

The forest fauna of the Northern Territory: knowledge, conservation and management

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ABSTRACT

The Northern Territory contains about 20% of Australia's eucalypt forests, and of the nation's forests and woodlands generally. Relative to forests and woodlands in other jurisdictions, clearing rates have been low and these forests remain largely continuous. This paper briefly reviews the main forest and woodland types of the Northern Territory, noting characteristics of their fauna and their main management issues. The conservation threats are pervasive and insidious: landscape-wide degradation by weeds and exotic animals, and sub-optimal fire regimes. Largely unrecognised in the general community, these threats are eroding the great national asset of a vast relatively unmodified forest ecosystem.

Key words: eucalypt, savanna, northern Australia, wildlife, clearing, fire.

Introduction

The Northern Territory has national significance for the conservation of forest environments and their fauna. It holds about 20% of the nation's total forest extent, and the Northern Territory forests have suffered far less clearing than forests in all other Australian jurisdictions (Table 1). The asset of extensive largely uncleared tropical forest is also remarkable on a global scale, as tropical forests elsewhere are typically suffering rapid depletion.

At a coarse scale, the characterisation of Northern Territory forest and woodland environments is simple. Spatial variation is controlled mainly by the distinct rainfall gradient - from higher rainfall (around 1800 mm per year) in the monsoon-controlled north to the arid south (Fig. 1) - augmented by a less regular patterning of soil texture (Williams *et al.* 1996). Thus, monsoon rainforest patches occur mainly in the far north and

Table 1. Extent of forest and woodland types, and of their proportion cleared, in the Northern Territory, relative to national tallies. Data from National Land and Water Resources Audit (2001). Vegetation groups are listed in order of decreasing extent in the Northern Territory ("NT"). Note that vegetation groups other than forests and woodlands are not listed.

signifies vegetation groups included within total eucalypt forest (in text).

* as defined in the source document, this category comprises a heterogeneous collection of environments including some that are not forests and woodlands (e.g. 'tidal mudflats, samphires and bare areas, claypans, sand, rocks, salt lakes, lagoons, lakes')

vegetation group	NT area in km ² (% of national extent)	% cleared in NT	% cleared nationally
eucalypt open woodland	175,775 (45.7)	0.0	25.2
eucalypt woodland	123,087 (17.8)	0.7	17.8
tropical eucalypt woodland/grassland	107,254 (42.2)	2.0	0.9
eucalypt open forest #	58,471 (24.3)	1.5	29.5
acacia open woodland	48,703 (42.4)	0.2	2.7
mallee woodland and shrubland	35,450 (14.2)	0.0	34.7
acacia forest and woodland	29,866 (5.3)	1.9	14.7
"other" forest and woodland	29,497 (24.7)	0.0	4.7
melaleuca forest and woodland	19,244 (21.3)	0.8	3.2
mangroves, tidal mudflats, etc.*	5,410 (5.1)	2.5	4.5
rainforest and vine thicket	977 (3.2)	0.1	30.5
eucalypt low open forest #	70 (0.5)	0.0	14.2
eucalypt tall open forest #	0	-	32.8
callitris forest and woodland	0	-	10.5
casuarina forest and woodland	0	-	17.1
low closed forest and woodland	0	-	44.8
total forest and woodland	633,795 (21.2)	0.8	22.2
total eucalypt forest only	58,541 (20.6)	1.5	29.3

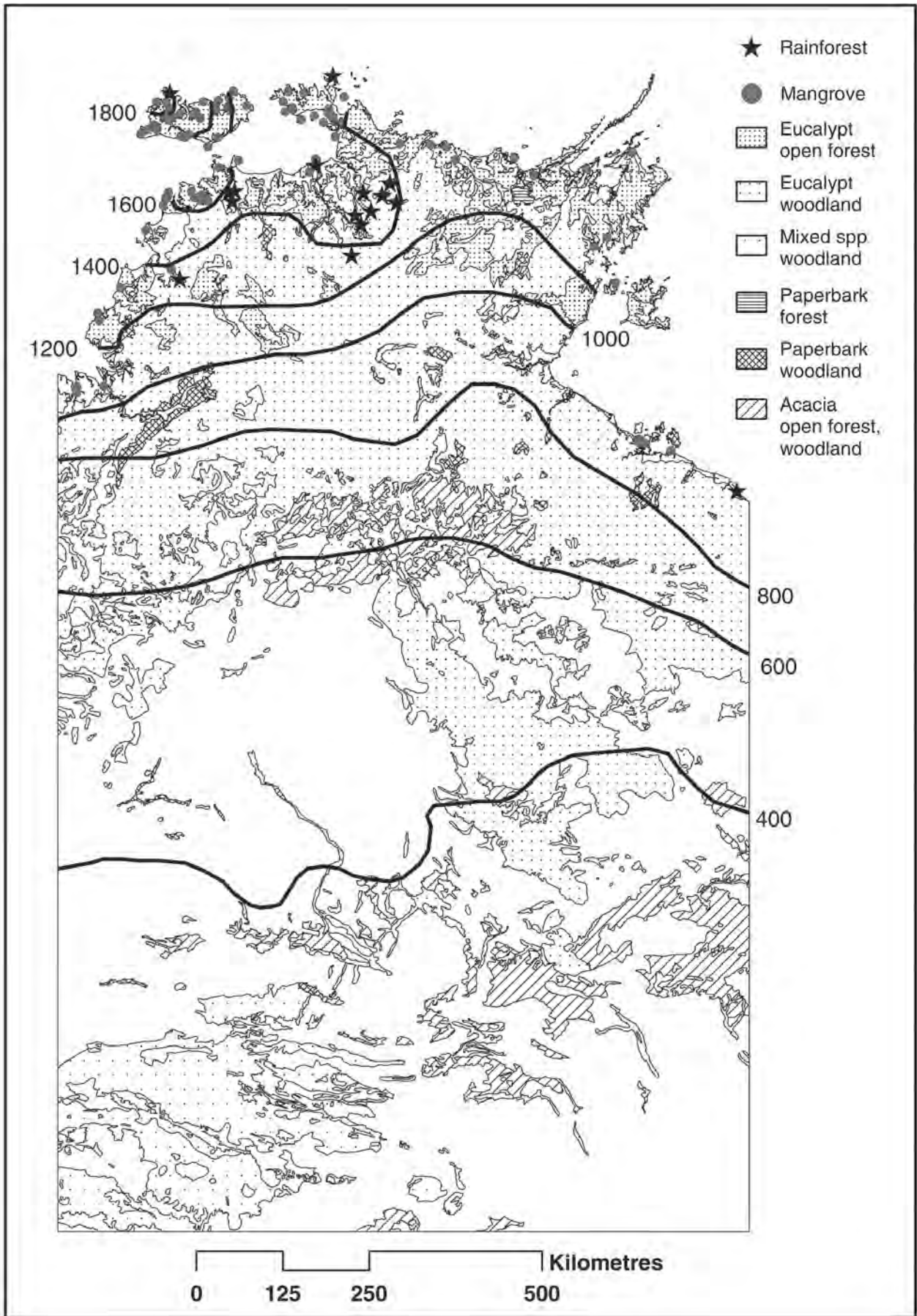


Figure 1. Distribution of forest and woodland types in the Northern Territory (categories grouped up from Wilson et al. 1990), and rainfall isohyets.

become attenuated in species richness and patch size down the rainfall gradient (Russell-Smith 1991; Russell-Smith *et al.* 1992). However, they are generally minor elements of the landscape (comprising only 0.4 % of monsoonal tropics of the Northern Territory: Russell-Smith *et al.* 1992), largely restricted to small areas of permanently accessible water and/or topographic protection from fire (Russell-Smith 1991). Eucalypt forests and woodlands are the dominant landscape element in the higher rainfall north, but decline (typically gradually) in stature, basal area and canopy cover, and change in species composition, down the rainfall gradient (Williams *et al.* 1996; Bowman 1996; Bowman and Connors 1996). The tropical north also includes small areas of *Melaleuca* (paperbark) forests, typically on parts of the seasonally-inundated floodplains and lowland margins of watercourses. In the south, there are very extensive environments dominated by a range of *Acacia* (wattle) species, the most important being mulga *A. aneura*, gidgee *A. cambagei* and *A. georginae*, and lancewood *A. shirleyi*. These formations are typically tall shrublands, woodlands or thickets, rather than forest; however, lancewood formations have been included as forests within national assessments of forest status and management (e.g. Resource Assessment Commission 1992). Other notable treed environments in the arid and semi-arid areas include riparian open forests or tall woodlands dominated by river red gum *Eucalyptus camaldulensis*; open woodlands dominated by desert oak *Casuarina decaisneana* and by white cypress-pine *Callitris glaucophylla*; and shrublands and tall woodlands dominated by mallee eucalypts. In mid-rainfall zones, there are extensive areas of open woodlands dominated by nutwood *Terminalia arostata*, and to a lesser extent, other *Terminalia*, *Hakea* and *Grevillea* species.

