicts the location and extent of native vegetation that is woody or non-woody in each of the extent modification categories.

Map 5.1: Extent of woody and non-woody native vegetation in NSW in various states of modification

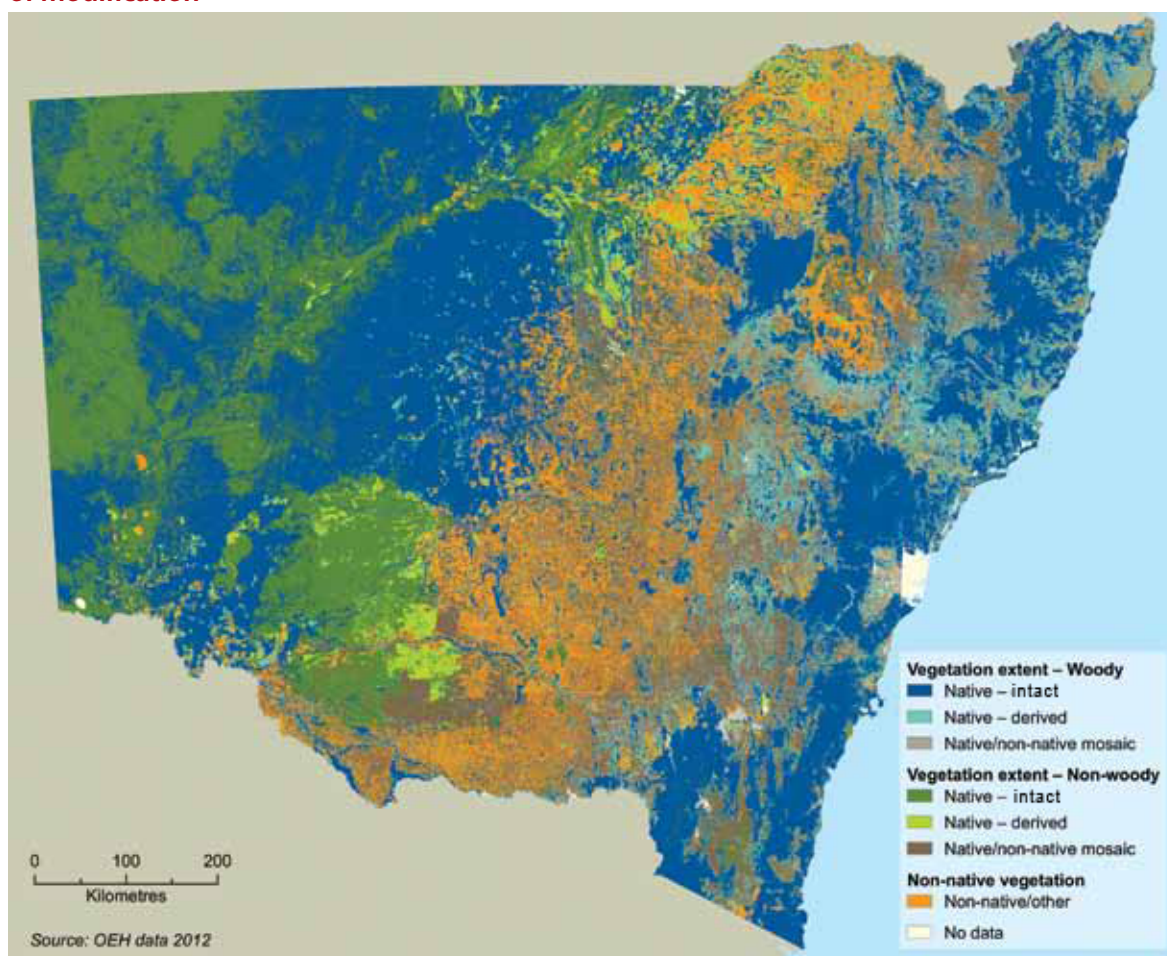


Table 5.4: Proportion of extent modification categories that is woody or non-woody

Extent modification category	Area of extent modification category (sq km)	Percentage of total area analysed*	Area of woody vegetation (sq km)	Area of non-woody vegetation (sq km)	Percentage of category that is woody vegetation
Native – intact	489,670	61%	267,960	221,710	55%
Native – derived	60,090	8%	29,970	30,120	49.9%
Native/non-native mosaic	161,780	20%	23,950	137,830	15%
Total – all categories containing native vegetation	711,540	89%	321,880	389,660	45%
Non-native/other	86,660	11%			
Total*	798,200	100%			

Notes: * This is not the total area of NSW: the analysis excluded an area of metropolitan Sydney which was not assessed.

Extent of woody and non-woody vegetation by extent modification category

The data extracted from Map 5.1 indicates the changes affecting native vegetation modified to various levels in NSW and the confidence in this information, which is greater for woody vegetation. The results are shown in **Table 5.4**.

Table 5.4 shows that 45% of all native vegetation in NSW is woody and 55% non-woody. However, this pattern is reversed for intact native vegetation, where the proportion of woody vegetation is greater (55%). Most derived and mosaic vegetation is therefore non-woody, reflecting the significant changes that have occurred to native vegetation in NSW.

The most extensive changes have been to native grasslands, most of which no longer exist as natural grasslands, and to grassy woodlands, where removal of the tree layer has created non-natural (not naturally occurring) grasslands. While the overall area of grasslands has probably now increased, most are not naturally occurring and do not consist of vegetation that can be categorised as intact native vegetation.

Extent of intact native vegetation

‘Native – intact’ vegetation covers 61% of NSW. As native vegetation in this category retains its structural integrity, naturally occurring vegetation communities can still be identified (Keith & Simpson 2006; Keith & Simpson 2008), but these communities are not necessarily in good condition. Much of the vegetation in this category faces a range of impacts on its condition from a variety of land uses, including changes to species composition and ecological function, reduced vigour or regeneration, and diminished habitat values. Only 9% of native vegetation in NSW is regarded as being in close to natural condition as it is managed with conservation as the primary objective and is therefore not subject to land-use pressures.

The current extent of intact native vegetation in NSW reflects differing rates of clearing across various parts of the state. Generally, flat productive lands have been favoured for development, with particularly high rates of clearing in native grasslands, grassy woodlands, some types of wetlands and eucalypt forests. Some other native vegetation formations, such as arid shrublands and alpine areas, occur on land that is less attractive for development and so have experienced little change in extent. **Table 5.5** summarises the status of a range of intact native vegetation formations.

Table 5.5: Extent of clearing of native vegetation formations in NSW since 1750

Vegetation formation	Status
Native grasslands	Extensively cleared or modified with only small fragments remaining outside the semi-arid zone, although some grazing lands retain important remnants
Grassy woodlands	Substantially depleted with less than 10% of some classes remaining
Rainforests	Littoral rainforests and those on coastal lowlands have been substantially reduced. Other classes of rainforests occurring in more rugged terrain are less depleted, although changes in structure and species composition have occurred in areas with a history of timber harvesting.
Dry sclerophyll forests	Less cleared, because of constraints imposed by terrain and less fertile soils, although levels of depletion are still substantial in some classes
Wet sclerophyll forests	Less cleared, because of constraints imposed by terrain and less fertile soils, although levels of depletion are still substantial in some classes
Semi-arid woodlands	Have undergone low to moderate levels of clearing (10–60%), although this has increased in recent decades
Arid shrublands	Still largely intact as they are generally less suitable for development
Heathlands	Still largely intact as they are generally less suitable for development
Alpine complex	Still largely intact as they are generally less suitable for development

Source: Keith 2004

Extent of modified native vegetation

Modified or 'derived' native vegetation covers 8% of NSW. Although the structure of derived native vegetation has been deliberately modified, more than 50% of the vegetation cover is composed of native species, so it still makes some contribution to overall native habitat values in NSW (DECC 2008b).

Vegetation described as 'native/non-native mosaic' (see Map 5.1) covers 20% of NSW and contains a mixture of native and non-native vegetation which cannot be distinguished, so this category could be regarded as indeterminate (DECC 2008b). Much of this vegetation is grassland used for grazing and the inability to categorise it reflects the less advanced state of monitoring of non-woody vegetation.

Vegetation condition

Where native vegetation has not been cleared, its condition ranges from pristine when undisturbed to heavily degraded. Between these two extremes, the condition of native vegetation may be modified to varying degrees by land management practices and unplanned threats such as weed invasion, drought and fire. The negative impacts of these threats include:

- changes to the structure, ecological function and species composition of native vegetation

- lower rates of regeneration and reduced vigour
- the prevalence of parasites and diseases
- the presence of weeds and pests.

The combined effect of these impacts diminishes habitat values and impairs ecosystem processes. Decline in vegetation condition is generally less visible than clearing and occurs over a longer time frame. It is therefore more difficult to detect and assess.

A broad assessment of vegetation condition, largely based on generalised land use where vegetation condition declines with an increase in land-use intensity, was presented in Map 7.2 of *SoE 2009* (DECCW 2009a). The map described the broad transformation that occurred to the structure of vegetation across the landscape when it was modified to make land suitable for a range of human uses, but it is static in nature and can only be updated if a further major land-use change occurs.

A more detailed analysis which incorporates site survey data on the condition of vegetation and relates it to land use and present land management practices is being developed, but this is not yet available statewide. This analysis will better reflect ongoing changes to vegetation condition that are produced by improved land management practices than the static map of land use described above.



Pressures

Vegetation extent

Land clearing

Native vegetation has been extensively cleared in NSW for settlement, industry and agriculture. Clearing facilitates land-use change and is generally irreversible due to the ongoing nature of the subsequent uses of cleared land. The process of clearing actively displaces many native animals and plants and has a negative impact on biodiversity. Over time, through the effects of fragmentation and disturbance, it leads to weed invasion and further deterioration in the condition and habitat values of the vegetation that remains.

Clearing is therefore accepted as being the main cause of vegetation change and decline. Clearing of native vegetation, and associated destruction of habitat has been identified as the process representing the greatest single threat to biodiversity in NSW (Coutts-Smith & Downey 2006). Land clearing is also listed as a key threatening process under both the *Threatened Species Conservation Act 1995* and *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth).

However, not all clearing occurs through the direct removal of vegetation. Much of the native grassland in NSW has been cleared or modified by pasture improvement, through the application of fertilisers, and by the ploughing and sowing of introduced

grasses and clovers. Some freshwater wetlands and arid shrublands have also been cleared, in effect, by prolonged overgrazing.

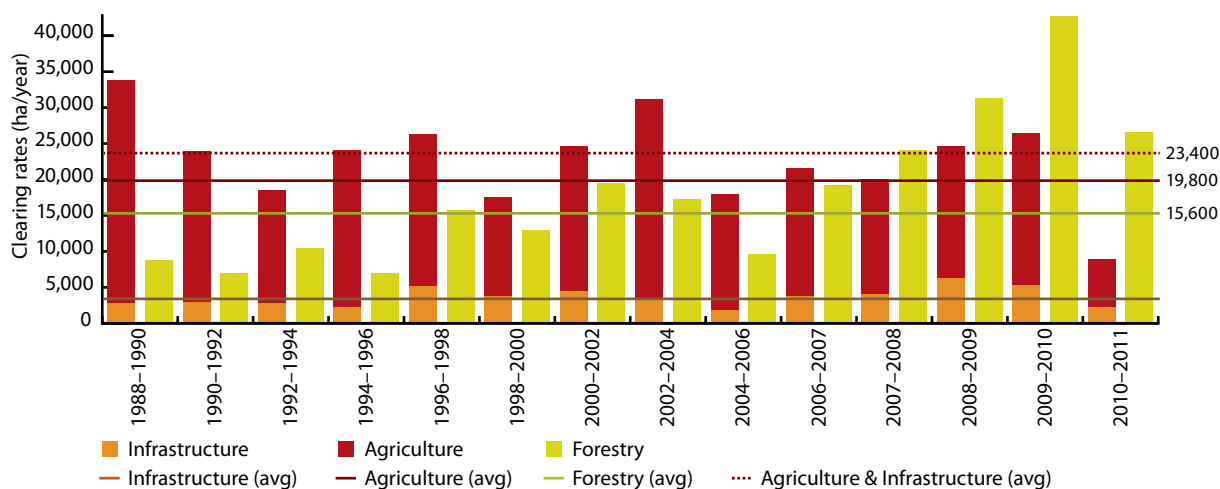
Clearing of woody vegetation

The annual record of woody vegetation change is produced by analysing Landsat remote sensing data using the SLATS methodology, developed in Queensland (DNRW 2007). This record provides an indication of the rate of clearing of woody vegetation, which is vegetation that is over two metres in height with a canopy cover of 20% or more. Generally, woody vegetation is found in forests and woodlands.

The SLATS methodology identifies changes in the extent and structure of woody vegetation that are due to agriculture, infrastructure development and forestry. **Figure 5.5** presents data on these changes.

The estimate of clearing discussed in this report relates only to activities that lead to permanent changes in land use and landscape function, that is, changes due to agriculture and infrastructure development. Since 2005, the clearing of woody vegetation has been relatively stable, fluctuating around the long-term combined average for agriculture and infrastructure of about 23,400 hectares per annum. However, in the last period of monitoring for which data is available (2010–2011) it dropped sharply to around 9,000 hectares. Most of the recent clearing has been in the wheat–sheep belt, along the eastern fringe of the semi-arid zone (DLWC 2002; Keith et al. 2009; OEH 2011a).

Figure 5.5: Woody vegetation change in NSW, 1988–1990 to 2010–2011



Source: Office of Environment and Heritage (OEH) data 2011

Notes: Until 2006–2007, the annual rate of clearing was derived from change detected over a two-year period (for example, 1988–1990 represents two years from around the end of 1988 to around the end of 1990) with the value averaged over the two years. From 2006–2007 onwards, assessments have been conducted yearly.

There is some variability in the actual length of the two-yearly or yearly intervals, depending on the availability of remote sensing data suitable for analysis due to seasonal factors.

Forestry operations have not been included as clearing because they do not lead to land-use change. Most of the areas where change is detected due to logging are expected to be regenerated as regrowth forest. A spike in forestry activity is evident in the data since 2006–2007, with levels in subsequent years above the long-term average of about 15,600 hectares per annum. However, this trend had begun to decline in 2010–2011, the final year for which data is available.

Monitoring of revegetation is inherently more complex than monitoring of clearing. A preliminary analysis in 2009 appeared to show that the overall level of woody vegetation has been stable since 2003, with clearing being balanced by regrowth, revegetation and restoration. However, further work is needed before a detailed interpretation of this result is possible.

Clearing of non-woody vegetation

Non-woody vegetation is generally all vegetation that does not meet the criteria to be classified as woody vegetation. It refers to all grasslands and large areas of open woodlands and arid shrublands characteristic

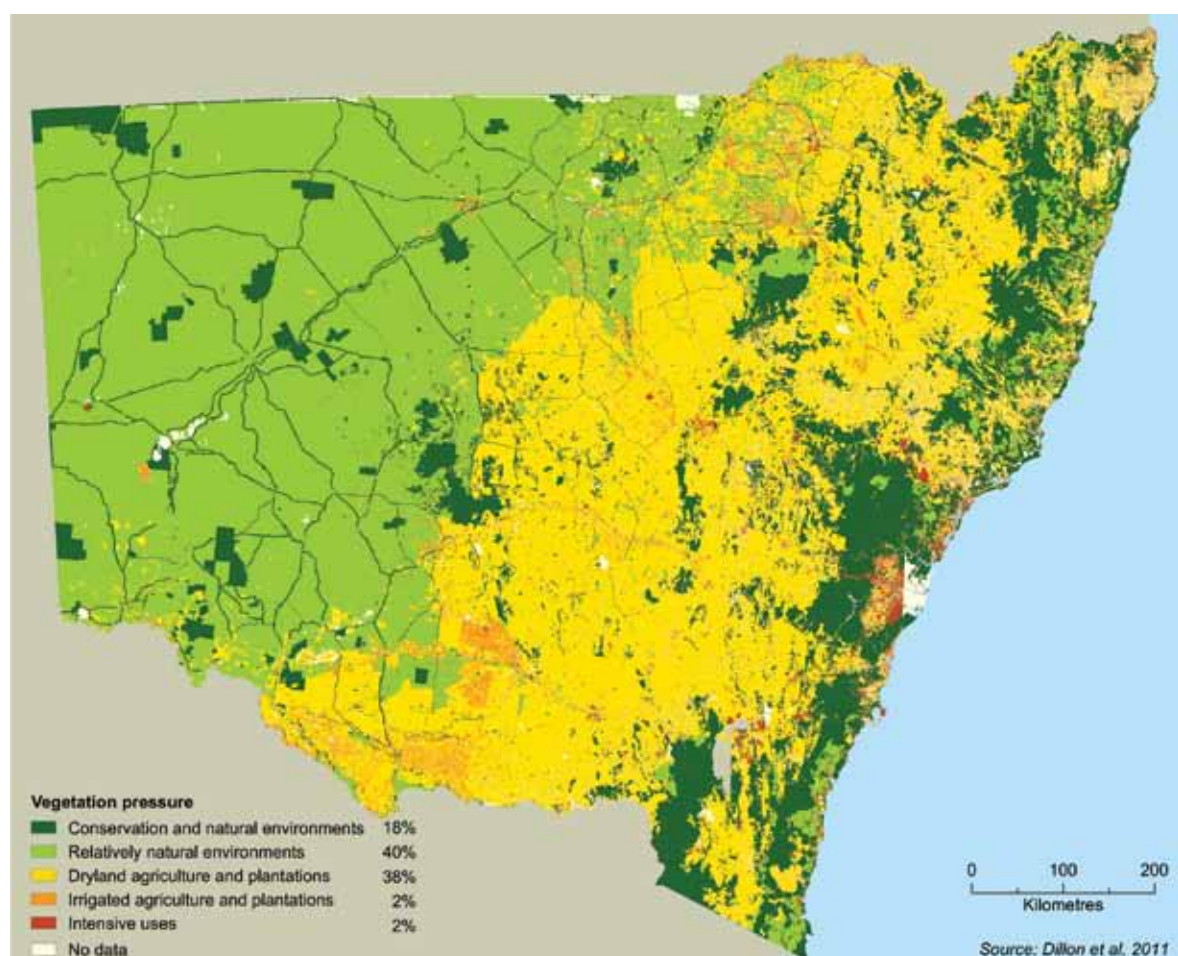
of western NSW, where densities of trees and shrubs are below the threshold of reliable detectability by the SLATS methodology. As discussed previously, 55% of all vegetation is non-woody, but it is difficult to detect change in this type of vegetation or monitor clearing of it. The processes and dynamics that affect change in non-woody vegetation are different from those affecting woody vegetation so it is not possible to use woody vegetation data to draw conclusions about the clearing of non-woody vegetation. All that is known about the overall level of clearing of all vegetation in NSW is that it is likely to be somewhat greater than the annual level of clearing detected for woody vegetation.

Vegetation condition

Land use

Map 5.2 shows the levels of pressure from a variety of land uses on vegetation extent and condition. The land uses themselves are described in *Guidelines for Land Use Mapping in Australia: Principles, procedures and definitions* (ABARES 2011). They have been reclassified

Map 5.2: Land-use pressure on the extent and condition of NSW native vegetation



into five categories of inferred pressure that describe the generally increasing levels of disturbance to native vegetation as the intensity of the operations or processes associated with a primary land use increases.

The five land-use pressure categories are:

- **conservation and natural environments** – land set aside primarily for conservation, where natural ecosystems are maintained
- **relatively natural environments** – land used primarily for agriculture, with limited changes to native vegetation
- **dryland agriculture and plantations** – land used mainly for agriculture, based on dryland farming
- **irrigated agriculture and plantations** – land used mostly for agriculture, based on irrigated farming
- **intensive uses** – land subject to extensive modification, generally in association with residential settlement, or commercial or industrial uses.

General pressures

Not all the pressure on vegetation is due to land use.

Table 5.6 summarises the main pressures affecting vegetation condition, the number of vegetation classes affected and the general changes to condition that have occurred over the past decade.

Assessment of the pressures is based on how many of the 99 NSW vegetation classes defined by Keith 2004 are affected. This assessment broadly indicates the extent of the pressure but not necessarily its intensity or significance. For instance, land clearing and the fragmentation that results is the most severe pressure but it affects only 60 vegetation classes, whereas climate change affects all 99 classes, invasive species 95, altered fire regimes 84 and soil degradation 86.

Table 5.6 demonstrates that over the past 10 years most pressures have been ongoing with little sign of abatement. There are relatively few instances where pressures are easing and most are either intensifying or stable. The main reasons for intensifying pressures are:

- changes in flows due to river regulation, compounded by a severe drought cycle during most of the past decade (2002–2010)
- climate change
- the appearance in 2010 of myrtle rust, a new fungal pathogen that threatens forests on the east coast.

The impacts of land clearing on habitat have been discussed in 'Vegetation extent'. However, habitat fragmentation caused by clearing continues to have long-term impacts on native vegetation well after the initial clearing occurs, primarily through dieback, invasions of weeds and feral animals, and loss of native species.

Changes to water regimes, combined with a particularly severe drought until 2010 (see Water 4.1 and Water 4.2) resulted in extensive dieback in floodplain forests and woodlands and this was compounded by the impacts of salinisation in the lower Murray–Darling Basin.

Climate change is pervasive and is expected to have increasing effects on all classes of vegetation in NSW. Alpine vegetation, wetlands and rainforests are likely to be especially sensitive (Laurence et al. 2011). The continuing reduction in snow cover in alpine habitats (Nicholls 2009) is decreasing the area and suitability of habitat for a range of specialised alpine species (Green & Pickering 2009).

While most arid shrublands and grasslands are not subject to extensive clearing, they are affected by overgrazing, which represents the cumulative impact of native species, farm stock and feral pest animals. The effects of overgrazing have been compounded by the drought cycle from 2002–2010, which reduced the cover of ephemeral plants. Overgrazing simplifies fauna habitat and promotes an overabundance of species which are less palatable to grazing animals.

Other significant and pervasive pressures affecting vegetation condition are discussed as separate issues in this report. These include soil degradation (Land 3.1), invasive species (Biodiversity 5.4) and fire (Biodiversity 5.5).

