Submission 060
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Inquiry into Australia's biodiversity in a changing climate

Submission from the Invasive Species Council, August 2011



invasive species council

ISC campaigns for better laws and policies to protect the Australian environment from weeds, feral animals, exotic invertebrates and pathogens.

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Inquiry into Australia's biodiversity in a changing climate by the House Standing Committee on Climate Change, Environment and the Arts

Submission from the Invasive Species Council

Invasive Species Council

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1. Introduction

The Invasive Species Council is an environmental NGO that campaigns for stronger laws, policies and programs to keep Australian biodiversity safe from weeds, feral animals and other invaders.

The three direst threats to Australian biodiversity are habitat loss, invasive species[1] and climate change.[2] Our focus in this submission is the interaction of two of these threats: invasive species and climate change. As recognised in the 2009 assessment of the vulnerability of Australia's biodiversity to climate change by Will Steffen and colleagues, in many cases the biodiversity impacts of invasive species benefiting from climate change are likely to exceed the direct impacts of climate change.[3] This is because:

- many invasive species are highly adaptable, tolerant of a wide range of climatic conditions and advantaged by disturbance;
- extreme events often facilitate biological invasions;
- native species under stress due to climate change are less competitive with and more vulnerable to harm by invasive species; and
- human responses to climate change are likely to provide more invasive opportunities and may result in less effective control.

We discuss and exemplify four types of interactions between climate change and invasive species in this submission:

- Abiotic: in which invasive species directly benefiting from climatic changes (temperature, rainfall, CO2, extreme events, fire) threaten biodiversity
- Biotic: in which invasive species benefiting from the effects of climate change on other species threaten biodiversity
- Anthropogenic: in which invasive species benefiting from human responses to climate change threaten biodiversity
- Carbon balance: in which invasive species exacerbate climate change impacts on biodiversity by increasing greenhouse gas emissions

Many of the recommendations in this submission are essential for biodiversity conservation irrespective of climate change. There are major deficiencies in current invasive species policies and programs that will inevitably result in further declines in biodiversity, which are likely to accelerate under climate change. A much stronger focus on environmental biosecurity should be a top priority strategy for climate change adaptation.

Most of the material in this submission is covered in three fact sheets published by the Invasive Species Council – attached to this submission. We have also published six issues of Double Trouble, an e-bulletin summarising scientific papers on invasive species and climate change that provide many examples of the issues discussed here (see http://www.invasives.org.au/page.php?nameIdentifier=doubletroublepestsandclimatechange).

2. Invasive species and climate change – interactive threats

Different species – native and exotic – will respond to climate change in different ways. CSIRO researchers Mike Dunlop and Peter Brown outlined three models of response.[4]

Model 1 'gradual changes in distribution' predicts that species will move gradually and at different rates to maintain a similar climatic niche as the climate changes. This is an intuitively appealing model and the most popular but Dunlop and Brown caution that the preference for it may not reflect reality. It does not apply to a substantial proportion of biodiversity for many species will not 'migrate': plants are often constrained by soils rather than climate, and many species are constrained by biological factors such as competition or predation.[5] The obvious conservation response under this model is to ensure that species are able to migrate, by removing barriers to movement and creating corridors to potential habitats. This would need to be complemented by action to prevent the movement of invasive species in response to changing climatic conditions.

Model 2 'rapid changes in distribution' predicts range expansion for some species that can take advantage of changing conditions. Fire pioneers, for example, will benefit from more fires; wind- and water-dispersed species may benefit from more cyclones and floods; and higher CO_2 levels will give some plant species a competitive edge. This model is particularly applicable for invasive species likely to benefit from more extreme events or more CO_2. The impacts of climate change 'winners' will be detrimental to some native species. In some cases, native species that benefit from the changes may also become invasive. Conservation responses to this model need to include addressing the threats caused by invasive climate change winners.

Model 3 'changes in abundance' predicts that climate change will affect the abundance of some species rather than their distribution. Some will decline and others will proliferate, and that in turn will affect ecosystem structure and function. Species vulnerable to climate change may retract to climate refuges, such as cooler or wetter locations in their range. Some invasive species are likely to become more abundant and increase pressure on declining species. Conservation responses to this model need to include protection of refugia for declining species and control of threats deriving from more abundant native and exotic species.

All three models are likely to account for some changes, and under each model invasive species are likely to strongly undermine the capacity of native species and ecosystems to adapt to and survive under climate change.

