Lesson #1  Field research exposes a moment in time, but landscape transformation has a long term dynamic
Lesson #2  We expect a considerable extinction debt in this landscape
Lesson #3  Whereas in some landscapes the agricultural matrix might support significant biodiversity, or offer opportunities in a fine grained heterogeneous mix, this is not the case in this landscape
Lesson #4  Biodiversity losses are so extreme that it challenges ideas about what useful conservation goals might be
Lesson #5  Some elements of biodiversity show surprising signs of resilience to extreme fragmentation
Lesson #6  In spite of extensive clearing on the plains some connectivity of native vegetation remains in a network of linear remnants. These remnants have heightened value in this landscape, as a resource to be protected and as the foundation for improving biodiversity outcomes in the future
Lesson #7  Management of biodiversity in this landscape must learn to acknowledge the strong influence of erratic rainfall on both the native and agricultural biota
Lesson #8  There are few agricultural options known to be profitable in this low rain, dryland agriculture landscape, and so future land use scenarios are constrained

Introduction

- Focal landscape is Central NSW. Our research has been concentrated in an area approx 50 km radius from 33° 54’S, 146° 18’ E. Dominant agricultural practice today is dryland cereal cropping (especially wheat) with livestock (primarily sheep) often part of the enterprise mix, and used in rotation.
- Mean annual rainfall approx 400 mm, but erratic within and between years. The plain is mostly at 150-200 m ASL. Paddock size often ~ 4-6 km².
- The landscape has a short (<200 yrs) and fast history of agricultural development (Fig 1). In 1817 the lowland plans of our study landscape were dominated by mallee woodlands and associated plant communities. In the
following century agriculture would have been based on livestock, with incremental clearing of native vegetation. In the second century (1917-present) the massive growth of cereal cropping transformed the landscape such that there is now less than 10% of native vegetation remaining on the plains (Sivertsen and Mcalfe 1995, Driscoll 2005). A burst of land clearing was experienced in the wheat belt as recently as the 1970s, when >50% of the remaining remnant vegetation on the plain was cleared (Sivertsen 1994).

- What does intensification mean in the context of these landscapes? As we describe below, the lands that we describe in this chapter are extensively cleared, and those cleared elements are typically intensively managed. Whether this is a landscape that is intensifying is debateable. Given tight controls on land clearing, it may be that intensification peaked in terms of spatial extent of intensive use, and that future changes may constitute a lesser intensity of land use for production. However, sheep grazing is in long term decline, and continuous cropping is now possible, thus even more intensive use of some proportion of the production areas is also likely (Duncan et al 2008).

- From 1997–2010 the authors explored the influence of the fragmented habitat structure on metapopulations, species richness of functional groups of fauna, pollination and plant pollinator interactions of the woodlands of the mallee plains vegetation in this landscape, and some similar landscapes in South Australia and Victoria.
Figure one: Summary of the history of agricultural development in the focal study landscape.¹ Sivertsen and Metcalfe (1995), ² Driscoll (2005), ³ Australian Bureau of Statistics (2004). Land clearing data are only available for a few points of time from the 1970s, but data on the area of wheat in NSW are likely to provide a surrogate (inverse) for the temporal pattern of land clearing.

Main text

Lesson #1 Field research exposes a moment in time, but landscape transformation has a long term dynamic

Our field studies describe patterns and processes observed in a series of relatively short term projects in beginning in the late 1990s. At this stage the conversion of the mallee landscape to a primarily cropping landscape was complete, and had been so for a few decades. Therefore insights into the temporal course of land use intensification require the methods of a historian as much as an ecologist. In the absence of long term studies we resort to reconstruction of history, and methods such as “space for time” substitution. While our studies were conceived to provide insight into the consequences of fragmentation and other features of landscape modification, the perspective of a land use intensification comes as paradigm laid over existing ideas and data. To a greater or lesser degree this will often be the true history of our data for any landscape – as true land use intensification studies are rare.

The conversion of intact mallee landscapes to an extensively cleared and intensively managed landscape occurred very swiftly and recently (figure one; Duncan and Dorrough 2009). The resultant landscape is strongly polarised, with engineered surfaces for cereal production interspersed with native elements that often retain considerable native structural and compositional diversity. These native habitat elements occur most commonly on the plains as narrow linear strips along road and rail lines, and infrequently as small or large reserves. Native habitats also remain on rocky ridges.

Some of the native remnants are exposed to frequent disturbance such as grazing livestock, earthworks (e.g. roadsides, stock reserves), some from grazing and forestry (state forests). Even the remnants in nature reserves are chronically exposed to fertiliser run off and fall out (e.g. Duncan et al 2008).