Table 5.6: Changes to pressures on NSW native vegetation, 2002–12

Pressure	No. of affected vegetation classes			Comments on the main dynamics and trends from 2002–12
	Intensifying	No change	Abating	
Land clearing and resulting fragmentation	9	50	1	This is the most severe* pressure, affecting about 60% of classes. Intensification is due to coastal and urban development and expansion of plantations and cropping. Some abatement has occurred following introduction of the <i>Native Vegetation Act 2003</i> and an increase in reservation of significant areas.
Climate change	99	0	0	The most pervasive threat – climate change – continues to intensify with an increasing impact across all classes. Alpine, coastal, rainforest, wetland and arid classes are the most sensitive.
Invasive species (weeds, feral animals and pathogens)	25	70	0	This is the second most pervasive threat which affects around 90% of all classes, an increase from 75% in 2006. The threat has intensified due to invasion and establishment of weeds and diseases in riparian areas and the introduction of a new pathogen, myrtle rust.
Altered fire regimes	4	78	2	This pressure is a continuing threat to more than 80% of classes, including fragmented landscapes where fire exclusion limits regeneration. Alpine and subalpine classes have experienced increased pressures due to extensive fires.
Overgrazing	24	34	3	Overgrazing affects around 66% of vegetation classes. Increased pressures to overgraze have come from the drought, especially in the south of the state.
Soil degradation	60	26	0	Erosion has continued or intensified where there are long-term effects from reduced perennial plant cover. Salinisation has intensified in lowlands due to long-term effects from less deep-rooted vegetation in recharge zones. Acidification has intensified where drying wetlands release acid sulfates.
Changes to water regimes	5	7	0	In wetlands and riparian and floodplain areas, the long-term effects of over-extraction of water during the 1970s and 1980s continue. Pressures on other vegetation classes are partially compensated for by reduced drought stress and increased environmental flow allocations since 2009.
Harvesting of native species for firewood and timber	0	8	11	Firewood collection has accelerated in woodland, while timber harvesting abated in some wet and dry sclerophyll forests due to the expansion of reserves, although this was offset to some extent by increased harvesting on private land.

Source: OEH data 2012

Notes: Totals across columns may not add up to 99 (the total number of vegetation classes) as not all vegetation classes are affected by all pressures.

* Severity refers to the intensity of the pressure and is not necessarily related to the number of classes affected. For example, the effects of land clearing are more severe but affect fewer classes than invasive species, which are more pervasive.



Responses

Established responses

NSW 2021

NSW 2021: A plan to make NSW number one (NSW Government 2011) is the Government's 10-year plan for NSW. Under Goal 22 – 'Protect our natural environment', the plan contains the following target: 'Protect and conserve land, biodiversity and native vegetation' which will be achieved through the following strategies:

- 'Identify and seek to acquire land of high conservation and strategic conservation value for permanent conservation measures'
- 'Establish voluntary arrangements with landowners over the next decade to bring an average 20,000 hectares per year of private land under conservation management and an average 300,000 hectares per year of private land being improved for sustainable management'

The priority actions associated with this target are to 'work with catchment management authorities and local community groups to protect and improve habitats on private lands'. Actions to conserve biodiversity and native vegetation include:

- 'Regenerate degraded natural bushland, including riverbanks, and degraded waterways through a \$10-million fund'
- 'Purchase and protect strategic areas of high conservation value and ensure more green spaces across Sydney and NSW through the \$40-million Green Corridors Program'

These targets and activities are described in greater detail under 'Responses' in Biodiversity 5.1.

Native Vegetation Act

The *Native Vegetation Act 2003* (NV Act) is the key legislation regulating the clearing of native vegetation in NSW. The Act came into effect in December 2005 and aims to prevent broadscale land clearing unless it maintains or improves environmental values. The Act regulates the clearing of native vegetation in most of NSW, except on land in urban areas and land excluded for major development, and in national parks, conservation areas, state forests and reserves.

The Government is presently reviewing the Native Vegetation Regulation 2005 and various other provisions under the NV Act, including the Environmental Outcomes Assessment Methodology (EOAM) and *Private Native Forestry Code of Practice*. The review is intended to cut red tape and simplify requirements, while still protecting native vegetation, soil, land and water.

Catchment action plans

Catchment management authorities (CMAs) play a central role in delivering programs to protect, maintain or improve native vegetation. They are responsible for developing catchment action plans (CAPs) which establish regional priorities for natural resource management and coordinate the delivery of programs at the regional level. More information on the role of CMAs is provided in Biodiversity 5.1.

Property vegetation plans

The provisions of the NV Act are largely implemented through a framework of voluntary agreements called property vegetation plans (PVPs), which only permit clearing on properties if environmental values are maintained or improved. PVPs are based on maintaining or improving outcomes under four criteria in the EOAM: biodiversity, soil health, water quality and soil salinity. CMAs play a pivotal role in establishing PVPs with private landholders.

A range of other measures to improve landscape management, enhance the condition of native vegetation and maintain biodiversity are also implemented through PVPs. For example, special protection is provided for landscape and vegetation types that have been cleared to below 30% of their original extent, and measures are in place to reward landowners for voluntary conservation activities. Other activities are described under 'Restoration or revegetation of native vegetation' and 'New management of native vegetation' in **Table 5.7**.

Management of native vegetation

Since 2006, the NSW Government has been collecting data on native vegetation programs from various agencies to produce a native vegetation 'report card' for publication in the *NSW Annual Report on Native Vegetation* (OEH 2011a). Table 5.7 shows the extent of activity in the following categories:

- New conservation areas
- Restoration or revegetation of native vegetation
- New management of native vegetation
- New clearing of native vegetation.

The first three categories affect the extent or condition, or both, of native vegetation positively, while the last category describes approved losses in the extent of vegetation. Table 5.7 reports on the most recent three-year period and also provides cumulative totals since data was first collected in 2006.

Table 5.7: Native vegetation report card – area of land where actions to protect or manage native vegetation in NSW have occurred

	Total (2006–08)	2009	2010	2011	Total (2009–11)*	Total (2006–11)*
New conservation areas						
Public reserve system: national parks and reserves	253,770	45,360	228,120	107,570	381,050	634,820
Public reserve system: flora reserves	2,730	0	0	0	0	2,730
Private conservation areas: voluntary conservation agreements	9,200	29,810	78,840	3,550	112,200	121,400
Private conservation areas: conservation covenants	64,150	193,190	420,390	322,660	936,240	1,000,390
Private conservation areas: Nature Conservation Trust covenants	2,320	4,810	6,120	9,810	20,740	23,060
Private conservation areas: Nature Conservation Trust revolving fund properties	7,320	9,370	540	3,350	13,260	20,580
Private conservation areas: wildlife refuges	70,370	310	110	40	460	70,830
Private conservation areas: PVPs in perpetuity	3,240	6,480	63,390	7,710	77,580	80,820
Private conservation areas: BioBanking agreements	0	0	80	330	410	410
Total area	413,100	289,330	797,590	455,020	1,541,940	1,955,040
Restoration or revegetation of native vegetation						
Incentive PVPs	252,560	126,620	144,250	63,180	334,050	586,610
PVP offsets	14,520	7,360	19,970	4,040	31,370	45,890
Native plantations	60,500	4,360	10,470	4,690	19,520	80,020
Revegetation through other incentives (non-PVPs)	662,940	42,120	50,680	25,900	118,700	781,640
Retained as a condition of approval to clear: <i>Plantation and Reafforestation Act 1999</i> and <i>Native Vegetation Conservation Act 1997</i>	24,980	650	170	20	840	25,820
Wildlife refuges: habitat restored	131,940	550	7,970	280	8,800	140,740
Natural regeneration excluding invasive native scrub	22,930	0	0	0	0	22,930
Total area	1,170,370	181,660	233,510	98,110	513,280	1,683,650

Table 5.7: Native vegetation report card – area of land where actions to protect or manage native vegetation in NSW have occurred (continued)

	Total (2006–08)	2009	2010	2011	Total (2009–11)*	Total (2006–11)*
New management of native vegetation						
Invasive native scrub PVPs	1,329,260	562,410	589,920	459,430	1,611,760	2,941,020
Thinning to benchmark PVPs	1,330	910	350	280	1,540	2,870
Public forest estate	-20,540	2,570	-106,460	-39,640	-143,530	-164,070
Private native forestry on state protected land	29,720	0	0	0	0	29,720
Private native forestry PVPs	156,210	108,870	68,600	73,120	250,590	406,800
Improved rangeland management	515,680	312,750	231,430	145,940	690,120	1,205,800
Weed removal programs	474,660	70,100	169,620	30,330	270,050	744,710
Total area	2,486,320	1,057,610	953,460	669,460	2,680,530	5,166,850
New clearing of native vegetation						
Clearing PVPs approved where environmental outcomes maintained or improved	4,650	1,820	3,500	990	6,310	10,960
Clearing under <i>Native Vegetation Conservation Act 1997</i>	2,520	0	0	0	0	2,520
Clearing under <i>Plantation and Reafforestation Act 1999</i>	1,090	30	<10	<10	50	1,140
Clearing under local government routine agricultural management activities (RAMAs)	10	0	<10	<10	20	30
Clearing for increased infrastructure – RAMA buffers	10	<10	0	<10	20	30
Total area	8,280	1,860	3,520	1,020	6,400	14,680

Source: OEH and Department of Primary Industries data 2011

Notes: All areas are shown in hectares.

There may be some differences between individual figures and overall totals due to rounding.

* Cumulative totals for the previous years of reporting shown.

In general, the total area of land being conserved, restored or undergoing improved management is substantially greater than the area approved for clearing. However, while the areas to improve the condition or management of native vegetation are quite substantial it is still too early for most of the measures listed in Table 5.7 to be detectable as changes in vegetation extent or condition.

Reservation

Figures for new conservation areas (Table 5.7) represent additions to the public and private reserve system. A dedicated public system of parks and reserves is the cornerstone of conservation programs to preserve biodiversity and protect native vegetation (see Biodiversity 5.3). These areas are protected from clearing and will be managed for conservation in perpetuity. About 8.8% of all land in NSW has been incorporated into the reserve system, including

the newly proclaimed Dharawal National Park in March 2012. Sufficient representation of all vegetation formations and classes is a key consideration in planning the future development of the reserve system (see Table 5.9 in Biodiversity 5.3).

Greater importance is now being placed on conservation across whole landscapes and protection in the reserve system is increasingly being supplemented by measures promoting conservation on private land (see Biodiversity 5.3). The NSW Government is implementing the Great Eastern Ranges Initiative and Green Corridors Program to further advance these objectives.

Restoration and revegetation

'Restoration or revegetation of native vegetation' in Table 5.7 refers to measures to improve the condition of native vegetation or increase its extent in NSW. These include incentive PVPs and PVP offsets, CMA-funded programs and other initiatives. Restoration of native vegetation is undertaken to improve the condition and habitat values of existing vegetation, while revegetation aims to increase the extent of native vegetation. Undertaken strategically, revegetation can buffer existing reserves, provide wildlife corridors and reduce fragmentation of the landscape. There has been a major and sustained increase in revegetation since the implementation of the NV Act and PVP framework in 2005.

New management of native vegetation

'New management of native vegetation' in Table 5.7 describes activities undertaken to enhance the condition of vegetation, such as the clearing of invasive native scrub, removing weeds and regulating private native forestry. *NSW 2021* has a strong focus on regenerating bushland by improving the management of private land to enhance and maximise its environmental values and by supporting CMAs in involving local communities and landholders. Actions include protecting areas that are sensitive or have high conservation value by fencing, weeding, and other measures that address specific ecosystem, habitat or species needs.

Regulating clearing of native vegetation

Under the NV Act, clearing is not permitted on properties unless it improves or maintains environmental values. A system of offsets has been introduced which allows landowners to clear native vegetation, provided they agree to plant, improve, or better manage other vegetation on their own property or elsewhere. The offsets required are described under 'Restoration or revegetation of native vegetation' in Table 5.7, while the areas permitted to be cleared are reported on in the 'New clearing of native vegetation' category.

Compliance and enforcement

The *Native Vegetation Compliance and Enforcement Strategy* (DECCW 2009b) has been developed by the NSW Government to promote compliance with the NV Act and assist with community understanding of its provisions and requirements. Remote sensing technologies have been used extensively to enable statewide monitoring and reporting. There have been a number of successful prosecutions for breaches of the NV Act through illegal clearing.

Future opportunities

Regional programs involving local communities should provide more opportunities to improve vegetation condition, enhance habitat connectivity and reduce fragmentation which will, over time, lead to the increasing resilience, health and productivity of all native vegetation types on public and private land.

A framework to record natural resource management activities and works delivered regionally has been established. This will provide better alignment between program objectives and overall outcomes, enhancing the capacity for adaptive management and providing better information and support to guide local community involvement.

Although clearing may be slowed and fragmentation reduced, the pressures that affect vegetation condition are likely to continue in future, due to further weed invasion and new weed incursions, the effects of plant diseases and pathogens, and the effects of climate change and related changes to fire regimes.



5.3 Reserves and conservation

The area of the reserve system has grown by 5.7% since 2009, with significant additions to under-represented areas.

At January 2012, the New South Wales terrestrial reserve system covered almost 7.1 million hectares or 8.8% of the state. Since the beginning of 2009, the reserve system has grown by 380,247 hectares, an increase of 5.7%.

The representativeness of the protected area system is improving, but some bioregions and vegetation classes are still under-represented, particularly in the central and western regions.

In regions where remnant vegetation is scarce, opportunities for additions to the public reserve network are limited and measures to promote conservation on private land and other tenures are being pursued.

Conservation on both private and public land provides greater connectivity across landscapes. Conservation measures beyond the public reserve system expand the range of natural values that are protected and provide buffers and corridors to enhance the network of reserves.

The system of marine protected areas covers 345,100 hectares or approximately 34% of NSW waters and most NSW marine bioregions are well-represented.

NSW indicators

Indicator and status	Trend	Information availability
Area of terrestrial reserve system	Increasing	✓✓✓
Area of the marine protected areas system	Stable	✓✓✓

Notes: Terms and symbols used above are defined in *About SoE 2012* at the front of the report.

Introduction

Addressing the decline of biodiversity is one of the greatest environmental challenges in NSW. Conservation in public and private reserves plays an important part in the strategy to deal with this challenge.

Protected areas are the cornerstone of conservation efforts in NSW. The state's public reserve system comprises a substantial network of protected areas which:

- conserves the full range of habitats and ecosystems, plant and animal species, and significant geological features and landforms in NSW

- protects areas of significant cultural heritage
- provides opportunities for recreation and education.

However, more than 90% of land in NSW is not in the public reserve system. To provide effective conservation across the whole landscape and conserve all natural values, measures are increasingly being focused on public and privately owned areas outside the reserve system.

In the NSW marine environment, six marine parks with multiple-use zoning plans conserve marine and coastal ecosystems and habitats, while permitting a wide range of beneficial uses. Twelve aquatic reserves protect important marine habitats and nursery areas.

Status and trends

Terrestrial reserve system

Extent of public reserve system

At 1 January 2012, the area of the NSW public reserve system protected under the *National Parks and Wildlife Act 1974* and *Brigalow and Nandewar Community Conservation Area Act 2005* had grown to 861 parks, a total of 7,080,934 hectares, or approximately 8.83% of NSW.

Since 1 January 2009, the area protected under both these Acts has increased by 380,247 hectares, an additional 5.7% of the total area reserved. Significant additions to the reserve system since January 2009 include Toorale National Park and State Conservation Area (85,251 hectares), the Riverina Red Gum Reserves

(106,364 ha), South-Western Cypress Reserves (54,387 ha) and further additions to the Brigalow and Nandewar Community Conservation Areas (22,277 ha).

Map 5.3 shows the location of national parks and reserves managed by the NSW National Parks and Wildlife Service (NPWS) and reserves managed by Forests NSW, as well as the marine parks and aquatic reserves.

Table 5.8 describes the main types of protected area in the terrestrial reserve system and the additions between 2009 and 2012. There have been significant additions to most types of protected area and these have largely focused on addressing gaps in the system and enhancing the representation of poorly conserved ecosystems and natural values.

Map 5.3: National parks and forest reserves, marine parks and aquatic reserves in NSW

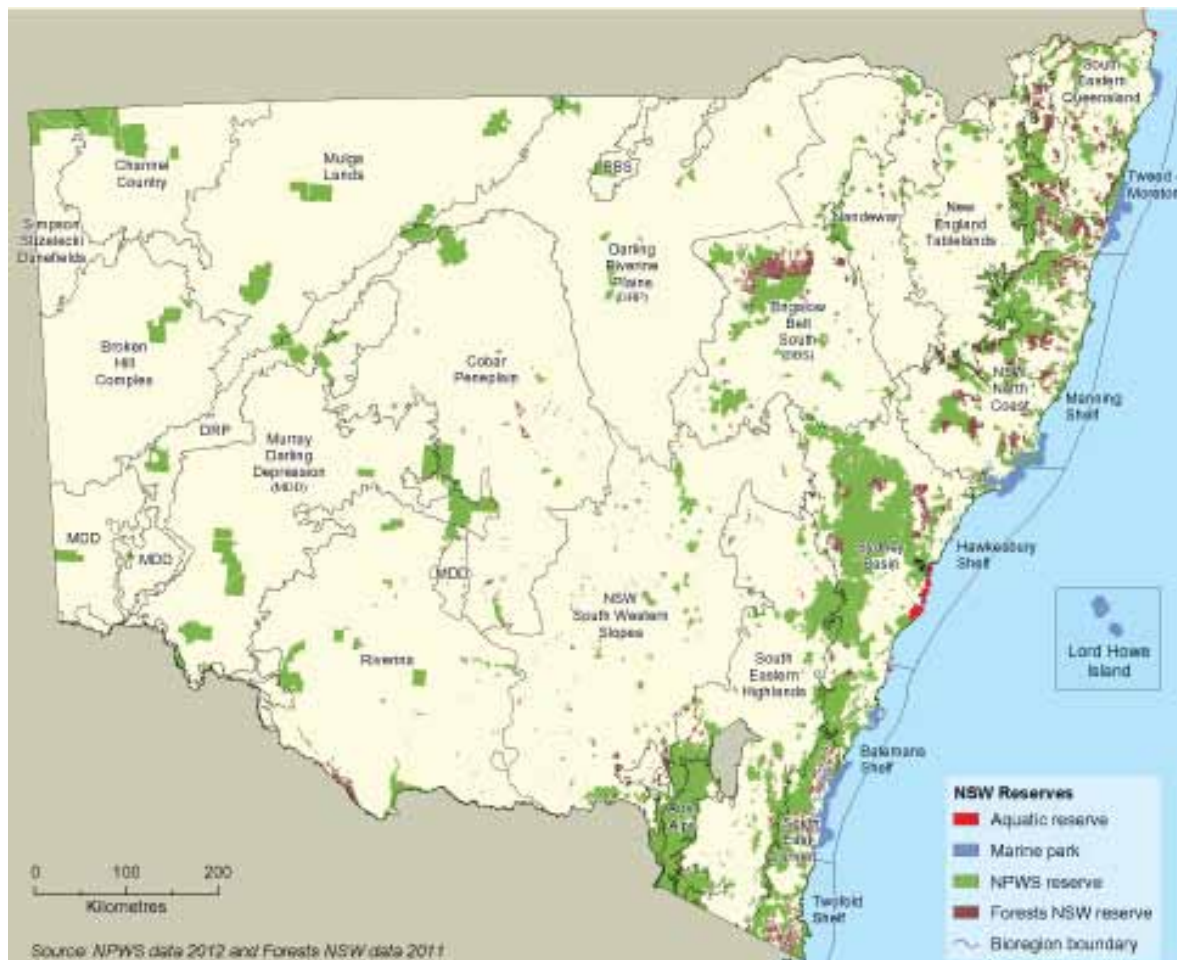


Table 5.8: Extent and types of terrestrial protected areas in NSW and changes since 2009

Type of protected area	Description	Number of areas (size in hectares)	Change since January 2009
NSW national parks and reserves			
National parks	Large areas encompassing a range of ecosystems, allowing for recreation that is compatible with the area's natural features	199 (5,188,434 ha)	14 new national parks (increase of 171,223 ha)
Nature reserves	Areas with significant biodiversity values, generally smaller than national parks	417 (942,761 ha)	21 new nature reserves (increase of 54,985 ha)
Aboriginal areas	Places of significance to Aboriginal people or sites containing relics of Aboriginal culture	19 (14,171 ha)	5 new areas (increase of 2,454 ha)
Historic sites	Areas of national importance, including buildings, objects, monuments and landscapes	16 (3,023 ha)	1 new area (overall decrease of 43 ha)
State conservation areas	Areas managed for conservation while providing opportunities for sustainable visitor use and permitting mining	125 (554,370 ha)	16 new areas (increase of 113,679 ha)
Regional parks	Conserved areas in a natural or modified landscape which provide opportunities for recreation	19 (22,354 ha)	5 new parks (increase of 15,065 ha)
Karst conservation reserves	Areas of limestone or dolomite characterised by landforms, such as caves and their decorative features, produced by solution, abrasion or collapse, or by underground drainage	4 (5,172 ha)	No new reserves, but an increase of 607 ha to existing reserves
Community conservation areas: Zone 1	As for national parks	34 (132,464 ha)	7 new parks (increase of 11,162 ha)
Community conservation areas: Zone 2	As for Aboriginal areas	5 (21,661 ha)	No new areas, but an increase of 43 ha to existing areas
Community conservation areas: Zone 3	As for state conservation areas	23 (196,524 ha)	4 new areas (increase of 11,072 ha)
Total		861 (7,080,934 ha) 8.83% of NSW	380,247 ha
Wilderness declarations			
Wilderness areas	Remote and undisturbed areas of sufficient size to enable long-term preservation of their natural systems and biological diversity, currently gazetted over existing national parks and nature reserves	51 contiguous areas (2,091,318 ha)	2 new wilderness areas and additions to 15 existing areas (increase of 207,314 ha)

Type of protected area	Description	Number of areas (size in hectares)	Change since January 2009
NSW national parks and reserves			
Wild rivers	Waterways in near-pristine condition in terms of animal and plant life and water flow, which are free of unnatural rates of siltation or bank erosion, currently gazetted over existing national parks and nature reserves	7 rivers and associated tributaries	No new rivers and associated tributaries
Reserved areas in state forests			
State forest dedicated reserve: special protection	Dedicated reserve managed to maximise protection of very high natural and cultural conservation values and not available for timber harvesting (Zones FMZ1 and PMP1.3)	29,177 ha (1.33% of total native forest estate)	4,773 ha reduction with transfer of estate to NPWS for addition to national parks
State forest informal reserve: special management	Informal reserve (special management): allowing specific management and protection of natural and cultural conservation values where it is not possible or practical to include them in Zone 1. Not available for timber harvesting (Zones FMZ2 and PMP1.2.)	167,177 ha (7.59% of total forest estate)	Reduction of 57,428 ha
State forest informal reserve: harvest exclusion	Informal reserve (harvest exclusion): managed for conservation of identified values and ecosystems and their natural processes. In these areas, timber harvesting is excluded but other management and production activities not permitted in Zone 1 or 2 may be appropriate, such as grazing or mineral exploration (Zone FMZ3a).	229,544 ha (10.43% of total forest estate)	Decrease of 52,230 ha Transfer of tenure to NPWS as part of the Western Regional Assessment

Source: NPWS and Forests NSW data 2012

Note: Data is as at the beginning of 2012

Progress towards a comprehensive, adequate and representative reserve system

The NSW Government is committed to building a comprehensive, adequate and representative (CAR) system of reserves and has adopted national targets for reserving ecosystems which are set out in *Australia's Strategy for the National Reserve System 2009–2030* (NRMCC 2009) and the *NSW National Parks Establishment Plan 2008* (DECC 2008c). The targets are based on bioregions and subregions defined in the Interim Biogeographic Regionalisation for Australia (IBRA) (Thackway & Cresswell 1995).