In this paper, I concentrate particularly on the eucalypt forests of the monsoonal north of the Northern Territory, but include also some consideration of the other forest environments of the tropical north, and of eucalypt savanna woodlands. I describe briefly the state of knowledge of the fauna of these environments and the biogeographic patterning of this fauna. However, the focus is on the management of these forests and their biota. The central thesis is that the values of these forest environments are being diminished, mostly by relatively subtle but pervasive factors. There is little community awareness of this degradation largely because of their still vast extent, the gradual incrementalism of the loss and the lack of conspicuous causes.

The terminology relating to forest and woodland environments has been applied very inconsistently to vegetation in northern Australia. "Forest" and "woodland" are used almost interchangeably for many eucalypt formations. "Savanna" is used broadly to encompass almost all vegetation types in northern Australia, or far more narrowly to describe vegetation types where the tree layer, if present, is low and sparse, and functionally less important than a dense grass layer. Rainforests have been variably labelled monsoon forests, monsoon rainforests, jungles, and vine thickets. Definitions applied locally have been inconsistent with those applied at national levels, and with those in

neighbouring jurisdictions. These imprecisions can be confusing, but are relatively unimportant, especially because the Northern Territory has a well-established foundation of a well-recognised vegetation map and description, applying uniformly over the entire jurisdiction (Wilson *et al.* 1990), which has recently also been woven into a vegetation map across all jurisdictions of northern Australia (Fox *et al.* 2001).

The main forest environments

Mangrove forests

In an Australian context, the Northern Territory's mangrove forests are unusually diverse and extensive (Wightman 1989). They have been a highly dynamic environment over the last 15,000 years in response to pronounced changes in sea level, most notably with rapid retreat inland of the coastline from about 15,000 to 7,000 years ago, followed by less marked fall around 6,000 years ago, during which time some extensive mangrove forests disappeared from large areas of coastal plains (Russell-Smith 1985; Chappell and Thom 1986).

Over the last 50 years, mangrove communities have expanded significantly in some areas, due to increasing penetration of saline influences along many river systems (Eliot *et al.* 2000), and "saltwater intrusion" in some floodplain areas, largely because of the impacts of feral water buffalo *Bubalus bubalis* (Whitehead *et al.* 1990).

There has been little research devoted to the fauna of mangrove forests in the Northern Territory. The most notable published study is that of the community ecology of birds at one mangrove site near Darwin (Noske 1996). There have also been several studies of mangrove invertebrates (Clay and Andersen 1996; Nielsen 1997), and anecdotal records of some other mangrove animal species (e.g. the false water-rat *Xeromys myoides*: Magnusson *et al.* 1976). Current research includes PhD studies on the mangrove gerygone *Gerygone levigaster* (Y. Mulyani), mangrove monitor *Varanus indicus* (J. Smith) and on mangrove biodiversity more generally (K. Metcalfe).

A feature of the mangrove forests is the distinctiveness of their biota relative to most other regional environments (e.g. Woinarski *et al.* 1988). With the exception of local losses to urban and industrial development in Darwin Harbour, mangrove forests, and their associated fauna, are relatively unthreatened in the Northern Territory.

Monsoon rainforests

The Northern Territory rainforest network is small in total area and highly fragmented. These factors have militated against the retention or development of a rich, specialised fauna such as in the rainforests of north-eastern Australia (Kikkawa *et al.* 1981; Bowman and Woinarski 1994).

The flora of the Northern Territory rainforest network has been remarkably well surveyed, with more-or-less complete floristic lists for 1245 of the estimated 15,000 individual patches (Russell-Smith 1991; Russell-Smith *et al.* 1992; Liddle *et al.* 1994). Every individual patch greater than about 100 m² has been mapped (Russell-Smith *et al.*

1992). The fauna has been chronicled in less detail, but targeted surveys of 50-100 patches have provided sufficient information to describe distributional patterns, relative richness and compositional characteristics of the rainforest vertebrate and ant assemblage (Menkhorst and Woinarski 1992; Woinarski 1993; Gambold and Woinarski 1993; Reichel and Andersen 1996). The invertebrate fauna is far less well described than the vertebrate fauna, but includes some narrowly restricted specialist endemics (Anon 2002), as evident also from far more intensive sampling in the even more attenuated rainforest network in the Kimberley of north-western Australia (Solem and McKenzie 1991).

In addition to these inventories, there have also been more detailed ecological studies of the monsoon rainforest fauna. The most substantial was a landscape scale consideration of vertebrate frugivores (black flying-fox *Pteropus alecto*, and a suite of birds, particularly the Pied Imperial-Pigeon *Ducula bicolor*) and their relationship to spatial (between monsoon rainforest patches, and between patches and the surrounding extensive eucalypt open forests) and temporal variation in the seasonal fluctuations in fruit availability (Price *et al.* 1999; Palmer and Woinarski 1999; Palmer *et al.* 2000; Bach 2002). This multi-disciplinary study demonstrated the importance of these highly mobile vertebrate frugivores for the dispersal of monsoon rainforest plants, and thus the maintenance of floristic diversity within patches (Shapcott 1998a,b; 1999, 2000). The study also documented the need to maintain the archipelago of rainforest patches in order to maintain the dependent vertebrates: the loss of even single patches could destabilise the broader community (Price *et al.* 1999).

But simply maintaining monsoon rainforest patches is insufficient. Rainforests are relatively well represented in conservation reserves in the Northern Territory (Table 2), but threats to their conservation mostly pervade all tenure classes (Fig. 2), such that reservation extent is a misleading index of their security. There is broad-scale degradation of most patches by feral animals, inappropriate fire regimes and weeds (particularly exotic grasses, that form high fuel loads at the patch margin), acting independently or synergistically. In this case, rainforest condition is probably a sensitive indicator of the operation of threats applying

across the broader landscape. There is a little information on the impacts of this degradation on rainforest fauna (Braithwaite *et al.* 1984; Friend and Taylor 1984). The most substantial study demonstrated the at least short-term loss of a specialised fruit- and seed-eating rodent, the Arnhem rock-rat *Zygomys maini*, following a single fire in a rainforest patch (Begg *et al.* 1981). Modeling, based largely on results from this study, infers that such losses are likely to lead to at least local extinctions under regimes of frequent fire (Brook *et al.* 2002). The species most threatened by such degradation will be those with poorest ability to recolonise across the dominant matrix of eucalypt open forest from other rainforest patches, and those with most restricted distributions. Hence, it is unsurprising, but disconcerting, that five species of monsoon-rainforest dependent land snails are now listed as threatened in the Northern Territory (Anon 2002).

Melaleuca forests and woodlands

Melaleuca forests and woodlands occur mostly in seasonally waterlogged or inundated areas, especially in the floodplains of the lower reaches of the major river systems. These are floristically simple formations, typically being dominated by one or few species of *Melaleuca* (Cowie *et al.* 2000). A recent study (P. Brocklehurst pers. comm.) has provided detailed mapping of their extent and floristic composition. There has been some limited fauna inventory, typically within broader studies examining distributions of species across a range of locally available vegetation types (Martin and Freeland 1988; Woinarski *et al.* 1988; Friend and Cellier 1990; Morton and Brennan 1991; Braithwaite *et al.* 1991).

