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Response of *Acacia* Species to Soil Disturbance by Roadworks in Southern New South Wales, Australia

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Abstract: Heavy machinery is regularly used throughout the world to maintain infrastructure corridors. The purpose of this study is to investigate the response of roadside populations of three *Acacia* shrub species to soil disturbance from roadworks. Results were highly variable. However, resprouting and seedling emergence led to a 6.2 percent population increase at four road reserves. Two years after grading, there was significant resprouting of *A. decora* and resprouts reached a mean height of 72 cm. One year after disturbance, 71 percent of *A. decora* resprouts flowered and 49 percent also set viable seed. In contrast, there was patchy seedling emergence of *A. pycnantha* and *A. montana*. These results show that grading of roadsides appears to favor plants with strong resprouting ability and that the scale of response depends on the plants life-history attributes and the prevailing disturbance regime. Further studies of individual plant responses to soil disturbance can only better our understanding of plant dynamics in road and other transportation corridors.

Introduction

Heavy machinery (such as the Caterpillar grader) is commonly used throughout the world to construct and maintain roads and transport corridors (Forman et al. 2003) (figure 1). Recently, a number of studies have considered the effects of disturbances from heavy machinery on plant populations (Webb et al. 1983; Olander et al. 1998; Milchunas et al. 2000). As soil disturbance from heavy machinery is highly intensive and extremely variable, local extinctions of roadside plant populations often occurs (Lugo and Gucinski 2000).

Figure 1. A Caterpillar grader, which is commonly used for roadworks in southern NSW.

However, recent evidence suggests that in some situations, disturbance-tolerant plants can proliferate in transportation corridors (Forman and Alexander 1998). The purpose of this study is to investigate the response of three *Acacia* species to soil disturbance from roadworks in roadside environments in southern New South Wales, Australia. In this study, roadside populations of three *Acacia* species were monitored to test the hypothesis that soil disturbance from grading will facilitate resprouting and seedling emergence of *Acacia* species, depending on the life-history attributes of each species (e.g., Noble and Slatyer 1980; Clarke 1991).

Background: importance of roadside vegetation

Temperate woodlands are the most extensively cleared vegetation type in southern Australia. In many regions, these woodlands have almost been completely eliminated, with as little as 1 percent remaining in some areas (Prober and Thiele 1993; Sivertsen 1995; Benson 1999). On private farmlands, there are few remaining woodlands, which are mostly confined as small remnants on less fertile soils, more rugged outcrops, or hard to access areas (Yates and Hobbs 1997) (figure 2a).

However, in the development of agriculture in NSW in the 1870s, a network of road reserves was developed to provide access to fields, most of which contain a narrow strip of native vegetation (Breckwoldt 1990; Spooner 2005a). Road reserves are areas of public land, where clearing of vegetation has been restricted to road-construction purposes. As many reserves are over 60-m wide, this has resulted in the development of an extensive network of vegetated corridors, often referred to as ‘roadside vegetation’ (figure 2b).

In 1991, it was estimated that the network of road reserves (i.e., the total strip of land reserved for transportation purposes) occupied over 80 percent of the equivalent combined area of national parks in NSW (Bennett 1991). Yet despite the fortuity of past land-use decisions in creating such corridors, the importance of road reserves to conservation has mostly been undervalued, perhaps due to the ubiquitous nature of roads in the landscape (Cooper 1991).

Figure 2. (a) Typical cleared agricultural landscape of southern NSW, where most woodland vegetation is located in narrow road reserves, and (b) a wide stock route containing a large tract of roadside vegetation (images courtesy of NSW Land Information and CSIRO).

In Australia, the principle managers of road reserves are local government authorities (councils). Although the main function of road reserves is to provide a transportation corridor, most councils have become increasingly responsible for the maintenance of the conservation, historical, aesthetic, and amenity values of road reserves. Many councils have now completed biodiversity surveys of road reserves in their jurisdiction and promulgated roadside-management plans which highlight the conservation value of each reserve. As consequence of this process, many road reserves are now listed as high conservation status (Dennis 1992; Bull 1997; Spooner 2004a).

