Tools for managing and restoring biodiversity

Tara G. Martin, Josie Carwardine, Linda Broadhurst, Simon Ferrier, Craig James, Andy Sheppard, Stuart Whitten and Iadine Chades

Key messages

- The challenge of managing and restoring biodiversity is being met with a multitude of tools and approaches for developing and improving decision-making and on-ground actions.
- Plans for managing biodiversity have to be formulated in the context of constrained resources, imperfect knowledge and likely conflicts between value sets.
- Land managers now have a toolbox of potential actions to choose from, depending on the threat and its scale: implementation of conservation reserves; control of invasive species; restoration of degraded ecosystems; and last-resort translocation or captive breeding of endangered plants and animals.
- Decision tools allow the best choices to be identified: what management actions should be taken, when and where, given competing societal values, economic constraints and scientific uncertainty.

INTRODUCTION

Managers of biodiversity face future uncertainty, with limited resources and competing values hindering timely responses.[1] Even with ample funds, it is often still unclear what management action will give the best chance of recovering biodiversity. This uncertainty has many causes: being unsure how many individuals of an endangered species exist; the condition or extent of habitats; the likelihood of success of management actions or their political and social feasibility; and the influence of emerging threats such as climate change. This chapter turns attention to the tools of biodiversity protection and restoration, and the improved decision-making demanded for effective management. We first discuss the actions that are now available to arrest declines, and then we illustrate ways to make sound choices between management actions. The next chapter deals in greater detail with one particularly important strategy for biodiversity management – Australia's system of protected areas.

ACTIONS TO MANAGE THREATS

There are two leading threats to Australia's biodiversity. The first is the loss and fragmentation of native habitat as a result of agricultural expansion and urban and industrial development, and the second is the impact of invasive species, particularly non-native. Other threats include over-grazing, altered fire regimes, over-harvesting, water pollution, disease (Table 4.1) and climate change (Table 4.2).

Habitat protection and restoration

Clearing of ecosystems over the last 220 years, and the resultant fragmentation of forests, woodlands, savannas and grasslands, is responsible for the status of many threatened and endangered plants and animals.[2,3] The establishment of state and Commonwealth legislation concerning broad-scale clearing of native vegetation has reduced the rate of vegetation loss, although widespread clearing of regrowth continues. Mitigation of these effects takes two forms: protecting existing ecosystems and restoring them (Table 4.1).

Habitat restoration activities are gaining pace both passively (allowing native species to repopulate in their own time) and actively (seeding, planting and translocation). Plant growth can be enhanced through inoculation of roots with nitrogen-fixing bacteria; likewise, bacterial inoculation encourages beneficial mycorrhizal fungi.[4] Elevated nutrient levels caused by agriculture constrain restoration in many Australian ecosystems by promoting rapid growth of non-native plants that out-compete natives.[5] Use of particular native plants, and other soil treatments, can reduce nutrient levels.[6]

Table 4.1: Major threats to Australian biodiversity and management actions to abate them

Threat	Management actions
Habitat loss and fragmentation	Halting clearing of native vegetation via legislation Expanding the National Reserve System (see Chapter 5) Protection and restoration of native vegetation on private land through incentives Restoration via native revegetation, and inoculation of soil with beneficial micro-organisms Passive natural rehabilitation via fire and grazing management Captive breeding and translocation
Invasion by non-native species	Preventing introductions via regulation and quarantine Surveillance, detection and eradication of new arrivals Containment of slow-spreading species Controlling existing invaders by pesticides or herbicides, baiting, and culling Protection of ecosystems and species by removal (plants) or fences (feral predators and herbivores), or moving at-risk species to islands Biological control
Livestock grazing	Management of grazing (stocking rate and access to water) Protecting vulnerable species or ecosystems by fencing Spelling areas from grazing to allow recovery
Altered fire regimes	Instigation of less intense, smaller fires to create a mosaic of age-since-burn where too frequent and on too broad a scale Controlled burning where fires are too infrequent Suppression of non-native invasive grasses with high fuel load (e.g. gamba grass and buffel grass) or fire-assisted shrubs (e.g. broom)
Over-harvesting of native species	Regulation and anti-poaching enforcement Compensation to offset loss of harvests Captive breeding and reintroduction programs
Water pollution, both marine and fresh water	Regulation of chemical and fertiliser use and dumping of waste Minimising water use in irrigated agriculture Increasing biodegradability of waste Improved sewage treatment and containment
Disease	Lower risk of spread through strategies based on epidemiology Maintain disease-free locations of suitable habitat Quarantine through isolation or destruction of infected individuals to minimise spread Captive breeding and release of disease-free populations

Fertile land has been cleared of native vegetation to make way for agriculture. In some regions, less than 5% of native vegetation remains. Photo: Tara Martin, CSIRO.

