GREG MILES

THE FLAME OF CONVENIENCE

Early dry season burning on trial in Kakadu and the western Top End of the Northern Territory

WHERE HAS ALL OUR WILDLIFE GONE?

This book adds another piece to the jigsaw of our understanding of wildlife declines in northern Australia.

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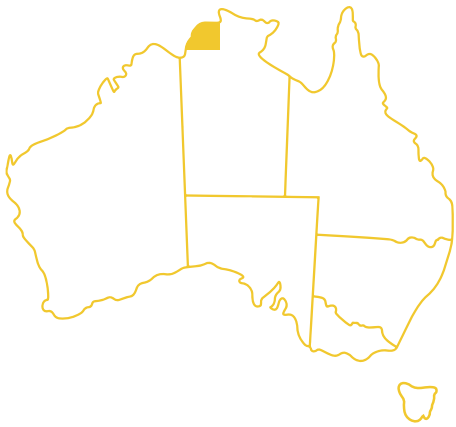
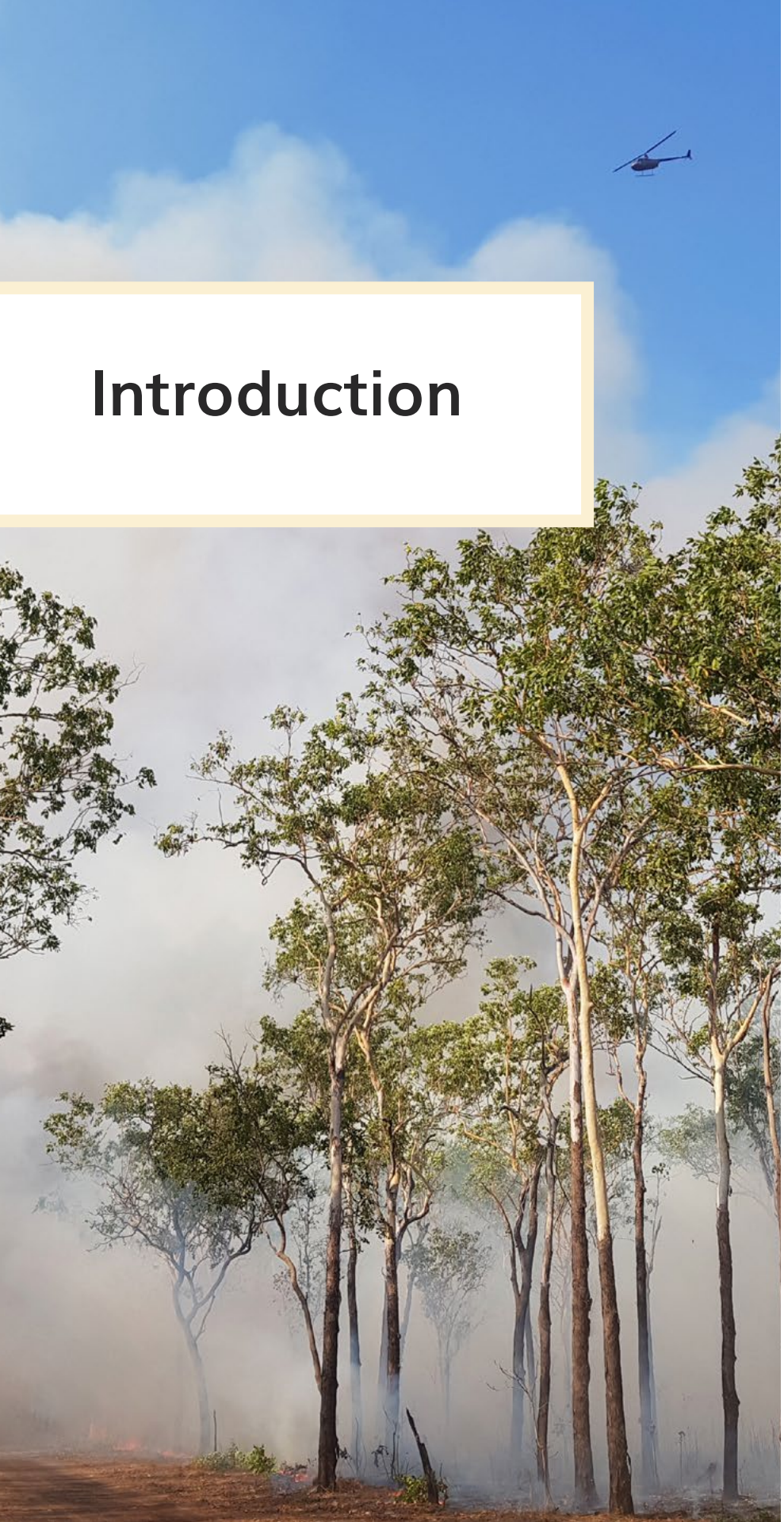


Introduction



DEDICATION: This book is dedicated to the endemic plants and animals of Kakadu who, amongst all of the Park's loud and competing stakeholders, have the weakest voice and are rarely heard or considered.

Why is it that wildlife in Kakadu and the Top End began disappearing in the late 1990s?

Australia's best ecologists have been pondering this question for many years, but no single cause has been identified. This book lays the blame in large part on institutionalised and culturally accepted early dry season burning of our natural bushland.

The following discussion is to do with the wooded savannas that are mainly free of gamba grass and stretch westwards from the Arnhem Land border to Darwin and beyond. This book does not dwell on the growing fire crisis posed by invasive perennial grasses.

Is early dry season burning simply the *flame of convenience?*

Prior to the Park's proclamation in 1979, the Kakadu area had regularly been burnt by uncontrolled, late dry season wildfires.

Since proclamation, the fire regime applied in Kakadu National Park (and many other properties between Arnhem Land and Darwin and beyond) has mainly been erratic and piecemeal. Late season fires continue to be too frequent.

Ecologists long aimed for a change from these late season hot fires, to a regime of fine scale, patchy burning in the early dry season with significant areas remaining unburnt for five years or longer. Jeremy Russell-Smith – internationally recognised expert in fire ecology – has described it thus:

> *With respect to fire management of tropical savannas, by far the most important requirement for conservation of biodiversity is the imposition of patchy management regimes. No single fire regime, nor spatial scale, will suffice for all species; rather, imposition of a fine-grained mosaic will optimise habitat diversity.* [1, 56]

In response, (and for several decades) land managers – on protected area lands at least – have unsuccessfully been pursuing this goal by using annual, early dry-season burning.

Although things are better than they were, in my view, the overall result remains a mess.

This book will argue that:

- The unnatural density of native annual spear grass found across much of the region today results in early dry season fires that are too hot, too extensive, and too frequent.
- Because of the point above, *'fine-grained mosaic'* burning has, in the past three decades or so largely become impossible to achieve at the scale needed and over the time frame required.
- Early dry season burning should be seen as a means to an end, not a fundamental objective. The 'end' should be long-term sustainable survival of the bio-diverse woodlands.
- The relentless pursuit of annual, early dry season burning is cumulatively crippling the ecology of the lowlands.

In addressing the issue of excessive burning, it is proposed here that if the landscape is going to be fired in a sustainable manner – one that will restore healthy ecosystems – nothing less than a dramatic redirecting of the annual fire regime is required.

I believe that redirection involves a profound switch from emphasising early dry season burning, to prioritising landscape-scale, early wet season burning.

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Personal overview

This book is a review of my experience as a chief ranger in the northern half of Kakadu over almost 30 years (1976 – 2004). In that time, I was able to observe firsthand the destructive environmental impact of tens of thousands of buffalo. Later in Kakadu, I was one of four rangers chosen to shoot buffalo by helicopter as part of the national Brucellosis and Tuberculosis Eradication Campaign (BTEC). Apart from shooting several thousand buffalo and numerous horses, cattle and pigs, I had a rare aerial seat from which to examine many aspects of the Kakadu landscape.

Perhaps the most dramatic change in the wake of buffalo removal was the explosion in density of grasses.

In the absence of buffalo, I was now observing a landscape waiting to be incinerated. And incinerate it did – and continues to do so.[57] Tourists rarely start wildfires, and the notorious buffalo-catching/fire lighting grader drivers are now extinct. But, at the time of writing (late September 2018) there were

several large fires burning in Kakadu, mainly in locations where only Aboriginal people may enter.

It quickly became clear to me that the old 'she'll be right mate' style of fire management was not going to work if wildlife and the natural environment were to survive. But everywhere I looked, I saw land managers employing early dry season burning as the primary way to 'look after country', without apparently noticing that the intensity of annual burning, year by year, was going through the roof. As a ranger, I too was guilty of excessive burning. There were times that I would burn more than 1,000 square kilometres in a day from a chopper.

But my evolving thoughts immediately put me at odds with what was perceived as traditional Aboriginal burning. Indeed, over the years, working with older Aboriginal men, I have learned that they appeared generally unconcerned about fire on the landscape – including furnace-like late season fires. One elderly traditional owner once told me: *'Any fire is a good fire – unless it burns your swag'*. But he said that standing on a fire-prone landscape that would have been scarcely recognizable by his grandfather.

As a result of this attitude, the rangers in Kakadu watch in helpless dismay, year after year, when the country is torched in September and October.

Even though we often knew who lit these fires, we were discouraged from recording them. But after an inferno had passed, I would walk on the ashen and blistered landscape and could clearly see that this was not right.

However these repeated, disastrous, late season fires forced the Kakadu rangers to implement a 'defensive' fire regime with a 'burn it now, before they burn it later' mentality. In this mindset there is very little room to worry about impacts on biodiversity - but instead mainly push the early dry season *'flame of convenience'*. This is fire management driven by desperation.

Since 2016, Kakadu has made significant improvements in its fire methodology and results. This will be discussed as a case study from page 71.

So, for most of Kakadu, it was (and still is) a case of burn it early every year or watch it get incinerated later. But sadly, due in part to the absence of grazing megafauna, these frequent early fires are often too hot and too extensive and lead to more grassy fuels and more destructive fires ad infinitum.[21]

This is not a healthy scenario and in my view is now leading to the environmental degradation of much of the World Heritage national park.

To this day in Kakadu there is a major dissonance over fire management between some of the key traditional owners and the non-Aboriginal park managers.

This cultural clash was described by Dr Chris Haynes in his 2009 PhD thesis: *Defined by contradiction: the social construction of joint management in Kakadu National Park.*

Historically, the onslaught of the European world, with its foreign animals and plants, had changed everything: the human population crashed, buffalo numbers were sky high (before collapsing with BTEC) and traditional fire management, with its ecological subtleties, food gathering rationales and cultural sensitivities, was mainly non-existent for nearly 100 years. By the 1990s, when the dust had settled on this chaos, the landscape had changed so dramatically that I came to the view that, in Kakadu at least, the age-old Indigenous approach to burning country – on a vastly changed landscape – is now 'wrong way'.

This book records some of the examples that I have gathered to support this claim.

The discussion focuses on the woodlands and sandstone regions of Kakadu. But what is said here is relevant for similar country outside of that park.

Greg Miles

Spear grass is pretty in the wet season...
...but destructive in the dry.

NOTE: Early dry season burning is in violation of the evolutionary history of the animals and plants we are discussing. Before the arrival of humans on the Australian continent, there was no such thing as early dry season burning. In contrast, lightning induced late dry and early wet season fire was a natural part of their world. In other words - early dry season burning in north Australia is unnatural (in evolutionary terms), while early wet season burning is natural.'

Part I.

Spear grass on trial

Building the case against early dry season burning

Research carried out by Patricia Werner, Jeremy Russell-Smith, Alan Andersen, David Bowman, Aaron Petty, John Woinarski and many other eminent scientists, points to the need to reduce fire frequency. However, the frequency for much of Kakadu has been one year in two, and for many localities, a burn every year.

While I agree that Russell-Smith's *'fine scale mosaic'* (referred to in the introduction) is the 'right way' to burn, no one has proposed a clear way to carry this out. This book proposes a means to achieve it.

Protected area land managers (amongst many other landowners) have been using the early dry season burning method mainly to prevent even more destructive late dry season fires.[5] Early dry season burning does much to reduce the incidence of intense late dry season fires. Unfortunately it does little to achieve the preferred goal of reducing fire frequency or extent.

The Kakadu Threatened Species Strategy 2014, aims to reduce fire in the park with these goals:

> *Across the extent of lowland woodlands, (i) increase extent of 'longer-unburnt' (>10 years since last fire) habitat to at least 5%; (ii) increase extent of >3 years unburnt to at least 25%; (iii) reduce average patch size of fires to <1 km.*[6]

This book argues that fire frequency is largely linked to the distribution and density of annual spear grass, *Sorghum stipoideum*. I suggest that managing spear grass is doable within the current management context. Controlling the other factors, such as unauthorised ignition, and the strategic use of firebreaks and firefighting will be more difficult and more costly.

I contend that the 'right time' to burn the north Australian woodlands in the early dry season exists only for 4 to 6 weeks. This is not long enough. I now believe that the preferred 'right time' is in the early wet season.

A wholesale switch from early dry to early wet season burning is not being proposed here, but rather a determined transition to balance the two methods.

ABOVE: A hot afternoon in September, several years after a wet season burn. Yet this fire is tame enough to step over. Note the absence of spear grass.

Changed burning practices

This book argues that the destructive annual burning in Kakadu – and much of the Top End, is the result of a cascade of profound human and environmental changes. One outcome of these events has led to the hyper abundance of native spear grass.

The changes broadly follow the following sequence:

1. The arrival of Europeans lead to a collapse of the Aboriginal population from Arnhem Land to Darwin, down from approximately 3,000 to a couple of hundred individuals by 1900.[2] This resulted in the end of high fidelity traditional burning activities.
2. For the next 80 or years or so, fire in the region was mainly chaotic, thus creating a spear grass/fire cycle.[3] Spear grass now proliferated across the landscape.
3. The population explosion of water buffalo – peaking in the 1960s.[57]
4. The arrival of *balanda* (Aboriginal name for non-Aboriginal people) rangers in the Kakadu region, growing from 5 in 1979 to more than 40 by the year 2000 – most of them keen firelighters.
5. The (BTEC)[4] eradication of buffalo between 1980 and 1992 had the effect of releasing the newly dominant spear grass from its last constraint.
6. Early dry season fires become hotter and more extensive.[20, Pg 16]
7. The implementation of industrial scale, annual, early dry season burning by Kakadu rangers and others. By 1992 (post BTEC) without buffalo grazing – the full destructive impact of intense spear grass fuelled fires is realised.
8. This increase in intensity, extent and frequency of fire improved the hunting efficiency of cats.
9. In 1996, Woinarski et al. found the first signs of small mammal disappearances.
10. In 2001 the first cane toad was found in Kakadu.

As a result of this chain of events – fire, cats and toads – now cripple Kakadu's biodiversity.

I believe there is no prospect of improving this environmental tragedy as long as early dry season burning is seen as the primary fire treatment and is widely accepted. The solution to the current regime of destructive burning in the greater Kakadu region lies in dramatic and sustainable fuel reduction.

This can only be realistically achieved through the fulsome implementation of early wet season burning, coupled with a major reduction in early dry season burning.

While recent research on the decline of small native animals strongly implicates fire, a single clear cause remains elusive. Equally elusive is agreement amongstconservationbiologists about the role of fire in these declines. [11, 67, 68]

So, what is wet season burning?

In the north Australia, wet season burning can be used from November to January to clear a given area of spear grass, (Sorghum spp.) and other annual plants. A fire at this time will kill newly germinated seedlings growing amongst the stalks of last season's parent grass. As Sorghum is an annual, almost all seed in the soil will germinate in the early wet season. Following a wet season fire, there will be little or no seed remaining and the affected area will be largely free of spear grass and other annual grasses, (and therefore fire) until the grass population reasserts itself. This may take three to five years. In this time, any fire that does burn will effectively be a leaf litter fire. Wet season burning does not work so well on perennial grasses as these simply re-shoot from their underground base.

Germination rates are variable. Seeds beneath a scant layer of dead grass will sprout early, as it will be triggered by light rain. However, a heavy grass layer will soak up rainwater and require more rain to start mass germination.

Wet season burning does involve risk. To be effective, spear grass must be retained over a full dry season in order to supply enough fuel to carry fire in December-January: the risk occurs during the late dry season when areas that have been saved for wet season burning are ignited by lightning or, (more commonly), arsonists.

TIMING is critical for a successful wet season burn. Go too early and not all of the seed in the soil will have germinated.

Go too late and monsoon rains can eliminate the opportunity to burn till the next season.

The best fires happen on dry days from late November to late January when a good breeze is blowing. Wet season burning does not work well in still conditions.

The ideal scenario is to burn with the wind ahead of a rainstorm front.

Crucially, burning must occur before the grass produces its new season's seed.

RIGHT: A December fire at Humpty Doo killing off seedling spear grass and other annuals.

RIGHT BOTTOM: Two years after the fire at left and now spear grass is rare while the middle story is flourishing. The area is mainly non-combustible and will remain so for 1 or 2 more years. When fire does return it will initially be subdued.

BELOW: A dry day in December is a prime time to burn. Seedling spear grass is growing up through the stalks of last dry season's mature, dead grass.

Benefits of wet season burning in the face of a late season fire

TOP RIGHT: Humpty Doo, 6 September 2018. Even though this area carried only moderate fuel loads (it was previously burnt in May 2017) and the winds were light, this late season fire caused 100% scorch of the canopy and incinerated everything at ground level.

MIDDLE RIGHT: This area is immediately adjacent to the above photo. It was wet season burnt 10 months earlier in November 2017. Despite attempts to back burn from this on September 6, the area refused to burn.

BOTTOM RIGHT: Also nearby, this area had been wet season burnt in November 2016. Although it carried the September fire, it was of low intensity. The mid story is burnt, but the canopy is unaffected. This area would not have supported an early dry season fire.

These examples demonstrate the value of wet season burning to mitigate the effects of late season fires. •

So what is wrong with native spear grass?

If we are to understand the dynamics of fire in much of the Top End's woodlands, we need to appreciate the role of spear grass. Considering that spear grass makes up 60% of the standing fuel in vast areas of the region, it is surprising how little is known about the history of density and distribution of spear grass in the literature, Elliott, Franklin and Bowman being notable exceptions.[60, 54, & 46]

I have long held the view that the hyper abundance of Sorghum is modern and unnatural.

Upon what do I base this opinion? Many indicators inform my view:

1. Visitors to the Kakadu region from northeast Arnhem Land are taken aback by the sight of so much grass. *What is wrong with this country*? they ask.

2. The old timer Fred Pocock, who lived on the Wildman River in the 1960s, told me that ground dwelling birds such as emus, quail and bush curlews used to be more common in the old days, "before spear grass took over".

3. There are a number of locations in Kakadu where extinct jungle fowl nest mounds stand under a blanket of sun-baked spear grass, where monsoon forest must have once stood.

