EFFECTS OF SOIL DISTURBANCE FROM ROADWORKS ON ROADSIDE SHRUB POPULATIONS IN SOUTH-EASTERN AUSTRALIA

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Abstract: In many fragmented agricultural regions of south-eastern Australia, roadside vegetation provides important refuges for threatened native fauna and isolated populations of plant species. However, as roads are transport corridors for humans and their vehicles, species survival is affected through destruction and modification of remaining habitat by human activity. The effects of soil disturbance from roadworks on the structural dynamics and spatial patterning of roadside *Acacia* populations was investigated in the Lockhart Shire study area, NSW, Australia. Classification and ordination of size structures of *Acacia pycnantha, A. montana* and *A. decora* showed distinct groups of colonising, stable and senescent populations. Soil disturbance from previous roadworks was recorded in 88 percent of populations, and there was a significant relationship between major recruitment pulses and roadworks events in *Acacia* populations. Spatial pattern analysis using the Network K-function showed significant clustering of older senescent populations, and Discriminant Function Analyses revealed that road verge width, road category, disturbance intensity, and distance to nearest town were highly significant variables in relation to disturbance regimes from roadworks activities. These results have highlighted the importance of understanding human logic regarding roadworks activities, in ongoing management of roadside vegetation, and has important consequences regarding conservation of these unique environments.

Introduction

The development of agriculture in south-eastern Australia in the last 150 years has resulted in the clearing of over 85 percent of once continuous Eucalyptus woodland ecosystems (Yates and Hobbs 1997). This process has created a matrix of cropping and grazing paddocks, separated by narrow road corridors containing roadside populations of varying quality (Hobbs and Saunders 1994). Intact native vegetation is now mostly confined to these road corridors, many of which are of high conservation status (figure 1).Roadside environments often provide important refuges for isolated populations of many threatened fauna and flora species. However, roads are transport corridors imposed on landscapes by humans for the movement of people, livestock and materials. Owing to their relatively large area, road networks have a significant effect on the natural environment (Bennett 1991, Foreman and Alexander 1998).

Few studies have recognised the effects of human disturbances, in the form of road construction and maintenance activities, on adjacent roadside vegetation (Bennett 1991, Yorks et al. 1997).

Fig. 1. A typical roadside environment of “medium” conservation status in SE Australia, showing a flowering population of Acacia decora.

Though human disturbances can have obvious negative impacts on many plant populations, some native species may prosper under such regimes, owing to individual plant life-history attributes. For example, where there is intensive management, disturbance-tolerant species can dominate (Forman and Alexander 1998). Developing a better understanding of the spatial and temporal patterns of the prevailing disturbance regime is important in determining the age distribution and overall persistence of native plant populations in a given landscape.

Spatial pattern analysis based on Ripley’s K-function has become a widely used ecological application, and is a measure of complete spatial randomness of point patterns. However, the “normal” planar K-function assumes a homogenous environment to calculate the Euclidean distance between points (or straight-line distance) and, therefore, is an inappropriate tool for analysing point patterns confined along irregular road networks (Yamada and Thill 2003). Okabe and Yamada (2001) have developed a *Network* K-function to analyze point patterns on a network, which may become an important statistical application in road ecology (Forman 1999).

The main aim of this project was to determine the effects of roadworks on roadside shrub populations. Three common woody shrubs (*Acacia* species) were studied in the Lockhart study region in south-eastern Australia. Using these model shrubs, we aimed to investigate:

a. The structural dynamics of roadside *Acacia* populations, and effects of soil disturbance from road construction activities.

b. Spatial patterns of roadside *Acacia* populations, and which variables are important in predicting human disturbance processes from roadworks, and at what scales.

Methodology

Stem size data were collected from 135 populations of *Acacia pycnantha, A. montana* and *A. decora* along roadsides in the Lockhart region of south-eastern Australia. Road construction data were sought from the Lockhart Shire Council, which was limited to resealing, construction and management activities on bitumen roads. Disturbance data were collected, and a separate dendroecological study carried out. Stem size data were classified and ordinated, and resampling techniques used to analyse correlations between recruitment pulses in *Acacia* populations and road construction events (Spooner et al. 2003a).

