Bolstering the Refuges Symposium

Euroa, May 2019

www.biolinksalliance.org.au

Symposium Presentation No. 2

Insects in fragmented farming landscapes

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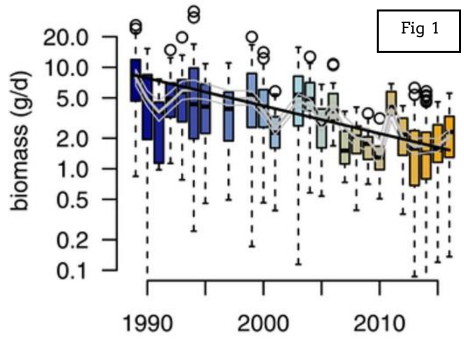
Note: A selection of slides was taken from the powerpoint presentation to make this transcript easier to follow. The full set of slides is available on the powerpoint presentation.

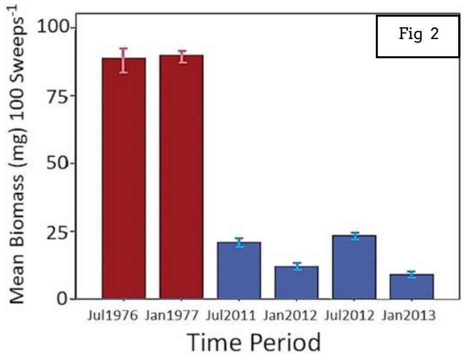
Summary

Insects are in decline around the world and agricultural practices are a major factor in this decline. This talk reported the results of several case studies of beetles in particular. These studies in fragmented landscapes showed that different communities of beetles live in different elements of the landscape and that the characteristics of species determines which elements they use. Many species were abundant in paddocks and other high nutrient sites, but some species were confined to remnant native vegetation and others were dependent on remnants for part of their life cycle. In pine plantations and adjacent remnants, the beetle community was just a small subset of the original beetle community in the area. In cropping areas, the high abundance of beetles in cropland declined after cropping except where woody mulch was used to add habitat after cropping. In the older Buttongrass landscape, the interaction between dispersal ability and competitive ability or predatory interactions influenced the species composition in the different elements in that landscape. Finally, a study of insectivores in Africa showed a significant change in the dynamics of invertebrates leading to plant mortality. These studies suggest that the changes can have a cascade of effects on ecosystem functions that may locked them into a state that could be hard to restore and transform.

Insect decline around the world

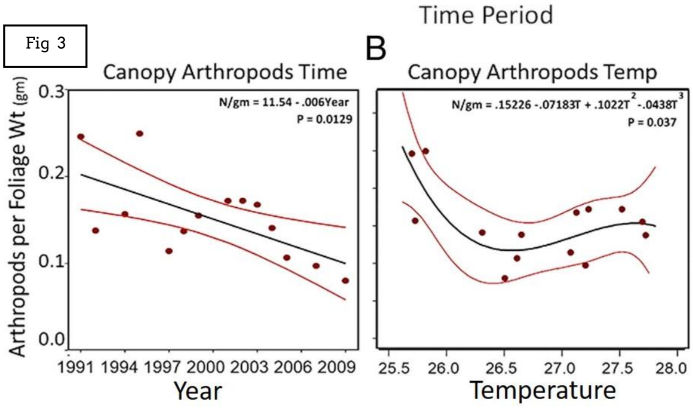


We've seen in the media that insects are in trouble around the world. This came out firstly from a study in Germany in 2017 where they studied flying insects from 63 reserves over 27 years and they found a 76% decline in biomass from agricultural areas in Germany (Hallman et al 2017; Fig 1).



This was followed up last year by a paper from Puerto Rico (Lister and Garcia 2018; Fig 2) where they had some long-term data and noted that the average temperature had increased by two degrees since 1976. At one of the sites, they found that the average biomass had obviously declined by a massive amount from the 1970s through to more recently. So just the sheer amount of insects in the landscape has totally dropped off.

At their other site they looked at canopy arthropods over time(Fig 3). From 1991 through to 2009, arthropods from the foliage declined massively. And this was linked to temperature. The implication here is that species are declining, potentially because of increases in temperature associated with climate change.



This year, a paper has come out talking about worldwide decline in insects (Sanchez-Bayo F. & Wyckhuys K. A. G. 2019). They managed to find 73 long-term studies of insects, mostly from North America and Europe with a smattering from other countries, one from Australia. They've reported that 41% of insects are declining across those studies, 31% are probably threatened with extinction, with an annual rate of decline of 1%. Comparable figures for mammals show that 22% are declining, 18% are threatened and the annual rate of decline is 2.5%, The proportion declining and the proportion of insects threatened is higher than for vertebrates, although the rate of annual decline is lower for insects.

If we look at that across the different regions from the world, we can see Europe is quite variable, probably related to the degree of agricultural intensification across Europe. The UK has very highly intensive agriculture and the biggest impacts on invertebrates. North America is also quite high. The rest of the world is somewhat lower, and that includes Australia.

Fig 4

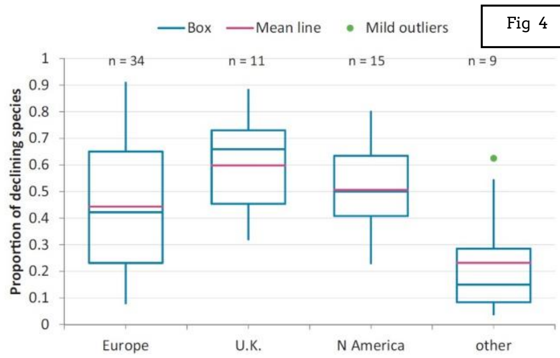
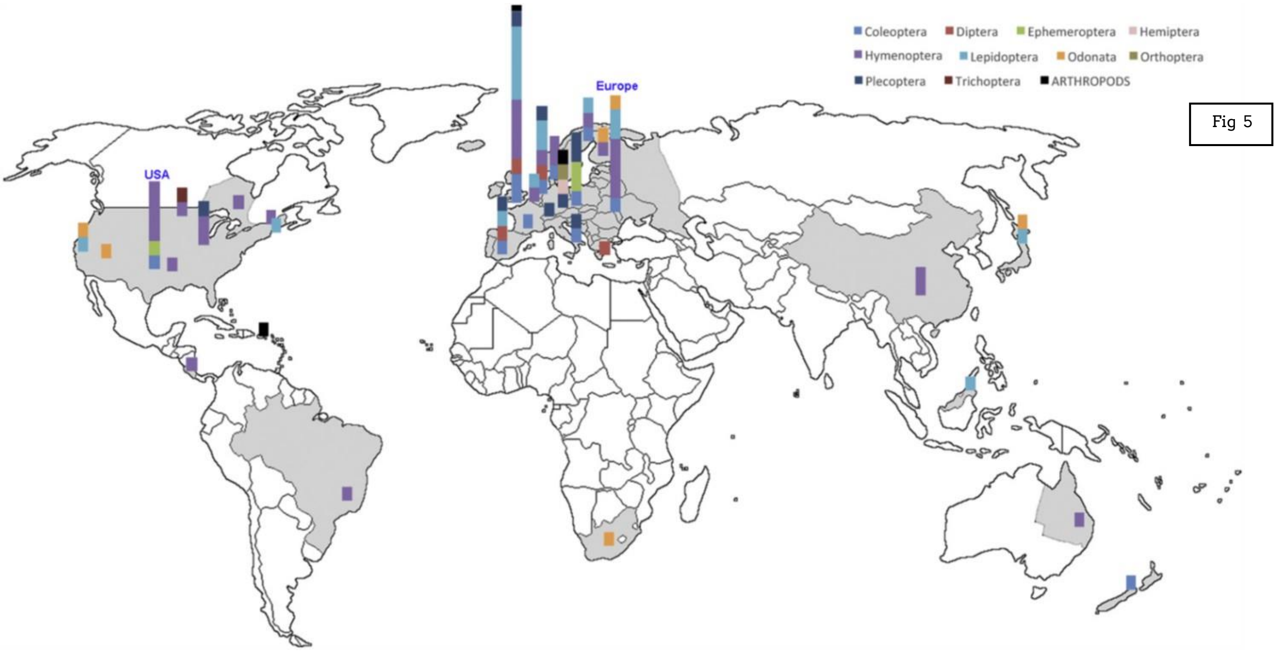
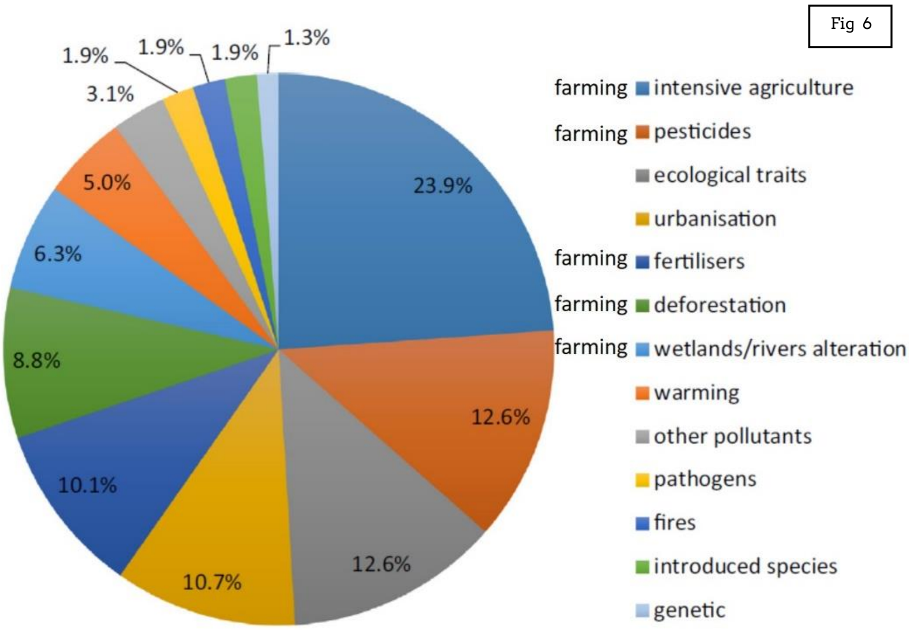