To understand the likely future trajectory of this landscape one needs to appreciate that many of the landscape changes have happened rapidly relative to the life-histories of many of the organism affected. For example, seed production by Eremophila glabra and Acacia brachybotrya (and Dianella revoluta) is lower in linear remnants than in larger reserves (Cunningham 2000, Elliot thesis) however, there is no evidence yet that this has effected recruitment. Given that recruitment events are likely to be extremely episodic, driven by temporally- pulsed phenomena such as rare wet years and fires (see lesson 7), we do not know when population level effects will be expressed, if at all.

Lesson #2 We expect a considerable extinction debt in this landscape

While many mammals in this landscape have already become regionally extinct (Bilby, Western Quoll, Brush Tail Bettong, Eastern Hare Wallaby, Bridle Nail Tale
Wallaby, Gould’s Mouse, Koala) Mallee fowl, one of the archetypal species of this landscape are still in the process of contracting in distribution, so that while they were recently known from some of the small reserves, they are now only found in the very largest patches of remnant vegetation. This contraction continues even while the rate of land clearing has stabilized, albeit at a level with only a very small percentage of remnant cover.

Among the reptiles, two species appeared to be locally extinct, and a further five species had declined or were declining from linear remnants, leaving remaining populations isolated in reserves. A further nine reptile species had patchy distributions through the strips and reserves (Driscoll 2004). These species appeared to be vulnerable to extinction, with the risk that isolated populations may die out over coming decades, with no possibility of recolonisation (Driscoll 2004). A similar picture emerged for the beetles in these landscapes. Driscoll and Weir (2005) estimated that 21% of the beetle fauna may be at risk of decline over coming decades. Driscoll (2004) recommended that widespread revegetation would be necessary to avoid paying back the extinction debt, representing one possible future scenario for these mallee landscapes. This revegetation would have to occur largely on the privately held farmland that dominates land tenure on the plain.

Lesson #3 Whereas in some landscapes the agricultural matrix might support significant biodiversity, or offer opportunities in a fine grained heterogeneous mix, this is not thought to be the case in this landscape.

The landscape is quite unlike those known from many other parts of the world where agricultural land management can be seen as a valuable tool in the conservation of certain species or communities (refs for corn and vege farming in central America?, old grazing landscapes of Europe, “rustic” coffee plantations (cite Tscharntke cacao and VP coffee)). In this landscape the contrast between the dominant agricultural form (a wheat field) and a remnant mallee is stark in both structure and composition. Paddock sizes are great (e.g. 4-6km$^2$) and natural features in fields (e.g. paddock trees) are rare, providing little scope for connectivity through the matrix, except through linear remnants (see lesson 6). Whereas in some fine-grained heterogeneous agricultural landscapes different agricultural land uses can be viewed as offering a dynamic range of ecological opportunities (eg mass flowering, Westphal ref, or ref chaprters in the book)), in this landscape the current agricultural land uses have led to large scale homogenization and simplification.

We know of no native species of conservation concern that rely on the agricultural part of this landscape. Extensive survey for reptiles in the interior of paddocks found only two individual blind snakes (compared to 1128 individuals and 29 species in remnants, Driscoll 2004, and unpublished data). Seventeen of 116 beetle species were collected more frequently in the paddocks than remnants (Driscoll and Weir 2005), but there is no evidence that they depend on this habitat for their regional persistence. No endemic flora appears to be dependent on agriculture.

In short, the simplistic habitat – non-habitat paradigm is almost true of the current landscape (in this pecific example), and this must change to improve biodiversity prospects. This could change if there were a significant move toward extensive perennial grazing as a land use (see Duncan and Dorrough (2009) and Bryan et al (2011) for discussion). Native habitat value of Atriplex (saltbush) on farms has been
demonstrated (Seddon et al 2009; Collard et al 2011) and Smith (2009) also demonstrated how oil mallee plantations are providing habitat value.

Although there were fewer species, beetles were twice as abundant in paddocks as in remnants, and this likely reflects substantial biological activity (Driscoll and Weir 2005). These paddock specialists included scavengers, omnivores, and predators, implying that beetles contribute substantially to nutrient and energy flows in paddocks. One direct biological service that was observed in the field involved the predatory carabid beetle *Calosoma schayeri*. Coloquially known as the stink beetle for its odorous defence mechanism, this beetle achieved enormous densities as it preyed upon lepidopteran larvae that in turn were feeding on a nitrogen-fixing crop (Driscol, unpublished). We expect that without the service provided by this carnivore less nitrogen would have been fixed through the rotating-crop approach.