2.1 Interactions with abiotic changes – temperature, rainfall, CO_2, extreme events, fire

Following are a few examples of invasive species expected to directly benefit from future climate patterns, such as higher average temperatures and more extreme events. They are predictable to some extent based on current patterns of invasion.

Warmer temperatures: Foxes are already increasing their numbers at higher altitudes in the Australian Alps as the climate warms. Bogong moths are arriving later, forcing endangered mountain pygmy possums (*Burramys parvus*), which eat them, to forage more widely. This makes them more vulnerable to predation by foxes, which also eat bogong moths.[6] Hares, house mice and feral horses are also increasing at high altitudes. Weeds too will spread further up the slopes, pushing out less competitive native species.[7] They could have a particularly severe impact because many alpine plant communities are localised with rare endemic species, and there are numerous weed species at lower altitudes.

A warmer Antarctic peninsula is more favourable for establishment of seeds, insects or spores transported by visitors or blown by wind or stuck to birds. On subantarctic Heard Island, the weedy winter grass (*Poa annua*) has been spreading rapidly on deglaciated sites.[8]

After existing along the Victorian coast for almost a century, European green crabs (*Carcinus maenas*) invaded Tasmanian waters after a run of unusually warm winters in 1988 to 1991.[9]

As the climate warms, cane toads (*Bufo marinus*) are predicted to expand southwards[10] and several weeds will be able to expand their range into new areas. The tropical weed prickly acacia (*Acacia nilotica spp. indica*) is likely to spread south[11] and athel pine (*Tamarix aphylla*) could spread throughout inland rivers as far south as the Murray River in Victoria.[12] Lowland species such as lantana (*Lantana camara*) may be able to shift into the uplands.[13]

Most aquarium fish in are from tropical waters, so increases in average water temperatures will provide more habitat for released or escaped fish.[14] Tropical aquarium fish are the largest category of invasive vertebrates in Australia.

A new invader – the pathogen myrtle rust (*Uredo rangelii/Puccinia psidii*) that infects plants in family Myrtaceae – grows optimally when temperatures are between 14 and 20 degrees. Its risk in southern areas is likely to increase as the temperature warms. Warmer temperatures may accelerate the life cycles of many invasive pathogens and insects.

However, some invasive species will suffer. Higher temperatures will disadvantage rabbits because they need cool weather for breeding.

Changed rainfall patterns: Southwest Western Australia is in the grip of a plant disease –dieback caused by *Phytophthora cinnamomi* – that has infected a million hectares of native bush, threatening dozens of endemic species.[15] Climate change is expected to bring more rain during summer, which would spread the disease more rapidly because the spores travel with flowing rainwater. This could result in plant extinctions and ecosystem collapse.[16] The disease could also worsen in south-eastern Australia if there are wetter summers and warmer winters under climate change.[17]

Feral animals can compromise the capacity of native species to survive droughts – by depleting limited resources and dominating refuge areas. Rabbits probably contributed to the decline of rufous hare wallabies during droughts in central Australia.[18] Some weeds (eg. serrated tussock *Nasella trichotoma*) colonise bare patches, replacing native plants killed by drought.

Cats may be able to spread to some islands currently too wet for them now and which serve as sanctuaries from exotic predators.[3]

More-intense cyclones and storms: Lurking in many gardens in the Wet Tropics are exotic plants that have not yet had the right conditions to spread beyond the garden fence. More-intense cyclones under climate change bringing forest damage and flooding could provide opportunities for their spread. Many are rainforest plants that could colonise clearings in rainforest caused by storms.[6]

By linking outdoor ponds with waterways and waterways with each other, floods spread feral fish such as cichlids (*Cichlidae*) and carp (*Cyprinus carpio*).[19] Storms and cyclones can destroy fences, allowing animals to escape from deer farms, game reserves and animal parks. During cyclone Larry more than 200 deer of various species escaped in the Wet Tropics. Weed seeds can be washed or blown from gardens and paddocks into bushland.[20]

Many of Australia's worst weeds benefit from extreme events, including at least 13 of the country's 20 Weeds of National Significance.[6] Athel pine (*Tamarix aphylla*), for example, spread along 600km of the Finke River in central Australia after severe flooding in the 1970s and 1980s, replacing river red gums. It could spread much further under climate change.[12]

More fire: Exotic pasture grasses in northern Australia up to 4 metres tall (gamba grass *Andropogon gayanus*) fuel fires so intense they can kill trees. In a damaging cycle that can turn native woodlands into exotic grasslands, such fires promote yet more grass invasion.[21] Climate change could increase the frequency of fires, facilitating the further invasion of exotic grasses.