'Comprehensiveness' requires that each recognised ecosystem is represented in protected areas. The broad national target is for at least 80% of regional

ecosystems to be included in the national reserve system (NRS) in each IBRA bioregion by 2015 (NRMCC 2009).

'Representativeness' means that the full variability of biodiversity within each ecosystem is protected. The broad national target is for at least 80% of regional ecosystems to be included in the NRS in each IBRA subregion by 2025 (NRMCC 2005).

'Adequacy' is the long-term capacity of protected areas to sustain the biodiversity within their boundaries. The viability of reserves in achieving their conservation objectives depends on their size, shape, configuration and location, as well as the land uses and management regimes on adjacent land. No specific targets have been established for the

Biodiversity

adequacy of the NRS, but wherever possible, reserves are located in areas where there is still relatively good habitat connectivity. In this way, reserves form the foundation of efforts to retain and reconnect habitat and establish corridors to facilitate species' migration in a changing climate.

Map 5.4 shows the proportion of land in public reserves in each of the 18 bioregions of NSW. The National Land and Water Resources Audit landscape health assessment recommended that 15% of the area in each bioregion should be protected in public reserves (CoA 2002).

The bioregions of eastern NSW are generally well-represented in the reserve system compared with bioregions in the centre and far west of the state which are mostly under-represented. However, significant progress has been made recently in adding under-represented areas to the reserve system. The same map in *SoE 2009* showed four bioregions (NSW South Western Slopes, Darling Riverine Plains, Riverina and the Broken Hill Complex) with less than 2% of their area reserved. Now, only the Broken Hill Complex has

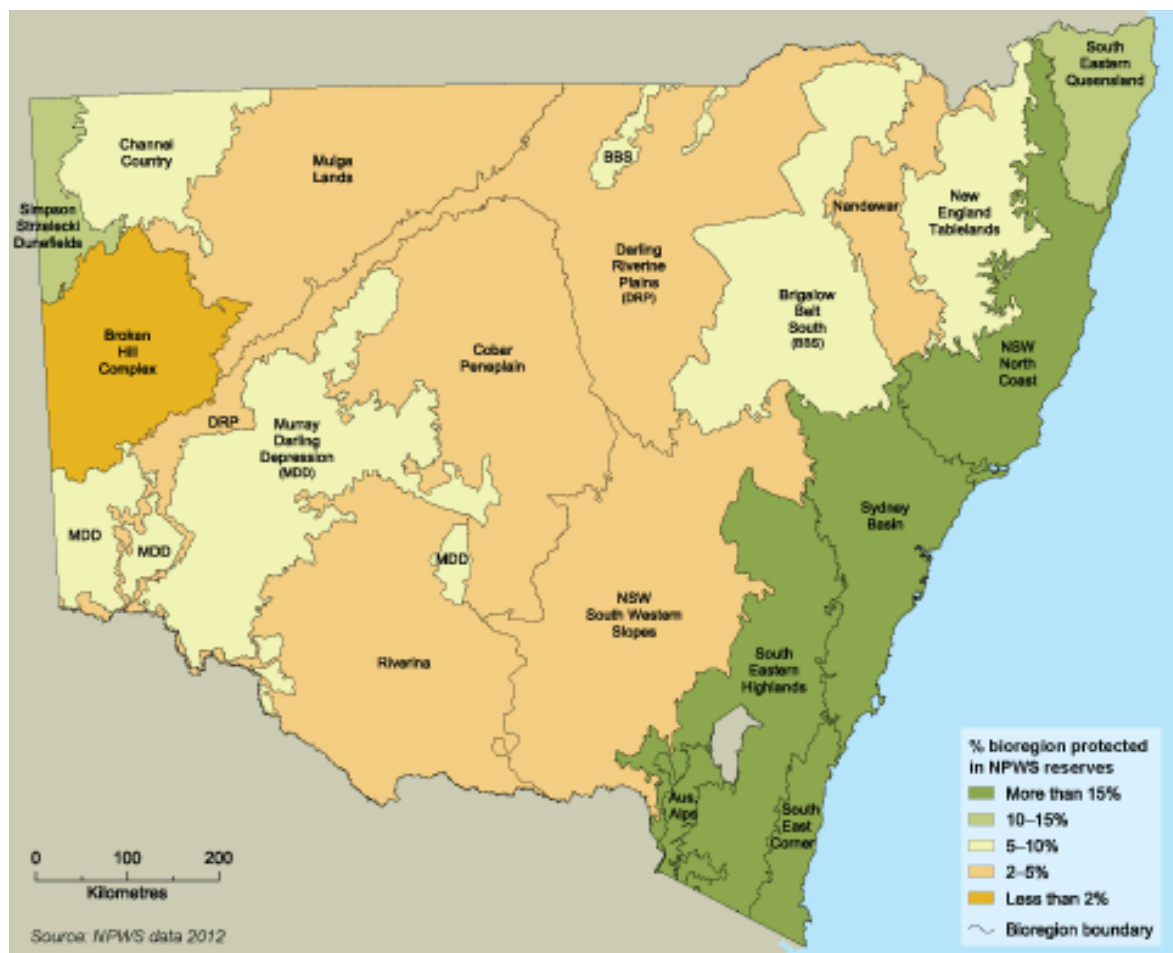
this level of representation and coverage has improved in all four bioregions. These figures demonstrate that the new additions to the reserve system have been targeted effectively to under-represented areas.

Of the 18 bioregions in NSW, four still have fewer than 50% of their regional ecosystems included in the reserve system. At a finer scale, 29 of the 129 subregions in NSW still have fewer than half of their regional ecosystems represented in the reserve system.

Despite the relatively high levels of comprehensiveness and representativeness of ecosystems in the eastern and alpine bioregions (Map 5.4; Table 5.9), the adequacy of the reserves in these bioregions could still be improved.

The goals in the *NSW National Parks Establishment Plan 2008* are based on the principle that existing and future opportunities for building a full CAR system will vary greatly across the state (DECC 2008c). In regions where over 70% of native vegetation remains relatively intact, the objective of building a full CAR

Map 5.4: Reservation of bioregions in NSW



system remains achievable. In areas with less than 70% of native vegetation remaining, realistic long-term reservation goals have been adjusted, depending on the proportion of native vegetation intact. However,

in areas where less than 30% of native vegetation remains, a full CAR reserve system is not practically achievable. **Table 5.9** describes progress in meeting CAR objectives across the state.

Table 5.9: Progress towards meeting long-term reservation objectives in NSW bioregions

NSW section of the bioregion	Area (hectares)	Area in formal reserves managed by NPWS (hectares)	Reserves (% of bioregion)	Remaining native vegetation cover (% of bioregion)	Progress towards comprehensiveness (%)	Progress towards representativeness (%)
Regions where over 70% of native vegetation remains relatively intact						
Mulga Lands	6,592,311	286,929	4.4	100	59	56
Channel Country	2,340,556	219,140	9.4	100	41	43
Simpson–Strzelecki Dunefields	1,069,837	119,090	11.1	100	43	35
Broken Hill Complex	3,795,093	75,526	2.0	100	36	27
Australian Alps	460,321	376,403	81.8	96	100	100
Murray–Darling Depression	7,929,235	461,262	5.8	93	72	55
South East Corner	1,162,086	496,694	42.7	82	97	97
Riverina	7,019,310	240,705	3.4	72	78	48
Regions where 30–70% of native vegetation remains relatively intact						
Cobar Penepplain	7,377,200	192,564	2.6	69	50	52
NSW North Coast	3,996,115	992,839	24.9	66	92	88
Sydney Basin	3,795,733	1,460,733	38.5	66	96	89
Darling Riverine Plains	9,409,645	233,471	2.5	65	48	42
South Eastern Queensland	1,662,539	226,652	13.6	53	95	86
South Eastern Highlands	4,718,158	719,905	15.3	42	86	74
New England Tableland	2,860,044	274,402	9.6	42	86	71
Brigalow Belt South	5,636,565	490,879	8.7	42	65	48
Nandewar	2,073,150	80,520	3.9	34	68	68
Regions where less than 30% of native vegetation remains relatively intact						
NSW South Western Slopes	8,198,413	174,529	2.1	16	53	40

Source: Adapted from DECC 2008c; NPWS data 2012

Notes: The NRS target for comprehensiveness is for at least 80% of extant regional ecosystems in each IBRA bioregion to be protected in public reserves by 2015. Ecosystems in a bioregion are excluded from the calculation where they lie along the margins of the region and their occurrence is relatively insignificant.

The NRS target for representativeness is for at least 80% of extant regional ecosystems in each IBRA subregion to be protected in public reserves by 2025. Ecosystems in a subregion are excluded from the calculation where they lie along the margins of the region and their occurrence is relatively insignificant.

Private land conservation

To maintain productivity and healthy ecosystems across whole landscapes, areas need to be conserved beyond the borders of the public reserve system. Many reserves are relatively small and isolated, rather than being the large, continuous areas needed to optimally maintain biodiversity. As more than 90% of the land in NSW lies outside the reserve system, private land conservation can play a key role in enhancing landscape connectivity and resilience, and protecting threatened species, populations and ecological communities.

Where native vegetation types are substantially under-represented in the public reserve system, complementary conservation measures on private land are important. In many regions that have been highly cleared, all remaining native vegetation has significant conservation value. Some native vegetation formations are now found almost entirely on private land, with only 1% of grasslands, 3% of grassy woodlands, 3% of semi-arid woodlands and 4% of arid shrublands contained in the public reserve system.

Table 5.10 shows the area of private land subject to the various conservation programs in NSW discussed below. To date, this area amounts to around 3,215,750 hectares or about 3.9% of NSW.

Private land conservation programs

The NSW Government has developed a range of measures under its Conservation Partners Program to encourage and support conservation on private land. The options available provide flexibility for property owners wishing to conserve biodiversity and natural heritage on their land. Differing levels of government assistance are available, depending on the level of commitment preferred.

The level of involvement of private landholders in biodiversity and natural heritage conservation has grown substantially over recent years in response to the various options now available, which are described below.

Conservation agreements are legally binding covenants that are entered into voluntarily to protect biodiversity and natural and cultural heritage values in perpetuity on private and other public lands. The area under the agreement is registered on the land title, ensuring that if the land is sold the agreement and management requirements remain in place. Rate relief and tax concessions are available to landholders for land subject to a conservation agreement. There are currently 344 conservation agreements protecting 135,855 hectares of high conservation value land in NSW.

Table 5.10: Areas of land subject to a private land conservation agreement in NSW at 30 June 2012

Conservation measure	Number	Area (hectares)
Conservation agreements	344	135,855 ha
Wildlife refuges	670	1,936,198 ha*
Property registration	845	62,487 ha**
Conservation covenants	Not available	1,000,390 ha
PVPs in perpetuity	Not available	80,820 ha
Total	1,859	3,215,750 ha

Notes: * 10–20% is dedicated to conservation; 80–90 % is managed with compatible land uses.
** Includes around 30,000 ha of natural bushland and 4000 ha of rehabilitated bushland.

Wildlife refuges are legal declarations that enable landholders to voluntarily nominate all or part of a property where land will be managed to retain wildlife and habitat values. A property report and management plan are prepared outlining actions needed to maintain natural values, while ensuring that other compatible property management objectives will still be achieved. A wildlife refuge declaration is free and provides landholders with the flexibility to change the status of the refuge if required. There are currently 670 wildlife refuges providing protection for all or part of properties covering a total area of 1,936,198 hectares in NSW.

Property registration: This arrangement suits landholders wishing to conserve wildlife on private land who prefer not to enter into a legal agreement. Applicants can voluntarily register all or part of a property under the Land for Wildlife scheme. This scheme provides information and support to assist landholders in managing wildlife and habitats, as well as opportunities to share experiences with other landholders. There are currently 845 private landholders registered in Land for Wildlife committing more than 62,487 hectares of land to wildlife conservation in NSW.

Conservation covenants: perpetual lease conversion program

The conversion of Crown leases to freehold under the *Crown Lands (Continued Tenures) Act 1989* has enabled conservation covenants to be placed on property titles during the conversion process. Over a million hectares of private land are subject to conservation covenants in NSW.

Property vegetation plans

A property vegetation plan (PVP) is a voluntary but legally binding agreement between a landholder and the local catchment management authority (CMA). While PVPs were introduced to approve native vegetation clearing by offsetting other areas for conservation, a range of PVPs are now available covering various aspects of habitat improvement, such as revegetation or restoration of vegetation and better management of land and habitat. Some PVPs are agreed to in perpetuity for the permanent protection of native vegetation. More information on PVPs can be found in Biodiversity 5.2.

Nature Conservation Trust

The Nature Conservation Trust of NSW (NCT) is an independent organisation promoting nature conservation on private land. The NCT operates a revolving fund scheme that buys properties with high conservation value, registers an in-perpetuity trust agreement on their title, and then resells the properties with the agreement on the title. Private landowners entering into covenants may access a range of benefits, including technical advice and assistance with management costs. The NCT has purchased 21 properties under this scheme, protecting 21,865 hectares of high conservation value land.

Privately-owned conservation reserves

Some high conservation value properties in NSW are owned and managed by non-government organisations, such as Bush Heritage Australia and the Australian Wildlife Conservancy. Most properties are legally protected in perpetuity under conservation agreements. Bush Heritage Australia has five properties in NSW: Scottsdale (1328 hectares), Burren-Burren (411 ha), Brogo (120 ha), Tarcutta Hills (432 ha) and Sylvan Reserve (54 ha). The Australian Wildlife Conservancy owns and manages Scotia Sanctuary in NSW (65,000 ha).

Conservation on other tenures

Forests NSW conservation zones

Forests NSW uses a land classification system in state forests that sets out management intent and identifies areas set aside for conservation (SFNSW 1999). Through this zoning system, about 426,000 hectares of state forest (19%) are excluded from harvesting for conservation reasons. A similar amount of land is also excluded from harvesting for silvicultural reasons. These areas make a significant contribution to the protected area network in NSW.

Travelling stock routes

Travelling stock routes (TSRs) are authorised thoroughfares for moving stock from one location to another. On a TSR, grass verges are wider and property fences are set back further from the road than is usual, so the stock can eat the vegetation.

TSRs are located on Crown land, and are often found in environments that are poorly represented in the public reserve system, heavily disturbed and in poor condition. In many of these areas, TSRs remain in relatively good condition and provide the best or only opportunity for improved conservation of threatened species or communities. They form a fundamental network of corridors connecting fragmented landscapes, particularly in the sheep–wheat belt and the tablelands. The natural values of approximately 700,000 hectares of TSRs in the eastern and central divisions of NSW are currently being assessed.

Marine protected areas

Marine protected areas are coastal, estuarine or oceanic areas that are managed to conserve marine biodiversity. Some are small, highly protected areas that focus on species or community protection. Others are large multiple-use areas that contain complex ecosystems and habitats which are managed within a multiple-use framework to provide various levels of protection while permitting recreational and commercial uses (NSW Government 2001).

The establishment of a representative system of marine protected areas is widely regarded, both nationally and internationally, as one of the most effective mechanisms for protecting biodiversity (ANZECC TFMPA 1998).

The National Representative System of Marine Protected Areas is being established by the Australian and state governments throughout Australia's marine jurisdictions. The primary goal in NSW is to establish a comprehensive, adequate and representative (CAR) system of marine protected areas that includes the full range of biodiversity, ecosystems, habitats and species (NSW Government 2001).

The integrated marine and coastal bioregionalisation of Australia (IMCRA) describes a series of bioregions for oceanic, near-shore marine and coastal waters (EA 1998; CoA 2006). The NSW Government has adopted this framework for establishing and managing a representative system of marine protected areas in NSW (EA 1998; CoA 2006). There are six bioregions in NSW waters (Map 5.3).



Types of marine protected areas

There are three types of marine protected area in NSW: marine parks, aquatic reserves and the marine components of national parks and nature reserves (NSW Government 2001).

Marine parks are zoned to conserve marine biodiversity, maintain ecological processes and provide for a range of sustainable uses such as recreational and commercial fishing, diving, boating, snorkelling and tourism. There are four types of zone: sanctuary, habitat protection, general use and special purpose.

Aquatic reserves are declared primarily to conserve the biodiversity of fish and marine vegetation and protect important habitat or nursery areas. The type of protection and the activities permitted vary among reserves.

National parks and nature reserves: Many national parks and nature reserves contain significant and extensive marine ecosystems and habitats.

Extent of marine protected areas

An integrated system of marine protected areas is being developed in NSW to conserve marine biodiversity, recover threatened species, and allow for the sustainable use of resources (NSW Government 2001). Marine protected areas are located in all marine and coastal bioregions along the coast of NSW, from the Tweed estuary in northern NSW to Nadgee Lake in southern NSW.

The state's marine parks are managed by the Marine Parks Authority. Six marine parks have been declared and zoned for multiple uses: Cape Byron, Solitary Islands, Lord Howe Island, Port Stephens–Great Lakes, Jervis Bay and Batemans marine parks. This system of marine parks covers approximately 345,100 hectares (around 34%) of NSW state waters (Map 5.3). No additional marine parks have been declared since 2006 but the zoning plans for Batemans and Port Stephens–Great Lakes marine parks began operating in 2007.

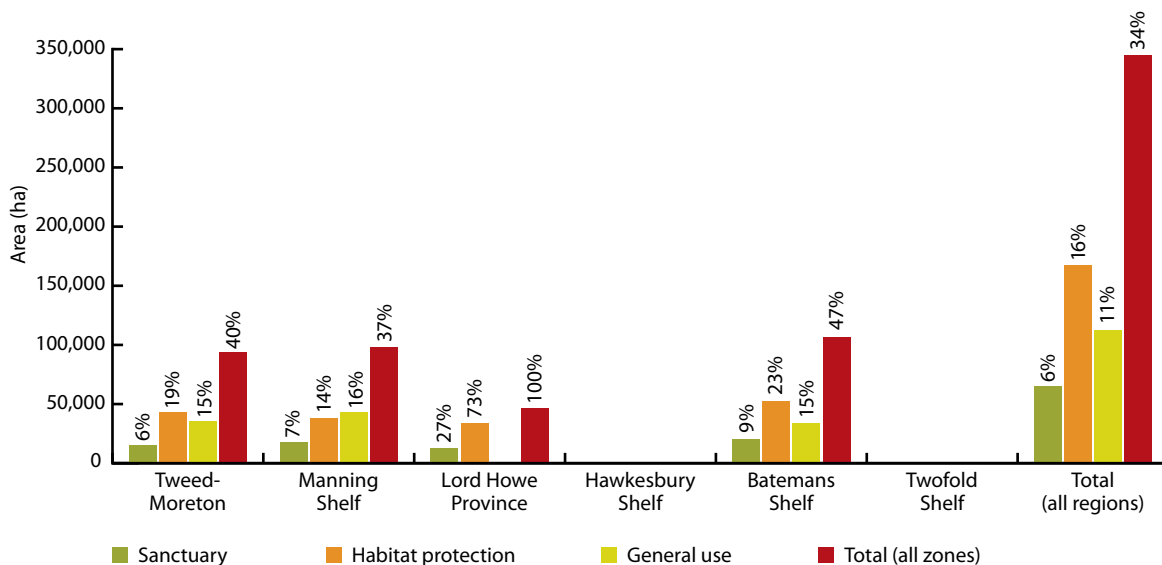
Twelve aquatic reserves cover around 2000 hectares of NSW waters. Ten of these are located in the Hawkesbury Shelf bioregion around Sydney, and there is one on the north coast and one on the south coast.

Marine and coastal areas are protected in 62 national parks and nature reserves within the terrestrial reserve system (2004 data), covering more than 10% of NSW estuary waters and incorporating about 46% of the NSW coastline. These areas include ocean coastlines, estuaries, coastal lakes, wetlands, intertidal areas, ocean beaches and rocky shores, and islands.

Some national parks and nature reserves adjoin marine parks, such as in the Myall Lakes region, or aquatic reserves, such as at Barrenjoey Head and Towra Point.

Figure 5.6 shows the area of NSW waters included in marine parks in each bioregion.

Figure 5.6: Area and percentage of each marine park zone in force in NSW bioregions



Source: Marine Parks Authority data 2009

Notes: 'Total (all zones)' refers to the percentage of each bioregion in NSW waters incorporated into marine parks (not the total % of zones within parks).