Although roadside vegetation is important for conservation of biodiversity in rural landscapes, many reserves are still under threat from human disturbances such as roadworks. Due to growth in human settlements and increases in intensive farming practices, there are greater demands to develop rural-transportation networks. Narrow 20.12 m (1 chain)-wide road reserves that were originally surveyed for farm access, were not designed to facilitate modern heavy transport, and are under most threat (Prichard 1991). One of the future challenges for local councils and government environment agencies is to reconcile transportation and conservation values of roadsides (figure 3).

Figure 3. A typical narrow 20.12 m (1 chain) road reserve in southern NSW where a gravel road and adjacent table drains have been recently graded as part of a regular maintenance program. In the process, all previous vegetation (approx 2 m x 1.7 km) has been removed, apart from a narrow strip of native vegetation (mostly *Acacia* and *Senna* species) along the fenceline.

Lockhart study area

This study was conducted from 2001-2004 in the Lockhart Shire council area (35.12° S, 146.43° E), a rural local government area of 365 km² which is located in southern NSW, Australia (figure 4). The area has a cool temperate climate, with mean annual rainfall ranging from 500-600 mm and altitude ranging from 200-450 m. Topography consists of low undulating hills and flat riverine plains with occasional granitic outcrops. Over 95 percent of native vegetation has been cleared for agriculture. Less than 1 percent has been formally protected in conservation reserves (Benson 1999). In many regions, roadsides provide vital refuge for many threatened species.

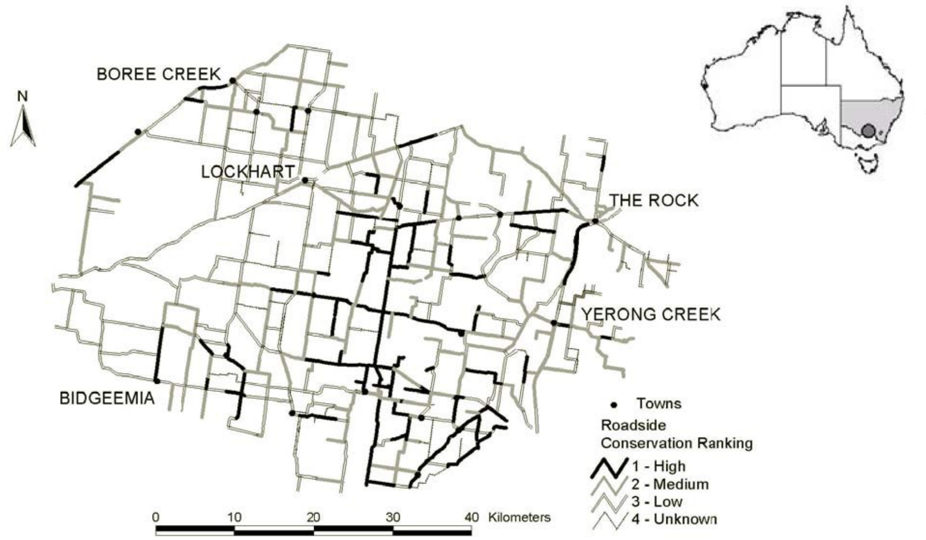

Figure 4. Location of the study area in southern NSW, Australia showing roadside conservation rankings for the Lockhart Shire council area (based on data in Bull 1997).

Study *Acacia* species

Acacia species (Mimosaceae) are woody shrubs and small trees that are widely distributed in temperate woodlands in southern Australia (Maslin and Pedley, 1998) and are commonly recorded species in many segments of roadside vegetation (McBarron 1955; Bull 1997). Most *Acacia* species are highly adapted to fire by hard-coated seed and re-sprouting ability. Though the post-fire response of *Acacia* species has been well documented, little is known of how soil disturbances affect *Acacia* populations.

Three widespread *Acacia* shrub species with different life-history attributes were selected for study, based on previous roadside survey reports in the Lockhart region:

1. Golden Wattle (*Acacia pycnantha*) is a loosely branched shrub 3-8 m tall found on a wide range of sandy or red-loamy soils. It is fast growing, with leathery dark-green phyllodes or 'leaves', large golden flower heads in showy racemes, brown flattish seed pods 5-12 cm x 5–7 mm, and is an obligate seeder (figure 5a).
2. Mallee Wattle (*A. montana*) is a dense and rounded green shrub 1-3 m tall and found on well-drained sandy red earths or heavy clay soils. It is also fast growing, with small narrow and 'sticky' green phyllodes, golden-yellow flower heads along branches, distinctive white-woolly seed pods 2–5cm x 3–4 mm, and is a facultative seeder and resprouter (figure 5b).
3. Western Silver Wattle (*A. decora*) is a rounded spreading shrub 1-4 m tall and found on well-drained light to heavy soils. It has grey-green thick phyllodes, bright golden flower heads on short racemes in branchlets, dark straight seed pods 5-10cm x 4-8 mm, and is a facultative seeder and vigorous resprouter (Costermans 1981; Tame 1992) (figure 5c).

