MANAGING FIRE IN THE NEW MILLENIUM
(Author: Dr Neil Burrows)

Thanks for that introduction Sam. As you will have gathered from that introduction, I've been around for quite a while, nearly 40 years as a bushfire scientist working in conservation and land management agencies in Western Australia. I've had the good fortune to not only do some really interesting, exciting bushfire research in a number of landscapes in WA, but I've also worked closely with the fire practitioners, so I've been closely involved with influencing fire policy, planning and operations, and I would take this opportunity, and it's consistent with the theme of this conference I guess, to urge all bushfire scientists to work collaboratively, closely and constructively with your local fire and land management agency.

Now as we know, the fire regime experience in a region is largely determined by climate variability, weather embedded within that and vegetation patterns, and it's these fire regimes that give rise to the consequences, impacts or effects of bushfires on the things that are important to us, including our communities, our biodiversity and our environmental services. However, there is one other really important factor influencing regional fire regime and that is people. In addition to climate and vegetation, people can be powerful drivers of fire regimes, particularly, with regard to how much fire they put in to a landscape and how much fire they can put out, and really, that's the key message of my address.

For a very long time, people, have managed or influenced the fire regime on this continent, and we heard some examples of that this morning. And when I say continent, I off course include Tasmania, so if there's Tasmanians here who may be offended when I refer to 'the continent' I include Tasmanian. I consider myself an honorary Tasmanian having bought property down there a few years ago with the intention of spending large part of my retirement there. So people have influenced fire regime for thousands of years. But it hasn't always been so.

Australia was in fact a wilderness at one time before the arrival of people. And we know from charcoal in the Pleistocene sediment and beyond - so we're going back beyond 5 million years - that there were combinations and fluctuations of vegetation, climate and fire going back millions of years. The primary cause of fires then was probably lightning but there may have been geothermal activity; we can't be sure, but certainly, non-anthropogenic causes were the ignition source for fires - the fire regime before people was pretty much an interaction between vegetation and climate. So, way back then, fire became an evolutionary force acting on our biota and today we see a range of adaptive traits or adaptations to fire that enables our biota to persist and in many cases, depend upon certain fire regimes for its persistence.

That all changed about 50,000 years or so ago; people arrived. People with their fire sticks. Aboriginal people used fire skilfully, purposefully and ubiquitously to make this continent give up things that Aboriginal people needed to live. Fire frequency increased. We can't be certain about what the fire regime looked like across the continent at that time, but certainly, the charcoal record, the sedimentary

record shows an increase in charcoal about the time of arrival of people. People became the predominant ignition source; as an ignition source, lightning paled, I suggest to you. A new dynamic equilibrium was established as people used fire sticks to encourage food, to encourage medicine plants and for all sorts of other reasons, some of which, again, you heard about this morning.

As I said, we don't know what the fire-prone landscapes might have looked like, but my view is that with so many ignition sources was probably largely a fine scale mosaic of diverse serial stages or patches of vegetation at different times since last fire.

This slide is an aerial photograph taken of part of the Western Desert in northwest WA - taken in 1953 during the halcyon days of rocket testing, post-War, and it was taken at a time when Aboriginal people were still living a traditional lifestyle in these areas. At the time of the photography, they had not been contacted by Europeans. In fact this part of the world was where the last bushman came out of the bush and first made contact with Europeans in 1984 – the so-called Pintupi nine, and that's probably within the lifetime of many of you in the room. So, we are not talking hundreds of years ago - we're talking recent times. I was incredibly fortunate to return back to the bush with some of the people that came out, mainly driven by my interest in how they used fire. But this is one of dozens of aerial photographs I have of this part of the desert from which the last bushman came. I'll point out a couple of features - you can see the east/west trending longitudinal or the linear lines – these are sand dunes - this is sand dune/sand plain country, covered with spinifex and low shrubs. It is desert country. So, there are sand dunes you can see there. The pale patches are fire scars and most of those were lit by Aboriginal people. If you look closely, you can see a number of places where they've dragged fire sticks to burn country - up here for example. This is not an exceptional photo. I've got, like I said, probably dozens and dozens covering an area of 2,500 square kilometres that look similar to this. Having said that, this is one snapshot in time and it's one location, as large as it is, but we can't assume that this is how the entire Western Desert looked. But if you talk with Aboriginal people, as I've done, spent time in the bush with them, I got a sense that where they went and where they were camped up, they did a lot of burning like this. And they traversed a lot of country.