Fig 5



The paper also reported some of the main factors that they thought were associated with the decline. If we lump some of those causes as being associated with farming, we can see that around 62% of the decline in these insects are associated with the impacts of agriculture.

Fig 6

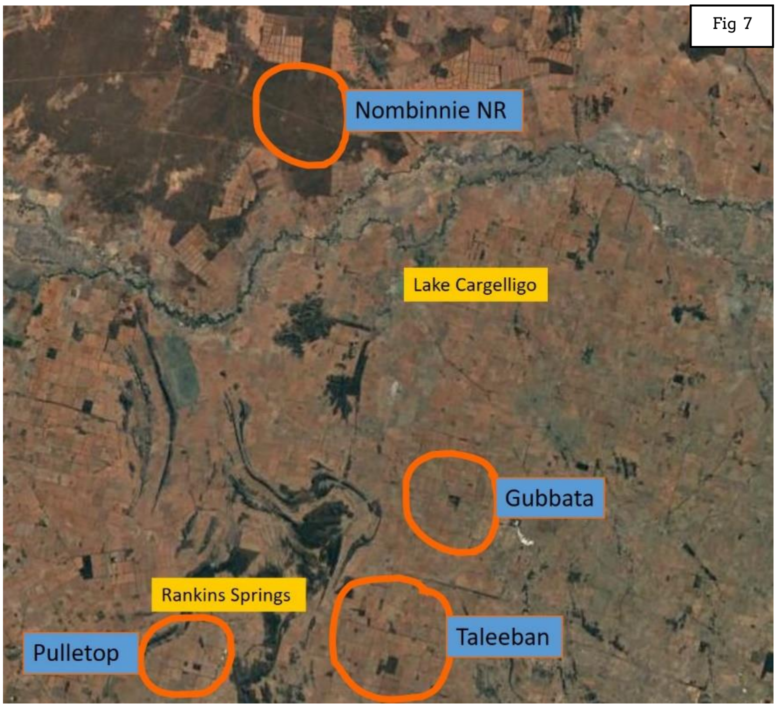


Case studies across Australia

That sets the scene for what I'm going to talk about today. I'm going to talk about some case studies - a bunch of the work that we've done over the years in agricultural landscapes, mostly looking at beetles. I thought I'd be able to give a talk about insects, but, no, I've really just studied beetles. Beetles are insects, and the most diverse group of insects, which is why I like to focus on them.

I'm going to talk about some work I did when I was at CSIRO and Jacqui was there. I looked at Mallee remnants and the species characteristics that influence the kind of species that disappear from these landscapes. Then I'll talk about some work that I did when I was at ANU in a pine farmland landscape near Tumut, and we'll see there that the pine matrix causes homogenisation of the fauna. Then another project, in Victoria, showed surprisingly little response of beetles to some of the landscape structures that we investigated. Then some more recent work we've done in Box woodland across New South Wales where we particularly looked at how different kinds of farmland around remnants influence what happens in the remnant and what happens in the farmland. Then I'm going to diverge a bit from agricultural landscapes so that I can talk a bit more about some of the discoveries we've made relating to how insects might interact with each other in relation to the kind of landscapes that they're living in. And finally, I'm going to go even further afield and talk about a project from the Ivory Coast that I wasn't involved with, to give you an idea of the kind of consequences of changes in the invertebrate fauna for the rest of the ecosystem. So heaps of fun coming up.

Case study 1: Beetles in Mallee remnants, NSW



This is the region I worked in, between Rankins Springs and Lake Cargelligo in central western NSW (Driscoll and Weir 2005). I worked in three main landscapes in the agricultural area, and also some in continuous Mallee.

The landscape is typical agricultural landscape for those dry areas - lots of linear remnants and occasional little nature reserves. In those landscapes there's a range of what I'm going to call landscape elements. These are the paddocks, the grazed and ungrazed linear strips (you'll see there's some subtle differences in the understorey between the grazed and ungrazed strips), the woodlands and nature reserves, and the roadsides. Roadsides are subject to a range of different influences compared with those linear strips and paddocks. You get lots of dust dumped on these roadsides, as well as wash-on from the adjacent paddocks.

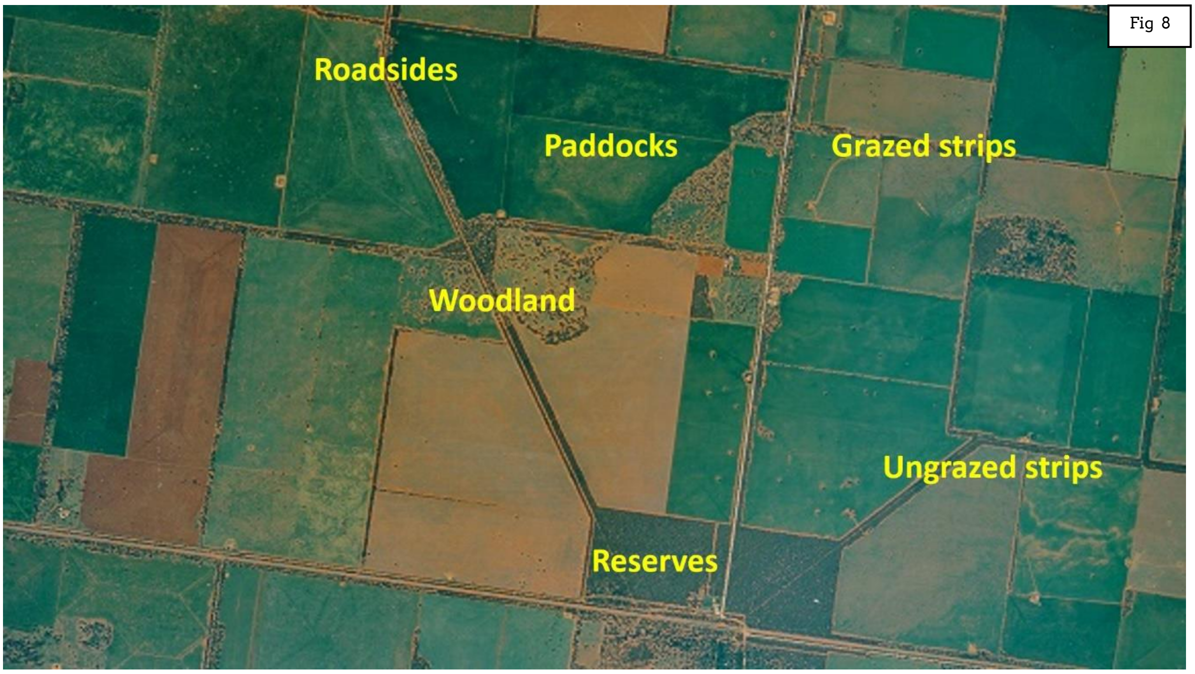


Fig 8

Numbers of species

I looked at the beetles in these landscape elements. If we look at the average number of species in each of these landscape elements (Fig 9), we can see that the reserves have quite a few species but not as many as in other elements. Linear strips, grazed strips, roadsides and woodlands all have more species than we found in the reserve, and the paddock is up there as well. So, contrasting to what we expect for most vertebrates and certainly for the reptiles in this landscape, a lot of beetles do occur in the paddocks.