Spatial analysis of population dynamics on the road network was carried out using Network K-function univariate and bivariate analysis, using SANET software (Okabe et al. 2002, Spooner et al. 2003b). Discriminate function analyses were then used to investigate disturbance processes from roadwork events at varying spatial scales, to determine variables which affect roadside shrubs structural dynamics (Spooner et al. 2003c).

Results

Pooled population data showed that *Acacia* species were expanding, and a high ratio of seedlings to adults for all three species indicated the potential for colonisation along many roadsides. However recruitment was often highly pulsed, with distinct groups of colonising (sites with high recruitment), stable and senescent (sites with low recruitment) populations identified for all three *Acacia* species. Over 88 percent of *Acacia* populations showed some evidence of soil disturbance from previous roadworks events. There was a significant relationship ($P < 0.001$) between major *Acacia* recruitment pulses and dates of road construction in populations on bitumen roads, and a similar relationship appears to exist on other minor rural roads. For further details see Spooner et al. (2003a).

Spatial pattern analysis of combined *Acacia* populations using the Network K-function showed significant clustering of older senescent populations, which were also strongly correlated to proximity to human localities (figure 2), but younger colonising populations were more randomly distributed on the road network.

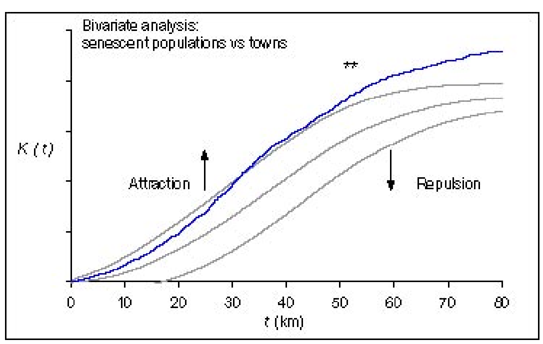

Fig. 2. Bivariate network K-function analysis of point patterns of 'senescent' *Acacia* populations versus towns, showing significant (**) spatial attraction at scales >30km. These results suggest that human disturbance processes vary in relation to proximity to towns, and have a strong influence on the dynamics of roadside plant populations.

Discriminant function analyses revealed varying scale effects of human disturbance processes from roadworks on *Acacia* structural dynamics, and distance to township, road category, road verge width and soil disturbance intensity were significant variables in predicting 58.1 percent of roadside shrub population structures ($\lambda^2 = 31.5$, $P < 0.001$). In general, colonising populations were more abundant along gravel roads where soil disturbance intensity was high, whereas stable populations were more abundant where soil disturbance intensity was low. Senescent populations were more abundant in narrow little-used road verge corridors at a distance of four to six kilometers from nearby towns. For further details see Spooner et al. (2003c).

Discussion

Impacts of Roadworks on Acacia Populations

The age structures of plant populations often reflect past patterns of colonisation and population growth, with pulsed recruitment suggesting discrete disturbance events (White 1980, Marks and Gardescu 2001). In this study, *Acacia* populations were mostly located near road surfaces in adjacent drains, previously graded areas or earthworks sites, as a result of previous road construction or management activities. The high frequency of soil disturbance in *Acacia* populations suggests recruitment has occurred after soil disturbance, and analysis of populations adjacent to bitumen roads showed a significant correlation between road construction and recruitment events (Spooner et al. 2003a). Similar studies have shown how soil disturbances have promoted the recruitment of *Acacia melanoxylon* along roadsides in Australia (Farrell and Ashton 1978), woody weeds in Europe (Lepart and Debussche 1991), and shrub thickets in the USA (Boeken and Canham 1995).

Soil disturbance from roadworks appears to act as a surrogate disturbance agent for fire, which is now mitigated in most agricultural areas (Hobbs 1987). For fire-adapted shrubs such as Acacia species (Gill 1981), disturbance of the soil seed bank by roadworks assists establishment by breaking seed dormancy (through scarification of the seed) and provides an ideal substrate for establishment (Abrahamson 1980, Mott and Groves 1981) (figure 2).