The other feature about this photograph, I should point out, as far as I'm aware, it is the only photographic evidence we have of how flammable landscapes looked under traditional owners or under indigenous people's management. I'm not aware of any other actual photographs revealing that. So, we're pretty fortunate, I think. But the other feature of that photograph is the scale of the patches; they are small. You can see the 1 kilometre scale bar there. Most of those burnt patches are under 100 hectares. When I digitised the fire scars on the 2500 square kilometres covered by these photographs, dozens and dozens of them, the biggest burnt patch I found was about 6000 hectares. So, lots of little burnt patches, which is consistent with what Aboriginal people told me they did in the old days, in the old times.

The people I worked with in the Western Desert were mainly Pintupi and Martu and I gathered lots of information about how and why they used fire, but to try and summarise it, perhaps unfairly so, fire is incredibly important to Pintupi people, both physically and spiritually. They used it for many reasons

but primarily to acquire food, either to clear the country to hunt sand goannas or to bring up bush tomatoes or some other source of food or medicine plant. That was the primary use, but there were many uses we documented of why they used fire. Most of the fires were small, but some were large and when they say large, they mean 6000 hectares or so, I guess, because that was the largest fire scar we digitised. They burnt when the spinifex was dense - they recognised five developmental stages in spinifex. Any spinifex older than about 12 or 15 years was considered 'old' whereas prior to interacting with Aboriginal people, I thought 30-40 year old spinifex was old, but they classified anything over about 12 to 15 years as old. They burnt it when it was dense - basically, they burnt it when the cover had developed sufficiently to carry fire. Early growth stages were most valued. They got most resources from the earlier growth stages, they got most of their food and medicine plants, but all growth stages offered something.

You're allowed to laugh at that picture, I think. European colonisation, obviously with the arrival of Europeans, Aboriginal culture across much of southern Australia in particular was displaced. People were decimated by disease and other things. Traditional burning practices basically ceased or were disrupted. The early Europeans were fire phobic; some still are. In fact, the first bushfire ordnance in the Swan River colony in about 1847 I think stated that minors, children, and Aborigines were to be flogged if caught lighting fires, so fearful where the early settlers of bushfires taking out their farms and their settlements and their towns. So, by the 1860s, traditional Aboriginal burning was virtually extinguished in southern Australia, and by the 1960s, traditional Aboriginal burning in central and northern Australia, had been extinguished or severely disrupted. And we saw earlier, a presentation on Cape York, where today they're trying to bring the traditional fire regimes back from late dry season fires to early dry season fires, which is more typically when traditional owners mostly burnt. That's happening right across tropical northern Australia - the top end.

The fire regimes changed with the cessation and disruption of Aboriginal burning patterns. The depopulation of the Western Desert was virtually complete by the 1960s, the last handful of people coming into European-type settlements in 1984. As I said, I had the privilege of going back into the bush with some of them for a few weeks to learn about their use of fire. Very quickly after depopulation, the fire regime flipped and this is how it flipped. So, there's that early black and white aerial photograph, one of dozens I have. You can see the right-hand image on the slide is a recent Landsat satellite image. You can see the fire scars - the yellow colour - light colours are fire scars in that landscape, but what's changed with the depopulation of these landscapes is the scale of the fires, the season in which they are burning and the intensity with which they are burning. While people were living in this landscape, the fires were mostly small, mostly frequent, mostly cool - not all fires- there were still some larger hot season fires, but they were less widespread and burnt a much smaller area compared with the fires of today. I should point out, in the late 1980s, there was what's been called a homelands movement. A lot of the desert people that had been basically cleared out of that country and herded into towns and other settlements in northwest and central WA, decided to move back onto country in the 1980s. So today around these communities, people are starting to get out and hunt and do traditional burning again, but where the people aren't in the landscape, lightning rules and fires are huge. On this satellite