4. The Munmarlary Fire Experiment (1973 – 1996)[59.] This long lasting and ambitious project was kept alive – just – by a succession of science heroes. One important nugget to come from this work was the finding that, at the outset, spear grass was uncommon in the open forest plots. But over the course of the experiment this annual grass became dominant while other grasses diminished. Russell-Smith puts it this way: "*It is feasible therefore that the increase in dominance of the vigorous annual Sorghum stipoideum, evident especially on open-forest burned treatments, was attributable to the imposition of invariant, frequent burning treatments*".[59]

5. The contrasting statements made by Woinarski between 1996 and 2014. (See following page). In my view, much of the burning that we see today does not make sense in the longer term. There is a fundamental mismatch between contemporary burning results and the sustainability of the ecosystems. This is supported – sometimes obliquely and often in scattered publications – by many scientists. For example, Lazarides et al. describe

spear grass in a manner that sounds to me exactly like a weed: *(It is) found on a range of shallow or deep soils of sandy, clayey, loamy or gravelly nature, on rocky or stony hill slopes and ridges, in skeletal sites over granitic, calcareous, quartzitic and lateritic rocks, and in varied habitats including levees, swales, depressions and coastal dunes.* [62]

6. The frequency whereby fires in the woodlands can result in 100% canopy scorch in mature eucalypts during the months of April and May.

I believe that, because of an increase in density of spear grass in many areas, early dry fires are becoming more intense and ecologically destructive.

If we are to burn in the dry season at all, the best time to burn is infrequently in mid dry season in a landscape of light to moderate fuels – not frequently in the early dry over heavy fuel loads as is the norm today.

I am not saying that we should suddenly cease early dry season burning, but rather use it as a transition towards burning infrequently in the early wet season.

▲ Munmarlary Fire Plot. 25 years without fire. •

So why does frequent fire produce masses of spear grass?

At its heart I believe that it is all to do with disturbance. There are a variety of forms of environmental disturbance but from the perspective of this grassy dominance, it is fire. Frequent fire benefits the dominant 'fire grass' species at the expense of everything else. For example it:

- Retards and displaces more conservative grass species
- retards or kills the shrub layer
- kills off most tree seedlings
- degrades the soil
- thins the canopy, allowing more light to ground level to the benefit of grass. •

Evidence of harm from early dry season burning

Land managers today see early dry season burning as the best option, in large part because it is a case of burning it early, or it will be burnt more destructively later.[60] I agree that this is a correct assumption.

But there is a problem with that thinking at the ecological level. At what moment in that mindset does this question arise: *are frequent, hot and widespread fires in the early dry season, good for the ecosystem?*

My answer is that the scale and frequency of dry season fires that we see today – are not 'good for the ecosystem' of the lowlands – far from it in fact.

To me, the evidence is pretty clear. One need only walk around in the freshly burnt landscape in the wake of a May or June fire in the woodlands of Kakadu, and ask how difficult it would be for a small terrestrial vertebrate to survive there. In my view, the answer is, 'very difficult'.

But early studies claimed little harm from early dry season burning

My view is inconsistent with the results of the CSIRO fire experiment conducted at Kapalga within Kakadu during the 1980s. How this can be remains a mystery to me. In my extensive field experience, all the indicators show that frequent hot and widespread fires damage the lowlands ecosystem. But in the words of one of the principal scientists of the Kapalga experiment, John Woinarski (1996) reported:

> *Much of the savanna biota showed little or no response to even the most extreme fire regimes and is therefore highly resilient to fire. Exceptions were riparian vegetation and associated stream biota, and small mammals.* [7]

Later statements confirmed harm caused by early dry season burning

In contrast to his 1996 statement shown above, in 2014 Professor Woinarski said: *The current fire regime is 60 per cent of those lowland woodlands being burnt in Kakadu every year and that's just completely unsustainable.*[8]

In addition, the authors of the 2014, Kakadu Threatened Species Conservation Strategy (including Professor Woinarski) state that management priority 'one' should be to *'enhance fire management in the lowlands, particularly to achieve a finer-scale mosaic of burning and an increase in the extent of longer-unburnt woodlands.'*

Furthermore, Elliott et al. say that *'early dry season burning can result in a more temporally (not spatially) homogeneous burning pattern which is not ideal for biodiversity'.* [60] This is typically understated in the academic way!

Another example of damage caused by early burning comes from the University of Melbourne's Dr Brett Murphy. His 2016 study revolved around the interaction between feral cats and fire in the north, this toxic combination being the major cause of small mammal declines. He says:

> *There is a general acceptance that fires are becoming hotter over time. Hot fires burn up logs and shrubs and make the habitat more open so feral cats can hunt more effectively. So we need to look at how we can manage fire better to allow for at least five years of unburnt habitat so mammals can survive.*[9]

The central point of this book is to argue that – in Kakadu at least – **'careful, strategic prescribed burning in the early dry-season..... to maintain small mammal diversity in tropical savannas'**, is mainly unachievable.

In 2016 Murphy, Woinarski and Russell-Smith further stated that (emphasis mine):

> *Extensive fires (at scales larger than the home ranges of small mammals) are the most detrimental, indicating that small mammals may not easily escape the effects of large and less patchy fires.*[10] *'Large fires that burn at a landscape scale (>1000 ha) appear to be burning small mammals out of the landscape. Savanna fire management must seek to reduce the spatial extent of fires.* ***Careful strategic prescribed burning in the early dry-season*** *under fire-weather conducive to achieve fine-grained, different age-since-fire patch mosaics with an overall increase in the extent of longer-unburnt habitat, is the proposed burning* ***regime to maintain small mammal diversity in tropical savannas.***[11]

In 2015, Jeremy Russell-Smith independently agreed, stating that *fire management in the sandstone uplands of Kakadu has been reasonable, but, in the lowlands (which make up about two-thirds of the park), intentionally lit, early dry-season fires are having almost the same negative effect on mammals with small home ranges as the big wildfires they are meant to avert.* He contrasts that with the successful burning programs being undertaken in western Arnhem Land: *'You'll see a lot of small burning – small patchy stuff. You go to Kakadu and they're much bigger fires.*[12]

LEFT: In the decades following the removal of buffalo, the intensification of prescribed fires played a major role in the near extinction of the beautiful Phascogale – along with numerous other vertebrate species.

Examples of harm from early dry season burning

ABOVE: A spotted tree monitor.

Example 1: Tree monitors devastated

In terms of ecological resilience to fire, a scenario counter to the CSIRO experience at Kapalga comes from Professor Sam Sweet's research into the population dynamics of the two species of tree monitors in the woodlands of Kakadu.[13]

He found that wet season reproductive effort exhausted the stored energy reserves of both sexes. It was critical to their survival that they fed immediately and extensively in the early dry to put on enough condition to tide them over the remaining dry season months. Through his daily radio tracking study of twenty-three animals, he found that if a fire occurred within their territory – even in the early dry season – most of the post-breeding monitors starved to death and the overall population was decimated. Professor Sweet believes that other species of terrestrial vertebrates are locked into the same reproductive timeline and suffer a similar fate in the wake of prescribed early dry season burns.

Example 2: Disappearing termites

Invertebrates also appear to be suffering in Kakadu.

On the drive into Maguk, one can now see dead and dying cathedral termite mounds. When I first visited there in the late 1970s – and up until recent decades – the cathedral mounds were abundant and robust. I argue that incessant early dry season burning, which prematurely removes dry season grasses and litter – has starved these colonies to death. The demise of termite mounds cannot easily be attributed to cats, cane toads or novel diseases – the culprit is almost certainly frequent, early dry season burning. Indeed, it could be argued that infrequent, hot, late dry season fire could be less damaging to cathedral termites: the insects would have had the opportunity/time to harvest and store grass material during the dry months of April till August – prior to late season fires.[14]

Some cathedral mounds, such as these photographed in Kakadu in the 1990s, now appear to be dying of starvation due to premature removal of grass caused by incessant early dry season burning. •

Example 3: The birds and the bees

An item on the ABC NT News site claimed that commercial beekeepers are losing their annual harvest of honey as a result of prescribed, early dry season burning: '*Controlled burns and bushfires in the Top End are making it difficult for beekeepers to find enough native flowers for their bees, leaving some in the already small Northern Territory beekeeping industry considering a move interstate*'.[15]

If this is true, it is an indicator of early dry season causing a serious interruption of the nutrient cycle in Top End woodlands – with all that that implies.

Termites play a major role in mitigating greenhouse gas release across the savannas. They do this by gathering and consuming vast amounts of grass and leaf litter, which would otherwise be burnt thus releasing noxious gasses. We need as many termites as we can get.

In response to this news item, I have been surveying my own unburnt 40 acres against my neighbour's 360 acres of identical native bush – which was last burnt in 2016. Two years on and there are several times more eucalypt flowers and birds (and presumably bees) in my canopy, compared to that of my burnt neighbour's.

In a 2015 report, Woinarski and Legge conclude that, "the current fire regime is suboptimal for many species of birds, particularly for granivores, frugivores, hollow-dependent species and those that nest on or near the ground. [16]

The statements above by the apiarists, Woinarski and Legge, also stand at odds with the CSIRO findings at Kapalga where Dick Williams (1996)[7] observed that 'while early fires did not affect flower production in the dominant eucalypt species, it did substantially reduce seed production.' It is my view that the fuel loads at Kapalga (and elsewhere) in the 1980s were probably lighter than they are today – due to the large numbers of buffalo present and therefore less grass.

Example 4: Disappearing echidnas

Along with emus, echidnas are rarely seen in Kakadu. Why is this? In my view, it is because of excessive fire.

ABOVE: A honeybee hive on a eucalypt stem. •

By way of example, I use the situation of a colony of echidnas near West Alligator Head in Kakadu's northwest corner. These delightful creatures were living in an area known as Palm Valley. They could be seen there at any time. But I fear for their existence as, for many years now, Kakadu management has been targeting this area for aerial incendiary bombing.

On the map shown on the following page, and circled in black, can be seen what appears to be the flight path of an incendiary dropping aircraft. The orange colour surrounding that is the resulting fire. The year of this image was 2016. North Australian Fire Information (NAFI) maps indicate that the area has been burnt this way for 15 years or so. In my view the large population of echidnas could only exist there due to the absence of fire.

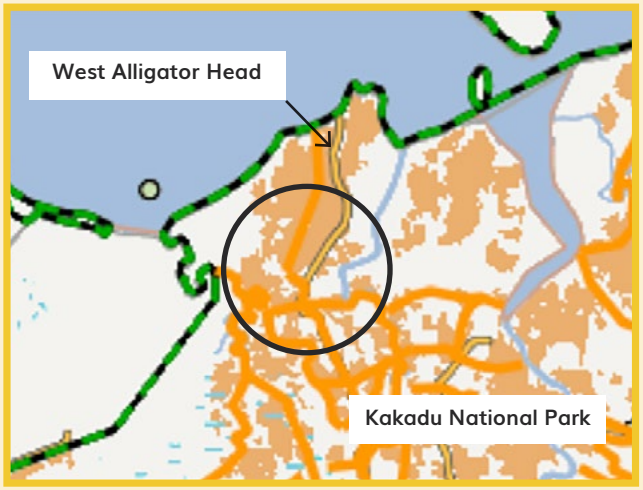
A little bit of history: the area in question is the north west corner of what was called Kakadu Stage 2, which was proclaimed in 1984. At that time Stage 2 covered about 6,000 square kilometres and was managed by two chief rangers, Greg Ryan and myself. We worked together cooperatively. From the day that that part of Kakadu was proclaimed, Ryan and I decided to exclude fire from the entire coastal headland. We decided on that course of action for several reasons:

- These headlands had not been burnt for a very long time. (The reason for this is discussed below). There was no good reason to change that status. We wanted to have some areas under our control that were not subject to frequent, high intensity burning.
- We were aware of the large colony of echidnas living at a place called Palm Valley in the rocky ridge adjacent to the access track to the coast. The echidnas were obviously thriving in a fire free environment, revelling in the deep litter amongst the ironstone boulders at Palm Valley. It was the largest colony that I was aware of anywhere in Kakadu.
- There was a family living in a caravan at the coast and we did not want to burn them out, their occupancy having predated the park's proclamation.

The floodplains immediately to the south of these headlands provided the ideal topography for the placement of a strong firebreak to prevent late season fires accessing the headlands. On only one occasion on our watch (a period of approximately ten years) did a late fire make it to the 'Heads'. We summoned rangers from all over Kakadu to battle this fire and successfully prevented it from spreading.

But sadly, and for no good reason that I can see , Kakadu has been firebombing this area now for many years.

I find this distressing. Frequent fire prevents the build up of the litter that provides the preferred habitat for echidnas. It is my expectation that most of the echidnas would have been directly killed by these fires or died indirectly of starvation as a result.



Example 5: Spear grass as a driver of Kentia palm, *Hydriastele ramsayii,* declines

An example of successful wet season burning was enacted near the West Alligator River crossing on the Arnhem Highway adjacent to Kapalga. At this locality, endemic Kentia Palms were being roasted every year by hot, spear grass fuelled fires. Juvenile palms were unable to break through the scorch height of dry season fires and were killed.

In late 1993 rangers subjected the area to a wet season burn. This was a particularly well-timed fire that rendered annual spear grass almost extinct at that location. Without any further fire suppression work, the area remained untouched by fire until July 2000: a period of seven years without fire resulted from one strategic wet season burn.

This result is precisely what scientists are calling for in terms of less frequent and less intense fire in the Top End, but to this day, wet season burning is not generally regarded as having a substantial role to play in ameliorating the incinerating grass/fire cycle.[23]

Early wet season burning devastates annual plants, especially grasses. It is not as effective against perennial plants such as weeds like gamba and mission grasses.

ABOVE: It took seven years after a 1993 wet season burn for spear grass and subsequent fire, to return to the Kentia palm grove shown above. Note the lack of young palms.

ABOVE RIGHT: This September 2019 photo shows that the old 'scorched earth' style of management has returned to the Kentia palms.

RIGHT: The break from fire from 1993 allowed these young Kentia palms to raise their crowns above scorch height. Note lack of grassy fuel.

LEFT: Unburnt cypress pines near Darwin. In Kakadu these trees are mainly seen as skeletons.

BELOW: A Kakadu pitta.

Example 6: Spear grass as a driver of Cypress Pine declines

Professor David Bowman et al. have studied the impacts of contemporary fire on cypress pine stands in the Top End. It appears that their findings concur with and strengthen my hypothesis. They found that:

> *Experimental fires, (in Cypress stands) with fuel loads >10 t ha caused significant mortality due to complete crown scorch. Lower fuel loads cause reduced canopy cover through defoliation of the lower canopy. These results help explain how increases in grass biomass are coupled with the decline of Cyprus intratropica throughout northern Australia by causing a switch from litter and sparse perennial grass fuels, and hence low-intensity surface fires, to heavy annual grass fuel loads that sustain fires that burn into the midstorey. This study demonstrates that changes in fuel type can alter fire regimes with substantial knock-on effects on the biota.*[3]

Bowman calls this the 'grass/fire cycle' and in my view it is this cycle that - in large part - is killing the bush.

Example 7: Spear grass as a driver of Anbinik declines

The observations above concerning cypress pines equally apply to the large and endemic sandstone tree *Allosyncarpia ternata* (Anbinik).

The scree slopes and valleys of the western fringe of the Arnhem plateau, and its outliers, are the most bio-diverse regions in the NT and are listed as a nationally important biodiversity hot spot. Today, thick blankets of spear grass are a feature of many of these valleys and dissected creek lines. Competing for space with spear grass in this intricate network of deep ravines and valleys, are fire sensitive plant communities. Australia's most recently listed threatened plant community: the Arnhem Land sandstone heath habitat, is found only here. This habitat is directly threatened by frequent fire fuelled by native spear grass. Frequent burning of this environment is a grave threat to the quality of the fragile stone country ecology.

Some might argue that the intention is to burn these valleys and gorges only once in 3 years or so. The problem with this scenario is that an unburnt interval of 3 or 4 years results in the accumulation of 3 or 4 years of fuel, since grass and leaf litter takes time to break down. Thus, if an area is targeted for

burning only once in 3 years, then each fire will potentially be much hotter and much more destructive than an annual fire. Catch 22!

Sadly the western flank of the Arnhem plateau contains numerous areas where the grass/fire cycle is irreparably damaging ancient stands of the endemic tree *Allosyncarpia ternata*.

Professor Sam Sweet wrote in 2013: [13]

> *I was intimately familiar with my 60 ha study site in rocky monsoon forest at Koongarra, and was anxious to see it again after seven years' absence. I made several visits in the peak of the wet season, and was acutely disappointed by two things: Firstly, there was no sign of small mammals in the rocks, nothing was collecting fruits and seeds, pitta nest sites and hammerstones were abandoned, the whole forest was silent. Secondly, at least one fire had burned along the entire forest margin and had killed all of the Anbinik trees (Allosyncarpia), of all ages from saplings to giants, that had slowly grown out 30-60 metres from the protection of the cliffs. The largest of these trees were many hundreds of years old, and none of the disruptions of colonization had touched them until this decade. As you may know, Anbinik trees rarely set seed, and seed will grow only under the canopy of the parent.*
>
> *'This means that Anbinik forests expand at a rate of a few cm/decade at best, and this one fire was a setback of thousands of years. While I was in Kakadu in 2002 a fire devastated Anbinik forests along the N slope of the Gubara basin, and more of the edge at Koongarra burned. Mildly put, this is criminal and utterly unacceptable under any standard of management.'*

My broader observations of the escarpment and plateau more generally, concur with those of Professor Sweet. As usual, it is hyper abundant spear grass and the resultant grass/fire cycle that is carrying fire into the Anbinik forests.

A 2017 paper by Jeremy Freeman, Andrew Edwards and Jeremy Russell-Smith, titled ***Fire-Driven Decline of Endemic Allosyncarpia Monsoon Rainforests in Northern Australia,*** found that upland Anbinik forest have shrunk by 9.5% in the past six decades.

The aerial image above features a gorge in the west Arnhem Land sandstone country. This region is one of Australia's biological hot spots. When I began visiting this gorge in the late 1970s, it was filled from end to end and side to side with large Anbinik trees. But even then, spear grass was establishing a foothold at the western end of the valley near the Oenpelli Road. On later visits I found that the forest had been burnt back to the area where the white sandy ground shows against some relic trees. In April 2006, Cyclone Monica smashed the forest. After they dried out, the dead trees were subsequently burned in a dry season fire, resulting in the sad image below. The whole Anbinik forest has been gutted. This monsoon forest was the biggest of its type in the Oenpelli region. The valley is now ripe for spear grass invasion and an endless succession of annual fire will follow. Over the next few years the remaining trees will be destroyed and will never be replaced – ever.

Although spear grass is a native plant, the corruption of the landscape caused by decades of pyro-anarchy has permitted it to behave in the manner of an invasive fireweed. As a result, it is now super abundant in much of Kakadu and the western Top End. For the purpose of this publication, I group all local species of annual Sorghum collectively under the name of spear grass.

Aboriginal traditional burning of the stone country is documented in the book *Culture, Ecology and Economy of Fire Management in North Australian Savannas*, Russell-Smith, Whitehead and Cooke (2009)[2]. In the book, senior Aboriginal people relate a history of detailed, annual fire management which persisted up until the early 1970s. Prior to that, scenes such as the one above would be unlikely. But today, people are no longer living on the stone country throughout the year. Informants in the book describe burning the sandstone at any time except the late dry season. But other senior people have claimed the opposite to be true. (see page 39 below).

My concern is that in the in the decades since people left the country, the highly flammable grass/fire cycle has promoted a whole new world of spear grass at the western end of the Arnhem Plateau in Kakadu. Because the stone country dries out earlier than the lowlands, frequent and widespread early dry season burning will continue to encourage spear grass and result in destructive, annual fires.

