

15 INVASIVE SPECIES



Invasive species, including pest plants and animals, fungi and a range of pathogenic microorganisms, are widespread across NSW. Once established, invasive species are difficult to manage effectively and remain a significant threat to biodiversity. Many invasive species are listed as key threatening processes in NSW legislation, with pest animals and weeds identified as a threat to over 70% of all threatened species.

Most pest animals have been established in NSW for many years. Predation by introduced carnivores, particularly foxes and cats, has led to the significant decline or extinction of a range of native fauna species. Grazing and browsing by introduced herbivores or omnivores, such as rabbits, goats and pigs, leads to habitat degradation and a decline in native flora species. Pest fish have significant impacts on key species and aquatic ecosystem processes, with carp constituting 83% of total fish biomass across much of the Murray–Darling Basin. Most parts of NSW are affected by weeds that have an impact on native species, ecosystems and agriculture.

Pathogens and diseases are an emerging threat to both biodiversity and agriculture and they are becoming increasingly prevalent in Australia.

Invasive species place a substantial burden on the Australian economy. In NSW, weeds account for \$1.8 billion per annum in lost production and control costs while the cost to the Australian economy of dealing with the impacts of pest animals is over \$1 billion annually.

The proposed *NSW Invasive Species Plan 2015–2022* sets out goals and provides strategic direction and guidelines to exclude, eradicate or manage invasive species as appropriate to their situation.

NSW indicators

G Good M Moderate P Poor U Unknown

Indicator and status		Environmental trend	Information availability
Number of new invasive species detected	M	Stable	✓
Spread of emerging invasive species	M	Increasing impact	✓
Impact of widespread invasive species	P	Stable	✓✓

Notes: Terms and symbols used above are defined in About SoE 2015 at the front of the report.

Context

Invasive species are animals, plants or other organisms introduced into places out of their natural range, where they become established and disperse, generating a negative impact on the local ecosystem and species (IUCN 2014). The current report considers predominantly the effects of invasive species on native fauna and flora. The report does not review in detail additional impacts on industry (such as agriculture, forestry, and fisheries) and human health and wellbeing (such as diseases or parasites).

In NSW, many established invasive species were introduced for specific purposes before their invasive potential was realised. Common examples include species introduced for:

- agricultural production (domesticated animals and crops)
- aesthetic purposes (pets and garden plants)
- sport (foxes for hunting)
- land management initiatives (bitou bush used for sand dune stabilisation).

The introduction of new invasive species in NSW is usually inadvertent, with unintended transport throughout NSW and Australia, or into Australia via natural or human-mediated means such as in vehicles, equipment, packing material, soil or garden refuse, or through ocean shipping. It is also important to effectively manage the import and the keeping of exotic plants and animals in NSW to prevent the establishment of new pest species in the open environment.

Invasive species affect the environment through a range of mechanisms: from predation and consumption, to competition, habitat modification and degradation, and even disease transmission. Invasive species have been implicated in the decline of many native species, and are thought to affect over 70% of entities listed under the *NSW Threatened Species Conservation Act 1995* (TSC Act) (Coutts-Smith et al. 2007).

Invasive aquatic species have been recognised as having an impact upon native fish species including threatened species. Several key threatening processes have been listed under the *Fisheries Management Act 1994* (FM Act). These include 'Introduction of fish to waters within a river catchment outside their natural range' and 'Introduction of non-indigenous fish

and marine vegetation to the coastal waters of New South Wales'.

Status and trends

Extent of invasive species

Since 1788, around 3000 introduced plant species have established self-sustaining populations in Australia. More than 1750 of these have been recorded in NSW, with over 340 weeds recognised as posing significant threats to biodiversity (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 native fauna and flora. Introduced fish species make up around a quarter of all freshwater fish species in the Murray Darling Basin (Lintermans 2009).

Australian waters host over 200 species of introduced marine organisms (DPI 2008); however not all of these are considered invasive. It is not known how many insects and other invertebrates have been introduced into Australia (Coutts-Smith et al. 2007).

