5 Limitless lands and limited knowledge:
coping with uncertainty and ignorance in northern Australia

John Woinarski and Freya Dawson

Introduction

After more than a century of European settlement, northern Australia remains a frontier land. Its strange landscapes and vastness have repeatedly attracted developers with grand vision. Typically these developers have ignored the constraints imposed by the environment, the visions have failed, and the remnants of forsaken development have been left to be reabsorbed by a resilient land. This chapter examines some of the reasons for this pattern, and notes characteristics which may be general to other frontier regions (e.g. Holmes 1992). This contribution builds on some major, but more sectoral, analyses of development attempts in northern Australia (most notably Davidson 1965; Lacey 1979; Bauer 1964, 1977; Mollah 1980).

Essentially, the argument developed links several features:

- The environment is poorly known and dissimilar to that from which its developers originated. This strangeness has contributed negatively to the attribution of value to that environment and its component parts.
- The environment is extensive and this scale engenders the perception that successful use of the lands can be achieved only by large-scale development.
- The environment is perceived to be so extensive and of so little value that little safeguard needs to be built into development proposals.
- Repeated development failure reinforces the perception that the land is of limited value, and hence few resources should be directed towards understanding it (or rehabilitating it after development failure).

- The environment is perceived to be so marginally productive that the only route to substantial profit is through intensive modification of the environment and large-scale development.
- The economic framework supporting the settlers is so tenuous that developers and their supporters (government) consider that development shouldn't be burdened by substantial imposed conservation regulations.

Despite (or perhaps ironically because of) the developers' approach, northern Australia continues to have vast areas of relatively unmodified landscapes. Gradually this is being recognized as an asset rather than an affront. This change in attitude stems from a range of factors including: increased power of Aboriginal landowners; ongoing uncertainty about land tenure; the rise of the tourist industry; the inclusion of the frontier lands within national environmental strategies; a larger and more stable settler population; and, belatedly, some learning from the mistakes of the recent past.

Geographic and environmental setting

Northern Australia as defined here (Figure 5.1) occupies about 1.5 million square kilometres of mainly open forest and savanna lands. In this chapter, we concentrate on one political component of this region, the 'Top End' of the Northern Territory (NT), as this is the area with which we are most familiar. The patterns apparent in the Northern Territory have been general across northern Australia, with the exception that environments of tropical Queensland have been subjected to more intensive modification.

Across this region, soils are almost universally low in nutrients (Davidson 1965; Christian 1977). The climate is characterized by a short wet season (November to March) alternating with a long period of little or no rain. This general pattern varies considerably from one year to another (Christian 1977; Taylor and Tulloch 1985). Frequent cyclones add a further dimension to the climatic capriciousness (Lourensz 1981).

Many of the environmental values of northern Australia are obvious and substantial, if largely taken for granted. Its vast landscapes retain the most extensive eucalypt forests in the world (Woinarski *et al.* 2000). Its savannas are less intensively modified and support a vastly smaller human population than all other tropical savannas. Its ecological processes remain relatively undisturbed and its wildlife remains relatively undiminished: for example, in contrast to the catastrophic fate of native

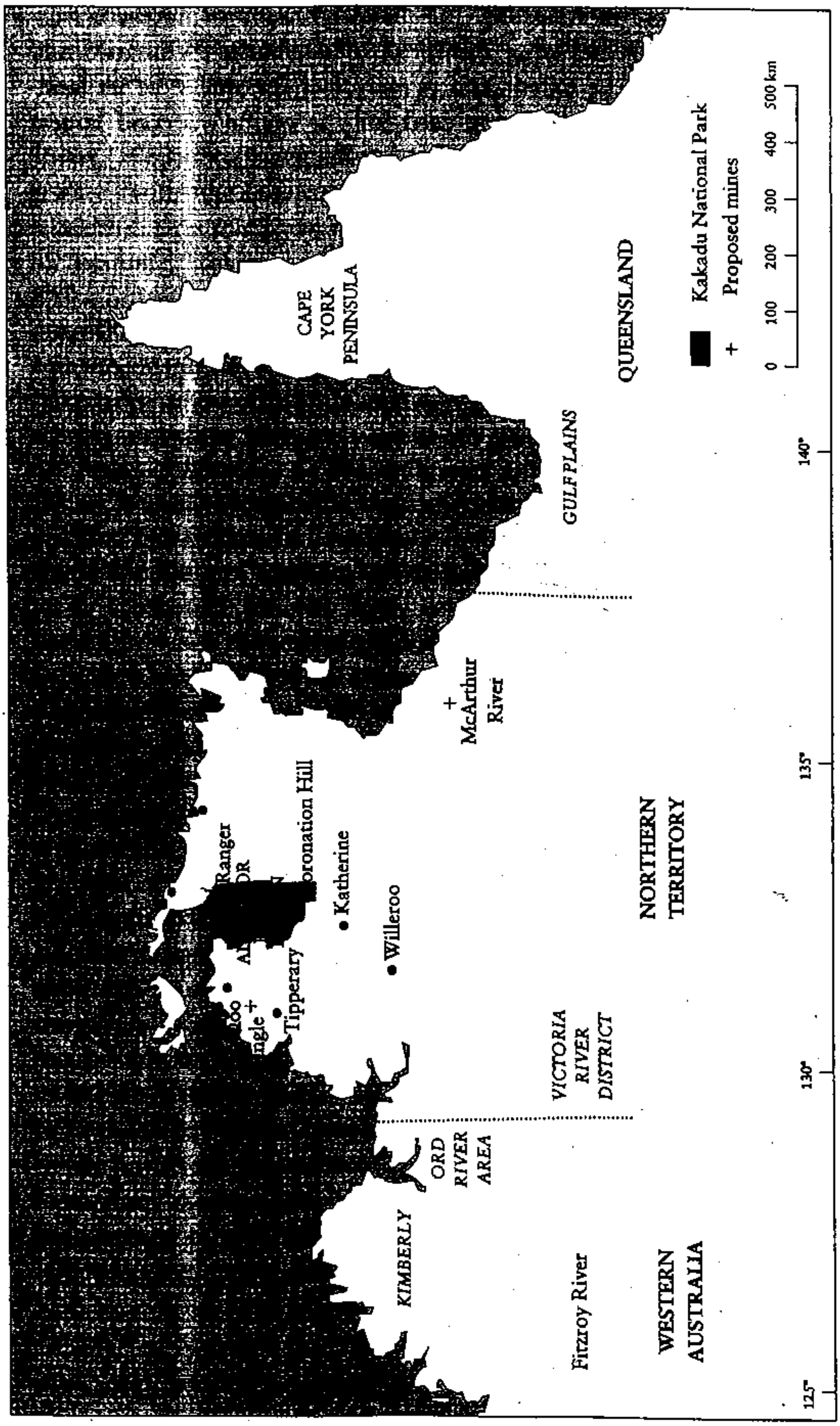

Figure 5.1 Northern Australia, showing place names referred to in text

mammals elsewhere in Australia, the mammal fauna of northern Australia has lost no species since European management (Woinarski and Braithwaite 1990). The extent and perceived 'naturalness' of its landscapes provide the main drawing card for the region's second largest industry, tourism.

Development philosophy

Aboriginal people entered Australia from the north at least 60 000 years ago. The extent of their modification of Australian environments remains hotly disputed (e.g. Flannery 1994; Bowman 1998). However, substantial environmental change following the removal of their land management in parts of northern Australia over the last 50 years (e.g. Price and Bowman 1994) suggests that they imposed considerable control on vegetation dynamics. Aboriginal people developed a complex and intimate relationship with the north Australian environment (e.g. Russell-Smith *et al.* 1997), with survival depending upon detailed knowledge of its components, and appreciation of their requirements.

European settlement of the area began in the 1820s, and consisted initially of small military outposts on the northern coastal rim, whose purpose was to protect the English colonial settlements of southern Australia from invasions from the north. Setting a recurring pattern, these 'forsaken settlements' (Spillett 1972) were typically underresourced and defeated by failures to appreciate their environment. Of the first three attempts at coastal settlement, Fort Dundas lasted five years before being abandoned due to hostility from local Aboriginal people; Fort Wellington lasted two years before being abandoned for logistic reasons, and Victoria Settlement was abandoned after 11 years due to high mortality, 'despondency', and general failure to find exploitable resources. The Aboriginal peoples' bountiful home became 'the White Man's frontier of adventure, isolation, difficulty and forbidding nature' (Jull 1991).

Penetration of the interior by pastoralists quickly followed accounts of explorers such as Leichhardt, Gregory and Stuart during the period 1844–1862. Many of these explorers, beguiled by the apparent luxuriance of grass at the end of the wet season and/or the demands to reward their financial backers with significant discoveries, falsely interpreted the potential of the northern Australian landscape. Thus,

> I have no hesitation in saying that the country I have discovered on and around the banks of the Adelaide River (near present-day Darwin) is

> more favourable than any other part of the continent . . . I feel confident that, in a few years, it will become one of the brightest gems in the British crown. (Stuart 1865)

Stuart (1863) also repeatedly noted that the landscape was 'beautifully grassed' with 'the country of excellent quality and great extent'. Even when their eyes told them otherwise, imagination got the better of them: for example, Stokes in 1846 called the Gulf Plains of Queensland 'the Plains of Promise', as

> . . . even in these deserted plains, equally wanting in the redundance of animal, as in the luxuriance of vegetable life, I could discover the rudiments of future prosperity, and ample justification of the name which I bestowed upon them . . . I could not refrain from breathing a prayer that ere long the now level horizon would be broken by a succession of tapering spires rising from the many Christian hamlets that must ultimately stud this country. (quoted in Bauer 1959)

Such overblown praise was generally greeted more warmly by sponsors than the assessments of the more perceptive Cassandras, such as Cadell, who described the previously recommended Victoria River District as 'a most wretched, rocky, barren, and waterless country . . . if the Elysian fields had been beyond it I should have felt it to have been a duty to report against its selection' (cited in Bauer 1964).

