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What's missing and why does it matter?: Restoring ecosystems by bringing back the diggers

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Note: A selection of slides was taken from the powerpoint presentation to make this transcript easier to follow. The full set of slides is available on the powerpoint presentation.

Summary

Digging mammals like bettongs, bandicoots and bilbies were very abundant prior to European arrival. Most are now rare or extinct, with their previous distributions largely unknown. These animals turned over huge amounts of soil and this had many ecological functions. They reduced soil compaction and increased water infiltration, buried and converted litter to organic matter in the soil, enhanced the dispersal and recruitment of plants and fungi across the landscape, consumed many invertebrates including some pest species, and reduced the flammable litter and hence moderated fire behaviour. Our landscapes have been transformed by the loss of these species. Introduced predators have had a big impact on these animals, enhanced by clearing, over-grazing, inappropriate fire regimes and rabbits. But re-introductions can succeed, even in heavily modified habitats, if there is sufficient cover and low numbers of predators. Novel approaches are also being used including Maremma dogs and breeding or training these mammals for anti-predator behaviour.

Thank you for the introduction and for the invitation to be here. What I would like to do, hopefully, is convince you just how important this group of animals is, and why we need to bring them back to some of our ecosystems, as soon as we possibly can. It was really

interesting seeing that previous talk, I just kept looking at bettong habitat and thinking, it looks so good. That area, Castlemaine in particular, just looked like it's ready for bettongs.

I want to paint a picture for you about just how abundant our mammals were prior to European arrival. Quotes from one of the early explorer's diaries in southern Australia show the numbers of animals that were out there.

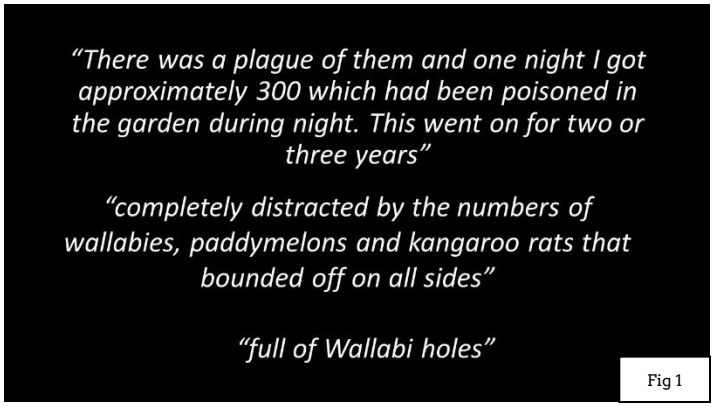


Fig 1

The first quote refers to Eastern Quolls. Has anyone been to Bruny Island, in Tasmania? If you go for a drive on the main road of the northern island, particularly at night-time, you will never see so many Eastern Quolls. It's a little bit like stepping back in time, to see how abundant these animals can be under the right conditions. The second quote refers to the fact that the horses and the dogs were really distracted by the many wallabies, pademelons and kangaroo-rats (and probably bettongs in that group as well) that were giving them a bit of a hard time on their travels. As were the "wallabi holes" in the third quote.

Digging species

Species like bettongs dig really quite large holes in many cases, and that provided a real issue for people's wagons. They would often get bogged in these holes, much to the frustration of the early pioneers. It's true that rabbits dig holes, but scientific research shows that Australian diggers are much better than European Rabbits. European Rabbits dig really small, narrow holes, bettongs dig really deep ones. And that's really important.