Mechanical removal of the above-ground organs from roadworks activities also promotes vegetative resprouting in some species (figure 3). As fire was absent in all but two sites, soil disturbance from past road construction appears to explain much of the pulsed recruitment in roadside Acacia populations (Spooner et al. 2003a). However, the intensity and frequency of road construction events may exceed those of a natural disturbance regime, the effects of which may take decades for a population to fully recover from (Webb et al. 1983).

Fig. 2. Even-age stand of Acacia pycnantha that has regenerated along a drainage line.

Fig. 3. Example of a minor rural road, where a population of *A. decora* was mostly destroyed in grading operations of table-drains, but in the following year, many individuals have resprouted, flowered and produced seed.

Whilst soil disturbance may promote *Acacia* species, it is likely to have obvious adverse impacts on other elements of roadside environments, facilitate invasion by weeds and result in a simplified system of disturbance-tolerant species (Hobbs and Huenneke 1992, McIntyre and Lavorel 1994).

Spatial Analyses of Acacia Populations
Whilst the spatial pattern of natural disturbances is normally strongly influenced by environmental factors, human disturbances are often highly selective and spatially arrayed in a logical way (de Blois et al. 2002). Univariate network K-function analysis of individual population structural groups showed that 'senescent' populations were significantly clustered, 'stable' populations tended to cluster, and 'colonising' populations were more randomly distributed. Bivariate Network cross K-function analyses also showed strong spatial interaction between senescent populations and the location of towns or other human localities. This clustered pattern of older senescent populations was highly unusual, suggesting a strong influence from human disturbance processes on the maintenance of *Acacia* populations.

As previously described, the effects of disturbance from roadworks on plant populations depends on complex interactions between the spatial and temporal structure of the prevailing disturbance regime and individual species life history attributes (Clarke 1991, McIntyre and Lavorel 1994, Yorks et al. 1997). Discriminant function analyses revealed the highly complex nature of underlying disturbance processes from roadworks. Road verge width was an important variable in predicting shrub population structures, as well as disturbance intensity from roadworks and road category (e.g., bitumen or gravel road). Road verge width is likely to govern the size and shape of disturbance from roadworks, and road category influences the frequency at which roadworks occur, as funding sources vary according to road classification. Therefore, these results suggest that the size, shape, intensity and rate of the human disturbances from roadworks are important in determining the age distribution of roadside *Acacia* populations, which has important implications regarding their persistence in the landscape (Spooner et al. 2003a,c).

Conclusion

These results suggest that ongoing management of disturbance regimes may be critical to the persistence of *Acacia* shrubs and associated fauna habitat in many roadside environments of SE Australia. Though soil disturbance from roadworks can have obvious deleterious effects on many native plant species, and recovery can be slow, they are important in maintaining healthy populations of disturbance-tolerant species such as *Acacia* shrubs. This particularly applies in roadside environments with a long history of disturbance inputs from roadworks. Further investigations are required to develop a better understanding of the effects of road management activities on other native plant species. These results highlight that attempts to undertake regional conservation planning in fragmented landscapes may be fruitless, without due consideration of historic and current human disturbance processes that have helped shape roadside environments.

Biographical Sketch: Peter Spooner is a Ph.D. candidate in ecology at the Johnstone Centre for research in natural resources and society, Charles Sturt University, Albury NSW, Australia. His Ph.D. dissertation, titled "Effects of anthropogenic disturbance regimes on roadside environments in SE Australia," is supported by postgraduate scholarships from CSU and CSIRO Sustainable Ecosystems. He holds a BSci (Honours First Class), of which his thesis "Short-term effects of stock exclusion in remnant grassy woodlands in S.E. Australia" was recently published in the Australian Journal for Ecological Management and Restoration, and awarded the best student presentation at the 2000 ESA annual meeting in Melbourne.

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