In the century since the hopeful vision of most of these early explorers, northern Australia has continued to be viewed as a land of promise, waiting for the right key to release its riches. This desire to use the land is linked to a broader national context. The development philosophy of northern Australia is still very much tied to the perceived need to protect the nation from invasion from the north, explicitly with the military as a major user of the northern environments (Barton and McDonald 1996) or implicitly with federal support of projects in northern Australia which can help populate the lands to the deterrence of invaders.

The more enthusiastic developers rail against constraints imposed by land tenure, concerned that lands retained as Aboriginal living space or as conservation areas ('locked up forever if possible, in Aboriginal lands with unique occupancy rights or in wilderness areas protected by United Nations conventions': Blainey 1992) thwart their promise of riches (Ewing 1996). The Northern Territory is often singled out as the place where most land has been 'quarantined' from major development because of the greater influence of the national government.

Who owns the land?

Land tenure is a significant factor for development and conservation. Its significance lies in the connection between property rights in land and the ownership and control over resources which are connected to or dependent on that land. Land tenure in the Northern Territory clearly reflects the history of European settlement. The tropical savannas of the north were one of the last frontiers of settlement for European pastoralists in Australia aided by the doctrine of *terra nullius* as a basis for the dispossession of Aboriginal people. Vast tracts of land were occupied under leasehold title, many of which remain under pastoral lease even though they are barely able to support one family (Holmes and Mott 1993). Despite the low productivity of these pastoral properties, at the time they were established the land they covered represented the resources of greatest value in the region. Pastoral leases still cover almost half of the Northern Territory.

Almost all of the Northern Territory not under pastoral lease is owned by Aboriginal people under the *Aboriginal Land Rights (Northern Territory) Act 1976* (Cth) (henceforth, the Land Rights Act). The tenure of Aboriginal land differs radically from the transferable title that is granted to non-Aboriginal pastoralists and holders of a 'normal' freehold. The main difference is that the tenure created by the Land Rights Act incorporates a partial recognition of Aboriginal custom and law (Neate 1989). The Aboriginal traditional owners of this land are entitled to occupy the land and use the biological resources on that land in accordance with Aboriginal tradition governing the particular group of people. The extent to which the general laws of the Northern Territory governing such things as wildlife conservation, fire management, planning and water resources can apply to Aboriginal land without interfering with these rights is a matter of considerable legal uncertainty (Dawson 1996). This creates two very different regimes of property rights in biological resources in the Northern Territory.

The land tenure regime in the Northern Territory is currently under pressure stemming from the recognition of native title under common law, by the High Court in *Mabo v. Queensland* (No. 2), and subsequently in legislation by the *Native Title Act 1993* (Cth). 'Native title' means the communal, group or individual rights and interests of Aboriginal people or Torres Strait Islanders to land or waters under their own laws and custom. It is not yet clear how much land or sea in the Northern Territory will be able to be claimed under the *Native Title Act*, or what the exact nature of this interest will be. The full impact of the

recognition of native title on the land tenure system in the Northern Territory is unlikely to be seen in the near future. The recognition of native title has been vigorously opposed by many sections of the pastoral and mining industries because they feel it creates uncertainty over land tenure and the access they might have to the land to pursue commercial development (e.g. Ewing 1992).

Land tenure in the Northern Territory creates a challenge for conservation measures which seek to deal with ecological processes across the whole landscape (Hughes 1995; Dawson 1996). Native title simply adds a further layer to an already complex situation. The mix of jurisdictions across northern Australia further complicates conservation planning. The relatively continuous and homogeneous environments of northern Australia are partitioned between two states and the Northern Territory, with different laws and strategies for land use and conservation planning. Within the Northern Territory, some conservation reserves are managed by a federal government agency and others by the Territory authority, with inconsistent and, at times, conflicting practice and objectives. As an example of the distortion of information and planning due to the political dissection of northern Australia, each of the states and the Northern Territory has their own vegetation mapping scheme, and these are mutually incompatible and stop at the state/territory borders. Such parochialism hampers conservation planning across the broad environments of northern Australia.

Case studies

We introduce some of the main development and conservation players and issues of northern Australia by way of a series of examples which provide the flavour of, and indicate the flaws in, the pervasive development philosophy and its attempts to deal with (or paper over) the environmental ignorance and uncertainty within settler society.

Case study 1: Forestry

The history of forestry in the Northern Territory provides an expensive but telling lesson in the costs of environmental ignorance (Lacey 1979) . The relatively limited supply of prime durable timbers, principally ironwood (*Erythrophleum chlorostachys*) and northern cypress-pine (*Callitris intratropica*), was rapidly depleted for railway sleepers and construction around Darwin within the first 40 years of settlement, and well before any substantial resource inventory or investigation

of recruitment and growth rates (Hanssen and Wigston 1989). Subsequent early investment in plantations of exotic timber species generally failed as most species proved susceptible to the termite *Mastotermes darwiniensis*.

The next major phase of forestry activity in the NT occurred from the late 1950s to the late 1970s, and involved a more concerted campaign of timber plantations (principally on Melville Island) and prospecting for major areas of native forest production. The philosophical change underlying this development was described by Hanssen and Wigston (1989):

> The preceding century of exploitative disregard for NT forest resources was displaced by a welcome enthusiasm but a disastrous optimism.

While there were sober assessments of the limited availability of timber (Bateman 1955), these were largely ignored by misplaced confidence in forestry technology. Lack of information on forest characteristics was belatedly recognized to be a problem, which was addressed in 1958 by the establishment of a forest research station, charged initially with establishment of plantations and investigation of tree growth. The research station grew into a government department with a clear vested interest in the maintenance and expansion of forestry. Their 'assessments of forestry resources and their potential to supply timber became progressively more hopeful as the demand for timber rose and the actual production of sawn timber progressively fell' (Lacey 1979), and 'any research findings that were counter to the spirit of the plantation program were suppressed or discouraged' (Cameron 1985). For both plantations and native forests, the projected growth rates, timber yields, projected economic returns and potential for pulpwood turned out to be wildly exaggerated, if not duplicitous (e.g. Higgins and Phillips 1973), at least partly due to facile extrapolation of data from temperate Australia. For example, estimates given to the Forwood Conference (1974) suggested an increase in future availability of forest product from an actual yield in 1971 of 3300 cubic metres to 58 000 cubic metres by 1980, a hopeful estimate raised in 1977 to 82 000 cubic metres. The eventual tally for 1980 was zero. Estimates given for yield in the Maningrida area were 13 cubic metres per hectare, whereas these proved to be only 0.6 cubic metres per hectare. Estimates of the surveyed area of high-quality forests on Melville Island were 20 per cent greater than the total land area of that island (Anon. 1978).

Contemporary but less ambitious timber harvesting projects, such as the establishment of sawmills at Murganella and Maningrida, also quickly foundered, due to inaccurate assessments of the resource and/or conflict over ownership of the land and its products. The more than AUD30 million outlaid (Lacey 1979) for negligible returns led to a federal government inquiry in 1978, which effectively closed down the NT Forestry Program.

This inquiry concluded that the plantation and native forests programmes had failed largely because of inadequate research: 'fundamental data on the type, volumes and accessibility of native timber stands which should have been the

starting point for an exploitation program was not available in any meaningful form' (House of Representatives Committee on Expenditure 1978), and that at least ten years of detailed research on such topics was required before addressing the feasibility of any future timber industry in northern Australia.

Just over ten years after this inquiry, and flying in the face of its main recommendation, a major new export-oriented forestry operation was announced for the NT, based on lancewood (*Acacia shirleyi*) and, less importantly, gutta-percha (*Excoecaria parvifolia*). That this major development came out of left field is indicated by a complete lack of mention of it in a major outlook paper for forestry and forest research in the NT published four years before its commencement (Cameron 1985). The sorry history of this project is described in the Forest and Timber Inquiry of the Australian Resource Assessment Commission (RAC 1992) and submissions to that inquiry. An initial licence was granted in 1989 by the NT government to harvest 360 000 tonnes of these timbers over a five-year period, mostly from pastoral leases. At the time of licence issue there were no estimates of timber volume nor of growth rates for these species, nor was there any information on the wildlife values of lancewood-dominated vegetation (Bowman 1991). Following the issue of licences to cut, the federal government granted export licences on condition that:

- a report should be prepared on the conservation status of lancewood and gutta-percha;
- an agreement should be reached with the company to ensure the sustainable utilization of the two species;
- programmes should be introduced to monitor and report on the operations; and
- pre-logging surveys should identify significant cultural, biological and geological data.

Research into the conservation values of this environment and sustainability of the industry were to be supported by service fees and royalties paid by the company to the NT government.

Within two years of commencing logging, the company reduced their projected cut from 72 000 tonnes per year to 3000 tonnes per year. No pre-logging biological surveys were conducted and there was no reporting on the conservation status of lancewood or the associated bullwaddy (*Macropteranthes kekwickii*) communities. By the following year, the operation had been abandoned, with licences rescinded by the NT government, a total of only 200 tonnes cut over the life of the industry, complaints of large areas of cut and left logs, and failure of the industry to pay any service charges.

Failure of the industry was due partly to unrealized market projections, but, more importantly, to completely unrealistic estimates of timber availability and quality. The first detailed estimates of wood volume were produced only after the folding of the industry, and indicated that the total amount of lancewood (pole and sawlog equivalent) across the entire Northern Territory was only 5.2

million tonnes, of which most was unsuitable for logging due to inappropriate growth form or defects (NFI 1993). The government's role in this doomed industry was not atypical – enterprises were to be facilitated, rather than be hampered by any need to ground assessment of their viability, sustainability or impact in relevant information. The first examination of the wildlife of lancewood communities (Woinarski and Fisher 1995a,b) did not appear until well after the closure of the industry. There is still no lancewood within conservation reserves in the Northern Territory.

Case study 2: Agriculture

It is in agricultural ventures that northern development has had its mosr spectacular failures. The causes and economic costs of these debacles have been widely reviewed (notably by Davidson 1965; Bauer 1977; Mollah 1980; MacKenzie 1980). Davidson (1965) argued that large-scale agricultural developments in northern Australia were almost inevitably doomed by the small population base and (hence) distance from markets and large transportation costs, compounded by poor soils and erratic climate. Ignorance about the environment and the absence of risk assessment were also major contributors to failure. While the environments of a relatively benign temperate Australia were strange and initially an impediment to the transfer of the agricultural customs of European settlers, those of tropical Australia were doubly so, and proved completely unsuitable for most of their traditional stock and produce.