Captive breeding and translocation of endangered species are a last resort. A quick decision to augment the captive population of orange-bellied parrots, *Neophema chrysogaster*, narrowly avoided their extinction.[1] Translocation of several small- to medium-sized mammals to enclosures and offshore islands free of predatory cats and foxes has also saved these species from extinction.[7] However, translocation has its challenges because it can lead to conflict among human interests; may have negative consequences for either the target species or the recipient ecosystem; can be costly relative to other actions; and, finally, often fails.[8] Under climate change the challenges will be exacerbated because translocation may need to occur to sites outside historical distributions.[8–10]

Fewer than 100 breeding orange-bellied parrots, Neophema chrysogaster, *remain in the wild. Thanks to prompt action to increase the captive-bred population, extinction may have been avoided.[1] Photo: Chris Tzaros.*

Restoring sufficient genetic resources is fundamental to the sustainability of plant populations and biodiversity in general. Low genetic diversity can lead to inbreeding and decline, widely reported for fragmented plant populations,[11] and insufficient capacity to evolve during environmental change. New gene-sequencing technologies may improve restoration through rapid assessments of the genetic quality of wild and restored populations, highlighting ‘hidden’ species, and broadening our understanding of adaptation.

Management of non-native invasive species

In the absence of natural enemies or diseases to moderate their abundance, non-native invasive species are expanding in Australia – there are over 800 such plants, 34 fishes, 25 mammals, 20 birds, four reptiles, more than 400 marine pests, and many invertebrate and plant diseases.[12] There are also species regarded as native to Australia that are becoming invasive, but they are still a comparatively minor part of the invasive problem. Management of non-native species involves keeping them out of Australia, containing them if they get in, and controlling them if they escape. Australia puts a major effort into preventing entry. Despite this, such species still arrive and are then often subject to costly eradication. Where eradication is no longer possible, we must learn to live with them and seek to minimise the harm they cause.

The only continent-wide and long-term means of managing an established non-native invasive species is biological control, the introduction of highly specific natural enemies or diseases from the invader's native range. Such control has been successful with many non-native weeds, for example rubber vine, *Cryptostegia grandiflora*, and bridal creeper, *Asparagus asparagoides*, and also for rabbits via myxomatosis and rabbit haemorrhagic disease. The exploration of cyprinid herpesvirus 3 (CyHV-3; formerly known as koi herpesvirus) for the control of carp, *Cyprinus carpio*, in wetlands is among the next generation of promising opportunities.

Predation by feral cats and foxes presents a major threat to Australian wildlife. Management ranges from construction of predator-free enclosures to culling of predators. Photo: Chris Tzaros.

Livestock grazing management

Livestock grazing is the most extensive land use across Australia and has contributed – along with grazing by feral animals – to biodiversity loss through the removal or alteration of native vegetation and degradation of drought refuges (permanent water sources that sustain wildlife during times of low rainfall).[13] Management of grazing through fencing and better distribution of water points is bringing grazing more in tune with variability in climate, and removal of grazing from vulnerable habitats such as the alpine zone and riparian areas will lessen impacts (Table 4.1).

Ecologically sustainable livestock grazing in Queensland. Photo Tara Martin, CSIRO.

Fire management

Much of Australia's vegetation is adapted to periodic burning. Bushfires recur with intervals of a few years to many decades, particularly in northern Australia but also in other parts of the country. Occasional large fires in the eucalypt forests and alpine woodlands of south-eastern Australia would seem at first sight to be bad, but they have no negative long-term impact on the diversity of plants and animals as long as intervals between fires remain long enough for regeneration.[14] In the northern savannas, fires are a frequent occurrence to which the vegetation is generally well adapted, but they have become more frequent, intense and widespread, threatening the persistence of some sensitive species. Here, less intense and less extensive wet-season burns prevent large hot dry-season fires, as long as highly flammable non-native grasses are contained (Table 4.1).