Impacts of invasive plant and animal species

The native plants and animals in Australia's ecosystems have co-evolved over millions of years. When invasive species are introduced to these systems, they can have significant negative impacts because native species have not evolved mechanisms to deal with the specific threats they represent. Although these invasive species have similarly not evolved with native conditions, other disturbance events of the native systems often allow for their initial establishment and subsequent significant environmental impact.

Hence, predation by introduced carnivores, such as foxes and cats, has led to significant decline and extinction of a range of native fauna species. Grazing and browsing by introduced herbivores, such as rabbits and goats, have also led to habitat degradation and a decline in native flora species. Competition and habitat structural change by weeds has similarly affected native plants and animals.

Since 1788, the influence of invasive species on the NSW environment has been significant, with pest animals and weeds thought to impact over 70% of entities listed under the TSC Act (Coutts-Smith et al. 2007). Addressing the impacts of pest animals and weeds is a significant component of the NSW Government's new *Saving our Species* program, which sets priorities for ensuring threatened species are secured and remain viable into the future.

Invasive species also place a substantial burden on the Australian economy. In NSW, weeds account for \$1.8 billion per annum in lost production and control costs (NRC 2014). The cost to the Australian economy of dealing with the impacts of pest animals is over \$1 billion annually (DPI 2008). These costs comprise cost of labour, chemical and machinery on agricultural lands, the lost production on agricultural lands, lost value due to price responses in agricultural markets, and expenditure by public agencies. They do not include environmental and social impacts.

Categories of invasive species

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

- **new species:** any 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
- **emerging species:** a subset of invasive species that has established a self-sustaining population and is actively expanding its range or has the potential to spread further
- **widespread species:** a smaller subset of invasive species that has been present for some time and has now established a broad range across a region or the whole state.

New and emerging pest animals

In late 2014, two new invasive species with the potential to have significant impacts on the environment of NSW were identified and management programs were put in place. These were the red imported fire ants, for which an eradication program was established and the fish species known as tilapia, for which an extensive advisory and education program was established.

Red imported fire ants: On 28 November 2014, a suspected incursion of fire ants was detected in Port Botany. This incursion was confirmed as red imported fire ants (RIFA), with DNA testing showing the infestation may have come directly from Argentina. RIFA have previously been detected in areas around Brisbane in Queensland, where control efforts are ongoing. Although listed as a key threatening process, this was the first record of the ants in NSW.

RIFA are aggressive with a painful bite and are highly invasive. Fire ants can significantly affect public health and lifestyle, the environment and agriculture. The one nest at Port Botany was located and destroyed. Assessment of the nest suggested it had been there for at least six months. A two-kilometre radius around the infected site was inspected for any other evidence of RIFA. Beyond this, key habitat areas were inspected, including the third runway at Sydney Airport and Kamay Botany Bay National Park (at La Perouse and Kurnell). No other nests were found. A second round of surveillance was completed in August 2015 as part of a national eradication plan. Luring and baiting programs will continue as prescribed by the plan. A complementary passive surveillance program is also in place to ensure the Botany Bay community and surrounding communities have the capacity to quickly identify and report red imported fire ant if it is found.

Tilapia: Tilapia is an internationally recognised pest fish that originates from the warm waters of southern Africa. It is a hardy fish that tolerates both fresh and salty water and was a popular ornamental species before being banned in NSW and other Australian jurisdictions. Tilapia has established wild pest populations that dominate native fish in parts of Queensland, including catchments that lie directly adjacent to the Murray–Darling Basin (MDB). So far, the species has not been detected in the MDB; however, a coastal population was detected in northern NSW in November 2014. Research has suggested tilapia could become widespread if introduced into the MDB.