Agricultural failures became a regular feature soon after the first settlement of Darwin in 1869. Large-scale projects began and failed between 1875 and 1884 (sugar cane around Darwin), and continued intermittently in northern Australia (e.g. cotton plantations at Derby in the 1920s). However, such ventures grew grander in scale after the Second World War, when the threat of invasion from the north encouraged a strong development push (with enthusiastic support or compliance from the federal government). Beginning in 1955, massive American capital was injected into rice production at Humpty Doo, a site considered by the local government agricultural agency 'a more suitable track (sic) of land (than) anywhere in the world for mechanised rice growing' (Curteis 1961). This scheme aimed to produce 400 000 tonnes of rice annually from 200 000 hectares of intensive cultivation. In the eigbt years before it was abandoned, it produced a total of only 3000 tonnes. Although consumption and trampling of crops by magpie geese (*Anseranas semipalmata*) was blamed for the failure, the real cause was inadequate knowledge of environmental constraints, most notably the availability of water (Fisher *et al.* 1977). One benefit of the scheme was the establishment of a government-sponsored research station focusing mainly on agronomy, but also examining the ecology of floodplain environments. The latter included detailed studies of the native potential 'pest' species, magpie goose and dusky rat (*Rattus colletti*) (e.g. Frith and Davies 1961; Redhead 1979). These remain some of the few detailed animal autecological studies in northern Australia.

Detailed knowledge about the environment was belatedly recognized to be a prerequisite for the successful establishment of major agricultural developments (e.g. Forster *et al.* 1960). To this end, a government agency, the North Australian Development Committee, directed a major series of land capability studies describing soils, vegetation and agricultural potential (CSIRO 1952, 1965, 1969, 1970, 1976; Christian and Stewart 1953; Perry 1960). Notwithstanding such information about land capability (CSIRO 1965), and substantial relevant agronomic research (Basinski *et al.* 1985), the next major development scheme, grain sorghum production at Tipperary, was another disaster. With an investment of more than AUD20 million (much of it American capital), this scheme was established in 1967 and predicted annual production of 300 000 tonnes of grain sorghum from almost 10 000 square kilometres. To facilitate the scheme and its projected township of 15 000 people, the NT Legislative Council made substantial changes in leasehold conditions to allow broad-scale land clearance (Mollah 1980). By the abandonment of the scheme in 1973, only 16 000 tonnes of sorghum had been harvested (and almost all of this was below export standard): but at least 10 000 hectares of forests had been destroyed. Tipperary failed partly because it was directed from so far away, partly because its planners had neglected to consider the unpredictability of climate, partly because too few of the techniques and crop strains had been adequately trialled on a small scale, but largely because of a misplaced confidence in technology: 'There is no comparable region in Australia where the white man has so consistently overestimated the power of his technology in the field of primary industry to draw forth bounty from the land' (Lacey 1979).

Despite this obvious failure, but spurred on by the land clearance incentives offered in the Tipperary legislative amendments, a similar scheme commenced at the 6 000 square kilometres of Willeroo in 1971. This venture proposed to clear 120 000 hectares within five years for crop sorghum and high-quality beef (Fisher *et al.* 1977). Unlike the Tipperary scheme, no detailed land capability surveys preceded decisions about clearing and cropping, although land resource survey scientists apparently accompanied or followed the bulldozers (Bauer 1977). The venture was abandoned within four years. Of about 50 000 hectares cleared, only 16 000 hectares was used for cultivation. Failure was due to 'a fundamental lack of understanding of the limitations of soils and climate' and 'the Company grossly overestimated the savings of large-scale operations' (Fisher *et al.* 1977).

At least recognizing the limitations of soil nutrients across much of the north Australian landscape and the problem of inadequate knowledge, the next major venture picked an area with more fertile (though still nutrient-deficient) soils and preceded large development with research and pilot farms. However, this next development was linked to the fancy that irrigation was the key to unlocking the resources of northern Australia. Haigh (1963), for example, championed this vision, claiming that northern Australia had 3.2 million hectares of potentially irrigable lands (of which only 5 per cent was developed), compared to half that amount in southern Australia (of which 90 per cent was developed), and the

north had 27 billion cubic metres of 'uncommitted water potentially available for irrigation'. Such beguiling figures readily convinced politicians keen to establish monuments. The Ord River Irrigation Area Scheme was established in 1963, primarily to produce cotton on irrigated blacksoil plains in the north of Western Australia. Within ten years the cotton venture collapsed, despite public expenditure of almost AUD100 million (1978 value: Anon 1978). It failed partly due to higher transport and infrastructure costs relative to other cotton-producing areas, inappropriate cultivars, and inability to control insect pests (Fisher *et al.* 1977; Anon 1978; Graham-Taylor 1978). The detailed agronomic research had helped indicate what crops had highest potential and suggested that insect pests would be a problem in extensive crops (CSIRO 1978), bur its caveats were ignored and it had not provided solutions which were economical for the scale of development which followed. As with research associated with the Humpty Doo rice venture, some of the studies associated with the Ord provided major contributions to our understanding of the ecology of northern Australia, including some detailed autecological studies of vertebrate species (e.g. Beeton 1977); although these studies were always coloured by the framework of 'pest' designation.

The development of these agricultural ventures has been characterized by disregard for environmental consequences, with the occasional exception of some concern for land erosion. There were no assessments of the conservation values of the areas developed. With minor exceptions (e.g. rbe Ord scheme left five chains from each side of the river: Graham-Taylor 1978), no natural areas were reserved from development to maintain representative undisturbed habitat. Typically, there was no monitoring of the ongoing impacts of the agricultural activities. For example, after 15 years of the Ord scheme, the Government Review Committee rather lamely noted that

> Generally speaking, the Review Committee concludes that known environmental effects of the development of the ORIA to date do not appear to be very significant. However, in the absence of adequate data few detailed conclusions can be drawn. (Anon. 1978)

Twenty years further on, there are still no adequate data to assess the environmental impacts of this scheme.

The agricultural developments have typically lacked risk assessment, despite the now well-recognized climatic vagaries and the repeatedly catastrophic impacts of lack of rain or too much rain during critical phases of crop production. Regard to resource conflicts and environmental sustainability has generally not been part of the development planning either. Whitehead (1991) noted that the development of extensive tropical fruit orchards near the Top End floodplains would inevitably lead to crop damage by magpie geese and other vertebrates (reviewed in Lim *et al.* 1993), and that such likely lost production (or the expenses associated with preventative measures) should be included at initial planning and project justification. Belatedly, planning for agriculture within such an environmental

framework is now being undertaken, at least in some cases (e.g. Whitehead *et al.* 1990; Anon. 1995).

Subsequent to the failure of cotton, the Ord scheme has persisted on a generally less ambitious scale and with more diversified cropping. However, over the last five years, grand plans have resurfaced to develop the lower Ord for intensive sugar plantations (Sinclair Knight Merz 1996). Tipperary development returned in the late 1980s, repeating the grand vision and accompanied by even more extensive forest destruction. Horticultural production has increased in the Darwin-Katherine area, and a major intensive farming scheme for the Douglas-Daly catchment is again proposed.

Case study 3: Pastoralism

Pastoralism is the dominant industry across northern Australia, monopolizing land use in almost all environments. It has succeeded, or persisted, where agriculture has failed, largely because its establishment and operational costs are generally low.

Pastoral intrusion into northern Australia quickly followed the generally enthusiastic, if less than perceptive, reports of the first European explorers (Bauer 1959, 1964). Favourable reports led, in 1858, to a land grab of what is now the Northern Territory by the colony of South Australia, which then promptly sold over 200 000 hectares to pastoral investors sight unseen; in many cases, the actual location of the lots was unknown (MacKenzie 1980). This action set the tone of distant management which still characterizes much of the pastoral industry. Fiascos followed this first land trade, with problems in survey and unsuitability of lands leading to the first years of South Australian governance being described as 'a decade of ineptitude' by MacKenzie (1980). Despite administrative bungling, north and west Queensland were 'opened up' in the 1860s; and by the 1880s, cattle and sheep had reached the Victoria River District and the Kimberley (Bauer 1984). In many areas it was clear that the promises painted by the explorers would not be readily realized. Bauer (1984) reported the surveyor McKinlay's description of his livestock's first experience of the wet season: '. . . stock did not fatten, even when standing in grass higher than they; several horses died of plant poisoning and most of the others lost their hair from the continual drenching. The sheep did even more poorly . . .'

Notwithstanding such reports (and the very limited experience of pastoralism in the region), by 1881 the 'fantastic rush for pastoral land' (Bauer 1984) resulted in pastoral leases granted for over 95 per cent of the Northern Territory (despite the fact that most of the area had never experienced cattle nor Europeans). Speaking of the Gulf Plains area, but apposite generally, Bauer (1959) noted that 'there seems to have been what amounts to a refusal on the part of many settlers to recognise that (the lands) had definite limitations'.

In some areas, the livestock and pastoralists prospered. However, in many parts, the more attractive and less resilient plants declined and unsustainable

stocking pressure quickly produced soil erosion, degradation of water bodies, and vegetation change. Even proponents of the pastoral industry began talking about 'abuse of our rich pastoral areas' (Wise (1929), cited in Riddett (1990)). After little more than 50 years of pastoral use, Medcalf (1944) reported that 10 per cent of the area he surveyed in the Ord valley was affected by erosion to varying degrees, with the formation of deeply eroded gullies, and progressive deterioration proceeding rapidly in many other areas. By 1976, over 30 per cent of the Fitzroy River catchment was degraded to poor or very poor condition (Payne *et al.* 1978). Such degradation was not seriously addressed until its impact was felt on other land uses. When overgrazing led to an annual deposition of 24 million tonnes of sediment into the Ord River, the well-founded concerns about effects on the irrigation scheme on the lower Ord, and the massive capital investment spent on dams (Winter 1990) forced reduction in stocking rates and stock removal. However, much of the damage has persisted, and there is little knowledge about recovery from degradation (Foran *et al.* 1985). The impacts of pastoralism upon biodiversity have not been examined systematically or in any detail. For many environments, there has been substantial, and possibly irreversible, change in vegetation composition due to grazing or trampling by livestock and/or feral stock (Stocker 1970; Winter 1990). The impact upon wildlife of pastoral hegemony in northern Australia is almost unknown, but it has clearly contributed to the decline and local extinction of riparian birds in East Kimberley (Smith and Johnstone 1977; Woinarski 1993) and in Queensland (Barnard 1925). Increased grazing pressure has been shown to be associated with decreased abundance of granivorous birds in the Victoria River District (Tidemann 1990). Medium-sized mammals have also declined precipitously in most areas subjected to extensive grazing (Kitchener 1978; McKenzie 1981).