EXAMPLES OF HARM FROM EARLY DRY SEASON BURNING

Clay Trauernicht et al., (2012) [19] states the following:

> *In Kakadu, the grass/fire cycle involving Sorghum brachypodum provides a prime example where continuous, monotypic fuel beds of the species in many areas drive more intense, large-scale fires. Although the same species is present in Arnhem Land, aerial surveys indicated low S. brachypodum cover at all central Arnhem Land sites versus high cover at over half the sites in Kakadu.*

In response to a history of hot late season fires sweeping the Kakadu stone country, the park's management has embarked on a program of extensive early dry season burning in the high country. (See Kakadu case study below). But, if spear grass is pre-existing in the area, I predict that this frequent burning will *intensify* spear grass densities (as described on page 67 below) and lead to the same destructive grass/fire cycle that is incinerating the lowlands of Kakadu. This danger is not so apparent deeper into Arnhem Land (in the WALFA[17] project area) because spear grass appears to be relatively rare in that region at present. The WALFA project is getting much better results than those in neighbouring, publicly funded, Kakadu. [20]

While overall fire management in Kakadu's stone country has improved in the past three decades, my deep concern is that magnificent *Allosyncarpia* valleys such as these remain at high risk from invading spear grass fuelled, early dry season fires over the coming decades.

Early burning in the stone country

But what exactly is 'early burning in the stone country'?

The rocky slopes of the plateau and escarpment fringe dry out earlier than the heavier soils of the lowlands. This can mean that a fire in June in the stone country behaves more like a late dry fire in the woodlands. The window of time within which managers must complete the intricate process of early dry season burning of the stone country, is therefore shorter than that suitable for the lowlands. This is very difficult to achieve without a hefty chopper budget.

In my view, wet season burning is the only method available that mitigates the concerns above and can reduce or eliminate early dry and late dry season fires. But soil erosion may be a real problem. This looks like a case of choosing the lesser of two evils. The land manager would have to weigh up the likely frequency of early dry and late dry fires against the soil erosion problem posed by infrequent wet season burning.

Example 8: Spear grass and the destruction of monsoon forest patches

Scattered throughout the lowland woodlands, floodplain fringes and plateau of Kakadu, are isolated patches of monsoon forests. Some, such as the one above, are spring fed.

In many cases these 'islands' are surrounded by dense spear grass. Today, the novel density of spear grass poses a serious threat to the continued existence of these forest patches and their biodiversity. Ironically, these forest islands were protected from fire by buffalo for perhaps 80 years. But that protection no longer exists. The 1976 photo on this page illustrates how buffalo were able to strip vegetation from the landscape – thereby excluding fire.

The photos on the following page show two examples of these forests surrounded by highly flammable native grasses. Paradoxically – without grazing buffalo – they are now exquisitely vulnerable to being damaged by dry season burning, including prescribed early dry season burning. Carefully executed early wet season burning can provide lasting protection for these fragile natural assets.

ABOVE: Magela Creek, late dry, 1976: 'Wouldn't burn with napalm!'.

The 2005 paper by Daniel S Banfai and David M J S Bowman, ***Forty years of lowland monsoon rainforest expansion in Kakadu National Park, Northern Australia,*** states that rainforests generally have expanded in Kakadu. Jeremy Freeman et al. later contested this finding in 2017. See footnote on page 27 above.

Example 9: burning and the future of the eucalypts

A major 2019 paper by Professor Patricia Werner and Stephanie Peacock, has cast light on the long-term interaction between fire and the three dominant eucalypts in the Top End woodlands. The paper is titled ***Savanna canopy trees under fire: long-term persistence and transient dynamics from a stage-based matrix population model.***[58] It is an epic piece of work that provided new insights into the dynamics of the eucalypt forests.

This heroic paper is essential reading for anyone concerned about the future ecology of our northern savannas. It is the culmination of 25 years of research and data collection centred on Kapalga within Kakadu.

It is the only study of its type to examine the longer-term fate of individual trees of all ages (defined by eight life history stages) across a broad range of burning scenarios, and in two different understory types, one of which is spear grass. From this data, population demographic techniques were used to predict future sizes and numbers of the trees under various fire regimes: their population methods are the same types used to set fishing quotas and number of hunting permits, or to determine how many schools will be needed in x-number of years in a growing city.

The overall thrust of the paper, with regard to frequent fire in *Sorghum* understory, reveals how frequent fires (one year in one, or one year in two) will ultimately lead to a complete loss of the canopy tree population— slowly killing the ecosystem on which many animals and other plants depend.

This finding agrees with my hypothesis, which (as detailed in this publication) is more broadly based.

The key findings by Werner and Peacock are:

- Fire is necessary for long-term persistence of these eucalypts, that is, eucalyptus domination of the savannas cannot occur without humans!
- Annual fires are not conducive to long-term persistence. At minimum, three year gaps.
- Fire season and frequency determine population persistence.
- Irregular timing of fires promotes persistence more than regular managed prescribed fires.
- Understory type influences tree population dynamics, for example, the absence or presence of spear grass.
- Stage distributions of tree populations (proportional numbers within each of the eight stages) can change rapidly.

Eucalypt trees do not live forever. They die of natural causes and must be replaced by seedlings or regeneration from subterranean lignotubers. Seedlings are very rare. And their survival rate – even under optimal conditions is low – approximately 25%.

The study suggests that the ideal burning pattern should be infrequent during the dry season. I agree and argue that intermittent wet season burning may be the only practical way to achieve this goal, by limiting annual grass densities and therefore fire frequency and or intensity.

There are parts of this paper by Werner and Peacock that intersect with what I write here. An example at page 5:

> *Early dry season fires are almost always slow moving, trunk-scorching, ground fires of low intensity, usually creating incomplete, patchy burn patterns. Rarely, early dry season fires may be of high intensity and/or with little patchiness when fires are not allowed to burn naturally.*

They cite nine scientific references for this statement, but also go on to say, citing three references, that these fires may be 'of high intensity and/or with little patchiness if the site has not burnt for a long time'.

I believe that, although the early dry season fires were mainly mild fires when the field data was taken for this study, today that is less often the case. In my experience, early dry season fires commonly cause 100% canopy scorch and leave zero patchiness on the landscape. This is particularly so in areas of high spear grass density and areas which are burnt frequently – these two elements go together. Indeed, in another paper on patchiness of fires by Werner[56], it was reported that there was very little ground left unburnt under early dry season fires in *Sorghum* understory.

Wet season burning can disadvantage small eucalyptus because the flush of shrubby ground cover (including smaller tree species) that follows a wet season

burning, competes with the slower and less aggressive juvenile eucalypts. But since wet season burning can only occur once every three or more years, this is not likely to be a problem in the real world. (Serendipitously wet season fires burn most thoroughly where annual grasses are excessively thick and do not burn where there is thin grass cover).

Interestingly, spear grass does not compete with small eucalyptus (Werner and Franklin 2010;[32a] Werner 2012[33]). This is because *Sorghum* stops growing as soon as the rain stops. Thus, competition from spear grass ceases soon after the rains stop –while soil moisture keeps benefitting small trees.

The Werner[56] study found patchiness of fires to be important. But patchiness can be achieved only in areas of moderate fuel loads. In Werner's words: *'Only a regime of early dry season fire with little or no Sorghum in the understory creates potential windows of escape for juvenile trees.*[56]

I believe that the only effective way to thin *Sorghum* for any meaningful period is via wet season burning.

The Werner/Peacock[58] study found that although fire is necessary for the long-term persistence of the eucalypts, it also found that *too-frequent* dry season burning – in spear grass dominated country – is a threat to their continued long-term persistence.

Such fires keep burning the young trees down to the ground, forcing them to reshoot every year. They cannot break out of this mode and are stuck in an endless 'fire trap'.

ABOVE: Munmarlary fire plot. Twenty five years without fire - on the left of the road.

The Werner and Peacock study found that infrequent hot, late dry season fires are not such a big problem for many young eucalypts because up to a certain size they are deciduous and dormant, as described by Werner (2012[33]). They may be burnt back but will reshoot with vigour at the next wet season.

Paradoxically, the larger saplings are more likely to be killed by late dry season fires as they have experienced rapid height growth from underground stores not yet replaced and are only partially deciduous, so hot fires strip their still-functioning leaves, causing total top-kill without the capacity to replace lost tissues. Thus, even the comparatively vigorous re-growth from underground rootstock of *Eucalyptus tetrodonta* (when the adult tree is damaged or destroyed) is vulnerable at certain times of the year.

Recent research by Russell-Smith and others also point to a surprising degree of resilience shown by the three main eucalypts after a calamity such as total loss of adult canopy trees in a cyclone.

In places in central north Arnhem Land, cyclone Monica flattened large areas of eucalypt woodlands in 2006. But despite frequent (but not annual) fires and fierce competition from other native vegetation, resurgent eucalypts in that area have forced their way to the top of the vegetative pyramid and escaped the 'fire trap' (Russell-Smith, pers. comm.)

On the other hand, Russell-Smith echoes Werner in a 2017 paper where he describes Kakadu as having (especially in the woodlands) 'ongoing significant challenges facing delivery of effective fire management for biodiversity conservation outcomes in Kakadu.' [20]

Sadly, in the final analysis, the greatest threat to the eucalypt woodlands in the Top End is – without a doubt – gamba grass.

Traditional Aboriginal burning

I believe that traditional Indigenous burning – before the rise and rise of spear grass – would have caused no particular problem for the tree monitors, termites or flowering trees in the early dry season. This is because ancient burning was probably *'careful, strategic and prescribed'* (Woinarski et al. 2016). I believe that traditional burning took place most of the year without any particularly harmful consequences.[5] Ancient dry season fires (before the dominance of spear grass) surely would have been mild compared to what we see today.

The old tradition of being able to light fires at almost any time of year, might help to explain why many Indigenous people these days show little or no reluctance to start fires in the late dry season, such as those lit along the Arnhem Highway in Kakadu in late September 2014 and the huge fire south of Patonga in late September 2018. (See maps on page 79 below). There is a long but undocumented history of Indigenous people lighting problem fires in the late dry season in the Alligator Rivers region.

Petty and Bowman (2007), found that contemporary Aboriginal burning in Arnhem Land is spread evenly across the dry season: it does not stop at the end of the cool weather.[5]

By contrast, land managed principally by balanda in the Top End, is mainly burnt in the early dry season. Is it a coincidence that this land is so heavily blanketed with spear grass in comparison to Arnhem Land?

Much of the ecosystem of Arnhem Land (the eastern half of the Top End) appears today to be faring better than most European managed landscapes, (the western Top End) including Kakadu.[19]

Carmor Plains (on the north west boundary of Kakadu) and Ringwood Station (near Pine Creek) appear to be notable and happy exceptions. See Carmor case study below.

ABOVE: This fire in spear grass country was lit in the evening in mid-May. It resulted in 100% scorch in places. That is not normal or healthy. Such fires will kill frill-necked lizards and chameleon dragons.

Traditional burning and buffalo

We know that spear grass today constitutes 60% of the standing fuel at the ground story. Werner found that the grass layer biomass of the Kapalga woodlands more than doubled within 3 years after the removal of buffalo.[19a] I observed the floodplains experiencing an even greater relative increase in combustible biomass.

If, therefore, spear grass in its current distribution and density is a recent phenomenon, it stands to reason that – while traditional Indigenous fires of old may have been just as frequent as today – without spear grass, they would have likely been 60% less intense and probably 60% less extensive. Yet today, many land managers (including Kakadu rangers) are still clinging to what was once seen as a suitable fire regime (the convenience of early dry season burning) but evidently are not recognising and adapting to the dramatic increase in the flammable biomass since the removal of buffalo in the 1990s.

This I believe is the core of the problem.

I would further speculate that cats – which we know have lived in the region for more than 100 years - may again have been 60% less effective at catching small mammals and the like before the arrival of spear grass fuelled – industrial scale – burning.

At a national fire conference held in Darwin in 1995, an expert Aboriginal informant (who is often employed by land management agencies to give the Indigenous perspective on fire), gave a presentation during which he said that Aboriginal people (in his central, north Arnhem Land area) do not burn late in the dry season. When asked by a delegate why this is so, he explained that if you burn in the late dry, the fire will be so big that it will '*make the stars jealous*'.

Such understandings are commonplace in the traditional Aboriginal community. In another instance senior people will say that it is a bad thing to burn country too early in the dry season. If you do, the moist base of grass canes will not burn fully. Instead they form needle sharp, fire hardened spikes across the landscape. This is very difficult to walk upon. It is explained that if a pregnant woman walks upon this burnt ground, her new baby will go blind.

These examples serve to reinforce annual replication of traditional burning practices.

RIGHT TOP: Taking a well-earned rest after a night of carnage. *Photo: Jol Muller*

RIGHT CENTRE: This May fire has not completely burnt the vegetation at ground level. Because of the sharp spikes, Aboriginal people will avoid walking here.

RIGHT BOTTOM: In traditional times, burning the wrong country at the wrong times could bring on severe punishment.

With regard to Aboriginal traditional burning, the evidence points to a vanished world where Indigenous people in the region had a very hands-on and intimate knowledge of their clan estates and the process of burning thereon. It has been noted by a number of authors that in the region from Arnhem Land to Darwin, it is difficult if not impossible to replicate that world today. This is obvious. But what is less obvious is that in addition to the dramatic changes in lifestyles and movements of Aboriginal people in the region, the landscape itself has also gone through a seismic change. One has probably followed the other. I would suggest hypothetically, that even if the old people suddenly repopulated the region, that, because of the novel densities of spear grass, they would have difficulty in restoring the ancient burning patterns.

Times are a changing

Some older, traditional style people from central Arnhem Land say that burning in the early dry season in the woodlands is 'wrong way'. They base this in large part on the fact that the early dry season is the time to gather the bountiful harvest of the wet. In particular the staple foods of underground tubers and roots are prime for collection. But importantly, early fires will burn away the flimsy stems, tendrils and leaves that signal the location of the tuber. High value bush carrots, yams and potatoes are extremely difficult, or impossible to locate after a fire. Gathering vegetables such as these is mainly women's work. But burning country and hunting larger game (which may require fire) is men's work. There must be a high degree of co-operation and communication in order for each activity to be successful.

It is noteworthy that Aboriginal organisations in the Kakadu area are becoming much more involved in burning country. This can only be a good thing as skills and knowledge are developed and applied at greater intensity than can ever be achieved by Kakadu staff alone.

CLOCKWISE:

Eriosema chinense is another important bush food. It is only fat and edible in the early dry. It withers as the season progresses.

The bush carrot is a staple food item.

Typical woodlands of central north Arnhem Land. Note the absence of spear grass. Modest ground cover like this could be burnt over much of the year without causing great harm. Country like this is rare in Kakadu, because it is typically blanketed in spear grass.

Post-contact fire history in the Alligator Rivers Region

Following the collapse of the Indigenous population in the late 1800s, it seems there was minimal organised fire management from the western border of Arnhem Land to Darwin, for almost 100 years. Late season fires were the norm for decades.

It is evident that as well as Cypress pines, some animals were in decline because of these historic fires. They include the Brush-tailed Rabbit Rat, the Phascogale, the Golden-backed Tree Rat and the Spectacled Hare Wallaby. All of which were restricted or extinct in Kakadu by the 1980s.[66]

Apart from lightning strikes and sporadic burning during the pastoral years, the first wave of *organised* institutional burning arrived in Kakadu with the first rangers in that newly declared national park in 1979. Rangers of the time were much influenced by advice from the then Kakadu Park Manager, Dr Chris Haynes [24] and later by Dr Jeremy Russell-Smith. Haynes and Russell-Smith modelled Kakadu burning on what they learnt from Aboriginal people about 'cleaning up country' over the first half of the dry season.[25]

I agree with the core direction of these authors, but argue that while the Indigenous informants were accurately describing 'traditional Aboriginal burning', the landscape from Kakadu to Darwin were and are a very different kettle of fish to that which Haynes documented in Arnhem Land in the 1970s, and that which informed the elderly Indigenous authors of the Russell-Smith paper.[26] But, the new balanda rangers in Kakadu adopted that Arnhem Land methodology with evangelical zeal – on an already corrupted landscape! [27]

I know this, as I was one of them. I too, enthusiastically embraced the culture of early dry season burning and annually torched thousands of square kilometres in its pursuit. It seemed to make sense at the time.

At the conclusion of his paper, *Pre-contact Aboriginal, and contemporary fire regimes of the savanna landscapes of northern Australia: patterns, changes and ecological processes,* Russell-Smith states[28] (page 3 and in concluding remarks page 22):

> *With respect to fire management of tropical savannas, by far the most important requirement for conservation of biodiversity is the imposition of patchy management regimes. No single fire regime, nor spatial scale, will suffice for all species. Rather, imposition of a fine-grained mosaic will optimise habitat diversity. To date, outside of a small number of examples where such fine-grained management is undertaken, notably on Indigenous lands, this ideal is still to be realised.*

I agree with this statement. And the reason that this ideal has not been realised – in my view – is in large part because of unnaturally high fuel loads.

Anthropologists estimate that there were approximately 3,000 Indigenous people living on the coastal plains between Arnhem Land and Darwin – before balanda. It was 'rich man's country'.

In my view, the collapse of the Aboriginal population in that region by the 1890s, brought about an end of environmentally appropriate traditional burning practices. In the wake of this dramatic change, huge herds of buffalo became the main consumers of biomass - as well as fire. [31] Although late fires were frequent, their extent was partially limited by areas of intense buffalo grazing such as on floodplains and creek lines.

The breakdown of mosaic burning

Russell-Smith's call for the '*imposition of a fine-grained mosaic*' is no doubt entirely appropriate, but I argue that – in Kakadu at least – this is mainly impossible for a number of reasons. They include:

- The vast areas of vacant, continuous and densely fuelled landscape: spear grass creates such dense fuel loads that even early dry fires will often be too hot, too frequent and will cover abnormally large areas. [12]
- The lack of sufficient numbers of Indigenous people living on and utilising their land in a traditional way.
- The window of time for achieving fine-scaled patchy fires is very short. [29] As a result land managers will commonly continue to burn well after the 'sweet spot' for '*fine-scale patchy*' has passed.
- Rangers have insufficient resources to cover such large areas within the appropriate, seasonal time frame. [30] Because they have to fit so much burning into a narrow window – often dictated by the availability of funds and choppers – they necessarily have to burn vast areas in a short space of time – the opposite to '*fine grained mosaic*'. To do fine grained well, would require a large chopper budget, renewed very year. This is probably unsustainable.
- Even if this was done well, early dry burning does not reduce the abundance of spear grass seed in the soil. If an area is heavily blanketed by spear grass, early dry burning will not reduce its density in the following year, thereby locking the rangers in to yet more annual burning, ad infinitum.
- The high numbers of unauthorised, large, late dry season fires that are lit every year by local people.[53]
- Early dry fires are becoming hotter over time and are therefore increasingly destructive.[9 & 11]

The buffalo and fire nexus

In my view, the removal of buffalo was a major factor in Top End fires becoming lethal to the northern ecology. I believe that the apparently random coincidence of the removal of buffalo and the beginning of the decline of small mammals are connected.

John Woinarski first detected declining number of small mammals in Kakadu in 1996. The BTEC removal of buffalo in Kakadu ended in Kakadu in 1992. Can anything be made of the coincidence that the beginning of the collapse in small mammal numbers so closely followed the collapse in large mammal numbers – just four years earlier?