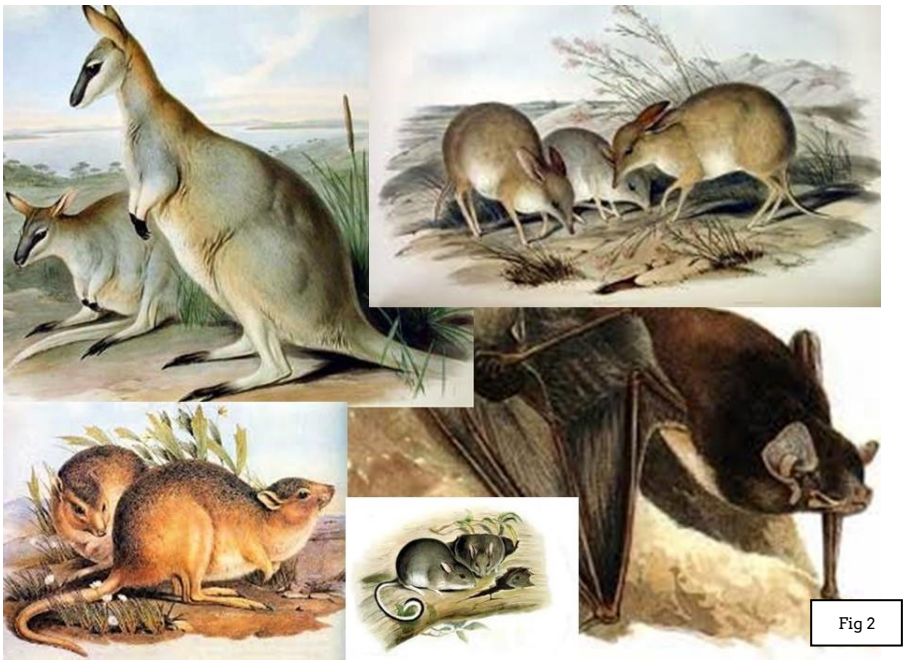


Fig 2

If anyone can tell me the names of all five of the animals in Fig 2, I'd be really impressed. *Answers from the audience: Toolache Wallaby, Pig-footed Bandicoot.* Yes, the Pig-footed Bandicoot is up on the top right. The bottom left is actually the Desert Rat-kangaroo or *Caloprymnus* sp. - amazing animals that used to live out on the gibber plain, so far from here. But incredible animals. At the bottom middle is the White-tailed Rabbit-rat, which is a Victorian species. All of these are extinct, and hence why they're only drawings.

I point that out because, if I was to put a picture of a Narwhal or a Dodo or something else, you would all name it quite easily. It always amazes me how little we know about our own fauna, and how quickly we forget. And I think that's a really important reason, beyond just the ecological reason, for bringing some of these animals back. Obviously, not ones that are extinct, but ones that are still clinging on to survival in some parts of Australia, as a way of actually reconnecting with our own wildlife.

Can anyone name what this critter is in Fig 3? These would possibly have been just outside the window here, going back in time. *Answer from audience: Brush-tailed Bettong.* Yes, that is a bettong, actually a Southern Bettong - I'm coming to the Brush-tailed Bettong in a second. But they would have been here. The Southern Bettong, otherwise known as a Tasmanian Bettong, is now extinct on the mainland except for a few isolated sanctuaries, and so forth. But it is maintained in Tasmania, as well as the quite prominent Mulligans Flat population near Canberra (see here).


Fig 3

This one (Fig 4)? *Audience: Hare-wallaby?* No, it's not a hare-wallaby, although it looks a little bit like a hare-wallaby. Not a pademelon either. It's the Rufous Bettong. These animals still exist in North Queensland, and also parts of New South Wales, and would have been here as well.


Fig 4

And lastly (Fig 5), you've mentioned the Brush-tailed Bettong, otherwise known as the Woylie. These animals had absolutely massive distributions, and obviously as you can see from the map (Fig 6), they would have occurred here. They currently exist in Western Australia and in a few isolated colonies in other parts of Australia. And again, we forget very quickly that they were here. I think that's really important in the context of ecosystem

restoration, and what species might potentially be in some areas and what effects that could have.


Fig 5

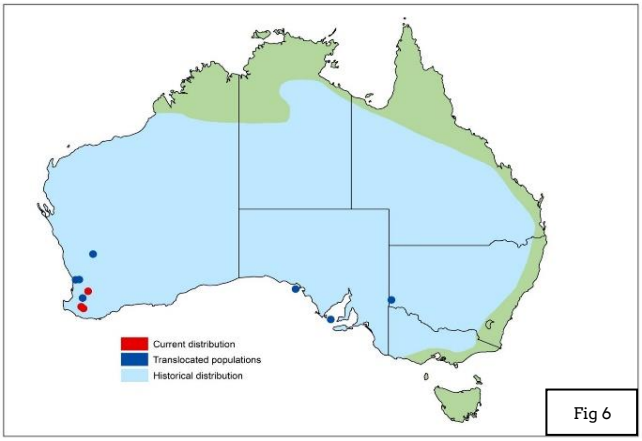


Fig 6

This one should be more familiar to most of you, hopefully (Fig 7). This is the Long-nosed Bandicoot, and they do occasionally pop up from time to time in this local area. But they are increasingly rare now, unfortunately. In southern Australia, in places like Wilsons Promontory and so forth, they're relatively stable but, in this region, they've declined quite substantially. So another local species that we really need to be keeping a better eye on and doing a better job of conserving where they still exist.


Fig 7

Extinctions

To put it in perspective, I'm sure many of you are aware that we are absolutely the world leaders in mammal extinction. If it was gold medals, we could be really cheering ourselves on. This is clearly shown on the world map for extinctions of mammals since the year 1600. That graph would actually get worse because, on top of that bar, we can now add species like the Christmas Island Pipistrelle and the Bramble Cay Melomys. The melomys recently went extinct or was declared extinct. It was probably the first mammal to go extinct as a result of climate change, so yay to us.

We really do have a big problem with conserving mammals in Australia. We should be bringing these animals back, in terms of conserving them as species, as well as for the really important functions that they have.