Preventing over-harvesting

Commercial fishing has resulted in diminished populations of many species (e.g. Murray cod, *Maccullochella peelii*; snapper, *Pagrus auratus*; and orange roughy, *Hoplostethus atlanticus*), as has illegal harvesting of molluscs, corals, orchids, birds, reptiles and fishes. Removal of native species that pose a threat to agriculture has also caused decline (e.g. Carnaby's cockatoo, *Calyptorhynchus latirostris*; emu, *Dromaius novaehollandiae*; and spectacled flying-fox, *Pteropus conspicillatus*), and even extinction (thylacine, *Thylacinus cynocephalus*). Actions to reduce over-exploitation include regulation, compensation, and encouragement of captive breeding (Table 4.1).

Box 4.1: Why biodiversity decline and management constitute a 'wicked' problem

The term 'wicked' here means not that the problem is evil, but that it is difficult or impossible to solve.

- The problem resists clear definition – views about it vary among interested people.
- The apparent cause may not be the root of the problem; it may result from interactions among causes.
- Potential solutions may lead to unforeseen consequences – for example, reconnecting remnants of bush may facilitate movement of pests and weeds.
- Problems and solutions change through time – the shifting distributions of invasive species as a result of climate change may create problems or might allow opportunities for control.
- Solutions are socially and organisationally complex – they impose costs on some individuals and benefits on others, and implementation requires coordination among many organisations.
- Solutions involve human behavioural change – the commitment of individuals to consider alternative values and to cooperate is essential.

Pollution control

In freshwater, estuarine and marine environments, pollution is a threat that involves chemicals, run-off of fertiliser and sediment, plastics and nets. Impacts on the Great Barrier Reef have prompted management of agricultural practices and the declaration of reserves and zones on reefs for different forms of commercial use (Box 4.1). The effect of discarded plastic bags on marine turtles has prompted campaigns to reduce their use and to intercept plastics in stormwater (Table 4.1).

Disease management

Phytophthora fungus, *Phytophthora cinnamomi*, and myrtle rust, *Uredo rangelii*, are examples of introduced diseases that affect native ecosystems and threaten the persistence of many plants. Neither can be eradicated: both are managed to minimise spread. Facial tumour disease in Tasmanian devils, and chytrid fungus (*Batrachochytrium dendrobatidis*) in frogs, have led to population declines and possible extinction. Actions to abate impact are diverse, from quarantine of non-infected populations through to treatment or destruction of infected individuals (Table 4.1).

Tasmanian devil, Sarcophilus harrisii, *infected with facial tumour disease. Photo: Menna Jones, University of Tasmania.*

Climate change adaptation

Climate change presents a particular challenge because of the breadth of its impact and its amplification of existing threats (Table 4.2).[15–17] For example, climate change may cause more high risk fire days (i.e. high temperatures and low humidity) and favour the spread of fire-prone non-native invasive grasses.[18] Research predicting future responses to climate of species and ecosystems suggests that management efforts focused on ecological processes, rather than on individual species or habitat patches, are likely to be most effective. The *Atlas of Living Australia* can help inform restoration options under climate change (Box 4.2). From here, there are broadly two pathways: to manage threats while letting biodiversity recover naturally; or to intervene by relocating species or ecosystems.

The tasks summarised in Tables 4.1 and 4.2 are so substantial, so inherently multi-scale and interactive, that resources are inevitably inadequate relative to the size of the challenge. Progress on these 'wicked' problems (Box 4.1) is often stalled due to uncertainty and disagreement on the best course of action.[19]