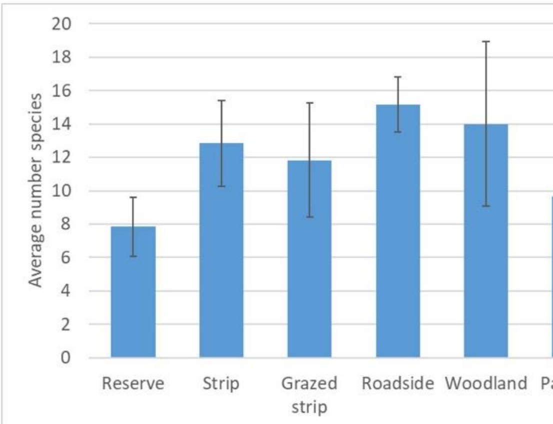


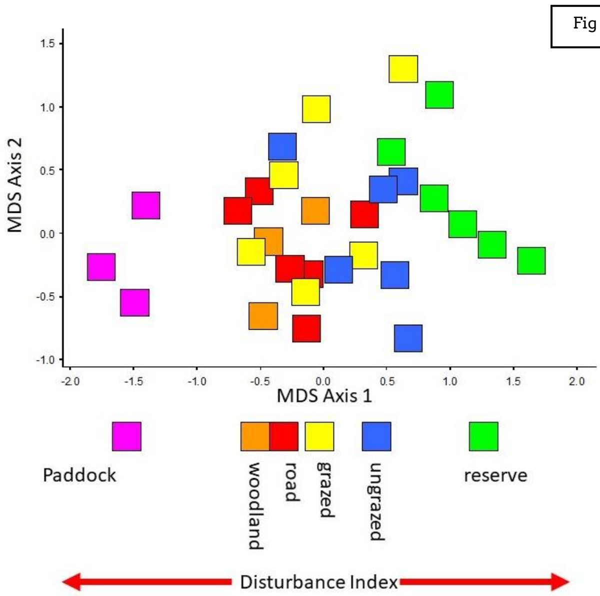
Fig 9

We've gone back in the last few years to work again in this landscape and collected soil data and we found that all of those elements have much higher nutrients - elevated nitrogen and phosphorous - compared with the reserves. This input of nutrients presumably leads to higher growth of plants, more nutritious plants leads to a more productive ecosystem, and that's supporting higher numbers and maybe more species.

Composition of communities

That's just the number of species. But what we're really interested in when we're trying to conserve biodiversity in these landscapes is the composition. Are there some species that are actually vulnerable in these landscapes?

Fig 10



I'm going to show a few of these graphs through this talk, so it's important that everybody understands what I mean by them (Fig 10). This is a kind of ordination. Essentially, it's got two axes and plotted into that area are sites. The distance between the sites represents how different they are in terms of their beetle community. So sites that are further apart have more divergent beetle communities than sites that are closer together. The sites separated along the bottom axis from paddocks at the left end through to the reserves over on the right basically equates to what I've called the disturbance index. So most disturbed sites are on the left and the least disturbed sites on the right.

Characteristics of species

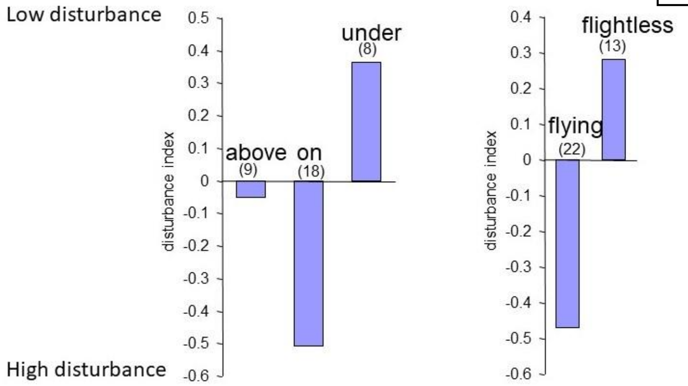
The question I wanted to ask was: Do the characteristics of the beetles influence their response to that disturbance gradient? And beetles have a range of characteristics. As examples, we have a flightless carnivorous beetle, flying carnivorous beetle, scavenging flightless beetle and flying herbivorous beetle.




So the character traits we looked at for these beetles were: can they fly or not? where do they live? do they live generally above, on or below the ground? are they predators, herbivores, omnivores or scavengers? and how big are they? Do any of those characteristics influence how they respond to those different landscape elements?

We found first of all that burrowing species preferred the least disturbed sites (Fig 12). Species that live on the ground were able to cope with the more disturbed sites, so they're the kinds of species you might find in the paddock. The other finding was that flightless species also prefer the least disturbed sites.

Fig 12



So if you were a burrowing flightless species, you're really going to be found most often in those nature reserves or the least disturbed linear strips. Whereas, to be able to exploit the resources in the paddock, you need to be good at dispersing. So mostly flying species will be found in the paddock.

But when you dig into the combinations of traits that are possible, you find that it's more nuanced than that. So just looking at the species that could fly and live on the ground, and looking at the trophic group and size: if you're a flying carnivore that lives on the ground and you're small, you're able to take advantage of those two linear strips more so than the paddock. Whereas if you're any other sort of flying beetle that lives on the ground, you're more likely to be found in the paddock.

So the characteristics of the species really do influence their capacity to use those different elements of the landscape. And we'll see later on when we talk about that Tasmanian example, how interactions amongst species could drive some of these things.

Conservation status of species

In this landscape, I calculated that 24% of the total species in the study were most abundant in the paddocks and are probably doing okay in these landscapes. The caveat to that is that all of these landscapes have about 10 - 15% native vegetation left - all the remnants add up to about that much. Potentially a lot of these species still depend for part of their life cycle on having that remnant vegetation. If that remnant vegetation was lost, perhaps some of these paddock specialists wouldn't be able to survive in the landscape.

15% of the species were most abundant in reserves, and 6% were most abundant in the strips, suggesting they specialise in these aspects of the landscape. So that means they're confined to very small parts of the landscape, so we can regard those as likely to be more at risk of decline and disappearing. So that adds up to about 21% of species at risk of local extinction.

