# The Influence of Disturbance (Fire, Mining) on Ant and Small Mammal Species Diversity in Australian Heathland[1]

Barry J. Fox[2]

Abstract: Multiple linear regression equations describe responses for both taxa to temporal, floristic and structural vegetation change. Mammal succession is a replacement of dominant species, ant succession is a replacement of groups of species. Many plant species show adaptations to frequent burning and a high proportion of resprouters ensures a rapid recovery, reflected in the mammal community. Mammal recolonization is slower when mining destroys the soil profile and plant regeneration occurs from seed. High-diversity sites support more fire-adapted mammal species. Species diversity is linearly related to habitat diversity. Management for maximum species diversity requires vegetation of all seral stages to accommodate many different taxa.

This paper draws on a number of closely related studies to make comparisons between different disturbance effects in the one area, and from this come to some more general conclusions using information available in the literature.

To monitor post-disturbance changes I have chosen two taxa, small mammals and ants, to represent the range of animals affected. The area considered is in coastal heathland in Myall Lakes National Park (32°28'S, 152°24'E), experiencing a sub-mediterranean climate with peak precipitation in early winter (May-June), and reduced and unpredictable rain during the summer months.

The study sites regenerating after strip-mining cover a time span from four to eleven years and provide a range of simplified habitats from very sparse vegetation cover, progressing towards cover similar to the surrounding plant community. Detailed descriptions of these sites are provided in Fox and Fox (1978). Detailed information at one heathland site (ML), before, and for 5 years after fire, is provided for a species-rich small mammal community (Fox 1980). A study of regenerating sites of different ages in the heath understorey of nearby open forest provides similar information and conclusions (Fox and McKay 1981).

There are few studies dealing specifically with the effects of disturbance on heathland small mammal communities. Cockburn (1978) found the abundance of the Heath Mouse (*Pseudomys shortridgei*), in the Grampian Mountains of Victoria, to be strongly correlated with sites that had burned 6 to 9 years previously and had high plant species diversity. Fox (1980) found that seven species of small mammals in coastal heathland formed a secondary succession following fire. Although largely a study of forest fire, Newsome and others (1975) did include some heathland sites, recording the post-fire appearance of the opportunistic House Mouse (*Mus musculus*), not previously recorded there. There is considerably more in the literature dealing with the effects of fire on forest small mammals; these are reviewed in Fox and McKay (1981).

The effects of disturbance on ants in Australia is much less well known. Fox (1978) deals with the effects of strip-mining in eastern Australian heathlands, as do Fox and Fox (in press), while Majer (1978) and Majer and others (in press) have studied the effects of bauxite mining in western Australian forests.

## MINING

Sequential replacement of top soil, on sand, strip-mined for heavy minerals, produces a regenerating ribbon of heathland where position is a function of time since mining. Mining results in the complete removal of vegetation, destruction of the soil profile and complete homogenization of the overburden

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[2]Senior Tutor in Zoology, University of New South Wales, Kensington, N.S.W., 2033, Australia.

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before its replacement; plant regeneration must occur from seed. A full description of the mining and rehabilitation procedures for the Hawks Nest study sites (HN) is given in Fox and Fox (1978), together with descriptions of the methods used to monitor changes along this mining path.

Structural changes in vegetation were monitored with a light meter, using a method developed to estimate the amount of vegetation present in a number of layers (Fox 1979). There is an overall increase in the amount of vegetation in each layer as a function of time, except for the marked decrease in the lowest 20 cm after eight years. There was little vegetation present above 1 m until after this time (Fig. 1). Plant species