Special purpose zones are very small and are therefore not shown in the figure. They cover 0.05% of the Tweed–Moreton bioregion, 0.1% of Manning Shelf and 0.2% of Batemans Shelf.

Zoning plans

Zoning plans provide various levels of biodiversity protection in marine parks by regulating activities according to zones, regulating specific activities to manage environmental impacts, and protecting particular species. The purpose and characteristics of the different zones (shown in Figure 5.6) are described below.

Sanctuary zones comprise between 6 and 27.5% of each marine park and provide the highest level of protection by prohibiting all forms of fishing and collecting. Activities that do not harm plants, animals and habitats are permitted, including boating and diving.

Habitat protection zones comprise 14–73% of each marine park and conserve marine biodiversity by protecting habitats and reducing high-impact activities. Recreational fishing and some forms of commercial fishing are permitted.

General use zones comprise up to 16% of each marine park. A wide range of activities is permitted, including commercial and recreational fishing provided they are ecologically sustainable.

Special purpose zones are very small and apply to up to 0.2% of each marine park and are used when there are special management needs, including protection of Aboriginal and other cultural features, or for marine facilities.

Zoning plans regulate some specific activities: for example, there are restrictions on anchoring and the use of vehicles and personal watercraft in some areas. They may also provide additional protection for species of particular significance. Only some species can be taken from habitat protection zones while some species are protected throughout marine parks.

Protection under other legislation, such as controls on fisheries operations under the *Fisheries Management Act 1994*, or protection of threatened species under the *Threatened Species Conservation Act 1995*, also applies.

Pressures

Threats to values in terrestrial reserves


Park managers have identified the five major threats to national parks and reserves as weeds, pest animals, fire, illegal activities, and habitat and species isolation (**Table 5.11**). Weeds are a threat in the most parks due to localised or scattered infestations, but the area affected is less than that affected by pest animals. Weeds mainly threaten biodiversity, particularly threatened species, native flora and ecological communities. Many pest animal species are widely distributed and can travel long distances and damage large areas. For more information on the impacts of pest animals and weeds, see Biodiversity 5.4.

Table 5.11: Extent and severity of the threats to park values most commonly reported by NSW park managers


Type of threat	No. of parks identifying this threat as a concern	Estimated severity of impact (proportion of park area affected)				Total area of all parks affected
		Mild	Moderate	High	Severe	
Weeds	634	1.0%	11.2%	8.2%	1.7%	22%
Pest animals	546	0.9%	15.2%	14.5%	6.5%	37%
Fire	347	0.6%	6.5%	14.8%	3.1%	25%
Illegal activities	485	0.5%	6.1%	4.7%	0.2%	11.5%
Habitat isolation	194	0.6%	1.2%	5.2%	0.1%	7%

Source: NPWS State of the Parks data 2010

Notes: The estimated severity of impact is calculated by taking the median point from data for the following categories: mild threats – localised (<5% of area); moderate threats – scattered (5–15%); high threats – widespread (15–50%); and severe threats – throughout a park (>50%). A severe threat is defined as being likely to lead to a loss of natural values in the foreseeable future if it continues at current levels.



Bushfires occur sporadically and vary greatly in their impact due to the intensity, frequency and season of occurrence as well as the recent fire history of the area affected. Their severity has been moderated since the last survey due to above-average rainfall and improved management. When fire does occur, however, the potential severity of the threat is greater than the threat posed by either pest animals or weeds. For more information on the impacts of bushfires, see Biodiversity 5.5.



Illegal activities such as trail biking, vandalism, dumping, stock encroachment and pig dogging are increasing but the impacts tend to be localised. These activities affect biodiversity, particularly threatened species and native flora, and Aboriginal cultural values, and have a negative effect on the experience of visitors to parks.

Parks where habitat or species isolation are a concern typically lack connectivity with other natural areas as they:


- consist of remnant vegetation within a cleared landscape
- are internally fragmented in design with a series of parcels of land separated by other land tenures
- contain internal physical barriers, such as major roads, that limit opportunities for recruitment or migration of some native fauna.



Climate change

Climate change is likely to:

- exacerbate the impacts on biodiversity caused by fragmented landscapes, introduced species and altered fire regimes
- alter the representativeness of reserves due to losses and gains of native and exotic species and ecosystems.



To manage the impacts of climate change, the objectives of future reserve management should shift from preventing ecological change to managing change to minimise the loss of biodiversity (Dunlop & Brown 2008).

The most important strategies for managing the effects of climate change in NSW reserves are building ecological resilience, improving landscape connectivity, ensuring effective fire management, and identifying priorities for pest and weed control.

Threats to conservation on private land

The pressures that affect protected areas on private land are much the same as those affecting public reserves. These include weeds and pest animals, fire regimes, climate variability such as drought and flood, activities such as firewood and bushrock collection, stock encroachment, and different neighbouring land uses.

Where the primary land use is a form of agricultural production, some activities may not be completely compatible with specific conservation objectives. Land managers may need to address potential threats from agricultural land uses that threaten conservation values. Unpredictable events, such as bushfires or sustained drought, may periodically exacerbate these threats and highlight the pressures arising from incompatible management objectives on private land.

To enable private landholders to successfully manage their land for conservation in the long term, it is critical to maintain monitoring and support services. Support includes continuing to recognise that private landholders' legal commitments to protect and conserve biodiversity and natural heritage are in the public interest through rate and tax concessions.

Threats to values in marine protected areas

The key threats to marine protected areas include overuse of resources, invasive species, marine pollution, land-based impacts and climate change (MBDWG 2008).

Resource use

Resource use includes fishing, aquaculture, mariculture, shipping and tourism, dredging and spoil dumping, and exploration and extraction of minerals, oil and gas. Marine protected areas conserve marine biodiversity and maintain ecological processes while providing for the sustainable use of resources. They work in concert with other programs that manage resource use. Activities conducted in marine protected areas are managed to ensure they are sustainable and do not threaten protected area values. Some activities are restricted to particular zones or may be prohibited throughout marine protected areas.

Invasive species

Invasive species are mainly associated with the shipping industry and ballast water exchange, but can also be associated with the aquarium industry and recreational boating (MBDWG 2008).

Invasive species are managed in marine protected areas by:

- restricting ballast water exchange
- ordering the removal of boats with heavily-fouled hulls from marine parks
- conducting monitoring programs to detect invasive species
- on-site management to enable a rapid response to threats
- maintaining or improving the health and resilience of the marine environment.

Marine pollution

Marine pollution includes debris from boating and shipping activities, nutrients from aquaculture, and spills or leakage of oil and toxic substances from the mining of oil, gas and minerals from the seafloor (MBDWG 2008).

In marine parks, zoning and operational plans aim to reduce the overall threats by eliminating, regulating or reducing the activities with the highest risk to marine park values. Many activities that may cause pollution are managed by agencies other than the Marine Parks Authority, but close relationships exist with these agencies to manage the risks.

Land-based impacts

Land-based sources of pollution that can impact on marine biodiversity include pesticides, heavy metals, nutrients, sediment and litter (Hobday et al. 2006; MBDWG 2008). The land-based activities most likely to affect the marine environment are foreshore development, sewage outfalls, and stormwater or catchment runoff.

Land-based threats are managed by locating marine protected areas where the threats are relatively small or through land-use planning, management of catchments and pollution reduction programs.

Climate change

Marine life in south-eastern Australian waters is increasingly being affected by the combined effects of changes to weather patterns and oceanographic factors such as currents. The effects of climate change on the marine environment (Hobday et al. 2006) are expected to include:

- changes in the distribution and abundance of species such as the southward movement of species along the NSW coast in response to higher temperatures
- changes in the timing of life cycle events, such as earlier spawning migrations

- changes in physiology, morphology and behaviour, such as the rates of reproduction and development
- impacts on biological communities due to different effects on individual species.

Comprehensive, adequate and representative systems of protected areas are an effective response to the threat of climate change (Hobday et al. 2006; Dunlop & Brown 2008). They can build resilience by returning areas to a more natural condition and will be important in assessing the impacts of climate change by providing benchmark areas for monitoring.

Responses

Established responses

NSW 2021

NSW 2021: A plan to make NSW number one (NSW Government 2011) is the Government's 10-year plan for NSW. Under Goal 22 – 'Protect our natural environment', the plan contains the following target: 'Protect and conserve land, biodiversity and native vegetation' to be achieved through the following strategies:

- 'Identify and seek to acquire land of high conservation and strategic conservation value, for permanent conservation measures'
- 'Establish voluntary arrangements with landowners over the next decade to bring an average 20,000 hectares per year of private land under conservation management and an average 300,000 hectares per year of private land improved for sustainable management'.

The priority actions associated with this target are to 'work with catchment management authorities (CMAs) and local community groups to protect and improve habitats on private lands'. Actions to conserve biodiversity and native vegetation include:

- 'Purchase and protect strategic areas of high conservation value and ensure more green spaces across Sydney and NSW through the \$40-million Green Corridors Program'
- 'Establish more national parks including a new national park to protect the sensitive Dharawal State Conservation Area and continue the reserve establishment program'.

These targets and activities are described in greater detail under Responses in Biodiversity 5.1.



Additions to the terrestrial reserve system

Since 1 January 2009, over 260 additions were made to the reserve system across 15 NSW bioregions. These included 60 additions to parks in the Great Eastern Ranges and additions to over 40 areas protecting lowland coastal ecosystems. There have also been significant additions to:

- semi-arid grasslands and woodlands in the Murray–Darling Depression, Cobar Penneplain, Riverina and Mulga Lands bioregions
- river red gum forests mainly in the Riverina bioregion
- the creeks and upland swamps in the south of Sydney in Dharawal National Park
- the blue gum high forests and associated biodiversity in the Berowra Valley National Park north of Sydney.

Plans of management for the terrestrial reserve system

Under the *National Parks and Wildlife Act 1974*, a plan of management must be prepared for each terrestrial park and reserve. These plans identify the natural and cultural features that must be protected and specify ways to best manage them. By 1 January 2012, a total of 331 plans had been adopted, covering 472 parks and reserves. In total, more than 5.5 million hectares are now covered by a plan of management, representing around 79% of the reserve system.

Managing threats in the terrestrial reserve system

Pest and weed management: The management of pests and weeds in reserves focuses on areas where native animals and plants are the most threatened or where pests are likely to affect neighbouring land. Key strategies in managing these threats include:

- regional pest strategies – by June 2012, updated strategies for 2012–15 had been developed for all reserves
- identifying and prioritising sites where biodiversity is at greatest risk from widespread pests and weeds
- threat abatement plans such as those for the fox and bitou bush
- the *Management Plan for Myrtle Rust on the National Parks Estate* (OEH 2011b).

Fire management: Fire is managed in national parks and reserves by reserve fire management strategies (FMSs) which are map-based plans for managing fire. At 30 June 2009, all parks and reserves were covered by an adopted FMS. Around 580 separate strategies cover more than 6.6 million hectares across 793 reserves or reserve areas. Since June 2009, NPWS has acquired about 70 new reserves for which strategies are being prepared.

The FMSs feed into the NPWS annual program of hazard reduction burns. In 2009–10, favourable conditions allowed a record 93,000 hectares to be burnt in 269 operations to reduce fuel loads, particularly on the urban edge of parks.

Following the 2009 Victorian Bushfires Royal Commission, a \$106.9-million bushfire protection package was announced by the NSW Government, resulting in the development of the Enhanced Bushfire Management Program. This program has enabled the annual hazard reduction program for NSW parks to be doubled and provided further resources for remote area fire suppression.

Sustainable tourism and visitation

The NSW Government provides a range of recreational opportunities in its parks and reserves that allow residents and visitors to appreciate and learn about the state's natural environment and cultural heritage. A *Sustainable Tourism Action Plan* was developed in 2010 which aims to encourage more people to visit parks and stay longer, while conserving the natural values of parks.

Private land conservation

Outside the public reserve system, the NSW Government is working with landholders, CMAs and other government agencies and non-government organisations, such as the Nature Conservation Trust, Bush Heritage Australia and Australian Wildlife Conservancy, to establish a range of conservation arrangements over private and other public lands which contain important natural and cultural heritage values (DECC 2008c).

Audit of marine protected areas

The NSW Government is committed to implementing an evidence-based marine parks policy that balances conservation and sustainable use of the marine environment and delivers tangible results. The Government commissioned an independent scientific audit of NSW marine parks to help deliver on this commitment. The audit has now been completed and the *Report of the Independent Scientific Audit of Marine Parks in NSW* (Beeton et al. 2012) released.

Zoning plans for marine protected areas

Zoning plans are used to deliver effective multiple-use management of marine parks. Under the provisions of the *Marine Parks Act 1997*, zoning plans must be reviewed after their first five years of operation and every 10 years thereafter. Since *SoE 2009*, reviews of zoning plans for Jervis Bay, Solitary Islands and Lord Howe Island marine parks have been conducted.

Amendments to the Jervis Bay and Solitary Islands zoning plans commenced on 1 March 2011 but were repealed on 26 May 2011 by the newly elected NSW Government pending its written response to the *Report of the Independent Scientific Audit of Marine Parks in NSW* (Beeton et al. 2012). The existing zoning plan for Lord Howe Island Marine Park remains in place, with options to address key issues to be developed with the local advisory committee.

The *Marine Parks Amendment (Moratorium) Act 2011* commenced on 16 September 2011 and introduced a five-year moratorium on declaring marine parks, altering the area of existing sanctuary zones, classifying new sanctuary zones, and conducting zoning plan reviews.

Operational plans for marine protected areas

An operational plan is required for each marine park, which details the strategies and actions needed to meet the key objectives of the park and provides a basis for assessing the performance of marine park management in meeting these objectives. New operational plans for Batemans Bay, Port Stephens–Great Lakes and Cape Byron marine parks commenced in 2010.

Strategic research framework for marine protected areas

The Marine Parks Strategic Research Framework 2010–2015 (MPA 2010) provides guidance to marine researchers on the principal research and monitoring needs of marine parks in NSW for the next five years.

Developing responses

Private Land Conservation Working Group

In March 2012, the Private Land Conservation Working Group was established to advise the NSW Government about how it could better support the conservation efforts of private landholders and non-government organisations. The working group reviewed existing private land conservation programs in NSW and those operating in other states, nationally and internationally and identified some emerging trends in private land conservation.

Great Eastern Ranges Initiative

The Great Eastern Ranges Initiative aims to maintain, improve and reconnect natural areas along a 3200-kilometre corridor stretching from the Grampians in Victoria, through the ACT and NSW, to the Atherton Tablelands in north-eastern Queensland. The objective is to provide healthy, functioning landscapes that will enable species to survive and adapt to environmental threats. Communities, agencies and governments are all involved in this project. The NSW Government is providing more than \$4.4 million up to 2015, through the NSW Environmental Trust, to implement the initiative in NSW.

Ecological risk assessment for marine biodiversity in NSW

An ecological risk assessment of NSW marine biodiversity commenced in June 2011. The results of the assessment will reveal how effective marine parks are in conserving biodiversity and provide a guide for managing threats and stressors in future.

Future opportunities

The main priorities for further development of the terrestrial reserve system are to continue to incorporate under-represented ecosystems and habitats, rivers and wetlands into reserves and establish landscape corridors and buffers to enhance the resilience and flexibility of reserves.

Conservation on private and other public land will play an increasingly important role in supplementing the public reserve system by expanding the range and extent of the natural values that are protected. Measures that encourage further conservation on private land will be actively supported and new initiatives that facilitate conservation will continue to be explored and refined.

Efforts to promote greater use and increased public awareness and appreciation of parks, reserves and protected areas will play an important role in maintaining support for reserves and conservation. An important objective in future park management will be to improve public accessibility to parks.

The NSW Government is preparing a response to the *Report of the Independent Scientific Audit of Marine Parks in NSW* (Beeton et al. 2012). This response will help to determine the future management arrangements for marine protected areas.



5.4 Invasive species

Invasive species (including pest animals, weeds and diseases) are widespread across New South Wales. They are difficult to manage effectively and remain one of the biggest threats to biodiversity. Many are listed as key threatening processes in NSW legislation, with pest animals and, in particular, weeds identified as a threat to over 70% of all threatened species.

Most pest animals have been well established in NSW for many years, with foxes and cats found across virtually the whole state. The decline or extinction of numerous small- to medium-sized native animals has been attributed to their predation.

Introduced herbivores, particularly rabbits and feral goats, have adverse impacts on native species and ecosystems through overgrazing of native vegetation, land degradation and competition with native herbivores. Deer continue to expand their range with increasing impacts while new sightings of individual cane toads continue to occur intermittently.

To date, over 1650 exotic plant species have become established in NSW and more than 300 of these have been described as significant environmental weeds. New invasive species, particularly weeds, continue to be discovered from time to time at scattered sites in NSW and, when identified, are subject to eradication measures.

Introduced pathogens and diseases have emerged as increasingly significant threats to biodiversity, particularly the plant diseases root-rot fungus (*Phytophthora*) and myrtle rust, and the amphibian chytrid fungus.

NSW indicators

Indicator and status	Trend	Information availability
Number of new invasive species detected	Unknown	✓
Spread of emerging invasive species	Stable	✓
Impact of widespread invasive species	Stable	✓

Notes: Terms and symbols used above are defined in *About SoE 2012* at the front of the report.

Introduction

Invasive species have been broadly established across NSW for many years and most areas now contain a range of weeds and pest animals. Historically, introduced species have contributed significantly to the decline and extinction of native species in NSW. In particular, foxes and cats have been implicated in the extinction of numerous small- to medium-sized ground-dwelling mammals (OEH 2011d). Human disturbance has greatly accelerated the invasion of introduced species (Coutts-Smith & Downey 2006; Coutts-Smith et al. 2007).

The collective impacts of invasive species are still poorly understood, whether on biodiversity or on the health of the environment as a whole. However, some recent advances have been made in understanding the impacts of invasive species on threatened species (Coutts-Smith & Downey 2006; Coutts-Smith et al. 2007; NLMG 2009). Statewide monitoring programs are also being established, which will enable reporting on the distribution of new and emerging pests and weeds and the extent of widespread pest species.

Status and trends

Extent of invasive species

Around 3000 introduced weed species have established self-sustaining populations in Australia since 1788. More than 1650 of these are recorded in NSW, with over 300 recognised as significant environmental weeds (Downey et al. 2010).

More than 650 species of land-based animals have also been introduced to Australia. Of these, 73 have established wild populations (NLWRA 2008), but not all are regarded as a threat to biodiversity. Introduced fish species make up around a quarter of all freshwater fish species in NSW rivers (DPI 2008a).

Australian waters host over 200 species of introduced marine organisms (DPI 2008a). However it is not known how many insects and other invertebrates have been introduced into Australia (Coutts-Smith et al. 2007).

Invasive species place a substantial burden on the Australian economy. Invasive weeds have been estimated to cost about \$4 billion per year in lost production, control costs and dealing with the

impacts (McLeod 2004; Sinden et al. 2004); in NSW alone, weeds account for \$1.2 billion per annum in lost production and control costs (LGSA 2011).

The cost to the Australian economy of dealing with the impacts of pest animals is over \$1 billion annually (DPI 2008a), while pest animal control alone exceeds \$60 million per year (Bomford & Hart 2002).

Categories of invasive species

Invasive species are generally categorised as widespread, emerging or new species, depending on their current extent and ability to persist and spread as described below:

Widespread species: any invasive species that has been present for some time and has now established a broad and relatively stable range across a region or the whole state, close to the limits of their likely distribution

Emerging species: any invasive species that has established a self-sustaining population and is actively expanding its range or has the potential to spread further

New species: any invasive species that has not been recorded previously in NSW or has not established self-sustaining populations, but has the potential to invade and spread across broad areas.

Assessment of the threat posed by species that are not yet present is based on their potential to spread and significantly impact on the environment or production.

Distribution of pest animals in NSW

Thirty pest animal species have been identified as posing a threat to at least one endangered or vulnerable species in NSW (Coutts-Smith et al. 2007). Foxes, feral cats and wild dogs are the carnivores with the greatest impact on biodiversity. The herbivores or omnivores of greatest concern are rabbits, feral goats and feral pigs, while in aquatic environments European carp and gambusia are the most significant pests.

Table 5.12 lists the state's main pest animals.



Table 5.12: Main introduced animal species in NSW with an impact on listed threatened species

Carnivores	Herbivores/omnivores	Fish	Other
Feral cats	Feral goats	Gambusia	Honey bees
Red foxes	Rabbits	European carp	Grass skinks*
Wild dogs	Feral pigs	Redfin perch	Feral pigeons
Cane toads	Feral deer	Goldfish	Buff banded rail*
Masked owls*	Wild horses	Tench**	Introduced worms
Blackbirds	Black rats	Weatherloach	Black ants*
Songthrushes	Brown rats	Rainbow trout	
	House mice	Brown trout	
		Banded grunter***	

Source: Coutts-Smith et al. 2007

Notes: Introduced species are species found outside their normal range and include both exotic species and translocated native species (those moved from their natural habitat to other locations in NSW).

* Native species translocated from mainland NSW to Lord Howe Island where they are a threat to endemic native species

** Tench was identified as a threat in this study, but has not been recorded in NSW for over a decade and is no longer considered to be a significant threat.