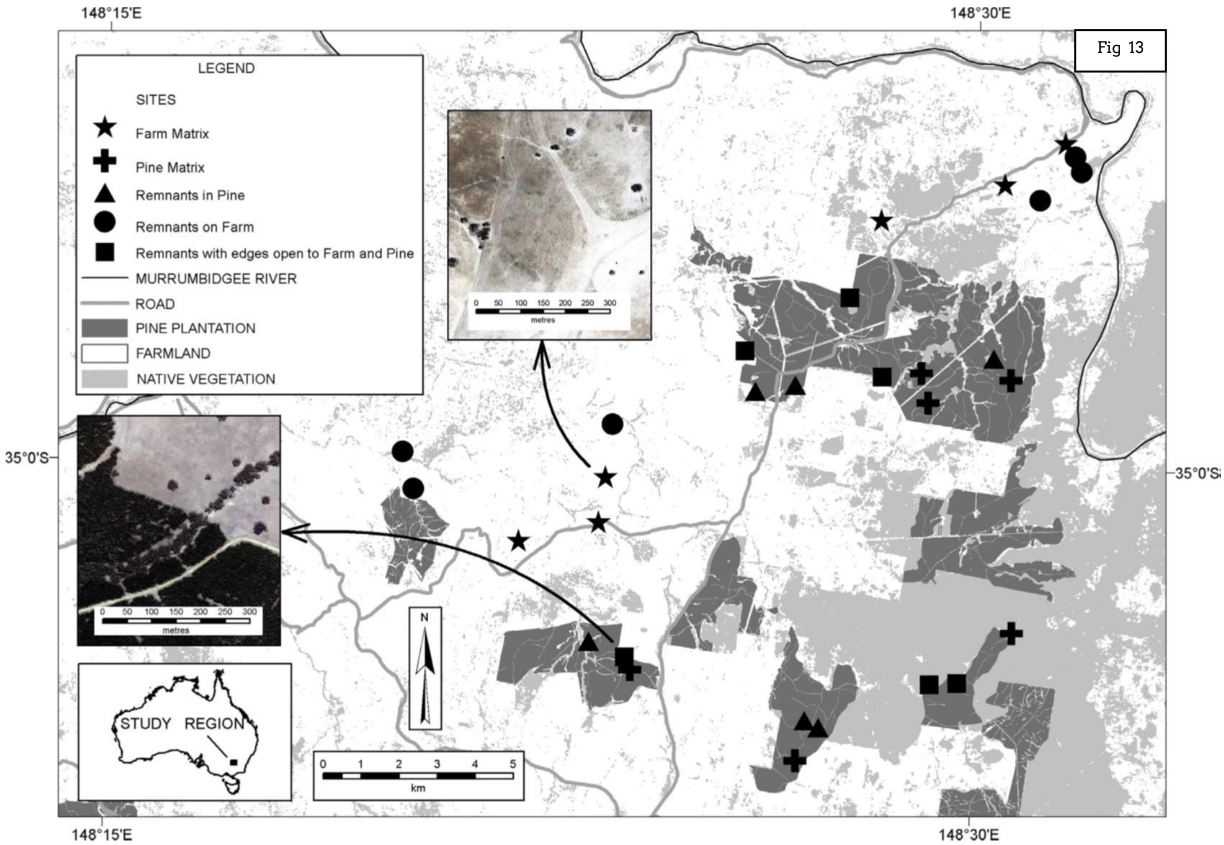
If we compare these results to other taxa in that same Mallee landscape, I found that about a quarter of the reptiles were at risk of declines. This compares with other studies of species at risk: 27% of birds from the WA wheatbelt, 33% of mammals in a North American wheatbelt, and 42% of birds, a substantially high proportion in the Mount Lofty ranges in South Australia. So insects are probably at similar risk of decline, but at the lower end compared with some of the vertebrates.

Key messages:

Different communities of beetles live in different elements of the landscape. The characteristics of species determines which elements they use. Although many species were abundant in paddocks, some species were confined to remnants and others may be dependent on remnants for part of their life cycle. These species are at risk.

Case study 2: Beetle studies in the Tumut region, NSW

I want to talk about some of the work that we did in the Tumut region to illustrate how the fauna can be homogenised just by changing what happens in the areas around remnant patches. This is Nici Sweaney's PhD work (Sweaney *et al.* 2015). To understand what goes on here, you really need to understand the different landscape elements that we're studying. It's a typical agricultural landscape with remnant vegetation and pine plantations. The elements we looked at were the farm matrix just out in the farm paddock, the pine matrix in the middle of the pine forest, remnants embedded within the pine, remnants on the farm, and remnants that were between both, so had a pine side and a farm side.

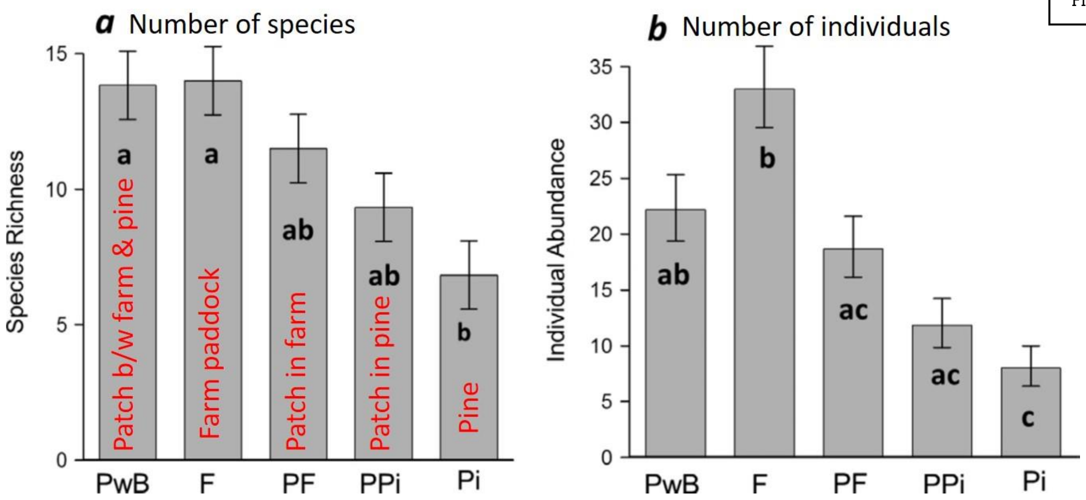


Numbers

First of all, if we look at the number of species (Fig 14a), we see that remnants between the farm and the pine, and just the farm paddock, had the highest numbers of species. The number of species then drops off – a remnant patch in the farm had fewer species, a patch in the pine less, and the pine itself had the least number of species.

Looking at the number of individuals (Fig 14b), the farmland had the most individuals, which probably related to the amount of resources and nutrients available, the nutrient availability. And again, the number of individuals drops off down to the lowest abundance in pine plantation. So conversion of farm to plantation reduced the number of species and reduced abundance.

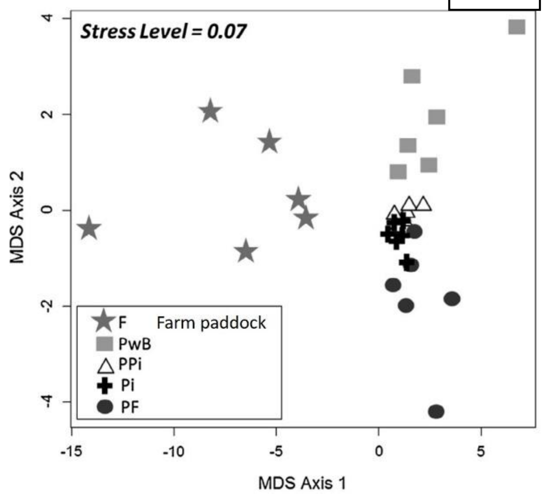
Fig 14



Communities

But we're really interested in the actual species, not just the numbers. We looked at another of these multidimensional scaling plots, where the distance between points represents how different sites are from one another(Fig 15).

Fig 15



The pine sites are highly clustered, with the farm paddocks outside the cluster. Within the cluster is a tight group with both the patches in the pine and the pine plantation. The key thing to notice is that, amongst all of these other landscape elements, the beetle communities are quite diverse - they've got a range of different species and one patch is not necessarily going to have the same set of species as another patch. Whereas if you just convert the farm to a pine plantation, you totally homogenise that community - they all end up with the same subset of species that you formerly had across the landscape. In this context, what's in your remnant vegetation is strongly influenced by what's surrounding it.

Key messages

Conversion of farmland to pine plantation reduced the numbers of beetle species and individuals. Species in remnants had similar species to the surrounding plantation – but this community of beetles in the pines was only a subset of the original community in the area. This shows that what's in your remnant vegetation is strongly influenced by what's surrounding it.

Case study 3: Beetle studies around Benalla and the Wimmera

Sasha Jellinek's PhD looked at sites around Benalla and some out in the Wimmera (Jellinek, Parris and Driscoll 2013; Fig 16a & b). And again, we were asking this question about the role of different landscape elements in influencing where beetles can occur. In this study we compared the beetles in a cleared linear strip with a revegetated linear strip, a remnant linear strip and a remnant patch (Fig 16c).