Petty and Werner et al. found that the rise in buffalo numbers and their influence on the landscape, from the 1880s and peaking in the 1960s and 1970s, was having the effect of suppressing fire at a time when traditional Aboriginal control of fire was disappearing. [42 & 57]

Grazing by ungulates has an interesting effect on the landscape. Too much grazing has many harmful consequences, while light grazing has minimal affect. But moderate grazing appears to have a beneficial impact. There is a case to be made that light to moderate grazing improves habitat richness for native animals. It does this by eliminating or reducing the intensity of fire, while retaining hollow trees, logs and ground debris which is crucial to small mammals and other terrestrial animals. Importantly, this cover makes hunting harder for cats.

In the decades before BTEC, buffalo were perhaps the predominant force on the landscape suppressing fire through trampling and grazing, while Aboriginal people were not.[63] Remembering that at the time of the park being declared, only about 70 Indigenous people lived in the Kakadu region and for the most part, they did not have access to motor vehicles. The western side of Kakadu (Stage 2) was mainly unpopulated.

Building on this 'paucity of people' concept: prior to the bridging of the Adelaide and Mary Rivers in 1972, the only way to get to the Kakadu region was via the 47 Mile turn off on the Stuart Highway or via Pine Creek. Both of these were long, rough, unsealed roads and 4 wheel drives (as we know them today) were only just beginning to appear.

These roads were closed during the wet season and did not open till well into the dry each year. It is worth reiterating therefore that the population of people in the region (before the South Alligator was bridged in 1974) was very small, not very mobile and restricted by seasonal conditions.

ABOVE: These buffalo photographed in 1977, completely removed flammable vegetation on and adjacent to the East Alligator River floodplain. As a result, the wetlands, fringing forests and creek lines were fire resistant for decades. This scenario was common across much of the northern Top End.

BELOW: Buffalo mustering, East Alligator River area, 1976. Note rarity of grass.

As a result of this, most fires were relatively late in the dry[17a] as that is when people would have been moving around, albeit on very few tracks. On the other hand, the lack of people meant that there were few areas of early burnt country to pull a fire up. However, the severity of these fires would probably have been countered by the reduction of fuel density caused by large herds of grazing and trampling buffalo. [42 & 57]

I suggest that the increase in intensity and destructiveness of today's fires is not fully understood by the people setting them.

Fire and the pastoral industry

It would be interesting to learn more of the burning patterns of the pastoralists who controlled fire on Mudginberry, Munmarlary, Gimbat and Goodparla stations in the years that they operated. In those years, most of the Alligator River Region was under the control of the pastoralists on these four huge properties.

Aboriginal people were often employed as stockman. Mr John Lord, a pastoralist who managed Munmarlary (between the South Alligator River and Magela Creek) in the 1960s, explained to me that land managers of the region followed a 'no burn' land management policy. According to Mr Lord, the success of these pastoral enterprises was in no small way linked to this no-fire policy because fires meant loss of stock food and a loss of income.

However, contradicting Mr Lord's assertions about 'no fire' was an item in the NT News of September 1964. This piece of evidence indicates a lack of intentional burning by pastoralists but does not mean that there were no fires. The NT News story told of a 'rescue mission' by a benevolent truck driver – en route from Darwin to the Cannon Hill abattoir – who dropped off a load of hay to Mr Yorky Billy's (Alderson) camp at Spring Peak. The story told how an extensive wildfire (in September) had burnt out the standing fodder in the region. As a result, Mr Alderson's stock horses were in danger of dying of starvation.

During the period 1979 to 1987 Mr Helmut Schimmel was in residence at Gimbat Station in what is now the south east of Kakadu. In that time, he could recall only one year when they were completely burnt out. He claims that this was a fire lit by Kakadu rangers to the north. Generally he pursued a policy of some early burning and some wet season burning to achieve the right mix of fire protection and supply of stock fodder for the property. He notes that Goodparla (to the west of Gimbat) tended to burn their land in a more widespread fashion. (Schimmel pers. comm.)

The comments by Lord and Schimmel, suggest that pastoralists used fire sparingly.

However this is somewhat at odds with the observations of this writer who began working in the north of what was to become Kakadu, in 1974. I routinely observed fires in that region, most commonly in September. This was during the mid 1970s when all of the region's pastoral properties were still operational. It was commonplace for fires to be set by musterers and the property grader drivers in order to clear the grass and make their work easier and safer. As a general rule these colourful characters set fires in the late dry season as this was when mustering was at its peak each year. Yet wildlife was abundant throughout the land.

Conversely, early dry season burning had limited practical benefit to the buffalo catchers or pastoral property managers – indeed, it would have been a costly exercise to try to gain access to their large properties in the early dry for the purpose of burning. In addition, the removal of grass by early burning would likely have prompted buffalo to migrate away from the burnt property to one where fodder was still plentiful. So, from my observations, the pastoral managers did not commonly light fires in the early dry season, but contract catchers and grader drivers frequently lit the country up in the mid to late dry season.

By the time the buffalo catchers moved onto the land in the mid to late dry season, the buffalo were mainly sheltering in the woodlands and emerged onto the floodplains to graze at night. Musterers would also push them out onto the dry and hard plains where they were easier to catch or trap.

LEFT BOTTOM: During the buffalo era, denuded floodplains eliminated fire in the late dry season. These fire-proof wetlands and creek lines created fire shadows at adjacent, downwind woodlands, which were also grazed and had reduced flammability.

CENTRE BOTTOM: Seen from above, a denuded floodplain with bovine culprits on the run.

This Death Adder was overtaken and killed by an early dry season floodplain fire.

Today, in the absence of buffalo, floodplains will burn furiously. Flightless animals such as snakes, lizards, small mammals, and frogs rely on escaping fire on the plains by sheltering deep in the cracks in the black soil. NP

But in the early dry season, the cracks are not deep enough to provide a safe haven. A fire will kill animals such as death adders, bluetongue lizards, frogs and native rodents.

Where they sheltered during the day under trees on the woodland fringe and along shady creek lines, the buffalo denuded the understory. In addition, they stripped the plains bare, thus inhibiting fires (or even making fire impossible) on the floodplains, around the fringes of monsoon forests and the adjacent woodlands.

For the most part, it was evident that the dramatic reduction in vegetation caused by grazing buffalo was of no great inconvenience to most of the small mammals and other fauna of the region. They remained abundant in all habitats – as revealed by the early CSIRO fauna surveys [49] and my own observations.

However, Gordon Friend noted that buffalo, stripping the covering vegetation, disadvantaged some vertebrates including the wetlands dusky rat. [35]

My own experience of dusky rats at Cannon Hill in the mid to late 70s (when buffalo were very numerous) was the opposite.

Dusky rats were in such high numbers that they caused damage to household appliances and even ate out the foam seat of a parked motorbike. They chewed the electrical wiring in my car and the insulation in the back of our refrigerator. This was in the wet season when flooding forced them off the floodplain and into the fringing forest where the ranger station was situated.

I am not suggesting here that buffalo did not do a great deal of damage to the natural environment – they certainly did. But the comments above are strictly in the context of their impact on fire.

I also speculate that the collapse in numbers of buffalo after BTEC led to a concomitant fall in the numbers of dingoes. Dingos kill and eat kittens before they are old enough to climb. Fewer dingos may have led to more cats. Thus the removal of buffalo could have resulted in a double whammy for wildlife; more fire and more cats.

Fire suppression by grazing

I have written at length about the use of wet season burning as a mechanism to turn around the current, ecologically unsustainable fire regime in the Top End. To me, this is the only method that can have any use at the landscape scale. But it is possible that controlled grazing could have a role in fire suppression also. [57]

The photo at right on this page shows the effect of feral buffalo on gamba grass and other weeds in the Black Jungle Conservation Reserve near Darwin. The photo was taken in the early dry season of 2018. The removal of grass by buffalo in the reserve on the left-hand side of the fence can clearly be seen. The right-hand side of the fence is freehold land minus feral buffalo, and gamba is rampant. It can be expected that later in the dry season the freehold land will be vulnerable to high intensity wildfires while the buffalo infested conservation reserve will experience a much-reduced fire risk.

Harm done by grazing is well documented and understood. Amongst the many problems are soil compactions, denudation of the ground surface, salt-water intrusion, erosion, selective grazing on certain native plants, and weed disbursal and cultivation.

But in the Top End there are two overarching issues that push these problems to one side, these being (1) invasive weeds and (2) excessive fire.

There is a case to be made that light to moderate grazing can ameliorate these major problems, but not necessarily create or sustain the overgrazing problems listed above. It is all a matter of degree. Example: I argue that if an acreage landowner in a fire prone area of the Darwin rural region wanted to manage their land to promote and conserve wildlife (like a mini conservation reserve) perhaps the only practical way to achieve this is to run a few head of stock on the land. We know that all manner of wildlife can co-exist with large herds of cattle and buffalo, especially if stock watering points are made native animal friendly. [E.g. 47]

Is it possible that this might be the future of our government run conservation reserves – that they become the homes of carefully managed herds of cattle or buffalo?!

BELOW: The freehold land to the right of the fence was indeed incinerated by a wild fire on September 5, 2018. The grazed land in the conservation reserve (left side of fence) was untouched.

LEFT: This picture shows how buffalo clip the gamba grass to knee height. Flammable biomass is greatly reduced, and the grass is unable to produce seed.

The photo at left shows a fence line separating two 16 hectare (40 acre) rural blocks in the Darwin hinterland. The property on the right carries three horses. The property on the left has none. The horse grazing shown here is more complete than that of the buffalo in Black Jungle (previous page). Horses and cows have a similar grazing effect to buffalo although there are differences. But the results are similar in terms of fire risk.

The horse property is surrounded by privately owned and council land that is heavily infested with gamba grass, mission grass and other weed species. If a fire enters this area – not an unlikely scenario - it is only the horse property that has any degree of fire protection. But importantly, in both cases the ecosystem created by these two grazing scenarios appears to be highly suitable for small mammals and other wildlife. This is for two primary reasons: firstly, the grazed properties are either fireproof or at worst would only burn gently, and secondly the micro habitat created by the grazing still carries all the cover needed by terrestrial vertebrates.

In other words - without fire, the bunch grasses, tussocks, logs, stumps and fallen leafy branches remain intact on the ground. These items are of no interest to grazing animals but are an impediment to cats.[64] Perhaps the only thing missing in large quantity are grass seeds for granivores, but these can be found in abundance on the neighbouring grass infested properties – until the next fire.

Professor Werner warns us that removing fire completely will see the eventual extinction of the Eucalypts through intense competition with the other vegetation.[58] But this competition does not occur so much in the grazing scenario because ruminants and horses eat the competition. At ground level – on this property – there are numerous (possibly too many) young eucalypts and other tree species that have escaped the 'fire trap' and are thriving. The grazed property also carries a dense and rich tree canopy, alive with flowers and birds of many species. This property is transitioning to monsoon forest. But with rotational grazing, or by reducing the number of horses, it would be possible to do some limited burning to maintain a balance between open woodlands and forests. At this small scale it is possible to manipulate the variables to attain the type of environment that one prefers.

The dewfall hypothesis

In 2009 Louise Emmons published a paper titled, *Long-Term Variation in Small Mammal Abundance in Forest and Savanna of Bolivian Cerrado.*[34] She proposed a novel hypothesis about declines in small mammal numbers in the savanna country of Bolivia, South America where her mammal trapping study ran from 1996 to 2008. This is roughly the same period during which the Top End experienced its most dramatic collapse in small mammal numbers. Emmons observed the collapse of seven highly divergent species of mammals in her study area from 2003 to 2007. Some species became totally extinct over the period.

But it was puzzling for Emmons as (and this is the situation here) there was no clearly identifiable explanation. Variables such as rainfall, fire, predation, epidemic disease and flooding were examined. There was an increase in the amount of burning in the region as a whole and some fires affected the plots over the period, but mammal numbers also collapsed on the unburned sites. The cause of the collapse proved elusive.

Emmons came up with a new idea. I will use her words to describe it:

> *When the study began in 1998, we were soaked to the waist from dew on the grass, shoes squelching, each morning when checking savanna traps. In later years the morning grass was usually dry. This observation led to a novel hypothesis to explain the rodent decline in the savannas. I propose that nocturnal dry-season dew on savanna ground-cover vegetation is important to the microbiota of the grasslands, and that the pall of dense smoke generated by regional dry season fires prevents dew formation and deprives the flora and fauna of a critical resource, resulting in lower rodent abundance.*

To substantiate this idea, Emmons obtained weather data from the nearest commercial airports. They confirmed a strong decline in air visibility over the period 1990 – 2007, a period of extensive land clearing and burn off in the region. In addition, continental scale research showed a significant increase in overnight minimum temperatures since the 1970s for many weather stations in that area of South America. All these elements served to strengthen the hypothesis.

A Kakadu dunnart. Does its survival dependent on dewfall?

Emmons cites work by Professor Bowman in Australia:

> *Bowman et al (2007) have documented increasing dry-season smoke in the Northern Territory since 1955. The transition from Aboriginal to European land management has been associated with an increase in fire activity early in the dry season.*[38]

But one significant deficiency in this study concerns records of small mammal dependency on dewfall for drinking water. Little is known about this.

I find this concept compelling as my experience concerning dewfall echoes that of Emmons. In my time as a fire lighter in Kakadu, I would burn in the early dry season knowing that the fires would generally go out overnight – because of dewfall. But in more recent years I observe that this is not necessarily the case. Fires today can readily burn through the night and flare up the next day – even in May.

Emmons' closing words:

> *In conclusion, a smoke-effect hypothesis could account for all aspects of the 6-yr rodent decline in the Los Fierros savanna, and there is support for several predictions that flow from it. There is no obvious simple alternative hypothesis. Nonetheless, it is based on anecdotal observations, and I lack data showing a link between dew and rodent resources or declines.*
>
> *Because continental-scale smoke and industrial aerosols increasingly blanket vast areas of the globe for many weeks of each year, negative effects on savanna or forest plants and fauna could result in subtle but cascading ecosystem degradation hundreds of kilometres from the originating fires.*
>
> *Rodent declines without recovery could be the canary in the mine. I present this hypothesis as a challenge for testing by experimentation and remote sensing.*

Closing statement in the case against spear grass

There is no doubt in my mind that the unnatural, modern densities and distribution of spear grass from the Kakadu escarpment to Darwin and beyond, is fuelling fires that are cumulatively killing our country.

In my view, as long as we pursue a policy of burning frequently *mainly* in the dry season, scenes of destruction such as this at Marrakai on the Arnhem Highway in September 2017, will continue to be commonplace. The natural environment as well as life and property will continue to be at risk. (See the Marrakai case study below)

It is worth reiterating that all that has been written here deals with country mainly without gamba grass. Gamba changes everything. If gamba is not or cannot be controlled in any given landscape – then all that I am saying about spear grass becomes irrelevant. Gamba grass is rapidly and radically transforming the Top End environment from one of eucalypt dominated woodlands – featuring hot frequent fires – to a monoculture of grasslands featuring potentially lethal, furnace-like annual fires.

Managing fire in or around rural residential communities brings with it many more complications than burning for wildlife conservation in remote areas. In the years to come, gamba grass fuelled fires will make it almost impossible for people to reside in peri-urban communities such as Marrakai without highly effective grass reduction strategies. Perhaps the only way whereby they can live without fear is to collectively surround their properties with a wide and continuous buffer zone, stocked with cattle or buffalo. Such a concept could be fostered by the local shire council. It might involve all residents paying an annual fire safety levy which would cover the costs associated with running a herd of bovines.

Part II.

The solution - wet season burning?

The most powerful habitat management tool in northern Australia

The case for wet season burning

ABOVE: A mild December fire destroying seedling spear grass.

By this stage you might be asking: 'but what is the alternative to early dry season burning?'

Answer: the problem can only be solved by permanently reducing fuel loads, namely spear grass. I argue that land managers intent on protecting the ecosystem of their estates across the Top End should attenuate burning in the early dry season and progressively switch to early wet season burning – that is, in late November, December and January. If this was done, I can see a transition away from frequent, hot and destructive early dry season burning, to more mild, patchy and manageable fires in the early wet.

Because of their nature and timing, fires at this time of year rob less nutrients from the ecosystem – or at least, because of the imminent rain, the patchiness and relatively mild intensity of fire – wet season burning does not disrupt the energy transfer process for very long.

In addition, leaving grass unburned from the preceding dry season [37] provides for that landscape to reabsorb as much of the available nutrients into the system as it can, prior to a wet season burning late in the year. But more importantly, early wet season fires have the potent, ongoing benefit of drastically thinning annual fire grasses – such as spear grass and annual exotic weeds like annual *Pennicetum*, *Hyptus* and others – for several years. [23, 51] Early dry season burning does this for less than 12 months.

There is nothing new about wet season burning in the context of non-Aboriginal style land management. It has been in use in the Top End since 1966.[51] Rangers in Kakadu first formally investigated it in the early 1980s. But the take up of wet season burning as a strategic form of burning has been poor. For decades rangers in Kakadu have included wet season burning almost as an

> It is remarkable that the main—maybe only—ecological management tool (apart from a massive chopper budget) available to significantly manipulate fire on a landscape scale, has attracted such little scientific attention.

BELOW: A nestling Buk Buk. •

afterthought – 'By the way, we also do a bit of wet season burning.' Rarely is it pursued with determination and vigour. This is what needs to change. It should be at the front and centre of all fire planning and action.

One or two traditional owners in Kakadu are opposed to early wet season burning, while the majority are in favour of it.[39] [40]

With a major swing to wet season burning there would be a need for on-going research into its effects.

Research needs to focus on issues such as:

- Increased risk of soil erosion
- Risk of siltation of creeks and streams
- Effects on soil structure
- Impacts on fruiting trees and shrubs
- Proliferation of perennial weeds in the fire's aftermath
- Changes to availability of food for grain eating animals
- Impact on ground nesting animals.

For example: I would speculate that the *Buk Buk* (pheasant coucal) which nests in thick grass tussocks in the wet season, could be disadvantaged by wet season burning in the short term. However, it would likely benefit in the longer term as longer unburnt patches become more common.

On the other hand, I can think of a long list of animals, including endemic and threatened animal species that are disadvantaged by early dry season burning in spear grass country. The same is true for some tree species: *Prior and Werner et al., 2013 and Prior et al. 2009*[22] found that frequent early dry season fires were negatively correlated with tree recruitment.

Is it possible to switch from early dry to early wet season burning?

Some will counter-argue that an end to early dry burning is impossible. But from my 30 plus years' experience as an early dry *and* wet season burning practitioner, I believe that this shift is doable over time. But I am not suggesting that everybody should immediately stop early dry season burning and switch to wet season burning: this would lead to a late dry season fire disaster. What I am advocating is a strategic, graduated move away from emphasising early dry burning, in favour of emphasising wet season burning – over a time frame of years.

It would take more than a decade to safely transition from early dry to early wet season burning on a land parcel the size of Kakadu. Smaller holdings could transition much faster.

A good land manager can achieve this by:

- Opportunistically wet season burn areas left by chance at the end of the normal year of burning
- Deliberately leaving strategic 'low risk' blocks of land unburnt – in anticipation of wet season burning later
- As blocks are in-filled, the manager can be more ambitious in leaving the more 'at risk' blocks unburnt in future years.