More fires could increase predation by cats and foxes on declining species by removing protective vegetation cover.[22] Predation after fires is believed to be reducing numbers of the endangered eastern bristlebird,[23] and probably contributed to the disappearance of numbats from arid Australia.[24] In Victoria, predation of endangered pygmy possums increased after fires on Mount Buller.[6] After fires, feral herbivores can prevent regeneration. Unless fenced out, feral sambar would prevent regeneration of the endangered tree *Nematolepis wilsonii*, the populations of which were mostly destroyed in the 2009 Victorian fires.[25]

Native invaders: Some native species are likely to do much better than others under climate change – surviving extreme events, migrating into new areas, or flourishing under new weather patterns – and the more successful species could become so dominant they suppress biodiversity, and effectively become native weeds or pests.

Australia already has many native plants considered weeds,[26] either because they have spread from cultivation into new areas or because they have multiplied from human impacts and outcompete other native species. Some of our worst weeds – eg. sweet pittosporum (*Pittosporum undulatum*) and cootamundra wattle (*Acacia baileyana*) – are Australian. Because of this we need to think carefully about what 'invasive' may mean in the future. Is a newly arriving native plant or animal an invader or something responding as it should? Laughing kookaburras are an example. They have moved higher in the Australian Alps and are hunting alpine skinks, which have not previously been subject to bird predation and are highly vulnerable because they are live-bearers and need to bask in the sun for incubation.[6]

2.2 Interactions with biotic changes

Following are examples of how invasive species may benefit from changes to other organisms caused by climate change. They are much harder to predict because they involve a sequence of interactions.

Reduced competitiveness and increased vulnerability of native species: Plants and animals stressed by climate change-induced drought are likely to be more susceptible to disease – during drought southern hairy-nosed wombats are more susceptible to mange caused by an exotic mite (*Sarcoptes scabiei*), for example.[27]

Conversely, native animals under stress due to predation by foxes or cats or habitat degradation by goats or deer are likely to be more vulnerable to stress caused by a changing climate and less able to adapt. The grazing pressure of rabbits, goats and other invasive herbivores reduces the resilience of native plants to drought. Many marsupials, including bridled nailtail wallabies (*Onychogalea fraenata*), golden bandicoots (*Isoodon auratus*), banded hare wallabies (*Lagostrophus fasciatus*) and rufous hare wallabies (*Lagorchestes hirsutus*) – which survive only in the northern parts of their former range – may be particularly vulnerable because they have suffered from fox predation in the southern parts of their range but may no longer be able to survive further north.[6]

Less effective control of invaders: Some biological control agents may become less effective under climate change. Under experimental conditions of high CO_2 and temperature, a leaf- miner (*Dialectica scalariella*) introduced as biocontrol for Paterson's curse (*Echium plantagineum*) became less effective because of reduced nutritional quality of leaves.[28] (Conversely, some biocontrol agents are likely to become more effective.) Glyphosate, the most important herbicide, is also likely to become less effective under climate change.[29]

Compromised dispersal of native species: Many native plants that need to move in response to higher temperatures rely on birds to spread their seeds. But in many areas fruit-eating birds, including currawongs, figbirds and silvereyes, now live largely upon the fruits of weedy garden plants, and the seeds of weedy camphor laurel (*Cinnamomum camphora*), privet (*Ligustrum species*) and others are therefore more likely to be dispersed than the seeds of native plants. Weedy shrubs and trees can produce larger crops of fruit than native plants because they are not attacked by insects or diseases that control them in their countries of origin.[30]

2.3 Interactions with anthropogenic changes

Following are examples of how invasive species may benefit from human responses to climate change.

New agricultural and horticultural products: There are plans to grow biofuels such as giant reed (*Arundo donax*) over vast areas in Australia. Giant reed is a catastrophic riparian weed in the US, costing millions of dollars to control.[31] The attributes sought of biofuel crops – rapid growth rates with minimal input of fertilisers, high water use efficiency, lack of pests and diseases – are those of many weeds.[32]

Breeders are developing new drought-tolerant and hardier plant varieties for gardens and pastures. Many of the species are already weedy, and hardier cultivars could increase their invasion into natural areas.[33] With an increased potential for hybridisation and genetic recombination, some could become super-invaders.[34] New drought-hardy breeds of goats could breed with feral goats, exacerbating their impacts.