Fig 16c

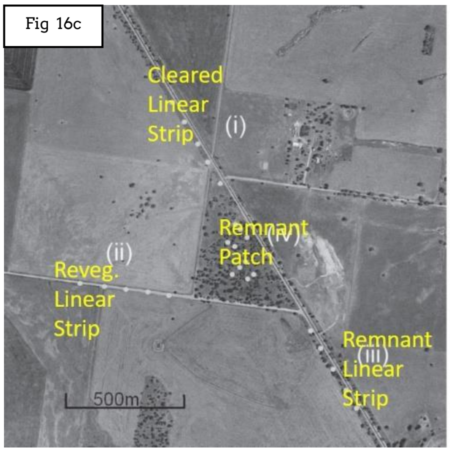


Fig 16a

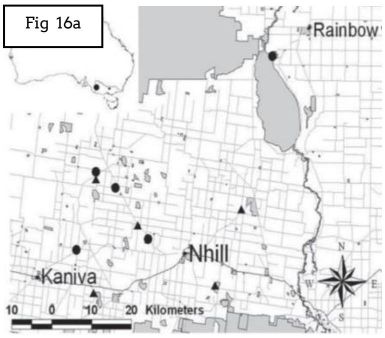
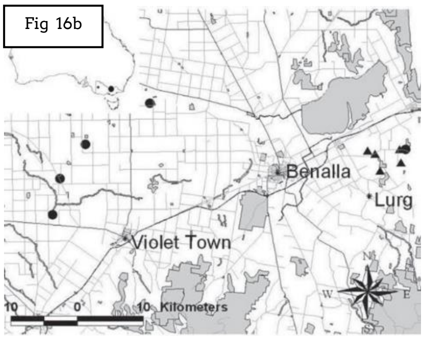
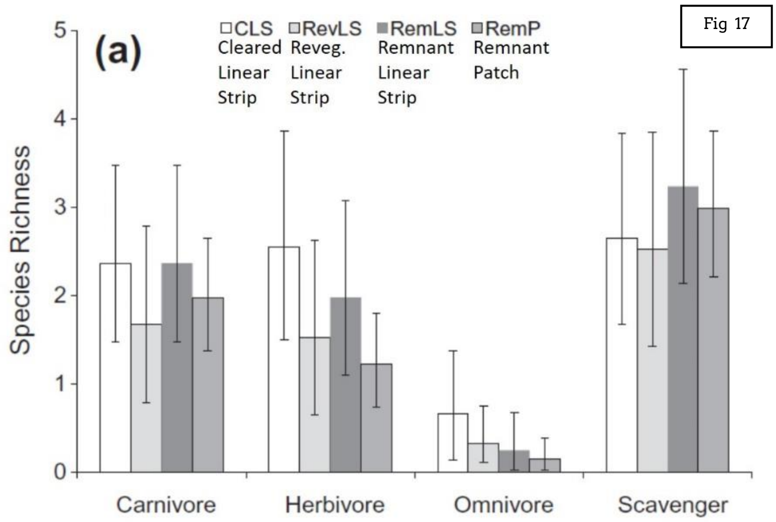


Fig 16b



While there were differences in abundance amongst the different trophic levels of beetles across the landscape, there were no significant differences between the landscape elements (Fig 17). The remnant vegetation sites had essentially the same beetle community as in the cleared linear strips with just grassy understorey. That was surprising.

Fig 17



What we thought might have been going on was that all the patch-dependent species in this landscape had already gone. In that landscape, the remnants may have been in such poor condition for so long that the sensitive species were already lost.

We should also bear in mind that, if they're already lost, that means restoration really needs to consider bringing these species back, to get back whatever functions those species were performing. But a little caveat is that we did sample in 2008 and 2009, towards the end of the millennium drought. It would be really interesting to go back and compare those sites now with what we found during the drought, because perhaps only those really robust species were the ones that were abundant enough for us to catch. We can be optimistic even after the other weekend!

Key messages

This study did not show differences in the communities of beetles in different landscape elements, but the study was done during drought and many patch-dependent species may have already been lost from the landscape.

Case Study 4: Beetle studies in the Lachlan catchment, NSW

How do different kinds of paddock affect the beetles? Essentially we're asking about the matrix effect and edge effects. Kat Ng's PhD work was across a fair chunk of New South Wales, extending from Cootamundra, Grenfell, right out past West Wyalong out to near Rankins Springs, in mixed cropping and grazing land (Ng *et al.* 2018; Fig 18).

We found some remnant vegetation, mostly Grey Box woodland, and some Mallee out in the west. And we found patches that had different management of the paddocks around those remnants.

So we compared areas with crops, areas that were fallow, areas that had been cropped but were grazed at the time, and areas with plantings. We added fine woody debris (that's like coarse woody debris that won't stuff up your plough next time you plough it) – these sites were basically the same as a cropped site but with the mulch added after harvest. We sampled in spring when the crop was up, and again in summer after the crop had been harvested. We ran transects from inside the remnant out into each of these different kinds of paddock and sampled right at the edge and 20m and 200m either side of the edge (Fig 19), using pitfall traps either side of a drift fence so that we can get some idea of which direction the beetles were moving. Kat was insistent that we point out how long it actually took to collect this data set – it's a massive data set with over 11,000 individuals that took a year to sort.

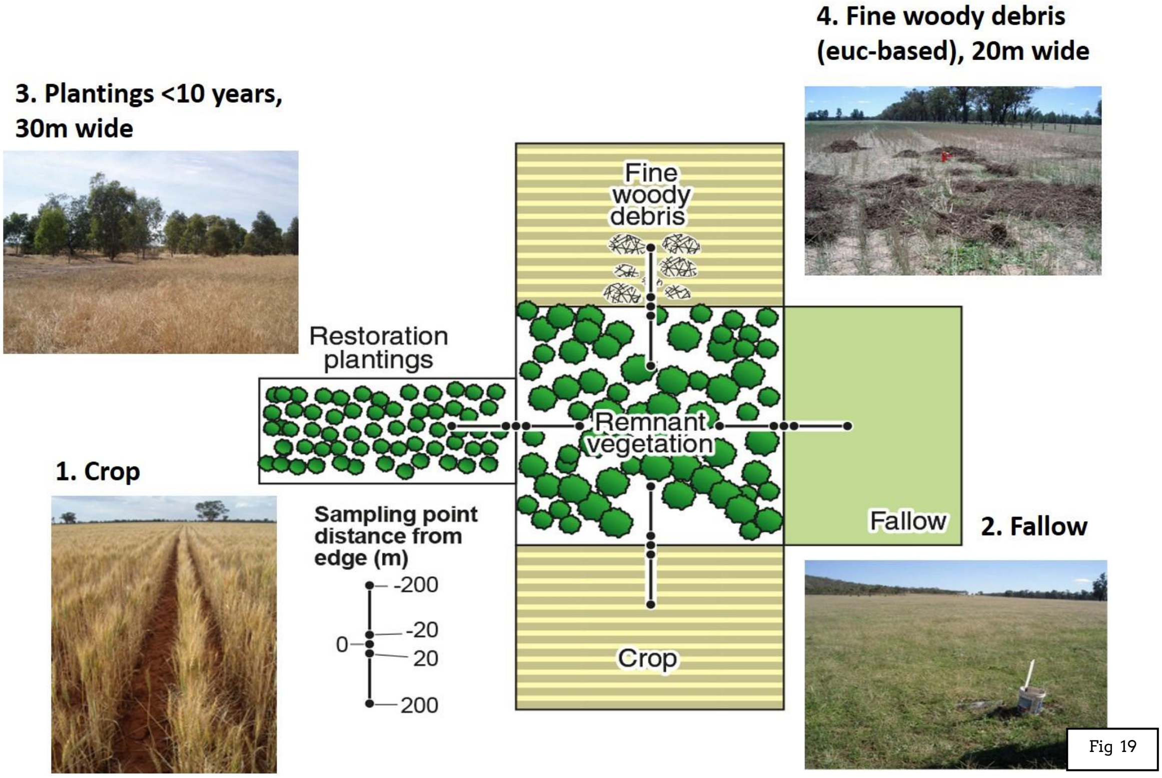


Fig 19

Species diversity

The farmland had many more species than the remnants (it seems to be a theme that is emerging here). But species composition again showed really different species across the landscape elements. Ordination graphs show that patches have a different community to the farmland and a different community at the edge, where species seem to be influenced by both of those adjacent landscape elements (Fig 20). About a third of species were only in the remnants, about a third only in the farmlands, and about a third were able to use both.

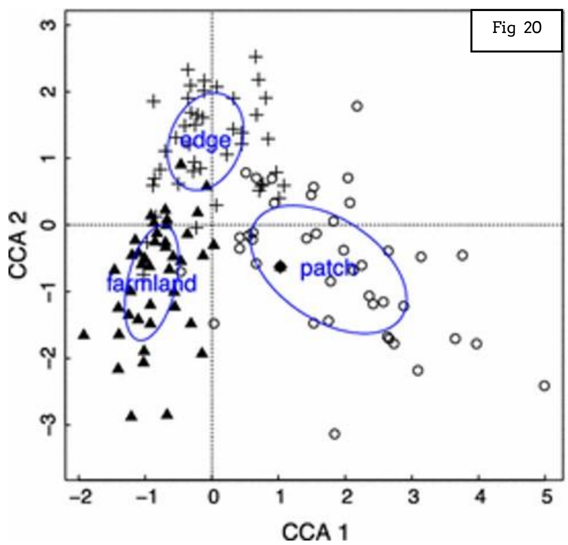


Fig 20

I'll talk about the results for the predator beetles (Fig 21). Cropping had a big influence on the number of predators in the landscape. There were lower numbers in the remnants. That's what we expected based on the overall species richness. But there was a big reduction after cropping. When the crops were up, lots of predators are out there doing their thing. After the crops were harvested, the number of predators declined.

