PROBLEMS IN THE LANDSCAPE

In previous chapters we described some of the outstanding natural values of Northern Australia, noting that the North retains extensive natural landscapes, operating with unusually intact ecological functionality and offering exceptional levels of landscape health to its residents. It is an inspiring landscape to those who visit and a precious home to those who live there.

But not all is well in this landscape. It is not robust beyond measure. Over the last 100 or so years, almost all of its environments have been exposed to a wide range of novel pressures and impacts, and those landholders who now manage it are generally less environmentally conscious or informed than their predecessors. Even within these extensive natural landscapes, there are indications of some breakdown in ecological structure and function.

This chapter describes some of the signs of problems in this landscape and links them to possible causes. Chapter 6 provides suggestions about the maintenance, repair and planning that may be required to sustain these lands and prevent further decline.

In this chapter we argue that the values described previously cannot be taken for granted; that they will not persist through default or inaction. Without long-term and large-scale planning and without the sustained work of its land managers, the North's natural values will wither and the distinctive character of Northern Australia will be reduced to a shrinking facade. Perhaps superficially there will still be extensive savanna, but with major impairment of the underlying and fundamental ecological processes that sustain it.

The examples of loss we discuss here mostly refer to impacts on biodiversity in largely natural landscapes. We do not here consider the more acute problems that arise from vegetation clearance, the impoundment and diversion of water, and related intensive development. Such issues are considered more in Chapter 6.

WHY WORRY?

Should we worry if there are a few blemishes, some indications of imperfection in an otherwise overwhelmingly natural landscape? Who cares? Who notices? There are several answers to these questions.

KNUT DAHL & HIS BOUNTEOUS MAMMALS

One of the few accounts of the status of wildlife in Northern Australia around the time of European settlement was provided by the young Norwegian zoologist Knut Dahl, who travelled extensively in the Top End of the Northern Territory and parts of the Kimberley, from 1894 to 1896. His observations were recorded racily in the book *In Savage Australia* (Dahl 1926) and somewhat more prosaically in scientific journals (Dahl 1897). Dahl was a good and capable observer, and also respected Aboriginal knowledge of wildlife. His comments on the status of many species in the 1890s contrast sharply with what we know of their current status. For example, Dahl noted:

- For the Burrowing Bettong (in the south-east Kimberley) '*the ground was nearly everywhere and in all directions excavated by the burrows of this little Macropod … all the scrubs, and especially the slopes … are inhabited by countless numbers*'. This species is now extinct in Northern Australia.
- The Golden Bandicoot was '*very numerous in the coast country around Roebuck Bay … great numbers being brought to me*'. It now occurs in only 2–3 small areas of the Kimberley mainland, one island off Arnhem Land, and two islands off the Kimberley coast (McKenzie *et al.* 1978; McKenzie 1981; Southgate *et al.* 1996).
- For the Golden-backed Tree-rat (in the south-west Kimberley) '*the houses of settlers … are always tenanted by (this species)*'. This species now occurs only in a few small areas of the Kimberley, and there have been no confirmed Northern Territory records since 1967 (McKenzie 1981; Woinarski 2000).
- For the Brush-tailed Rabbit-rat, *Conilurus penicillatus*, '*in Arnhem Land is everywhere common in the vicinity of water*', and '*numerous all over Arnhem Land, and in great numbers on the rivers on the lowlands*'. This species is now known from the Northern Territory mainland only on Cobourg Peninsula and one small area within Kakadu (Firth *et al.* 2006a, b).
- For the Brush-tailed Phascogale, *Phascogale tapoatafa*, '*on the rivers Mary and Katherine it was frequently observed. In fact, nearly everywhere inland it was very constant, and on a moonlight walk one would generally expect to see this little marsupial*'. This species is now rare and highly localised in Northern Australia, with fewer than ten records over the last two decades.

The species considered above provide much of the most distinctive elements of the mammal fauna of Northern Australia. In most cases, the evidence suggests widespread decline, across more developed and remote areas. Where recent evidence is available (see box *'Declines in Mammals'* on page 66), this suggests that the declines may be continuing.

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We should heed the lessons learnt from environments that have been pushed further than the North, such as the Murray-Darling system or the intensively-grazed lands of the Burdekin system in Queensland. Once on the trajectory of decline, it becomes either very expensive or impossible to restore the health of large natural systems; and their malfunctioning has disruptive and costly impacts well beyond their immediate geographic confines. It is good economic practice to maintain environmental health over the long-term in our landscapes. It is both responsible and efficient practice to attempt to redress environmental problems as quickly as possible once they are apparent. And we do not yet know these systems well enough to figure out where the point of no return is, how far we can push the landscapes and stay within bounds of retrievability.

There are legal and policy reasons to maintain the integrity of these systems. Australia has international legal obligations to conserve biodiversity, including those stemming from the Convention on Biological Diversity. Our national and state legislations, notably the *Environment Protection and Biodiversity Conservation Act 1999*, commit Australia to conserving biodiversity and to ensuring that developments occur within sustainable limits.

Species have their own intrinsic worth. *The UN World Charter for Nature*, states that '*Every form of life is unique, warranting respect regardless of its worth to Man*'. The Charter also notes that '*Mankind is a part of nature and life depends on the uninterrupted flow of natural systems*' and that '*Lasting benefits from nature depend upon the maintenance of essential ecological processes*' (United Nations 1982). Every species has some right to persist. And the world would somehow be a poorer place without Gouldian Finches, Golden Bandicoots or any of the other species that are declining or under threat in Northern Australia.

Many species have particular values to people. Indigenous people have spiritual affiliations with many plants and animals, and their culture is degraded when these are lost. Other plants and animals may have some economic value: for example, fish are necessary for fishers; bird-watchers are an important component of the tourist industry in Northern Australia; and some unusual or currently threatened species are particular attractions. Plant or animal species may have economic value as genetic resources, for medicines, for

Indigenous arts, or for directly or indirectly supporting industries such as pastoralism.

The wildness and beauty of Northern Australia's landscapes is a fundamental attractant to the tourism industry, and its major marketing feature. Tourism is one of the region's largest economic and employment contributors, and is unlikely to flourish if the region's environments become increasingly diminished, degraded or reduced to more closely resemble those of everywhere else in the world.

We should also be concerned about the blemishes because they provide a performance measure on our land management. Most descriptions of sustainable development recognise as an explicit principle that development should entail no net biodiversity loss. Most landholders and other natural resource managers want to foster the legacy that they are responsible for and will be handing on to the next generation.

It reflects poorly on managers if species are lost or environments become degraded on their lands and under their management.

Species that are declining or environments that are degrading are indicative of problems in the landscape. They provide early warning that the landscapes are not being managed sustainably or sympathetically. They will usually be the heralds of more widespread loss. Responding to the early signs will allow us to address the problems while still solvable and will provide the most cost-effective opportunities for their solution or amelioration.