These studies suggest that the vertebrate fauna of Northern Territory *Melaleuca* forests is relatively species-poor, and contains no strictly endemic species (although a few species such as bar-breasted honeyeater *Ramsayornis fasciatus*, and paperback flycatcher *Myiagra (inquieta) nana* are mostly associated with these forests). There is strong seasonality in the faunal assemblages of *Melaleuca* forests, reflecting their exposure to seasonal flooding, and the limited floristic diversity, which dictates that resources (especially nectar) undergo extreme seasonal variability, typically being either superabundant or absent. In the

Table 2. Tenure status of broad forest and woodland classes in the Northern Territory. Note that forest and woodland categories differ from that given in Table 1 because this Table is based on the Northern Territory vegetation classification of Wilson *et al.* (1990), whereas Table 1 is based on a national overview.

vegetation class	area (km ²) (and % of total) in Northern Territory				
	total	pastoral leasehold	Aboriginal lands	conservation reserves	other tenure (e.g. military training areas, freehold, etc.)
rainforest	1,025	106 (10.3%)	630 (61.5%)	271 (26.4%)	18 (1.8%)
eucalypt open forest	57,133	3,729 (6.5%)	41,422 (72.5%)	7,529 (13.2%)	4,453 (7.8%)
eucalypt woodland	455,152	238,152 (52.3%)	137,990 (30.3%)	40,652 (8.9%)	38,358 (8.4%)
Melaleuca forest	1,539	200 (13.0%)	892 (58.0%)	431 (28.0%)	16 (1.0%)
Melaleuca woodland	13,275	6,241 (47.0%)	5,047 (38.0%)	1,126 (8.5%)	861 (6.5%)
mangrove	2,483	66 (2.7%)	2,183 (87.9%)	116 (4.7%)	118 (4.8%)
mixed species woodland	82,763	18,736 (22.6%)	60,337 (72.9%)	3,213 (3.9%)	477 (0.6%)
Acacia open forest	75,710	64,486 (85.2%)	9,466 (12.5%)	408 (0.5%)	1,350 (1.8%)

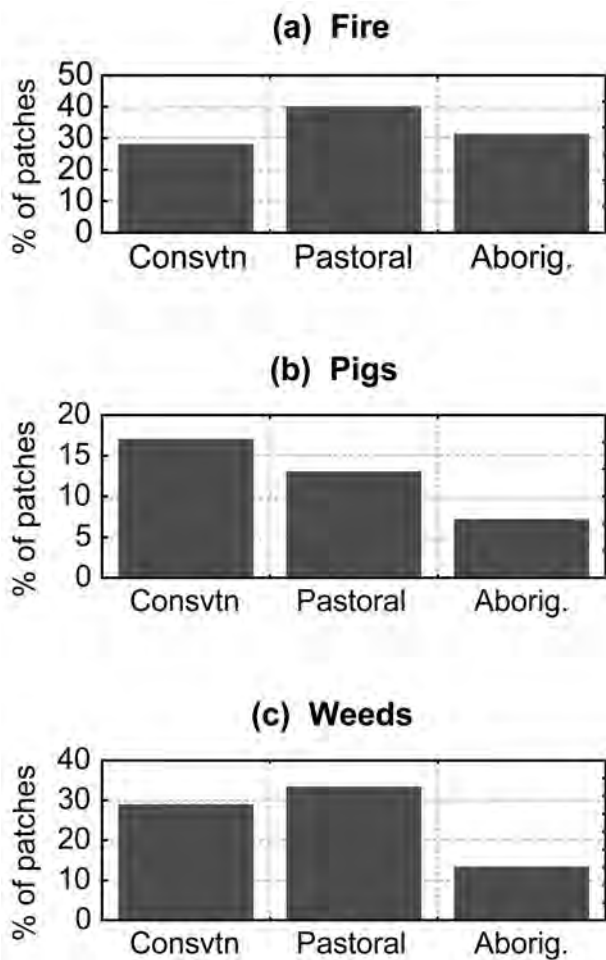


Figure 2. Histograms showing the percentage of rainforest patches that have been scored as "severely disturbed" by each of three disturbance agents - fire, pigs and weeds. Rainforest patches are also categorised according to land tenure, either as conservation reserves ("Consvtn"), pastoral leases or Aboriginal lands ("Aborig."), showing that condition is affected across all land tenures. Data from Russell-Smith and Bowman (1992). Note that the source document does not provide data for disturbance categories other than "severe", but that the majority of patches were scored with severe or minor disturbance for all three of these agents (J. Russell-Smith unpubl.).

north of the Northern Territory, *Melaleuca* species typically flower during months when few other plant species provide nectar resources (presumably largely because of their exposure to very different hydrological cycles). The rich and copious nectar produced in these typically dense forests of *Melaleuca* then serves as a keystone resource for nectarivores across the broad landscape, attracting nectar-feeding animals that otherwise occur mostly in contrasting habitats (Morton and Brennan 1991; Franklin and Noske 2000; Palmer *et al.* 2000; Woinarski *et al.* 2000a; Vardon *et al.* 2001). A broad range of other fauna, known to include some frog, reptile and mammal species, also uses *Melaleuca* forest as part of a seasonal cycle of habitat shifting in response to annual flooding events (Martin and Freeland 1988; Friend and Cellier 1990; Bowman and McDonough 1990; Morton and Brennan 1991; Braithwaite *et al.* 1991; Madsen and Shine 1996, 1999a,b).

Seasonally-flooded *Melaleuca* forests in the northern wetlands of the Northern Territory also support many nationally significant rookeries of a broad range of colonially-nesting waterbird species (Chatto 2000).

Melaleuca forests and woodlands may be highly unstable. Given that they typically occur at sites with very limited topographic variation, they are highly susceptible to broad-scale impacts of any threats introduced to the system. Over the last few decades, more than 6,000 ha of *Melaleuca* forests have been killed by saltwater intrusion (Sterling 1992): only major (and expensive) remedial engineering work has halted the process in the one system, the Mary River, for which pressure for management response has been strongest (Whitehead *et al.* 1990). Conversely, favourable timing and extent of wet season rains may trigger major episodes of *Melaleuca* germination, leading to cohorts expanding into grassland areas. This expansion has been far better documented in comparable environments of Queensland, where it threatens the most critical habitat for the endangered golden-shouldered parrot *Psephotus chrysopterygius* (Crowley and Garnett 1998), than in the Northern Territory.

As with most other vegetation types in the Northern Territory, the *Melaleuca* forests are being degraded by altered fire regimes, feral animals and weeds. However, there has been little detailed assessment of their impacts upon the fauna.

Riparian forests

At least partly because of their narrowly linear nature, riparian forests were not mapped, or considered as a distinct vegetation type, in the base vegetation mapping of the Northern Territory (Wilson *et al.* 1990). They are also a hybrid habitat, variably including mangroves, monsoon rainforests ("gallery forests"), *Melaleuca* forests, and eucalypt open forests, depending upon proximity to river mouth, topographic positioning and broad climate zone. There has been little systematic study of the vegetation of Northern Territory riparian forests. The most substantial study on their fauna is that of Woinarski *et al.* (2000b), which sampled birds at 100 riparian sites (and matched non-riparian sites), spread across much of the north of the Northern Territory. They reported that riparian forests were an important habitat for many birds, especially in relatively low rainfall areas, where they provide a distinctly contrasting suite of resources to that available in the surrounding landscape, and they allow many birds typical of higher rainfall areas to extend into drier regions. Other studies of riparian fauna include a demonstration of reducing density and diversity of invertebrates from aquatic channels, through riparian areas to open forests distant from watercourses (Lynch *et al.* 2002), and an assessment of the role of frogs as predators of aquatic invertebrates (Cappo 1986).

Riparian forests also provide important sites for nesting colonies of waterfowl (Chatto 2000) and camps of the flying-foxes *Pteropus alecto* and *P. scapulatus* (Vardon *et al.* 1997; C. Tidemann *et al.* 1999).