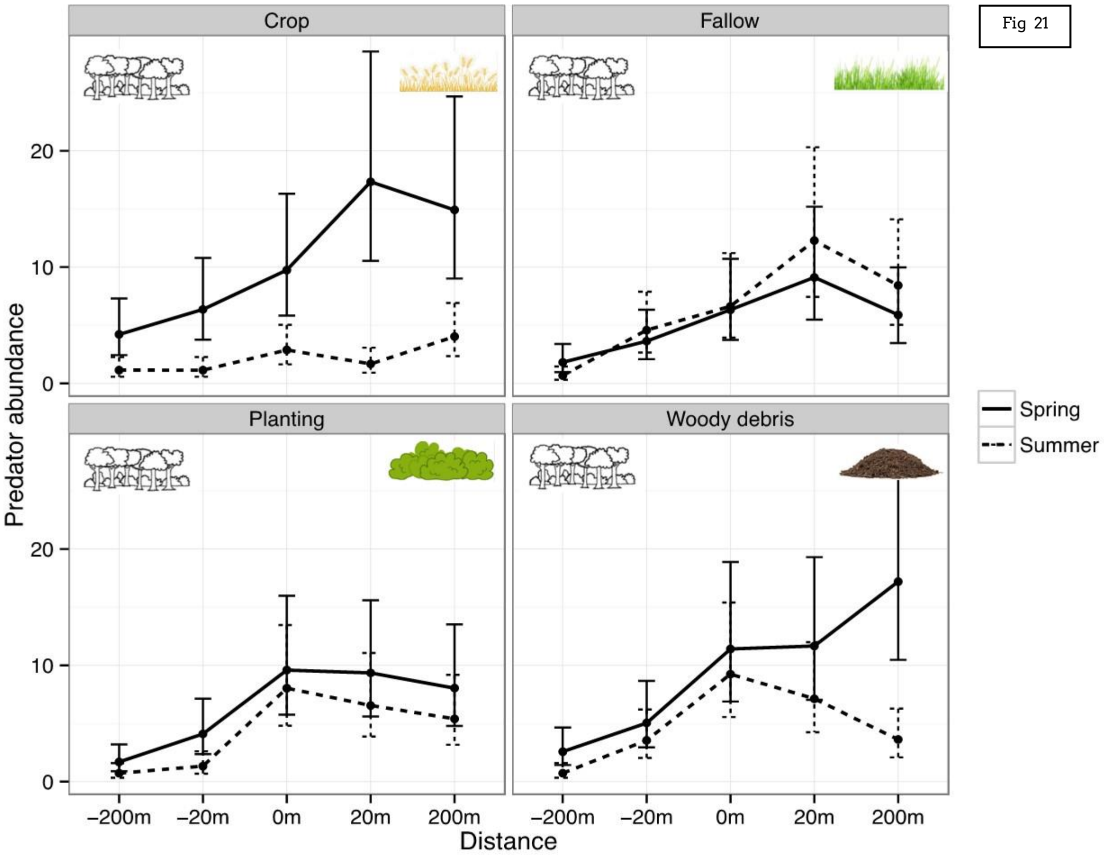


Fig 21

We saw different things happening in some of the other landscapes between seasons. In the woody debris, the treatment is essentially the same as the cropping treatment but with mulch dumped on after harvest. And that seems to have really quite changed the response – the woody debris maintained numbers at the edge and even 20m into the paddock.

Movement of species

I mentioned that we looked at the direction of movement using pitfall traps on either side of a drift fence. We didn't really see any major movements in spring. But there were significant movements in summer (Fig 22), when we generally saw movements from 20m out in the paddocks towards the remnants in the fallow, in the crop, and in the woody debris sites. In all of these, the beetles seemed to be moving towards the remnants in summer.

But in the woody debris, we also saw movement from the remnants towards the edge, which is consistent with having higher numbers at the edge, suggesting that adding mulch actually attracted these beetles from the remnants out to the edge.

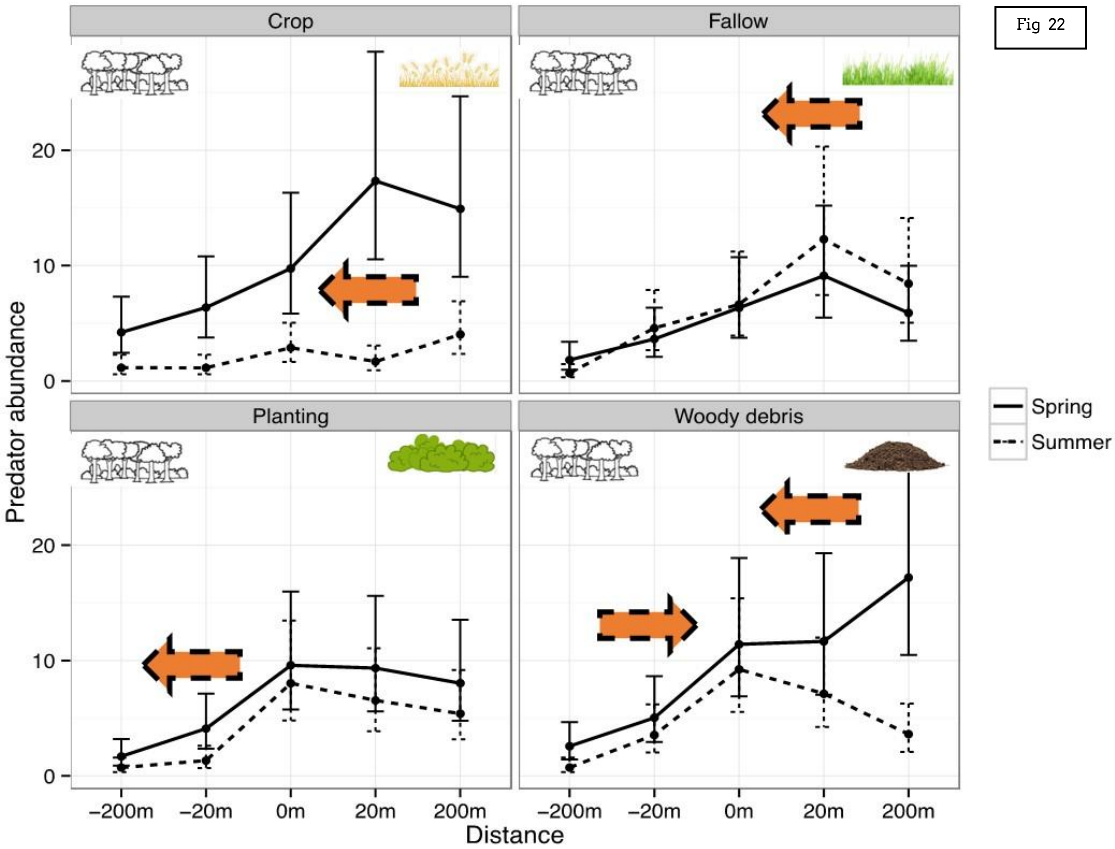


Fig 22

In the plantings we didn't see movement out of the plantings in summer. So the plantings seemed to be providing some sort of stable habitat for the beetles in those landscapes. But weirdly we saw movement away from the edge of plantings into the remnants; that's hard to explain and may be something to do with other species that perhaps move out of the patch - other scary species.

Key messages

Summing up that set of studies, the predatory beetles had high abundance in crops but emigrated out towards the remnants after harvest - they're basically spilling over into the remnants. You can imagine that has some implications for the community living in the remnants. The woody debris seems to maintain higher numbers after cropping, including attracting beetles from the remnants. And no emigration from the plantings in summer, but movement away from the planting edge for some mysterious reason that we need another PhD to look at.

Case study 5: Beetles in Buttongrass in Southwest Tasmania

We've exhausted my beetle research in agricultural landscapes, so we will now talk about beetles from Southwest Tasmania (Driscoll 2008). And I particularly want to talk about these because they start to illustrate the kind of interactions that can happen when you have these really diverse communities. Basically there's a beetle for all purposes, as far as I can tell.