Introductions in new areas: There is considerable talk of agriculture moving north as conditions become drier in southern Australia under climate change. This would inevitably result in the introduction of new potentially invasive species.

Native species thought to be threatened by climate change may be deliberately shifted to new locations with more suitable climates, running the risk that they will become invasive.[35]

Changes to agricultural practices: Farmers may switch to goats in areas where other livestock are affected by heat stress, which would be detrimental to rare plants and result in erosion and loss of habitat for native animals.[5]

Less control effort: A recent NSW survey found that feral animal numbers did not decline during a drought, attributed to fewer control efforts by farmers under economic stress.[36] The challenge of coping with climate change events may compromise the control of pests and weeds. Governments may have less money to direct to such efforts.

Extreme events: If water is spread between catchments to avert shortages, aquatic pests such as tilapia (*Oreochromis mossambicus*) will have an opportunity to spread. Invasive ants can be transported when debris is cleaned up after cyclones, and firebreaks and tracks created for fire control can serve as conduits for feral animals.[6]

2.4 Invasions that increase greenhouse gas emissions

Harm to biodiversity may also result due to some invasive species increasing greenhouse gas emissions and thus exacerbating climate change.

Flammable weeds promote more and higher intensity fires that kill sapling trees and sometimes adult trees and promote grass invasion – a positive feedback loop (see box below).[21, 37] Lower tree density reduces carbon storage in woodlands. Many of Australia's major weeds are large flammable grasses: gamba grass (*Andropogon gayanus*), mission grass (*Pennisetum polystachion*), molasses grass (*Melinis minutiflora*), para grass (*Urochloa mutica*), veldt grass (*Ehrhata calycina*), buffel grass (*Pennisetum ciliare*), and African lovegrass (*Eragrostis curvula*) and the proposed biofuel giant reed is a potential major weed.

Weeds can increase greenhouse gas emissions by stimulating higher rates of soil carbon decomposition and reducing carbon stores.[38] Some weeds that invade wetlands – willows (*Salix spp*.) for example – release methane, which they extract from the mud they grow in.[39]

Below-ground invaders such as earthworms can increase decomposition rates and reduce soil carbon stores – by making conditions favourable for more-rapid decomposers (eg. bacteria over fungi) and for low- biomass tree species, for example.[37, 40]

Most feral animals in Australia – pigs, goats, deer, donkeys, horses, cattle, buffalo, rabbits – emit methane and nitrous oxide (as byproducts of bacterial fermentation of cellulose) and therefore contribute to greenhouse gas emissions. Feral animals are responsible for an estimated 4-5% of the Northern Territory's emissions.[41] These herbivores can also contribute to climate change by changing the structure and composition of the ecosystems they invade. The most profound impacts occur when herbivory both damages trees and prevents subsequent recovery of forests.[37]

Invasive leaf-eating insects and plant pathogens can also substantially reduce carbon uptake by forests. Large- scale disease and herbivory is turning some northern hemisphere forests from carbon sinks into carbon sources.[42, 43] Longer-term impacts on carbon uptake depend on which species replace trees killed. If myrtle rust compromises regeneration of Australia's dominant trees, it could undermine the national capacity to sequester carbon.

Predators can also affect the carbon dynamics of forests. Invasive yellow crazy ants (*Anoplolepis gracilipes*) are changing the structure and composition of forests on Christmas Island. By preying on the red crabs that process leaf litter, they reduce the decomposition of forest litter (which would reduce emissions). But by protecting honeydew-secreting scale insects from predators, they increase the growth of sooty mould, which reduces photosynthesis and leads to canopy dieback and sometimes tree death (which is likely to increase emissions).[44]

2.5 Positive feedback loops of invasive species and climate change

Some interactions between invasive species and climate change are particularly worrisome because they exacerbate positive feedback loops – problems cyclicly begetting worse problems.

Flammable invasive pasture grasses such as gamba grass (*Andropogon gayanus*) and mission grass (*Pennisetum polystachion*) promote fire by providing very high levels of dry fuel for fire.[21] They also benefit from fire by increasing in its wake. Climate change is likely to intensify fire regimes, which in turn will promote more exotic grass invasion, tree death and higher greenhouse gas emissions.