Probably more than for any other vegetation type, riparian forests have been affected by disturbance associated with European colonisation. Prior to the widespread development of artificial watering points (mostly since the 1950s), livestock drank directly from watercourses, and congregated around them in the shade provided by riparian forests. Even today, stock have unfettered access to watercourses on most pastoral properties, and many riparian areas have been substantially degraded (de Salis 1993). Weeds are now common in most riparian forests, and exotic species such as bellyache bush *Jatropha gossypifolia*, castor oil plant *Ricinus communis* and noogoora burr *Xanthium strumarium* are dominant in the understorey of many riparian forests. As with rainforest patches, riparian forests may also be particularly susceptible to the impacts of extensive wildfires that move from the open forests and savannas (Douglas *et al.* 2003).

However, unlike riparian systems in most other parts of Australia, the Northern Territory riparian systems are still underpinned by largely unmodified natural processes. There are no impoundments on the major Northern Territory rivers, no artificial channelisation, and relatively little off-take for irrigation or domestic uses. There is also little pollution (of sediments and nutrients) from cleared catchments and urban or industrial point sources.

Acacia woodlands

In the Northern Territory, *Acacia* formations vary gradationally from relatively tall woodlands and thickets to sparse low shrublands in response to climatic and edaphic factors. Greatest stature (averages of around 12 m canopy height and 10 m²/ha of basal area for dense stands: Woinarski and Fisher 1995a) is achieved in woodlands dominated by lancewood *A. shirleyi*, occupying an area of about 24,000 km² across a band between latitudes 14 and 18°S (around 550-950 mm annual rainfall), typically on Tertiary lateritic surfaces.

The vertebrate fauna of lancewood woodlands is now comparatively well known, through an inventory of 61 patches by Woinarski and Fisher (1995a,b). This fauna is relatively impoverished and contains no endemic species, although there is a small set of species (including hooded robin *Melanodryas cucullata*, apostlebird *Struthidea cinerea*, grey-crowned babbler *Pomatostomus temporalis*, and the geckoes *Diplodactylus ciliaris* and *Oedura rhombifera*) that are substantially more abundant in lancewood woodlands than in the broader surrounding matrix of eucalypt woodlands. In most cases, this is because these species favour the understorey in lancewood woodlands (sparse grass but dense leaf litter) rather than the dense grass layer typical of the eucalypt woodlands.

A major scheme to harvest lancewood was initiated in 1989, with the prospect of harvesting 360,000 tonnes over a 5-year period (Woinarski and Dawson 2001). The scheme collapsed within a few years, largely because of unrealistic estimates of markets, and of timber quality and quantity; and the total material cut was only about 200 t (Woinarski and Dawson 2001). Lancewood woodlands continue to be affected by less acute threats, most particularly by increasing frequencies

of intense wildfire (Woinarski and Fisher 1995a). Only a very small proportion (<1%) of these woodlands is represented within conservation reserves. Most is on pastoral leasehold, in which there is an increasing trend for broad-scale introduction of the exotic buffel grass *Cenchrus ciliaris*, known elsewhere to substantially diminish biodiversity richness and values (Franks 2002).

There has been no comparable systematic study of the fauna of the other main *Acacia* woodland formations in the Northern Territory, mulga *A. aneura* and gidgee *A. cambagei* and *A. georginae*. However, aspects of this fauna have been considered within broad inventory studies (e.g., Reid *et al.* 1993), localised studies of particular groups of vertebrates (e.g., Recher and Davis 1997), and with limited sampling in the Northern Territory as part of studies extending to other States (Cody 1994). The conservation and management problems of these formations are generally similar to those of lancewood, except that gidgee formations have had some measure of protection from intensive pastoralism, because of their toxicity to stock. Mulga communities are mostly monopolised by pastoral use, and the exotic buffel grass is spreading rapidly, with consequent increases in the intensity and extent of fires.

Eucalypt forests and woodlands

Eucalypt forests and woodlands form the major fabric of the northern half of the Northern Territory. There is extensive floristic (Bowman *et al.* 1991, 1993) and structural (Williams *et al.* 1996) variation in these eucalypt formations. However, this variation is generally gradational and typically played out over very large distances (Fig. 3). The characteristic eucalypt forests are those dominated by either or both of Darwin stringybark *Eucalyptus tetrodonta* and Darwin woollybutt *E. miniata* (Fig. 4), which extend almost unbroken over more than 180,000 km² in the Northern Territory alone (Wilson *et al.* 1990), and also occupy large areas of northern Western Australia and north Queensland.

As befitting their status as the principal landscape element, many aspects of the vegetation ecology of these forests have been described, including phenological patterning (Williams *et al.* 1997, 1999a; O'Grady *et al.* 2000); water and soil relations (Bowman and Minchin 1987; Wilson and Bowman 1994; Myers *et al.* 1997; Prior *et al.* 1997; Hatton *et al.* 1998; Prior and Eamus 1999); floristic variation and its association with a range of environmental factors (Langkamp *et al.* 1981; Burgman and Thompson 1982; Bowman and Wightman 1985; Bowman and Dunlop 1986; Bowman 1986; Wilson and Bowman 1987; Kirkpatrick *et al.* 1987, 1988; Bowman and Minchin 1987; Fensham and Kirkpatrick 1992; Bowman *et al.* 1993; Wilson and Bowman 1994); allometry and biomass (O'Grady *et al.* 2000; Werner and Murphy 2001); and response to storm and cyclone (Wilson and Bowman 1987; Williams and Douglas 1995), to elevated CO₂ (Eamus *et al.* 1995a,b), to fire (Haynes 1985; Bowman *et al.* 1988; Fensham 1990; Bowman and Panton 1995; Williams *et al.* 1999b; Russell-Smith

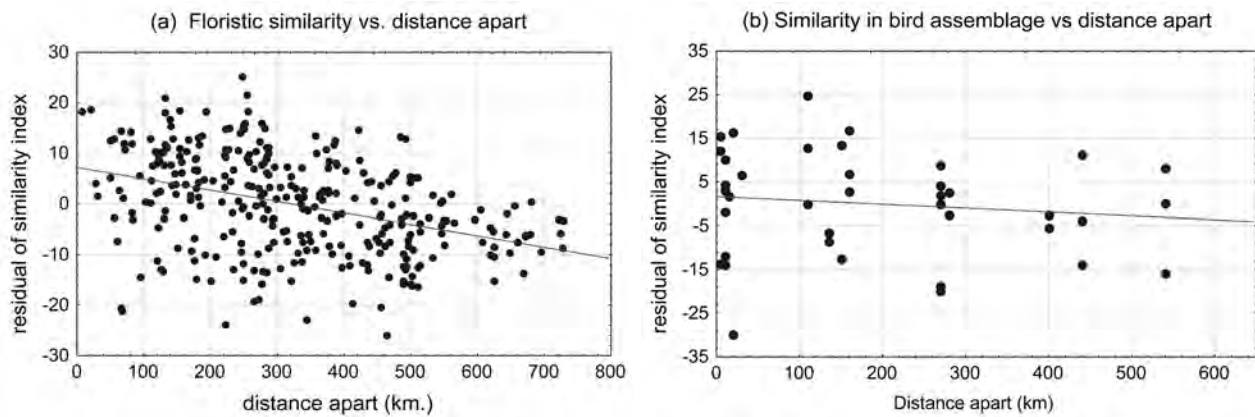


Figure 3. The Northern Territory eucalypt forests extend almost uniformly over vast areas. The graphs here illustrate the very limited floristic and faunal change over very large areas. Both graphs are based on information presented in Woinarski *et al.* (submitted, b). At a series of sites located in eucalypt forests across the north of the Northern Territory, complete inventories of plants and vertebrate animals were made. Similarity indices were calculated between each pair of sites. Differences in annual rainfall explained much of the variation in this similarity, but the residuals after annual rainfall was taken out are well related to the geographic distance between the site-pairs. The slope of this relationship is extremely gradual, illustrating a very minor turnover in species composition across very extensive areas, once annual rainfall is controlled for. At this rate, a complete turnover in plant species composition would require a geographical separation of about 4000 km.