The environmental impacts of pastoralism are magnified when pastoral managers transform the land to increase its suitability (at least over the short term) for stock. In northern Australia, such 'improvements' have been eagerly sought, and have included removal of trees, modification of the fire regime, alteration of water supply and, particularly, introduction of exotic plants. While there has been a very large investment in research aimed at such pastoral 'improvements' (e.g. Eyles *et al.* 1985), little of this research has considered the environmental costs of such transformation (though there are a few notable recent exceptions: Gillard *et al.* 1989; Glanznig 1995; Scanlan and Turner 1995). Lonsdale (1994) illustrated the problem with such an unbalanced research agenda. He found that, of nearly 500 plant species introduced for pasture improvement in northern Australia, only 21 were eventually listed as useful, whereas 60 became listed as weeds (incidentally including all but four of the 'useful' species). Many of the plants introduced to improve pasture are now major threats to conservation (and other) values and will cost millions of dollars to control (Whitehead and Dawson 2000).

While some environments in northern Australia clearly support economically sustainable pastoralism (and the economic viability of many holdings has been

substantially improved by the recent burgeoning live cattle export trade: Stewart 1996), much of the land remains marginal or submarginal (e.g. Holmes 1990). Governments have shown a marked reluctance to remove pastoralism from such areas (Anon. 1991), presumably because the retention of nonviable pastoralism is sufficient to stake a claim to the area rather than to leave a land use vacuum, which may provide an opportunity for Aboriginal people to reclaim part of their lost estate.

Case study 4: Mining

The mining industry in northern Australia provides clear examples of the difficulties associated with decision making in the context of environmental uncertainty and ignorance and the added challenge of strongly conflicting cultural values.

The impact of the Rum Jungle uranium mine should provide a clear lesson of the dangers of ignoring environmental considerations. The Rum Jungle mine, 80 km south of Darwin, was Australia's first major uranium mine. Development and operation of the project was carried out by a subsidiary of Consolidated Zinc Pty Ltd (now known as C.R.A. Pty Ltd.) as an agent for the Commonwealth government. Mining operations began in 1953 and finished in 1971.

Towards the end of the life of the mine the Australian Atomic Energy Commission undertook a series of studies aimed at identifying the extent and degree of environmental damage (Davy 1975). This review found the overburden heaps at the mine were oxidizing and producing acid mine drainage containing heavy metals, sulphates and acid. Pollution was entering the East Finniss River, ground water and surrounding ground. The open cut pits had filled with water, which had become polluted with heavy metals and acid to the extent that one of the pits had a pH of approximately 2.4. The tailings dam was acidic, contaminated with heavy metals and was also a low-level source of radiation. By 1974, 150 000 tonnes of these tailings had been eroded from the tailings dam and had entered the river system. Estimates of the time for the environment to recover naturally from the effects ranged from 100 to 1000 years (NT Department of Mines and Energy 1986).

The Commonwealth government eventually agreed to fund a rehabilitation project to reduce the environmental effects of the mine. The project cost AUD16.2 million in 1982 values. The long-term effects on the flora and fauna of the Finniss River and its radiological safety are not fully known (NT Department of Mines and Energy 1986).

Since the operation of the Rum Jungle mine, much has changed in terms of the attitudes, expectations and requirements of society with respect to environmental issues. By 1974, much had also changed in terms of the development of environmental law. Arguably, the most significant of these changes in relation to the mining industry was the enactment of the *Environment Protection (Impact of Proposals) Act 1974* (Cth). The Administrative Procedures under this Act deal in detail with the requirements for the environmental assessment of projects likely to have a significant effect on the environment.

In July 1975 the Commonwealth directed that an inquiry should be conducted pursuant to the *Environment Protection (Impact of Proposals) Act 1974* (Cth) in relation to a proposal for the development of uranium deposits in the Alligator Rivers Region of the Northern Territory by the Australian Atomic Energy Commission in association with Ranger Uranium Mines Pty Ltd. Many submissions were received, most of which opposed the project proposal. The Commissioners made an extensive inquiry into the natural features of the Alligator Rivers Region and the potential environmental impact of the Ranger proposal. Their findings are set out in the *Ranger Uranium Environmental Inquiry Second Report* (known as the Second Fox Report) (Fox *et al.* 1977). No reference is made in the Fox Report to the Rum Jungle mine and the associated environmental disaster.

What emerges from the Second Fox Report is an approach to dealing with uncertainty and ignorance that has become typical for mining projects in the region in the era of environmental assessment. The report accepts the contention of a number of biologists that the then existing information was not sufficient to enable the ecological effects of mining to be predicted, especially the long-term effects on aquatic ecosystems. This was not viewed as a sufficient reason to recommend that the project should not proceed, or that it should be delayed until more information is collected. Instead, the report recommends that the best practicable technology should be used and that standards for contaminant releases should be strictly defined (Fox *et al.* 1977). Since these standards are being defined against unknown baseline data they must, in fact, be determined arbitrarily.

The federal government decided to allow the development of the Ranger Uranium mine. To ensure that something was being done to reduce the ignorance and uncertainty surrounding the environmental impact of the mine they established the Office of the Supervising Scientist (now known as the Environmental Research Institute of the Supervising Scientist) for the Alligator Rivers Region to coordinate research and monitoring operations and generally to supervise the performance of the mining company in the environmental field. The Supervising Scientist does not have any powers of enforcement if the environmental requirements established for the project are not complied with (Fry 1980). The impact of the Ranger mine on the wetlands downstream of the mine has been the subject of fierce debate. Releases of contaminated water from the mine have caused considerable distress to Aboriginal traditional owners, uncertain of the effects these releases may have on the aquatic life which forms a large component of their traditional food supply. The traditional owners were unsuccessful in their attempts to challenge these releases in court in the case *Northern Land Council, Big Bill Neidjie and Ors v. Energy Resources of Australia Ltd and the Minister for Mines and Energy* (Supreme Court of the Northern Territory of Australia, Martin CJ, 24 March 1995).

The timing of the Fox Report was significant in that it coincided with the passage of the *Aboriginal Land Rights (Northern Territory) Act 1976* (Cth) (the Land Rights Act). The Fox Report also made recommendations in relation to a land claim made by the traditional owners of the Alligator Rivers Region (Fox *et al.* 1977). Ultimately, the recognition of traditional ownership of most of the

Alligator Rivers Region has had a significant impact on its development. This is particularly so in relation to Kakadu National Park which now surrounds the Ranger mine, and which is jointly managed by the traditional owners and the Australian Nature Conservation Agency (Press *et al.* 1995).

One of the effects of the legislative recognition of the traditional Aboriginal relationship with the land has been to highlight the great differences between the cultural values of Aboriginal and non-Aboriginal people in Australia. White Australians generally have a poor understanding of Aboriginal culture, and yet the impact that mining may have on the exercise of Aboriginal tradition, including spiritual matters, must now be considered in relation to many development proposals in Northern Australia. This change has been perceived by the mining industry to add a further element of uncertainty to that already created by environmental impact assessment.

The combined effect of concern over environmental impact and opposition from Aboriginal people to disturbance of their land by mining was seen most acutely in relation to the Coronation Hill Joint Venture project. This project proposed to mine gold and palladium in a window within Kakadu National Park known as the Conservation Zone. The normal process of environmental assessment under the *Environment Protection (Impact of Proposals) Act 1974* (Cth) was completed and yet the information so obtained was seen as inadequate to provide a basis for decision making. In particular, scientific research conducted by CSIRO was almost completely at odds with the draft environmental impact statement produced by consultants Dames and Moore for the joint venture partners (Toyne 1994). A land claim had also been made under the Land Rights Act and the area registered as a sacred site under the *Aboriginal Sacred Sites Act 1978* (NT). The elders of the Jawoyn people (the traditional owners) opposed the Coronation Hill project.

The response of the Commonwealth government to this difficult situation was to order an inquiry under the *Resource Assessment Commission Act 1989* (Cth). The Resource Assessment Commission was a primarily research-oriented body, collecting and analysing information in order to make recommendations about resource development issues. The inquiry ran for just over one year, received 199 written submissions and held numerous public hearings. Although the inquiry acknowledged the outstanding conservation value of the region and the fact that environmental risk could not be eliminated, it concluded that a single mine, properly managed and monitored, would have a small and geographically limited impact on the known biological resources of the Conservation Zone (RAC 1991). The finding of the inquiry which most influenced the ultimate decision makers was the conclusion that mining would adversely affect the ability of the Jawoyn people to sustain cultural and religious values, beliefs and practices that are important to them. In June 1991 Federal Cabinet decided that the mine should not proceed. The Conservation Zone was then included in Kakadu National Park.

The Coronation Hill case shows an attempt by the federal government to come to terms with the full range of issues relevant to sustainable development in a systematic way in relation to a particular mining project. However, there

has been a considerable backlash against the decision. The range of matters dealt with in the inquiry served to highlight the deficiencies of the regular environmental assessment process, and yet this process was subsequently weakened by the announcement in 1992 by the Prime Minister that development projects of AUD50 million or more would be 'fast-tracked' through the approvals process (Toyne 1994).