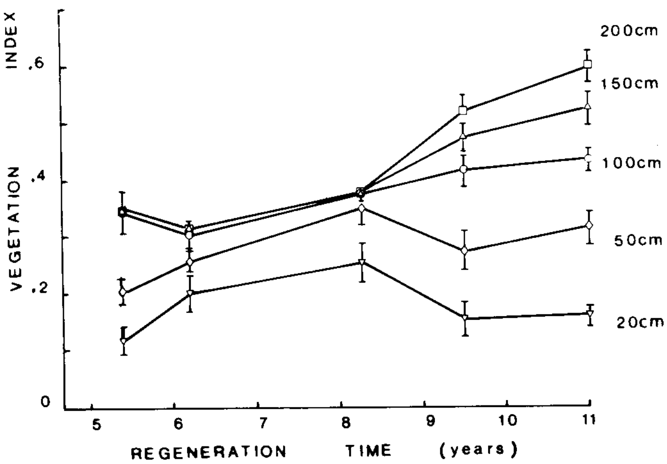


Figure 1--Changes in vegetation structure with regeneration age for five study sites on the Hawks Nest sand mining path. Error bars at the top of each layer are ± 1 s.e.m. for that layer.

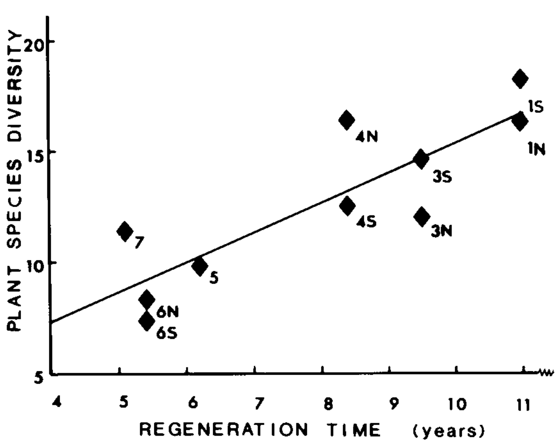


Figure 2--Changes in plant species diversity ($\Delta_3$) with regeneration time for the same mining path ($\Delta_3 = [\Sigma(P_1)^2]^{-1}$, $P_i$ = proportion of cover contribution by species i).

diversity showed a significant linear increase with regeneration time (Fig.2) ($r=0.80$, $n=10$, $p<0.01$). A total of 30 environmental variables were measured for inclusion in a multivariate analysis; from these a subset of 10 variables was selected for further analysis (see Fox and Fox 1978 for full details).

Small Mammals

Small mammals were simultaneously trapped on the 10 mined and 4 control plots, using 25 traps per plot, set on a 5x5 grid with 20 m spacing. Using multiple linear regression and path analysis (see Fox and Fox 1978) a path diagram can be constructed to illustrate which variables contribute significantly to the variance of the biomass of the New Holland Mouse (*Pseudomys novaehollandiae*) on the mined sites (Fig.3). Plant species diversity at each site makes the greatest contribution, followed by a

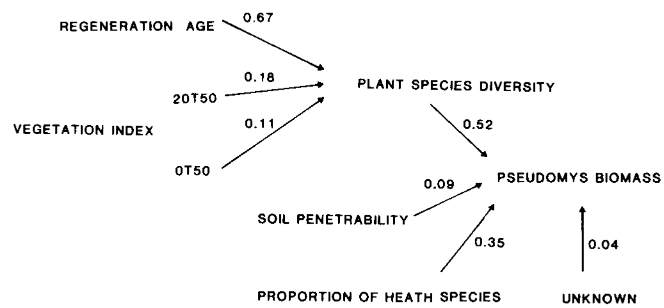


Figure 3-- A path diagram showing factors contributing to changes in *Pseudomys* biomass (PNHBIOM) on sand mined plots. Variables are plant species diversity (PLSPDIV), proportion of heath plant species (HEATHNES), soil penetrability (PENOTIS) and a vegetation index for two structural layers 0 to 50 cm (OT50) and 20 to 50 cm (20T50).

measure of the proportion of those plant species present which are true heath species and then a measure of the soil hardness on the site. Plant species diversity is itself dependent on regeneration age and to a lesser extent on the vegetation structure. From this I can summarize that the New Holland Mouse is associated with areas having a wide variety of heath plants, with vegetation cover below 50 cm on softer substrates and that abundance increases with increasing regeneration age.