The damage that cyclones cause to rainforests promotes invasion by exotic vines such as blue thunbergia (Thunbergia grandiflora) and turbina (Turbina corymbosa). Vine invasion prevents canopy recovery, rendering forests more vulnerable to future cyclone damage and vine invasion. Climate change is predicted to increase the intensity of cyclones, exacerbating this cycle.[6]

Tree pathogens that benefit under climate change – Phytophthora cinnamomi in southwest Australia and myrtle rust in southern Australia, for instance – can render trees more vulnerable to the impacts of climate change (eg. drought or fire) and contribute to greenhouse gas emissions if infected trees die. Weeds may take the place of trees killed.

There are human-based feedback loops as well. The more invasive species that establish, the less many people are inclined to do about it – due to the feeling that the problem is too big and hopeless. Climate change will exacerbate this trend by driving even more environmental problems. Promoting motivation to avert invasive species threats is a key climate change challenge.

3. Responding to the double trouble of climate change and invasive species

Climate change strengthens the imperative for addressing invasive species threats to biodiversity. Climate adaptation and mitigation measures should address invasive species threats in four ways:

- Reduce existing invasive species threats to increase the capacity of native species and ecosystems to adapt to climate change;
- Control invaders or potential invaders likely to benefit under climate change; and
- Prevent new introductions, ensuring that responses to climate change do not create new invasive species problems.
- Control invasive species that directly or indirectly contribute to greenhouse gas emissions.

3.1 Reduce invasive threats to increase capacity for adaptation

Extinctions are often the result of multiple, cumulative threats. Reducing other threats is essential to providing species with the best prospects of surviving and adapting to climate change. With invasive species one of the top three threats to biodiversity, they should be a very high priority in efforts to facilitate adaptation to climate change. Reversing the long-standing under-investment in environmental biosecurity is essential.

Some species have survived past climate change by retracting to refuges. Identification and protection of refuges from invasive species and other threats should be a high priority. Fire refuges, for example, need protection from invasion by flammable weeds and drought refuges from predation by cats and foxes and exotic competitors for resources.

3.2 Control invaders likely to benefit under climate change

Climate change will change priorities for managing invasive species, with new threats emerging, some existing threats increasing and others declining. It is prudent to substantially reduce the number of potential invasive species (eg. eradicate sleeper weeds) and control species likely to exert the most serious threats. For example, there should be programs to eradicate garden plants that could spread into the Wet Tropics after cyclones or invade warming alpine areas. A national priority should be fighting the dieback disease *Phytophthora cinnamomi*, as it is a major threat that could get much worse in some areas under climate change.

3.3 Prevent new harmful introductions

While Australia has a good risk assessment process for introductions of new species from overseas, most species imported prior to 1997 (when risk assessment was introduced) have never been assessed and can be freely imported. Most states and territories regulate the use of only a very small proportion of invasive species, allowing new introductions without risk assessment (Western Australia is the exception to this). New hardier varieties of existing weedy garden plants or pasture plants that could greatly exacerbate their threats can also be introduced without assessment.[33] It is important to ensure that any translocation of native plants and animals to more suitable habitats under climate change does not lead to them becoming invasive.

3.4 Reduce greenhouse gas emissions by reducing invasive threats

Some invasive species threats could be addressed as part of efforts to reduce Australia's greenhouse gas emissions. A high priority should be to limit the spread of flammable weeds that both increase fuel loads well beyond natural levels and increase emissions due to more fires and in some cases the death of trees. There would be both biodiversity and mitigation benefits in reducing the numbers of feral animals in many areas. It is also important to ensure that climate mitigation efforts do not increase invasive species threats. For example, plants used as carbon sinks or biofuels should not be invasive species.[32]

3.5 Summary of needed measures

Reduce invasive threats to increase capacity for adaptation

- Reduce invasive species and other threats to native species and ecological communities likely to decline under climate change.
- Protect likely climate change refuges from threats, including those due to invasive species.
- Control invaders likely to benefit under climate change
- Develop programs to prevent potential invasive species threats under climate change, including eradicating potential weeds from gardens in the Wet Tropics and alpine areas.
- Direct strong research and control efforts to invasive species likely to exert the highest threats to biodiversity under climate change, eg. *Phytophthora cinnamomi* and flammable invasive pasture grasses.