NSW and Queensland governments and the Murray–Darling Basin Authority have recognised the critical importance of stakeholder education to exclude tilapia from reaching the MDB. The agencies have identified areas of high incursion risk and have developed a community

education package for landholders living in the high risk areas. This cooperative work is helping to improve knowledge of pest fish issues and reducing the risk of tilapia being intentionally translocated into the MDB. The project has demonstrated the value of governments working with communities to help rapidly detect and respond to new tilapia incursions.

Emerging pest animal species that are already having severe impacts on biodiversity include deer and cane toads, both of which are listed as key threatening processes under the TSC Act.

The increase in distribution of deer species was described in SoE 2012 (EPA 2012) and demonstrated their expansion.

Cane toads in Taren Point: Cane toads were reported as an emerging species of concern in 2012 with viable populations established on the far north coast and at Taren Point in southern Sydney.

A cane toad containment line has been successfully established, with only one breeding population of cane toads known south of the Clarence River. This isolated southernmost population was discovered in Taren Point in Sydney in 2010. A successful cane toad management program has been led by Sutherland Council. As part of this program, 1680 cane toads were caught and euthanised between 2010 and 2013. Extensive monitoring surveys conducted in 2014 resulted in the capture of only 11 cane toads. This program should result in a cane toad-free Taren Point in the near future.

New and emerging weeds

A total of 243 plant taxa have naturalised or were in the process of naturalising in NSW from 2000–12 – a rate of 18–19 per year (Hosking et al. 2003; Hosking et al. 2007; Hosking et al. 2011; Johnson et al. in prep.). It is likely that new naturalisations will continue in NSW. Ongoing research is helping to identify the main causes and risk factors, but the rate of naturalisations has been less comprehensively studied since the last reporting period. It is essential that new naturalisations are reported (refer to the mouse-ear hawkweed example below) to enable evaluation of weed risk and the deployment of rapid responses (including eradication where possible) for the high risk species. Below are two examples of how this work is being undertaken to control mouse-ear hawkweed and orange

hawkweed in our sensitive and unique alpine environments.

New weed – mouse-ear hawkweed:

On 12 January 2015, a bushwalker and camper reported a possible location of mouse-ear hawkweed (MEHW) in a remote part of Kosciuszko National Park (the park). National Parks and Wildlife Service (NPWS) staff inspected the location and confirmed the find. This was the first record for NSW; there is another infestation under active management in the Victorian Alps. In New Zealand, this is a major widespread weed impacting conservation and grazing areas.

The MEHW infestation in the park was estimated to cover 150 square metres. It is estimated that the infestation has probably been on site for around seven to 10 years and was probably transported on hiker boots, clothing or camping equipment from New Zealand.

The infestation was treated in January 2015 and the site quarantined. Joint surveys across the Main Range of the park were carried out under the direction of NPWS.

To date, 25 locations have been searched over 112 hectares of park around the only known infestation. No additional sites of MEHW have been reported. Further surveys are planned as well as follow-up treatment. Tools developed as part of the orange hawkweed program (see below) have been key to the rapid response to this species.

Emerging weed – orange hawkweed:

Originating from Europe, orange hawkweed (OHW) has become a major weed in the United States, Canada, Japan and New Zealand. This weed is at the early stages of invasion in Australia (present in Tasmania, Victoria and NSW), but has the potential to occupy large areas of south-east Australia. Economic modelling figures on the potential production losses in grazing areas in 2002 were conservatively estimated at \$48 million (DPI 2012) or about \$66 million today (CPI-adjusted to 2015). Based on the New Zealand experience, if OHW is left unchecked, the growth across south-east Australia could have disastrous economic and ecological ramifications, which would be impossible to reverse.

The only records of OHW in NSW are in Kosciuszko National Park. This weed was located after 2003 fires and is found in a

separate location to mouse-ear hawkweed and thought to be introduced during the construction of the Snowy Mountains Hydro-electric Scheme in the second half of last century. The cumulative area OHW had occupied was estimated at 8.2 hectares. A measure of the program's current success is the reduction of infestations to less than 4% of this original size.