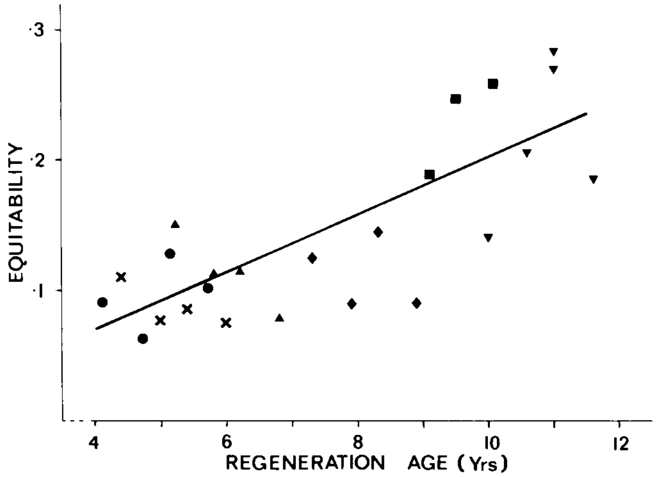


Figure 4--The equitability component (E) of ant species diversity for each mined plot, measured at each of 4 collections during two years, as a function of regeneration age ($E = 4_3/S, S$ = ant species richness). The circled point represents the community changeover.

## Ants

A similar analysis was performed for ants collected by simultaneously sampling all study sites using fifteen 2.5 cm (1") pitfall traps per site on a 3x5 grid with 20 m spacing. Sampling was carried out 4 times over 2 years. It is the equitability component of ant species that shows a significant linear relationship with regeneration time (Fig.4) ($r=0.65$, $n=24$, $p<0.01$). Increasing amounts of vegetation in the layers 20 to 50 and 50 to 100 cm are the variables contributing to ant species richness (Fig.5B), while 93 percent of the variance in ant abundance can be attributed to the presence of a group of heath plant species, low foliage height diversity and a soft substrate (Fig.5A).

Analysis of the species composition of the ant communities at each site reveals distinctly different communities: one most strongly associated with plots minted less than 8 years ago; a second most strongly associated with plots mined more than 8 years ago; and a third, most prominent on control plots.

The changeovers can be abrupt and are well illustrated by the frequency changes in the numerically dominant species: Tapinoma minutum and 5 species of Iridomyrmex (Fig.6). This represents replacement of the dominant species in a successful manner, I. sp C → I. sp A → T. minutum, as one moves along the mining path from younger to older and then to unmined heath. There is good evidence that these changes result from competitive interactions between the dominant species (Fox and Fox, in press).

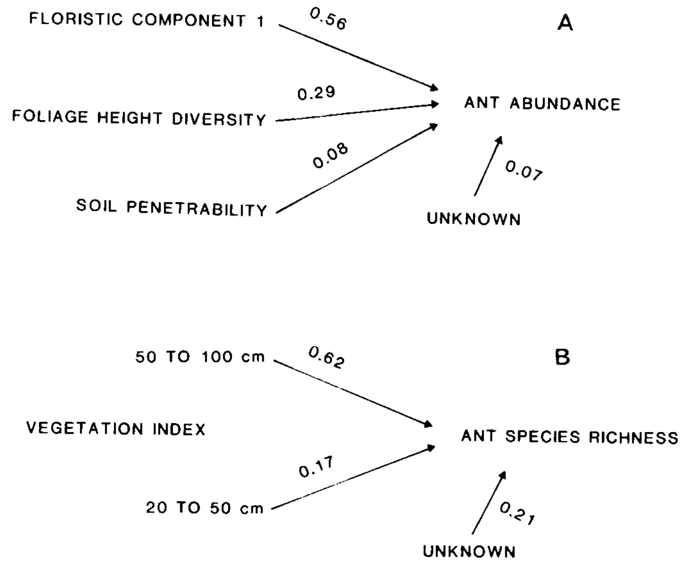


Figure 5--Multiple linear regression path diagrams showing significant contributions to the variance in A) ant abundance ($p<0.001$) and B) ant species richness ($p<0.001$).