Prevent new harmful introductions

- Adopt a permitted list approach to exotic species at the state level that permits release only if they pose low invasive risks.
- Ensure that all new cultivars or breeds of existing weedy or pest species undergo risk assessment and are permitted for import or release only if they pose low risk.
- Subject biofuel crop species and other species proposed for widespread cultivation to risk assessment, permitting cultivation only for low-risk species.
- Develop a national policy on translocation of native plants and animals that requires rigorous risk assessment of the invasive threat.

Reduce greenhouse gas emissions by reducing invasive threats

- Develop programs to limit the spread of flammable weeds to limit the risk of intensified fire regimes and increased greenhouse gas emissions.
- Fund control programs for feral animals as a mitigation measure.
- Ensure that climate change mitigation programs do not increase invasive species threats, eg. require risk assessment of any plants used for carbon sinks and biofuels and permit only low-risk options.

4. Governance issues

Australia's environmental biosecurity systems – consisting of a myriad of national, state and local laws, policies and programs – are far from adequate to arrest and reduce invasive species threats to the environment (see Table below). Unless there is substantial reform, Australia has no prospect of meeting Target 7 of the Australian Biodiversity Conservation Strategy:

> 'By 2015, reduce by at least 10% the impacts of invasive species on threatened species and ecological communities in terrestrial, aquatic and marine environments.'

Current biosecurity arrangements were devised to protect the comparatively simple systems of primary industries, not the millions of species and their complex interactions that constitute biodiversity. Recent, government-commissioned, independent reviews of Australia's national biosecurity laws (the 2008 Beale review) and environment laws (the 2009 Hawke review) have each found that environmental biosecurity has been neglected in comparison to that for primary industries. For example, the Hawke review found that:

> Environmental biosecurity issues have not traditionally received the same attention as the potential impacts of pathogens, diseases, weeds or pests on primary production. … The new biosecurity legislation should require that the environment must be given equal consideration alongside human health and economic and social considerations….

The Beale review found that:

> '…Australia has a relatively poor knowledge of the biosecurity threats to its natural environment. This is largely a function of the absence of commercial incentives to research and monitor environmental pests and diseases. As a result, the principal responsibility for biosecurity research as it relates to the natural environment lies with governments and the community. These activities have not received a high priority for funding. Unlike incursions that impact on primary production, where active engagement by business is motivated by self-protection, the effort required to respond to an incursion affecting the environment must be provided primarily by governments.

In its submission to the Beale review, CSIRO also highlighted the need for a stronger environmental focus:

> '... we lack national capacity to respond to pathogen and invertebrate threats to environmental biosecurity ... a holistic approach covering all biosecurity threat types and both industry and environmental sectors developed through regular reviews of risk prioritisation ...will be required.

Biosecurity requires a tripartite focus on (i) prevention of unsafe introductions (deliberate and accidental), (ii) eradication and containment of new and emerging invaders, and (iii) control of entrenched threatening invaders. Some of the broad challenges that need to be addressed include:

Prevention:

- High-risk taxa continue to be introduced, including new variants of existing invaders
- High-risk accidental invaders continue to arrive (myrtle rust, Asian honeybees, red imported fire ants, yellow crazy ants are recent examples)

Eradication and containment:

- There is a lack of preparedness (contingency plans and surveillance) for high-risk potential invaders
- Potentially eradicable or containable invaders are ignored due to insufficient focus and funding
- Invaders are deliberately moved into new areas due to lack of regulation (particularly with plants)

Control:

- There is insufficient focus and funding to control and reduce the threats of environmental invaders.

There are many reforms needed. An essential basis for doing so is a dedicated organisation to focus on developing more ecologically informed, efficient and effective ways to safeguard terrestrial and aquatic environments from invasive species, and to establish partnerships between the major stakeholders and participants in environmental biosecurity. We would be pleased to provide more detail on this and other reforms necessary to protect biodiversity from the synergistic impacts of invasive species and climate change.

Introduced, naturalized and invasive species in Australia

	Plants (vascular)	Vertebrates (not fish)	Freshwater fish	Marine organisms	Invertebrates	Micro-organisms & fungi
Introduced – exotic species	>30,000	~650	~1200	Unknown	Unknown - thousands	Unknown - thousands
Introduced – native but non-indigenous species[1]	>12,000	Unknown	>50	Unknown	Unknown	Unknown
Naturalised	>3,000	~60	>30	130->300	Unknown	Unknown
Environmentally invasive	>1,000	>30	~10	Unknown	Unknown	Unknown

[1] Species native to Australia that are introduced outside their natural range. Many weedy garden plants for example are native to Australia but not to where they are planted.

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