The impact of this policy decision fell first on the Northern Territory where it was applied to the McArthur River mine on the Gulf of Carpentaria and the Mt Todd mine near Katherine. The result of 'fast-tracking' was that the environmental assessment process was carried out to a timetable designed to meet the convenience of the mining company, and only the absolute minimum requirements of the Commonwealth and Northern Territory environmental assessment legislation (Dawson 1993). In the case of McArthur River, Aboriginal traditional owners in the area objected to the fast-tracking process and the negotiating techniques of the mining company (Land Rights News 1993). The environmental impact statement frankly admitted that the baseline environmental data were inadequate and that further studies were necessary to properly assess the impact of the project and yet this had no bearing on the hasty decision to allow the project to proceed. The weight of the environmental controls applied to the McArthur River mine are encompassed in an environment management plan (EMP), thereby shifting the responsibility of dealing with the uncertainty and ignorance associated with any environmental impact to the Northern Territory government as part of the overall regulation of the mine.

The Mt Todd mine was another notable case where assessment of the impacts of the mine was substantially clouded by uncertainty over the conservation values of the proposed mine site. The mineral deposit was located within or adjacent to a major breeding colony of the Northern Territory's only endangered bird species, the Gouldian finch (*Erythrura gouldiae*). The information on which the assessment of the mine's impact was based was insufficient to clarify the bounds of the breeding colony relative to the mine site, the number of breeding birds likely to be affected, the impacts that could be expected on the breeding colony, or the significance of the breeding colony relative to the total population of the species (Buckley 1993). In the absence of such data, the mine proposal was approved in 1992; but any impacts of the mine upon the Gouldian finch were to be ameliorated by a substantial research contribution from the mine proponents and the establishment of a monitoring programme to assess the mine's impacts. Given the risks associated with the location of a very large mine in or adjacent to a significant breeding colony of an endangered species, much of the protection of that colony was dependent upon the efficacy of the monitoring programme, and the ability to ensure that remedial action was taken if serious impacts were detected (Clancy 1995). However, the monitoring programme adopted (Zapopan 1993) had substantial limitations, and has now been abandoned. No relevant pre-impact baseline data were collected; the power of the programme to detect any change was very low (and never quantified); just one part of the life history

and resource requirements of the species was considered; the programme measured impact on an annual basis such that rapid remedial response may have been foreclosed, the threshold changes required to trigger remedial action were not specified, and remedial actions were not defined. This tolerance of uncertainty in impact assessment works heavily in the developer's favour (Green 1989) as 'low power research has a low probability of rejecting the idea of no effect, so the use of the environment is more likely to be approved without expensive environmental safeguards' (Leis 1992). In situations such as this where there is limited information but a risk of substantial conservation costs, it has been argued that the possibility of failing to detect a decline when one in fact occurs should be explicitly stated and minimized (Shrader-Frechette and McCoy 1992).

Case study 5: Sustainable harvesting

For at least 60 000 years, Aboriginal people of northern Australia have relied upon harvesting wildlife for sustenance. A few wildlife species (notably the two crocodile species *Crocodylus porosus* and *Crocodylus johnstoni*) are now being harvested commercially, and the economic value of this trade is being used as an argument to conserve the habitat of these species (Webb and Manolis 1993). Recently, the NT government has proposed a generic strategy for the sustainable use of wildlife (PWCNT 1995a), and specific trial sustainable use management programmes, for the red-tailed black cockatoo (*Calyptorhynchus banksii*) (PWCNT 1995b) and cycads (PWCNT 1995c). The establishment of sustainability in these industries is contingent upon adequate information about population size, reproductive rates, harvest rates, costs of surveillance and market demands. For red-tailed black cockatoos in the Northern Territory, no such information is currently available. Lacking such information, the proponents propose a monitoring programme linked to adaptive management (Walters 1986). The required monitoring and research into the ecology of the species would be funded by service charges from the commercial harvesters, in a manner similar to those proposed for lancewood harvesting. For monitoring to effectively assess the impact of harvesting, it must be capable of detecting changes in population size and demographic structure.

Surveying red-tailed black cockatoos has a number of inherent problems which reduce the statistical power needed to meet this objective (Pollock 1995; Marsh 1995). The species is highly mobile and may occur in large flocks, hence error bars are likely to be large relative to population estimates, and distributional responses to spatial variation in rainfall or food availability may mask impacts of harvesting (Ludwig *et al.* 1993). The species may be inconspicuous, particularly in its favoured recently burnt areas, hence population estimates may be inaccurate. The species has a very low reproductive rate, is long-lived and has a long period to maturity (Forshaw 1981), factors which would render it especially sensitive to overharvesting (Beissinger and Bucher 1992) as substantial changes in demographic structure resulting from harvesting may not be apparent until well after such

changes occur. The rapid decline of the red-tailed black cockatoo to the point of endangerment elsewhere in Australia (e.g. Joseph *et al.* 1991) should mandate that if commercial harvesting of this species is to be permitted in the Northern Territory, then the supervisory authorities must adopt a particularly cautious and well-informed approach, and clearly state and address the uncertainties involved in all aspects of the industry (Clark 1996).

Lack of information does nor necessarily preclude the establishment of a sustainable harvesting strategy, although it does magnify the risks. Beissinger and Bucher (1992) provided an approach to establishing sustainable harvesting from an initially inadequate information base: however, this strategy was dependent upon landowners taking only the additional population resulting from environmental modification which had improved habitat suitability. Such is not a component of the proposed NT scheme.

The effectiveness of these programmes in delivering their conservation goals (Anon. 1994) will be dependent upon, and measurable by, the extent to which the industry leads to a reduction in the rate of land clearing. In the case of the red-tailed black cockatoo, the financial inducements to landowners offered by the development of a sustainable harvesting regime may be difficult to translate into land protection and species conservation. This bird undertakes extensive landscape-scale movements in response to spatial variability in resources, rendering protection of only part of its used area an insufficient guarantee of persistence.

Case study 6: Land management and conservation planning

Uncertainty bedevils conservation planning in northern Australia. For most of this century, environmental concerns were not taken into account in development proposals (Frith 1961). Now, where there is some consideration of environmental impacts, the information hase for assessing conservation values is generally very limited: for example, despite a concerted effort to aggregate all availahle distributional data for vertebrates in the Northern Territory, the average density of records is 0.6 records per square kilometre (for all species combined), decreasing to < 0.05 records per square kilometre in the more remote hioregions (Connors *et al.* 1996). This is not an adequate information base to assess likely impacts of development, nor to undertake regional land use planning.

Further, any conservation assessment is difficult to set against the more clinical (if demonstrably often unrealistic) economic values ascribed to developments. In contrast to most Australian states, comprehensive regional land use planning has been undertaken on only one occasion in the Northern Territory (Anon. 1991), and in that case conservation values were generally subsumed to development goals. In many more cases, land use planning in northern Australia has been sectoral, seeking only to identify development opportunities and constraints (e.g. Forster *et al.* 1960). (Though in the Cape York Peninsula of far north Queensland, very detailed and relatively comprehensive land use planning has been attempted (Holmes 1992).) Without strategic and regional planning, the

assessment of environmental impacts of development proposals has been piecemeal and has evaded the issue of cumulative effects.

The conservation reserve system in northern Australia is unrepresentative of many environments (Woinarski 1992), especially those with high pastoral values. For example, pastoral leases cover more than 99 per cent of the NT's extensive Mitchell grasslands (Woinarski *et al.* 1996). While there has been a great deal of research aimed at increasing the productivity of these environments (e.g. Orr and Holmes 1984), almost nothing is known of their native fauna and its responses to grazing or other management practices, an imbalance explicitly justified by the pastoral scientists Orr and Holmes (1984):

> No large area of these grasslands is currently reserved in any form and at present there are no firm plans for any such reserve. The situation arises because the need and pressure for reservation is low. No information on fauna native to these grasslands has been collected.

While little is known of the effects of land use upon those wildlife species occurring mainly in poorly reserved environments, there is also negligible information on the management requirements of species more fortunate to live in conservation reserves. For many reserves, there has been no wildlife inventory and only superficial consideration of how the wildlife present can be maintained and prosper. This uncertainty about the identification and management of conservation values within northern Australia's national park system is accentuated by the fledgling state of joint management of many of these reserves by Aboriginal landowners and government conservation agencies. While such co-operation may bring many benefits, there is also much scope for discord in the establishment of management goals. This discord may produce a lack of conservation security for biota within national parks, a result which is foreign to long-held beliefs (at least within the settler society) about the purpose of such reserves. For example, Aboriginal traditional owners of Kakadu National Park, who form the majority of the management board of that park, and are now advocating extensive areas of buffalo farms within the park and the return of relatively high densities of feral animals, despite clear evidence of the conservation costs (Kakadu Board of Management and Australian Nature Conservation Agency 1996). The paramouncy of Aboriginal interests is explicit: 'Any conservation partnership must be based upon the premise that indigenous cultural objectives of a conservation program have priority over environmental issues', and 'Indigenous cultural practices, including the use of land and natural resources, should not be limited by formal conservation requirements set by governments' (Smyth 1995). The implications of this prioritization for the conservation reserve system in northern Australia are yet to be determined.

However, even sympathetic and informed management of reserves will not by itself ensure the persistence of 'reserved' species within northern Australia. While the vast open forests and savanna woodlands of northern Australia appear superficially homogeneous, there are many patches of distinct habitat

embedded within them, and substantial spatial variation in rainfall patterning leads to marked heterogeneity in resource availability, even within extensive environments. In response to this patchiness, many of northern Australia's animal species undertake extensive geographic dispersal and habitat shifts (Woinarski *et al.* 1992). Examples include: intercontinental migrants, notably shore birds (for which coasts and wetlands of northern Australia are of major significance: Lane 1987); continental migrants, including many bird species which breed in temperate Australia; long-distance nomads, notably including waterfowl (the northern Australian wetlands may occasionally hold virtually all of Australia's waterfowl population: Frith and Davies 1961); and species whose movements are largely restricted to the arena of north Australia. The magpie goose is perhaps the classic example of the latter, with the location of breeding colonies varying between years in response to a range of local rainfall factors, with substantial shifts in preferred feeding habitat depending upon gosling age, and with strongly differential use of habitat (and hence location) between breeding and non-breeding periods (including the occasional concentration of the bulk of the regional population within very limited areas) (Whitehead *et al.* 1992). Despite almost four decades of research directed at this species, it is still possible to make only loose predictions about the impacts upon it of alienation or modification of particular areas within its broad environment. Even where knowledge of the requirements of this species can be translated to explicit identification of threatening processes, it has proved difficult to have these considerations accepted by developers or government regulatory agencies (Whitehead 1991). It is far harder to guess the set of required areas (or resources) for the vast majority of unstudied vertebrates, let alone to ensure that these can be protected within the prevailing culture of facilitating development.