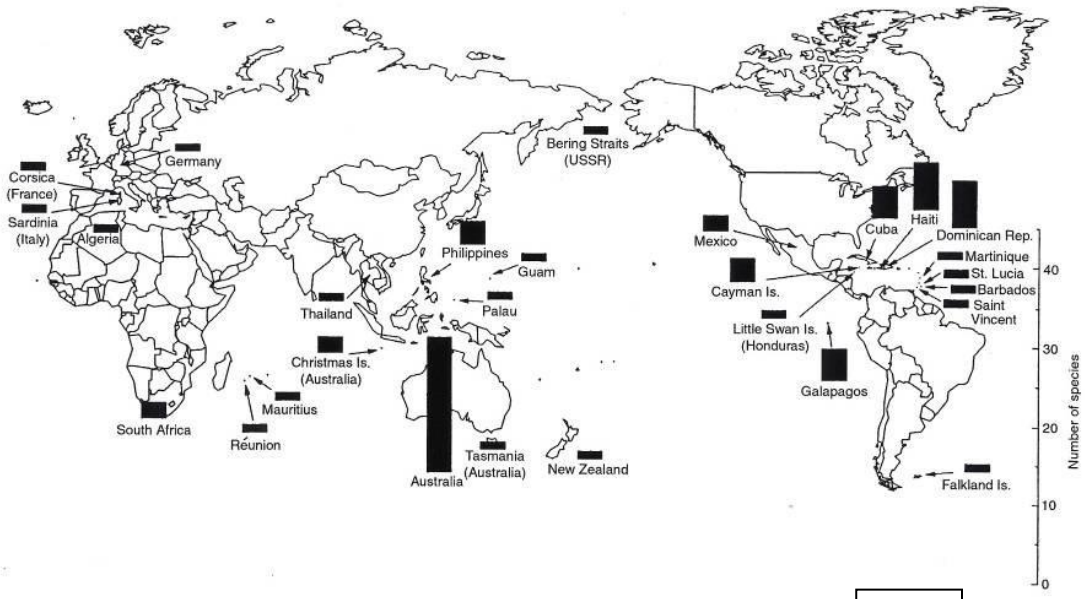


FIGURE 1 Known mammal extinctions since 1600.

Fig 8

Again, just to highlight how widespread many species were…

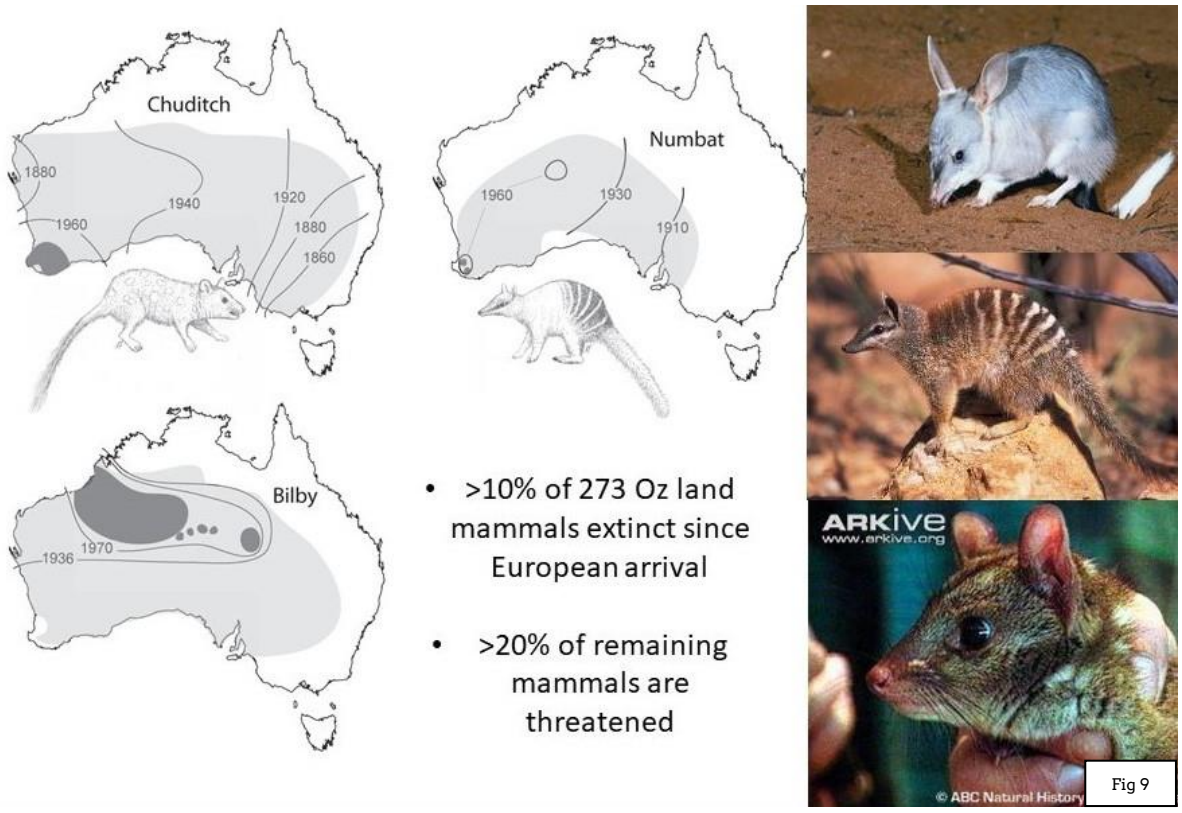


Fig 9

These are not all digging mammals. But even Bilbies made it into Victoria, and probably actually further than that map suggests. Paul Foreman mentioned before that we really have quite bad understanding of our vegetation communities. Likewise, our