Detection of every last plant is needed to ensure eradication, but the search area is remote, rugged and large, covering 8591 hectares. This area requires constant surveillance in order to find and treat plants before they set seed. Tools developed or being developed to assist eradication include development of effective control techniques, a volunteer program to hunt for OHW, the use of helicopters for remote aerial insertions, and novel techniques, such as the use of unmanned aerial vehicles to search new potential areas, and detector dogs being trained to find outlier populations. It is estimated that seeds can remain viable for five years; therefore, with these new tools, eradication could be achieved in five to 10 years.

Emerging weed – sea spurge: Sea spurge (*Euphorbia paralias*) is an invasive beach weed that originated from Europe. Sea spurge was probably introduced to Australia in ships' ballast water about 70 years ago. The plant first appeared in Western Australia and is now found throughout south-eastern Australia, including Tasmania and the islands of Bass Strait. In the past 20 years, it has colonised beaches along the NSW South Coast and is progressively working its way north.

Widespread pest animals and weeds

Widespread pest animal species have had significant impacts on native species throughout NSW.

Rather than attempting to eradicate widespread invasive species over the entire extent of their distribution, priorities for control of these species are determined and resources focused in areas where the benefits of control will be greatest. This asset-based approach ensures invasive species management is focused on protecting priority assets at affordable cost. The highest priority environmental assets for protection from invasive species are threatened species and other entities listed under the TSC Act.

Table 15.1 lists the top five widespread terrestrial pest animals that threaten native fauna and flora (Coutts-Smith et al. 2007) and shows that they are listed as key threatening processes (KTPs) under the TSC Act and whether there is a pest control order under the *Local Land Services Act 2013*.

Table 15.1: Top five terrestrial pest animals posing a threat to native fauna and flora in NSW

Common name	Scientific name	KTP listing	Pest control order
Feral cat	<i>Felis catus</i>	Yes	No
Red fox	<i>Vulpes vulpes</i>	Yes	Yes*
Feral goat	<i>Capra hircus</i>	Yes	No
Rabbit	<i>Oryctolagus cuniculus</i>	Yes	Yes
Feral pig	<i>Sus scrofa</i>	Yes	Yes

Source: Coutts-Smith et al. 2007

Notes: *Unlike the other pest control orders, this does not include a general destruction obligation as defined under the Act.

All parts of NSW are affected by weeds that threaten native fauna and flora. Weeds now make up 21% of the total flora of NSW. The numbers of weed species are highest near the coast, particularly around major towns and cities, and in regions with high rainfall. They tend to decline from east to west (Coutts-Smith & Downey 2006). Those with the greatest impact on NSW native fauna and flora and the biodiversity values most at risk have been determined and documented in the Biodiversity Priorities for Widespread Weeds (DPI & OEH 2011). Biological control agents have been successfully reared and released leading to a broadscale reduction in the threat to biodiversity from some of the most significant widespread weeds including bridal creeper, Madeira vine, bitou bush and mistflower.

Table 15.2 (overleaf) lists the top 20 widespread weeds based on their potential impact on biodiversity in NSW as a whole (Downey et al. 2010), and shows whether they are listed as a Weed of National Significance (WoNS), a key threatening process under the NSW TSC Act, or listed under the NSW *Noxious Weeds Act 1993*. Thirty-two WoNS have been identified by Australian governments based on their invasiveness, potential for spread, and environmental, social and economic impacts.

Table 15.2: Top 20 widespread weeds posing a threat to native fauna and flora in NSW