Figure 4. The most extensive forests in the Northern Territory are those co-dominated by Darwin stringybark *Eucalyptus tetradonta* and Darwin woollybutt *E. miniata*. This photograph shows such a forest on Melville Island, where extensive areas are being cleared for establishment of plantations of exotic timber species. (photograph: Craig Hempel)

et al. in press; Edwards *et al.* submitted; Woinarski *et al.* submitted, a), to aspect and solar radiation (Kirkpatrick *et al.* 1988; Fensham 1990) and to overstorey removal (Fensham and Bowman 1992). Apart from an important early characterisation (Bowman 1988), there has been no attempt to collate and synthesise these components into a coherent and comprehensive description of the ecology of these forests.

Likewise, there has been no substantial account of the ecology of the fauna assemblages of these eucalypt forests, however many individual components have been described. These include a comparison of the composition of some faunal groups with that of temperate eucalypt forests (Keast 1985; Woinarski *et al.* 1997); comparisons of the composition and abundance of some faunal groups with that of other, contrasting vegetation types within

the region (Braithwaite 1985; Kerle and Burgman 1984; Woinarski *et al.* 1988, 2000b; Menkhorst and Woinarski 1992; Woinarski 1993; Gambold and Woinarski 1993; Woinarski and Fisher 1995b; Andersen *et al.* 2000b); relationships of the distribution and abundance of particular species, or groups of species, to environmental variation within these forests (Friend and Taylor 1985; Kerle 1985); use of hollows by fauna (Taylor *et al.* in press); responses of groups of species to phenological patterning (Franklin 1997; Franklin and Noske 1998, 1999; Palmer and Woinarski 1999; Palmer *et al.* 2000; Vardon *et al.* 2001); autecological studies of some characteristic species (e.g. brushtail possum *Trichosurus vulpecula* (Kerle 1985, 1988; Kerle and Howe 1992), black-footed tree-rat *Mesembriomys gouldii* (Friend 1987), northern brown bandicoot *Isodon macrourus* (Friend 1990), and frillneck lizard *Chlamydosaurus kingii* (Griffiths and Christian 1996a,b; Griffiths 1999)); and responses of individual species or groups of species to fire (Kerle 1985; Woinarski 1990; Andersen 1991b; Trainor and Woinarski 1994; Griffiths and Christian 1996a.; Andersen and Muller 2000; Andersen *et al.* 2001; Pardon *et al.* 2003; Woinarski *et al.* submitted, a).

These studies indicate that there are some features that make the ecology and management of these eucalypt forests distinctive. The *Eucalyptus miniata*/*E. tetradonta* forests are unusually homogeneous (Woinarski *et al.* submitted, b), and extend almost unbroken over vast areas, allowing many species to occupy very extensive ranges (Fig. 3), but accentuating the need to protect and bolster the limited environmental heterogeneity. Ant diversity is phenomenally high compared with temperate eucalypt forests and with tropical forests and savanna woodlands on other continents (Andersen 1992, 2000). The two dominant eucalypts provide vast nectar sources during much of the dry season, a pivotal resource for many vertebrate and, presumably, invertebrate, species (Franklin 1997; Franklin and Noske 1998, 1999; Woinarski *et al.* 2000a). The density and diversity of folivorous mammals is low relative to that in eucalypt forests of temperate Australia. This is presumably because the northern forests have relatively low leaf area and their dominant eucalypts are phylogenetically distant (and hence probably possess very different nutrient content and defensive compounds) from those eucalypts most favoured by folivorous mammals in eucalypt forests elsewhere in Australia (Woinarski in press, a). Understoreys in these forests are typically dominated by dense cover of tall grasses ("savanna") rather than by a mid-storey diverse shrub layer (although the typically sparse shrubs present are an important source of fruits for many vertebrate species), thus granivores are a major component of bird, mammal and invertebrate assemblages (e.g. Franklin *et al.* 2000; Andersen *et al.* 2000a).

These forests continue to support many species that have declined or disappeared (or whose close relatives have disappeared) in forests and woodlands elsewhere in Australia (e.g. brush-tailed rabbit-rat *Conilurus penicillatus*, bush stone-curlew *Burhinus grallarius*). Notwithstanding this asset, there are increasing signs of decline across a range of mammal and, to a lesser extent, bird species (Franklin 1999; Woinarski *et al.* 2001a).

The conservation management issues for these northern forests are generally unlike those elsewhere in Australia. Here, we have the extraordinary asset of extensive forest continuing unbroken across vast areas, and responding to natural ecological processes little changed over thousands of years. It is a rich legacy. But even as we seek to highlight that value, we also increasingly recognise that the systems are being eroded.

The ecology of these forests is buffeted and shaped by frequent fire (currently with any site having a probability of about 0.5 of being burnt in any given year: Gill *et al.* 2000). However, notwithstanding some extremely detailed and long-term research on the responses of biota to fire regimes (Andersen *et al.* 2003; Williams *et al.* in press), we are still finding it hard to make clear prescriptions for fire regimes that optimise biodiversity outcomes, and land managers do not necessarily see these recommendations as appropriate for their own use of fire and/or are not necessarily capable of delivering those regimes. For example, in the Northern Territory, the common brushtail possum *Trichosurus vulpecula* is one of a group of species that occurs preferentially in forest areas that are relatively long-unburnt (Kerle 1985; Woinarski in press; Woinarski *et al.* submitted, a), presumably because these support higher densities and larger crops of fruit-producing understorey plants (Williams *et al.* 1999a), may have more hollows and large trees, and generally have understoreys with less dense grass, allowing for easier foraging and movement. But the contemporary high frequency and large extent of fires renders such areas vanishingly small. Even within the well resourced Kakadu National Park, with its detailed fire management plan, only about 1% of the eucalypt forest landscape has been unburnt for 10 or more years, and only about 5% has been unburnt for 5 to 9 years. The areas of highest suitability for this species (and others that share its habitat preference) are now few, highly isolated, and liable to twinkle out according to the caprice of fire in any year (Fig. 5). Management of fire in this environment is not easy.

The marked seasonality dictates that fire is a recurring unavoidable feature, and most managers and researchers note that the choice is between frequent intricate fires to break up the landscape, or neglect with the attendant risk of far more extensive uncontrolled fire, with the latter leading to greater homogenisation of the landscape. In the eucalypt forests, the conservation advantage is assumed to be with the former (Yibarbuk *et al.* 2001; Bowman *et al.* 2001; Pardon *et al.* 2003; Woinarski *et al.* submitted, b), but the evidence is still somewhat scanty; and the simple dichotomy of management options may need to be re-shaped, or made more sophisticated, to provide for species such as the common brushtail possum.

More so than for any other Australian jurisdiction, fire management in the forests of the Northern Territory is on the knife-edge of major change. Elsewhere, the burning regimes imposed for tens of thousands of years by Aboriginal people have largely been lost or supplanted, forcing a new forest equilibrium. In the Northern Territory, there are still large areas where the traditional regime has persisted (e.g. Haynes 1985), or has been lost so recently