SPECIES DECLINE

Over long periods of time, species come and go, and all landscapes change. There is good fossil evidence, particularly from one of Australia's most important fossil sites, Riversleigh in the

1 *(Page 62)* Introduced Water Buffalo, Top End. *Photo by Lochman Transparencies*

2 The now extinct Thylacine can still be seen in Northern Australian rock art. The Thylacine is spoken of as the dog of the rainbow serpent and its name still survives in the Kundedjnjenghmi language. *Photo by Peter Cooke*

DECLINES IN MAMMALS

It is tantalising but inexact to compare the commentaries by Dahl and others on historic mammal status with our current assessment of their status. The apparent changes may refer to events that happened long ago and have little relevance to the conservation challenges of today. State conservation agencies, and others, are now beginning to compile increasingly precise and systematic assessments of the status of mammals (and other animals and plants) from many areas in Northern Australia (e.g. Edwards *et al.* 2003; Woinarski *et al.* 2004b, 2006b; Start *et al.* in press). This allows for more powerful and exact monitoring of changing status, for more direct assessment of the factors affecting status, and for more rapid management responses.

One of the most substantial recent assessments of the abundance of native mammals has been at CSIRO's research station at Kapalga, within Kakadu National Park. Mammals have been systematically trapped at a set of sites at this location over the period 1986–1993, and again in 1999. Over this period, trap success (the percentage of live traps that catch mammals) decreased from 24% to 3% (at one main site) and from 6% to 2% (at a series of smaller sites). Declines were significant for Fawn Antechinus, Northern Quoll, Northern Brown Bandicoot, Brush-tailed Possum, Black-footed Tree-rat and Pale Field-rat, whereas there were significant increases for only Grassland Melomys, Western Chestnut Mouse and Delicate Mouse (Woinarski *et al.* 2001; Pardon *et al* 2003). The trend in these data is for declines amongst the larger, more specialised species and for increases in a smaller set of smaller, more generalist and disturbance-favoured species. These trends are consistent with patterns of decline elsewhere in Australia, where the most extinction-prone species include larger and more specialised rodents, bandicoots, possums and quolls.

It is not yet clear how representative these data are of situations more broadly across Northern Australia (Start *et al.* in press), nor whether the picture from Kapalga is of a continuing set of trends as opposed to a more chaotic series of fluctuations without long-term direction. However, the Kapalga data represent the largest monitoring data set we have in Northern Australia. Further, they derive from the best-resourced conservation reserve in Northern Australia, so it is reasonable to assume that if there is a downward trend in biodiversity here, then it may apply at least as much in other tenures.

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Gulf Country, that the biodiversity of Northern Australia has suffered some repeated major upheavals, and in the process lost many of its most spectacular plants and animals (Archer *et al*. 1991). Much of the loss of Australia's unique megafauna occurred during the severe climatic fluctuations between about 8000 and 80,000 years ago, coinciding also with the arrival of Aboriginal people into the Australian landscape (Johnson 2006).

Aboriginal people have left enduring images of some of these now-lost species: rock art paintings of Thylacines in the stone country of Arnhem Land are remarkably precise and vivid, beautifully representing the spirit and verve of the animal. These paintings also remind us that the Thylacine belonged to this country and was present here until a few thousand years ago.

The decline and loss of other species has been less well marked. The history of European colonisation of Northern Australia has been relatively brief, and there are few benchmarks from which to measure the changing status of species since European settlement. In the accompanying boxes, we summarise some examples, each providing insights into biodiversity change in Northern Australia over this period. The picture is not yet coherent, but there are enough indications to unsettle any cosy notions that these landscapes can look after themselves; that all species are robust in this rough and rugged land; and that, beyond the limited areas of development, there are untouched vastnesses that provide inviolable sanctuaries for all wildlife.

In Northern Australia, decline is not just some regrettable fate for a few tangential, unusual and/or ill-equipped species, it is also a pervasive feature for whole groups of species across most or all regions.

LANDSCAPE CHANGE

As with species, any assessment of the state of environments is hampered by the lack of broad-scale and systematic monitoring.

The best available information is from monsoon rainforests, particularly in the Top End of the Northern Territory. Here, rainforests occur in relatively small patches, embedded features typically associated with unusually wet (particularly springs or riparian areas) or unusually rugged (fire-protected) areas within the broader matrix of eucalypt forests and woodlands. Botanists have visited 1220 of these rainforest patches (Russell-Smith and Bowman 1992), and in each visit scored the condition of the patch with reference to four main

disturbance agents: fire, weeds, feral pigs and livestock (cattle and buffalo, feral or managed). The proportion of rainforest patches that they rated as 'severely disturbed' is given in Table 5.1.

About one-third of all rainforest patches were scored as severely disturbed by fire. Overall, there was relatively little difference between tenure types in the condition of rainforests. These results show that each of these disturbance factors, separately or interactively, is contributing to the degradation. The rainforest patches themselves suffer this extent of degradation, but these assessments are probably also indicative of the condition of much of the broader landscapes in which they are embedded.

An important feature of the results from this survey of rainforest patches is that the degradation is occurring through factors that

TABLE 5.1 **DISTURBANCE OF RAINFOREST PATCHES, ON LANDS OF DIFFERENT TENURE**

	Total (all tenures) (%)	**Patches on conservation lands** (%)	**Patches on pastoral lands** (%)	**Patches on Aboriginal lands** (%)
Fire	34	28	40	31
Weeds	22	29	33	13
Pigs	10	17	13	7
Stock	20	34	23	15

Figures are patches of rainforest rated as 'severely disturbed'. Percentages refer to all rainforest patches visited for each tenure type – thus, for example, 17% of rainforest patches sampled in conservation lands were severely disturbed by pigs, and 7% of the patches on Aboriginal lands were also severely disturbed by pigs. Data from Northern Territory only, from Russell-Smith and Bowman (1992).

DECLINE OF THE GRASS-SEED EATERS

Gouldian Finches, Golden-shouldered Parrots, and many other birds of great beauty have declined across the savannas over the last 100 years. Birds, such as quails, finches, parrots and pigeons, that feed largely on grass-seeds have shown major reductions in distribution and abundance over this period (Franklin 1999; Franklin *et al.* 2005). In some cases such as the Gouldian Finch, there have been major declines across most of their previous range.

The reasons for these declines are not immediately apparent because the habitat remains apparently intact. Across the savannas, grasses still dominate the landscapes. Grass seeds remain one of the major food sources for wildlife with massive amounts of grass seed produced annually. A square kilometre of savanna with native grasses can produce over a tonne of grass seed annually. This provides a rich, abundant and relatively reliable food source for many birds and mammals.

However, while the total amount of food remains abundant, many birds have declined. Research on some of these declining grain-eaters has shown that each species has specific needs that are not being met in many landscapes in recent years. Changed fire practices have altered habitat in subtle ways that make it harder for these species to make a living (Woinarski *et al.* 2005). In some areas over-grazing by stock and feral animals may also contribute to a subtle but fatal change in habitat for these birds (Crowley and Garnett 2001).

For example, Gouldian Finches face food shortages in the early Wet season after the first rains cause germination in the fallen seeds of Sorghum, their main Dry season food (Garnett and Crowley 1994; Dostine *et al.* 2001). They are dependent then upon a range of mainly perennial native grass species that rarely dominate the landscape and that typically decrease in abundance in grazed situations or in contemporary fire regimes. The decline or loss of these grass species may be imperceptible to us, but lead to a fatal gap in the resource availability for finches. It is then no consolation for these finches that the increasing Sorghum may produce superabundant seeds in another part of the year. Survival depends upon eking out an existence from critical resources during periods of shortage.