*** Native species translocated to other rivers in NSW

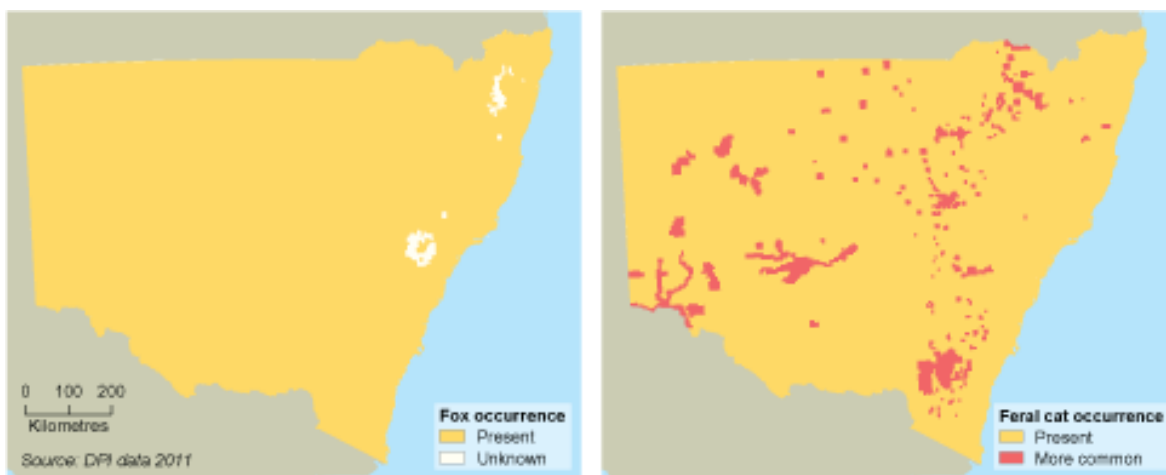
Widespread species

Widespread species have generally been present for a relatively long time, are broadly distributed and are close to the limits of their likely distribution, based on the availability of suitable habitat. The collective distribution and abundance of seven major widespread pest animals – foxes, cats, feral goats, rabbits, feral pigs, wild dogs and carp – was shown in Map 7.5 of SoE 2009 (DECCW 2009a).

As is evident from **Map 5.5**, foxes and cats are considered to be distributed throughout the state while the other five major pests also have wide distributions across NSW, with some limited potential for further expansion.

One of the greatest threats to biodiversity is predation by foxes and cats. These animals are thought to be responsible for the decline of many small- to medium-sized native animals as well as most of the extinctions that have occurred in mainland NSW.

Map 5.5: Occurrence of foxes and feral cats in NSW in 2009 as reported in surveys of land managers



Introduced herbivores, particularly rabbits, feral goats and feral pigs, have an impact on environmental values through land degradation, competition with native species for food and increasing grazing pressure. Agricultural systems also feel their impacts.

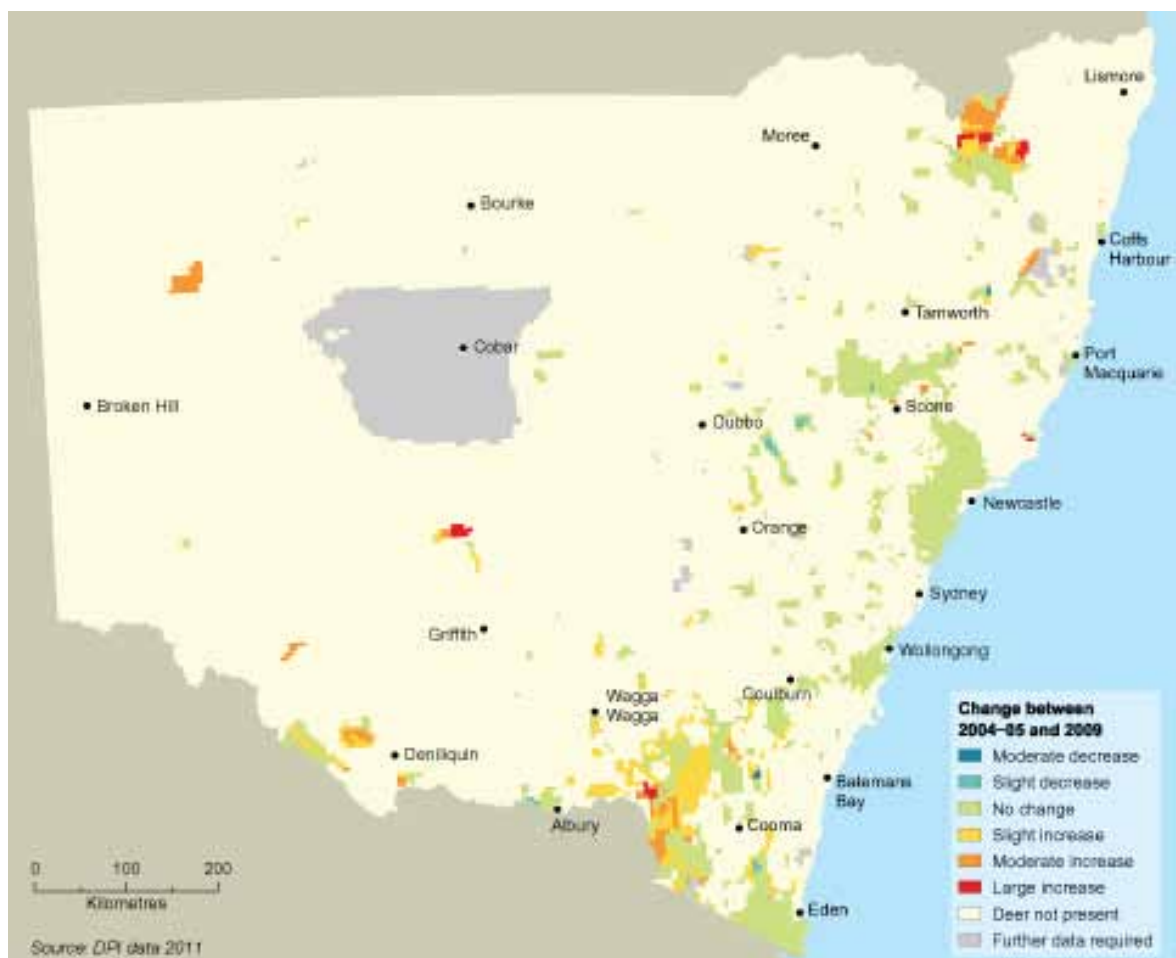
New and emerging species

New species are recent arrivals or species with a limited distribution that have not yet established self-sustaining populations. Emerging species are those that have become established and spread but have not yet reached their natural limits of distribution. Some emerging species are already having severe impacts on biodiversity or the environment, including deer and cane toads which are listed as key threatening processes under the *Threatened Species Conservation Act 1995*.

Monitoring and management of new and emerging species are generally more intensive than that for widespread species as the prospects for achieving control through eradication or containment are better, giving a greater return on the resources expended.

Deer are the main group of pest species that are expanding their range. **Map 5.6** shows the distribution of deer species between surveys in 2004–05 and 2009. Deer expanded their range from about 5% of NSW in 2002–03 (41,000 square kilometres) to about 6% in 2004–05 and then to about 8% of the state (64,000 km²) at the time of the 2009 survey. Their spread is continuing. While also found on the coastal slopes and plains, deer appear to be moving into forested areas that have remained relatively free of other pest species. The highly scattered nature of their distribution is unusual, as is that it involves more than one species.

Map 5.6: Change in reported distribution of deer in NSW from 2004–05 to 2009



Cane toads are also an emerging species of concern. While sporadic sightings of individual toads have been confirmed at various locations along the NSW coast, they have only established viable populations on the far north coast and an isolated population at Taren Point in southern Sydney. A small population established at Port Macquarie but now appears to have been eradicated.

Distribution of environmental weeds in NSW

Environmental weeds may be either exotic species or translocated native species, but those with the greatest environmental impact are predominantly introduced from overseas. Weeds threaten biodiversity both directly by competing with native species and indirectly through their impacts on ecosystem structure and function.

Under the *Australian Weeds Strategy* (NRMCC 2006), 20 plants were identified as weeds of national significance because of their invasiveness, potential for spread, and economic and environmental impacts.

Those widespread within NSW include alligator weed, bitou bush, blackberry, bridal creeper, Chilean needle grass, lantana, salvinia, serrated tussock and some species of willow. Several others have a restricted distribution, including Athel pine, boneseed, cabomba, hymenachne, mesquite and parkinsonia. Parthenium weed has also made occasional incursions into NSW from Queensland but on each occasion has been eradicated.

Additional weeds of national significance were announced in 2012. Species found in NSW include African boxthorn, asparagus weeds (six species in addition to bridal creeper), brooms (three species), cat's claw creeper, fireweed, Madeira vine, Opuntoid cacti (several species), Sagittaria, silver leaf nightshade and water hyacinth.

Over 1650 species of weeds have become established in NSW and more than 340 have significant impacts on biodiversity (DPI & OEH 2011). **Table 5.13** lists the top 20 weeds based on their potential impact on NSW biodiversity (Downey et al. 2010).

Table 5.13: The 20 weed species posing the greatest threat to biodiversity in NSW

Common name	Scientific name	Common name	Scientific name
Madeira vine	<i>Anredera cordifolia</i>	Cat's claw creeper	<i>Macfadyena unguis-cati</i>
Lantana	<i>Lantana camara</i>	Salvinia	<i>Salvinia molesta</i>
Bitou bush	<i>Chrysanthemoides monilifera</i> subsp. <i>rotundata</i>	Gorse	<i>Ulex europaeus</i>
Ground asparagus	<i>Asparagus aethiopicus</i>	Boneseed	<i>Chrysanthemoides monilifera</i> subsp. <i>monilifera</i>
Blackberry	<i>Rubus fruticosus</i> agg.	Serrated tussock	<i>Nassella trichotoma</i>
Scotch broom	<i>Cytisus scoparius</i>	Cape ivy	<i>Delairea odorata</i>
Japanese honeysuckle	<i>Lonicera japonica</i>	Blue morning glory	<i>Ipomoea indica</i>
Large-leaved privet	<i>Ligustrum lucidum</i>	Balloon vine	<i>Cardiospermum grandiflorum</i>
Small-leaved privet	<i>Ligustrum sinense</i>	Lippia	<i>Phyla canescens</i>
Alligator weed	<i>Alternanthera philoxeroides</i>	Bridal creeper	<i>Asparagus asparagoides</i>

Source: Downey et al. 2010

Widespread species

There are too many widespread weeds in NSW to map their distribution and abundance. A broad pattern of distribution is available by looking at the total number of weeds and the number identified as having an impact on threatened species, aggregated by catchment management authority (CMA) region (Table 5.14).

The widespread weeds with the greatest impact on NSW biodiversity and the biodiversity values most at risk have been determined and documented in *Biodiversity Priorities for Widespread Weeds* (DPI & OEH 2011). Priorities for each CMA region are listed in individual reports.

All parts of NSW are affected by weeds that threaten biodiversity. Weeds now make up 21% of the state's total flora. The numbers of weed species are highest near the coast, particularly around major towns and cities, and in regions with high rainfall, and tend to decline from east to west (Coutts-Smith & Downey 2006).

New and emerging species

Map 7.7 of *SoE 2009* (DECCW 2009a) showed the spatial distribution of new and emerging invasive weed species, based on their listing as noxious weeds Classes 1, 2, 3 or 5. The map displayed patterns of spread similar to those described for widespread species above.

The listing of noxious weeds is a means of preventing their further spread and these listings correspond well with the categories of new and emerging weeds. Noxious weeds have the potential to cause significant environmental or economic impacts, but can still be controlled through reasonable means. Most importantly, they are likely to spread further within an area or to other areas. Most listings apply regionally to local government areas, although some apply to the whole state.

Table 5.15 describes the five classes of noxious weed listed in NSW and the number of species currently listed in each class.

Table 5.14: Number of weeds in each CMA region in NSW

CMA region	Number of weed species present	Total number of flora species	Contribution of weeds to total flora (%)	Number of weed species with an impact on threatened species
Sydney Metropolitan	758	2,356	32	101
Hawkesbury–Nepean	733	3,012	24	98
Northern Rivers	627	3,282	19	100
Hunter/Central Rivers	580	2,893	20	96
Southern Rivers	577	2,907	20	98
Murrumbidgee	531	2,159	25	67
Central West	502	2,197	23	59
Namoi	475	1,917	25	72
Lachlan	447	1,781	25	54
Murray	439	1,641	27	55
Border Rivers–Gwydir	427	2,029	21	63
Western	242	1,463	17	29
Lower Murray–Darling	187	896	21	25
NSW total	1,386	6,634	21	127

Source: Coutts-Smith & Downey 2006

When a weed becomes so widespread that eradication or containment is no longer feasible, its declaration as a noxious weed may be repealed on the basis that it no longer meets the criteria for listing. Some widespread weeds are not listed in regions where they are abundant, but may be listed in neighbouring areas where their distribution is limited, they can still be controlled, and there is the potential for further spread.

Table 5.16 summarises outbreaks of new and newly emerging weed species that have occurred in NSW from 2008 to 2012. Predominantly, these are weeds that are listed as noxious weeds Class 1 or 2, but several are yet to be considered for listing. Eradication of these weeds to prevent their establishment and further spread has the highest priority in regional weed control strategies.

Table 5.15: Numbers and classes of noxious weeds listed in NSW

Control class	Definition	Objectives of management	Number listed 2008	Number listed at 30 Sept 2011
Class 1: State prohibited weeds	Plants that pose a potentially serious threat to primary production or the environment, and are not currently in the state, or are present only to a limited extent	Prevent introduction and establishment	27	30
Class 2: Regionally prohibited weeds	Plants that pose a potentially serious threat to primary production or the environment of a region, and are not currently in the region, or are present only to a limited extent	Prevent introduction and establishment	11	13
Class 3: Regionally controlled weeds	Plants that pose a serious threat to primary production or the environment of an area, are not widely distributed in the area and are likely to spread in the area or to another area	Reduce extent and impact	43	44
Class 4: Locally controlled weeds	Plants that pose a threat to primary production, the environment or human health, are widely distributed in an area and are likely to spread in the area or to another area	Minimise negative impact on community, economy or environment	96	95
Class 5: Restricted plants	Plants that are likely, by their sale or the sale of their seeds or movement within the state or an area of the state, to spread in the state or outside the state	Prevent introduction into NSW, spread within NSW or spread from NSW to another jurisdiction	36	28

Source: DPI data 2011

Notes: Apart from Class 1 which is statewide, weeds are counted in a class if they are listed in that class in any region or local area in the state. Some species will appear in more than one class as they may be listed under different classes in different regions. The numbers given reflect the minimum value as sometimes an entire genus containing a number of unspecified species is listed.

Orange hawkweed (*Hieracium aurantiacum*) is an example of a weed in the early stages of establishment. It is one of 28 weeds on the National Environmental Alert List for environmental weeds because it is a major weed overseas and is considered to be a serious threat to biodiversity in south-eastern Australia. It also has the potential to cause serious losses to the grazing industry, which in 2002 were predicted to be around \$48 million per year.

In NSW, orange hawkweed is currently only recorded in Kosciuszko National Park, where it was first detected in 2003. During 2010–11, the weed was discovered at 63 new locations in the park, bringing the total area detected since 2003 to 7.43 hectares. All known infestations have been managed, but ongoing surveillance is required to monitor known locations and search for new populations across a large remote and rugged area.

Table 5.16: Outbreaks of new and newly emerging weeds in NSW, 2008–09 to 2011–12

Weed	Noxious weed class	Number of new infestations	Number of repeat infestations
Aleman grass	2	11	0
Alligator weed	2	39	4
<i>Asparagus falcatus</i>	Not listed	2	0
Boneseed	2	12	0
Cape broom	2	1	0
<i>Cecropia peltata</i>	Not listed	1	0
Chinese violet	1	8	2
Gorse	2	2	0
Heteranthera	1	12	0
Horsetail	1	2	0
Hygrophila	2	1	0
Hymenachne	1	11	0
<i>Mahonia (Berberis) lomariifolia</i>	Not listed	3	0
Mesquite	2	5	12
Mexican feather grass	1	1	0
Miconia	1	21	0
Mimosa	1	0	2
Orange hawkweed	1	4	3
<i>Orbea variegata</i>	Not listed	1	0
Parkinsonia	2	7	2
Parthenium weed	1	15	6
Salvinia	2	4	0
Senegal tea plant	1	2	0
Tropical soda apple	2	42	0
Water hyacinth	2	12	1
Water lettuce	1	25	0

Source: DPI and OEH data 2012

Introduced aquatic species

Data on introduced freshwater fish species was collected from 669 sampling sites in NSW rivers in the three years up to the end of 2011. Across NSW, only 31% of the sites sampled – mostly coastal rivers – were free of introduced fish while 6.7% of sites contained only introduced fish. Averaged across all sites, 33% of the fish species at each site were introduced taxa, making up 34% of total fish abundance and 45% of total fish biomass.

The inland rivers of the Murray–Darling Basin were most heavily affected, with introduced fish present at 90% of all sites sampled. Introduced species made up 40% of all fish species, representing 44% of total fish abundance and 68% of total fish biomass.

Coastal rivers were less affected by exotic fish species. Introduced fish were present at 39% of sites, making up 10% or less of species collected, total fish abundance and total fish biomass.

Table 5.17 provides information on the abundance of individual introduced fish species. Since 2009, the pearl cichlid (*Geophagus brasiliensis*), a fish species native to

Central America, is the only newly established species with a population detected in the Tweed catchment.

It is estimated that over 400 exotic species have been introduced into Australia's marine environment, but most of these are not considered pests. Relatively few of the exotic marine species found in NSW, including several species of toxic dinoflagellates and several species of invertebrates, are considered to be a serious threat to biodiversity.

The European shore crab (*Carcinus maenas*) has been recorded in 22 estuaries and coastal lakes from Burrill Lake south to Nadgee Lake (DPI 2008b). Its distribution has not changed greatly since the last SoE report or indeed since the 1980s, despite many more estuaries and lakes being searched in recent years. Monitoring is in place to detect any future changes in its distribution. As yet, there is no evidence that the European shore crab causes severe environmental impacts, but some oyster farmers consider it a nuisance as it can eat juvenile oysters.

Table 5.17: Introduced fish at sampling sites

Fish species	% of sites where present: 2008	% of sites where present: 2011
European carp	56.5	38.8
Gambusia	47.9	41
Goldfish	33.7	29.2
Rainbow trout	10.8	5.2
Redfin perch	9.4	7.5
Brown trout	8.3	4.9
Eel-tailed catfish (translocated native species)	3.3	2.4
Oriental weatherloach	1.5	0.4
Climbing galaxias (translocated native species)	0.3	0.1
Platy	0.2	0.0
Silver perch (translocated native species)	*	0.3
Macquarie perch (translocated native species)	*	0.3
Swordtail	*	0.1
Pearl cichlid		0.1
Golden perch (translocated native species)	*	0.1
Murray cod (translocated native species)	*	0.1
Trout cod (translocated native species)	*	0.1
Rainbow fish (translocated native species)	*	0.1

Source: DPI data 2012

Notes: * Species present in very low numbers.

The marine weed caulerpa (*Caulerpa taxifolia*) is possibly the most significant threat to the marine environment of NSW as it spreads easily from small fragments and can quickly colonise large areas of subtidal soft sediment, including seagrass beds. Introduced initially as an aquarium plant, caulerpa's impact is mainly on soft-sediment invertebrates and sediment chemistry with no direct impacts on seagrasses, although investigatory work is ongoing.

Caulerpa was first recorded in NSW coastal waters in April 2000. It initially spread to 14 estuaries and coastal lakes, ranging from Lake Macquarie to Wallagoot Lake. After considerable control work, caulerpa has not been found in Lake Macquarie since 2006 or in Wallagoot Lake and St Georges Basin since 2009. It was not detected in underwater surveys in Narawallee Inlet and Durras Lake in late 2011, nor in Burrill Lake or Lake Conjola in surveys during 2012. It is believed that increased salinity due to drought conditions and closed entrances has caused the decline in caulerpa in some lakes, whereas greatly reduced salinity due to more recent flooding killed much (or possibly all) of the caulerpa in Burrill Lake and Lake Conjola.

The European fanworm and New Zealand screw shell are both still restricted to Twofold Bay on the NSW far south coast (DPI 2008b).

Pathogens and diseases

Pathogens and diseases are an emerging threat to biodiversity and are becoming more prevalent, both internationally and in Australia. The impacts of exotic and translocated native microorganisms on biodiversity are still poorly understood. However, four diseases are listed as key threatening processes (KTPs) under the *Threatened Species Conservation Act 1995* (TSC Act), with all four having potentially serious consequences for the health of the environment. The KTPs are:

- infection by psittacine circoviral (beak and feather) disease affecting endangered psittacine species and populations
- infection of native plants by *Phytophthora cinnamomi*
- infection of frogs by the amphibian chytrid fungus causing the disease chytridiomycosis
- introduction and establishment of exotic rust fungi of the order Pucciniales pathogenic on plants of the family Myrtaceae.

Psittacine beak and feather disease appears to have been present naturally in the environment and affects a number of species of parrots. Phytophthora root rot fungus is thought to have been introduced with European settlement. It is a soil-borne fungus that infects, and causes dieback in, a large range of mainly woody perennial plant species and some crops, particularly in higher rainfall areas.

The remaining diseases appear to have been introduced relatively recently. Chytrid fungus causes skin infections and death in native amphibians and is responsible for rapid declines in the populations of many native frog species.

Myrtle rust (*Uredo rangelii*) is a fungus which is a serious plant pathogen infecting species of the Myrtaceae family. This family includes many Australian native species such as eucalypts, paperbarks, teatrees and a range of understory shrubs. Myrtle rust was first detected in April 2010 on the central coast of NSW and despite containment efforts it has now spread widely in NSW, Queensland and Victoria. There is serious concern about the threat it poses to the survival of many native plants in bushland areas, particularly those which are either highly susceptible to the fungus or are naturally rare or threatened (OEH 2011b).

Environmental impacts of invasive species


Impacts on threatened species

Collectively, weeds and pest animals have been identified as a threat to approximately 70% of the threatened species listed under the TSC Act and *Fisheries Management Act 1994* (FM Act). Invasion by exotic species has an impact on the second highest number of threatened species, after land clearing (Coutts-Smith & Downey 2006).

Individual widespread animal pests such as feral cats and foxes have a far greater impact than individual weeds. However, the number of weeds is much greater and their combined impact is broader than the impact of pest animals. Weeds have a negative impact on 45% of threatened species, populations and ecological communities in NSW, while pest animals threaten 40% (Coutts-Smith & Downey 2006; Coutts-Smith et al. 2007).