distributions maps for most mammals are pretty poor as well. Many people are shocked to realise that Bilbies actually occurred in Perth, prior to that being established as a city. People often think of Bilbies as being these animals that cruise around in the desert. Yes, they do, but they can also cruise around in woodlands and other habitats. It makes the mind boggle about what might have been, and what might also be possible, potentially, in bringing species back.

To put that in perspective, in terms of what we've lost, more than 10% of the land mammals that were here prior to European arrival are now extinct, and a further 20% of those are threatened with extinction. The issue is not getting better - it's actually getting worse, unless we do something about it.

And the species that have suffered the most are ground-dwelling species that occur in open or arid habitats, and often referred to as what's called the Critical Weight Range. So, that is mammals in the range of 35g to about 5.5kg, or as I like to say, in a fox and cat snack range.

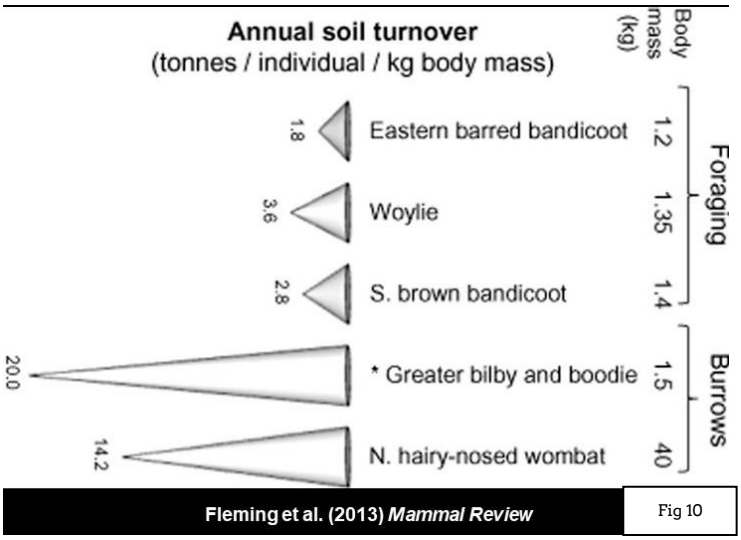
Extinction is a really tragic event, and unfortunately we're in the midst of the sixth mass extinction. It's very present, and we're aware of what's going on. We're seeing extinction rates that are hundreds of times higher than what we would consider normal. That's a tragedy of course, when we lose a species, but it's also really problematic because when we lose a species, we also lose what they do in the environment.

The ecological functions of digging mammals

The topic of this talk is about digging mammals. How good are Australia's digging mammals? The short answer is that Australia's digging mammals are amazing at what they do.

Soil turnover by digging mammals.

The annual soil turnover for a few different species of Australian mammal shows what they do. An Eastern Barred Bandicoot weighs in at the 'huge' weight of 1.2kg on average, and turns over 1.8 tonnes of soil per year. That's one bandicoot! Woylies at 1.3 kg turn over 3.6 tonnes of soil each year.



Fleming et al. (2013) *Mammal Review* Fig 10

Remembering back to what I said before about how abundant these animals were: if you look outside the window as you're driving down the highway, look at those paddocks, look at those woodlands, and think about