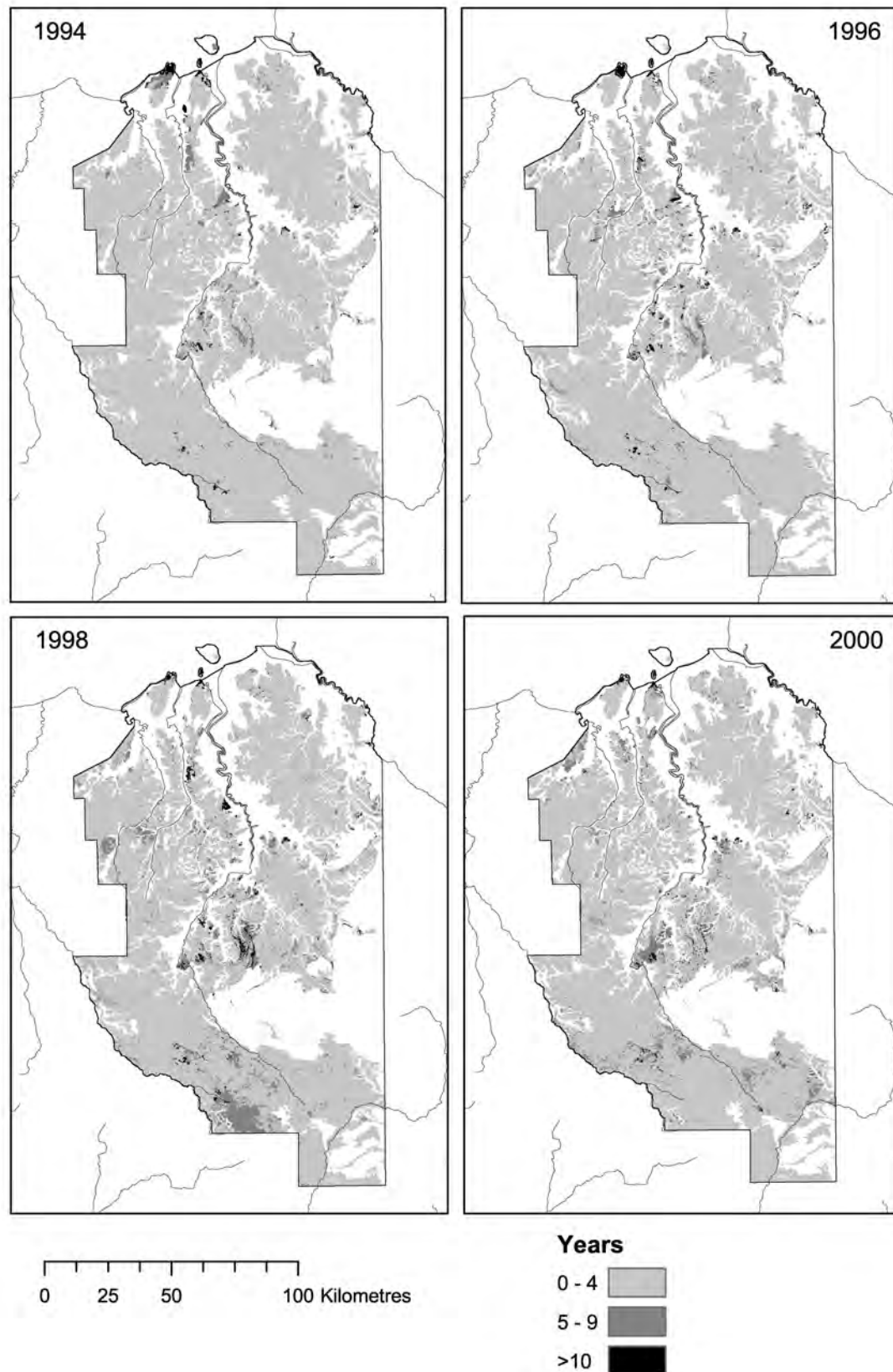


Figure 5. The occurrence of eucalypt forests and woodlands of different ages since fire at Kakadu National Park. Note that all other vegetation types are excluded. Areas that have been unburnt for at least 10 years are shaded black, those that have been unburnt for 5-9 years are shaded dark grey, and those that have been unburnt for 0-4 years are shaded light grey. Note that there are only very small pockets of “long” unburnt eucalypt forests, in this case, mostly connected with major ecological research plots, and that the location of these “long” unburnt patches is very inconstant in the landscape. Data taken from long-term satellite images of fire history at Kakadu NP (A. Edwards, J. Russell-Smith and G. Connors pers. comm.).

that the equilibrium is rapidly crumbling (Bowman *et al.* 2001). This forces a hard choice on forest managers, as the traditional regime relied on a relatively high density of people living intimately with the landscape, and responding intricately to fuel loads, rainfall and other dynamic signs to determine where and when fires could be lit. The systems have also been subverted by the introductions of exotic grasses and feral animals, which conspire to alter the consequences of traditional burning pattern.

Compared with the national value of about 15% of the total flora (State of the Environment Advisory Council 1996), the proportion of exotic plants in the Northern Territory flora is currently relatively low (5.2%: Bowman *et al.* 1988). In the Northern Territory's largest conservation reserve, Kakadu National Park, introduced species make up about 5.3% of the flora (Cowie and Werner 1993). Notwithstanding this relatively low proportion in terms of species richness, increasingly large areas of the eucalypt forests are being invaded by a set of landscape-altering weeds (principally African pasture grasses - notably gamba grass *Andropogon gayanus* and mission grass *Pennisetum polystachion*: Kean and Price 2003], that introduce far greater fuel loads than native grasses, and cure later in the dry season, thereby producing far more destructive fires (Dyer *et al.* 2001).

Unfortunately, some of the acute pressures faced in forests in other States are also now affecting Northern Territory eucalypt forests. From a low current level (across the Northern Territory, about 1% of lands have been cleared), the rate of clearing is increasing and there are proposals to greatly magnify this rate (Brock 2001). The very extent of the eucalypt forests is seen to excuse the impacts of clearing proposals: large areas can be cleared because very large areas remain uncleared (Woinarski and Dawson 2001). Eucalypt forests in three areas are currently most targeted for clearing. On Melville Island, plantation forestry has a chequered history extending back to the 1950s. The eucalypt forests here are among the best developed in the Northern Territory, because rainfall is highest and soils are deep, and these factors have particularly encouraged forestry proposals. Many of these forestry ventures have foundered, for a range of social, economic and environmental reasons. Timber of the eucalypts is typically of poor quality and slow growing, and the biomass in native forests is modest. Attempts to replace native forests with wood plantations of exotic species have had very mixed success, but a current project has been permitted to clear 30,000 ha of native forest for the establishment of plantations of the exotic *Acacia mangium* (Woinarski *et al.* 2000c; Brock 2001). Assessment of the proposal has been somewhat complicated by land tenure, with the entire island being Aboriginal freehold land.

Horticultural expansion is the main driver in the other two areas where forest clearing is concentrated, the Daly Basin and the Darwin-Litchfield area. In the Daly Basin, about 1500 km² (8% of the extent) has already been cleared, and current proposals seek to greatly expand this (Price *et al.* 2002). In the Darwin/Litchfield area, about 220 km² has been cleared, and this is rapidly escalating. In all three regions, the tall eucalypt forests are taking the brunt of the development.

Beyond the *Eucalyptus miniata*/*E. tetradonta* forests, eucalypt woodlands (variously dominated by one or more species from a large number of *Eucalyptus* and/or *Corymbia* species) extend into lower rainfall areas, rocky areas and finer-textured soils (Wilson *et al.* 1990; Bowman *et al.* 1991, 1993). The vertebrate fauna changes gradually in association with the typically gentle gradients of canopy height, basal area and floristic change, and substrates (Woinarski *et al.* 1988, 1992, 1999a; Woinarski and Gambold 1992), and most vertebrate groups decrease in richness from the eucalypt forests of high rainfall areas to the woodlands of lower rainfall areas (Woinarski *et al.* 1999a). There has been relatively little attention directed at the fauna of these woodlands. The most substantial systematic study considered the bird assemblage at a deciduous eucalypt woodland near Katherine (Woinarski 1990; Woinarski and Tidemann 1991: Fig. 6). Along with alpine eucalypt communities, these are the most seasonal of eucalypt environments in Australia, and the bird assemblage is correspondingly extraordinarily dynamic (Woinarski and Tidemann 1991; Franklin 1996; Dostine *et al.* 2001). Granivorous birds are even more prominent in these savanna woodlands (but arboreal rodents and marsupials even less abundant and diverse) than in the *Eucalyptus miniata*/*E. tetradonta* forests (Tidemann 1990; Franklin *et al.* 2000; Woinarski in press, a), reflecting the far less substantial tree layer, but highly diverse and dense grass layer.