Other species have variations on this problem. Changes in the savanna, some of them subtle, have led to reduced seed availability at particular times of the year, or changed the amount of cover, exposing birds to predators. These changes can reduce and eventually cause local and regional extinctions of populations of these eaters of seeds.

Barry Traill

Redhead Gouldian Finch. *Photo by Jo Heathcote*

A MEDLEY OF PROBLEMS: GOLDEN-SHOULDERED PARROT

Early European visitors to Cape York Peninsula describe a parkland landscape kept open by intense Aboriginal fire management. Sculptural termite mounds could be seen for miles through the scattered trees, and within some of them Golden-shouldered Parrots had excavated nesting hollows. But through the twentieth century this picture changed. Aboriginal burning was increasingly disrupted and cattle grazing reduced fuel loads. Thick stands of *Melaleuca* invaded once grassy drainage flats where termite mounds had been at their most dense (Neldner *et al.* 1997). At Silver Plains all burning was banned in the mid 1920s to let introduced legumes flourish for cattle feed. Within a few years the open grassland became a dense woodland.

With the grassland went the parrot – common in 1921, last seen briefly on Silver Plains after much searching in 1956. The parrots took a long time to go but research on the species suggests that the denser woodland allowed enabled predators like butcherbirds to prey more readily on nesting parrots, and gradually depleted their population. By the 1990s the species was confined to two small areas where a combination of more traditional fire management, remoteness and geology had allowed the species to persist. Even here their persistence is tenuous.

The parrot's fate is indicative of other environmental change. Black-faced Wood-swallows, open country birds with which the parrot commonly associates, are now notably less common, and Black-throated Finch also seem to be declining. The termite mounds, which may take 30 or more years before they are large enough to support a parrot nesting chamber, are also far less abundant. In some places, where parrots and mounds were common 70 years ago, neither remain. Elsewhere on Cape York rainforest is expanding. In the savannas, species that first evolved as separate species five million years ago are all but gone (Garnett and Crowley 2003).

Restoration of ecological function for these species and systems is not just a matter of declaring National Parks or removing land managers. Active land management is required, with restoration of fire regimes, control of feral animals and restriction of cattle movements (Crowley 2001; Crowley and Garnett 1998, 2001). Some pastoralists on Cape York have been pivotal in restoring the balance, with the result that parrot numbers have nearly stabilised where there is intensive management. Indigenous land managers in the area are also starting to undertake more traditional fire management.

Golden-shouldered Parrot on termite mound. *Photo by Cliff and Dawn Frith*

Stephen Garnett and Gabriel Crowley

operate across all tenures. For these rainforest patches, conservation security is not achieved passively by inclusion within a conservation reserve. The impact of stock is not restricted only to pastoral lands. Weeds occur across all tenures. Patches close to development centres are being degraded, but so too are those remote from such development.

Beyond the limited areas of intensive modification and development, landscapes are changing across much of Northern Australia. The most noted of these changes is 'woody thickening', an increase in the density of shrubs and trees. This phenomenon has been reported widely but particularly so in pastoral areas (Lewis 2002; Fensham and Fairfax 2003;

1 The Brush-tailed Phascogale has declined greatly since European settlement. *Photo by Lochman Transparencies*

Banfai and Bowman 2005, 2006). There is considerable argument about its causes, with some evidence that it is related to decadal-scale climatic fluctuations, directional change in global climates and the composition of atmospheric gases, and/or to local factors related to pastoral practices (particularly reduction in fire frequency and/or intensity). The issue of woody thickening has attracted considerable comment. Many, particularly pastoralists, regard it as detrimental, largely because it reduces grass production and availability for livestock. Others see woody thickening as some balance for the extensive clearing undertaken particularly in central Queensland.

For biodiversity, woody thickening is a nuanced change: some species (or environments) will benefit and others will be disadvantaged (Tassicker *et al*. 2006). Grasslands and their associated species will be those most detrimentally affected. One such example is the Golden-shouldered Parrot, adversely affected by invasion of *Melaleuca* trees into grasslands on Cape York Peninsula (Crowley *et al*. 2004). There is also evidence of increase in the extent of rainforest patches in several regions of Northern Australia (Bowman *et al*. 2001; Russell-Smith *et al*. 2004a,b; Banfai and Bowman 2006).

Perhaps the most dynamic environment across the world is the interface between land and sea. Sea levels have changed dramatically in Northern Australia over the last 20,000 years and are likely to change substantially in the future. In many parts of Northern Australia, coastal areas are changing now. Saltwater has intruded further up river mouths, extending inland the reach of mangroves and altering the hydrological character of the highly productive coastal freshwater swamps and floodplains (Bayliss *et al*. 1998; Eliot *et al*. 1999). These habitats, important

1 Ord River Dam. *Photo by Stuart Blanch*

for biodiversity, may be particularly vulnerable to even small rises in sea level, because they are situated in such flat and near coastal landscapes.

Some northern landscapes have lost much of their functionality and productivity. In some areas, the early days of pastoralism were highly destructive: managers were unskilled, the limits and processes of the landscape unknown, and infrastructure lacking. One of the most extreme cases of the consequent degradation was in the catchment of the Ord River. From around the 1930s to 1960s, high stocking rates, and reliance on natural water sources for watering cattle, led to a complex mosaic of environmental changes (some immediate and others still being played out). The lush riparian vegetation (often including dense stands of cane grass) was trampled or grazed out, leading to major declines in associated wildlife (such as the Purple-crowned Fairy-wren: Smith and Johnstone 1977; Boekel 1979; Rowley 1993) and increased susceptibility of the riverbanks to collapse, and hence further habitat loss. More extensively, trampling and grazing led to loss of vegetation cover, and consequent massive erosion (and hence further loss of vegetation), especially on alluvial soils in 'frontage' country along rivers and on fertile plains of shale and volcanic-derived soils. The fertile layers of soil were lost. Rainfall became less effective as run-off increased and infiltration decreased. Small natural lakes, swamps and other water bodies – important resource-rich sites for biodiversity and Indigenous culture and hunting – were degraded or lost. 'Rangeland degradation became a self-perpetuating process' (Blandford 1979). The problem and its impacts

were largely untreated until it was discovered that a direct consequence of the over-grazing was rapid siltation of the newly-built Lake Argyle, from an estimated 24 million tonnes of sediment load being deposited each year, mostly from the eroded landscapes. Subsequently, the changed hydrological conditions led to further distant changes in the ecology and physical characteristics of the Ord estuary system. The damage is still being remedied, through an expensive and long-lasting program of cattle exclusion and revegetation. But, in part, even these remedies form part of a broader problem, for almost all rehabilitation has used invasive introduced plant species, further compounding the transformation of natural systems and the patterning and process of biodiversity.

The Ord may be an extreme case (although some other catchments are directly comparable), but echoes of the same degradation are being felt across the North. For example, there are few places on Earth wilder than the upper Liverpool River in Arnhem Land, and by most measures this is land that benchmarks pristine or best condition. Here, a population of about 20 Aboriginal landowners lead largely traditional lives in an estate of a few thousand square kilometres; there are few tracks and no towns. But, in the last few decades, feral cattle, pigs and, especially, water buffalo have reached this land, and have changed its landscapes. In the fertile valleys, the trees now have distinct browse-lines, *Hyptis* and other introduced weeds form dense thickets, the kangaroo hunting-grounds are now no longer so productive, the water is no longer clear and sweet, the springs are polluted and trampled, and important cultural sites and camping grounds degraded.