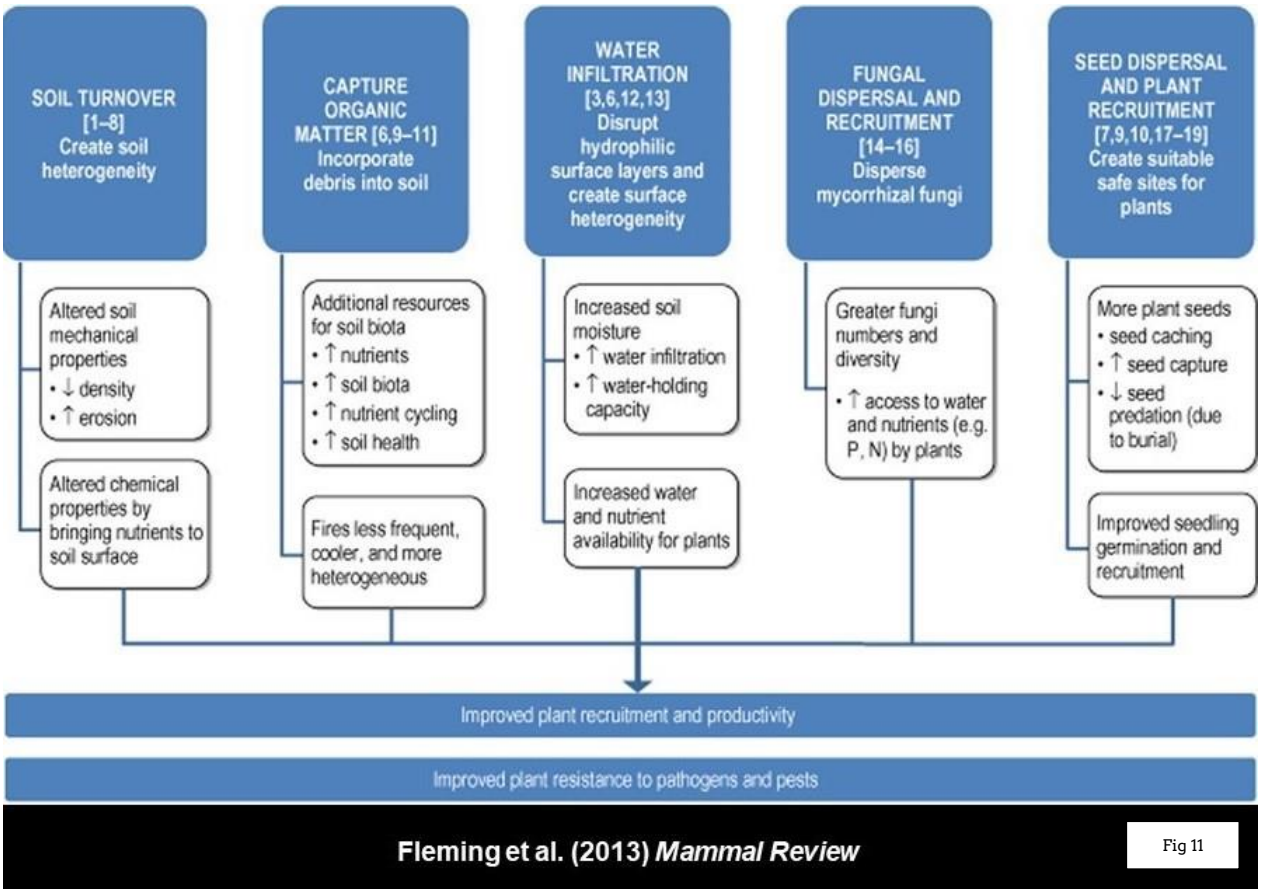
how many mammals would have been out there turning over that soil. Think about how that system has changed. Think about the profound change that has occurred because none of that soil processing is happening anymore.

If we look at burrows as well, so not just foraging pits: a Greater Bilby turns over 20 tonnes of soil per year. One bilby! It's just a phenomenal amount. Every time I look at that, I just think it's not possible. But I'm going to show you in a moment that it is possible, with some work that an Honours student has recently done for us at Deakin University.

The message is that these digging mammals, and also reptiles like goannas and birds such as lyrebirds, do a lot of digging. All of these animals are turning over soil, and have a really important role in the ecosystem:

Benefits to soil and plants of digging mammals

Digging over soil of course reduces compaction of soil (which we know is a huge issue) and that leads to increased water infiltration and increased soil fertility, and to fungal and plant dispersal and recruitment.



Digging animals also help convert leaf litter to organic matter in the soil. This is really important especially with Australia's soils that are already quite nutrient-poor. At present, a lot of that organic matter runs off and is lost. The organic matter in the soil results in an increase in microbial activity which is also beneficial in an ecosystem sense.

Lots of work has also been done in various parts of Australia looking at seed dispersal and plant recruitment in the presence of the diggings by these mammals.

This morning, Jacqui Stol spoke about fungi and the relationship between plants and truffles. Many of these mammals have really quite sophisticated, intricate relationships with fungi and with plants. As an example, I used to work on Rufous Bettongs in North Queensland. Very good truffle hunters. Often we'd find more than 30 species of truffle in their scats. And there's a really close association with the dung beetles. Basically, the Bettong hops along, defaecates, the dung goes on the ground, the dung beetles break it down and turn it into the soil, and that spreads the spores back into the ground. Those fungi are really important for the health of the trees. We all know that Australian soils are typically very nutrient-poor, and so those micronutrients are really hard to access. Fungi make it much easier for the plants because they provide the micronutrients to trees that they otherwise couldn't get. If that relationship has broken down in all these ecosystems, what effect has that had on plant health and vegetation communities? I think there's a lot more to be learnt there.

Bandicoots on Churchill Island

It's really hard to believe that these animals can turn over that much soil in a year, but they can. We had an Honours student who worked on Churchill Island where a recently introduced population of Eastern Barred Bandicoots is doing really well. She measured the number of foraging pits in that area. We know exactly how many bandicoots are on that island, and the numbers of pits dug per night per bandicoot. It turns out that a bandicoot can dig nearly 490 pits in a 24 hour period. You get some plaster of Paris and pour it into the hole, you take it out and put it in a beaker to measure the displacement. That tells you how much soil that these things are turning over. Although the pits are really small, they get really busy, so all that activity equates to about 4.8 tonnes annually. And that's the way that we know how much soil is turned over - really sophisticated!