image, I have superimposed the 1953 aerial photo so you can clearly see the contrasting scale of fire scars between then and now. Today, where there are no people burning, the fires are infrequent, probably 15-20 year cycles depending on rainfall which is a key driver there. They are mostly very large and when I say large, a 200,000-hectare fire is about normal for parts of the Western Desert. In 2012, we tracked one fire by satellite - it burnt 3.2 million hectares. And if you jump in a plane and fly from Perth to Broome and look out the window as you cross the Western Desert, you'll see very large areas of bare, red soil denuded by fire and a few small patches of unburnt vegetation. So, lightning in the absence of people, has taken over and we are seeing this changed fire regime - and it happened quickly, within about 15 years of depopulation.

I've tried to reconstruct what the annual area burnt in the Western Desert might have looked like when people were controlling, if you like, the fire regimes, compared with lightning, which is in charge of ignitions across most of the desert country at the moment. I've done this by - not so much from the black and white aerial photography - but by looking at the contemporary burning patterns around the Aboriginal communities, the remote communities, resulting from the homelands movement that exist in the Western Desert, where people still go out and hunt, burn the country, dig up sand goannas and so on, and I compared that with areas where people don't go because it's too far away or they can't get access to it because they use Toyotas and guns and things to hunt with these days. They still use fire sticks, but it's often drip torches and what have you - and this is what I find. Within a certain distance of the hunting tracks and the communities, the left-hand side of the graph is a reconstruction of the annual variability in area burnt where people are still firing the landscape. Beyond these areas, in the remote areas where people don't go, the annual area burnt by fire looks like the right-hand side of the graph. So, on the left-hand side, you're getting this fluctuation of proportion of the area burnt ranging from about 5% to 25% per annum, whereas on the right-hand side where people aren't burning, you're getting wild fluctuations ranging from up to 90% burnt in one year, and then not much burnt for the next 5-10 years because there's nothing left to burn, and so on. It is a 'boom and bust' fire cycle under a lightning driven system compared with a much more stable cycle under a people driven system or people-driven ignition system.

Okay so, we've had people arrive then, of course, we had Europeans come along and change things again. Their solution to bushfire threat in the early days was to stop people lighting fires and to put fire out. As I said, they were pretty much fire phobic, the early settlers. In the early days post-European settlement, most government land management agencies such as forests departments and so on across southern Australia had a policy of fire exclusion and suppression, with some exceptions. That was primarily their policy. Now, how they thought they were going to do that with the gear they had - check out that fire truck. How are you going to put fires out with that? I don't know. Perhaps the early fires were low intensity?

But the fire exclusion and a suppression policy eventually failed. We know that if fuels are allowed to build up over large areas, at some point, they will catch fire and you won't be able to put them out if the fire danger rating is anything much above about moderate. So, we do know that reducing fuel load and fuel structure will reduce the speed and power of a bushfire. That's just science, and if the speed and

power of a bushfire is reduced, it means it's going to be less harmful, less damaging, and it's going to give you better opportunities to put the fire out. In a landscape of low fuel loads, there will always be some part of the fire perimeter that can be attacked, even under extreme weather conditions – not so if the landscape has large tracts of old fuels.

Prescribed burning isn't a panacea. It does not prevent fires. It just gives you a better opportunity to control them and it reduces the severity and harm of fires. In southern Australia, hot season summer fires will always be part of the mix and that's probably a good thing because they do serve a purpose, but not at the scales and intensity that we have been seeing them recently.