Much of the eucalypt woodland has been devoted to extensive pastoralism, with largely unchronicled impacts upon the fauna. Evidence from eucalypt woodlands elsewhere in Australia's monsoon tropics suggests that these impacts may be substantial (Woinarski and Ash 2002; Woinarski *et al.* 2002a; Woinarski and Catterall in press). It is likely that vegetation change due to the impacts of pastoralism and altered fire regimes has led to broad-scale decline in some vertebrate species, such as the Gouldian finch *Erythrura gouldiae* (Tidemann 1990; Franklin 1999). More so than for the eucalypt forests, the eucalypt woodlands appear to have lost much of their small and medium-sized mammal fauna, probably over the last 50 or so years (Kitchener 1978; Johnson and Southgate 1990; Braithwaite and Griffiths 1994; Woinarski 2000; Woinarski *et al.* 2001a), and diversity in this assemblage is now typically extremely low (Catling *et al.* 1999; Woinarski *et al.* 1999a).

Vegetation change in the savanna woodlands includes "thickening" (increased tree cover) in at least some areas (Lewis 2002), presumably with attendant broad-scale increases of fauna species preferring denser woodlands and decreases in those preferring more open areas (Woinarski *et al.* 1999b). On the other hand, some eucalypt woodlands have been cleared, mostly for the introduction of exotic grasses (most pervasively buffel grass *Cenchrus ciliaris*, but also gamba grass in higher rainfall areas) as "improved" pasture. While the extent of such clearing in the Northern Territory savanna woodlands is low relative to that in comparable habitats in Queensland, the limited information available suggests that this rate is increasing (Hosking 2002).



Figure 6. Extreme seasonality controls the ecology of most forest fauna in the Northern Territory. This photograph shows one of the manifestations of this seasonality - a completely deciduous eucalypt woodland (dominated by *Eucalyptus tintinnans*). Such deciduousness is most unusual in Australian forests and woodlands, and places obvious seasonal resource constraints on some faunal groups, including folivorous mammals and invertebrates and birds that glean invertebrates from foliage (photograph: Michelle Watson).

Discussion: looking back and forward

There have been major advances in knowledge of the Northern Territory forest fauna since the review by Bowman (1991).

Over that time, systematic studies have detailed the character of the fauna of monsoon rainforests, riparian forests, and lancewood woodlands (Menkhorst and Woinarski 1992; Gambold and Woinarski 1993; Woinarski 1993; Woinarski and Fisher 1995a,b; Reichel and Andersen 1996; Woinarski *et al.* 2000b). Systematic surveys have provided a detailed inventory of most forested regions, including the previously poorly known Tiwi Islands (Woinarski *et al.* 2000c), island chains off north-eastern Arnhem Land (Woinarski *et al.* 1998, 1999c,d, 2001b), central Arnhem Land (Brennan *et al.* in press), the Daly Basin (Price *et al.* 2002), and parts of the Victoria River District (Woinarski *et al.* 1999b; Fisher and Woinarski 2002); and the bird fauna of Groote Eylandt has been thoroughly documented (Noske and Brennan 2002). There have been major advances in knowledge of the invertebrate fauna of forests and woodlands, particularly for ants (Andersen 1991a, b, 1992, 2000; Clay and Andersen 1996; Andersen *et al.* 2000a), but also for beetles (Blanche *et al.* 2001), grasshoppers (Andersen *et al.* 2000b, 2001) and other invertebrate groups (Andersen and Muller 2000).

The Kapalga Fire Experiment, one of Australia's largest research and management studies, has been undertaken (Andersen *et al.* 1998, in press), and results from this and many other studies are now influencing the management of fire across northern Australia (Dyer *et al.* 2001).

A series of studies has examined fauna ecology at a landscape scale, and the way in which particular species, or groups of species, respond to the major seasonal variation in the distribution and abundance of food resources (Price *et al.* 1999; Franklin and Noske 1999; Palmer and Woinarski 1999; Palmer *et al.* 2000; Vardon *et al.* 2001; Dostine *et al.* 2001). Such studies have been bolstered and increasingly well informed by information on the flux of the resources themselves (Williams *et al.* 1999a; Bach 2002), testimony to the strong collaborative and inter-disciplinary nature of research in this community. Knowledge of the seasonal variation in resources has been related to the breeding seasons of Northern Territory forest birds (Noske and Franklin 1999), and a series of studies has considered the influence of resource variation and climatic seasonality on the ecology of a range of reptile species (Christian and Bedford 1995, 1996; Christian and Green 1994; Christian *et al.* 1995, 1996a,b, 1999).

For the first time in this jurisdiction, the conservation status of all vertebrate, and many invertebrate, species has been thoroughly reviewed (Anon 2002), and there have been detailed reviews of the status of groups of species, including granivorous birds (Franklin 1999), rodents (Woinarski 2000) and possums (Woinarski in press, a).

The large array of systematically surveyed sites (>10,000) now provides a firm baseline for ongoing monitoring, and a series of monitoring programs is now underway (Woinarski *et al.* 2002b; A. Fisher pers. comm.).

In addition to the large body of work on the impacts of fire, current studies are considering the response of the fauna to invasion by exotic pasture grasses (PhD study by K. Beggs), pastoralism (A. Fisher *pers. comm.*), clearing and habitat fragmentation (Rankmore and Price 2003), spread of cane toads (PhD study by M. Watson), and harvesting of timber for digeridoo production (H. Puckey *pers. comm.*). The number of autecological studies remains relatively low, but current studies consider the forest-dependent brush-tailed rabbit-rat *Conilurus penicillatus* (PhD study by R. Firth), purple-crowned fairy-wren *Malurus coronatus* (PhD study by A van Doorn), common brushtail possum *Trichosurus vulpecula* (BSc. (Hons.) study by G. Pitman), black-footed tree-rat *Mesembriomys gouldii* (PhD. study by B. Rankmore), mangrove monitor *Varanus indicus* (PhD study by J. Smith), carpentarian rock-rat *Zyromys palatalis* (H. Puckey *pers. comm.*), gove crow butterfly *Euploea alcathoe enastri* (C. Wilson *pers. comm.*), microchiropteran bats generally (MSc. study by D. Milne), and mangrove gerygone and large-billed gerygone (PhD study by Y. Mulyani). Substantial studies completed since Bowman's (1991) review include those on frilled lizard (Christian and Green 1994; Christian and Bedford 1995; Griffiths and Christian 1996a,b; Christian *et al.* 1996a; Griffiths 1999), the agamid lizard *Lophognathus temporalis* (Christian *et al.* 1999; Blamires and Christian 1999), spotted tree monitor *Varanus scalaris* (Christian *et al.* 1995, 1996b; Christian and Bedford 1996), agile wallaby *Macropus agilis* (Stirrat 2000, 2002, in press), carpentarian rock-rat (Churchill 1996; Trainor *et al.* 2000; Brook *et al.* 2002), northern brown bandicoot (Pardon *et al.* 2003), northern quoll *Dasyurus hallucatus* (Braithwaite and Griffiths 1994; Oakwood 1997, 2000, 2002; Oakwood *et al.* 2001), black flying-fox *Pteropus alecto* (Vardon *et al.* 1997, 2001; C. Tidemann *et al.* 1999; Palmer and Woinarski 1999; Palmer *et al.* 2000), partridge pigeon (Fraser 2001), harvester ants (Andersen *et al.* 2000a), mangrove ants (Nielsen 1997), gouldian finch (S. Tidemann *et al.* 1992, 1999; Tidemann 1996; Dostine *et al.* 2001; Dostine and Franklin 2002), rufous-banded honeyeater *Conopophila albogularis* (Noske 1998) and mangrove gerygone (Noske 2001).

While this research activity is admirably fertile, research progress has come at the same time as the conservation outlook darkens. Over the decade or so since the previous review (Bowman 1991), many landscape scale management issues have deteriorated. Many of these detrimental changes have been occurring gradually and cumulatively for at least 50 years or longer (Woinarski in press, b), but the biodiversity impacts seem to be becoming more consequential, possibly as thresholds unknown to us are exceeded. There is also increasing penetration of weeds, feral animals and other agents of degradation into the remote "wilderness" areas, far from the main population centres (Bowman *et al.* 2001). Almost imperceptibly, but pervasively, all forest environments are losing their integrity.