I mentioned soil moisture before. We measured soil moisture and soil compaction, which I won't show here today. But the take home message is that where you have these diggings, you have water getting into those diggings, down the bottom of that digging pit, and that's 24% more moist than it would otherwise be.

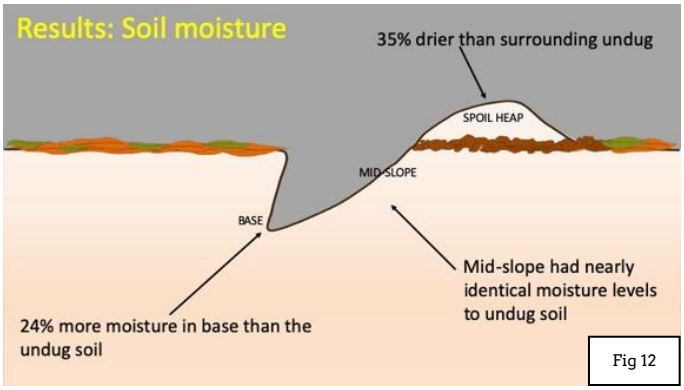


Fig 12

And that provides a nutrient pit as well. Nutrients slide into those pits, as do seeds, and that provides a really fantastic place to germinate and grow. So, these foraging pits are really important in the landscape where they do still exist.

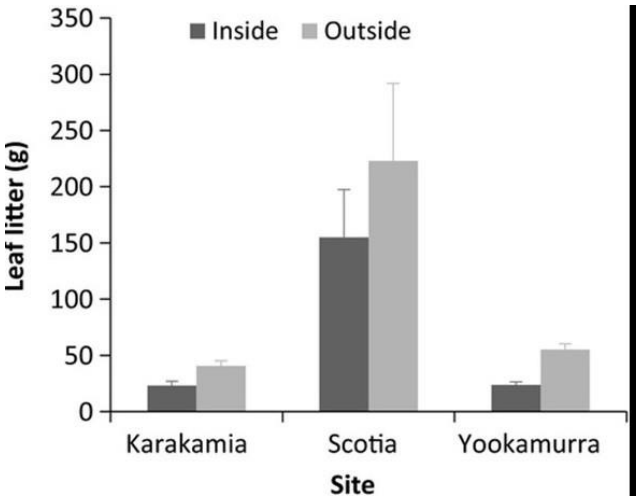
Why are these mammals digging? Of course, they're digging for food. Work on Churchill Island shows that Eastern Barred Bandicoots have a very broad diet. They're spending a lot of time digging holes, looking for invertebrates. Do we have many graziers here who have issues with cockchafer beetles? Cockchafer beetles can be a pest in pasture , and bandicoots really love to eat them. So you need to get some bandicoots. That's another really important potential service that these animals can perform. (It also turns out in Churchill Island that they have a taste for seafood as well. So, this is the first record I think, of bandicoots eating crustaceans. And it wasn't just one case, but multiple cases of bandicoots eating crustaceans.) So these bandicoots eat a really broad array of things. And therefore, presumably, have a pretty broad effect on the dynamics of these systems below the ground.

Again, if you think about how abundant and widespread these animals were, our landscapes have been completely transformed because of this loss of function of digging animals.

Fire risk and digging mammals

The previous talk also mentioned fire. And fire, as we know, is a problem - it places humans at risk. But it's also a really important part of our ecological processes. It turns out that these digging mammals can probably mediate fire risk as well. In a study done on Australian Wildlife Conservancy properties, the leaf litter was measured inside and outside the fence. Inside the fence, you still have digging mammals; outside the fence you don't, because they get eaten by cats and foxes. The short take home message is that inside the fence, there is a lot less leaf litter lying around on the surface of the ground.

This information was put through a modelling exercise to look at fire behaviour. It showed that, in the Scotia area in particular, flame height was estimated to reach about 1.4m outside and less than 0.5m inside the fence.