This is a graph of the annual area burnt by wildfire and annual area burnt by prescribed fire in south west Western Australia from the early 1950s through to 2015. I wouldn't give much credibility to the early data, stuff I've got circled there including the prescribed burn data - the way they mapped fires was pretty rough in the early days, but there's a pattern there. You can see that after the major bushfires in 1961, we had a Royal Commission, as you do, and the Royal Commission amongst other things recommended more prescribed burning, as they do. So, the then Forest Department took that on board and through the 1960s, 70s, 80s, and 90s, supported by a fire research program, they got stuck into broad area fuel reduction burning.

As you can see, it peaked close to 18% per annum in some years, but levelled out through that period at somewhere between around 10% or 12% per annum of prescribed burning. Then you can see, as we moved into the 90s, there's a downward trend in the area burnt by prescribed fire, through to now where we are struggling to meet about 5% or 6% per annum burnt. There's a clear downward trend in area burnt by prescribed fire.

Accompanying that, we can see an upward trend in area burnt by wild fire. Is that cause and effect, or is that just coincidence?

Since about 2000, we have seen almost every summer in south west WA bigger and bigger wild fires, the sort of size of wild fires we have not seen since pre-1960. Around the rest of Australia, and I haven't been able to get a lot of data, we can see on this slide the areas burnt by wildfire and prescribed fire over the last few decades or so by broad regions. For example, over this time period, the annual average area burnt by wildfire in Victoria was about 5.5% and the average area burnt by prescribed fire was about 1.2% per annum. In the southwest forest region of WA, in the last 10 or so years, we've had about 1.8% of the region burnt by wildfire, which is pretty high based on the last 6 decades or so of records. Over the same time period, the annual area of prescribed burning is very low at 5.2%.

The other feature to note of course is the top end, the tropical savannas. Almost every year, between 20% and 30% of the tropical savannas is burnt, which is not surprising - it's predominantly grassland. I guess the other point to make from that graph is that prescribed burning in terms of area burnt across the continent makes up a relatively small proportion of the total area burnt by fire. Most of the area that's burnt at the continental scale is by wildfire. So, we've got this trend certainly in southwest and southern Australia generally since the late 1990s into 2000 of decreasing area burnt by prescribed fire

and an increasing area burnt by wildfire. The top right graph is the same data I showed earlier but it's been simplified into annual decadal means.

So, we're getting this return to the big fires, maybe they are called mega fires, but they are certainly large, destructive fires and there are similar patterns across northern Australia although the pattern there is not so much an increase in the area burnt but a change in the seasons of burning from most of the fire now is late dry season whereas traditionally, a lot of the burning was done early dry season or late wet season. So, there's been some changes. The recent Waroona fire is an example and a reminder of the return of the megafires. I was involved in this fire as part of the incident management team and also as part of the investigation and reconstruction team. It burnt about 70,000 hectares - fortunately, only two lives were lost - I don't know how we got away with that - more than 150-odd homes lost plus damage to industries and infrastructure. The total cost of that fire according to the Ferguson Inquiry, was 155 million dollars. That's just one fire event.

Now, people have often said to me, well, what does it matter whether it's burnt by prescribed fire or wildfire? Fire is a fire. If you're going to burn 200,000 hectares with prescribed fire, you might as well let it burn by wildfire. Well, there are big differences between prescribed fire and wildfire as I'm sure you'll appreciate. With prescribed fire, we have some control over the time, place and the weather conditions under which we carry out the burning. There is some spatial control over where and how the fire burns. Generally, prescribed fires are cool or low intensity fires. They are relatively frequent, relatively low impact in terms of acute physical impacts on the vegetation in particular and other biota and they are generally patchy in terms of what burns and what doesn't burn. Basically, the opposite applies for wild fires - so they are quite different. On the other hand, wildfires are usually large, intense and mostly uncontrollable. The physical and biological impacts of a wildfire are quite different to a prescribed fire.