Our research on pollinators in this landscape highlighted bees that are capable of crossing into wheat fields in search of resources, and pollinating birds that transport pollen many kilometres from patch to patch. However, none of the agricultural crops currently grown in this landscape benefit from animal pollination, and an ecosystem service view will, in this respect, provide no incentive to farmers.(except maybe legume benefit to grazing??)

**Lesson #4 Biodiversity losses are so extreme that it challenges ideas about what useful conservation goals might be**

Investment in conservation is generally advocated in a triage mode, where resources are focused on cases where the urgency and likelihood of ecological recovery are greatest (Hobbs and Kristjanson 2003). With this view, landscapes such as ours might generally be overlooked (Duncan and Dorrough 2009). There are very few remnant patches on the plains, and the linear fragments that criss-cross the landscape are so thin or degraded that they may not be considered by many conservation planners to meet the criteria for conservation investment (but see lesson 6). Many species of conservation concern are already regionally lost and other species of interest are known to occur outside of the study landscape, especially in areas where mallee clearing has been less extensive. So what then become sensible conservation goals for such a transformed landscape?

One approach is to prioritise populations rather than species. Driscoll and Hardy (2005) found that populations of the dragon *Amphibolurus nobbi* in the farming landscape were genetically distinct from those in uncleared mallee to the north of our study region, and satisfy the criteria for an evolutionarily significant unit (Moritz 1994). This species has declined in the farmed landscape, and was among species that Driscoll (2004) regarded as at most risk of extinction. So loss of species from our study region may not represent a global extinction, but may represent an irreversible loss of evolutionary potential.

A more conservative goal would be to secure a landscape that will support at least those species that are resilient to the extreme land clearing. This would require a better understanding of the processes that support persistence in such an apparently fragmented state.
Lesson #5  *Some elements of biodiversity show surprising signs of resilience to extreme fragmentation*

While many species are in decline we also see many species that are predicted to survive in these landscapes. Fifteen percent of beetle species were more abundant in paddocks than strips or reserves. While some of these species may depend on remnant vegetation to complete part of their life cycle, they are surviving well in the current mix of remnants and extensive paddocks (Driscoll and Weir 2005).

One skink species *Lerista puntatovittata* was three times more abundant on roadside remnants, than in larger remnant patches, possibly linked to increased nutrient run-on beside dusty roads (Driscoll 2004).

Among the plants we have studied three species showed significantly lower fruit/flower ratios when in linear fragments, but this phenomenon was sometimes counterbalanced higher flowering intensity or lower fruit predation (Cunningham 2000b). Although *Eremophila glabra* has lower pollen receipt and lower seed set in linear strips (Cunningham 2000a&b, Elliott 2010) gene flow through pollination was remarkably resistant to fragmentation, with 70-80% of progeny being sired by pollen from outside the local patch, regardless of whether the patch was in a large remnant or narrow linear strip. This extraordinary pattern must be due to frequent long distance pollen dispersal by the pollinating birds (honeyeaters) combined with strong genetic selection mechanisms in the plant.

Visitation by native bees also seemed robust to fragmentation. For *Dianella revoluta* we found that isolated flowers in linear strips still received pollinating visits. Where there was a shortage of pollen, it was due not to a lack of visits but rather a reduced pollen supply due to reduced mate density (Duncan et al 2004). Most of the native bees ground nesting and probably have ample nesting opportunities even outside of large remnant patches, in road verges field margins.

Lesson #6  *In spite of extensive clearing on the plains some connectivity of native vegetation remains in a network of linear remnants. These remnants have heightened value in this landscape, as a resource to be protected and as the foundation for improving biodiversity outcomes in the future*

The fine cobweb of linear connections on the plains country of this landscape was found to be used by a wide range native fauna. Data of gene flow through long distance pollen transport, combined with observations of birds, suggest that the linear remnants provide important connectivity.

Theoretical ecology continues to emphasize the potential for dispersal to influence local community composition. High population growth rates coupled with dispersal have the potential to maintain populations across the intensively farmed landscapes through source-sink dynamics (Pulliam 1988). The hypothesis that linear remnants are particularly important in providing resilience deserves to be tested. In the meantime, we see degradation of remaining remnants by livestock grazing and piecemeal narrowing of roadside remnants through road-works and fence works. Reducing this loss is of paramount importance. Unfortunately the nature reserve paradigm places a low priority on this landscape element. Degradation of these remnants has led to substantial habitat loss and increased fragmentation, despite the
appearance of a relatively well-connected landscape (Driscoll 2004, Driscoll and Weir 2005, Driscoll and Hardy 2005).