THE CAUSES OF CURRENT DECLINE

Fire

The significant role of fire as an ecological process was considered in Chapter 3. As previously noted, there is an inevitability of fire in this land, but the pattern of fire regimes can provide benefit or disadvantage to different species.

Over thousands of years, the traditional fire regime routinely imposed by Aboriginal land managers shaped the landscape and the composition of its flora and fauna. The ecological equilibrium that was sustained by those traditions is now unravelling. Some species

TOO SLOW TO MATURE: HEATHLAND PLANTS

Most of the lowlands of Northern Australia are dominated by eucalypt forests and woodlands, with smaller areas of paperbark *Melaleuca* forests and woodlands, isolated patches of monsoonal rainforests, and tussock grasslands on heavier (clay) soils.

But the vegetation in the sandstone dominated uplands (and some lowland coastal sandsheets and dunes) is distinctively different. Particularly where soils in these areas are absent, skeletal or very low in nutrients, there is a very different plant community, whose floristic associations lie more with the rich heathlands of temperate eastern and south-western Australia than with that of the broader northern landscapes in which they are nestled (Specht 1981). These heathlands include endemic species of plant groups typical of heathlands in temperate Australia, such as *Banksia, Calytrix, Boronia, Grevillea* and *Drosera*, and their ecology is paced largely to a temperate rhythm (Duretto 1997; Duretto and Ladiges 1997).

One characteristic feature of heathland plants is the high proportion of species that reproduce only from seed produced by mature plants. Unless there is a durable and long-lasting soil seed bank, for such species to persist at any location, they must have a fire-free interval at least longer than that taken for a plant to grow from seed to maturity. Many of these plants require four, five or more years to reach maturity, and hence seed-production.

The problem for the northern heathlands is that the current fire regime tends to be frequent and extensive, and now does not reliably allow them the sequences of 4+ years of fire-free intervals to persist (Russell-Smith *et al.* 1998, 2002; Russell-Smith 2006). At sites where the fires recur at shorter intervals than this, populations of these plants will be locally eliminated. Where these fires are extensive, there will be far broader elimination, and re-colonisation of the plants to previously burnt sites will be unlikely.

The rich heathlands of sandstone environments in Northern Australia are now losing many of these obligate re-seeder species at an increasing number and proportion of sites. The rate of decline for many of these species is such that many are now listed nationally as vulnerable or endangered; and the richest sandstone heathland community, that of western Arnhem Land, has now been nominated (under the national *Environment Protection and Biodiversity Conservation Act*) as a threatened ecological community, the first such case for Northern Australia. The pace of life for these species has suddenly changed, and they are now fading from a world to which they are no longer adapted.

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GHOSTS IN THE LANDSCAPE: CYPRESS-PINE

The Northern Cypress-pine is an unusual component of the Northern Australian landscape. It is a Gondwanan relict, heavily outnumbered in the wet-dry tropics by plant species with pantropical and savanna affinities. But, in the North, it is an important tree. In the early years of European settlement, it was a highly valued resource, because of its termite-resistant and durable timber. It has many traditional uses in Aboriginal culture, mostly related to its aromatic wood and foliage.

The Northern Cypress-pine is widely distributed across Northern Australia. But across much of this broad range it is declining. This decline can be measured because, unusually for plants, dead cypress-pine trees remain standing for relatively long periods (a decade or more) and are easily recognised. There are now many parts of Northern Australia where these standing ghosts are all that remains of cypress-pine populations, unaccompanied by any new generation to replace them (Bowman and Panton 1993; Prior *et al*. 2007). It is feasible that the decline of cypress-pine may be representative of that of a range of other plant species with similar ecologies, but that these expire with far less signal.

The cypress-pine's problem is fire. Traditionally, healthy cypress-pine populations provided a very public feature of clan estates in which fire was well-managed. Cypress-pines reproduce from seed, and don't become mature enough to set seed until they are at least a decade old. The seedlings and younger trees are extremely fire-sensitive, and need a relatively long fire-free interval to be able to reach maturity. Older trees are also fire-sensitive, easily killed by severe fires, although better able to withstand less intense fires. High intensity fires will kill trees of all ages; and repeated higher intensity fires will eliminate the species locally. Persistence in a regime of lower intensity fires will depend upon the frequency of fires (Price and Bowman 1994).

The ghosts show that the cypress-pine is disappearing from much of the North, with populations persisting mostly in the most fire-protected areas (mostly highly dissected sandstone), although even in these refuges they are generally in decline.

Against this broad-scale trend, there are parts of the North where cypress-pine is increasing. These are mostly on intensively-managed pastoral properties, where fuel loads are now greatly reduced and/or where managers practise fire exclusion. These marked disparities both suggest that the landscape elements are now being re-assembled to a different equilibrium from that sustained under thousands of years of traditional Aboriginal management.

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and environments will benefit from the new regimes; but others will be disadvantaged. In many pastoral lands, decreased fire frequency has contributed to 'vegetation thickening'. Consequently, natural grasslands, and the plants and animals dependent upon them, have declined, because of invasion by woody plants. Across other parts of the landscape, an increase in fire frequency and/or severity has whittled the vegetation, driving out 'fire-sensitive' species, such as the Northern Cypress-pine, and diminishing ecological communities, such as sandstone heathlands. Across the entire landscape, there is now a disparity between traditional and current fire regimes, and consequently the structure and composition of vegetation is changing, in some places subtly and slowly, in others rapidly and dramatically.

Foreign animals

Many non-native animals have been introduced, deliberately or inadvertently, to Northern Australia. Most introduced animals will have some impact on the plants or animals of the country to which they have been introduced. The significance of this impact will vary between species, according to their final population size, particular ecological traits, and the extent of their interactions with native species. In this section, we consider some of the foreign animals and the mischief they bring.

The dingo was probably the first of these introductions, by Aboriginal people, about 4000 years ago. Its impacts on native Australian wildlife were probably substantial, although – now long after the event – it is difficult to tease this effect apart from other environmental factors that may have been operating at the same time. The dingo's current role is somewhat ambiguous: although it may have some detrimental impacts on populations of native animals, there is also substantial evidence that dingoes may suppress populations of the more pernicious introduced predators, the fox and cat (Pople *et al*. 2000; Newsome *et al*. 2001; Johnson *et al*. 2006). Nonetheless, dingo baiting is still widespread on pastoral lands across Northern Australia.

Cattle are now amongst the most pervasive invasive animals in Northern Australia: indeed cattle are one of the most widespread and abundant of all vertebrates in Northern Australia. The total herd size in Northern Australia is about five million: they outnumber humans in this region by a factor of about 20 to 1. The

1 Overgrazing by cattle can cause significant landscape degradation. *Photo by Barry Traill*

management of about 75% of Northern Australia is now directed primarily towards improving habitat suitability for this single species, and feral cattle are present across much of the remainder of the landscape. Management activities to promote conditions for cattle include vegetation clearance, provision of artificial water sources, deliberate or consequential transformation of grass species composition (including the introduction of invasive grasses), and generally a reduction in fire frequency. Grazing itself may alter the understorey plant species composition and phenology, reduce fuel loads and hence change fire characteristics, decrease vegetative cover and hence increase run-off and proneness to erosion; and result in trampling of the tunnels and nests of ground-dwelling animals. These direct or indirect changes in environments may benefit some native plant and animal species but will also disadvantage others – perhaps many more.