Conclusions

Our examples of attempts by European settlers to use the land of northern Australia suggest a pattern of general disregard for information and scant concern for environmental consequences of success (or failure). Although these developments have inevitably led to personal and environmental casualties, such losses have been deemed bearable in the context of a government drive to dominate or stake a claim on these lands, and the pervasive perception that environmental costs weigh little against the land's limited value and its excessive extent.

We have generally selected cases of failure, at least partly because these may better illuminate the importance of uncertainty, and perhaps because they outnumber the cases of clear success. However, not all development attempts in northern Australia have failed. Northern Australia has supported a moderately high density of Aboriginal people for at least

60 000 years, and for much of that period these people have relied upon careful management of resources, rooted in an intimate environmental knowledge (Hiscock and Kershaw 1992). The settler population in northern Australia has increased and become less transient, allowing greater knowledge of the environment by locally based decision makers. Darwin now houses 80 000 people and is a prosperous city: however, it is far from being self-supporting, with much of its income and population base derived from distant funding (Committee on Darwin 1995). Northern Australia has some large and magnificent national parks (most notably Kakadu: Press *et al.* 1995), which protect much of the region's biota. The significant rise of the tourist industry in northern Australia has forced a greater appreciation of the value of natural areas, wildness and national parks, leading to a gradually increasing recognition that extensive relatively unmodified environments are an asset and not an affront. The Northern Territory (and northern Australia generally) has also caught up with at least some environmental policy operating elsewhere in Australia, through its endorsement of a wide range of national strategies and agreements, such as the National Forest Policy Statement, National Strategy for the Conservation of Australia's Biodiversity, and the National Strategy for the Conservation of Australian Species and Communities Threatened with Extinction.

Many of the examples we have presented are now historic, and the evidence suggests that some of the lessons have now been learned, that the frontier mentality is gradually fading. Conservation issues are now generally included in reviews of development prospects (e.g. Moffatt and Webb 1992; Anon. 1995), and environmental research (including conservation issues) is being seen as an essential precursor of strategic development (ASTEC 1993). Although the number of researchers in northern Australia remains low relative to the rest of the nation (ASTEC 1993), there is now a substantial body of western scientific knowledge about the ecology of northern Australia (e.g. Ridpath and Corbett 1985; Haynes *et al.* 1991). Some of this research has now been of sufficient length to assess responses to climatic variability, and of sufficient relevance to provide clear warning of the environmental constraints to development. The limits to which lands can be pushed have been exceeded so frequently now that these limits are recognizable, and some land users have begun to operate sustainably, and search for indicators of sustainability (Winter 1990; Stewart 1996). In some cases (e.g. the use of exotic pasture grasses, and tree clearing) the conservation impacts of land use practices are now known, at least dimly, and, at times, factored into management advice (e.g. Scanlan and Turner 1995; Anon. 1995). There is also a growing

awareness of the importance of understanding the environmental consequences of pervasive land management practices, such as fire.

There is a growing diversity of interest groups in northern Australia, such that the land management agenda is now less monopolized by the previously dominant sectoral interest, pastoralism. There is also substantially increased communication between a range of researchers, landowners and other stakeholders, not least through the recently established Cooperative Research Centre for Sustainable Development of Tropical Savannas, which spans all jurisdictions across northern Australia and all main land user groups. Aboriginal people have far greater power than they did a generation ago, especially where land ownership is concerned. In some cases, their detailed environmental knowledge is now more widely respected and sought.

However, some of the ignorance, limited vision and/or hubris remains, at least partly because the history of European entry to this region has been so brief. Calls for large developments continue, with often little prospect of (or concern for) sustainability and little regard for other values. In some areas (notably in the Darwin rural area), the large developments have been replaced by a multiplicity of more modest enterprises, each of more limited impact, but together providing possibly greater cumulative change. In most of northern Australia, land use planning, if it occurs at all, is neither integrated nor strategic, so much decision making is piecemeal and impacts are incremental. The vastness of the region continues to daunt research: it is far more tractable to figure out the workings of a remnant woodland patch than of an environment in which there are no obvious limits to ecological processes. While that vastness remains a comfort (we can get things wrong here and there without fatal environmental consequences), it is very much an attribute which must be carefully protected.

There is still a need in settler society for far greater knowledge of the north Australian environments, and the impacts of development upon them. But development will continue to be pursued regardless of the adequacy of the information base. How then can such development be constrained within prudent environmental limits? Comprehensive regional land use planning, linked to environmental planning principles, may provide the most effective mechanism. A framework and principles should include: regionalization based on social and environmental criteria; collection or collation of sufficient environmental information to identify within the region sites of greatest conservation significance and to predict the environmental costs of possible development; an inclusive process to identify regional land use objectives and to identify sites of conservation

significance within the region; the incorporation of these land use objectives into legislation and/or planning instruments; the establishment and wise management of a comprehensive and adequate reserve network and the incorporation of ecologically sustainable management in unreserved lands; the participation of all stakeholders in land use decisions; and the staged expansion and monitoring of development such that management may adapt to unforeseen impacts before these become excessive and/or irreversible.

There is also a broader context from which environmental research requirements should be considered. Much of the Australian continent, and the world in general, has been substantially modified over the last 200 years, with fragmentation and alteration of previously extensive landscapes in most temperate areas. In much of these altered environments the workings of ecological processes have been distorted or lost. It may be that patching up such broken environments will require the knowledge of how intact landscapes operate. The relatively unmodified northern Australian environment can provide such an example. It is perhaps ironic that this opportunity might well have been foreclosed if many of the development schemes initiated in the north had achieved their ambitions; for ultimately, the failures have probably had fewer environmental impacts than the successes.

Acknowledgments

We thank Andy Chapman, David Bowman, Penny Wurm, John Childs and Peter Whitehead for comments on drafts of this paper, and Sam Lake for some unpublished information. Some of the land use planning principles noted in this paper were distilled from a fuller listing compiled by Peter Whitehead. We thank the Tropical Savannas Cooperative Research Centre for support.

References

Anon. (1978) Editorial: professional and organisational loyalty, *Australian Forestry* 41: 136–7.

Anon. (1979) *Ord River Irrigation Area. Review: 1978*. Canberra: Australian Government Publishing Service.

Anon. (1991) *Gulf Region Land Use and Development Study*, Darwin: Northern Territory Department of Lands and Housing.

Anon. (1994) *A Conservation Strategy for the Northern Territory*. Darwin: Government Printer.

Anon. (1995) *Report into Matters Relating to Environmental Protection and Multiple Use of Wetlands Associated with the Mary River System*. Sessional Committee on the Environment, Legislative Assembly of the Northern Territory. Darwin: NT Government Printer.

ASTEC (Australian Science and Technology Council) (1993) *Research and Technology in Tropical Australia and their Application to the Development of the Region. Final report*. Canberra: Australian Government Publishing Service.

Barnard, C.A. (1925) A review of the bird life on Coomooboolaroo Station, Duaringa district, Queensland, during the past fifty years. *Emu* 24: 252–65.

Barton, A. and McDonald, J. (1996) The Australian Defence Force and the future of tropical savannas. In: Ash, A. (ed.) *The Future of Tropical Savannas: an Australian Perspective*. Melbourne: CSIRO.

Basinski, J.J., Wood, I.M. and Hacker, J.B. (1985) *The Northern Challenge: a History of CSIRO Crop Research in Northern Australia*. Research report no. 3, CSIRO Division of Tropical Crops and Pastures. St. Lucia: CSIRO.

Bateman, W. (1955) Forestry in the Northern Territory. *Forestry and Timber Bureau Leaflet no. 72*.

Bauer, F.H. (1959) *Historical Geographic Survey of part of Northern Australia. Part 1: Introduction and the Eastern Gulf Region*. CSIRO Division of Land Research and Regional Survey report no. 59/2. Canberra: CSIRO.

Bauer, F.H. (1964) *Historical Geography of White Settlement in Northern Australia. Part 2: The Katherine-Darwin Region*. CSIRO Division of Land Research and Regional Survey report no. 64/1. Canberra: CSIRO.

Bauer, F.H. (1977) (ed.) *Cropping in North Australia: Anatomy of Success and Failure*. Canberra: Australian National University.

Bauer, F.H. (1984) What man hath wrought: geography and change in northern Australia. In: Parkes, D. (ed.) *Northern Australia: the Arenas of Life and Ecosystems on Half a Continent*. Sydney: Academic Press.

Beeton, R.J.S. (1977) The impact and management of birds on the Ord River development in Western Australia. M.Nat.Res. thesis, University of New England, Armidale.

Beissinger, S.R. and Bucher, E.H. (1992) Can parrots be conserved through sustainable harvesting? A new model for sustainable harvesting regimes when biological data are incomplete. *BioScience* 42: 164–73.

Blainey, G. (1992) Overcoming southern apathy towards Australia's northern regions. *The Mining Review* 16: 22–5.

Bowman, D.M.J.S. (1991) Aims and achievements in Northern Territory forest wildlife biology. In: Lunney, D. (ed.) *Conservation of Australia's Forest Fauna*. Mosman: Royal Zoological Society of NSW.

Bowman, D.M.J.S. (1998) The impact of Aboriginal landscape burning on the Australian biota. *New Phytologist* 140: 385–410.

Buckley, R. (1993) How well does the EIA process protect biodiversity? *Australian Environmental Law News* 2: 42–52.

Cameron, D.M. (1985) Forest crops. In: Muchow, R.C. (ed.) *Agro-research for the Semi-arid Tropics: North-West Australia*. St. Lucia: University of Queensland Press.