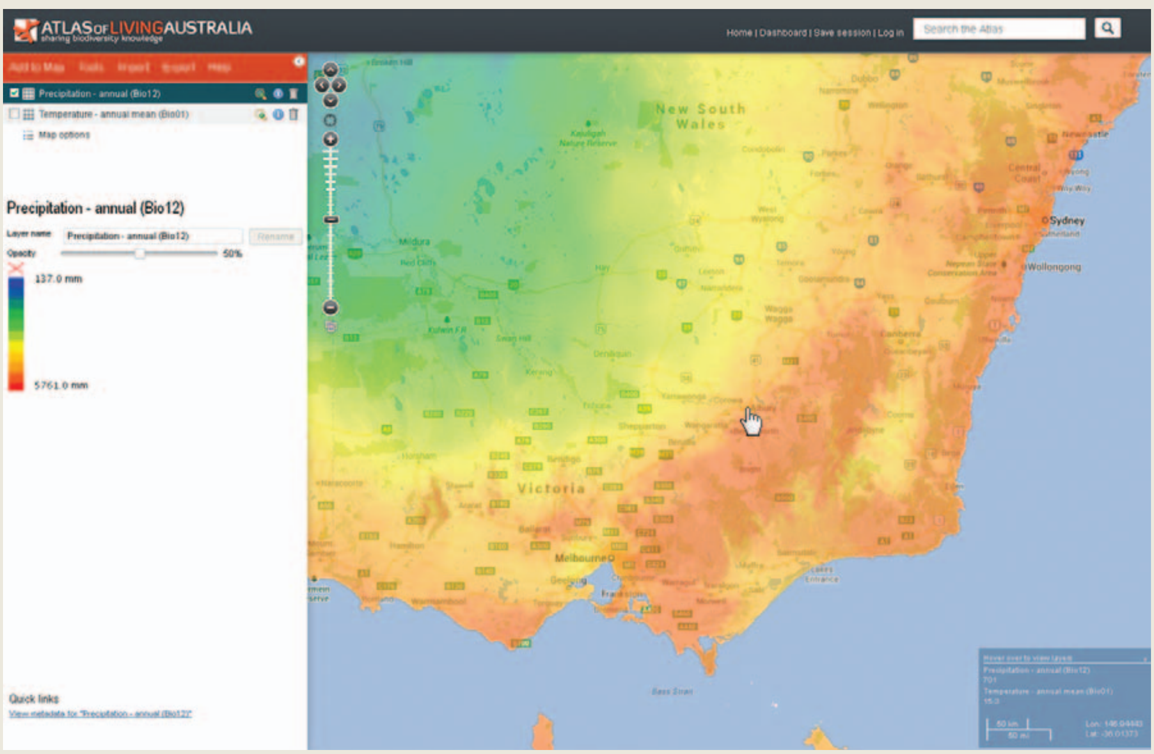
Table 4.2: Management responses to adapt to climate change

Impact on biodiversity	Examples of changed conditions	Examples of management actions
Environmental conditions no longer support species	Too hot, too wet, too dry	Facilitate movement along corridors Assist species to move by relocation Leave species to adapt as best they can
Extreme events damage environment	Large storms, damaging winds, floods	Plan for ecosystem defences (e.g. mangroves protect shoreline ecosystems) Ensure species are distributed in many populations to spread extinction risk associated with catastrophic events Relocate containment facilities for non-native species (zoos, aviaries, fish farms, botanical gardens) from vulnerable areas
Entire ecosystems change	Species disappear and are replaced by others Invasive plants change fire regimes	Identify and manage refuges that buffer species from rapid change Manage to avoid undesirable monocultures
Altered interactions among species	Prey populations escape control by their predators	Encourage novel combinations of species Respond rapidly to pest outbreaks
Ecosystem services change	Natural pest and disease controls break down Pollination disrupted	Manage for services that best equip systems to adapt

Box 4.2: The *Atlas of Living Australia* helps guide revegetation under a changing climate

The challenge of revegetating, rehabilitating and restoring landscapes intensifies in a changing climate because of the need to plant species suitable not just for current but also potential future conditions at a given location. The *Atlas of Living Australia* aids selection of plants that should be least vulnerable to changing environmental conditions at specific sites. The *Atlas* can identify tree, shrub and groundcover plants present in a given area, generate maps of their current distributions across Australia, and help to identify locations where particular plants are already experiencing relatively extreme climatic conditions (Figure 4.1). The *Atlas*'s environmental data layers, featuring soil moisture, bushfire frequency, rainfall and temperature, can be overlayed on the plant's distribution, and using this the range of conditions suitable for each species can be obtained.