We asked, in this landscape, how does patch size, shape and isolation influence the beetle community? The study areas were eucalypt patches embedded in the Buttongrass sedgelands in Southwest Tasmania. I wanted to work in this landscape not just because it's awesome and I enjoy bushwalking, but because it's a landscape that's been naturally fragmented for a long time.

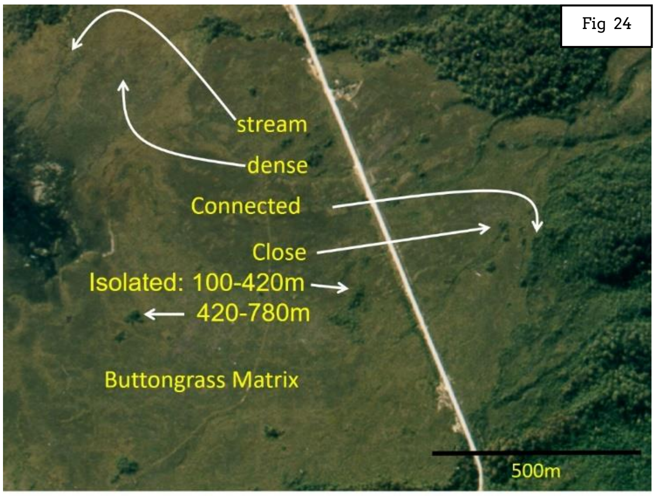
In agricultural landscapes, if you want to ask questions about isolation and size, it's harder to expect to get the end-answer because we haven't got to the end yet - there's a lag between clearing the landscape and finding out how the species respond at some sort of equilibrium. The Tasmanian landscape has been fragmented for hundreds, if not thousands of years. So the beetle communities are more likely to have stabilised in the kind of responses that they're showing to these fragmented areas.

Fig 23

Eucalypt patches in a buttongrass matrix, Tasmania

I studied three areas along the Scotts Peak Road (Fig 24), and in those areas I sampled a range of landscape elements - the linear streamsides, patches in "dense" locations where there is a cluster of eucalypt patches in close proximity to one another but not necessarily connected to other bigger patches, patches that are connected to the big eucalypt and rainforest areas, patches that were close but not connected to the big forest areas, and patches that were isolated from other patches. The isolated patches were isolated by either 100 - 420m and others that were really, really isolated, between 420m and 780m from other patches. And I also sampled in that matrix, the Buttongrass.

Fig 24



Species composition

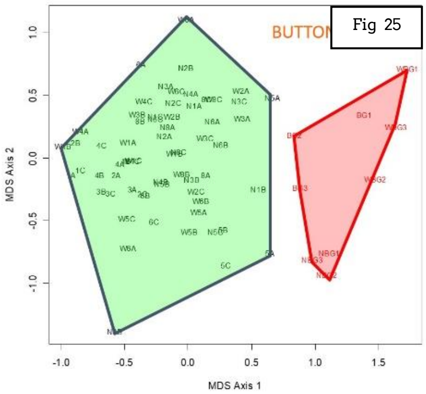


Fig 25

The first thing to realise is that the Buttongrass fauna is really different. There were two species that only were found in the Buttongrass. There were 88 only in the forest areas, and 21 in both. So when you look at the ordination, the forest and the Buttongrass communities were really very distinct (Fig. 21).

The second point is that patch isolation really limits where a species can occur. Some examples:

- Decilaus sp. and four other species were most likely to occur in patches that were connected to large patches, were pretty common in dense patches, and were often in streamsides (Fig 26a). But they never occurred in any of the patches that were not connected or near to these bigger patches or near them – they were not in any of the isolated fragments.
- *Chylnus ater* and three other species were really common in the connected and dense sites, sometimes in the streams, and were pretty rare in those more isolated sites (Fig 26b).
- There's an interesting variation on this pattern. *Sloaniana tasmaniae* is a small black carabid beetle. It is quite common in the dense sites but occurs much less often in all the other sites - the ones that are closer or connected and the ones that are more isolated (Fig 26c). It seems to be getting squeezed from both ends. It's got poor dispersal ability, so it's not able to get to the more isolated sites. But it's also not doing very well in the really connected sites as well.

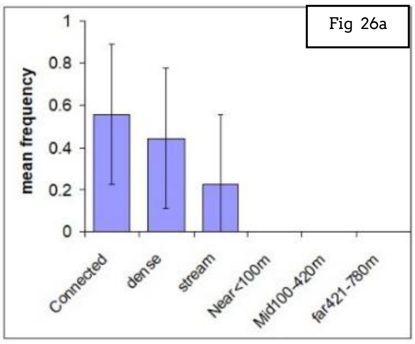


Fig 26a

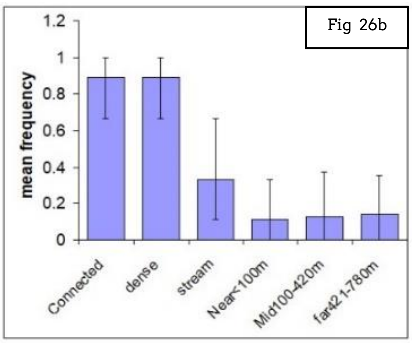


Fig 26b

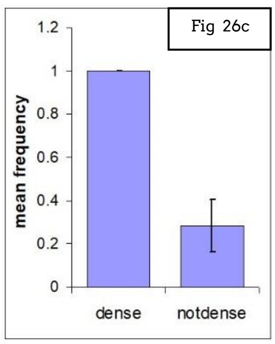


Fig 26c

I've argued that these nine species are dispersal-limited species because most of them are flightless and the two that could fly were probably poor flyers based on their wing size to body size. Compare that with all the other 32 commonly captured beetles: only four of these other species were flightless. So this does seem to be a dispersal-limitation pattern.

The interesting part though, is that there's also an inverse dispersal-limited pattern. Seven species increase with distance from the forest areas and large patches, and six out of seven of those could fly. For example:

- *Galerucinae* sp. (a chrysomelid beetle) were most likely to be found in the most isolated sites – and not in surrounding Buttongrass (Fig 27a). Three other species showed the same pattern – and all could fly.
- Another three, including *Baeocera* sp. (a small staphylinid beetle), not only occurred in these isolated sites but were also really common in the Buttongrass (Figs 27b,c). Their occurrence in these more isolated sites could be related to them occurring in the Buttongrass. Two of them could fly, so they're really good dispersers.

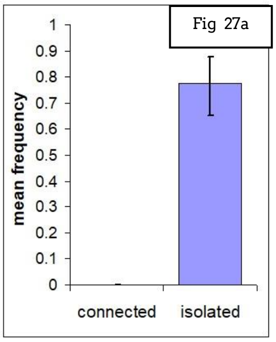


Fig 27a

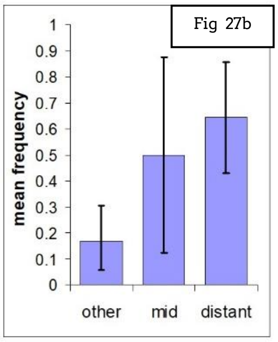


Fig 27b

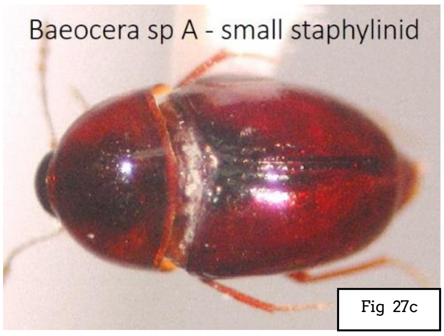


Fig 27c

Key messages

Studies in the older Buttongrass landscapes showed that

- *Dispersal-limited but good competitors or predators are using the well-connected sites.*
- *Dispersal-limited and not the best competitors are pushed out a bit further into the dense patches.*
- *Good dispersers that haven't become a good competitor and are also quite tasty are more likely to be found in the really isolated places.*

This interaction between dispersal ability and competitive ability or predatory interactions influences the species composition. These discoveries are likely to translate to beetle communities across agricultural landscapes where you have different levels of isolation and connectivity and patch size.