Listings of invasive species as key threatening processes




The magnitude of the impacts of pest and weed species is reflected in the listing of many invasive species as KTPs in both state and federal legislation. Twenty-three of the 45 KTPs listed in NSW under the TSC Act or FM Act relate to the impacts of weeds and pest animal species and a further four to pathogens. Pest animals listed as KTPs include foxes, feral cats, rabbits, feral pigs, feral goats, black rats, deer, cane toads, gambusia and four invertebrates (feral honey bees, fire ants, yellow crazy ants and large earth bumblebees). Weed species listed as KTPs include lantana, bitou bush, Scotch broom and African olive, while vines and scramblers are listed collectively, as are exotic perennial grasses.

Broader environmental impacts




It is difficult to quantify the total impact of introduced species on biodiversity and the environment as a whole. Most of the information available is specifically about impacts on threatened species, not on all native flora and fauna (Coutts-Smith & Downey 2006) and generally only describes the extent of these impacts, not their intensity or magnitude.




The broader impacts of invasive species on the environment and ecosystem health are substantial, but largely unassessed. These broader impacts include soil degradation, landscape and habitat disturbance, structural change and decline in vegetation condition, and changes to watercourses and water quality.

Pressures



Invasive species are not present in naturally functioning ecosystems and are recognised as a threat to them. Therefore the discussion of pressures in this section relates specifically to risk factors that exacerbate the impacts of invasive species or that facilitate their spread.

Habitat disturbance



Systems that are suffering from disturbance are at the greatest risk of incursion by invasive species as the balance in the dynamic processes that maintain natural systems in equilibrium has been upset. The disturbance may be physical or caused by an imbalance in the natural biota (Lake & Leishman 2004; DPI 2008a). Invasive species are generally less affected by the constraints and balances that operate in natural systems, so they can rapidly exploit suitable habitat where natural systems are disturbed or under stress and tend to have a lower impact on healthy ecosystems.

Greater mobility and trade

Greater mobility and the globalisation of international trade are significantly increasing the movement of people and goods across Australia's borders. The risk of accidental introductions, particularly of diseases, insects and other invertebrate pests, has therefore increased.

The nursery trade is responsible for introducing many new plant species into Australia with a significant number escaping from gardens to become weeds (Groves & Hosking 1998). Sixty-five per cent of the weed species that pose a risk to threatened species in NSW were introduced as ornamental plants (Coutts-Smith & Downey 2006) and some are still available for sale in NSW. The nursery trade may also have played a role in introducing new diseases, such as myrtle rust, as most early detections of this disease were found in nurseries.

The aquarium industry is also responsible for introducing a number of fish and aquatic plant species that have been released into the wild and flourished. Illegal international trade in a variety of exotic species is a further pathway for unplanned introductions. The ballast water of cargo ships and hull biofouling are well-known pathways for the incursion and spread of pests into the marine environment.

Expansions of range

Many invasive species are yet to reach the limits of their potential distribution. For example, weed species, such as orange hawkweed, boneseed, olive, cabomba and some exotic vines, occupy only a small part of their potential range. Even some widespread species, such as lantana, bitou bush, blackberry and Coolatai grass, have the potential to spread further. Emerging pest animal species, such as deer and cane toads, are also continuing to spread.

A national program is under way to eradicate red fire ants before they spread into NSW.

Climate change

Limited information is available on how climate change might affect invasive species, but it is likely that the impact of invasive species will increase (DPI 2008a). Invasive species are generally well-adapted as colonisers of disturbed ecosystems and are likely to cope better than native species with expected changes in environmental conditions, such as increased temperatures and changes in rainfall and fire regimes. Expansions and contractions in the range of both native and invasive species due to climate change are likely to differentially favour invasive species.

Lack of information

Information on the distribution and abundance of invasive species is patchy and largely subjective. A management framework has been established through the *NSW Invasive Species Plan 2008–2105* (DPI 2008a) and a monitoring program has been set up following the mid-term review of the Natural Resources Monitoring, Evaluation and Reporting Strategy 2010–2015 (DECCW 2010d) to provide high level information. A pest and weed information system has been established for NSW parks, but there are few standardised procedures and databases for collecting and maintaining consistent information on invasive species statewide.

As most of the information available concerns threatened species, further work is needed to estimate the impacts of invasive species on the environment as a whole. This information would assist in identifying priorities for control, and managing both the impacts of invasive species on biodiversity and the adaptation of invasive species to the effects of climate change.

Responses

Established responses

NSW 2021

NSW 2021: A plan to make NSW number one (NSW Government 2011) is the Government's 10-year plan for NSW. Under Goal 22 – 'Protect our natural environment', the plan contains the following target: 'Manage weeds and pests'. One of the strategies

for achieving this target is to 'Reduce the impact of invasive species at priority sites on National Parks and Wildlife Service (NPWS) parks and reserves, leading to a positive response of native biodiversity at 50% of these sites by October 2015'.

The priority actions associated with this target are to:

- '... use the knowledge and experience of local communities to target our resources to protect and restore natural ecosystems'
- 'address core pest control in national parks through the delivery of NPWS regional pest management strategies ...'

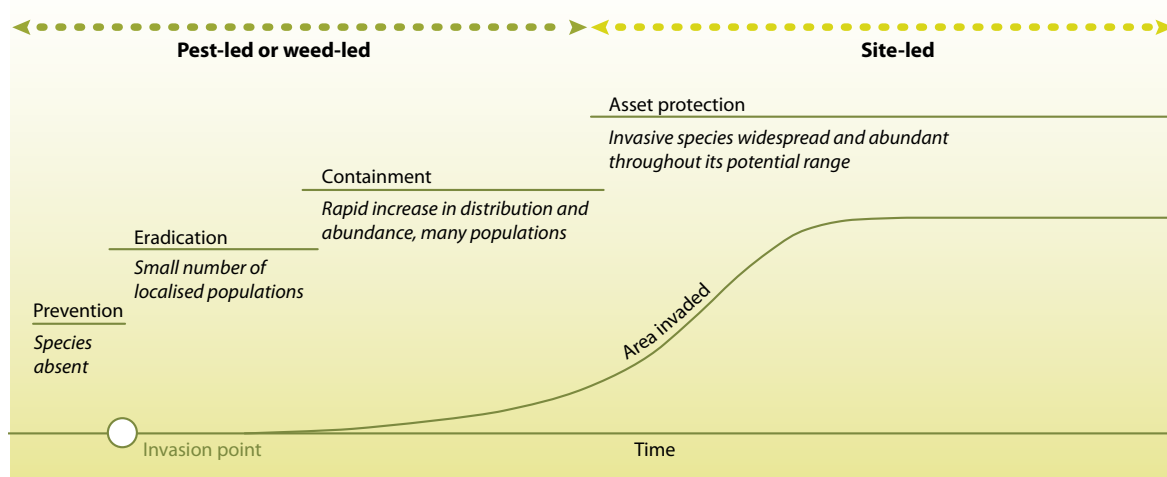
Legislation

The most important legislation relating to invasive species management is the *Noxious Weeds Act 1993*, *Rural Lands Protection Act 1998*, *TSC Act*, *FM Act*, *Game and Feral Animal Control Act 2002* and *Quarantine Act 1908* (Cwlth).

Invasive Species Plan

The response of the NSW Government to invasive species impacts is set out in the *NSW Invasive Species Plan 2008–2015* (DPI 2008a). The plan describes the control strategies that are most effective at different stages in the cycle of incursion and establishment of invasive species (**Figure 5.7**).

Figure 5.7: Strategies for managing new, emerging and widespread pests and weeds in NSW



Source: DPI 2009a

The four main strategies for managing invasive species in NSW (shown in Figure 5.7) are:

- **prevention** – precautionary measures which prevent the arrival of any new species that is likely to become invasive and have a significant impact on native species and ecosystems or agricultural production
- **eradication** – the detection and permanent removal of any newly arrived invasive species that is likely to have a significant impact on native species and ecosystems before it can establish self-sustaining populations
- **containment** – restricting the spread of recently established or emerging invasive species which cannot realistically be eradicated
- **asset protection** – targeting control at the most severe impacts of widespread invasive species in areas of high conservation value and where the prospects for successful control are greatest.

Programs that aim to prevent, eradicate or contain weeds or pests during the earlier stages of incursion are considered to be 'weed-led' or 'pest-led'. The focus of such programs is on individual weed or pest species and priorities are determined by the characteristics of each species and its potential impacts (Figure 5.7).

When invasive species are well established, programs for their control are considered to be 'site-led'. Rather than managing a specific weed or pest affecting the site, the focus is on protecting the native species or ecosystems (assets) that are most affected by the invasive species. Strategies target sites where the benefits of protection or control will be greatest.

Management of new invasive species: prevention and eradication

The most cost-effective means of managing invasive species are to:

- prevent their incursion, or
- if they occur, to rapidly detect and eradicate them.

Eradication is seldom feasible once an invasive species becomes established.

Preventing incursions is the primary focus of the Australian Biosecurity System for Primary Production and the Environment. This whole-of-government initiative brings together biosecurity activities undertaken by federal, state and territory governments, together with industry, landholders and key stakeholders in the fields of primary production and the environment within a national framework.

The *NSW New Weed Incursion Plan 2009–2015* (DPI 2009b) was developed to address the prevention and eradication objectives of the *NSW Invasive Species Plan 2008–2015* (DPI 2008a) for weeds. The incursion plan:

- coordinates surveillance in NSW
- identifies new weeds and weed incursions
- provides for risk assessments of species
- facilitates the implementation of effective barriers to prevent the establishment of weeds
- specifies ways in which responses to weed incursions are coordinated, implemented, monitored and reported.

Few management programs target invertebrates (including insects), apart from those which deal with regular outbreaks of plague locusts. However, one of the most successful programs has been the apparent eradication of an incursion of yellow crazy ants detected in 2004 at Goodwood Island, near the mouth of the Clarence River. Following a collaborative campaign of regular treatment and surveillance of the infested area during 2004 and 2005, no yellow crazy ants have been observed on the island since 2005.

Management of emerging invasive species: containment

Containment is the main focus of strategies for managing emerging invasive species. Once an invasive species becomes established and starts to expand in range, the main objective shifts from eradication to limiting its spread (see Figure 5.7). Containment zones have been established for several weeds of national significance including bitou bush on the south and far north coasts of NSW and lantana on the south coast. The objective is to completely eradicate the weeds from these zones.

As discussed earlier in this section, the listing of noxious weeds in the schedules of the *Noxious Weeds Act 1993* aims to prevent the establishment of significant new weeds and restrict the spread or limit the impact of existing significant weeds (see 'Distribution of environmental weeds in NSW').

Management of widespread invasive species: asset protection

Many invasive species are already widely established in NSW and these have the greatest impact of all invasive species on the environment. It is usually impossible to eradicate an invasive species that has become widespread or to achieve lasting control, regardless of the resources deployed. The rare exception is where a suitable biological control is identified and remains effective as is the case for prickly pear and water hyacinth, and was for rabbits for a time.

The control of widespread species must therefore be strategically targeted to reduce their impact on native species and populations, regional ecosystems and ecological communities. This targeting requires prioritising the natural values most at risk and identifying the sites where these values are greatest and controls are expected to be most effective, based on the likelihood of recovery or maintenance of biodiversity.

Biodiversity Priorities for Widespread Weeds (DPI & OEH 2011) and 13 regional documents produced by the CMAs have been developed to guide regional decision-making in:

- identifying weed priorities, asset importance and high value sites
- developing programs to control widespread weeds and manage assets and natural values.

Threat abatement plans (TAPs) have been developed to manage a number of invasive species identified as key threatening processes, including foxes (OEH 2011c), *Gambusia holbrooki* (NPWS 2003) and bitou bush (DEC 2006). All TAPs incorporate a monitoring program to measure their effectiveness and the response of the main threatened species affected.

As over 300 weed species are considered to have an impact on biodiversity, it is not practical to develop single-species TAPs for every weed species. Therefore, regional weed strategies which have a focus on protecting native species and ecosystems (DPI & OEH 2011) have been developed to apply to all widespread weeds.

Strategic priorities for weed management

Due to the number of invasive weed species that have become established in NSW, most CMAs have developed regional weed strategies, based on a strategic framework (DPI & OEH 2011) and a commonly accepted process for managing weeds (Randall 2000). These strategies take account of the weeds' impact, invasiveness, distribution and rate of spread. Highest priority is generally given to weeds that have a limited distribution and the lowest to those that are already widespread.

Controls for most pest animals and invertebrates are usually conducted individually, depending on the characteristics of the invasive species, even where the focus of the program is on protecting natural values.

Pest management strategies in national parks

Management of invasive species across NSW national parks and reserves is conducted in accordance with a statewide management framework (OEH 2011d)

and 14 Regional Pest Management Strategies. These are consistent with the principles set out in the *NSW Invasive Species Plan 2008–2015* (DPI 2008a). The state strategy sets the high level goals, objectives and the prioritisation methods under which regional pest and weed programs operate.

Management of aquatic pests

The FM Act lists noxious fish species and marine weeds. The species listed pose a significant threat to wildlife, ecosystems, human health or the aquaculture industry. The list is divided into three classes representing the level of threat the species poses to the aquatic environment. Most noxious fish are listed in Class 1 which prohibits their live possession and sale and applies to 108 species, 25 genera, one subfamily and one family. There is also one Class 1 noxious species of marine vegetation: caulerpa. Fisheries officers have the power to seize and destroy any live fish or plants listed as a Class 1 or 2 noxious species.

Future opportunities

With the growth in global travel and trade, new and potentially invasive species will continue to be introduced into NSW, either deliberately or accidentally. Improvements to surveillance and biosecurity measures may be needed to prevent new incursions from threatening natural ecosystems and the productivity of farming systems.

Biological controls will continue to provide the best opportunities for effective and affordable management of widespread invasive species and further opportunities should continue to be explored.

Pathogens and diseases are emerging as an increasing threat to natural systems and are likely to present new challenges for effective management and control.



5.5 Fire

Fire is a significant and ongoing threat to human settlement. While fire plays an important role in the health of natural ecosystems, it is also a threat to ecosystem integrity. An improved understanding of the role of fire in natural systems is increasingly being factored into fire management.

Fire is a natural part of the Australian landscape. Altered fire regimes since European settlement – too much or too little fire, or fire of too high or too low an intensity – can have major detrimental effects on the structure of most ecosystems and many threatened species.

The key to achieving appropriate fire management is achieving the right balance between maintaining natural ecosystems and ensuring community safety and the protection of property, infrastructure and livestock.

One of the principal tools for fire management is hazard reduction burning. The level of hazard reduction activity in New South Wales has increased over the past three years to cover an average of about 138,000 hectares per year.

More than 50% of all bushfires are started by humans in most years, with arson being the major cause of such fires.

NSW indicators

Indicator and status	Trend	Information availability
Average area of bushfires in the NSW reserve system	Unknown	✓
Ratio – area of bushfires to area of management burns in the NSW reserve system	Unknown	✓

Notes: These indicators only apply to areas managed by the NSW National Parks and Wildlife Service (NPWS). Terms and symbols used above are defined in *About SoE 2012* at the front of the report.

Introduction

Fire has been present on the Australian continent for millions of years and is a key factor in plant and animal population dynamics in most NSW ecological communities. Many Australian animals and plants have evolved not only to survive but also to benefit from the effects of fire. Much of the flora of NSW depends on fire to assist in reproduction and growth.

In Australia, fire has been managed since humans first settled on the continent. Although the fire regimes practised by Aboriginal people before the arrival of Europeans are not fully understood by the scientific community, the pattern of fire in the landscape has changed over the past 200 years (Williams et al. 2001). The introduction of property ownership by private individuals and corporations and the need to protect dwellings, infrastructure, such as fences and sheds, and livestock have altered fire regimes and resulted in ecological impacts across a variety of landscapes.

Status and trends

Incidence of fire

The effects of bushfires in NSW are generally described in terms of their extent, social impacts and costs. Bushfires can be extremely destructive and may result in substantial social costs, including the loss of human lives, buildings, infrastructure and livestock. In extreme cases, such as the Canberra bushfires of 2003 and the Victorian bushfires of 2009, they are natural disasters that have claimed many human lives, destroyed valuable property and infrastructure, and severely disrupted essential services.

The incidence of fire varies greatly each year (**Table 5.18**) with the number of fires closely linked to prevailing weather patterns. Total fire bans may be declared by the Minister for Emergency Services in any part of NSW, generally when hot, dry and windy conditions are predicted to occur in areas where

vegetation is dry and fire could easily spread. The number of statewide total fire bans declared each year is indicative of the extent of forecast fire-weather conditions across NSW and hence the severity of the fire season.

The main factors determining the severity and extent of a bushfire are:

- weather conditions, including wind speed, temperature and relative humidity
- the dryness of the fuel, the type of fuel and the fuel load
- the physical structure of vegetation and the terrain in which the fire is burning
- the effectiveness of fire suppression actions.

Table 5.18 shows the number of fires and the severity and length of the fire seasons over the past nine years.

Table 5.18: Data on NSW bushfires, 2002–03 to 2010–11

Fire season	No. of bushfires*	No. of grass fires	Statewide total fire bans (days)	No. of s.44 declarations in a fire season**	Days between first and last s.44 declaration in a fire season**	Lives lost as a direct result of fire
2002–03	5,642	n/a	13	61	151	3
2003–04	1,764	n/a	0	10	31	0
2004–05	2,659	n/a	1	20	16	0
2005–06	2,865	n/a	5	38	150	2
2006–07	3,361	n/a	0	36	151	2
2007–08	2,271	2,157	0	7	75	0
2008–09	2,522	2,689	0	10	60	1
2009–10	3,446	2,549	0	50	160	1
2010–11	1,897	2,316	0	0	0	2

Source: NSW Rural Fire Service (RFS) data 2011

Notes: * Derived by adding the number of fires from the four RFS regions. Any fire that occurred across the boundary of two regions has been counted twice.

** Section 44 declarations apply to fires where the RFS Commissioner controls operations.

Fire ecology

The impacts of bushfires are commonly described in terms of areas burnt and lives and assets lost, but this description provides little information on their ecological effects. These depend on:

- the intensity of a fire
- the season of the burn
- the previous fire history of an area
- the sensitivity of ecosystems affected.

Understanding the ecological outcomes of fire is further impeded by a poor knowledge of the responses of vegetation and wildlife to fire. Ecological communities are dynamic systems and fire is a natural disturbance that creates change. Fires shape the structure, composition and ecological function – including soil and nutrient cycles – of most plant communities, creating specific habitats required by a range of species. Differing patterns of fire history will favour some species and associations, and suppress others.

However when fires occur too frequently, even fire-tolerant species may become locally extinct due to their life cycles being interrupted. For example, a second fire in too short a time frame could kill all young plants and seedlings before they reach reproductive age, leading to the extinction of local populations of species. Conversely, the lack of fire may mean that fire-dependent species cannot regenerate, such as those that need fire for seed germination. Broad changes in fire patterns may result in habitat transformations, such as changes in the structure of vegetation, shifts from one vegetation type to another and reduced habitat resilience to invasive species.

Altered fire regimes have been described as a threat to over 80% of the state's vegetation classes (see Biodiversity 5.2). High-frequency fire has been identified as a significant cause of biodiversity loss in NSW and is listed as a key threatening process under the *Threatened Species Conservation Act 1995*.

The interval between fires is a critical factor in the capacity of individual species to survive and reproduce (Bradstock & Kenny 2003). Minimum fire intervals needed to maintain biodiversity have therefore been developed. These allow sufficient time between fires for species to complete the crucial stages of their life cycles essential for regeneration, such as plants being able to reach an age where they can produce adequate seed. **Table 5.19** presents minimum fire intervals for a range of vegetation formations. Table 5.19 also shows the maximum fire intervals generally needed by various vegetation formations to allow them to regenerate before they become too old. The

greatest biodiversity is maintained by varying the length of fire intervals between the maximum and minimum requirements as well as the location of fires (Kenny et al. 2003).

Refining knowledge about the frequency of burning and appropriate fire intervals for various vegetation formations in NSW is likely to remain the subject of scientific investigation for some time, due to the diverse array of species and communities and the time taken to determine the long-term effects of fire.

A key component of long-term monitoring of the effects of fire on ecological systems is matching fire history to vegetation formations. The NSW Rural Fire Service (RFS) is compiling fire history data across NSW, in conjunction with land management agencies. While there are still some limitations due to the nature of the historical data, it is now being collected on an annual, coordinated basis. The information on statewide vegetation is also being improved.

Fire management

Fire management strategies

The emphasis of fire management should be on reducing fire hazard and minimising risk (Ellis et al. 2004). The primary objective of fire management is to protect human life and property, with biodiversity conservation an important, but secondary, consideration. Asset protection zones provide for reduced fuel loads near houses and other built structures. The most common method of reducing fuel in these zones is through mechanical means, such as bulldozing.

The RFS develops regional bush fire risk management plans in consultation with the community. To achieve the objectives of these plans, some areas called 'strategic fire advantage zones' require fuel loads to be reduced more frequently than is specified by the minimum intervals for maintaining biodiversity (Table 5.19). Reduced minimum intervals have been developed for these areas that are absolute minimums for maintaining biodiversity as they provide little or no buffer for adequate seed production.

Biodiversity requirements can often be incorporated into fire management practices. However, compromises that result in suboptimal outcomes for biodiversity conservation may be required at times (DEC 2005), particularly in asset protection zones. Appropriate assessment is undertaken on a case-by-case basis in these circumstances.

Table 5.19: Fire intervals for NSW vegetation formations

Vegetation formation	Minimum interval between fires where managing biodiversity is the focus (years)	Minimum interval between fires where reducing risk to human life and property is the focus (years)*	Maximum fire interval (years)
Rainforests	No fire	No fire	No fire
Alpine complex	No fire	No fire	No fire
Estuarine and saline wetlands	No fire	No fire	No fire
Grasslands	3	2	10
Grassy woodlands	8	5	40
Dry sclerophyll forests (shrub/grass subformation)	8	5	50
Dry sclerophyll forests (shrubby subformation)	10	7	50
Semi-arid woodlands (shrub/grass subformation)	9	6	40
Semi-arid woodlands (shrubby subformation)	15	10	40
Arid shrublands (chenopod subformation)	No fire	No fire	No fire
Arid shrublands (acacia subformation)	15	10	40
Forested and freshwater wetlands (excluding montane bogs and fens, coastal freshwater lagoons and montane lakes which have no tolerance of fire)	10	7	35
Heathlands	10	7	30
Wet sclerophyll forests (grassy subformation)	15	10	60
Wet sclerophyll forests (shrubby subformation)	30	25	60

Source: Department of Environment and Conservation (DEC) data 2005

Notes: Vegetation formations are as described in Keith 2004.