The *Atlas* also contains climate change scenarios for 2030, allowing predictions on whether each species would be suited for revegetation at a particular site into the future. This enables sourcing of seed not only of a particular plant species, but also from a particular origin, to optimise future climatic compatibility.



▲ ***Figure 4.1****: Screenshot showing use of the* Atlas of Living Australia*'s mapping tools to determine climatic conditions at a target site, with data layers loaded over an underlying map.*

DECIDING ON MANAGEMENT ACTIONS

Some insights on biodiversity management are starting to emerge. The first is that management goals must be flexible, acknowledging that it may not be possible to return ecosystems to an earlier state following disturbance.[20] For example, restoration efforts may need to abandon long-held use of local seed sources in favour of genetically diverse seed to maximise adaptation under climate change.[21] Second, land clearing and shifts in species distributions are contributing to novel ecosystems. Assumptions of a static environment no longer hold, and it may now be necessary to embrace new possibilities and constraints.[22] Third, management and restoration are often costly. Hence, costs and benefits of an action, along with the social feasibility of undertaking it, must be factored in from the outset.[23,24] Finally, time is often critical.[1]

Failure to act quickly on evidence of rapid population decline led to Australia's most recent mammal extinction, that of the Christmas Island pipistrelle, Pipistrellus murrayi.*[1] Photo: Lindy Lumsden.*

Our ability to decide wisely among available options depends on knowledge of the issue, the various values brought to its consideration, and the surrounding legal constraints (such as land tenure or conservation covenants). How do we decide what threats to manage, what actions to use to manage them, where in the land or seascape to do so, and when? An essential approach to this problem is to use a framework that incorporates multiple competing priorities, imperfect knowledge about the future, and limitation in resources.

Structured decision-making is a framework for deciding between actions. It helps us to understand complex problems by defining alternative options, typically involving several groups of decision-makers.[25] The tools range from relatively simple spreadsheet analyses through to computer-based decision models. A challenging step is to evaluate the possible effectiveness of different management actions (e.g. different habitat restoration techniques or options for reserve design). Research aims to help improve this step by developing better ways of 'scaling up' local benefits of individual actions to predict collective outcomes from alternative sets of actions across ecosystems, regions, or even the entire continent.[26,27]

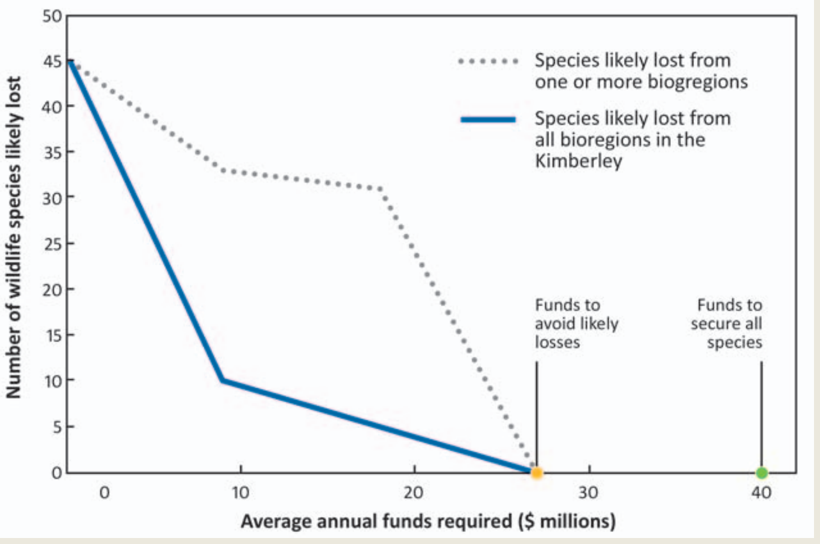
We now turn our attention to three examples of structured approaches to decision-making and how they can help highlight cost-effective management actions. A related example, systematic conservation planning, is highlighted in Chapter 5, which deals with our protected areas.