In contrast, much larger areas of remnant vegetation in this landscape occur on or around the ridges. While the plant communities of the ridges are distinct from those on the plain, some organisms could use the ridge top remnants in a way that helps their persistence. Our research strategies to date have not allowed us to explore this possibility. Future research and conservation planning should pay greater attention to the contribution the ridge remnants might make connectivity for plains-based biodiversity. For some species, the extensive ridges in the landscape may provide a stable source of individuals from where an ongoing source of propagules stream into the plains remnants. This potential influence of the large uncleared ridges on the biota of the extensively cleared plains warrants further investigation.

Lesson #7 Management of biodiversity in this landscape must learn to acknowledge the strong influence of erratic rainfall on both the native and agricultural biota

Inland Australia is characterized by extreme inter-annual variation in rainfall, driven in part by the El Niño/Southern Oscillation phenomenon. This is known to have great impacts on natural phenomena, such as flowering intensity, vegetation structure, population dynamics of short lived animals, movement dynamics of far ranging animals. Equally, agriculture responds such that in wet years cropping will be more extensive and in dry years cropping declines and livestock are moved around the landscape in search of grazing, including public land. These phenomena can be difficult to study because the events are difficult to predict. In practice though it might be that to understand long term population dynamics most of the critical activity might occur in one season after many years of drought.

As well as understanding the rare good years, managing threats requires attention to the bad years. Grazing of public land during drought is a feature of much of the Australian landscape, known to pose threats to biodiversity. Grazing had a big impact on three reptile species, including complete elimination of one species in grazed sites (Driscoll 2004). When remnant vegetation is grazed during drought the impacts on native species could be substantially magnified as the few resources available during drought are further reduced (Duncan et al 2008, Retzer et al. 2006).

Lesson #8 There are few agricultural options known to be profitable in this low rain, dryland agriculture landscape, and so future land use scenarios are constrained.

Cropping in this landscape is lower yield than further east where average rainfall is greater. Drought has been particularly frequent in recent decades (ref BOM?) and many models predict increasingly intense droughts associated with climate change (http://www.csiro.au/ozclim/home.do). Sheep grazing has been in long term decline with poor wool prices. Cattle grazing is more productive in more northern parts of Australia. As is the case in much of rural Australia farmer are getting older, and their children are more often choosing to live elsewhere. Given these trends it is difficult to anticipate what the future land use trends will be in this landscape, or where the investment will come from to pay for change.

In some nearby landscapes, declining profitability of agriculture is itself acting as a catalyst for potentially large scale recolonisation by native forest and woodland
species. By contrast Mallee eucalypts, the key structural habitat element in our landscapes, show no signs of seedling recruitment anywhere, let alone on formerly cleared agricultural lands.

While some anticipate a carbon price as a driver of future land use change (ref Greening Australia?) the potential to fix carbon is limited by rain, just as it limits annual crops. Bryan et al (2011) visualise Murray Mallee landscapes extensively replanted under carbon market conditions, as well as biodiversity and ‘conservation farming’ scenarios, but the requisite and radical structural changes to farm economy that would create these opportunities are not on the horizon.

**EXTRA BITS**

*Three bird species only ever seen in reserve interior* ((chestnut quail-thrush, crested bellbird and yellow-plumed honeyeater;)

*linear rems had more larger bodied honeyeater spp* (see fig in ch 3)

**Conclusions**

- 1-2 paragraphs of summarising material (still to be done)

**Acknowledgments**

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**Bio**

Don Driscoll has studied the consequences of habitat loss and fragmentation in most Australian States over the past 20 years, with an emphasis on frogs, beetles and reptiles. Some ambitious recent projects include attempting to integrate rational decision-making approaches with fire management, and developing methods for rapid measurement of dispersal. Don is currently a research fellow in the Fenner School of Environment and Society at the ANU. He supervises PhD scholars as they discover how to maintain biodiversity in fragmented landscapes, how to conserve threatened frogs, and how population and demographic traits of plants, birds and reptiles mediate fire effects.

David Duncan conducted his PhD research from 2000-2003 on the effects of habitat fragmentation on the pollination success of plants in NSW mallee woodlands. In 2004 David joined the Victorian Department of Sustainability and Environment where he works as a vegetation scientist. He continued to work in mallee systems in Victoria from 2004-2007, conducting broadscale surveys of ecological condition of remnant woodlands and an investigation into the effect of removing stock grazing pressure from degraded sites. David’s work continues to focus on modelling and measuring how vegetation structure and composition of sites and landscapes respond to current and historical land management practices.
Saul Cunningham studied habitat fragmentation impacts on plants and pollination in this landscape, commencing in 1997. He has maintained a connection with the area through supervision of students that have extended the project in the years since. Since 1999 he has been a research scientist with CSIRO. The major themes in his work are understanding pollination at a landscape with a recent focus on crop pollination and its significance to agriculture, and understanding how biodiversity (especially invertebrates) responds to different land management strategies.

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