Christian, C.S. (1977) Agricultural cropping in northern Australia: a general review. In: Bauer, F.H. (ed.) *Cropping in North Australia: Anatomy of Success and Failure*. Canberra: Australian National University.

Christian, C.S. and Stewart, G.A. (1953) General report on survey of Katherine-Darwin region, 1946. *CSIRO Land Research Series no. 1*. Canberra: CSIRO.

Clancy, T. (1995) Workshop report. Evidence of change – when and how should the manager respond? In: Grigg, G.C., Hale, P.T. and Lunney, D. (eds) *Conservation through Sustainable Use of Wildlife*. Brisbane: University of Queensland.

Clark, C.W. (1996) Marine reserves and the precautionary management of fisheries. *Ecological Applications* 6: 369–70.

Committee on Darwin (1995) *Report of the Committee on Darwin*. Canberra: Australian Government Publishing Service.

Connors, G., Oliver, B. and Woinarski, J. (1996) *Bioregions in the Northern Territory: Conservation Values, Reservation Status and Information Gaps*. Report to ANCA National Reserves System Cooperative Program. Darwin: Parks and Wildlife Commission of the Northern Territory.

CSIRO (1952) Survey of Barkly region, 1947–48. *Land Research Series no. 3*. Canberra: CSIRO.

CSIRO (1965) General report on lands of the Tipperary area, Northern Territory. 1961. *Land Research Series no. 13*. Canberra: CSIRO.

CSIRO (1969) Lands of the Adelaide-Alligator area, Northern Territory. *Land Research Series no. 25*. Canberra: CSIRO.

CSIRO (1970) Lands of the Ord-Victoria area, W.A. and N.T. *Land Research Series no. 28*. Canberra: CSIRO.

CSIRO (1976) Lands of the Alligator Rivers area, Northern Territory. *Land Research Series no. 38*. Canberra: CSIRO.

CSIRO (1978) CSIRO's research in and for the Ord River Irrigation Area. Submission to the Ord River Irrigation Area Review Committee.

Curteis, W.M. (1961) Prospects for Rice in the Northern Territory. In: Papers of the Northern Territory Scientific Liaison Conference. Melbourne: CSIRO.

Davidson, B.R. (1965) *The Northern Myth: a Study of the Physical and Economic Limits to Agricultural and Pastoral Development in Tropical Australia*. Melbourne: Melbourne University Press.

Davy, D.R. (1975) *Rum Jungle Environmental Studies*. Sydney: Australian Atomic Energy Commission.

Dawson, F. (1993) A major mining project is fast tracked in the Northern Territory, but at what cost? *Impact* 30: 6.

Dawson, F. (1996) *The Significance of Property Rights for Biodiversity Conservation in the Northern Territory*. Unpublished report to the Cooperative Research Centre for the Sustainable Development of Tropical Savannas, Northern Territory University, Darwin.

Ewing, G. (1992) The likely impact of the Mabo case on Aboriginal land rights claims. *The Mining Review* 16: 8–12.

Ewing, G. (1996) Sustainable mining in Australia's tropical savannas. In: Ash, A. (ed.) *The Future of Tropical Savannas: an Australian Perspective*. Melbourne: CSIRO.

Eyles, A.G., Cameron, D.G. and Hacker, J.B. (1985) *Pasture Research in Northern Australia – its History, Achievements and Future Emphasis*. Research report no. 3, CSIRO Division of Tropical Crops and Pastures. St Lucia: CSIRO.

Fisher, M.J., Garside, A.L., Skerman, P.J., Chapman, A.L., Strickland, R.W., Myers, R.J.K., Wood, I.M.W., Beech, D.F. and Henzell, E.F. (1977) The role of technical and related problems in the failure of some agricultural development schemes in northern Australia. In: Bauer, F.H. (ed.) *Cropping in North Australia: Anatomy of Success and Failure*. Canberra: Australian National University.

Flannery, T.F. (1994) *The Future-eaters: an Ecological History of the Australasian Lands and People*. Sydney: Reed.

Foran, B.D., Bastin, G. and Hill, B. (1985) The pasture dynamics and management of two rangeland communities in the Victoria River District of Northern Territory. *Australian Rangeland Journal* 7: 107–13.

Forshaw, J.M. (1981) *Australian Parrots*. 2nd (revised) edn. Melbourne: Lansdowne.

Forster, H.C., Kelly, C.R. and Williams, D.B. (1960) *Prospects of Agriculture in the Northern Territory*. Report of the Forster Committee. Canberra: Department of Territories.

Fox, R.W., Kelleher, G.G., Kerr, C.B. (1977) *Ranger Uranium Environmental Inquiry Second Report*, Canberra: Australian Government Publishing Service.

Frith, H.J. and Davies, S.J.J.F. (1961) Ecology of the magpie goose, *Anseranas semipalmata* Latham (*Anatidae*). *CSIRO Wildlife Research*, 6: 91–141.

Fry, R.M. (1980) Environmental protection and uranium mining in the Alligator Rivers Region. In: Harris, S. (ed.) *Social and Environmental Choice, the Impact of Uranium Mining in the Northern Territory*. CRES Monograph 3. Canberra: Australian National University.

Gillard, P., Williams, J. and Monypenny, R. (1989) Clearing trees from Australia's semi-arid tropics, *Agricultural Science* 2: 34–9.

Glanznig, A. (1995) *Native Vegetation Clearance, Habitat Loss and Biodiversity Decline: an Overview of Recent Native Vegetation Clearance in Australia and its Implication for Biodiversity*. Biodiversity series, paper no. 6. Canberra: Department of Environment, Sport, and Territories.

Graham-Taylor, S. (1978) A History of the Ord River Scheme: a Study in Incrementalism. PhD thesis. Murdoch University.

Green, R.H. (1989) Power analysis and practical strategies for environmental monitoring. *Environmental Research* 50: 195–205.

Haigh, F.B. (1963) Irrigation potential and problems. In: Tomlinson, J. and Walker, P. *Water Resources: Use and Management*. Melbourne: Melbourne University Press.

Hanssen, N.L. and Wigston, D.L. (1989) Approaches to a forest history of the Northern Territory. In: Frawley, K.J. and Semple, N. (eds) *Australia's Ever-changing Forests*. Campbell, ACT: Department of Geography and Oceanography, University College, Australian Defence Force Academy.

Haynes, C.D., Ridpath, M.G. and Williams, M.A.J. (1991) *Monsoonal Australia: Landscape, Ecology and Man in the Northern Lowlands*. Rotterdam: Balkema.

Higgins, H.G. and Phillips, F.H. (1973) Technical and economic factors in the export of wood chips from Australia and Papua New Guinea. *Australian Forest Industry Journal* 39: 47–53.

Hiscock, P. and Kershaw, A.P. (1992) Palaeoenvironments and prehistory of Australia's tropical Top End. In: Dodson, J. (ed.) *The Naive Lands: Prehistory and Environmental Change in Australia and the South-west Pacific*. Melbourne: Longman Cheshire.

Holmes, J.H. (1990) Ricardo revisited: submarginal land and non-viable cattle enterprises in the Northern Territory Gulf District. *Journal of Rural Studies* 6, 45–65.

Holmes, J. (1992) Strategic regional planning on the northern frontiers. Discussion paper no. 4. Darwin: North Australian Research Unit.

Holmes, J.H. and Mott, J.J. (1993) Towards a diversified use of Australia's savannas. In: Young, M.D. and Solbrig, O.T. (eds) *The World's Savannas, Economic Driving Forces, Ecological Constraints and Policy Options for Sustainable Land Use*. UNESCO Man and the Biosphere Series Vol 12. Paris: UNESCO.

House of Representatives Committee on Expenditure (1978) *Report on Forestry Program*. Canberra: Government Printer.

Hughes, C.J. (1995) One land: two laws – Aboriginal fire management. *Environment and Planning Law Journal* 12, 37–49.

Joseph, L., Emison, W.B. and Bren, W.M. (1991) Critical assessment of the conservation status of red-tailed black-cockatoos in south-eastern Australia with special reference to nesting requirements. *Emu* 91: 46–50.

Jull, P. (1991) *The Politics of Northern Frontiers*. Darwin: Australian National University, North Australia Research Unit.

Jull, P. (1996) *Constitution-Making in Northern Territories: Legitimacy and Governance in Australia*. Alice Springs: Central Land Council.

Kakadu Board of Management and Australian Nature Conservation Agency (1996) *Kakadu National Park Draft Plan of Management 1996*. Jabiru: Australian Nature Conservation Agency.

Kitchener, D.J. (1978) Mammals of the Ord River area, Kimberley, Western Australia. *Records of the Western Australian Museum* 6: 182–219.

Lacey, C.J. (1979) Forestry in the Top End of the Northern Territory. Part of the Northern Myth. *Search* 10: 174–80.

Land Rights News (1993) Fast tracking ignores Aboriginal interests. Vol. 2, No. 11, p. 4.

Land Rights News (1993) Borroloola clans want mining agreement. Vol. 2, No. 27, p. 3.