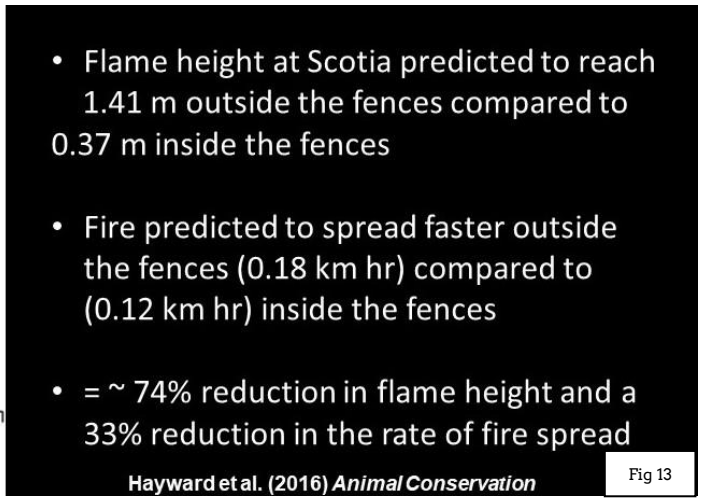


Fig 13

When you're talking about fire risk and fire behaviour, if you have a fire that's really high, that's problematic because it's more likely to go up into the mid storey, and then obviously potentially up into the upper storey and spread more easily. The rate at which the fire spreads was less in the areas inside, because there was less leaf litter there for the fire to spread across the ground or increase flame height into the mid or upper storeys. That all equates to about a 74% reduction in flame height and 33% reduction in fire spread.

So, not only are these digging mammals providing very important functions in terms of seedling germination, soil fertility, water infiltration and so forth, but they're potentially having again a really profound effect on fire risk. There's been some similar work done on lyrebirds published not long ago (Nugent *et al* 2014), and other people are looking at this same issue in other situations. So it's important to think about re-introductions of mammals as a potential way of trying to mitigate fire risk in some habitats.

Review of ecological functions

Trish Fleming and colleagues in Western Australia did a really big review of all the different functions that these mammals perform (Fleming *et al* 2013). And it's a very long list. And the converse of that, of course, is the long list of effects that we don't want but will have in the absence of digging mammals.

Re-introduction and restoration

I now want to champion re-introduction and restoration programmes. It's always a bit odd to me about why Victoria has so few mammal re-introduction programmes - I can't really understand why. I'll put on the table straightaway that I'm proudly advocating for them so I can study them as well. We have introductions elsewhere in Australia, such as the Southern Bettongs in Mulligans Flat and the re-introduction of Western Quolls into the Flinders Ranges. Booderee National Park in New South Wales has recently introduced Eastern Quolls. These programmes are all successful to varying degrees. And I would like to see a lot more of that happening in Victoria - there are some sanctuaries that of course already have digging mammals, but there's very few compared to other regions of Australia.

It does beg the question: why aren't we doing more of this? Particularly when we know they have these really important potential benefits. Places like Central Victoria just seem perfect for mammals like bettongs in certain contexts. That picture of Castlemaine in the previous talk (Paul Foreman Slides 32-34) just got me really excited, and I hope we put a fence around that and put some bettongs inside. Yes, please.

Providing habitat

The reason why many of our mammals have disappeared from parts of Australia is the impact of invasive predators - feral cats and foxes. But it's very easy to jump to the conclusion that it's just their fault. It's often forgotten how much clearing and overgrazing and inappropriate fire regimes have affected habitat cover, and therefore the exposure of these native mammals to predation. Predation is a normal thing. Back in the day, of course, there would have been many quolls also eating bettongs and other mammals.

The big thing that's changed is that there's been lots of clearing, and then the introduction of these two novel predators. I would argue that we really need to do a much better job in trying to promote habitat cover and complexity, and that seems to have already been a

theme from the previous talks. There's a lot more to be done about promoting this, and really trying to achieve some good outcomes for reintroductions.

I also want to challenge what we think of as good conservation areas. We often think about re-introductions having to happen in really pristine conservation reserves. However, an area near Cranbourne in southeast Melbourne has really good habitat for Southern Brown Bandicoots. Heavily modified of course, and often full of weeds, as people like to call them - like blackberry, gorse, and so forth. But they're really good for bandicoots. They provide lots of cover and protection from predators like cats and foxes. Sometimes I think we could probably do a better job thinking outside the square a bit more, about what might actually be suitable habitat for native mammals and having a go on the re-introduction programmes. Not to say that we shouldn't be trying to improve habitats and take advantage of existing ones that are in good condition, but we shouldn't write off ones that are in quite degraded states as well.

There is a bandicoot population at Cranbourne Gardens, and the foxes have been removed. It's a pretty good place for bandicoots. It also has quite unproductive soils – white, sandy soil low in fertility. Quail Island in Western Port Bay is different, but again a quite unproductive system.