Common name	Scientific name	Weed of national significance (WoNS)	Key threatening process (KTP) listing	NSW noxious weed*
Madeira vine	<i>Anredera cordifolia</i>	Yes	Yes	Yes
Lantana	<i>Lantana camara</i>	Yes	Yes	Yes
Bitou bush	<i>Chrysanthemoides monilifera</i> subsp. <i>rotundata</i>	Yes	Yes	Yes
Ground asparagus	<i>Asparagus aethiopicus</i>	Yes	Yes	Yes
Blackberry	<i>Rubus fruticosus</i> species aggregate	Yes	Yes**	Yes
Scotch broom	<i>Cytisus scoparius</i> subsp. <i>scoparius</i>	Yes	Yes	Yes
Japanese honeysuckle	<i>Lonicera japonica</i>	No	Yes**	Yes
Broad-leaf privet	<i>Ligustrum lucidum</i>	No	Yes**	Yes
Narrow leaf privet	<i>Ligustrum sinense</i>	No	Yes**	Yes
Cat's claw creeper	<i>Dolichandra unguis-cati</i>	Yes	Yes	Yes
Salvinia	<i>Salvinia molesta</i>	Yes	Yes**	Yes
Serrated tussock	<i>Nassella trichotoma</i>	Yes	Yes	Yes
Cape ivy	<i>Delairea odorata</i>	No	Yes	No***
Blue morning glory	<i>Ipomoea indica</i>	No	Yes	Yes
Balloon vine	<i>Cardiospermum grandiflorum</i>	No	Yes	Yes
Lippia	<i>Phyla canescens</i>	No	Yes**	Yes
Bridal creeper*	<i>Asparagus asparagoides</i>	Yes	Yes	Yes
Mickey Mouse plant	<i>Ochna serrulata</i>	No	Yes**	Yes
Turkey rhubarb	<i>Acetosa saittata</i>	No	Yes**	Yes
Sweet vernal grass	<i>Anthoxanthum odoratum</i>	No	Yes	No

Source: Updated list from Downey et al. 2010

Notes: * Noxious weed declaration may be at different control classes or only in certain parts of NSW. The Weeds Australia website contains a summary of the state and territory noxious weed legislation and associated lists.

** Relates to 'Garden escapes' KTP

*** Cape ivy is declared on Lord Howe Island only

Invasive aquatic species

Invasive aquatic species pose environmental, social and economic threats by damaging the natural balance of aquatic flora and fauna. Invasive species can threaten indigenous aquatic and terrestrial life directly as predators or competitors for food or indirectly by altering their natural habitat. It is believed invasive species can contribute to the decline of some threatened native species. Therefore the introduction of non-indigenous fish and marine vegetation to NSW waters is listed as a key threatening process under the FM Act. Table 15.3 lists common invasive aquatic species in NSW.

Table 15.3: Common invasive aquatic species in NSW

Common name	Scientific name	KTP listing
Carp	<i>Cyprinus carpio</i>	Yes
Redfin	<i>Perca fluviatilis</i>	Yes
Eastern gambusia	<i>Gambusia holbrooki</i>	Yes
Pacific oyster	<i>Crassostrea gigas</i>	Yes
Caulerpa	<i>Caulerpa taxifolia</i>	Yes
Tilapia	<i>Oreochromis mossambicus</i>	Yes

Source: Department of Primary Industries data 2015

Some invasive aquatic species have been introduced accidentally into NSW waters, while others were deliberately introduced, including eastern gambusia which was introduced in the early 20th century in an attempt to control mosquitoes.

Pathogens

Pathogens can emerge as threats to biodiversity, with some becoming more prevalent, both internationally and in Australia. Pathogens can also effect animal and plant production systems and human health, and biosecurity risk management as implemented by DPI (Biosecurity and Food Safety) contributes to sustainable economic growth, protection of the environment and improving community wellbeing.

Some of the impacts of exotic and translocated native pathogenic microorganisms on native fauna and flora are well understood. The impacts of some emerging pathogens may not be well understood. Four pathogens are listed as key threatening processes (KTPs) under the TSC Act, with all four having potentially serious consequences for the health of the environment.

The four KTPs are:

- Psittacine Circoviral (beak and feather) Disease affecting endangered psittacine species (endangered parrot)
- Dieback caused by the root-rot fungus (*Phytophthora cinnamomi*)
- Infection of amphibians (frogs) with chytrid fungus resulting in chytridiomycosis (disease)
- Introduction and establishment of exotic rust fungi of the order Pucciniales pathogenic on plants of the family Myrtaceae.