And prescribed fire ain't prescribed fire. To be effective - and I'm happy to discuss what 'effective' prescribed fire or prescribed burning is - it must be strategic, it must be in the right places - and Ross Bradstock talked a bit about that earlier on today - it needs to be done at the appropriate temporal and spatial scales and certainly, in southwest WA, we know that if we burn small cells, they're pretty well useless for wildfire mitigation. We've got to go to large prescribed burn cells in the order of 2000 to 5000 hectare cells. We've got to treat at least 8% to 10% of the region each year. You can see that graph there showing how the area burnt by wildfire goes up pretty hard when the area burnt by prescribed fire drops below about 6% or 7% - the effectiveness of prescribed burning reduces dramatically and rapidly. We need to keep at least 45% of the landscape - in this case, the forested southwest of WA, less than about 6 years old, and the burning needs to be done to the appropriate standards - so you need the appropriate levels of fuel load reduction and structural changes to the fuel to be effective. If these criteria aren't met, then yes, prescribed burning will be largely ineffective.

I think we're familiar with the cost of bushfires, so I won't dwell too long on this slide, but they are undesirable to say the least. Whether or not they occurred in the past at the scale they occur at now - and I don't believe they did - but if they did, to some extent, that's irrelevant because we, as a modern

society, can't tolerate the impact of these fires on people's lives, homes, communities, infrastructure, environment and just the straight-out monetary cost. This table summarises some of those costs. I won't go through it in detail but most of the impact in terms of on communities and dollar impacts obviously are in southern Australia and I roughly characterise southern Australia as south of a line between Sydney and Perth - this seems to be where we have most of the damaging bushfires probably because of the nature of the vegetation, the nature of the climate and the fact that it's much more densely populated and that you've got a lot more people living in and around the bush than is the case in the north.

You can see over a 10-year period, 5500 structures mostly homes, gone, over 200 lives lost. Some observers have put the monetary cost of bushfires since 2000 at around $7 billion dollars. I'm not sure how they got to that figure, but that's one estimate. There's a social cost, of course, which is hard to quantify, and a biodiversity cost again, difficult to quantify, and there are environmental services costs to our catchments, air quality, carbon emissions and so on and so forth again, all very difficult to quantify, but they are real.

With regard to biodiversity impacts, we've had a bit of a fright with some of the bushfires we've experienced in south west WA in recent times. A couple of examples here - one is Gilbert's Potoroo which is Australia's rarest mammal only recently rediscovered a couple of decades ago. We had a bushfire in Two Peoples Bay which decimated the population. We are very concerned about whether or not we will be able to keep this animal on the planet as a result of that bushfire. Similarly, Quokkas which actually occur on the mainland - most people think Quokkas are only on Rottnest Island, but they do occur on the mainland of southwest WA. We had a massive bushfire through the Northcliffe area recently and fortunately, there was a PhD student working on the Quokkas in this area leading up to the bushfire, so we got some good data on the impact of the bushfire on the Quokka populations. And it's reduced them by about 92% according to the PhD student, and those that survived the bushfire were living around the edges of the bushfire footprint where the fire intensity was a lower.

So nothing good to be said, as far as I'm concerned, about large intense bushfires. So why have we got this sharp increase in area burnt by bushfires, certainly in southwest WA and possibly southern Australia, since about 2000? Well, is it climate change as some have claimed? We can probably blame some of it on climate change. We know the climate's getting hotter and drier. You can see the blue line on that graph; that's the 15 yearly running average rainfall for south west WA. Southern Australia is suffering climate change, but the south west is probably suffering more than any other part of the continent with rainfall since the 1970s reducing by between 15% and 18% in that period to now. But that's only part of the story. Is it a reduction in anthropogenic burning? Is that playing a role in this increase in area burnt by wildfire? Is it multifactorial?

It may be a number of things, but I'm suggesting that the reduction in anthropogenic burning has resulted in an increase in the area burnt by wildfire. Similar to the pattern we saw in the Western Desert when people were no longer using traditional fire. Why has there been a decline in the area of prescribed burning? Climate change does play a role. We know it's getting warmer and drier. There are

more days of high plus fire danger rating – the dangerous part of the fire season is longer. So, all this combines to reduce the window for safe prescribed burning, certainly in the south west. I don't know how that formula might apply to other parts of southern Australia, but certainly we have found that the drier winters reduce the number of days where we can safely go out and conduct prescribed burning.