* These intervals are absolute minimums for maintaining biodiversity as they provide little or no buffer for adequate seed production.



Hazard reduction

Hazard reduction burning to reduce fuel loads is a key control strategy practised widely across the state. This burning is complemented by mechanical works, such as bulldozing, to maintain setbacks around properties, firebreaks and fire trails. The annual levels of hazard reduction burning and the total areas of hazard reduction management are described in **Table 5.20**. Over the past three years (for which data is available), the level of hazard reduction burning has increased to an average of about 138,000 hectares per year, from the previous level of about 112,000 hectares per year.

Rapid response to outbreaks of fire

The early detection and rapid suppression of bushfires is a key control strategy for managing and preventing their spread. As access to fires that start in remote areas is often difficult, special remote area fire teams have been set up by the RFS and the NSW National Parks and Wildlife Service (NPWS) to enable a rapid response to fires that start in such areas.

Ecological burns

Although some managed burns meet both hazard reduction and ecological needs, there is limited information on fires conducted solely for ecological purposes, such as those that aim to ensure the maximum fire interval is not exceeded. However, the NSW Government is identifying areas where vegetation formations are underburnt or overburnt, based on both fire history records and the fire intervals identified in Table 5.19.

Effectiveness of fire management

To monitor the effectiveness of fire management through hazard reduction burning and rapid response in NSW national parks and reserves, NPWS is developing performance indicators for fire management. 'Average area of bushfires in the NSW reserve system' gives an indication of the effectiveness of rapid response techniques in preventing the spread of fires. 'Ratio – area of bushfires to area of management burns' provides an indication of the effectiveness of bushfire suppression through hazard reduction burning, improved detection and rapid response techniques.

Table 5.20: Area of hazard reduction management by tenure

Year	Hazard reduction methods	Land tenure					Total
		Local council land	NSW national parks	Private land	State forest	Other	
2005–06	Burning only	838	29,070	3,155	38,008	790	71,861
	All methods*	31,387	32,026	3,647	38,008	2,674	107,742
2006–07	Burning only	177	23,718	8,498	43,715	1,905	78,013
	All methods*	25,495	23,840	8,892	43,716	2,295	104,238
2007–08	Burning only	1,163	48,497	13,958	30,719	3,861	98,198
	All methods*	10,464	49,514	21,656	30,719	12,203	124,556
2008–09	Burning only	35	59,068	8,214	29,008	7,360	103,685
	All methods*	12,304	60,117	8,897	30,652	11,364	123,334
2009–10	Burning only	981	93,424	16,072	36,083	7,945	154,505
	All methods*	16,091	95,673	16,758	36,216	9,968	174,706
2010–11	Burning only	396	56,060	4,734	10,857	2,811	74,858
	All methods*	31,573	58,092	7,398	10,884	9,686	117,633

Source: RFS annual reports, such as RFS 2011

Notes: All values in hectares

* Includes burning and mechanical works, but not grazing of land.

Table 5.21 shows that results for both indicators are well below the 10-year average over the past four years, which may appear to demonstrate that the two strategies are being implemented successfully. However, climatic conditions over this period have not produced extended seasons of severe fire-weather and it is still far too early to assess the overall effectiveness of these strategies in controlling bushfires.

Pressures

Since fire is itself a pressure on the environment, this section discusses the risk factors that exacerbate the threat of fire.

Causes of fire

Data has consistently shown that the incidence of fire is markedly higher in the more densely populated areas along the NSW coast than in less densely populated areas elsewhere. There appears to be a strong relationship between the incidence of fire and

population density. The proportion of fires caused by humans is higher in RFS data than the data compiled by NPWS as many national parks are located in less accessible areas.

RFS and NPWS data on the causes of fires indicates that most fires are due to human intervention rather than natural processes (**Table 5.22**). Such fires may be caused by arson, accidental ignition or escapes from prescribed burn-offs. Arson is the most common cause, responsible for over half of all fires. Investigations by the Australian Institute of Criminology into the causes of 466 fires using RFS data between 2001 and 2004 found that 64% were deliberately lit (AIC 2005a; AIC 2005b). However the number and proportion of deliberately lit fires has decreased over the past three years.

The main natural cause of fires is lightning strikes and the number and proportion of natural fires is highly variable from year to year. The proportion of naturally caused fires is higher in national parks and reserves, which are generally more remote from human settlement.

Table 5.21: Areas of hazard reduction and bushfire in NSW national parks

Period	Number of fires affecting parks	Area of bushfires	Average area burnt	Area of hazard reduction burns	Ratio – area of bushfires: area of hazard reduction
2001–02	356	593,388	1,667	31,703	18.7
2002–03	433	1,001,854	2,314	42,827	23.4
2003–04	263	38,120	145	65,451	0.6
2004–05	211	16,887	80	41,037	0.4
2005–06	202	26,695	132	27,400	1.0
2006–07	372	254,727	685	23,718	10.7
2007–08	160	43,726	273	48,514	0.9
2008–09	166	21,745	131	59,202	0.4
2009–10	327	121,941	373	93,117	1.3
2010–11	78	1,080	14	55,976	0.02
10-year total	2,568	2,120,163		488,945	
10-year average			826		4.3

Source: NPWS data 2012

Notes: All areas shown are in hectares.

Fire and climate change

Bushfires are associated with high fire-weather risk which is expected to increase as a result of climate change (Hennessy et al. 2006). Projections indicate an increase in fire-weather is likely across south-eastern Australia (Lucas et al. 2007). The frequency of days with 'extreme' ratings on the forest Fire Danger Index (FDI) is predicted to increase by 5–25% for low climate change scenarios by 2020 and by 15–65% for high climate change scenarios. By 2050, the increases are forecast to rise 10–50% for low climate change scenarios and 100–300% for high scenarios.

A more recent study (Clarke et al. 2011) has predicted that the forest FDI is likely to increase strongly in southern NSW by 2100, but remain stable in the

north of the state, as shown in **Figure 5.8**. Royal National Park and the forested escarpment behind Wollongong, including the Woronora Plateau, are at particular risk of more frequent and intense fires (Climate Commission 2011).

'Fire danger' seasons are predicted to become longer and start earlier in the year, but it is less certain whether the number of days when it is safe to conduct hazard reduction burning will decrease, or whether the window of suitable days will shift to earlier and later in the year. More intense fires will pose higher risks to human health, property and infrastructure (Williams et al. 2009) and increased fire frequency is likely to have detrimental effects on biodiversity and long-term consequences for terrestrial ecosystems (Banks et al. 2011).

Table 5.22: Causes of investigated bushfires in NSW

Period	Deliberate (includes juveniles, smoking)	Accidental (includes equipment use, rail, powerlines)	Natural (includes miscellaneous)	Debris burning (includes campfires)*	Undetermined	Total
RFS data						
2001–04	298	68	51	36	13	466
2005–08	450	30	75	73	92	720
2008–09	142	12	30	22	28	234
2009–10	217	36	182	58	74	567
2010–11	193	19	18	45	48	323
NPWS data						
2001–02	148	11	93	54	50	356
2002–03	85	13	236	42	57	433
2003–04	124	13	71	41	14	263
2004–05	111	16	52	20	12	211
2005–06	81	7	45	27	42	202
2006–07	79	4	201	30	58	372
2007–08	45	4	39	17	55	160
2008–09	46	3	73	13	31	166
2009–10	58	2	175	18	74	327
2010–11	34	1	12	5	26	78

Sources: RFS data 2012; NPWS data 2012

Notes: * Redefined from 'burn-off' in previous cycles of reporting

Responses

Established responses

Legislation

Under the *Rural Fires Act 1997* (RF Act), the RFS is responsible for preventing, mitigating and suppressing bushfires in rural fire districts. All functions performed by the RFS must be consistent with the principles of biodiversity conservation and ecological integrity stipulated by the *Protection of the Environment Administration Act 1991*.

Coordination of fire management

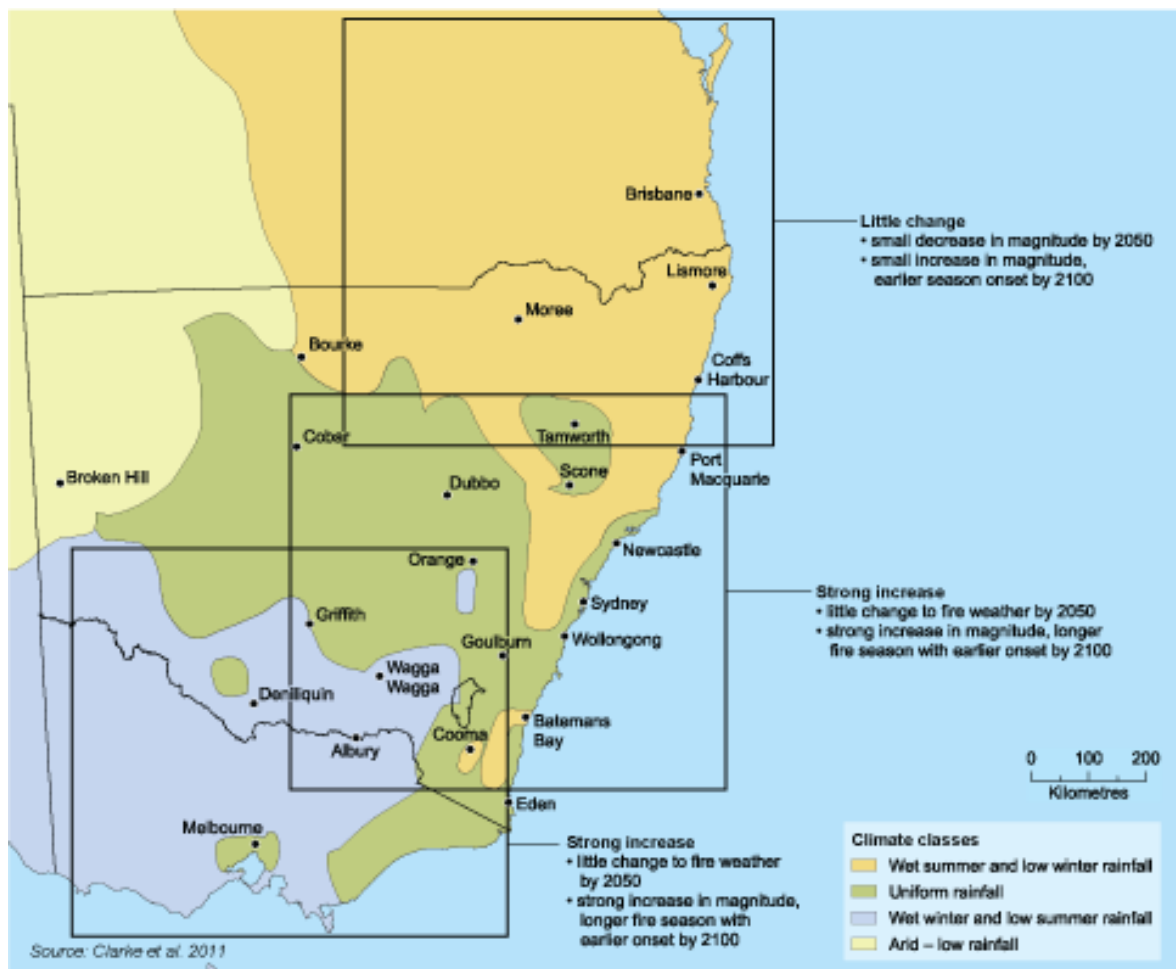
The RF Act provides for the establishment of the NSW Bush Fire Coordinating Committee (BFCC) and district Bush Fire Management Committees (BFMCs) which prepare and adopt bush fire risk management plans and operations coordination plans for each rural fire district. The risk management plans identify

assets at risk from bushfires, including environmental assets, and specify a range of strategies and actions to protect these assets and the agencies responsible for their implementation. Strategies and actions include hazard reduction, property planning, community education, preparedness and ignition management strategies.

Bush Fire Environmental Assessment Code

The Bush Fire Environmental Assessment Code 2006 provides a streamlined environmental assessment and approval process for bushfire hazard reduction works. Assessments under the code consider the impacts of prescribed burning and mechanical works on natural values, including vegetation, threatened species, heritage items, soil stability, and air and water quality. Minimum fire intervals for vegetation formations (see Table 5.19) and threatened species guidelines must be considered. The code is currently being reviewed to further streamline environmental approvals for hazard reduction.

Figure 5.8: Predicted changes in fire frequency and magnitude



Planning and land use

Land-use planning decisions are intrinsic to fire management and environment protection strategies. Integrating protection against bushfires into the planning and development system through the BAL Risk Assessment Application Kit ensures safer developments in bushfire-prone areas. One strategy is to set development back from bushland at the planning stage to protect dwellings from bushfires. Proposed developments may be re-sited or redesigned if the environmental impacts of these setbacks are likely to be significant. Higher building construction standards may also be adopted to offset the setback distance required and contingency measures for fighting fires incorporated into the construction design.

Enhanced Bushfire Management Program

The Enhanced Bushfire Management Program (EBMP) was set up by the NSW Government in response to the findings of the 2009 Victorian Bushfires Royal Commission to prepare for a potential increase in the threat of bushfires. EBMP funding has been allocated to NPWS between 2011 and 2016 to increase the level of hazard reduction works conducted annually and improve bushfire response capability in parks and reserves.

A key component of the EBMP is the establishment of teams across the state to conduct hazard reduction works and respond quickly to outbreaks of fire in remote areas. These teams include specially trained and equipped personnel with dedicated planes on standby to enhance the capacity for early detection and rapid suppression of fires in remote areas. NPWS will monitor the effectiveness of these strategies through a suite of key performance indicators.

Community education

Community engagement activities and resources are a key component of the bushfire risk management program. The Hotspots Fire Project involves state agencies and non-government organisations and provides landholders and land managers with the skills and knowledge they need to protect life and property while protecting and maintaining biodiversity. The project promotes the understanding that well-informed and prepared communities complement the roles of land managers and fire agencies.

The RFS has also established the AIDER Program to assist infirm, disabled and elderly residents living in bushfire-prone areas to undertake fuel reduction activities.

Arson prevention

A range of measures have been implemented to reduce the rate of arson in NSW. Information sharing between agencies responsible for preventing and investigating arson-related fires has vastly improved, through establishment of the Bushfire Arson Taskforce and a whole-of-government intelligence database. The development of cross-agency strategies by Arson Prevention District working parties has also reduced the incidence of arson-related fires in those areas where they have been established. NSW will continue to support the National Strategy for the Prevention of Bushfire Arson implemented in 2009.

Knowledge and information

The Bushfire Risk Information Management System (BRIMS) stores data on fires across the state and is maintained by fire authorities and public land managers. Long-term data on where fires start and how they spread will be invaluable for determining fire management strategies, the allocation of firefighting resources, and the prevention of fires caused by arson and accidental ignition. Collated data on prescribed burns will also provide greater insight into how fire history affects fire management and environmental impacts.

Future opportunities

Fire management strategies will increasingly be based on better knowledge of fire behaviour and ecology, and better techniques for fire suppression.

There is scope for better maintenance and use of the data and information that is collected about fire. Information is improving, leading to more sophisticated analyses of bushfire patterns, effects and environmental impacts, and the use of decision-support and related applications such as digital mapping systems for fighting fires and managing hazards.

Support for new and ongoing research is essential for all aspects of fire behaviour, management and suppression. There is a need to learn more about fire ecology and how to improve building design, property management and community resilience to better cope with fire.

The incidence of high fire-risk days – and consequently the frequency of bushfires – is expected to rise. The number of days when it is safe to conduct hazard reduction burning may be reduced or move to earlier and later in the year. Under such scenarios, fire management strategies will need to be flexible and informed.

References

- ABARES 2011, *Guidelines for Land Use Mapping in Australia: Principles, procedures and definitions*, 4th edition, Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra [adl.brs.gov.au/landuse/index.cfm?fa=main.specifications]
- AIC 2005a, 'Causes of investigated fires in New South Wales', *Bushfire Arson Bulletin 21*, Australian Institute of Criminology, Canberra [www.aic.gov.au/publications/current%20series/bfab/21-40/bfab021.aspx]
- AIC 2005b, 'Causal factors in New South Wales investigated bushfires: Part 1 – Deliberate fires', *Bushfire Arson Bulletin 22*, Australian Institute of Criminology, Canberra [www.aic.gov.au/publications/current%20series/bfab/21-40/bfab022.aspx]
- ANZECC TFMPA 1998, *Guidelines for Establishing the National Representative System of Marine Protected Areas*, Australian and New Zealand Environment and Conservation Council Task Force on Marine Protected Areas, Environment Australia, Canberra
- Banks, S.C., Knight, E.J., McBurney, L., Blair, D. & Lindenmayer, D.B. 2011, 'The effects of wildfire on mortality and resources for an aboreal marsupial: resilience to fire events but susceptibility to fire regime change', *PLoS One*, 6, e22952 [www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0022952]
- Beaumont, L.J., McAllan, I.A.W. & Hughes, L. 2006, 'A matter of timing: changes in the first date of arrival and last date of departure of Australian migratory birds', *Global Change Biology*, 12(7), pp.1339–54 [onlinelibrary.wiley.com/doi/10.1111/j.1365-2486.2006.01171.x/abstract]
- Beeton, R.J.S., Buxton, C.D., Cutbush, G.C., Fairweather, P.G., Johnston, E.L. & Ryan, R. 2012, *Report of the Independent Scientific Audit of Marine Parks in New South Wales*, NSW Department of Primary Industries and NSW Office of Environment and Heritage, Sydney [www.marineparksaudit.nsw.gov.au/imagesDB/wysiwyg/MPksAuditReport_2012_web_witherratum.pdf]
- Bellard, C., Bertelsmeier, C., Leadley, P., Thuiller, W. & Courchamp, F. 2012, 'Impacts of climate change on the future of biodiversity', *Ecology Letters*, 15(4), pp.365–77 [onlinelibrary.wiley.com/doi/10.1111/j.1461-0248.2011.01736.x/abstract]
- Bomford, M. & Hart, Q. 2002, 'Non-indigenous vertebrates in Australia' in Pimental, D. (ed.), *Biological Invasions: Economic and environmental costs of alien plant, animal, and microbe species*, CRC Press, Boca Raton, Florida, USA, pp.25–44 [www.crcnetbase.com/doi/abs/10.1201/9781420041668.ch3]
- Bradstock, R.A. & Kenny, B.J. 2003, 'An application of plant functional types to fire management in a conservation reserve in south-eastern Australia', *Journal of Vegetation Science*, 14(3), pp.345–54 [onlinelibrary.wiley.com/doi/10.1111/j.1654-1103.2003.tb02160.x/abstract]
- Chessman, B.C. 2011, 'Biological traits predicts shifts in geographical ranges of freshwater invertebrates during climatic warming and drying', *Journal of Biogeography*, 39(5), pp.957–69 [dx.doi.org/10.1111/j.1365-2699.2011.02647.x]
- Clarke, H.G., Smith, P.L. & Pitman, A.J. 2011, 'Regional signatures of future fire weather over eastern Australia from global climate models', *International Journal of Wildland Fire*, 20, pp.550–62 [www.frames.gov/rcts/ttrs/25000/25673.html]
- Climate Commission 2011, *The Critical Decade: Illawarra/NSW South Coast Impacts*, Canberra [climatecommission.gov.au/wp-content/uploads/4246-CC-Wollongong-Key-Messages_web.pdf]
- CoA 2002, *Landscape Health in Australia*, National Land and Water Resources Audit, Commonwealth of Australia, Canberra [www.anra.gov.au/topics/vegetation/pubs/landscape_health/landscape_health_contents.html]
- CoA 2006, *A Guide to the Interim Marine and Coastal Regionalisation of Australia Version 4.0*, Department of the Environment and Heritage, Commonwealth of Australia, Canberra [www.environment.gov.au/coasts/mbp/publications/imcra/imcra-4.html]
- Coutts-Smith, A.J. & Downey, P.O. 2006, *Impact of Weeds on Threatened Biodiversity in New South Wales*, Technical Series no.11, CRC for Australian Weed Management, Adelaide [www.canberra.edu.au/centres/iae/pdfs/2006_Coutts-Smith-and-Downey_Weeds-CRC-Tech-no-11.pdf]
- Coutts-Smith, A.J., Mahon, P.S., Letnic, M. & Downey, P.O. 2007, *The Threat Posed by Pest Animals to Biodiversity in New South Wales*, Invasive Animals Cooperative Research Centre, Canberra [www.feral.org.au/wp-content/uploads/2010/03/NSWBiodiversity.pdf]



DEC 2005, *State of the Parks 2004*, Department of Environment and Conservation NSW, Sydney [www.environment.nsw.gov.au/sop04/index.htm]

DEC 2006, *NSW Threat Abatement Plan: Invasion of native plant communities by Chrysanthemoides monilifera (bitou bush and boneseed)*, Department of Environment and Conservation NSW, Sydney [www.environment.nsw.gov.au/bitoutap/]

DECC 2008a, *Recovery Plan for the Koala (Phascolarctos cinereus)*, Department of Environment and Climate Change NSW, Sydney [www.environment.nsw.gov.au/resources/threatenedspecies/08450krp.pdf]

DECC 2008b, *NSW Interim Native Vegetation Extent (2008 – Version 1)*, report prepared by the Department of Environment and Climate Change NSW for the National Land and Water Resources Audit, Sydney [lwa.gov.au/products/pn21468]

DECC 2008c, *New South Wales National Parks Establishment Plan 2008*, Department of Environment and Climate Change NSW, Sydney [www.environment.nsw.gov.au/resources/protectedareas/0852npestplan.pdf]