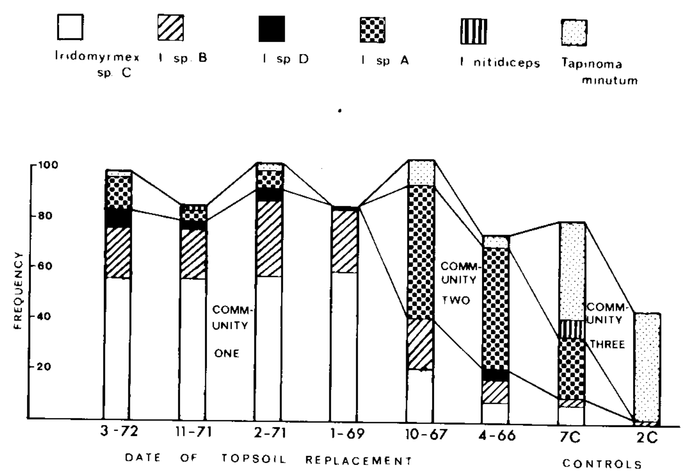


Figure 6--Changes in relative importance of dominant ant species as a function of time. Each large column contains four collections, of increasing age. The time of replacement of top soil is shown for mined plots and time of last fire on control plots. Species associated with younger plots are arranged from the bottom and those for older plots from the top. (Maximum frequency possible on any plot is 15).

FIRE

The 7 ha ML site was trapped using the same 20 m grid spacing. The site comprised a range of heathland habitats ranging from swamp, through wet and dry heath, to heath (closed scrub) with emergent mallee-form eucalypts. Seven species of small mammals were regularly encountered and the site was monitored for 6 months before a major wildfire and at about 2 monthly intervals for 5 years after the fire. Some species such as the Eastern Chestnut Mouse (Pseudomys gracilicaudatus) showed a marked increase (sixfold) over their pre-fire abundance, while others such as the Eastern Swamp Rat (Rattus lutreolus) were unable to reoccupy the area for more than 4 years after the fire. The resulting mammalian secondary succession is best summarized in terms of taxonomic groupings that match the ecological grouping into early, mid and late seral stage species (Fig.7). Species are not usually completely excluded, rather there are marked changes in relative abundance as each species reaches its peak abundance at a time when the regenerating vegetation best meets that species habitat requirements.

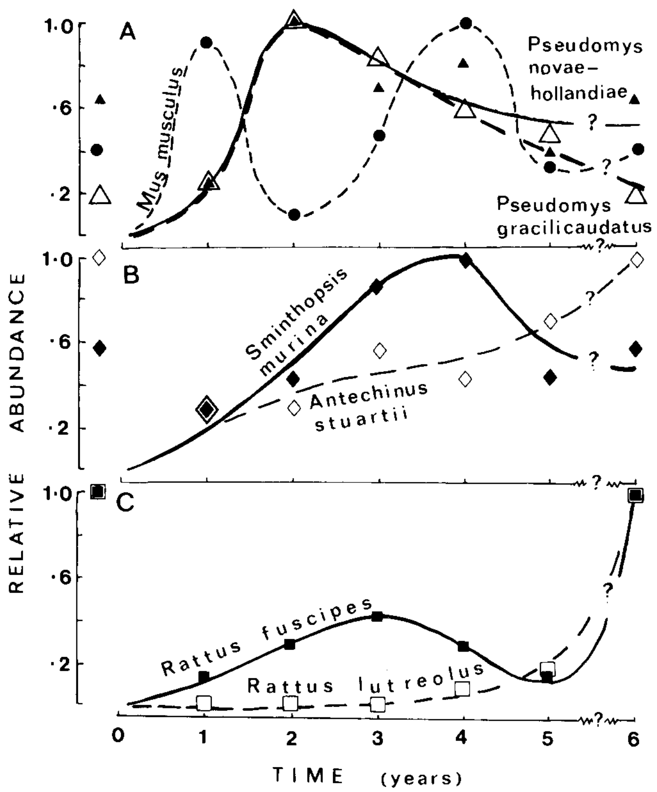


Figure 7--The maximum abundance for each small mammal species in each year since fire, relative to the maximum abundance for that species. Pre-fire abundance is plotted at 6 yrs, the time estimated since the previous fire.