Should it matter that there are some winners but also some losers? Unfortunately, it does matter – this is not simply some equitable re-balancing that emerges as a conservation neutral. There are typically more species that are disadvantaged than advantaged. Furthermore, the winners tend to be a small set of commensal species such as galahs and Crested Pigeons – those that like modified environments – and that tend to have very wide distributions. In some environments (such as Mitchell Grasslands) almost the entire landscape is devoted to pastoralism: in such cases, there is little room left for those native species that do not prosper under pastoral land management (Fisher 2001).

Water Buffalo were also introduced as livestock, including during one of the earliest European settlements of Northern Australia, at Port Essington in Cobourg Peninsula between 1838 and 1849. At the abandonment of that settlement, much of the stock was left behind. The feral Water Buffalo thrived and spread widely across the wetlands of the Top End. By the mid-twentieth century, they had become serious pests, with population exceeding 150,000 on the floodplains between Darwin and Oenpelli (Letts *et al.* 1979). In such large numbers, feral buffalo can, and did, change ecological processes dramatically. The floodplain environments were largely denuded; and their pathways and 'swim channels' were affecting hydrological patterning. In a landscape where centimetre-scale differences in topography may affect water retention and direction of flow over tens of square kilometres, feral buffalo proved to be potent ecological drivers. The natural barriers that regulated the bounds between saltwater and freshwater were broken down and saltwater intruded into some of the most important natural freshwater floodplain systems, leading to extensive death of salt-sensitive vegetation (Whitehead *et al.* 1990). Fortunately, the feral buffalo population was greatly reduced in a broad-scale eradication program

THE OTHER SIDE OF THE FENCE: IMPACTS OF PASTORALISM

Cattle occupy much of the savanna lands of Northern Australia. They have been around for more than a century, so long that it can now be a bit hard to imagine the landscape without them. In this nominally natural landscape, the total biomass of cattle far exceeds that of any native vertebrate species: the North has become a landscape designed for cattle. For such a pervasive factor, it is surprising that there has been relatively little assessment of their environmental impact. In part, this is because of that very pervasiveness: there are now few sites in Northern Australia that can serve as cattle-free benchmarks or contrasts. Most of the National Parks, including even the 'wildest' and seemingly most 'natural', such as Kakadu, are reclaimed pastoral properties. (Indeed, a buffalo farm continues to be operated within Kakadu National Park.) Even areas with no history as pastoral properties typically support feral cattle and/or water buffalo.

However there are a few sites in Northern Australia where it is possible to measure the impacts of pastoralism on biodiversity. One such study involved a cross-fence comparison of wildlife on grazed and ungrazed lands near Townsville (Woinarski and Ash 2002; Woinarski *et al.* 2002). In this case, the ungrazed land was managed as a military training area, from which cattle had been excluded for 32 years. In all other respects, the environments either side of the fence were well-matched.

This study found very marked differences in the fauna between the grazed and ungrazed sides. Most of the reptile, bird and mammal species recorded showed significant differences in abundance between grazed and ungrazed lands. Some were more common in grazed lands, but these were a minority: more species were more common in ungrazed lands. Those more common in grazed lands included many commensal species– those associated with human infrastructure and disturbance. Those more common in ungrazed lands included species that feed or shelter in dense grass. Comparable results were also found at this site for two invertebrate groups considered – ants and spiders. The abundance of half of the ant species considered varied significantly between grazed and ungrazed lands, and the total richness of ants was far less in grazed lands (43 species recorded in grazed sites compared with 64 in a similar number of ungrazed sites).

This study demonstrated that, at least at this site, grazing resulted in a very major upheaval of the native fauna, and that many species were disadvantaged by pastoralism. Given the extent of pastoralism across Northern Australia, these results suggest that this industry may be having, or have had, a very pronounced effect on the pattern of fauna communities across most of Northern Australia.

John Woinarski

TABLE 5.2 **ABUNDANCE OF SOME WILDLIFE SPECIES IN GRAZED & UNGRAZED LANDS**

Species	Abundance in grazed lands	Abundance in ungrazed lands
Eastern Grey Kangaroo	0.13	0.63
Eastern Chestnut Mouse	0.06	0.47
Common Bronzewing	0.19	1.10
Sulphur-Crested Cockatoo	0.63	0.06
Pheasant Coucal	0.06	0.35
Weebill	1.19	4.00
Rufous Whistler	2.19	1.32
Magpie-Lark	1.06	0.28
Willie Wagtail	1.38	0.13
Torresian Crow	4.81	0.28
Gecko *Gehyra dubia*	0.88	0.03
Two-Lined Dragon	0	0.35
Skink *Carlia munda*	0.19	1.16
Skink *Ctenotus eutaenius*	0	1.35

Abundance values are based on intensive survey of 24 plots in each land use type. In each case, all differences are highly statistically significant. Note that this table includes some species that respond favourably to pastoralism and others that respond negatively.

1 Feral horses cause significant problems through overgrazing in many parts of the North. *Photo by Charles Tambiah*

2 Overgrazing by feral donkeys has been a major problem in the Kimberley, until recent control efforts by the West Australian government. *Photo by Charles Tambiah*

in the late 1970s to mid-1980s, a serendipitous consequence of concerns amongst American importers about the disease status of Australian livestock (Skeat *et al*. 1996). Unfortunately, feral buffalo numbers have since increased again, especially so in more remote lands where there are few resources available for their control.

Feral pigs are now abundant and widespread in Northern Australia, especially favouring wetlands, riparian areas and rainforests, all environments associated with high conservation values. They are continuing to spread, largely unchecked: for example, in the 1990s they first colonised Arafura Swamp, one of Northern Australia's largest natural permanent wetlands, in central Arnhem Land; and in about 2000 they were (recklessly) introduced to Melville Island. Pig impacts are substantial: they have a very varied diet that includes small vertebrates, invertebrates, fruit, tubers and other plant products. They consume the eggs and young of ground-nesting birds, and marine turtles. They very efficiently dig up tuber-producing plants, including many yams that are also important components of traditional Aboriginal 'bush tucker', and they are recognised as the primary threat to several highly restricted threatened plant species. But the detrimental impact is not simply a conservation cost and problem: feral pigs have the potential to harbour many diseases, whose impacts upon the Northern Australian economy and human (and native wildlife) health may be very significant. And pigs are notoriously difficult to eradicate.

Feral horses and donkeys occur in many areas of Northern Australia. In part because of a perceived lack of significant impact and in part because of some residual goodwill (association with stockmen history), there has been some reluctance to address control of feral horses, even in some of the most important conservation reserves in Northern Australia (Robinson *et al*. 2005). The impacts of feral donkeys may be more substantial: they can occur at very high densities, have high reproductive output, and survive relatively well even in relatively dry seasons (during which their impacts on the sparse vegetation remaining may be profound).