And other management considerations include:

- Wet season burning is more difficult to implement that early dry burning. It requires more strategic thinking and preplanning. This means that the people involved need to be trained or experienced and have a 'big picture' view of what they are doing and what they hope to achieve.
- The land manager must think and plan with an eye to several years in advance.
- Wet season burning requires that the target area of land must be protected from early dry season and late dry season fires over a period of eight months or so. This can be difficult to achieve.

Petty et al. quantified the likelihood of unauthorised fires being lit in the context of distance from the nearest road. [5.] This opens an opportunity for land managers to be bold and leave more and larger areas in remote regions unburnt for later wet season burning – with reduced risk of unauthorised ignition. Much of the north and west of Kakadu enjoys relative safety in this regard, although lightning strike fires remain a factor. At the present time, rangers purposely burn many of these remote areas. This is unfortunate. It is a needless waste of money and opportunity in my view. Much of this land could be saved for later wet season burning. As the area of treated land grows, the risk of wildfire retreats.

On the other hand, if we continue down our current trajectory, I can see the inexorable conversion of much of our relatively healthy, diverse woodlands to skeletal monoculture woodlands as predicted by Werner in 2005, 2006 & 2018.[19a, *42, 58*]

However, as discussed previously, where gamba arrives, this destructive transition will occur at a vastly more rapid rate.

Carmor carries significant numbers of buffalo on the property. As I have described for Kakadu in past years, the presence of these bovines helps to limit fire on Carmor today. The same is true of Ringwood Station near Pine Creek. Ringwood carries an abundant assemblage of wildlife (including numerous Gouldian Finches) amongst the cattle. Fire is "*fine grained and patchy*" on Ringwood. In controlled numbers, it appears that there can be important environmental benefits derived from grazing animals in the Top End.

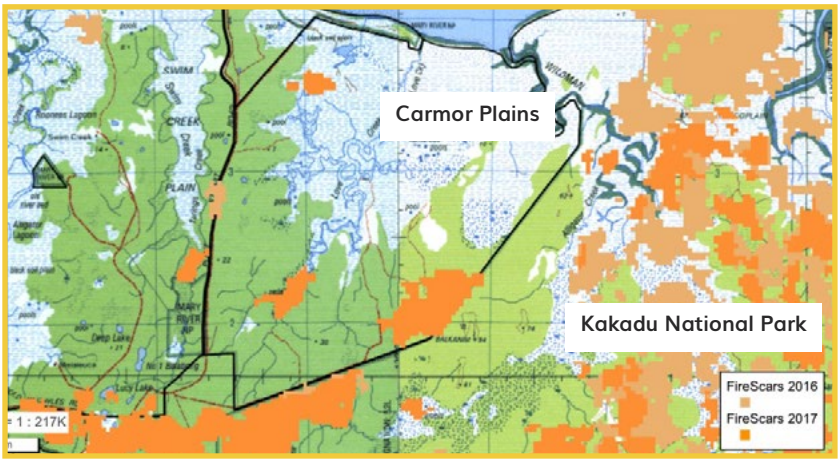
Case study: Carmor Plains station

The Carmor Plains pastoral property could be seen as a living example of how the switch from early dry season burning to wet season burning can be achieved.

Carmor abuts Kakadu at its northwest corner – where it meets the coast. The property is managed mainly as a safari hunting business. The managers have been employing wet season burning for a number of years. As a result, although there is very little annual spear grass on Carmor Plains, there is plenty of perennial grass suitable as fodder. The lack of spear grass, combined with grazing, means that the property rarely has a dry season fire.[43] Wet season burning at this location is modest in intensity, limited in area and is not done every year.

The owners of Carmor report that their property is teeming with wildlife, including unidentified species of 'bush rats' (and buffalo). I am advised that the staff of Carmor will see more wildlife between their homestead and their boundary fence (approximately 10 kilometres) than they will see on a drive from the Kakadu western boundary through to the East Alligator River Crossing in the east of the Park – a distance of about 90 kilometres. They can make this statement with authority, as part of their safari business requires that they regularly travel through Kakadu to Arnhem Land pointing out wildlife to their clients as they go.

Carmor Plains and Ringwood Stations appear to offer unique opportunities to carry out research on the biodiversity benefits of the combination of grazing and strategic burning – in stark contrast to what is happening in Kakadu with its chronic biodiversity loss. Evidence is emerging that pastoral properties such as these, can provide leadership for our national park agencies to follow - in terms of successfully protecting our wildlife.



Fire scars for 2016 and 2017. Carmor Plains in the centre of the image shows how infrequently it is burnt, compared to Kakadu on the eastern side of its boundary.

The economics of wet season burning

I make the case that wet season burning is likely to be a cheaper alternative to early dry burning in the longer term. This is because early dry burning requires an intensive, extensive and expensive effort *every year*. If wet season burning were to be applied successfully, the extent of prescribed annual burning would cumulatively lessen, saving human effort and therefore money.

Wet season burning and mitigation of greenhouse gas release

I am far from an expert on this topic. However, my understanding is that early dry season burning releases less greenhouse gas than late season wildfires – over a twelve month cycle. Without preventative early dry burning there is a high risk of late dry fires consuming vast areas of land and releasing far greater net amounts of greenhouse gasses. Late dry fires burn woody material, which permanently release more gasses than do grass and litter. Well-executed early dry fires on healthy natural bushland, release only a small, annualised net amount of gas. This is because the majority of gas released is taken up again during the following wet season's growth cycle.

Wet season burning would take this one step further. Early wet season burning interrupts the grass/fire cycle by eliminating a significant proportion of the flammable matter that would otherwise germinate, grow and be burnt.

It is noted that smouldering combustion of moist woody material (including accumulated leaf litter), which can be expected in the wetter months, releases more destructive species of gasses such as nitrous oxide and methane – than the cleaner burn of the dry season.

But on the other hand, wet season burning is not repeated every year and therefore results in no greenhouse gases being released at all for several years from a given parcel of land. In addition, the reduction of fire frequency coming from early wet burning gives more time for leaf litter to break down biologically with minimal gas release.

Generally speaking, early wet burning will maximise the time between fires – compared to early dry burning.

When early dry season fire returns to areas that have been wet season burnt, it does so 'gently', intensifying year on year till the fuel eventually reaches its pre-wet season burning density. Once this occurs it can once again be wet season burnt resulting in a mosaic patchwork over space and time.

Early dry burning is all about removing fuel *after* its growth event, while wet season burning is all about preventing the growth event in the first place and increasing 'time between fires'.

Also, it has been my experience that a good wet season fire does not usually have the energy to ignite dead timber, which is damp below its surface. Therefore, in my view, although a one-off event of wet season burning may produce relatively high amounts of noxious gasses, it does not release as much greenhouse gas as early dry burning does – over a multi-year time frame.

BELOW: This picture illustrates how fine woody material on the ground did not burn when a wet season fire passed through. Heavier timber is even less likely to burn.

Case study: Spear grass removal for protection of life and property

A fire on September 6, 2017 that threatened the community of Marrakai on the Arnhem Highway, 85 kilometres from Darwin, makes an interesting case study. This event illustrated how early wet season burning has potential to be used for safety purposes as well as ecological sustainability.

Outer rural estates (such as Marrakai) radiating around major towns are often firetraps. This comes about for a variety of reasons, which include:

- arrival and entrenchment of potentially lethal gamba grass
- relatively high numbers of deliberate or accidental arsonists
- multiple abutting land titles with many different land use objectives
- varying degrees of compliance with fire preventative legislation
- low levels of fire management experience and knowledge amongst residents
- complacency and ignorance of fire issues amongst some of the local residents
- gross accumulation of fuels on individual properties over time.

There is a fire protection 'catch 22' happening in many places like this, for example:

If an early burn is employed to remove the fuel at the outset of the dry season, then the opportunity to burn in the early wet season – with its longer lasting benefit - is lost.

However, if an area is not burnt each year, the fuel loads become denser and the potential danger from wildfire grows annually.

But, if an area is saved for wet season burning, there is a high likelihood of the area being burnt out badly in the late dry season, from fires lit by persons unknown.

The residents usually have little experience or knowledge of fire and its risk. This means that they are unlikely to do much protective burning on their own properties.

Sadly and inevitably, the fire threat to these communities will intensify dramatically as gamba grass silently tightens its fiery grip on the landscape.

Although the principle of the wet season burning concept is valid in this setting, its practical application in locations such as Marrakai is exceedingly difficult to do for the reasons given above. If areas such as Marrakai could be subjected to broad acre wet season burning, the risk of uncontrollable dry season fires would be dramatically reduced. But for Marrakai at least – this is unlikely to happen.

Perhaps their only hope of living without fear is to surround their community collectively with a long paddock stocked with cattle or buffalo! Imagine if Marrakai was situated in the middle of Carmor Plains or Ringwood stations. Not only would there be minimal risk of wildfire, but the residents could wake up to the sight of Gouldian Finches in their gardens!

Arguments against wet season burning

Photo Ian Morris.

1. Only temporary relief?

Some authors state that beneficial effects of wet season burning are very short lived:

- *At Bradshaw, wet season burning substantially reduced (generally by around 50%) fine fuels (grass and litter) for at least two following wet seasons.' (Russell-Smith et al. 2001)* [51]
- *At the Ranger Mine, (Williams and Lane 1999) considered that the positive effects of removing annual Sorghum by wet season burning may last only a couple of years.* [44]

I believe that these results are understated as described on page 25 above for the Kentia Palms. It takes a period of trial and error to develop the skills necessary to achieve the best results from wet season burning. Quality results are unlikely to result from a one-off burn without prior experience. It is arguable that Williams and Lane did not possess the experience necessary achieve the results described above for the Kentia palms.

Note also that the experimental plots used for the studies by Williams and Lane and by Jeremy Russell-Smith at Bradshaw were tiny compared to the 'free range' Kentia palm fire. Unpublished data (Kym Brennan) suggests that, *if an area large enough is burnt to restrict fringe recolonisation from surrounding areas, such effects may last at least four years.* [45] The Kentia example at the West Alligator River covered an area of many hectares, thereby minimising fringe reinvasion.

With all due respect to Williams and Lane, their results may be unintentionally misleading. Their conclusions may have the unfortunate effect of turning interest away from what is probably the most powerful habitat management tool available in north Australia. I strongly urge more research on this issue with a view to management application.

Partridge Pigeons nest on the ground in the early dry season. As a result, they are highly vulnerable to early dry season fires. These Ragul eggs were destroyed by an April fire.

2. Wet season burning and the grain eaters

Successful wet season burning can render annual grasses almost extinct for a number of years. The broad acre removal of annual grasses raises the obvious question of how this might affect the seedeaters. Spear grass carries relatively high levels of nutrients in its seed. [46] Pigeons, finches, rodents and numerous invertebrates rely on grass seeds during the dry season. For many years Kakadu managers have flagged this issue as an important area for additional research. But due to a range of factors, no substantial work has been done in this area, with the exception of Fiona Fraser's study on Ragul (partridge pigeon) in the Nourlangie Creek area. [47] This bird is listed as *vulnerable* on the NT Threatened Species List. Its numbers are in decline.

In terms of granivores like Ragul and wet season burning, I can only paraphrase Fraser's words: *'It is highly complex'*. She records that Ragul do not like widespread early fires as this *'leaves nowhere for pigeons to nest or shelter'*. It is noteworthy that she chose the Buffalo Farm in the Nourlangie Creek area of Kakadu for her study. The site was chosen in large part because of the abundance of Ragul there – in a grazed landscape! In my view it is not a coincidence that grazing and abundant Ragul occur together. The same appears to be true for Gouldian Finches, as detailed on page 61 below.

I believe that we can safely assume that historically, granivores existed/thrived prior to the rise and rise of spear grass and its associated fires. If spear grass was once again reduced to its ancestral population density, one would assume that life would go on for the grain eaters as it did in earlier times. (Note that frequent early dry burning also disadvantages the granivores [61]).

Leichhardt (in November 1845) noted that Ragul in this region shot for the pot, had *Eriachne* seeds in their crops. He did not note *Sorghum*. [48]

BELOW LEFT: This photo shows a partridge pigeon (Ragul) egg and squab. This nest was in the path of an early dry season fire lit by rangers. Luckily the rangers were on hand to quell the fire before it reached the nest. Ragul are not usually so lucky.

BELOW RIGHT: Masked Finch eggs destroyed by a fire in early May. *Photo Mark Lamble.*

It is also important to understand that spear grass seed does not lie about on the landscape for the convenience of grain eaters. Most spear grass seeds bury themselves soon after falling to ground and another approximately 40% is destroyed by fire.[60]

In addition, it would be a mistake to assume that no seed would remain in the wake of wet season burning. As Russell-Smith found at Bradshaw [51], annual *Sorghum* was in part, replaced by a variety of native perennial grasses that are not so much affected by wet season burning. Without competition from domineering annuals, the perennials increase their density rapidly, but not to the degree of flammability of annual spear grass. [60 page 59]

Also, unlike early dry burning, wet season burning tends to be a patchy mosaic and is, serendipitously, most effective in areas of dense spear grass. This means that in the real world (even if wet season burning is pursued with vigour,) the size of areas denuded of spear grass seed would be limited in any given year and would be replaced with seed from other species over the following few years. In most cases, annual spear grass will eventually reassert itself. However, follow up wet season burning is not feasible until fuel loads once again become high enough to carry fire.

In this 'real life' scenario, there would be only a short period of time, in limited areas, where edible seeds are scarce for fruit and seed eaters such as the Black Footed Tree Rat as shown above left.

Gouldian Finches are an interesting species in this regard as they breed between February and July in hollow tree limbs. Nesting in trees affords them more protection from early fires than shrub nesting birds.

Gouldians are obligate granivores and rely on a range of seed species to feed their nestlings. They appear to time their breeding with the season of grass seed set. Recent detailed observations near Pine Creek showed Gouldians having a clear preference for perennial grasses whose seeds they gathered from the ground. By comparison, they were only rarely seen in annual spear grass. (Mark Lamble pers. comms.)

In areas of heavy speargrass infestation, extreme fires can lead to habitat degradation and seed depletion over the Gouldians foraging range. This can lead to semi-starvation during the late dry and early wet seasons.[65] Where speargrass is in plague densities, the addition of small scale wet season burning into the fire matrix would provide greater heterogeneity to the 'seed-scape', to the benefit of granivores. But this should be avoided in areas close to nesting sites, as wet season burning removes most seed from the landscape for several years.

> Nobody knows the true toll of early dry season burning on ground and shrub nesting birds. But it is evident that the vast areas of early dry burning carried out in Kakadu must claim enormous numbers of eggs and fledglings from a wide range of species.

Benign early dry burning (on low fuel loads) and light grazing appear to be the ideal combination for Gouldian Finches. This is evidenced by flocks of these beautiful birds living on well-managed Top End pastoral properties. They are rare in Kakadu.

Despite the abundance of seed, it is noteworthy that granivores can be negatively impacted by early dry fire as well.[61]

I would speculate that in any given dry season there must be many hundreds of Ragul eggs and squabs killed by early dry season fires in Kakadu.

This cannot happen in the early wet season as Ragul do not nest at that time.

ABOVE: Finches such as this Masked Finch, are amongst many animal species that have young in the nest or at foot that are killed by early dry season fires.

RIGHT: This flock of Gouldian Finches is a small group of a much larger population of Gouldians thriving on a pastoral property in the Top End. *Photo Ian Morris.*

3. Burning vegetation at a botanically sensitive time of the year?

It might be argued that it is a mistake to burn the landscape at a time when the vegetation is in full growth mode following early wet season rains. At this time of year, most of the ground and mid-story (and therefore fire vulnerable) plants are bursting out in new, delicate growth and should not be burnt. This is particularly so for epiphytic plants emerging from tubers and bulbs – a group that is negatively affected by wet season burning.[51.]

Werner et al. found that seedling eucalypts can be killed by fire, (or competition from other plants post fire) at this time.[56] Also, many beneficial annual grasses are also in full growth mode at this time and will be killed off along with annual spear grass.

This crinum lily (a species which grows seasonally from a bulb) has been damaged, but not killed by a wet season burn.

Most land managers – including park rangers – see early dry season fires through the prism of 'protection from late dry season fires'. They generally do not see it through the prism of, 'How does the wildlife survive early dry season fire?'

All this is true, but the negatives are mitigated in the following way:

- Wet season burning is generally not very extensive. This means that – in stark contrast to early dry fires – vast areas of land are unlikely to be burnt in any given year. Wet season burning is more likely to lead to '*fine scale mosaic burns*' – the holy grail of fire management.
- Wet season fires are generally of low intensity and their scorch height is therefore modest. In addition, the low intensity causes reduced heat damage generally. I have observed raindrops remaining on undamaged *Terminalia ferdinandiana* leaves at waist height after a wet season burn had passed through. This is not always so. But on the other hand, and helpfully, any area carrying such heavy fuel loads that cause significant scorch from a wet season fire, must also be an area in urgent need of this treatment.
- At this time of year, the healing effect of rain generally arrives shortly after any wet season burn. In addition, the soil is already likely to be moist from earlier rain – thereby both protecting the soil from incineration and also providing stronger 'come back' potential.

4. Wet season burning and soil erosion

The potential for wet season burning to cause serious soil erosion on sloping landscapes was described in detail by Russell-Smith following his work at Bradshaw in the north west of the NT.[51] His findings present a management conundrum. Burning away the protective herbage on sloping sandy soil – just before the heavy rains of the wet season – is a sure-fire way to encourage erosion.

The scree slopes and valleys of the fringe of the west Arnhem plateau and its outliers are the most bio-diverse regions in the NT and are listed as a nationally important biodiversity hot spot. Dense blankets of spear grass are a feature of many of these areas, as is the decline of the quality of the fragile stone country ecology. This is no coincidence. In fact, Australia's most recently listed threatened plant community is the Arnhem Land sandstone heath habitat. This habitat is directly threatened by fire fuelled by annual native grasses.

The western flank of the Arnhem plateau contains numerous areas where spear grass fires are irreparably damaging ancient stands of the endemic tree Anbinik, *Allosyncarpia ternata*. Examples are described by Professor Sweet earlier.

There is an overwhelming need to rein in spear grass in these sensitive areas without triggering damaging soil erosion. In my view, early dry season burning is not the answer to this conundrum.

The heat generated from burning dense spear grass in the early dry – in this environment – is sufficient to kill many Anbinik.

And of course, the ever-present Achilles heel of early dry burning is that these early fires only cause the problem to go away for one year – after which it must be repeated year after year if a large and destructive late dry season fire is to be prevented.

But what soil damage is being done by the annual (or near annual) repetition of early dry fires in this fire sensitive environment?

Does early dry burning come with its own set of erosion problems? Apparently not in this situation. Work done by Russell-Smith et al. indicates that leaf litter accumulation after an early dry burn will build up to a point where it provides similar protection from rainfall triggered erosion as occurs with no burning at all! [51]

However, because the sandstone environment dries out earlier than the lowlands, early dry fires can get into the crevices in the rocks and burn out the roots of mature Anbinik, as well as all other sandstone vegetation. These crevice fires are almost impossible to control in a fire suppression sense. In my experience, wet season burning does not readily trigger crevice fires.