A variant (strain) of the rust fungus *Puccinia psidii* sensu lato (commonly referred to as myrtle rust) was first detected in Australia in April 2010 at a site on the NSW Central Coast (Carnegie et al. 2010). From there it spread rapidly reaching bushland in south-east Queensland in January 2011. The full impact of myrtle rust is yet to be realised, but the latest research indicates that highly-susceptible species in NSW, such as *Rhodamnia rubescens* and *Rhodomyrtus psidioides* are at risk of becoming threatened by this pathogen (Carnegie et al. 2015).

Pressures

SoE 2012 (EPA 2012) outlined key pressures in relation to invasive species as habitat disturbance, greater mobility and trade, expansion of range, climate change and lack of information on the distribution and abundance of invasive species.

Updates are provided below on pressure due to climate change and the consequences of the lack of information about invasive species.

Climate change and weed spread

The impact of climate change upon weeds is becoming clearer in Australia. As climate regimes continue to change it is likely that potential new weeds will emerge from the established pool of naturalised plants (Duursma et al. 2013). Consideration of climate change scenarios and species distribution models can be useful for predicting future breakouts of invasive plants. This allows land managers to pre-emptively manage and effectively control them.

The extent of suitable habitat of invasive and naturalised non-native species has been assessed and predicted under current and future climate conditions. The alpine ecoregion, including that within NSW, may be particularly vulnerable to future incursions by naturalised plants (Duursma et al. 2013). Although not all naturalised plants would be predicted to increase under future climate scenarios, changing climate regimes would have the potential to create more favourable conditions for naturalised plants in a southerly direction. For example, results suggest that the areal extent of hotspots in two ecoregions, Tasmanian temperate forests and Australian Alps montane grasslands, may increase.

Potential delays in management due to lack of biological data

The Office of Environment and Heritage (OEH) has attempted to undertake assessments using the NSW Weed Risk Management system for new and emerging weeds which impact environmental assets. Of the 218 species assessed, 72 lacked sufficient data to complete an assessment. Therefore, where a species is at

the early stages of invasion, but the information required to complete an assessment is unavailable, the risk that such a species will not be managed in a timely manner is high (Hamilton et al. 2014).

Responses

Determining priorities for managing widespread invasive species

The NSW Government determines priorities for control of invasive species and focuses resources in areas where the benefits of control will be greatest. The highest priority environmental assets for protection from invasive species are threatened species and other entities listed under the TSC Act. This prioritised approach to invasive species management ensures maximum benefit from finite resources.

Farmers contribute to protecting the environment from invasive species by playing an important role in soil, water and air quality, vegetation management and management of invasive species (including coordinated regional approaches that involve public and private landholders).

Containment of new and emerging invasive species

For the management of new and emerging invasive species, the focus is to eradicate or contain the spread of the invasive species before it can cause significant environmental impacts.

Some emerging species are already having severe impacts on native fauna and flora or the environment within their current distribution. For example, the establishment of strategic containment lines for cane toads serves to delineate different approaches to management. Containment lines are mapped lines, often delineated along natural landforms, such as a river or along local government boundaries or other management boundaries.

Containment lines are detailed in WoNS strategic plans. For example, under this approach, asset protection is undertaken within the core distribution, while populations just outside this distribution are locally eradicated (i.e. all individuals are removed). Any isolated populations well away from the core distribution are eradicated.

Establishment of regional weeds committees

The NSW Government is responding to a Natural Resources Commission review of weed management in NSW by establishing regional weeds committees in each of the local land services regions. The role of the committees will be to provide 'tenure neutral' strategic planning and coordination of weed management activities at the regional level – consistent with the goals of the NSW Invasive Species Plan – to minimise the impacts of invasive species in NSW.