Feral cats are now widespread and abundant across much of Northern Australia. Although there have been few studies of their status and impacts in Northern Australia, studies from elsewhere in Australia have demonstrated that cats can have major detrimental impacts on native wildlife, and in particular on small and medium-sized terrestrial mammals. Many such mammal species are now in decline in Northern Australia, and the feral cat is a principal suspect. The persistence of many native mammal species on islands but not in nearby mainland areas (Johnson and Kerle 1991; Abbott and Burbidge 1995; Southgate *et al*. 1996) provides

1 Cane Toads have now spread from Cape York Peninsula to the Eastern Kimberley. *Photo by Ian Morris*

2 Feral pigs are an enormous environmental problem in the higher rainfall areas of Northern Australia. *Photographer unknown, Wilderness Society photo library*

some evidence for the destructive impacts of feral cats in Northern Australia generally.

Parts of Northern Australia have been invaded by the introduced House Mouse and Black Rat. While most populations of these rodents remain associated with human infrastructure and more intensive development, some populations have established in less modified natural environments, including on some remote Northern Australian islands.

In contrast to temperate Australia, and to most other parts of the world, there are few foreign birds in Northern Australia, and even these are currently highly localised. However, in recent years the House Sparrow is spreading across more of the north, and there has been an increase in cases of foreign birds reaching Northern Australia on ships and other transport (e.g. Chapman 2000).

The cane toad is perhaps the most notorious invasive animal in Northern Australia. Its history is now well documented; and there is much public scrutiny of its continuing spread across Northern Australia. Many native predators, including some snakes, goannas and the Northern Quoll, fall victim to its toxin (Burnett 1997; Doody *et al*. 2006; Smith and Phillips 2006). However, it is not yet clear whether or not these species will gradually recover, and its less conspicuous impacts, on its invertebrate prey or native frog competitors, remain largely unknown. We are living in its unfolding story, as one of the world's most successful and adaptable creatures discovers a land particularly to its liking.

Less immediately obvious is the invasion of Northern Australia by a series of foreign invertebrates. For most people, an ant is an ant, and introduced ants are indistinguishable from natives. But Northern Australia is being invaded by a group of foreign 'supertramps', aggressive colonial species, that can wreak astonishing damage to native plant and animal communities (and to agricultural and other land uses). These ants include the Yellow Crazy Ant *Anoplolepis gracilipes*, which has invaded parts of eastern Arnhem Land, and the African Big-headed Ant *Pheidole megacephala*, which has invaded rainforest patches, urban and peri-urban areas at many sites in the Northern Territory (at least). Because of their aggressive nature and large population sizes, these invasive ants typically substantially reduce the diversity of native invertebrates, and may either directly or indirectly alter ecological processes, with detrimental impacts on native vertebrates, plants and ecosystem health (e.g. Hoffmann *et al*. 1999). A recent survey of the largely undeveloped Tiwi Islands revealed the presence of nine introduced ant species (Andersen *et al*. 2004; Hoffman *pers. comm*.). These invaders have slipped under our radar.

The European Honey Bee, *Apis mellifera*, has been deliberately introduced to many parts of Northern Australia, to provide honey and to increase the pollination rates in some horticultural crops. It has since spread widely, invading natural areas well away from its points of introduction. Like other introductions, its spread causes a rent in the fabric of the natural ecological systems. Much of the environmental cost of the introduction of honey bees is out of sight: their gradual but inexorable spread to natural areas, their usurpation of hollows (that otherwise would be used by a wide range of native vertebrates and native bees), and the competition they present to native species at nectar and pollen sources. Given wild honey produced by stingless native bees is an important bush tucker resource for Aboriginal people, this spread may have wide-ranging detrimental consequences, entirely unconsidered and discounted by

those that introduced, and approved the introduction of, this invasive species.

Marine and aquatic systems have also been invaded by foreign animals. Some river systems in Northern Australia now contain African and South American species, Nile Perch and Mosquito-fish respectively, and both are increasing in range. The South American Black-striped Mussel invaded Darwin harbour from a foreign ship in 1998, but a rapid response eliminated it. This species is a major threat to marine ecosystems, and the economic costs (to marine transport and fisheries) of any invasion would be in millions of dollars per year.

We've brought many other introduced species – cockroaches, fleas, worms, lice, and others – to Northern Australia, largely unnoticed. There is no tally of such species, and there has been no attempt to investigate the extent to which they may have spread to natural areas, and have had detrimental impacts upon biodiversity. Mostly, we remain blithely ignorant of their presence and detrimental potential, and largely uncaring. But we subvert this landscape not only through conspicuous major modifications, but also with the accumulation of almost imperceptible small changes, and especially so where these changes ripple out from their point of origin.

Disease

One more recognised example of the risks posed by the spread of invasive organisms is the recent substantial concern associated with the possibility of spread of bird flu to Australia, through migration of infected birds from Indonesia or elsewhere in Asia. While this spread is unlikely, it does provide an illustration of the potential major consequences, in this case to both wildlife and humans, of the spread of foreign diseases. It also reminds us that Northern Australia may well be the open frontier for such diseases. Some of these diseases, such as Japanese encephalitis, are likely to reach Australia 'naturally', without direct transport by humans. Others have come, or will come, as undesired and/or undetected baggage. It is likely that many of these newly introduced diseases will affect native plants and animals in Northern Australia. For example, dieback, probably caused by invasive *Phytopthera*, has recently been reported in some eucalypt stands in Northern Australia. In this case, detection is made easier by the highly conspicuous symptoms: but in most cases, we will remain

HABITAT LOSS & THE EMERGENCE OF INFECTIOUS DISEASES IN FLYING-FOXES

Over the past 12 years three new viruses have emerged from flying-foxes into domestic animals and humans in Australia: Hendra virus, Menangle virus and Australian bat lyssavirus. It is highly unusual for so many viruses to emerge from one host in such a short period of time and signifies a significant change in host ecology.

Taking a closer look at flying-foxes one may view the raucous large colonies in our urban centres and believe that their populations are robust or even increasing. This common misconception could not be further from the truth. In fact the presence of flying-foxes in urban areas is a symptom of problems that seriously threaten most flying-fox populations in Australia: habitat loss and fragmentation.

Flying-foxes move nomadically across the landscape tracking irregular flowering and fruiting events in our native forests. As forests are cleared and their native food supply dwindles, flying-foxes have begun to seek alternative food sources such as the native and exotic flowering and fruiting trees in urban areas. These regularly watered urban food resources are reliable and available year round, reducing the motivation for long-distance energy expensive foraging expeditions. Consequently, urban flying-fox camps are growing while more rural locations are being abandoned. This change in flying-fox ecology has major consequences for both ecosystem health and human health.

As flying-foxes move away from their natural habitat, they deprive our native forests of their essential pollination and seed dispersal services and come into closer association with human habitats, increasing the risk of emergence of rare viruses. Intact habitat is critical to maintain the ecology of flying-foxes, the health of the forests they pollinate and the health of humans and their domestic animals.

Raina Plowright

Little Red Flying-fox. *Photo by Raina Plowright*

(or have remained) largely unaware of the spread of diseases to native plants and animals.

Invasive plants

Native vegetation dominates almost all landscapes in Northern Australia; and the vast extent of the landscape appears natural. But there are conspicuous exceptions, and there is a gradually increasing proportion of the flora that is alien, and increasing abundance and distribution of many introduced plants. On current trends, much of the landscape will be transformed by invasive plants.