Weighing up the pros and cons; on balance I would argue that the gradual switch from frequent early dry to infrequent early wet season burning in this environment would give better long term environmental results.

5. Wet season burning and terrestrial invertebrates

The argument can be mounted that wet season burning will devastate the populations of invertebrates which are active on the soil surface at this time of year. This is an important point.

However, the killing of land snails, centipedes, spiders and other invertebrates would be mitigated by the fact that wet season burning can only occur during the heat of the day when these creatures are mainly hidden away underground. The moisture in the soil means that soil scorching only happens on the very surface layer and heat penetration into the soil is greatly restricted.

Also, regrowth of vegetation is rapid following a wet season fire, in contrast to dry season fire. In addition, wet season burnt areas are unlikely to be burnt thereafter for 2 to 4 years, unlike dry season burning frequency.

Finally, wet season fires constitute a relatively small total area of country burnt each year.

6. Wet season burning and perennial grassy weeds

In areas where annual spear grass and invasive perennial grassy weeds such as gamba grass, mission grass, *Humidicola* and para grass are jostling for pre-eminence, wet season burning will give an advantage to the perennial, rather than the annual weeds. Any application of wet season burning to such areas needs to be done with forethought and planning because this is a two-edged sword.

On the negative side is the obvious scenario where weeds like gamba grass will likely come to the fore in the wake of a wet season burn due to removal of the competing annuals.

On the plus side is the situation whereby wet season burning:

- clears the land and improves access to weed control teams
- exposes the early growth stages of weeds more readily
- exposes the regenerating weeds to more effective and economical application of herbicide
- allows for more ready identification of weeds versus natives.

But this positive note can only apply in a management situation where there are the staff and other resources available to tackle weeds in the wake of the fire. In the absence of these resources, the battle will quickly be lost to the weeds.

However, it is sobering to consider that even in the absence of any wet season burning – without aggressive weed management – weeds such as gamba and mission grass will come to dominate in any event. The difference is that it will be a slower defeat by the weeds under an early dry season fire regime. The good news is that (a) there are vast areas of the Kakadu woodlands, which do not (yet) have serious perennial weeds, and (b) annual weeds are almost as badly affected by wet season burning as annual spear grass.

Note of caution: Although burning gamba in the early wet season results in a more manageable fire than in the dry season, it can still be dangerous, producing prodigious amounts of heat.

Note: *Annual and perennial* weeds *thrive* under the regime of early dry season burning which is currently being employed across most of the Top End.

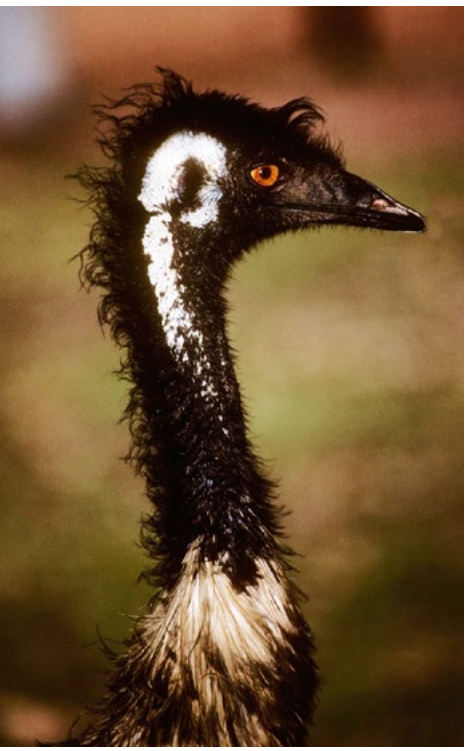
It is noteworthy that if our Top End national park agencies cannot defend our reserves from gamba and mission grasses, they will be lost forever. Kakadu should have a task force to confront this threat in the successful manner that they did for *Mimosa pigra*.

But alas, the Federal government has stripped Kakadu of that kind of resourcing and it appears that the park lies mainly defenceless against the inexorable onslaught of gamba grass.

ABOVE AND ABOVE RIGHT: Without any burning Gamba looks like this in the early wet season. It is ripe for poisoning due to its new flush of growth, but the large quantity of dead matter soaks up herbicide and weakens its effectiveness. Thus spraying under these conditions is expensive and inefficient.

RIGHT: But after a WSB (or an early dry season burn) it looks more like this – (a) easier to access (b) more cost efficient to treat, (c) results in higher mortality from less herbicide and (d) it is easier to identify weeds from natives.

Now to the negatives of early dry season burning



The previous pages examined the ecological damage that might be caused by the timing of wet season burns. But it is important to consider the alternative.

I believe that widespread and frequent early dry season burning in country laden with spear grass does more harm to the ecosystem than early wet season burning: (a) at the time of fire, (b) in the weeks following the fire and (c) cumulatively over years.

By way of comparison and review, the negatives of early dry burning are:

- In areas of heavy grass loads, country needs to be burnt in a short time frame, that is April to mid-May. Many land managers fail to carry out this burning in the 'safe' period and will continue into the fire danger period in order to burn the amount of land that they feel needs burning. This leads to large areas of land being burnt in the middle of the dry season when fires should not be lit. This also leads to fire 'over run' with fire sensitive country such as creek lines being burnt unintentionally.
- It is expensive to reach target areas, as aircraft must be used to access places before roads have dried out in the early dry. Only aircraft can ignite the huge areas targeted in large national parks such as Kakadu. But aerial burning cannot achieve 'fine scale mosaic' burning unless a huge aircraft budget is available.
- Each year vast areas of woodlands are burnt during the breeding season of ground and shrub nesting birds, for example, finches, curlews, partridge pigeons, quail, bustards and emus. It is likely that many terrestrial animals (in addition to birds) have young in the nest, or at foot, at this time of year. Without fire they have a wide selection of foodstuffs available and a good deal of protective cover. An early dry season fire removes much of that prematurely.

- Where early dry season burning results in 100% scorch, the dominant trees do not produce flowers for that year (probably even more). This lack of flowers means little nectar or pollen for the many vertebrates and insects that rely on this seasonal bounty. Nectar eating birds are forced to relocate from these areas. Commercial apiarists claim that trees burnt to the canopy do not flower for up to five years after.
- In spear grass infested country, early dry burns are usually too hot, and the landscape left behind is hostile to numerous species of terrestrial animals. Cover removed includes bunch grasses, stumps, hollow logs and general forest floor debris. The lengthy period of denudation of the forest floor (up to seven months) benefits the hunting success of cats.
- The total 'burn-out' nature of most early dry fires prematurely removes nutrients from topsoil and therefore the woodland ecosystem. These nutrients would otherwise naturally be reabsorbed over the remainder of the year. This leads to a cumulative diminution of nutrients available to the soil and the rest of the ecosystem.
- Some species of animals exhaust their energy reserves during the wet season breeding effort. An early dry season fire through their territory can deny them the resources they need to recover. Example: most breeding tree monitors are known to die of starvation if their territory carries a lot of spear grass and is subjected to early dry season burning.
- Although 'fine-grained mosaic burning at 3 to 5 year intervals' is called for, this is rarely achieved except on small, intensively managed areas of land.
- Even if a given area is unburnt for 3 to 5 years, this results in a subsequent early dry season fire being destructive as it will necessarily be burning the accumulation of 3 to 5 years of fuel loads.
- Land managers are trapped into a grass/fire cycle whereby they are (in my view) wrong if they do (early dry season) and wrong if they don't (risk of late dry season burn).

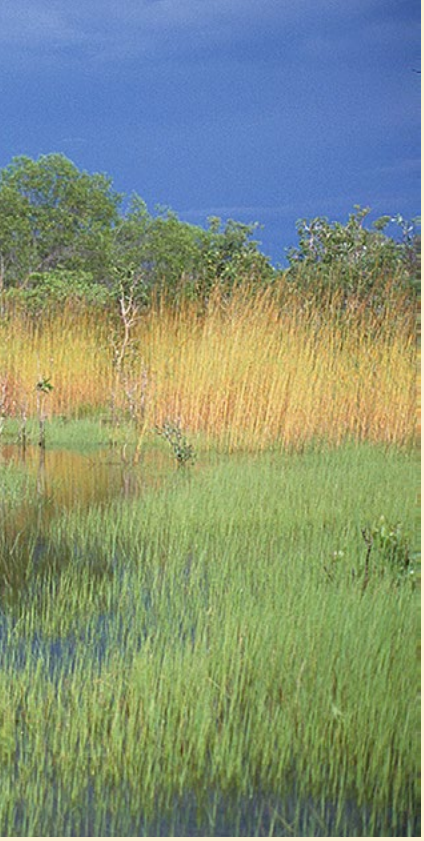
BELOW AND BELOW LEFT: There is no doubt in my mind that both of these species of lizards, along with many others, were in decline because of frequent early dry season burning – well before the arrival of the cane toad.

- Frequent early dry fire in spear grass country promotes yet more spear grass.
- This in turn promotes hotter fires, which spread further and are more frequent.
- This in turn encourages more spear grass, and so on. The effect of this is to compel the land manager to be even more rigorous in their early dry burning to prevent late fires getting into the high fire risk areas that they have created.
- Annual early dry burning in this scenario results in the loss of biodiversity in all habitats.
- It is very difficult to reverse this downward ecological spiral.

And the positives of early dry season burning

At this point it is fair to list the positive attributes of early dry season burning. While being important, they are comparatively few in number.

- Under favorable conditions, (light fuel loads) early dry burning will be of lower intensity and burn smaller areas when compared to mid and late dry season burning.
- Early dry season burning provides relatively assured seasonal protection for property and livestock from late season fires.
- There is a generous amount of fresh regrowth following most early dry fires.
- In the hands of skilled practitioners, early dry fires can be reliably replicated to protect natural assets (monsoon forest patches for example) and built assets every year. (And I endorse this on a case-by-case scenario).
- As a management strategy, early dry season burning is well understood by most land managers. It is therefore relatively easy to implement, regardless of scale and personnel training. But from the ecological perspective, I would say that it is very poorly understood.
- Depending on timing, prevailing weather and the state of the fuel, early dry season fires can cover a large area - but do a lot of ecological damage in the process. In fact, the greater the area, the greater the damage.

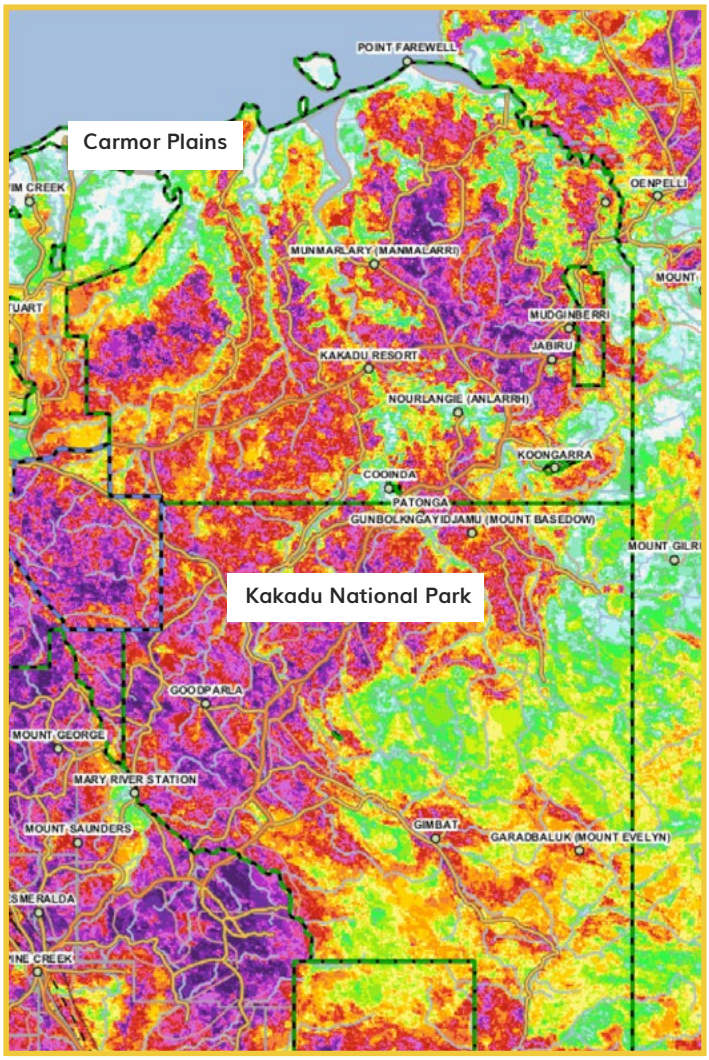


These images taken in the late wet season illustrate spear grasses' weed-like quality, whereby it can even invade wetlands subject to seasonal inundation. Spear grass is the yellow vegetation.

Part III.

Case study: fire management in Kakadu

The known history of fire management in Kakadu provides plenty of information to construct an interesting case study. The NAFI3 image on the page dramatically illustrates the frequency of fire in Kakadu over 17 years. Any colour with a warmer tone than pale green represents an area burnt too often.

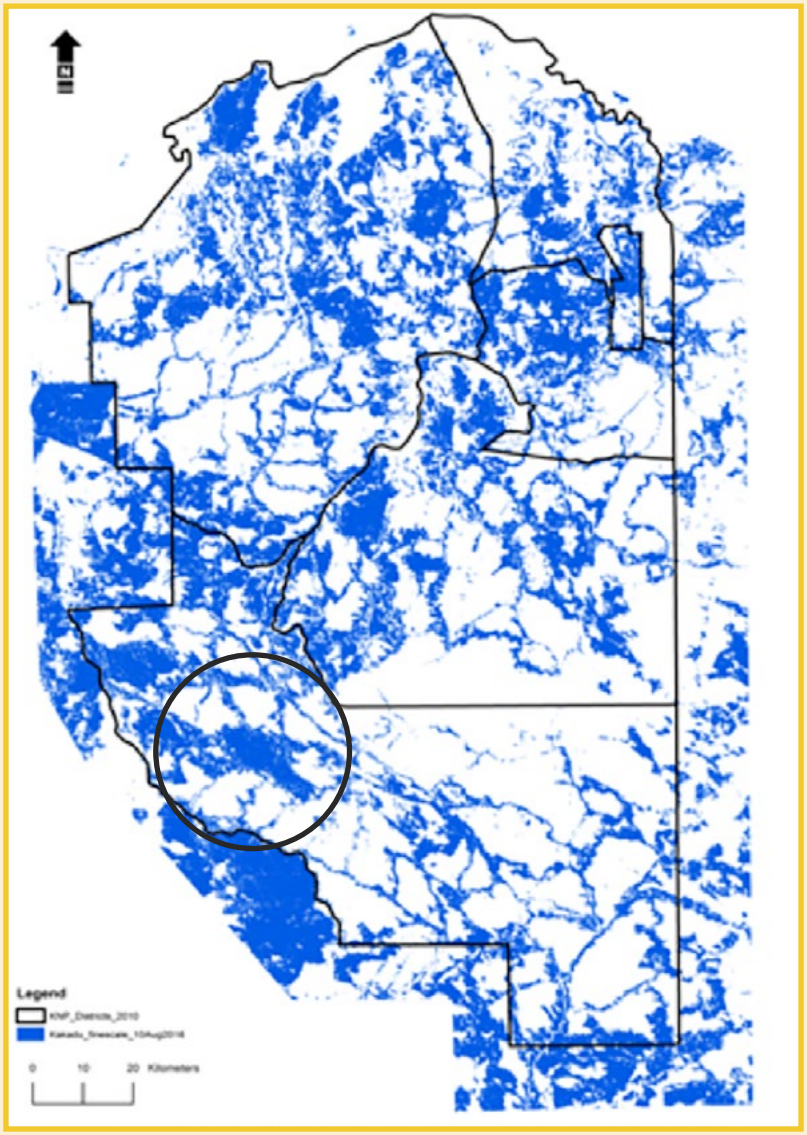


This is a picture of the destruction of a World Heritage national park.

Carmor Plains (upper left of the map) stands out as the model to emulate, in my view.

Innovation in Kakadu – is this the new way forward?

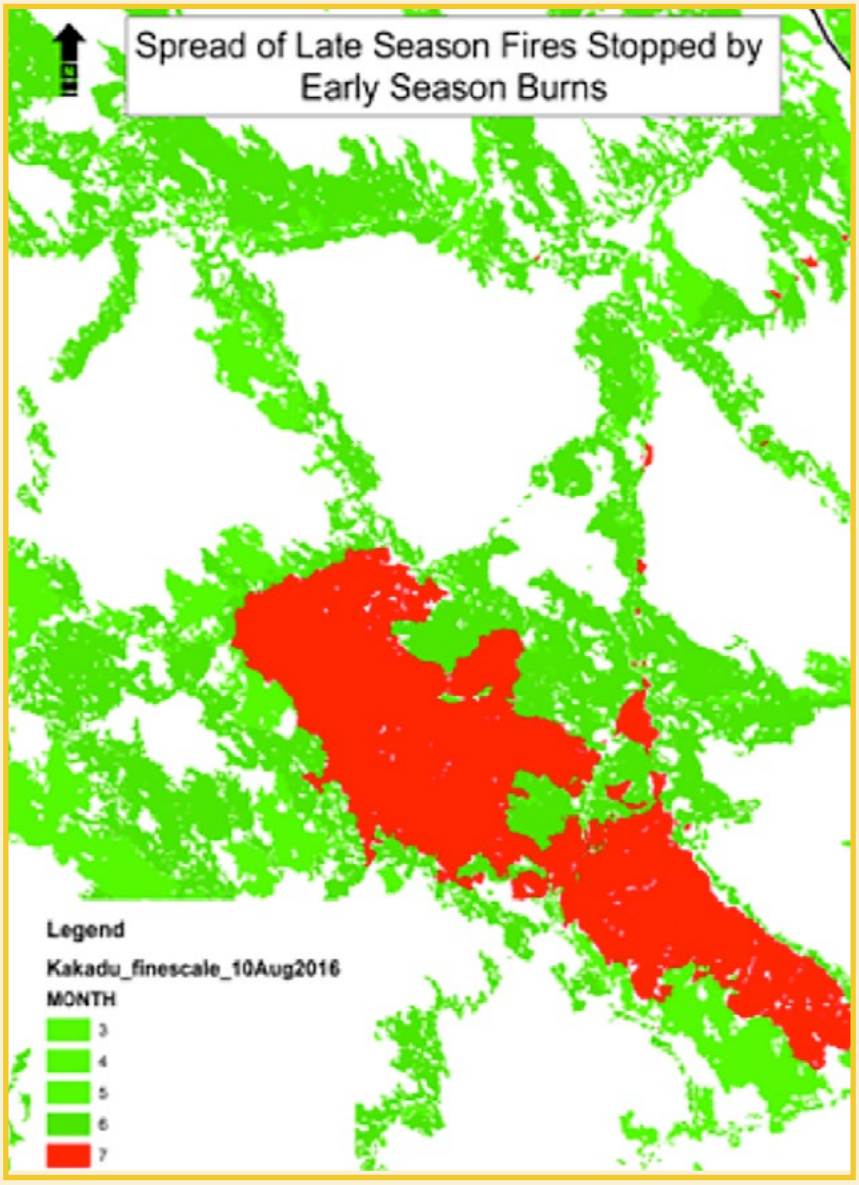
In 2016, in recognition of its disastrous fire management, Parks Australia and the traditional owners of Kakadu embarked on a new beginning with regard to annual burning. A specialist fire coordinator was appointed, and a significant amount of money was put aside for aerial incendiary work. Two years on and the results look encouraging, as testified by the following maps.