Almost identical results were obtained in a nearby forest (Fox and McKay 1981) using study sites burnt at five different times from 1 to 9 years previously and techniques similar to those used in the mining study (Fox and Fox 1978). Changes in the vegetation structure and plant species diversity of the understorey were similar to those observed on the heath plot (Ml) and shown for the HN mined plots (Fig. 1 and 2).

A COMPARISON OF FIRE AND MINING DISTURBANCE

Making use of the results from the 5-year study on ML it is possible to interpret the relative effects of fire and mining in the area. The three control plots used for the HN mining study had each burnt at a different time (4½, 8½ and 15+ yrs) so that direct comparisons can be made. In isolation the two sets of results for New Holland Mouse density from the mining study appear contradictory; however when combined with the results from ML it can be seen that the differences are due to a drastic shift in the time scale (Fig.8). After fire, New Holland Mouse density, on ML, peaked around two years before returning to pre-fire levels. Given that there are different baseline densities at the ML and HN sites, the HN fire curve would appear to be covering the return to baseline (15+ yrs) density, having peaked earlier as indicated by dashes. By analogy the mining curve not only shows a much slower rate of increase (2 animals $ha^{-1}y^{-1}$ versus 5 animals $ha^{-1}y^{-1}$ for the ML fire curve), but there appears to be a threshold at 5 years. Before this, regenerating mined sites do not appear to be suitable for New Holland Mice. Although not certain, it would appear that the mining curve may overshoot, as indicated by the dashed line, before returning to the baseline density.

The difference in recolonisation rates following the two types of disturbance reflects the different modes of vegetation regeneration. Vegetation on mined plots must come from seed, while burned plots afford much more rapid regeneration from resprouting species whose rootstock survive the fires.

Ant species richness shows a similar discordance in changes following fire or mining disturbance (Fig.8B). Again, this may result from differing recovery rates, but it is more complex and without more information on ant recolonization following fire it is impossible to do more than record the difference.