There have been land use changes in the last 20 or 30 years in the south west of WA, possibly across other parts of southern Australia. For example, where we once had cows wandering around on paddocks, we've got vineyards, kiwi fruit and other crops, and these farmers take exception to smoke tainting their grapes. We have softwood and hardwood plantations established throughout the south west, they're relatively sensitive to fire so we can't readily prescribe burn them with any confidence that we won't damage them. We have industrial legacies such as bauxite mining in the Darling Scarp. Over the years, the area affected by mining has steadily increased and today we have hundreds, perhaps thousands of hectares of rehabilitated mining pits which are mostly unavailable for prescribed burning. These rehabed areas will burn in a summer bushfire but are difficult to prescribe burn with any confidence that we're not going to damage the rehab. More than 100 years of timber harvesting in native forests has created basically a sea of re-growth particularly in the karri country – young regrowth is fire sensitive and we can't prescribe burn it until it's 25 or 30 years of age. So, there's large chunks of regrowth and mixed age forest that either can't be treated or is very difficult to treat with fire, so we have to sit on it and hope that a wildfire doesn't go through it. Unfortunately, there have been a couple of large fires in regrowth forest in recent times. The decline in the native forest timber industry in south west WA - it is a mere shadow of its former self – has reduced our fire management capacity both in terms of funding through timber royalties and the machinery and manpower that was associated with a significant timber industry in the southwest forest. Many forest tracks that were once maintained are now overgrown which means during a bushfire, these tracks have to be opened up or new tracks constructed.

Other factors such as air quality concerns - Ross again talked about this - so we avoid carrying out burns if the smoke is going to blow over Perth because it might make the washing smell – but there are more serious reasons of course – smoke can affect people's health and it can be difficult if they have respiratory diseases or problems. Population growth at the peri-urban interface makes prescribed burning challenging, risky and costly and Ross touched on this. We've had one misfortune with the Margaret River fire trying to do prescribed burning in an area that had people living in subdivisions surrounded by flammable bush. We have reduced capacity and resources. There's no doubt in the last 20 or 30 years, the capacity of my organization in terms of people power and dollars to do any work has declined, although in more recent times measures have been taken to rectify this. We've become risk adverse to some extent. We've had some bad experiences from prescribed burns that have escaped – usually associated with trying to burn long unburnt fuels surrounded by long unburnt fuels – the Margaret River fire is an example. We've had our butts kicked, deservedly so I guess, and that's put some of our people off burning through fear of things going wrong.

A feedback loop begins to develop. When you don't do as much burning, the fuels accumulate and get older and more flammable - you are then confronted with having to burn old fuels which makes you

even more fearful of doing it because trying to burn old fuels, surrounded by old fuels, is high risk, difficult – so fuels accumulate until they are burnt by a wildfire.

Onerous bureaucratic risk management processes also dissuade people from burning. And there's sometimes local community opposition to prescribed burning which generally, we can manage to negotiate our way through but there's some patches of bush that people feel precious about and they don't want any prescribed burning in there because they think prescribed burning is going to destroy its values.

Many challenges but what can we do about it? In my view, we need to maintain legitimate anthropogenic burning or prescribed burning in these landscapes if we are to mitigate or lessen the impacts, the effects, consequences of bushfires. Targets such as 8% per annum, 5% per annum, whatever, that you see around the place - I've got a few concerns with those sorts of targets. One, they may be unachievable consistently and that's certainly the case in south west WA in recent times - and it is the case in Victoria where they're been set a target of 5%. I think they're going to struggle to achieve that.

So, we need to take a more risk-based approach and I really like what DELWP are doing in Victoria. I've been fortunate enough to be part of an expert group who looked closely at their fire reform program and conceptually, I think it's really a neat piece of work. Now, it will be interesting to see how it works on the ground, but it looks good conceptually.