The spread of exotic pasture grasses and other weeds into forests and woodlands has been rapid and is now almost unstoppable (Kean and Price 2003), and this invasion has re-shaped ecological processes (Lonsdale 1994). Vigorous opposition by some community groups and ecologists

(e.g. Smith 2002), backed by ecological research (e.g. Whitehead 1999; Whitehead and Dawson 2000), has finally led to a stop on the advocacy by the primary industries agency of planting of the most environmentally damaging of these species (such as gamba grass), but other exotic plants have been substituted, and the proselytisation to "improve" the pastoral productivity of the landscape continues unabashed. Some of the exotic plants most detrimental to biodiversity (e.g. buffel grass, para grass) continue to be excluded from regulations listing proscribed weeds (e.g. Anon 2003), presumably because of their putative value to pastoralism.

Across much of the north of the Northern Territory (and particularly Arnhem Land), the density of large feral animals (particularly pigs and water buffalo) was checked by the major control effort of the Brucellosis and Tuberculosis Eradication Campaign from 1987 to 1991 (Boulton and Freeland 1991) in order to provide a disease-free guarantee for beef exports to the United States. Following its initial success at meeting the export regulatory goals, the BTEC campaign folded in 1991, and populations of feral animals have largely returned to their former high levels. Cane toads *Bufo marinus* have colonised the eastern half of the Top End (now including most of Arnhem Land) in the last decade, and, at the current rapid rate of advance, are likely to occupy all of the mainland north of the Northern Territory within the next three years. Exotic ant species (principally the big-headed ants *Pheidole megacephala* and crazy ants *Anoplolepis gracilipes*) with the capacity to cause major environmental disruption are expanding their range far beyond initial urban source areas (Hoffmann 1998; Hoffmann *et al.* 1999; Young *et al.* 2001). There also seems to have been an increase in the distribution of the exotic black rat *Rattus rattus*, to now include forest areas remote from urban sources (Griffiths 1997; Woinarski *et al.* 2002b).

The rate of vegetation clearance has increased substantially over the last decade (Brock 2001; Hosking 2002), with targets particularly in the tall *Eucalyptus miniata*/*E. tetradonta* forests. Notwithstanding a major outlook paper on the development of an enhanced national park system (Anon 1997), there have been very few new national parks or increases in the conservation reserve estate over the last decade, and the total proportion of reserved area in the Northern Territory (3.8%) remains the lowest of any Australian jurisdiction.

Presumably in response to this cocktail of environmental decay, we appear to be witnessing a decline in the abundance of many bird and mammal species across large areas of forest and woodland habitats (Woinarski *et al.* 2001a).

Perversely, the very extent, continuity and homogeneity of the Northern Territory landscapes has proven to be a weakpoint, as threatening factors spread unhindered across the landscape (Woinarski *et al.* submitted, b). In many ways, the type of acute change that has so remodelled forest environments elsewhere in Australia would be easier to manage. Such changes provide a clear focus (such as the Comprehensive Regional Assessment and Regional Forest Agreement process widely used elsewhere in Australia), are conspicuous, and can be dealt with by land-use decision-making processes that

can allocate lands into secure conservation areas and sacrificed areas. There is no similar stimulus and crucible in the Northern Territory, whereby managers have the resources and requirement to provide a detailed forest audit, to document the forest values, to describe and evaluate threatening processes and their management, and to engage landholders in a consultative planning process. There is still no Government strategy, policy or specific legislation for the use, management and conservation of the Northern Territory's forests, at either jurisdiction or regional level.

Fortunately, there have been some advances and successes in forest management. The first vegetation clearance legislation for freehold lands was enacted in December 2002. Although still clearly problematical, fire management is becoming increasingly effective on most conservation reserves (Edwards *et al.* 2001, submitted), and even on some unreserved lands (Dyer *et al.* 2001). There has been a rapid development of community ranger schemes across large areas of Aboriginal lands, charged mainly with maintenance and application of traditional ecological knowledge and weed control (Davies *et al.*, n.d.). There has been sustained effort to ameliorate the impacts of some weed species, particularly the highly invasive tropical American shrub *Mimosa pigra*. There is now an increasingly strategic approach to regional planning in the Northern Territory, and biodiversity values are now sufficiently well known to be considered in a mature and effective manner in this process.

There is a gradually increasing national recognition of the conservation value of the extensive relatively natural systems of northern Australia, of how these values cannot be presumed to be maintained simply because these environments are not grossly disturbed, and of how the resources needed to maintain these environments are relatively meagre compared with those needed to prop up forest systems elsewhere in Australia (National Land and Water Resources Audit 2002).

Given the shifting framework of management priorities, what should be the main features of the research and management agenda relating to forest fauna henceforth? Admitting to being not disinterested, I suspect that the current research portfolio is reasonably strategic. We have progressed substantially on assessing biodiversity values, and the response of these to the main threatening processes, and towards devising management regimes that can best combat these threats. Given the scale of Northern Territory conservation issues, there is a persistent need for studies to be undertaken at a broad landscape scale, in which the knit of various landscape elements is adequately considered. There is a priority for more research on the ecology of species that depend upon and exploit landscape heterogeneity. There is a need for far more detailed environmental mapping. In many forest and woodland environments in the Northern Territory, the 1:1,000,000 scale vegetation map of Wilson *et al.* (1990) is the best, or only, product available. This map is an extraordinarily useful resource for planning at regional and jurisdiction scales, but becomes almost useless for more local planning. Currently, it is generally not possible to describe the extent of existing vegetation clearance,

nor to evaluate clearing proposals, against vegetation mapping at finer scales. This is unacceptably crude. While our knowledge of the Northern Territory vertebrate fauna has increased substantially since Bowman's (1991) review, it is still thin. For example, a large series of wildlife surveys over the last five years on the Tiwi Island group (Bathurst and Melville Islands) failed to detect any individuals of the endemic subspecies of hooded robin *Melanodryas cucullata melwillensis*. It appears to have declined rapidly over the last few decades, possibly now to extinction, while we were unaware of its plight; and it is still not even listed as threatened under the *Environment Protection and Biodiversity Conservation Act 1999*. Across much of the Northern Territory, many other forest and woodland animal species appear to be declining rapidly, disappearing before we have had the opportunity to understand their ecology or plight, let alone develop appropriate management responses. The ecology and status of many invertebrate groups and some vertebrate groups (notably microchiropteran bats) remains poorly known.

The distinctive land tenure arrangement in the Northern Territory, where nearly half the land area is held as inalienable Aboriginal lands and nearly half as pastoral leasehold, imposes clear directions for conservation management priorities: on pastoral lands, to develop and encourage the uptake of management practices that will maintain biodiversity values, and on Aboriginal lands, to provide adequate resources for traditional Aboriginal landowners to manage their lands. It is heartening that, despite an array of new problems, there has been much progress in these two directions since the outlook presented in Bowman (1991).

In general, forest and woodland landscapes in the Northern Territory occur on lands of relatively low productivity and economic potential. In some ways, this makes their retention relatively more straightforward and cheaper than comparable forests in temperate Australia. But the low human population density (1 person per 10 km² for the Northern Territory as a whole) and typically meagre economic base means that there are few resources available for the extensive land management (e.g. weed surveillance and control) now needed. However, given the few economic and employment alternatives, any resources available for land management may be highly significant in many disadvantaged communities, such as many remote Aboriginal settlements. A little money for land management may go a long way. The relatively poor economic prospects in many forest and woodland areas in the Northern Territory have stimulated consideration of options for bioprospecting and sustainable economic use of fauna and forest products (e.g. Webb and Manolis 1993). While there have been some limited successes with a few species with well-established markets (most notably the saltwater crocodile *Crocodylus porosus*), such schemes have generally not yet demonstrated clear viability.

I see the other main priority as to continue to strive to change the public perception of the north Australian forests and woodlands. Many see these as a surfeit of the ordinary; and few see them as an extraordinary asset of one of the world's largest continuous forest environments.

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