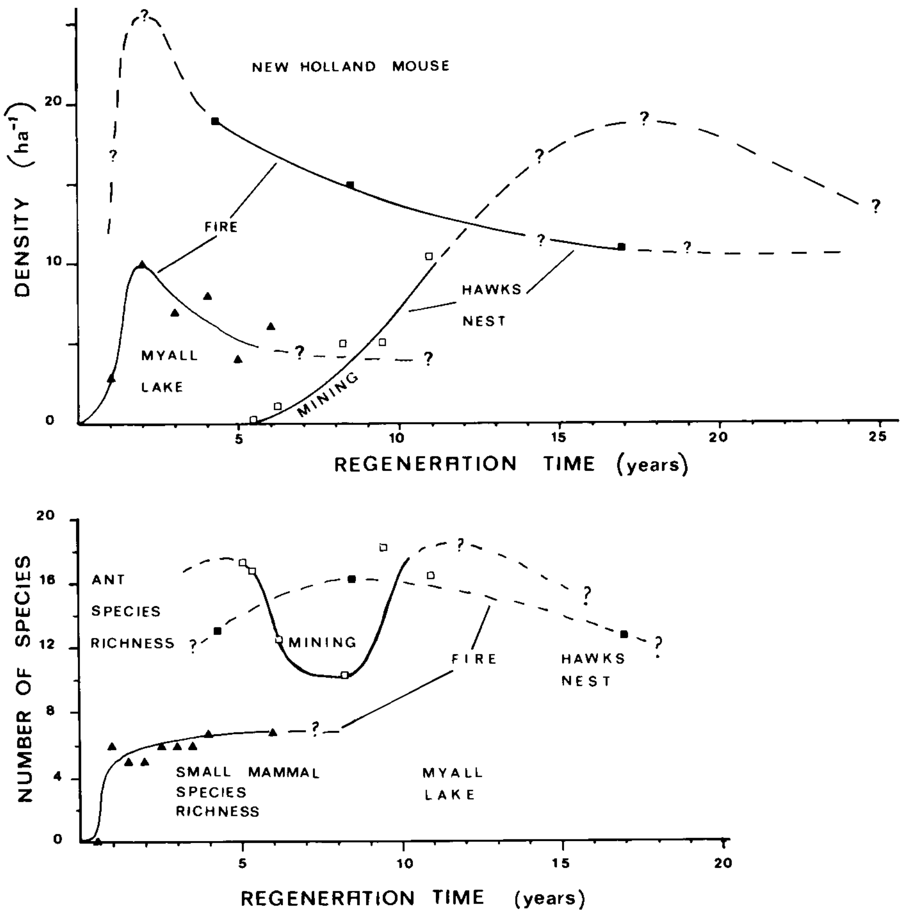


Figure 8-- A) Changes in the density of the New Holland Mouse with time on study sites regenerating after disturbance. Simultaneous data from Hawks Nest sites following mining (❑) and fire (■) are shown, together with annual maxima for a five-year record on the Myall Lake site (▲); dashed lines represent inferred extrapolations.

B) The mean number of ant species per collection for each HN plot, mined and controls. Symbols as for A).

## DISCUSSION

Several points emerge that have important implications for the management of heathland areas subject to disturbance, or where some form of disturbance is used as a management tool:

1) the abundance of individual species is a function of regeneration time and they reach maximum values at different times;
2) this results in a secondary succession or species replacement series occurring for each taxa;
3) different groups of species will be present at different times after disturbance;
4) species richness or diversity is a function of regeneration time;
5) ants and mammals show different responses;
6) the response of each taxa is different for each type of disturbance.

It is clear that there can be no single procedure for managing heathland following disturbance. Management procedures must be determined by the aim for which the area is being managed. For example, management of an area to benefit early successional species may require a frequent burning regime, but this will be at the expense of those species that do not reappear until late in a succession. This can occur within a taxa and the problem is exacerbated when trying to manage for a large number of different taxa. A management objective to maintain high species diversity, an often sought aim, would encompass all of these problems. The difficulty with this objective is, it requires that a wide range of different seral stages should always be available in the managed area. The best way to obtain this objective is to maintain a habitat mosaic comprising patches of sufficient size to support populations in each different seral stage, as ready sources of colonists. Evidence supporting this approach is available from the mammal communities of the Myall Lakes National Park.

### Species Diversity

Small mammal species diversity (MSD) in Myall Lakes N.P. show the typical asymptotic form of the species-area curve (Fig. 9A). The Victorian sites shown fall well below this line, and show a similarly reduced habitat diversity (HD) in relation to the area of the plot examined (Fig. 9B). An examination of the relationship between MSD and HD shows a very strong linear relationship for the Myall Lakes sites (Fig. 10) (r=0.95, n=10, p 0.001), and the Victorian sites also lie close to this regression line. This would appear to be good evidence for species diversity being directly dependent on habitat diversity and both increasing with increasing area.

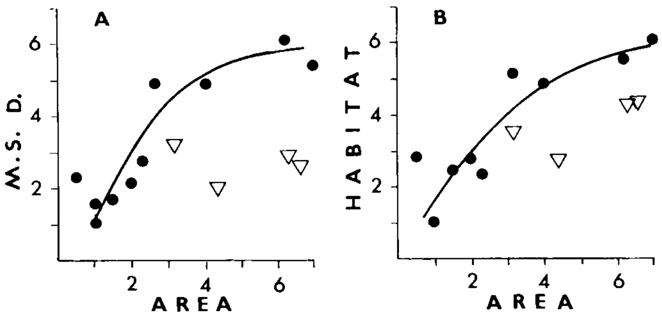


Figure 9-- A) Small mammal species diversity ($\Delta_3$) as a function of area and B) Habitat diversity ($\Delta_3$) as a function of area. Solid symbols from areas in Myall Lakes National Park, N.S.W. (author's data), open symbols from Victorian sites from Braithwaite and Gullan (1978) and Braithwaite, Cockburn and Lee (1978).