Prioritising management of threats

Optimising the management of threats requires prioritising on the basis of benefit per dollar spent and likelihood of success. Where likely benefit of management cannot be measured financially, cost-effectiveness analysis of any benefit divided by its cost is a useful tool for enabling more justifiable investments in management.[28] 'Co-benefits' such as improvements to human livelihoods, agriculture or ecosystem services can also be included.[24] Cost-effectiveness analysis is being used to prioritise actions to recover threatened species,[24,29,30] and inform landscape-scale restoration (Box 4.3).[31]

Box 4.3: Cost-effectiveness of management interventions in the Kimberley

State government agencies, Indigenous land councils, the pastoral industry and non-government organisations are responsible for implementation of actions to ensure persistence of the Kimberley's wildlife.[24] The aim was to assess cost-effectiveness of management actions, as measured by the benefits in terms of predicted persistence of 637 vertebrate species over 20 years. The study drew upon field data and the knowledge of 27 experts on the benefits of managing fire, introduced herbivores, weeds and feral cats. The study found that an average of $27 million per year was required to avoid likely losses of wildlife, while an average of $40 million per year would secure all species (i.e. estimated likelihood of persistence greater than 90%) (Figure 4.2).



▸ ***Figure 4.2****: The number of wildlife species predicted to be lost (i.e. chances of persistence estimated to be below 50%) from at least one bioregion (dashed line) and from the entire Kimberley (solid line), at various levels of investment in management.[24]*

Managing endangered and invasive species

Decisions about managing species, be they rare and endangered or a damaging invasive species, reflect two extremes of the same issue. Detecting an invading pest at an early stage and managing an endangered species constitute the same problem of allocating limited resources. In the case of pests you want to know where they first appear, and with rare and endangered animals you need to know when they're no longer around. But many threatened or invasive species are difficult to detect when numbers are low, when an invader first appears or an endangered population is on its last legs. Even large endangered mammals can be surprisingly hard to detect.[32] Consequently, it is possible that effort is invested in management even after the invasive pests, diseases or threatened species have disappeared. Conversley, in the absence of sightings, managers might give up too early. Hence, the manager needs to know when to start or stop work, and where. Using an optimisation technique for making decisions in uncertain circumstances, the best course of action can be determined to solve such problems.[33]

Decision-making under conditions of climate change

The approaches to decision-making outlined here aim to find solutions to current problems. However, decision-making during a period of climate change adds further complexity requiring us to mention several pertinent principles.

Past assumptions will be challenged because change is inevitable. Approaches to management have tended to assume that ecosystems are relatively static, but with climate change there will inevitably be widespread change to ecosystems. Managers may need to think differently about the definitions of 'natural' and 'invasive' species because some native species might end up having undesirable consequences in areas that they invade as the climate changes.[34] Future efforts may need to look beyond idealistic approaches and concentrate on new, more pragmatic options.

Management objectives will change. Should we focus on managing species or ecosystems and, given that not all can be saved, which particular species or ecosystems should be the focus? Societal values and management objectives will change, so plans need to be flexible.

Future landscapes will be designed. It is likely to be preferable to engineer a desirable future landscape rather than allow the processes to run their course towards an unhappy future. Techniques such as relocation of species are likely to be supported socially and scientifically if the alternative is to watch them become extinct.[8]

Decision-making will be complex. Some guidelines help to simplify.

- Actions with long-lived outcomes should be considered most carefully, given uncertainty about the distant future. Planting of long-lived trees requires that they persist for a century or more, but will that species survive in the location 100 years hence?
- Actions that are difficult to reverse should be considered carefully because they reduce options to do other things in future.
- Uncertainty should not prevent decisions; not acting is in itself a decision to be evaluated against other possible decisions.

CONCLUSION

Managing biodiversity requires good decisions in the face of limited money, short time-frames, trade-offs with other societal priorities, and incomplete knowledge. The stakes are often high, the outcomes often have immediate effects upon people, and the trade-offs can be morally and emotionally taxing.[22] The development and refinement of management actions, tools allowing choice among them, and monitoring of their effectiveness can help us navigate these wicked problems. In some cases, solutions will be found and biodiversity protected, whereas in others the best solution may be to stop and instead divert the resources to a problem with a higher likelihood of being solved.[35] Using these tools and the expertise at hand, Australia has a great opportunity to manage and restore its biodiversity values.

FURTHER READING

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