We, in Western Australia, are not above pinching ideas from others if they're good ones, so we're looking at what DELWP are doing and we're also looking at a zoning concept by increasing or intensifying the fuel mitigation around where communities are and then zoning out from that. I've got a note down there - zoning is not establishing a medieval fortress. That is, we are not just going to try and mitigate or lessen or reduce fuel loads around communities, but we need to do it in the broader landscape as well for the simple reason that a lot of our fires start out beyond the communities and burn into the communities. Unless you've got at least a 3 kilometre, certainly in our forest, a 3-kilometre low fuel load area around your communities, the fires will push through or they'll throw embers across. It's going to be incredibly difficult and expensive to treat fuels in these convoluted boundaries at the peri-urban interface where communities are. We have values outside the fortress of communities. We've got critical infrastructure such as power lines, water catchments and transport corridors. There are also conservation values that exist beyond communities that need to be protected from damaging wild fires. There are farms - all that sort of stuff - we have to attempt to protect all these values so we must try and manage fuels around communities as well as in the broader landscape. You just can't fall back to a 'medieval fortress' mentality.

Other things we can do, and I'll flick through these pretty quickly, is increase prescribed burning to get back to where we were in the 70s and 80s with our prescribed burning program which has declined in recent decades. We're exploring things like doing larger burns; a better bang for your buck if you like - widening the prescription window in the light of climate change, winter burning, night burning, adoption

of new technologies, drones and so on, better weather forecasting, et cetera, et cetera. But importantly, and an area I think that we havn't done well enough, is better collaboration and cooperation with other land owners, because we being a public land management agency, don't carry all the fuel, all the risk. We need to work with others who carry some of that risk as well, so we might do as much as we can on our land but that might only reduce the risk by say 20% or 30% if others in that landscape aren't doing something as well. So, we need to work harder and better in those areas.

Most fire and land management agencies have two primary goals and they're worded all sorts of ways but basically, it's about mitigating harmful effects of bushfires which is by and large, recognising the vegetation as fuel, as the hazard, and treating it. But we, as a conservation agency have this duality of objective which is to ensure that we maintain healthy ecosystems, biodiversity and environmental services. Now that's not many words for a hugely complex understanding of what's going on there, but basically that means treating the vegetation as biodiversity in its own right and as habitat, and there's an argument to be said that they are mutually exclusive goals. Well, they're actually not. You can do both. There's trade-offs and compromises along the way, but you can actually do both.

So, in terms of doing both, and I'm running out of time, obviously the second bit, treating vegetation as biodiversity and as habitat, you need to have a basic understanding of fire ecology and how these things respond to fire and fire regimes. We accept fire ecology is complex and that we'll never understand everything. But we don't need to – you've got to start somewhere, so we are focusing on our threatened taxa because we have a legal obligation to our threaten taxa - our endangered species. So, we are looking at what their fire requirements are and we are using fire ecology to understand that. I know single species management is sometimes frowned upon but where they occur, we have an obligation to look after them, so we will manage fire according to their needs.

We can use, and this is pretty common stuff, vital attributes, life histories, particularly of keystone or umbrella species – this information is not that difficult to obtain. Where we don't have good science, or even if we do, knowledge of indigenous fire regimes is really important to us, certainly in our more remote areas such as the Kimberly and Pilbara regions and the Western Desert country where Aboriginal people, traditional owners, still a have profound knowledge of how country was traditionally burnt and they have looked after country long before European arrival. So, we use that – traditional knowledge. It worked for 40,000 years.

Creating diverse serial stages - so that's just punting for structural diversity, a landscape of patches of different times since last fire. And emissions abatement. We're following the lead of Jeremy Russell-Smith, a man I admire enormously for what he's done in the Northern Territory. We're trying to develop similar regimes to reduce emissions in parts of northern and central Western Australia.