For most regions of Northern Australia, naturalised (that is, now wild-living) foreign plants comprise about 5% of the total flora. This is relatively low by Australian standards (where the overall proportion is about 12%), but still substantial. Invasive plants are diverse and widespread even in remote largely unmodified lands, and in National Parks: for example Kakadu contains about 100 species of alien plants in a total flora of about 1800 plant species (Cowie and Werner 1993; Brennan 1996).

There are widely acknowledged problems with some of these invasive plants. Those that are universally recognised as weeds include the floodplain shrub Mimosa *Mimosa pigra* (from tropical America), the floating aquatic weeds *Salvinia molesta* (from South America), cabomba *Cabomba caroliniana* (from tropical America) and water hyacinth *Eichhornia crassipes* (from tropical America); the invasive woody shrubs *Parkinsonia aculeata* (from central and South America), *Acacia nilotica* (from tropical Africa and Asia), rubber bush *Calotropis procera* (from Asia), chinee apple *Ziziphys mauritiana* (from tropical Africa and Asia), parthenium *Parthenium hysterophorous* (from tropical America) and hyptis *Hyptis suaveolens* (from Asia).

This smorgasbord of some of the world's most harmful weeds combines to degrade values of lands and waters for all land users, including for pastoralism, horticulture, recreational fishing and Indigenous use. Removed from their normal controlling influences, these species have prospered and spread through large areas of Northern Australia, in some cases completely dominating particular environments or localities (e.g. Cook *et al*. 1996). These species turn Australian environments into a medley of odd global elements, generally substantially less suitable for the native plants and animals of Northern Australia. But in part because of their disadvantage to all land users, these species are now the focus of a range of control and weed management actions, sometimes successful, sometimes forlorn, and usually expensive. For example, Kakadu National Park has employed a team of three to four staff full-time for at least the last two decades mostly to attempt to keep Mimosa out of the park, with an annual cost of about $500,000. While this has been largely successful to date, it does not solve the core problem: Mimosa is still largely unchecked outside the park, and will invade the park should the intensive exclusion management be halted.

In part because the plants considered above are conspicuous and in part because they bring problems to all land users, weed management has focused on those species. But these are just one element of the environmental weed problem of Northern Australia (Grice 2006; Martin *et al*. 2006). Probably more pernicious is the continuing spread, including ongoing deliberate planting, of introduced invasive pasture grasses (and other pasture plants) largely for perceived increase in pastoral productivity, but also in some cases for rehabilitation and erosion control. In a recent article, Cook and Dias (2006) charted the history of introduction of these (mostly African) plants to Australia, particularly in the north. They note that the spread of these plants was a calculated and deliberate strategy to transform the full extent of Northern Australia from landscapes of native vegetation to designed landscapes dominated by 'more productive' foreign plants that would form the foundation for a greatly increased cattle industry. They note that the number of foreign grass and legume species deliberately introduced to Australia was about twice the number of native species present in Australia, and represented about 20% of the total world's species of grasses and legumes.

This was environmental transformation planned at a massive scale, explicitly with little or no regard to environmental consequences or the values of land uses other than pastoralism. It was more subtle than working with bulldozers, but its environmental consequences have probably been far more pervasive. The itch to de-Australianise these landscapes came early, from some of the first pastoral enterprises, but peaked especially in the 1950s, when teams of agricultural scientists worked assiduously to import more and more rampant species.

The philosophy and practice continues today. There is an ongoing push for pastoral intensification, and the principal mechanism for this intensification is through the deliberate and authorised spread of foreign invasive grasses, including Buffel Grass, Gamba Grass and Para Grass. It is a peculiar thing, but most of the pasture plants introduced are found, often too late for effective remedial control, to be useless for pastoral purposes, and in many cases actually become pests even for pastoralism. There is a recurring theme in the history of pastoral introductions for plants to be proselytised enthusiastically, planted widely, nurtured and tended, found to be useless, become uncontrollable and then, usually 20–30 years later (typically when it is someone else's problem to deal with) become officially declared as weeds.

Gamba and Para Grass are moving towards the end-game of this process now, but it is an end point marked by almost irretrievable loss. Once these are established in the landscape they can't

1 Monitoring rangeland condition, Mornington Station, Kimberley (Jo Heathcote, Emma Flaxman). *Photo by John Augusteyn*

2 Gamba Grass, introduced pasture grass that is now a major weed in the Northern Territory. *Photo by Stuart Blanch*

1 Gubara, Kakadu National Park, Top End. *Photo by Glenn Walker*

2 Simon Ward and Graham Friday, a member of the Lianthawirriyarra Sea Ranger Unit, doing wildlife survey work on Sir Edward Pellew Islands, near Borroloola. *Photo by Felicity Chapman*

be easily whistled back. The very qualities that were sought in a foreign plant by the pastoral interests – good reproductive potential, ability to spread from point of introduction, hardiness, ability to out-compete native species, high production – are the very same qualities that make for weeds (Whitehead 1999). But, while there is still some hope that they may bring benefit to pastoralism, there has been an enduring reluctance to regulate or prohibit their use, or to officially recognise them as weeds.

The problem is not widely recognised because for most people a grassland or grassy understorey looks much the same whether dominated by invasive or native grasses. Furthermore, pastoralists and land managers may categorise a monoculture of invasive foreign grasses as a healthy landscape, a valuation based on a very narrow perspective or understanding of ecological function and process, and of what is meant by environmental sustainability.

What do these plants do that is wrong?

Firstly, they displace native plants. Plant species richness in landscapes dominated by invasive grasses is almost invariably lower than in landscapes without them (Fairfax and Fensham 2000). In some cases, the native plants displaced provide key resources for fauna, and so inexorably these animals will also become rarer or be lost from invasive grasslands. Invasive pasture grasses typically also produce more growth – for this is the key attribute for which they were selected. In most places (other than where there may be very high densities of cattle) this results in a substantially increased fuel load and grass cover. This strongly disadvantages the many native plants and animals that require some patchily open understories to germinate, grow or forage. It also means that fires will burn at greatly increased intensities, typically being more destructive, more extensive and less patchy. For Gamba Grass, fuel loads are typically four to five times that of native grasses, and fires eight times the intensity (Rossiter *et al*. 2003). Scientific simulation modelling has shown that over a period of a few decades, Gamba Grass infestation will transform a native savanna woodland to an African-style grassland, with wholesale elimination of trees. Fire-sensitive plants, animals and communities will be lost. Modelling has also indicated that all or most regions of Northern Australia have viable habitat for the current medley of invasive pasture plants; and indeed the current spread of many of these invasive pasture grasses is proving to be rapid.

The vision of the landscape engineers of the 1950s is not far over the horizon. But it may be a dystopic reality, as the alien grasses and their consequent fires become uncontrollable and result in increasing damage not only to environmental values but also to infrastructure, health (e.g. through increased incidence of asthma: Johnston *et al*. 2002) and public safety.

The invasive grasses do not respect tenure boundaries, and will increasingly spread from pastoral properties to lands managed primarily for biodiversity conservation. This will erode the functionality of those conservation areas, greatly increase their management costs, and further smear the landscape to a continuum of modified and degraded environments. A perverse outcome of the cross-boundary spread of invasive pasture grasses is that some National Park managers (and their pastoral neighbours) are now contemplating the need to agist cattle in conservation reserves in order to keep down the fuel load of unwanted invasive grasses.