Saving our Species program

Invasive species management is an important component of the NSW Government's *Saving our Species* program, which sets priorities for ensuring threatened species are secured and remain viable into the future. With invasive species thought to impact over 70% of entities listed under the TSC Act, actions to ameliorate the fate of threatened species will continue to be identified, acted upon and reported against as the program progresses.

NSW Invasive Species Plan

The proposed NSW Invasive Species Plan 2015–2022 (a consultation document released in August 2015) (DPI 2008) focuses on the four goals of:

- Exclude – prevent the establishment of new invasive species
- Eradicate or contain – eliminate, or prevent the spread of new invasive species
- Effectively manage – reduce the impacts of widespread invasive species
- Capacity building – ensure NSW has the ability and commitment to manage invasive species.

NSW Biosecurity Strategy 2013–2021 and new Biosecurity Act

The NSW Government launched the NSW Biosecurity Strategy 2013–2021 in May 2013. The NSW Biosecurity Strategy is based on the principle of shared responsibility for effective biosecurity management and increases awareness about biosecurity issues in NSW. The Strategy aims to expand on the former

2007 NSW Department of Primary Industries' Biosecurity Strategy to address not only primary industries, but the broader biosecurity spectrum in terms of biodiversity and the natural environment, infrastructure and service industries as well as lifestyle, recreation, sport and social amenity. It also outlines how the NSW government will partner with other levels of government, industry and the community to identify and manage biosecurity risks.

The strategy identifies four key goals focusing on biosecurity:

- shared responsibility
- contribution to sustainable economic growth
- protects the environment and community
- underpinned by a responsive and consistent legislative framework.

A key component of the Strategy will be the *Biosecurity Act 2015*, which has been passed by the NSW Parliament and is awaiting assent and commencement. The Act will provide for the prevention, elimination, minimisation and management of biosecurity risks; and for other purposes.

Future opportunities

Continual improvements to surveillance and biosecurity measures may be needed to prevent new and potentially invasive species from threatening natural ecosystems and the productivity of farming systems.

Development of biological controls and other new techniques will continue to provide opportunities for effective and affordable management of widespread invasive species and further opportunities should continue to be explored.

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

References

- Carnegie, AJ, Lidbetter, JR, Walker, J, Horwood, MA, Tesoriero, L, Glen, M & Priest, MJ 2010, '*Uredo rangelii*, a taxon in the guava rust complex, newly recorded on Myrtaceae in Australia', *Australasian Plant Pathology*, 39, pp. 463–6 [dx.doi.org/10.1071/AP10102]
- Carnegie AJ, Kathuria A, Pegg GS, Entwistle P, Nagel M, Giblin FR 2015, Impact of the invasive rust *Puccinia psidii* (myrtle rust) on native Myrtaceae in natural ecosystems in Australia. *Biological Invasions* (accepted 16 September 2015)
- Coutts-Smith, A & Downey, PO 2006, *Impact of weeds on threatened biodiversity on New South Wales*. Technical series No. 11, CRC for Australian Weed Management, Adelaide [www.southwestnrm.org.au/ihub/impact-weeds-threatened-biodiversity-new-south-wales]
- Coutts-Smith, AJ, Mahon, PS, Letnic, M & Downey, PO 2007, *The threat posed by pest animals to biodiversity in New South Wales*, Invasive Animals Cooperative Research Centre, Canberra [www.pestsmart.org.au/the-threat-posed-by-pest-animals-to-biodiversity-in-new-south-wales]
- Downey, PO, Scanlon, TJ & Hosking, JR 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, pp. 111–26 [www.weedinfo.com.au/ppq_abs25/ppq_25-3-111.html]
- DPI 2008, *NSW Invasive Species Plan 2008–2015*, Department of Primary Industries, Orange [www.dpi.nsw.gov.au/agriculture/pests-weeds/nsw-invasive-species-plan]
- DPI 2012, *New South Wales Orange Hawkweed strategy 2011–2017*, State of New South Wales through Department of Primary Industries [www.dpi.nsw.gov.au/agriculture/pests-weeds/weeds/strategy/state/orange-hawkweed-strategy]
- DPI & OEH 2011, *Biodiversity priorities for widespread weeds*, report prepared for the 13 Catchment Management Authorities (CMAs) by NSW Department of Primary Industries and Office of Environment and Heritage, Orange (Authors: Whiffen, LK, Williams, MC, Izquierdo, N, Downey, PO, Turner, PJ, Auld, BA and Johnson SB) [www.dpi.nsw.gov.au/agriculture/pests-weeds/weeds/publications/cmases]