Lane, B. (1987) *Shorebirds in Australia*. Melbourne: Nelson.
Leis, J.M. (1992) The dilemma of power. *Australian Natural History* 24: 72.
Lim, T.K., Bowman, L. and Tidemann, S. (1993) Winged vertebrate pest damage in the Northern Territory. Department of Primary Industries and Fisheries Technical Bulletin no. 206. Darwin: DPIF.
Lonsdale, W.M. (1994) Inviting trouble: introduced pasture species in northern Australia. *Australian Journal of Ecology* 19: 345–54.
Lourensz, R.S. (1981) Tropical cyclones in the Australian region July 1909 to June 1980. Canberra: Bureau of Meteorology, Australian Department of Science and Technology.
Ludwig, D., Hilborn, R. and Walters, C. (1993) Uncertainty, resource exploitation, and conservation: lessons from history. *Science* 260: 17, 36.
MacKenzie, I. (1980) European incursions and failures in northern Australia. In: Jones, R. (ed.) *Northern Australia: Options and Implications*. Canberra: Australian National University.
Marsh, H. (1995) The limits of detectable change. In: Grigg, G.C., Hale, P.T. and Lunney, D. (eds) *Conservation through Sustainable Use of Wildlife*. Brisbane: University of Queensland.
McKenzie, N.L. (1981) Mammals of the phanerozoic south-west Kimberley, Western Australia: biogeography and recent changes. *Journal of Biogeography* 8: 263–280.
Medcalf, F.G. (1944) *Soil Erosion Reconnaissance of the Ord River Valley and Watershed*. Perth: Department of Lands and Surveys.
Moffatt, I. and Webb, A. (1992) (eds) *Conservation and Development Issues in North Australia*. Darwin: North Australia Research Unit.
Mollah, W.S. (1980) The Tipperary story: an attempt at large-scale grain sorghum development in the Northern Territory. *North Australian Research Bulletin* 7: 59–183.
Neate, G. (1989) *Aboriginal Land Rights in the Northern Territory*, Vol. 1. Sydney: Alternative Publishing Cooperative.
NFI (National Forest Inventory) (1993) Lancewood communities. *Australian Forest Profiles* 2: 1–8.
Northern Territory Department of Mines and Energy (1986) *The Rum Jungle Rehabilitation Project Final Project Report*, Darwin: Northern Territory Department of Mines and Energy.
Orr, D.M. and Holmes, W.E. (1984) Mitchell grasslands. In: Harrington, G.N., Wilson, A.D. and Young, M.D. (eds) *Management of Australia's Rangelands*. Melbourne: CSIRO.
Payne, A.L., Kubicki, D.G., Wilcox, D.G. and Short, L.C. (1978) A report on erosion and range condition in the West Kimberley area of West Australia. *Western Australia Department of Agriculture Technical Bulletin* no. 42.
Perry, R.A. (1960) Pasture lands of the Northern Territory. *Land Research Series* no. 5. Canberra: CSIRO.
Pollock, K.H. (1995) The challenges of measuring change in wildlife populations: a biometrician's perspective. In: Grigg, G.C., Hale, P.T. and Lunney, D. (eds)

Conservation through Sustainable Use of Wildlife. Brisbane: University of Queensland.

Press, T., Lea, D., Webb, A., Graham, A. (1995) *Kakadu Natural and Cultural Heritage Management*. Darwin: ANCA and NARU.

Price, O. and Bowman, D.M.J.S. (1994) Fire-stick forestry: a matrix model in support of skilful fire management of *Callitris intratropica* R.T. Baker by north Australian Aborigines. *Journal of Biogeography* 21: 573–80.

PWCNT (1995a) *A Strategy for Conservation through the Sustainable Use of Wildlife in the Northern Territory of Australia*. Darwin: Parks and Wildlife Commission of the Northern Territory.

PWCNT (1995b) *A Trial Management Program for the Red-tailed Black Cockatoo* Calyptorhynchus banksii *in the Northern Territory of Australia*. Darwin: Parks and Wildlife Commission of the Northern Territory.

PWCNT (1995c) *A Trial Management Program for Cycads in the Northern Territory of Australia*. Darwin: Parks and Wildlife Commission of the Northern Territory.

Redhead, T.D. (1979) On the demography of *Rattus sordidus colletti* in monsoonal Australia. *Australian Journal of Ecology* 4: 115–36.

Resource Assessment Commission (RAC) (1991) *Kakadu Conservation Zone Inquiry. Final report*, Vol. 1. Canberra: Australian Government Publishing Service.

Resource Assessment Commission (RAC) (1992) *Forest and Timber Inquiry. Final report*. Canberra: Australian Government Publishing Service.

Riddett, L.A. (1990) *Kine, Kin and Country: the Victoria River District of the Northern Territory 1911–1966*. Darwin: North Australia Research Unit.

Ridpath, M.G. and Corbett, L.K. (1985) *Ecology of the Wet-Dry Tropics. Proceedings of the Ecological Society of Australia* 13.

Russell-Smith, J., Lucas, D., Gapindi, M., Gunbunuka, B., Kapirigi, N., Namingam, G., Lucas, K. and Chaloupka, G. (1997) Aboriginal resource utilisation and fire management practice in western Arnhem Land, monsoonal northern Australia: notes for prehistory, lessons for the future. *Human Ecology* 25: 159–95.

Scanlan, J.C. and Turner, E.J. (1995) *The Production, Economic and Environmental Impacts of Tree Clearing in Queensland*. A report to the working group of the Ministerial Consultative Committee on tree clearing. Brisbane: Department of Lands.

Schrader-Frechette, K.S. and McCoy, E.D. (1992) Statistics, costs and rationality in ecological inference. *Trends in Research on Ecology and Evolution* 7: 96–9.

Sinclair Knight Merz (1996) *Public Environment Review. Ord River Irrigation Area: Stage* 2. Perth: Sinclair Knight Merz.

Smith, L.A. and Johnstone, R.E. (1977) Status of the purple-crowned fairy-wren (*Malurus coronatus*) and buff-sided robin (*Poecilodryas superciliosus*) in Western Australia. *Western Australian Naturalist* 13: 185–8.

Smyth, D. (1995) *Protecting Country: Indigenous Protected Areas*. Report to Australian Nature Conservation Agency. Atherton: D. Smyth and C. Bahrdt, Consultants in Cultural Ecology.

Spillett, P.G. (1972) *Forsaken Settlement: an Illustrated History of the Settlement of Victoria, Port Essington North Australia 1838–1849*. Sydney: Landsdowne Press.

Stewart, J. (1996) Savanna users and their perspectives: grazing industry. In: Ash, A. (ed.) *The Future of Tropical Savannas: an Australian Perspective*. Melbourne: CSIRO.

Stocker, G.C. (1970) The effects of water buffaloes on paperbark forests in the Northern Territory. *Australian Forest Research* 4: 31–8.

Stuart, J. McDouall (1863) Diary of Mr John McDouall Stuart's explorations from Adelaide across the continent of Australia. *Journal of the Royal Geographical Society of London* 33: 276–321.

Stuart, J. McDouall (1865) *Explorations in Australia: the Journals of John McDouall Stuart during the Years 1858, 1859, 1860, 1861 and 1862*. W. Hardman (ed.). London: Saunders Otley & Co.

Taylor, J.A. and Tulloch, D. (1985) Rainfall in the wet-dry tropics: extreme events at Darwin and similarities between years during the period 1870–1983 inclusive. *Australian Journal of Ecology* 10: 281–96.

Tidemann, S.C. (1990) Relationships between finches and pastoral practices in northern Australia. In: Pinowski, J. and Summers-Smith, J.D. (eds) *Granivorous Birds in the Agricultural Landscape*. Warsaw: PWN – Polish Scientific Publishers.

Toyne, P. (1994) *The Reluctant Nation, Environment, Law and Politics in Australia*. Sydney: ABC Books.

Walters, C. (1986) *Adaptive Management of Renewable Resources*. New York: McGraw Hill.

Webb, G.J.W. and Manolis, S.C. (1993) Viewpoint: conserving Australia's crocodiles through commercial incentives. In: Lunney, D. and Ayers, D. (eds) *Herpetology in Australia: a Diverse Discipline*. Sydney: Royal Zoological Society of New South Wales.

Whitehead, P.J. (1991) Magpie geese, mangoes and sustainable development. *Australian Natural History* 23: 784–92.

Whitehead, P.J. and Dawson, T. (2000) Let them eat grass! *Nature Australia*. Autumn: 46–55.

Whitehead, P.J., Wilson, B.A. and Bowman, D.M.J.S. (1990) Conservation of coastal wetlands of the Northern Territory of Australia: the Mary River floodplain. *Biological Conservation* 52: 85–111.

Whitehead, P.J., Wilson, B.A. and Saalfeld, K. (1992) Managing the magpie goose in the Northern Territory: approaches to conservation of mobile fauna in a patchy environment. In: Moffatt, I. and Webb, A. (eds) *Conservation and Development Issues in North Australia*. Darwin: North Australia Research Unit.

Winter, W.H. (1990) Australia's northern savannas: a time for change in management philosophy. *Journal of Biogeography* 17: 525–9.

Woinarski, J.C.Z. (1992) Biogeography and conservation of reptiles, mammals, and birds across north-western Australia: an inventory and base for planning an ecological reserve system. *Wildlife Research* 19: 665–705.

Woinarski, J.C.Z. (1993) Australian tropical savannas, their avifauna, conservation status and threats. In: Catterall, C.P., Driscoll, P.V., Hulsman, K., Muir, D. and Taplin, A. (eds) *Birds and their Habitats: Status and Conservation in Queensland*. Brisbane: Queensland Ornithological Society.

Woinarski, J.C.Z. and Braithwaite, R.W. (1990) Conservation foci for Australian birds and mammals. *Search* 21: 65–8.

Woinarski, J.C.Z. and Fisher, A. (1995a) Wildlife of lancewood (*Acacia shirleyi*) thickets and woodlands in northern Australia: 1. Variation in vertebrate species composition across the environmental range occupied by lancewood vegetation in the Northern Territory. *Wildlife Research* 22: 379–411.

Woinarski, J.C.Z. and Fisher, A. (1995b) Wildlife of lancewood (*Acacia shirleyi*) thickets and woodlands in northern Australia: 2. Comparisons with other environments of the region (Acacia woodlands, Eucalyptus savanna woodlands and monsoon rainforests). *Wildlife Research* 22: 413–43.

Woinarski, J.C.Z., Whitehead, P.J., Bowman, D.M.J.S. and Russell-Smith, J. (1992) The conservation of mobile species in a variable environment: the problem of reserve design in the Northern Territory. *Global Ecology and Biogeography Letters* 2: 1–10.

Woinarski, J.C.Z., Connors, G. and Oliver, B. (1996) The reservation status of plant species and vegetation types in the Northern Territory. *Australian Journal of Botany* 44: 673–89.

Woinarski, J.C.Z., Connors, G. and Franklin, D.C. (2000) Thinking honeyeater: nectar maps for the Northern Territory showing seasonal variation in nectar supply from the monsoon tropics to arid central Australia. *Pacific Conservation Biology* 6: 61–80.

Zapopan N.L. (1993) *Mt Todd Gold Mine Environmental Management Plan*. Perth: Zapopan.