Right: The fire scar map of Kakadu at right was made in September 2016. It shows an important change from previous years. In 2016 the park made a valiant effort to rein in fire. The map shows the result of an intensive aerial incendiary campaign in the early dry season across the lowlands and in the stone country. They were able to do this by dramatically increasing their chopper budget.

A close examination of the map shows that extensive linear burning has created multiple fire break 'compartments' across the landscape. The aim of this being to break the country up into rough blocks of unburnt land, surrounded by lines of burnt country which act as breaks later in the year. Although this entails a great deal of deliberate burning, it paradoxically results in less overall burning by the end of the year. This dramatic increase in aerial ignition has also reduced the need for ground ignition which is expensive and not very effective. To do all this, the park now has staff members dedicated to the burning effort. This has not been done before.

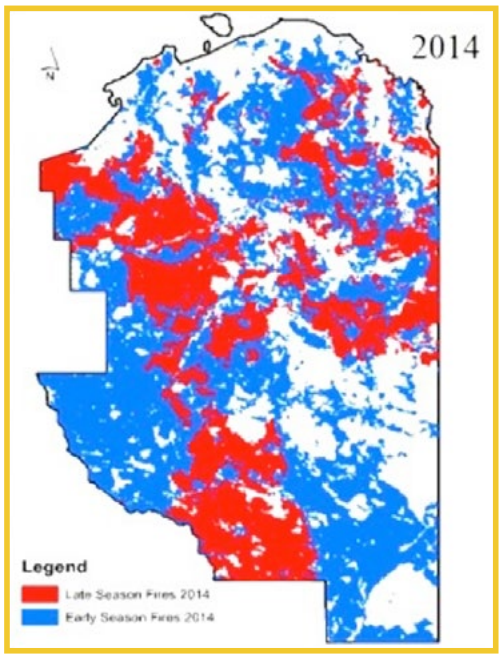
The area circled is enlarged on the map on the following page.

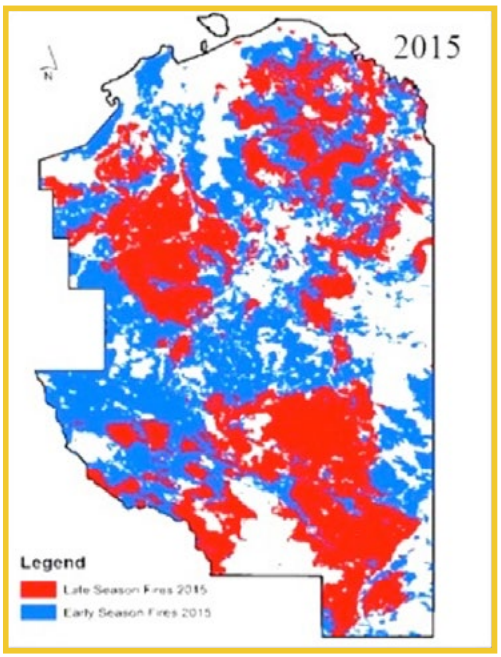


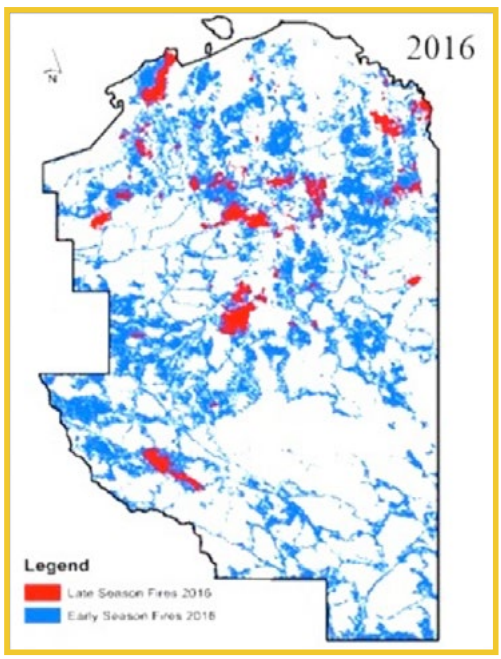
The image at left presents an example of how this method works. The map shows a late dry season fire (in red) that burnt in August. As can clearly be seen, the earlier aerial burns, shown in green, have contained this fire. Without the earlier burning the red August fire would have consumed a far greater area of land as there would be little or nothing to contain it. This is a highly desirable situation.

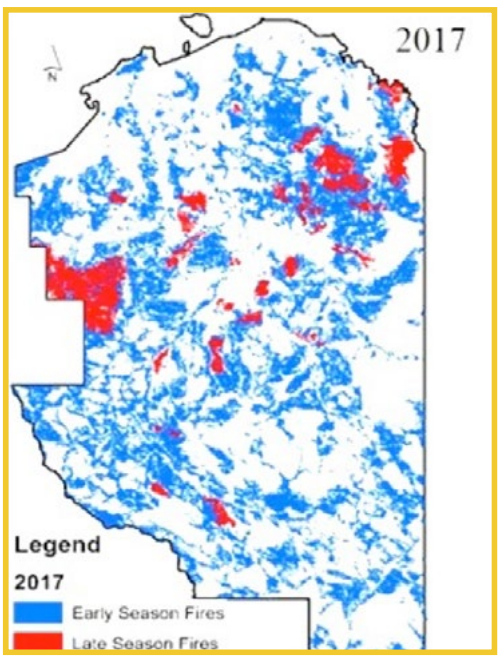
The table and maps below show the dramatic change in area burnt over a period of four years.

KAKADU BURNING:	2014	2015	2016
Area burnt by end of July	43.7%	34.4%	26.0%
Area burnt by end of August	55.2%	42.4%	28.1%









NOTE: The percentage of area burnt in 2014 and 2015 was as high as 76%. The red colour shows late season fires and the colour blue shows early season fires.

Maps courtesy of Parks Australia

There are questions surrounding this expensive new approach:

- Is it financially sustainable in the long term?
- Is it ecologically sustainable?
- Will the environmental effects be monitored?
- How does it work in terms of reducing fire frequency over time?
- What are the long-term environmental consequences?

On face value, this approach looks promising. It is clearly better than what has gone before. Parks Australia can claim credit for this initiative.

However, there are several potential problems apart from the cost:

1. This method appears to rely on the **annual burning** of contiguous firebreaks. If these breaks follow the same alignment each year, in my view the frequency of burning of those strips is too high especially if they follow creek lines. Ecologists know that burning of riparian vegetation is destructive.[7]
2. In the stone country it would be necessary to follow the **same lines each year** due to the nature of the topography. If this method is used where spear grass is not yet entrenched, there is a risk of facilitating the spread and intensification of spear grass and creating the annual 'grass/fire cycle'. This could ultimately destroy the fragile sandstone environment that the aerial burning is meant to protect. Even if spear grass does not come to dominate these rocky areas, dry season burning every year will – in my view - destroy the fragile sandstone ecosystem. Even spinifex is removed by annual burning.
3. The twin dangers of **fuel accumulation and fire frequency.** Where these contiguous breaks are successful at eliminating fire for two or more years, there is the problem of grassy fuel accumulation. Without grazing animals present, it takes several years for dead grass to break down. This means that where a section of land is protected from fire, the fuel accumulates year on year. Then, when a fire does arrive, it will be more destructive than a fire with only twelve months of fuel accumulation. Catch 22.
4. **Inconsistent results.** Following on from the point 3 above, there is also the possibility whereby a fire will behave in a certain way at a certain place in year one, but it may not behave that way in year two or three. This is because of the double (or triple) thickness of fuel blanketing the ground. This could mean that the desirable white areas of unburnt country shown on the map, could be consumed by the aerial bombing in year two or three. But because it will be burning through a double (or triple) layer of grass and litter fuels, it will be hot and destructive – even in the early dry season. Wet season burning negates this problem.
5. The compartments shown on the map remain too large for **terrestrial animals with small home ranges**. Incorporating wet season burning will add more habitat diversity to the matrix.

Ground burning in Kakadu. It can be risky.

In late 2018 I sent a final draft of this book to Kakadu for fact checking and to gain more information about the questions posed above. Unfortunately, the response I received was of limited use. But I hope that their reading of this book will influence their attitude towards wet season burning in the future. I am confident that this book revealed to them to a good deal of information about which they were previously unaware.

But sadly, Kakadu is in a bad state. Successive governments have stripped its one-time healthy budget to that of a 'poverty Park'. The staff in Kakadu barely have the means to save themselves, let alone save the biodiversity of the national park.

To add insult to injury, all the newly announced money coming from the federal government (2019) is earmarked exclusively for the saving of the township of Jabiru and for tourism purposes. None is available for environmental management in the Park.

In November 2017, UNESCO re-evaluated Kakadu's conservation situation. They chose to degrade the Park's status to that of "Significant Concern". In my view they substantially underestimated the decline of the park's values. I believe that issues such as fire, weeds, toads, cats and disappearing wildlife have placed the park firmly in the World Heritage Property In Danger classification.

Kakadu is jointly managed by the Aboriginal traditional owners of the region and Parks Australia which is a Federal body.

The sorry state of Kakadu's management is neatly encapsulated in a 2019 investigation into the office of the Federal Director of Parks Australia conducted by the Federal Auditor General.[41] This report found that the Director had failed in virtually all of her/his managerial responsibilities.

But it must be noted that the fault lies not with the Director, but with the Federal government, which has brutally slashed the budget of Parks Australia.

Parks Australia is declining as fast as the biodiversity it is charged with protecting.

The Director's job is a poison chalice writ large.

But now the good news

If these unburnt 'compartments' (shown on on the map above) are subjected to wet season burning, several positive things can result:

- Progressively in-filling those unburnt compartments (the white areas) with wet season burning would dramatically expand the firebreaks – as the entire block becomes a firebreak. Importantly the main difference is that the wet season burned areas will be effective firebreaks for several years, not just one.
- As these areas are in filled with wet season burning (over a period of years) together with ongoing aerial linear burning, the need for annual burning along the same alignments will decrease.
- In the stone country – while recognising the problem of soil erosion – a series of wet season burns will minimise annual fire grasses such as spear grass - while at the same time curtail the need for annual early dry burning and all the monetary and environmental costs associated with that. The role of the fire officer would focus more on monitoring the returning fuel levels rather than simply burning the same gorges and valleys every year.

Some observers might wonder why rangers do not rush out and do battle with destructive fires. In the Kakadu context, the park is so large and fires so common that it is simply not practical or economical to fight fires with on-ground resources. However, Kakadu rangers will fight fires in environmentally sensitive areas where assets are threatened, or in areas where there is a strong strategic firefighting benefit to be gained.

Kakadu is putting a great deal of effort into getting local Aboriginal people back on their country as part of the annual burning regime. This is to be applauded as there are a number of beneficial outcomes for this endeavour with fire management being just one.

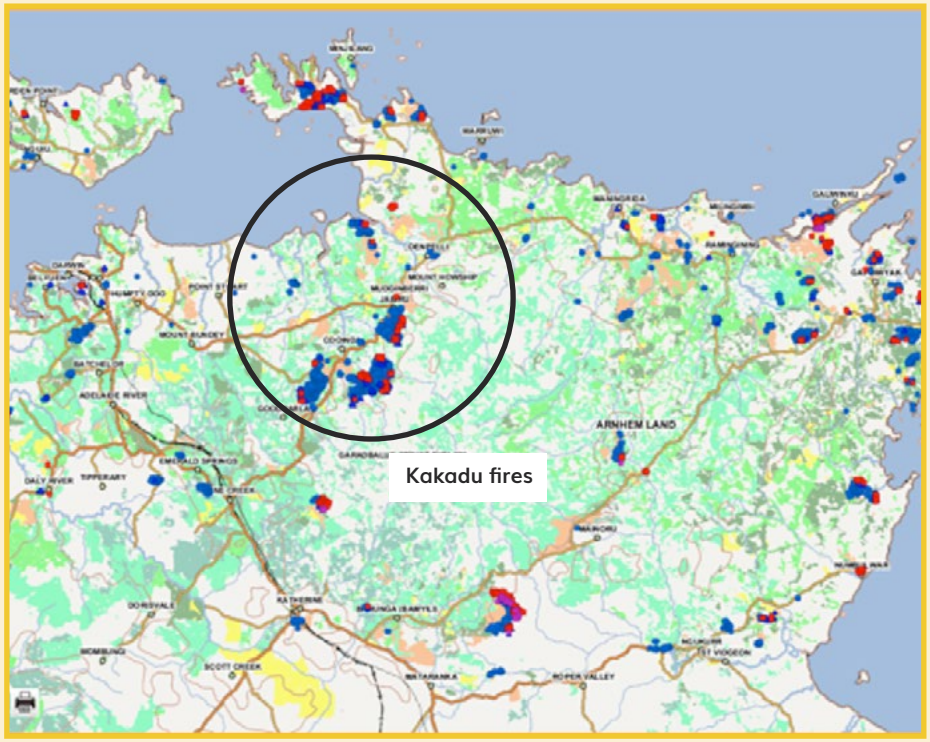
However, it can be very difficult to keep these enterprises working into the longer term – for many reasons.

I wish them every success in being able to keep this initiative functioning.

In 2018, the Park planned to do more ground burning. Ground burning from quads or Toyatos across thousands of square kilometres is a task of epic proportions and not to be taken lightly.

So how did it all go in the late dry season of 2018?

2 October 2018



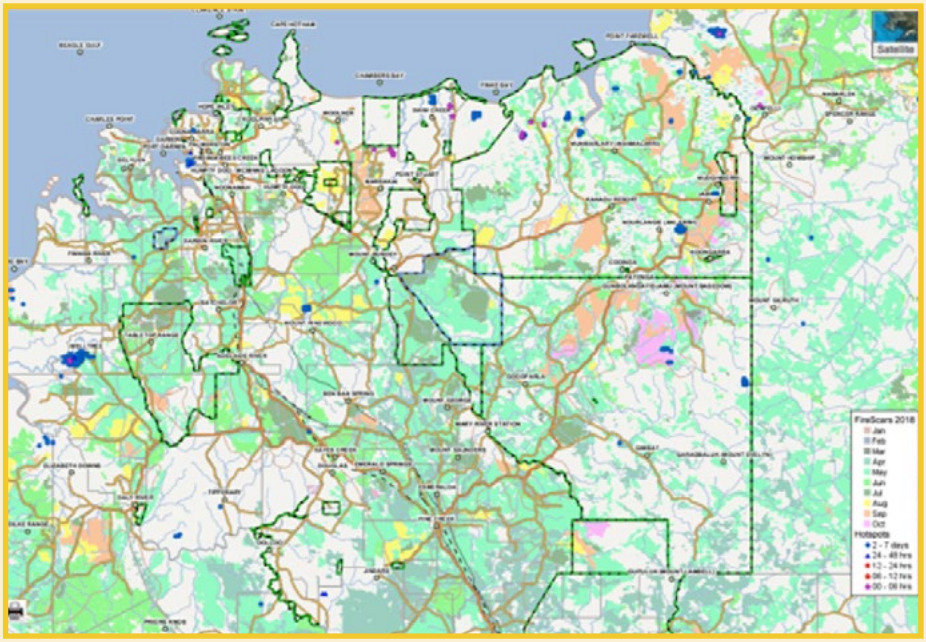
Not too well I would say.

It can be seen on the image at left that of the six largest fires burning in the entire Top End – on a severe fire warning day – four of them were burning in Kakadu! This is not a good look and does not speak well of the park's new strategy to reduce late season fires.

20 October 2018

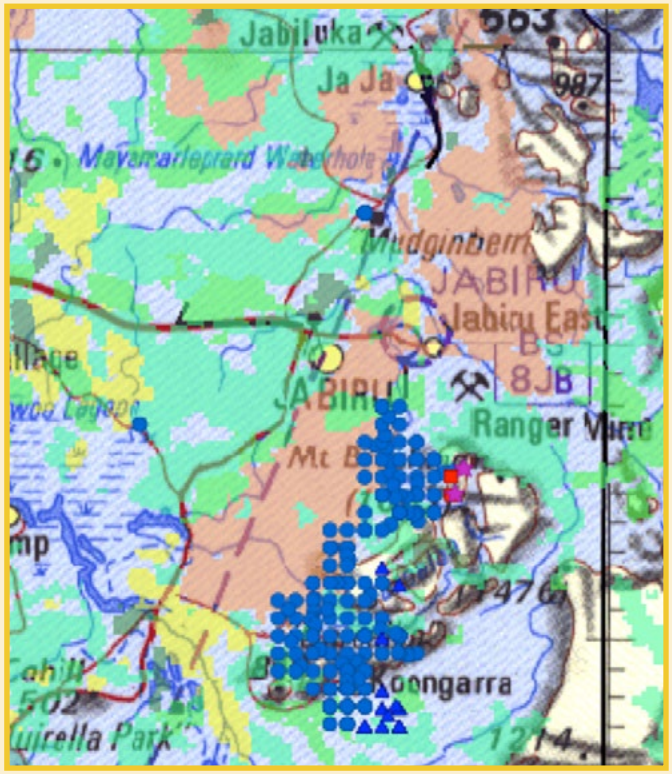
Perhaps more troubling still is that later – after the smoke had cleared – it can be seen on the image at right, that within the entire western half of the Top End of the NT, the largest fires at the worst time of year in that vast region – occurred in the heartlands of World Heritage Kakadu. The colours yellow, beige and pink collectively represent destructive late season fires.

It appears that no other single land tenure in the Top End was burnt as badly as Kakadu in 2018

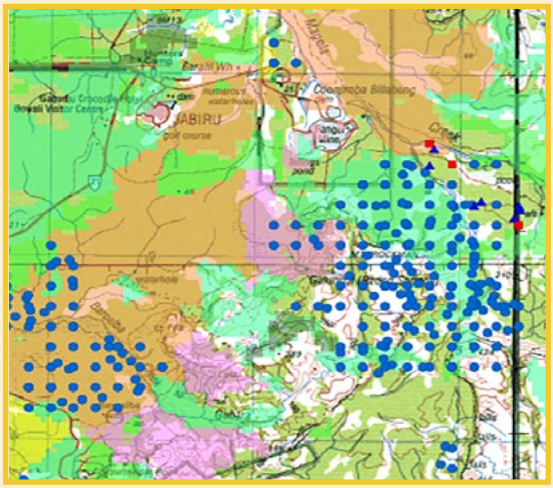


The fire south of Jabiru was particularly problematic – as the map below at left shows

6 October 2018



August 2019



ABOVE: 2019 UPDATE A hot fire again impacted the nothern half of Mt Brockman in August 2019. This fire scar map indicates that parts of Mt Brockman (which was unaffected by the fire in 2018) appears to have been burnt in part at least this year as I predicted at point 2 on page 82 below.

The 6 October fire (left above) had started a week earlier, adjacent to the East Alligator River road. It was almost certainly lit by a local person. In the course of its life it had burnt out most of the beautiful Djabiluka lease area, threatened the Ranger mine and the town of Jabiru, before continuing south to burn the area shown on the map on this page. It burnt onto the western side of the Mt Brockman outlier from Gulungul Springs in the north to Nourlangie Rock in the south.