With the mosaic stuff, we're trialling if we want a patchwork of different serial stages, what should be the spatial and temporal scales? The picture on the left is pretty much where we are. Each of those blocks or cells are about between 2000 and 8000 hectares, pretty much uniformly burnt although there is some patchiness within those. We've been trialling mosaic burning in the last 10 years near Walpole,

breaking up those cells by introducing fire fairly regularly and the right-hand graph shows what we've been able to achieve in a 5000 hectare forest block just north of Walpole in south west WA. We've just got this nice fine grain mosaic of fuel or vegetation of different times since last fire as you can tell by the different colours there. Now what we don't know is whether that's good, bad or indifferent for biodiversity, and how good that is in terms of wildfire mitigation, but we're in the process of finding out - we've had that pretty well studied with a whole bunch of different ecologists looking at how effective that is as a landscape in terms of its benefits for biodiversity and hopefully we'll have something published on that in the next year or two.

There is an apparent conundrum - how do fire sensitive species and communities persist in flammable landscapes? There are some examples up there, rainforest and the tropical savannas, rock-out crops in forests, mulga groves in spinifex meadows. Now the reason they persist is because flammability differentials exist between these ecosystems and the surrounding more flammable landscape. So, rainforests are wetter generally than surrounding landscape, in mulga groves, as you can see from the aerial photo the spinifex is sparser than the surrounds. Similarly, on rock-out crops, the fuels are less continuous compared with the surrounding bush. These flammability differentials only exists when conditions for fire spread are relatively mild or moderate and fuels are low. As soon as we have large, intense wild fires crashing into the systems, they tend to burn.

Two slides to go; Some of the important knowledge gaps - I mean you could go on forever listing research needs - but from a quasi-fire operator, quasi fire manager, being in a position of both doing fire science and also involved in a fire management agency, some of the things we need more info on, and some of these have been around long time, include the long-term fire effects. There's been a lot of short-term studies. We need some work on long-term effects of fire regimes. Not only of prescribed burning, which seems to get a lot of attention - a lot of people are interested in what prescribed burning does probably because it's something we control, but also on fire exclusion and the impacts of large wildfires, somewhat problematic to a study.

I would like see more work on fire response models for vulnerable biota in a changed climate and certainly in our landscapes, the vulnerable biota are those water-loving or moisture-loving things in the landscape. What's going to happen with those in a changed climate in terms of fire interaction? Interactions with other threatening processes including fragmentation, weeds, introduced predators and the like. Fire regimes for emissions abatement, as I said Jeremy Russell Smith has done some outstanding work in the Northern Territory. How far can we push that sort of model or that sort of approach into other vegetation types? And this whole issue of landscape fire ecology, understanding the patchiness of fire under different conditions of fire danger rating and times since last fire and so on and so forth - how do we create patchy fires and is that good or is that bad depending on what you are valuing.

So, to finish up, I'll leave you with these thoughts. There's my fire triangle; climate, vegetation and people. If you take people out of the equation in terms of ignition sources and legitimate burning in the landscape, you'll end up with large fires - guaranteed. People have been burning for thousands of years

and must continue to do so. When people burn less, there's more wildfire. I reckon I'll put my house on that. Large wildfires, whether or not they occurred in the past, today are unacceptable, in my view, for the many reasons I've given - relying on a strategy of fire exclusion and suppression, even with the Americans with their suppression might and hardware, still cannot mitigate or lessen the impacts of bushfires. We must burn smarter though and Ross again, touched on this earlier this morning. It must become risk based rather than area based or percentage of proportion of landscape burnt out each year. A risked-based approach will generate burn area targets, but it these should be an outcome of a risk-based approach. We must look at what we need to do to mitigate risk and I would say, yes, obviously, human communities is first but also risk to other values, other things we think are important. We need to work with nature, understand the ecology, understand what traditional owners, Aboriginal people, used to do in the past. If that worked for 40,000 or 50,000 years, it just might work for us into the future. Again, I implore scientists to work with fire managers constructively to come up with some solutions because that's the only way we'll meet challenges going into the new millennium. Thank you.