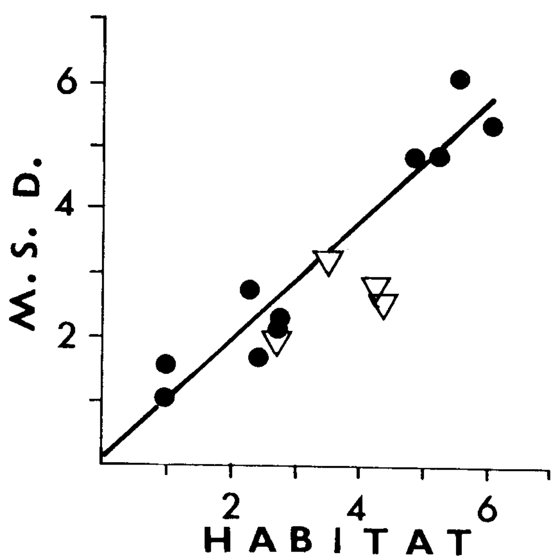


Figure 10--Small mammal species diversity as a function of habitat diversity (symbols as for Figure 8).

The increased MSD in some New South Wales (N.S.W.) sites results from an increased species richness when compared to Victorian sites (Table 1). Close examination reveals that the additional richness is provided by the presence of early successional species that are able to benefit from the vegetation changes following fire ($F^+$ species, from the genera Pseudomys (Native Mice), Sminthopsis (Dunnarts) and Isoodon (Bandicoots), see Fox 1980). There is a core of 4 non-$F^+$ species in both states, to which 2, 3 or 4 $F^+$ species are added in N.S.W., while only 1 (or 2 with a reduction of 1 core species) may be added in Victoria. This is despite the fact that regionally, there are equal numbers of $F^+$ species inhabiting heathlands in both states, and almost twice the number of non-$F^+$ species inhabiting heathland in Victoria (Table 1). This evidence supports the hypothesis that high habitat diversity (resulting from a mosaic of patches with different fire histories in Myall Lakes N.P.) has meant that patchily distributed early successional species have been able to survive, along with mid and late seral stage species, to ensure the maintenance of high local species diversity.

Table 1. The number of species (including bandicoots) advantaged ($F^+$) and not advantaged (Non-$F^+$) by fire, that contribute to the total small mammal species richness of local and regional areas in Victoria and N.S.W. (Data sources as for Fig.9 and from Fox 1980).

| | $F^+$ Species | Non-$F^+$ Species | Total Species |
|---|---|---|---|
| VICTORIA | | | |
| Mt. William | 1 | 4 | 5 |
| Mirranatwa | 1 | 4 | 5 |
| Bemm River | 1 | 4 | 5 |
| Kentbruck | 1 | 4 | 5 |
| Syphon Road | 2 | 3 | 5 |
| Cranbourne | 2 | 3 | 5 |
| Regional Total | 4 | 9 | 13 |
| N.S.W. | | | |
| Marley, Royal N.P. | 2 | 4 | 6 |
| Brisbane Waters N.P. | 2 | 5 | 7 |
| Port Stephens | 3 | 4 | 7 |
| Myall Lakes N.P. | 4 | 4 | 8 |
| Regional Total | 4 | 5 | 9 |

I feel these observations on existing systems provide a good basis on which management decisions can be taken with an objective of maintaining high species diversity.

Acknowledgement: I was able to carry out this analysis by drawing on several earlier studies carried out with my colleague Marilyn Fox; I thank her for this, and for reading the manuscript.

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