The extent of this single fire can be seen on the map as indicated by the beige colour as well as the blue symbols.

The Mt Brockman outlier is one of the major jewels in Kakadu's crown. It contains an immeasurable wealth of both cultural history and threatened and endemic biodiversity. This area embodies the reason that Kakadu is a World Heritage property, listed for its 'outstanding universal natural and cultural values'. Yet once again it has been burnt – in part at least.

More generally speaking, even if it can be shown that the extent of late season burning in Kakadu in 2018 is less than in previous years, it is not acceptable that **premium** World Heritage country is burnt so badly. '*Total areas burnt*' tell only half the story. The *nature* of the land burnt is the other untold half of the story. Example: the large fire in Kakadu near the mouth of the East Alligator River (seen on the map on page 79 above) was of far less bio-cultural importance than the one at the Mt Brockman outlier.

But it is important not to blame the park managers for these and the other late dry season fires that happen every year. Kakadu staff are doing all they can to prevent fires like this. Rangers are left exhausted and despondent in the wake of such fires. These are not lit by rangers or by tourists and most often not by traditional landowners. But people who are local to the region mainly light them. These are people who have no idea of the damage done – or don't care. The park managers often know who these people are, but they are not held accountable for lighting these fires.

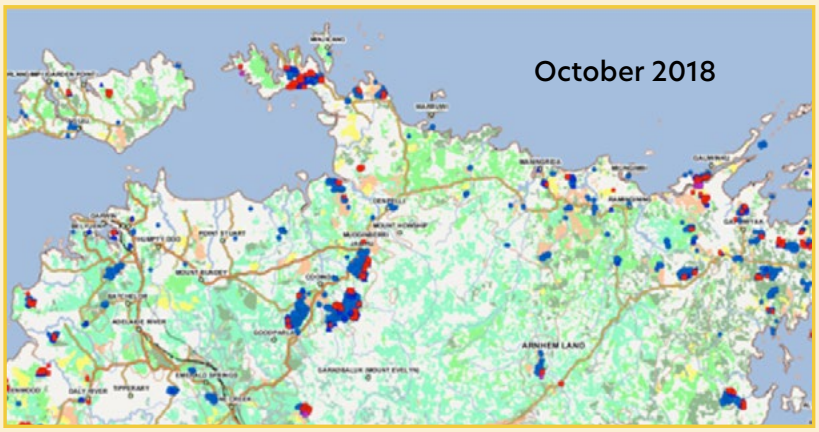
That's just the way it is in Kakadu and as long as there are no consequences resulting from these actions; it's not going to change any time soon.

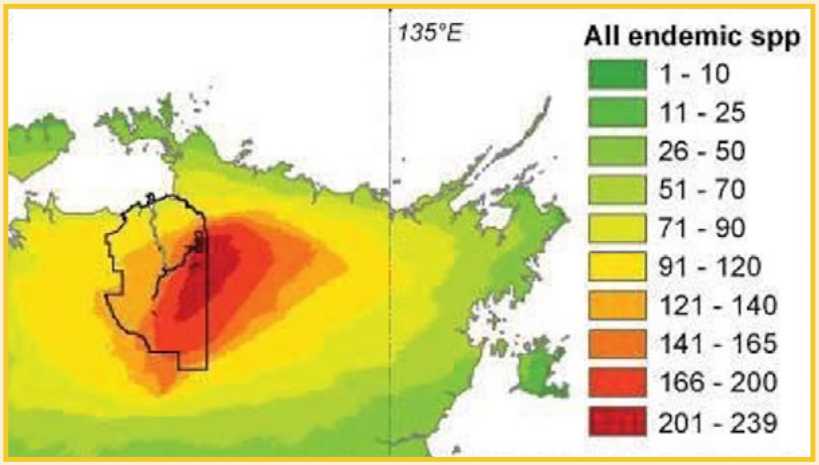
BELOW AND RIGHT: The Mt Brockman outlier is as good as it gets in the NT, (Australia even) but frequent fires are threatening its biodiversity. *Photo Ian Morris.*

What does the future hold for Kakadu? The maps tell it all

There are two things here that I find particularly worrying:

1. Firstly, the collision of the two maps shown below. If the lower map is overlain with the upper, we can see a biodiversity crisis right there. Here we see in the upper map (in the late dry season) the largest fires in the Top End of the NT. They were burning out of control right over the bullseye of where the NT's highest number of rare and endemic animals and plants live! In fact, this region is amongst the nation's most important 'biological hotspots'. Fire events like this are clearly unacceptable, yet they are the 'norm' in Kakadu.
2. Secondly, the same scenario may play out again next year – and the year after that and so on. As far as I am aware there is no strategy in place to prevent this situation happening repeatedly, even annually, into the future.





The lower map shows where Kakadu's fire control efforts should be concentrated. Although good fire management is important throughout Kakadu, it is critical that effort and resources are mainly targeted in the area shown in red. Unfortunately, in 2018, the worst fires in Kakadu were in large part in the red area.

There is no doubt that for a diabolically complex range of socio-political, cultural and financial reasons, Kakadu cannot solve this by itself. In addition (for these same reasons) it cannot call for outside help.

I feel that the only way for Kakadu to be rescued from continuing environmental decline – which is mainly of no fault of its own – is for NGO conservation organisations to come together to call for UNESCO to inquire into whether or not Kakadu is a World Heritage property '*in danger*'.

A public and transparent inquiry such as this would likely compel the federal government to restore funding in Kakadu to a level that makes good management possible again.

BREAKING NEWS 2019!

Evidence of a meaningful change of direction in Kakadu?

It is with cautious optimism that I report that during the wet season of 2018-19, Kakadu carried out an unprecedented amount of early wet season burning, as testified by the example maps at right.

This particular wet season was well below average. Extremely light rains were recorded across the Top End. This provided land managers throughout the region with a rare opportunity to carry out extensive wet season burning for months.

It is very encouraging to see Kakadu management embrace this opportunity.

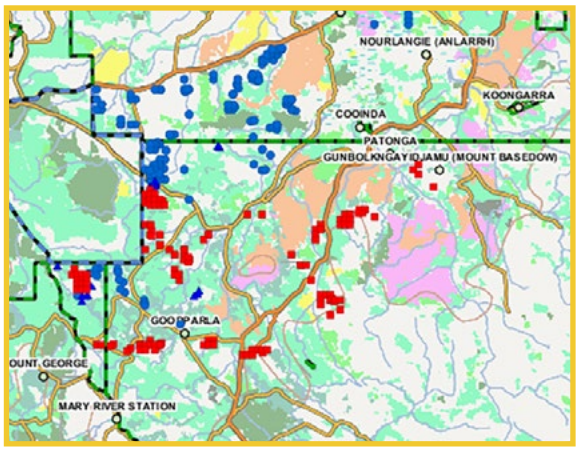
It remains to be seen how extensive and effective these fires were in terms of achieving wet season burning goals.

Will this be a rare one off (not to be repeated) or could it be that this activity is going to be carried through into the long term? I certainly hope so.

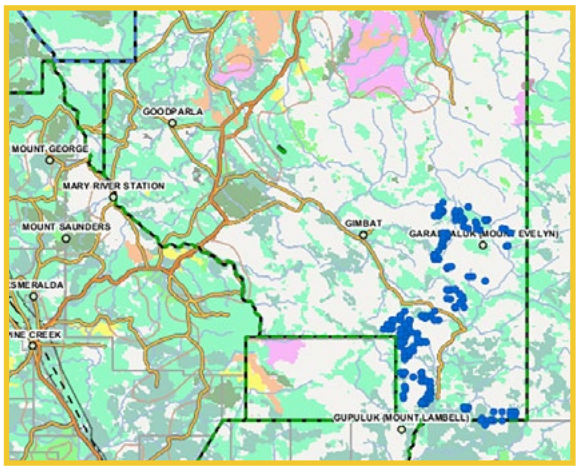
In overview, if Kakadu can maintain this level of wet season burning, in combination with a resultant reduction of early dry season burning, reinforced by Aboriginal led ground burning - then an ideal pattern of ecologically sustainable fire management can be achieved – in my view.

It appears Kakadu just might be heading that way.

13 January 2019



21 January 2019



Closing summary points

Wet season burning remains elusive

To me, its benefits are manifold and obvious. But amongst orthodox fire managers the idea has failed to gain meaningful acceptance.

This was highlighted on September 18, 2018 when the ABC ran a story about the bushfire problem in the north: *http://www.abc.net.au/news/2018-09-18/why-are-there-so-many-fires-burning-the-top-end-black-every-year/10238998*

I was intrigued to note that of the several local fire experts quoted, not one mentioned wet season burning as a strategy to calm the tenor of wildfire in the Top End.

In summary:

- The relatively recent spread of spear grass has perverted the traditional and ecologically appropriate fire regime in much of the north.
- The traditional Aboriginal burning methods that shaped and nurtured the ecosystems in the past are no longer appropriate for the modern, grass-laden landscape.
- Today's orthodox fire regime – relying on early dry season burning – does not reduce fuel loads over time and must be repeated annually. This is expensive and ecologically unsustainable.
- In order to achieve the desired '*fine grained mosaic burning*', future fire managers on conservation lands in the northern savannas should focus on dramatic and enduring fuel load reduction.
- The current regime of frequent, hot and widespread annual early dry season fire is giving support to the hunting effectiveness of feral cats. The combined predations of fire and cats is *a* – if not *the* – main driver for the loss of wildlife in the north, followed closely and more recently by cane toads.

- Wet season burning dramatically disadvantages spear grass and other annual plants. By thinning annual grasses on the landscape, the fuel load is reduced and the overall tenor of fire is calmed.
- The effects of wet season burns are generally less intense, less frequent and less extensive, that is, '*fine grained mosaics*', than an early dry season fire.
- Wet season burning is less likely to benefit cats, as it does not clear the understory to the same extent and its effects are relatively short lived as shrubby re-growth is almost immediate.
- In Kakadu, the current pattern of uncontrolled late dry season fires following on from prescribed early dry season burning is unlikely to change because of the large numbers of unauthorised, late dry season fires that are lit every year by local residents and others.[53]
- The new approach in Kakadu described on pages 72-75 represents an important and welcome breakthrough. But it is not without its problems. Time will tell.
- In my view, wet season burning is the only available tool in the land manager's toolbox that is powerful enough to reverse the current destructive, but generally accepted fire regime.
- In the woodlands at least, wet season burning has the potential to 'reset the clock' back to how things once were – but within the limits imposed by other environmental destructors such as invasive exotic plants and animals.

Conclusion

This book provides information that suggests that over the previous three to four decades, the policy of early dry season burning in Kakadu (and elsewhere where spear grass is prolific) has mainly been a policy failure.

Natural area land managers and private landholders in the north are struggling to find a fire regime that offers asset protection without destroying the natural environment. Few are successful.

Despite a slow overall improvement in burning outcomes in Kakadu, managers there struggle to achieve results that are environmentally sustainable.

Natural area land managers (and others) should be robustly trialling, refining and advocating wet season burning as the means to achieve this balance.

In spear grass country, there is an urgent need to emphasise wet season burning before the damage is irreversible.

The information within this book was correct to the best of my knowledge till late 2019, at which time the book went to press.

Greg Miles
August 2020

Acknowledgements

The vast amount of published work and generous personal input from Professor Patricia Werner has been invaluable.

I am also grateful for the politeness, patience and persistence shown to me by Professor Alan Andersen.

Other people who generously guided me in the writing of this book were Andrew Spiers, Professor Jeremy Russell-Smith, Professor David Bowman, Associate Professor Brett Murphy, Dr Aaron Petty, Dr Chris Haynes and many others.

I also thank the Aboriginal owners of Kakadu: a special thanks to Sandra and Peter Christophersen and Jonathon Nadji.

And, of course my old mate Ian Morris who has explored so many corners of Kakadu with me over the past 30 years.

My greatest thanks go to my wife Jane Moore for the line drawings of little critters.

Finally, I offer a big thank you to all the environmental scientists who work in this field. These people often work in unspeakably harsh conditions for long hours with minimal recompense. I would often look on, from the comfortable position of a Chief Ranger and think that these sweating, bleeding and exhausted people must be nuts. But they are not nuts, they are just wonderful people committed to trying to save our precious landscapes and wildlife. There would be no hope without them.

If we had more of this - early wet season fire killing off annual grasses...

Synopsis A

The negatives of early wet season burning

- Wet season burning is more difficult to implement than early dry burning. It requires more strategic thinking and preplanning. This means that the people involved need to be trained or experienced and have a 'big picture' view of what they are doing and what they hope to achieve.
- Wet season burning requires that the target area of land must be protected from early dry fire and late dry season fire, over a period of 8 months or so. This can be difficult to achieve.
- Wet season burning may give an advantage to perennial weeds such as gamba and mission grass.
- Wet season burning will result in greater soil erosion in hilly country.
- Wet season burning can have a damaging effect on vegetation that grows from tubers and bulbs.
- It may cause problems for pheasant coucals which breed in clump grass during the wet season.
- Wet season burning generally affects smaller areas than early dry fires. This means a higher level of persistence and determination is needed to cover sufficient areas. This will make it initially more expensive than early dry burning, but hopefully cheaper in the longer term.
- A change from emphasis on early dry to early wet burning across the Top End would require a major change in mindset amongst diverse types of land managers. This would be an epic achievement if it could be done.

The positives of early wet season burning

- Wet season fire is generally limited in intensity, extent and frequency. This is both good and bad!
- Fires at this time of year are manageable and rarely escape.
- Rainfall usually follows quickly after the burn. This has the effect of softening the impact of the fire and 'fast–tracks' the recovery of vegetation. This in turn frustrates the hunting efforts of cats.
- The 'cool' nature of early wet season burning, coupled with recent rain, means that there is comparatively little damage done to the soil.
- Early wet season burns are most often, '*fine-grained, mosaic burning at 3 to 5 year intervals*', just as fire ecologists, such as Russell-Smith, prescribe.
- Relatively few animals have nests at ground or shrub level at this time of year. Most breeding in the woodlands happens later in the wet season or in the early dry season.
- The dominant trees and shrubs are not developing flower buds in the early wet season. Their canopy is generally well above the scorch height of a wet season burn.
- Once burnt in the early wet season, the removal of annual grasses from the landscape means that fire will not reappear for 3 to 5 years. When fire does return, it does so at relatively low intensity.
- Wet season burning can be very useful in providing easy access to perennial weeds such as gamba and mission grass at a time when they are readily killed with minimal effort and a minimal amount of herbicide.

Synopsis B

A comparison of fire types:

The positives of early dry season burning

- Early dry burning provides relatively assured seasonal protection for property and livestock from late season fires.
- Early dry fires can be reliably replicated to protect natural and built assets every year.
- As a strategy, early dry season burning is well understood, it is a '*convenient flame*'. It is therefore relatively easy to implement, regardless of scale, scope and personnel training.
- Depending on timing, early dry fires can cover a large area (and do a lot of ecological damage in the process.)

The negatives of early dry season burning

- In areas of heavy grass loads, country needs to be burnt in a short time frame, that is, April to mid May. Many land managers fail to carry out this burning in the 'safe' period and will continue on into the fire danger period in order to burn the amount of land that they feel needs burning. In spear grass country this leads to large areas of land being burnt in the middle of the dry season when burning should not occur. This also leads to fire 'over run' with fire sensitive country being burnt unintentionally.
- It is expensive to reach target areas, as aircraft must be used to access places before roads have dried out. Only aircraft can ignite the huge areas targeted in large national parks such as Kakadu. Aerial burning cannot achieve '*fine scale mosaic*' burning unless a huge aircraft budget is available.
- Each year vast areas of woodlands are burnt during the breeding season of ground and shrub nesting birds, for example, finches, curlews, partridge pigeons, bustards and emus. It is likely that many terrestrial animals (in addition to birds) have young in the nest, or at foot, at this time of year. Without fire they have a wide selection of foodstuffs available and a good deal of protective cover. An early dry season fire removes much of that.
- When early dry burning results in 100% scorch, the dominant trees do not produce flowers for that year (possibly even more). This lack of flowers means no nectar or pollen for the many vertebrates and insects, which rely on this seasonal bounty. Nectar eating birds are forced to relocate from these areas. It is telling that commercial apiarists claim that eucalypts burnt to the canopy do not flower for up to five years thereafter (pers/ comm.).
- In spear grass infested country, early dry burns are usually too hot, and the landscape left behind is hostile to numerous species of terrestrial animals. Cover removed includes bunch grasses, stumps, hollow logs and general forest floor debris. The lengthy period of denudation of the forest floor benefits the hunting success of cats.
- Frequent, hot dry season fires cause lasting damage to soil structure.
- The total 'burn-out' nature of many early fires prematurely removes nutrients from the woodland ecology. These nutrients would otherwise naturally be reabsorbed over the remainder of the year. This leads to a cumulative diminution of nutrients available to the soil and the rest of the ecosystem.

- Some species of animals exhaust their energy reserves during the wet season breeding effort. An early dry fire through their territory can deny them the resources they need to recover. Example: most breeding tree monitors are known to die of starvation, if their territory carries a lot of spear grass and is subjected to early dry burning.
- The call for "*fine-grained mosaic burning at 3 to 5 year intervals*" is rarely achieved except on intensively managed, small areas of land. It is a common event for very large areas of land – even in national parks – to be early dry season burnt every year.
- Even if a given area *is* unburnt for 3 to 5 years, this results in a subsequent early dry season fire being more destructive, as it will necessarily be burning the accumulation of 3 to 5 years of fuel loads.
- Land managers are trapped into a grass fire cycle whereby they are (in my view) wrong if they do (early dry season) and wrong if they don't (risk of late dry season burn).
- Frequent early dry fires in spear grass country promote yet more spear grass. This in turn promotes hotter fires which spread further and are more frequent. This in turn encourages more spear grass, and so on. The effect of this is to compel the land manager to be even more rigorous in their early dry burning to prevent late fires getting into the fire risk areas that they have created. Annual early dry burning in these situations results in the loss of biodiversity in the woodlands and sandstone environments. It is very difficult to reverse this downward ecological spiral.

BELOW: The barren, homogenous result of frequent early dry season burning. This scene is not much different to that of a landscape suffering from frequent late season burning. Few native animals can tolerate this environment.

Appendices.

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27) In saying this, I intend no criticism of Chris Haynes or Jeremy Russell-Smith. I too enthusiastically embraced the culture of early dry season burning, and annually torched thousands of square kilometres in its pursuit. It made sense at the time.

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Why is it that wildlife in the Top End began disappearing in the late 1990's?

Some of Australia's best biologists have been trying to answer this question for decades. But no clear answer has yet appeared.

Wildlife loss in Australia's monsoonal tropics (including Kakadu National Park) is the result of a complex range of issues, most recently topped off by the toxic Cane Toad.

This book approaches the tragedy of these declines from a different angle than most, and offers a solution (at least in part), which has so far received little attention.

Greg Miles suggests that much of the natural landscape between the Arnhemland border and the western Top End is not as natural as we may think. He argues that the fire regime currently employed by natural area land managers and others, is largely off target if wildlife protection is the goal.

PART ONE draws together a wealth of clues that point to serious problems with prescribed, early dry season burning.

PART TWO proposes a reorientation of annual, controlled burning as a means to overcome these problems.

PART THREE examines the fire history of Kakadu National Park as an instructive case study.

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