DEPOPULATION AND LACK OF RESOURCES

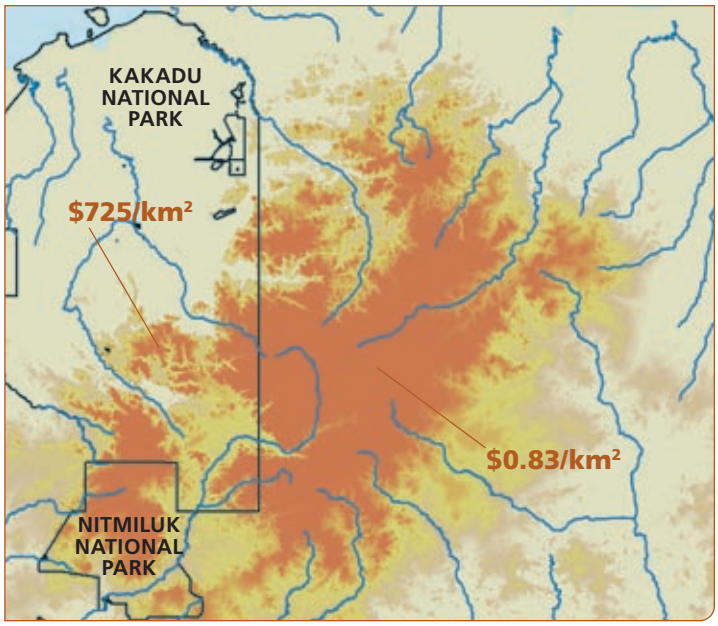
There was a time when conservationists idealised land devoid of humans and their artefacts as the ultimate standard for biodiversity protection. That vision does not work in Northern Australia. In Northern Australia, most of the remote wild lands are the estates and homelands of Indigenous people, and their ancestors have shaped and protected those landscapes for millennia. In Northern Australia, biodiversity is detrimentally affected by factors – inappropriate fire regimes and the spread of introduced plants and animals – that require active human intervention. A depopulated 'wilderness' may become barren (Bowman *et al*. 2001; Yibarbuk *et al*. 2001), the land losing its wildlife and its people their culture.

But having people in the landscape does not alone make for good management. Communities blighted by poverty, unemployment, poor health and poor education may see management for biodiversity as an unaffordable luxury, and look to their land not so much for its nurture but rather as a resource to be sold.

In many Indigenous lands, there are now few people living on country, and few resources available for land management. Some of the most expert land managers in Northern Australia look after their country full-time and unpaid, but even this expertise may be lacking when faced with novel threats and breakdown of land management in neighbouring estates. The Arnhem Land plateau provides a simple illustration of the issue (Figure 5.1). An artificial tenure boundary splits this plateau, with Kakadu National Park to the West and Arnhem Land Aboriginal land to the east. Kakadu is a relatively well-resourced National Park and annually spends about $\$725/km^2$ on land management (a figure about par with world standards: du Toit *et al*. 2003). But cross the line to the east, and the amount spent on land management is less than $\$1/km^2$, and the number of people living in the plateau landscape and available to do that management is fewer than one person per 100 km^2. That land has been largely depopulated and its threatening processes left mostly unchecked. The problem is not constrained: because most threatening

FIGURE 5.1 **FUNDS SPENT IN KAKADU NATIONAL PARK & ADJACENT ABORIGINAL LANDS**

Annual funding per square kilometre in adjacent land tenures in the Top End. The different land tenures have similar environmental values.



processes occur pervasively across tenures. Unmanaged lands then provide the ongoing genesis for feral animals, weeds or fires to spread back to more intensively-managed lands.

Limited resourcing is not an issue that affects Indigenous lands only. In Northern Australia, most National Parks have appreciably fewer management resources than Kakadu; and rising running costs and reduced profitability constrain the resources available on pastoral lands for land management activities other than those most focused on short-term pastoral productivity.

CLIMATE CHANGE

The environments of Northern Australia will be affected directly and indirectly by rapid global climate change. Indeed, some effects may already be evident. In north-western Australia, rainfall has increased substantially over the last 100 years, particularly in the last 30 or so years. In many regions, the density of trees has increased, woodlands have extended into grasslands, and rainforests into woodlands and open forests. This change is comparable to changes observed in savanna regions elsewhere in the world, and probably driven at least partly by increased levels of atmospheric carbon. In Northern Australia, there is increasing evidence of seawater intrusion to coastal floodplains and wetlands, and spread of mangroves further up coastal waterways (Eliot *et al*. 1999).

These direct environmental changes are likely to continue and perhaps accelerate over the next few decades. Most susceptible will be the internationally-significant wetlands, particularly the extremely fertile and biodiversity-rich floodplains, as even small rises in sea levels will have extensive impacts on this low-lying flat landscape. Although climate change predictions for Northern Australia are very imprecise, it is likely that the main features will be (i) minor rise in temperatures; (ii) increased rainfall; and (iii) increased incidence of severe storm events (most notably, cyclones). A possible significant environmental impact of these changes may be an increase in fire intensity, frequency and extent, if fuel levels increase following Wet seasons with high rainfalls. The changes in rainfall and temperatures may also differentially affect survival and habitat suitability for some native plant and animal species, perhaps especially crocodiles and some turtles, where sex determination in eggs is geared to a narrowly defined temperature trigger point. Climate change may also affect those species in Northern Australia with restricted geographic range and/or narrow climatic tolerances, such as those species occurring in mountain tops in north-eastern Australia. These projected climate changes may also increase the competitive advantage of some foreign species and the incidence of some infectious diseases, as these may be more attuned to the Northern Australian climate of the future.

However, in general, the direct impact of climate change on the environments of Northern Australia are likely to be subdued relative to those in other parts of the world, because (i) the projected climate changes are relatively minor; (ii) the environments remain highly connected and extensive (permitting some possibility of movements to track suitable climate); and (iii) there are no abrupt and pronounced climatic specialised features in Northern Australia (such as alpine areas) that elsewhere are most vulnerable to climate changes.

Instead, the impacts of climate change on the conservation values of Northern Australia are likely to be mediated more by indirect (extrinsic) factors. The future is likely to bring greater pressure on Northern Australia for production,

1 Above Gunlom Falls, Kakadu National Park, Top End. Adjacent Aboriginal Lands receive much less management resources. *Photo by Glenn Walker*

if the prime horticultural areas of temperate Australia, and perhaps even more importantly, much of south Asia, become increasingly unproductive in the future as a result of a critical decline in rainfall and water availability.

SOLACE

This is a chapter that views the glass half empty; that presents a series of examples of decline and degradation. We chronicle these cases not to downplay the natural values of Northern Australia, nor the current management of that land, but rather because we should recognise and heed the early warning signs, and not complacently think that the extent and relative naturalness of the landscape will be adequate protection for its biodiversity.

The natural values of Northern Australia are substantial. But their persistence cannot be taken for granted. Some important components of biodiversity are faring poorly under current management practices, policies and levels of resourcing. The following chapter offers some hope for better sustaining the North's natural values.

①