Case study 6: Insectivores in West Africa

I want to now finish up with the idea that it is an ecosystem out there, using this example of changes in the insectivore community influencing beetles in the Ivory Coast of West Africa. I was asked to give a talk about interactions amongst species, so I dug this up article by Amy Duggan of the Department of Ecology and Evolutionary Biology, Rice University Houston, Texas (Duggan 2008). I'm intrigued by the whole landscape and the whole conservation issue around what's happening in rainforests around the world. Habitat fragmentation is a big deal virtually everywhere, including in these tropical rainforest countries (Fig 28a). In this country, palm oil plantations are expanding into former rainforest areas (Fig 28b). Of course, we know that palm oil is related to what we all eat and buy at the shops. It is Unilever's products that this particular rainforest was going to be cleared for.


Fig 28a

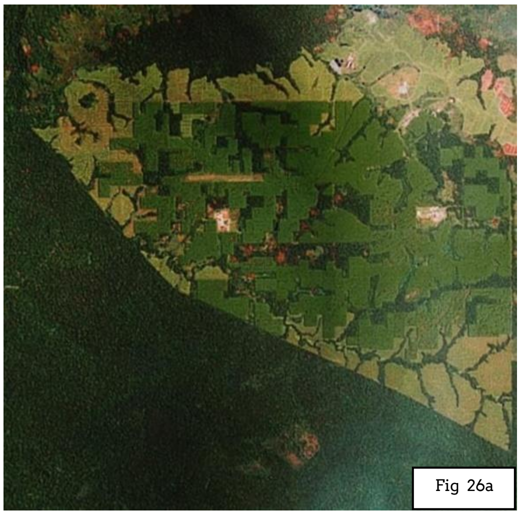
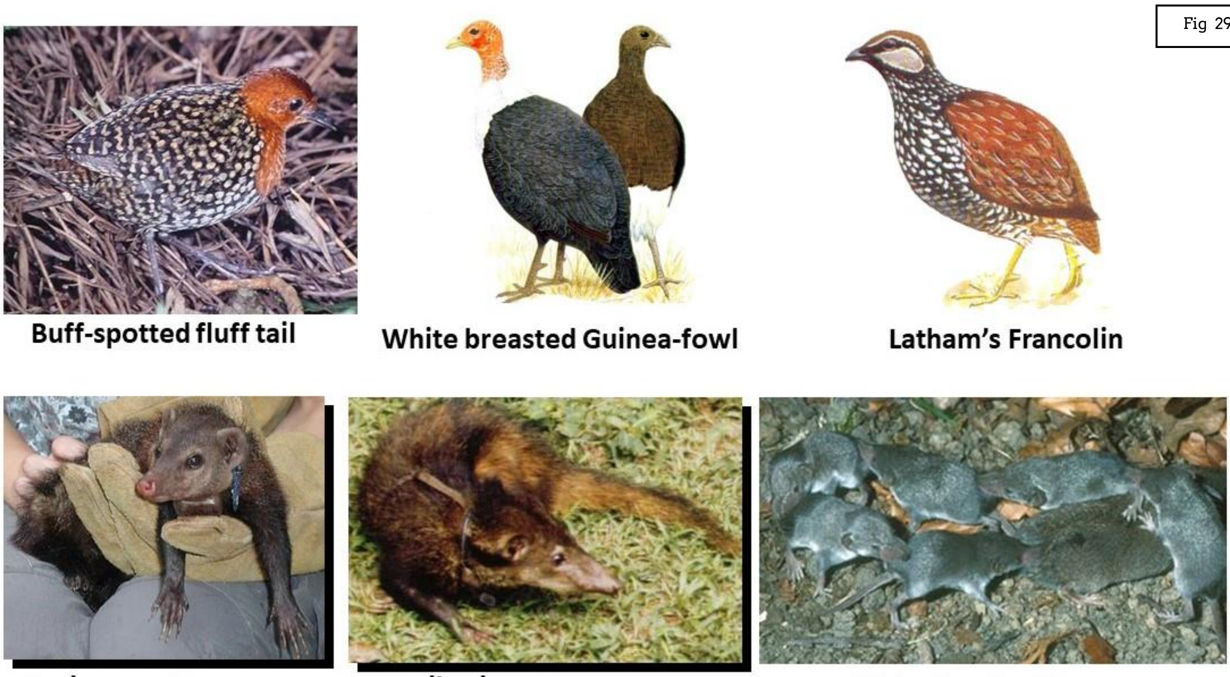


Fig 26a

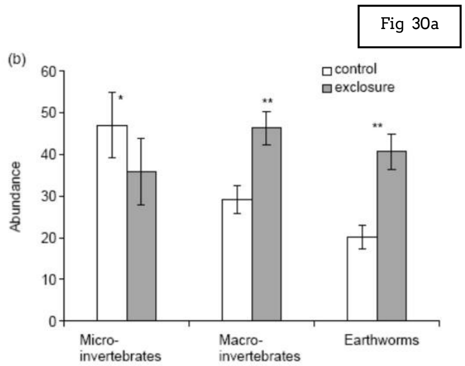
When you clear a landscape like that, and it's true for our landscapes in Australia as well, you lose some of the bigger creatures. In this study, the insectivorous birds and mammals decline after fragmentation, so they aren't out there eating all the insects. Something's going to happen. This study was about what does actually happen.

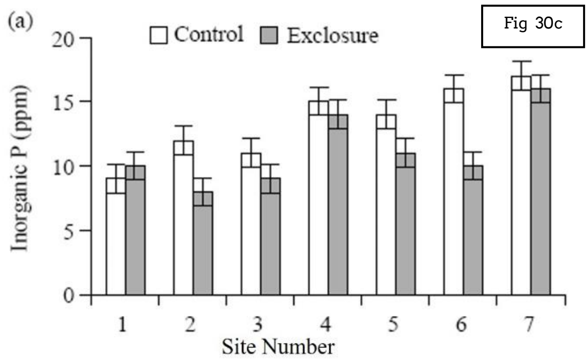
Fig 29


Buff-spotted fluff tail
White breasted Guinea-fowl
Latham's Francolin
Cusimanse Mongoose
Liberian Mongoose
White Toothed Shrew

In one of the national parks they selected seven sites with a control plot and a 3x3m caged plot that excluded the insectivores. After nine months of the cages being in place, they measured the macro-invertebrates, the micro-invertebrates that are too small for the vertebrates to eat and the earthworms, as well as herbivory and nutrient cycling.

- The micro-invertebrates decreased in the caged plots, and the macro-invertebrates and earthworms - the things that the mammals were eating – increased (Fig 30a).
- That had consequences for the plants: herbivory increased and plant mortality increased (Fig 30b).
- It also had consequences for nutrient cycling: available phosphorous was on average 20% lower when the insectivores were excluded (Fig 30c).





They used a path analysis to find out what were the likely relationships amongst these different components, or how does this actually happen. Essentially the relationships are that insectivores have a strong negative effect on the non-predatory macro-invertebrates and also a negative effect on spiders. The spiders have a bit of a negative effect on the macro-invertebrates, but not as big as the insectivores. The spiders also eat the micro-invertebrates, and the micro-invertebrates are really good at helping with the cycling of inorganic phosphorous. If there are heaps of spiders, the spiders eat the micro-invertebrates, and that slows down nutrient cycling.

Key messages

By losing insectivores at the top has a major impact on ecosystem processes in the rainforest:

- *macro-invertebrates increased, as did herbivory and plant mortality*
- *spiders increased, reducing micro-invertebrates and nutrient recycling.*

Implications for restoration

And that has implications for how the plants were doing in terms of survival and herbivory. It's all linked. I've extrapolated this last example to a revegetation case – a worst-case scenario - just to cheer you up at the end of the talk. Habitat loss and fragmentation exterminates these insectivores. This happens in our remnants as well. This has cascading effects through the invertebrate community, which we've seen. You end up with high herbivory, and that exterminates many plants, making it hard to get your restoration to work nicely. And some plants might fail because of that change in nutrient cycling. That might cause your re-vegetation to remain in a degraded state, which means it's unsuitable for the vertebrate insectivores to be reintroduced in the first place.

This gets back to what Jacqui was saying about state-and-transition models. Potentially, by the loss of those vertebrate insectivores, you lock this system into a state that it's really hard to get it back from.

The implications for restoration? In a new system we need to discover which species are missing from fragmented landscapes and plantings. We need to know how strongly those species interact with other species. The strong interactors are the ones you need to really put back. And then we need to attempt to restore those strongly interacting species to reduce impacts of habitat loss and to expect our restoration to be successful.

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