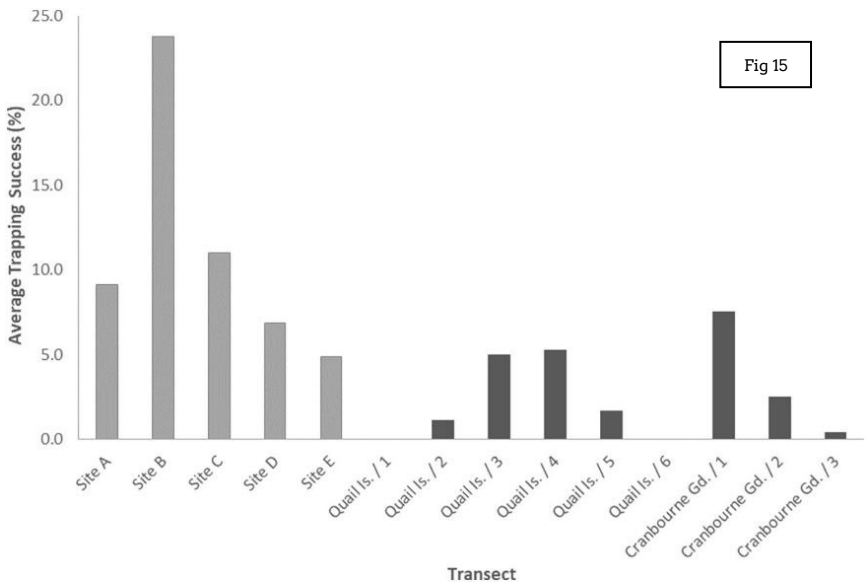


Fig 15

And then there are the linear roadsides or drainage ditches in the Koo Wee Rup area. This area was a very large swamp, and a very productive swamp. Vegetables are grown there because the soil is really good. The linear roadsides and drainage channels have some remnant vegetation in various states - in some cases quite degraded states. And the bandicoots are doing really well there (sites A to E in Fig 15). In fact, bandicoots are more abundant in those areas than they are inside the Cranbourne Gardens, where conservation of the species has been prioritised. Again, we often think that peri-urban areas are no good for wildlife, but that's not the case for bandicoots. They're making quite a good go of it, even in the presence of cats and foxes, because there's sufficient cover and because there's a relatively productive system.

Other approaches

There's a lot more that could be done, thinking more broadly about where some of those native species could actually exist if we gave them a go.

So, what's needed for restoration to work? There is a role for fences, but I hope that I live long enough to see lots of our native wildlife outside of fences as well.

Previous talks have mentioned the importance of cover. Driving up this morning and looking out across those paddocks, you don't see a lot of coarse woody debris, you don't see a lot of ground cover. And that creates big challenges for reintroducing native ground dwelling mammals, or any other ground dwelling species for that matter. We need to really think about ways to promote ground cover or maintain it where it still exists.

We also need to think about more integrated approaches towards restoration and management of species. We know from recent work that we've done on rabbits, that if you can knock down rabbit populations far enough, and maintain them at low levels, native mammals respond quite strongly. And that's because cat and fox numbers decline quite substantially. Cats and foxes are really dependent on rabbits in some areas, and their abundance is much higher than it would otherwise be if rabbit populations were kept low. If we could control rabbits in some areas, it may be that we can also reduce cat and fox numbers to a level that may actually promote the co-existence of some native mammals and other wildlife.

We know this is happening where foxes are absent. On French Island we're doing some work on Long-nosed Potoroos and feral cats. The potoroos in the area that we've been working in are quite abundant, even though there are feral cats on that island. That's because there's lots of cover, and there's also not very many rabbits in the area we're working in.

There are also new ways and new tools that are emerging that might help us to advance our restoration and re-introduction successes.

Zoos Victoria has a really interesting project looking at Maremmas, which traditionally are used to protect livestock. Many of you have seen the movie 'Oddball' about Maremmas protecting penguins at Warrnambool. The question is: can they protect bandicoots against foxes? There's potential in small areas where we may not ever be able to control cats and foxes. But it may be too difficult. Can guardian dogs actually exclude those predators from areas, and therefore provide an indirect benefit for native mammals? I'm hopeful that the Zoos Victoria work will be promising, and that Maremmas might be rolled out in other areas to provide another way of getting these animals back into the landscape.

Another emerging and really interesting idea is using techniques to essentially speed up evolution. The idea is to take individuals that have had some exposure and co-existence with our predators, and therefore have behaviours to avoid predators. One of the problems was that, when cats and foxes were introduced following the European arrival, fauna was

completely naïve to those predators, and they cleaned up the native animals pretty quickly, especially in those areas where cover was not maintained. But there are situations where native mammals are co-existing already with cats.

Rufous Bettongs are living in New South Wales and Queensland in the presence of cats and foxes. People always say "Bettongs can't exist with foxes". Not true. They can and they do. I suspect that cover in those cases is really important, but it does make you think. If there are populations of bettongs that are co-existing with these predators, if we could take some of these individuals and breed up colonies that have this potential avoidance behaviour, that may actually help accelerate the process of reintroduction's success.

What's happened largely in the past is that we take animals from a captive situation where they have never seen a cat and fox before, and we put them outside the fence and they all get gobbled up. We do the same many times over. I think it was Einstein that said "The definition of insanity is doing the same thing over and over again, and expecting a different result." Anti-predator training is where you expose animals to their potential predators in varying ways, to hopefully encourage them to realise that they're not animals that you bound up to and check out. You flee from them – and have a higher chance of survival in the future.

We do need to do things differently, and these new tools are really encouraging in terms of ways of actually speeding up this process of re-introductions.

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