- Duursma, DE, Gallagher, RV, Rogers, E, Hughes, L, Downey, PO & Leishman, MR 2013, 'Next-generation invaders? Hotspots for naturalised sleeper weeds in Australia under future climates', *PLoS ONE*, 8(12), p.e84222 [dx.doi.org/10.1371/journal.pone.0084222]
- EPA 2012, *New South Wales State of the Environment Report 2012*, Environment Protection Authority, Sydney [www.epa.nsw.gov.au/soe/soe2012]
- Hamilton, MA, Cherry, H, Martin, LJ, Turner, PJ & Johnson, SB 2014, 'Using Weed Risk Management assessments to inform on-ground action for new and emerging environmental weeds in New South Wales', in *Proceedings of the 19th Australasian Weeds Conference* (ed. M Baker), pp. 269–72, Tasmanian Weed Society, Hobart [www.caws.org.au/awc_contents.php?yr=2014#v_p267]
- Hosking, JR, Conn, BJ & Lepschi, BJ 2003, 'Plant species first recognised as naturalised for New South Wales over the period 2000–2001', *Cunninghamia*, 8(2), pp. 175–87 [https://d1nu2wha2fqai.cloudfront.net/RoyalBotanicGarden/media/RBG/Science/Cunninghamia/Volume%208%20-%202003/Volume-8(2)-2003-Cun8Hos175-187.pdf]
- Hosking, JR, Conn, BJ, Lepschi, BJ & Barker, CH 2007, 'Plant species first recognised as naturalised for New South Wales in 2002 and 2003, with additional comments on species recognised as naturalised in 2000–2001', *Cunninghamia*, 10(1), pp. 139–66 [https://d1nu2wha2fqai.cloudfront.net/RoyalBotanicGarden/media/RBG/Science/Cunninghamia/Volume%2010%20-%202007/Cun101139Hos.pdf]
- Hosking, JR, Conn, BJ, Lepschi, BJ & Barker, CH 2011, 'Plant species first recognised as naturalised or naturalising for New South Wales in 2004 and 2005', *Cunninghamia*, 12(1), pp. 85–114 [https://www.rbgsyd.nsw.gov.au/RoyalBotanicGarden/media/RBG/Science/Cunninghamia/Volume%2012%20-%202011/cun121hos085.pdf]
- IUCN 2014, *United Nations issues guidelines to minimize risk of invasive species*, news article, International Union for Conservation of Nature, Gland, Switzerland [www.iucn.org/news_homepage/news_by_date/?18462/United-Nations-issues-guidelines-to-minimize-risk-of-invasive-species]
- Johnson, SB, Hosking, JR, Conn, BJ & Lepschi, BJ (in prep.), 'Plant species first recognised as naturalised or naturalising for New South Wales in 2006 and through to, and including, 2012', *Cunninghamia* (in preparation)
- Lintermans, M 2009, *Fishes of the Murray-Darling Basin: An introductory guide*, Murray-Darling Basin Authority, Canberra [www.mdba.gov.au/media-pubs/publications/fishes-murray-darling-basin-intro-guide]
- NLWRA 2008, *Assessing Invasive Animals in Australia*, National Land and Water Resources Audit and Invasive Animals Cooperative Research Centre, Canberra [http://lwa.gov.au/products/pn20628]
- NRC 2014, *Weeds – Time to get serious: Review of weed management in NSW*, Final Report and recommendations, Natural Resources Commission, Sydney [www.nrc.nsw.gov.au/weed-management]