DECCW 2009a, *New South Wales State of the Environment 2009*, Department of Environment, Climate Change and Water NSW, Sydney [www.environment.nsw.gov.au/soe/soe2009/]

DECCW 2009b, *Native Vegetation: Compliance and enforcement strategy*, Department of Environment, Climate Change and Water NSW, Sydney [www.environment.nsw.gov.au/resources/vegetation/09465nvcestrategy.pdf]

DECCW 2010a, *NSW Climate Impact Profile: The impacts of climate change on the biophysical environment of New South Wales*, Department of Environment, Climate Change and Water NSW, Sydney [www.environment.nsw.gov.au/resources/climatechange/10171climateimpactprof.pdf]

DECCW 2010b, *Draft NSW Biodiversity Strategy 2010–2015*, Department of Environment, Climate Change and Water NSW, Sydney [www.environment.nsw.gov.au/resources/biodiversity/strategy/10821DraftBioStrat.pdf]

DECCW 2010c, *Priorities for Biodiversity Adaptation to Climate Change*, Department of Environment, Climate Change and Water NSW, Sydney [www.environment.nsw.gov.au/resources/biodiversity/10771prioritiesbioadapcc.pdf]

DECCW 2010d, *NSW Natural Resources Monitoring, Evaluation and Reporting Strategy 2010–2015*, Department of Environment, Climate Change and Water NSW, Sydney [www.environment.nsw.gov.au/resources/soc/10977nrmmstrat1015.pdf]

DECCW 2011, *Biodiversity Certification Assessment Methodology*, Department of Environment, Climate Change and Water NSW, Sydney [www.environment.nsw.gov.au/resources/biocertification/110170biocertasessmeth.pdf]

Dickman, C.R. 1996a, 'Impact of exotic generalist predators on the native fauna of Australia', *Wildlife Biology*, 2, pp.185–95 [abstract at www.wildlifebiology.com/Volumes/1996++Volume+2/Number+3/92/En]

Dickman, C.R. 1996b, *Overview of the Impacts of Feral Cats on Australian Native Fauna*, Australian Nature Conservation Agency, Canberra [www.environment.gov.au/biodiversity/invasive/publications/pubs/impacts-feral-cats.pdf]

Dickman, C.R., Pressey, R.L., Lim, L. & Parnaby, H.E. 1993, 'Mammals of particular conservation concern in the western division of New South Wales', *Biological Conservation*, 65, pp.219–48 [abstract at dx.doi.org/10.1016/0006-3207(93)90056-7]

Dillon, M., McNellie, M. & Oliver, I. 2011, *Assessing the Extent and Condition of Native Vegetation in NSW*, Monitoring, Evaluation and Reporting Program, Technical report series, NSW Office of Environment and Heritage, Sydney [www.environment.nsw.gov.au/resources/soc/20110713NativeVegTRS.pdf]

DLWC 2002, *Rates of Clearing of Native Woody Vegetation 1997–2000*, prepared by the Environmental Research and Information Consortium Pty Ltd for the Department of Land and Water Conservation, Sydney [www.pandora.nla.gov.au/tep/24231]

DNRW 2007, *Land Cover Change in Queensland 2004–2005: A statewide land cover and trees study (SLATS) report*, Department of Natural Resources and Water, Brisbane [www.derm.qld.gov.au/slats/pdf/slats_0405_sect_4to5_1.pdf]


Downey, P.O., Scanlon, T.J. & Hosking, J.R. 2010, 'Prioritising weed species based on their threat and ability to impact on biodiversity: a case study from New South Wales', *Plant Protection Quarterly*, 25(3), pp.111–26 [www.weedinfo.com.au/ppq_abs25/ppq_25-3-111.html]

DPI 2008a, *NSW Invasive Species Plan 2008–2015*, Department of Primary Industries, Orange [www.dpi.nsw.gov.au/__data/assets/pdf_file/0020/236900/nsw-invasive-species-plan.pdf]

DPI 2008b, *Keeping Your Boat & Gear Clean Will Save Money on Fuel, Increase Boat Performance, Stop the Spread of Marine Pests*, Department of Primary Industries, Orange [www.dpi.nsw.gov.au/__data/assets/pdf_file/0016/261205/marine-pests-booklet.pdf]

- DPI 2009a, *Weed Management: Understanding weed management in NSW*, Department of Primary Industries, Orange [www.dpi.nsw.gov.au/agriculture/pests-weeds/weeds/legislation/state/weed-management]
- DPI 2009b, *NSW New Weed Incursion Plan 2009–2015*, Department of Primary Industries, Orange [www.dpi.nsw.gov.au/___data/assets/pdf_file/0011/286427/nsw-new-weed-incursion-plan-2009-2015.pdf]
- DPI & OEH 2011, *Biodiversity Priorities for Widespread Weeds: Statewide framework*, NSW Department of Primary Industries, Orange and NSW Office of Environment and Heritage, Sydney [www.dpi.nsw.gov.au/agriculture/pests-weeds/weeds/publications/cmas]
- Dunlop, M. & Brown, P.R. 2008, *Implications of Climate Change for Australia's National Reserve System: A preliminary assessment*, report to the Department of Climate Change, Canberra [www.csiro.au/en/Organisation-Structure/Flagships/Climate-Adaptation-Flagship/DunlopBrown2008.aspx]
- EA 1998, *Interim Marine and Coastal Regionalisation for Australia: An ecosystem-based classification for marine and coastal environments – Version 3.3*, IMCRA Technical Group, Environment Australia, Canberra [www.environment.gov.au/coasts/mbp/publications/imcra/pubs/imcra3-3.pdf]
- Ellis, S., Kanowski, P. & Whelan, R. 2004, *Report of the National Inquiry on Bushfire Mitigation and Management*, Council of Australian Governments, Canberra [www.coagbushfireenquiry.gov.au/findings.htm#downloading]
- Gardner, J.L., Heinsohn, R. & Joseph, L. 2009, 'Shifting latitudinal clines in avian body size correlate with global warming in Australian passerines', *Proceedings of the Royal Society of Biological Sciences*, 276, pp.3845–52 [www.ncbi.nlm.nih.gov/pubmed/19675006]
- Garnett, S.T., Szabo, J.K. & Dutson, G. 2010, *The Action Plan for Australian Birds 2010*, CSIRO, Australia [www.publish.csiro.au/pid/6781.htm]
- Green, K. & Pickering, C. 2009, 'Vegetation, microclimate and soils associated with the latest-lying snowpatches in Australia', *Plant Ecology & Diversity*, 2, pp.289–313 [dx.doi.org/10.1080/17550870903019275]
- Groves, R.H. & Hosking, J.R. 1998, *Recent Incursions of Weeds to Australia 1971–1995*, Technical Series 3, CRC for Weed Management Systems, Adelaide [Pandora.nla.gov.au/pan/64168/20080620-0000/www.weeds.crc.org.au/documents/tech_series_3.pdf]
- Hennessy, K., Lucas, C., Nicholls, N., Bathols, J., Suppiah, R. & Ricketts, J. 2006, *Climate Change Impacts on Fire-weather in South-east Australia*, CSIRO, Australia [www.cmar.csiro.au/e-print/open/hennessykj_2005b.pdf]
- Hobday, A.J., Okey, T.A., Poloczanska, E.S., Kunz, T.J. & Richardson, A.J. 2006, *Impacts of Climate Change on Australian Marine Life*, report to the Australian Greenhouse Office, CSIRO Marine and Atmospheric Research, Canberra [www.cmar.csiro.au/climateimpacts/reports.htm]
- Hughes, L. 2011, 'Climate change and Australia: key vulnerable regions', *Regional Environmental Change*, 11(1) Suppl, pp.S189–195 [link.springer.com/article/10.1007%2Fs10113-010-0158-9?LI=true]
- Keith, D. 2004, *Ocean Shores to Desert Dunes: The native vegetation of New South Wales and the ACT*, Department of Environment and Conservation NSW, Sydney [summary at www.environment.nsw.gov.au/publications/ostdd.htm]
- Keith, D.A. & Burgman, M.A. 2004, 'The Lazarus effect: can the dynamics of extinct species lists tell us anything about the status of biodiversity?' *Biological Conservation*, 117, pp.41–8 [abstract at dx.doi.org/10.1016/S0006-3207(03)00261-1]
- Keith, D.A. & Simpson, C.C. 2006, *Spatial Data Layers for NSW Extant Native Vegetation*, internal report, Department of Environment and Conservation NSW, Sydney [metadata at canri.nsw.gov.au/nrdd/records/ANZNS0208000230.html]
- Keith, D.A. & Simpson, C.C. 2008, 'A protocol for assessment and integration of vegetation maps, with an application to spatial data sets from south-eastern Australia', *Austral Ecology*, 33(6), pp.761–74 [abstract at dx.doi.org/10.1111/j.1442-9993.2008.01844.x]
- Keith, D., Orscheg, C., Simpson, C., Clarke, P., Hughes, L., Kennelly, S., Major, R., Soderquist, T., Wilson, A. & Bedward, M. 2009, 'A new approach and case study for estimating extent and rates of habitat loss for ecological communities', *Biological Conservation*, 142(7), pp.1469–79 [abstract at dx.doi.org/10.1016/j.biocon.2009.02.015]
- Kenny, B., Sutherland, E., Tasker, E. & Bradstock, R. 2003, *Guidelines for Ecologically Sustainable Fire Management*, NSW National Parks and Wildlife Service, Sydney [www.environment.nsw.gov.au/resources/biodiversity/FireGuidelinesReport.pdf]
- Klamt, M., Thompson, R. & Davis, J. 2011, 'Early response of the platypus to climate warming', *Global Change Biology*, 17(10), pp.3011–18 [dx.doi.org/10.1111/j.1365-2486.2011.02472.x]





Lake, J.C. & Leishman, M.R. 2004, 'Invasion success of exotic plants in natural ecosystems: the role of disturbance, plant attributes and freedom from herbivores', *Biological Conservation*, 117(2), pp.215–26 [dx.doi.org/10.1016/S0006-3207(03)00294-5]

Laurence, W.F., Dell, B., Turton, S.M., Lawes, M.J., Hutley, L.B., McCallum, H., Dale, P., Bird, M., Hardy, G., Prideaux, G., Gawne, B., McMahon, C.R., Yu, R., Hero, J.-M., Schwarzkopf, L., Krockenberger, A., Douglas, M., Silvester, E., Mahony, M., Vella, K., Saikia, U., Wahren, C., Xu, Z., Smith, B. & Cocklin, C. 2011, 'The 10 Australian ecosystems most vulnerable to tipping points', *Biological Conservation*, 144(5), pp.1472–80 [dx.doi.org/10.1016/j.biocon.2011.01.016]




Leadley, P., Pereira, H.M., Alkemade, R., Fernandez-Manjarrés, J.F., Proença, V., Scharlemann, J.P.W. & Walpole, M.J. 2010, *Biodiversity Scenarios: Projections of 21st century change in biodiversity and associated ecosystem services*, Technical Series no.50, Secretariat of the Convention on Biological Diversity, Montreal, Canada [www.cbd.int/ts]

LGSA 2011, *Local Government and Shires Association Submission for the NSW budget for 2011–12*, Local Government and Shires Association, Sydney



Lucas, C., Hennessy, K., Mills, G. & Bathols, J. 2007, *Bushfire Weather in Southeast Australia: Recent trends and projected climate change impacts*, consultancy report for The Climate Institute of Australia, Bushfire CRC and Bureau of Meteorology, Victoria [www.bushfirecrc.com/publications/citation/bf-1038]

Lunney, D., Curtin, A.L., Ayers, D., Cogger, H.G., Dickman, C.R., Maitz, W., Law, B. & Fisher, D. 2000, 'The threatened and non-threatened native vertebrate fauna of New South Wales: status and ecological attributes', *Environmental and Heritage Monograph Series*, No. 4., pp.1–132, NSW National Parks and Wildlife Service, Hurstville



Lunney, D., Crowther, M.S., Shannon, I. & Bryant, J.V. 2009, 'Combining a map-based public survey with an estimation of site occupancy to determine the recent and changing distribution of the koala in New South Wales', *Wildlife Research*, 36(3), pp.262–73 [dx.doi.org/10.1071/WR08079]

MacNally, R., Bennett, A.F., Thomson, J.R., Radford, J.Q., Unmack, G., Horrocks, G. & Vesk, P.A. 2009, 'Collapse of an avifauna: climate change appears to exacerbate habitat loss and degradation', *Diversity and Distributions*, 15(4), pp.720–30 [dx.doi.org/10.1111/j.1472-4642.2009.00578.x]

Mahon, P., King, S., O'Brien, C., Barclay, C., Gleeson, P., Mcllwee, A., Penman, S. & Schulz, M. 2011, *Assessing the Sustainability of Native Fauna in NSW*, Monitoring, Evaluation and Reporting Program, Technical report series, NSW Office of Environment and Heritage, Sydney [www.environment.nsw.gov.au/soc/socTechReports.htm]

MBDWG 2008, *A National Approach to Addressing Marine Biodiversity Decline*, report to the Natural Resource Management Ministerial Council by the Marine Biodiversity Decline Working Group, Canberra [www.environment.gov.au/coasts/publications/marine-diversity-decline/index.html]

McLeod, R. 2004, *Counting the Cost: Impact of invasive animals in Australia*, Cooperative Research Centre for Pest Animal Control, Canberra [www.feral.org.au/counting-the-cost-impact-of-invasive-animals-in-australia-2004]

Millennium Ecosystem Assessment 2005, *Ecosystems and Human Well-being: Biodiversity synthesis*, World of Resources Institute, Washington DC, USA [www.millenniumassessment.org/en/Synthesis.aspx]

Morton, S.R. 1990, 'The impact of European settlement on the vertebrate animals of arid Australia: a conceptual model', in Saunders, D.A., Hopkins, A.J.M. & How, R.A., *Australian Ecosystems: 200 years of utilisation, degradation and reconstruction*, proceedings of a symposium held in Geraldton, Western Australia, 28 August– September 1988, *Proceedings of the Ecological Society of Australia*, 16, pp.201–13

MPA 2010, *Marine Parks Strategic Research Framework 2010–2015*, Marine Parks Authority, Sydney [www.mpa.nsw.gov.au/research.html]

Nicholls, N. 2009, 'Estimating changes in mortality due to climate change', *Climatic Change*, 97(1-2), pp.313–20 [dx.doi.org/10.1007/s10584-009-9694-z]

NLMG 2009, *Draft Plan to Protect Environmental Assets from Lantana*, prepared for the National Lantana Management Group by Department of Environment and Climate Change NSW, Hurstville [www.weeds.org.au/WoNS/lantana/#nppeal]

NLWRA 2008, *Assessing Invasive Animals in Australia*, National Land and Water Resources Audit and Invasive Animals Cooperative Research Centre, Canberra [lwa.gov.au/products/pn20628]

NPWS 2003, *Threat Abatement Plan: Predation by Gambusia holbrooki (Plague Minnow)*, NSW National Parks and Wildlife Service, Hurstville [www.environment.nsw.gov.au/pestsweeds/TAPPlagueMinnow.htm]

NRMMC 2005, *Directions for the National Reserve System: A partnership approach*, Natural Resource Management Ministerial Council, Department of the Environment and Heritage, Canberra [www.environment.gov.au/parks/publications/nrs/directions.html]

NRMMC 2006, *The Australian Weeds Strategy. A national strategy for weed management in Australia*, developed by the Australian Weeds Committee for the Natural Resource Management Ministerial Council, Canberra [www.environment.gov.au/biodiversity/invasive/weeds/publications/strategies/weed-strategy.html]

NRMMC 2009, *Australia's Strategy for the National Reserve System 2009–2030*, Natural Resource Management Ministerial Council, Canberra [www.environment.gov.au/parks/publications/nrs/nrsstrat.html]

NSW Government 2001, *Developing a Representative System of Marine Protected Areas in NSW: An overview*, NSW Fisheries, NSW National Parks and Wildlife Service and NSW Marine Parks Authority, Sydney [www.mpa.nsw.gov.au/news.html]

NSW Government 2011, *NSW 2021: A plan to make NSW number one*, Sydney [www.2021.nsw.gov.au]

OEH 2011a, *NSW Annual Report on Native Vegetation 2010*, NSW Office of Environment and Heritage, Sydney [www.environment.nsw.gov.au/vegetation/reports.htm]

OEH 2011b, *Management Plan for Myrtle Rust on the National Parks Estate*, NSW Office of Environment and Heritage, Sydney [www.environment.nsw.gov.au/pestsweeds/20110683myrtlerustmp.htm]

OEH 2011c, *NSW Threat Abatement Plan for Predation by the Red Fox (Vulpes vulpes)*, NSW Office of Environment and Heritage, Sydney [www.environment.nsw.gov.au/pestsweeds/foxes.htm]

OEH 2011d, *Draft Regional Pest Management Strategy: Part A – 2012–2015*, NSW Office of Environment and Heritage, Sydney [www.environment.nsw.gov.au/pestsweeds/draftpeststratA.htm]

Paton, D. & O'Connor, J. 2010, 'The state of Australia's birds: restoring woodlands habitats for birds', *Wingspan*, 20(1), Supplement [www.birdlife.org.au/education-publications/publications/state-of-australias-birds]

Priddel, D. & Carlile, N. 2009, 'Key elements in achieving a successful recovery programme: a discussion illustrated by the Gould's petrel case study', *Ecological Management and Restoration*, 10(S1), pp.S97–S102 [dx.doi.org/10.1111/j.1442-8903.2009.00460.x]

Priddel, D., Carlile, N., Humphrey, M., Fellenberg, S. & Hiscox, D. 2003, 'Rediscovery of the "extinct" Lord Howe Island stick-insect (*Dryococelus australis* (Montrouzier)) (Phasmatodea) and recommendations for its conservation', *Biodiversity and Conservation* 2003, 12(7), pp.1391–403 [dx.doi.org/10.1023/A:1023625710011]

Priddel, D., Carlile, N. & Wheeler, R. 2006, 'Establishment of a new breeding colony of Gould's petrel (*Pterodroma leucoptera leucoptera*) through the creation of artificial nesting habitat and the translocation of nestlings', *Biological Conservation*, 2006, 128(4), pp.553–63 [dx.doi.org/10.1016/j.biocon.2005.10.023]

Priddel, D., Carlile, N., Wilkinson, I. & Wheeler, R. 2011, 'Eradication of exotic mammals from offshore islands in New South Wales, Australia' in Veitch, C.R., Clout, M.N. & Towns, D.R., *Island Invasives: Eradication and management*, Proceedings of the International Conference on Island Invasives, International Union for Conservation of Nature, Gland, Switzerland and Centre for Biodiversity and Biosecurity, Auckland, New Zealand, pp.337–44 [www.issg.org/publications.htm#iucn_publications]

Randall, R. 2000, 'Which are my worst weeds? A simple ranking system for prioritising weeds', *Plant Protection Quarterly*, 15(3), pp.109–15 [www.weedinform.com.au/ppq_abs15/ppq_15-3-109.html]


RFS 2011, *NSW Rural Fire Service Annual Report 2010/11*, NSW Rural Fire Service, Sydney [www.rfs.nsw.gov.au/dsp_content.cfm?cat_id=540]

Saunders, D., Margules, C. & Hill, B. 1998, *Environmental Indicators for National State of the Environment Reporting: Biodiversity*, Department of the Environment, Canberra [www.environment.gov.au/soe/publications/indicators/biodiversity.html]

SFNSW 1999, *Managing Our Forests Sustainably: Forest management zoning in NSW state forests*, State Forests of NSW, Sydney [www.forests.nsw.gov.au/resources/pubs/corporate/rfa-review-report]


Sinden, J., Jones, R., Hester, S., Odom, D., Kalisch, C., James, R. & Cacho, O. 2004, *The Economic Impact of Weeds in Australia*, CRC for Australian Weed Management, Technical series No.8 [pandora.nla.gov.au/pan/64168/20070119-0000/www.weeds.crc.org.au/documents/tech_series_8_summary.pdf]





Steffen, W., Burbidge, A.A., Hughes, L., Kitching, R., Lindenmayer, D., Musgrave, W., Stafford Smith, M. & Werner, P. 2009, *Australia's Biodiversity and Climate Change: A strategic assessment of the vulnerability of Australia's biodiversity to climate change*, report to the Natural Resource Management Ministerial Council, Department of Climate Change, CSIRO Publishing, Canberra [www.climatechange.gov.au/publications/biodiversity/biodiversity-climatechange.aspx]

Telemeco, R.S., Elphick, M.J. & Shine, R. 2009, 'Nesting lizards (*Bassiana duperreyi*) compensate partly, but not completely, for climate change', *Ecology*, 90, pp.17–22 [[dx.doi.org/10.1890/08-1452.1](https://doi.org/10.1890/08-1452.1)]



Thackway, R. & Cresswell, I.D. 1995, *An Interim Biogeographic Regionalisation for Australia: A framework for setting priorities in the National Reserves System Cooperative Program – Version 4.0*, Australian Nature Conservation Agency, Canberra [www.environment.gov.au/coasts/mbp/publications/imcra/imcra-4.html]

Williams, J., Read, C., Norton, A., Dovers, S., Burgman, M., Proctor, W. & Anderson, H. 2001, *Biodiversity: Australia State of the Environment Report 2001*, theme report, CSIRO Publishing on behalf of the Department of the Environment and Heritage, Canberra [www.environment.gov.au/soe/2001/publications/theme-reports/biodiversity/index.html]



Williams, R.J., Bradstock, R.A., Cary, G.J., Enright, N.J., Gill, A.N., Liedloff, A.C., Lucas, C., Whelan, R.J., Anderson, A.N., Bowman, D.M.J.S., Clark, P.J., Cook, G.D., Hennessy, K.J. & York, A. 2009, *Interactions between Climate Change, Fire Regimes and Biodiversity in Australia: A Preliminary Assessment*, report to the Department of Climate Change and Department of the Environment, Water, Heritage and the Arts, Canberra [www.climatechange.gov.au/publications/adaptation/fire-regimes-and-biodiversity.aspx]