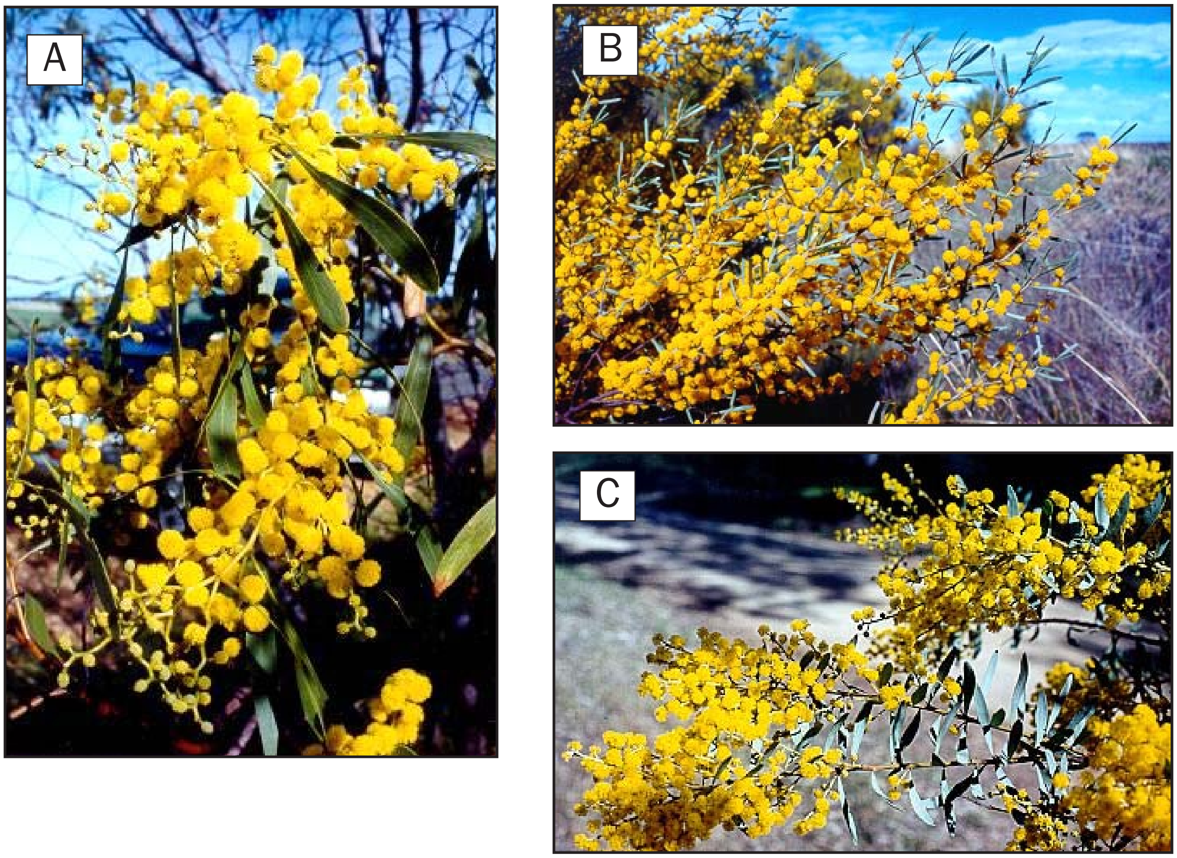

Figure 5. Model *Acacia* shrubs in the Lockhart study area, showing flowering branches of (a) *Acacia pycnantha*; (b) *A. Montana*, and (c) *A. decora*.

Methods

Studies were conducted from 2001 to 2003 in the Lockhart Shire Council area (figure 4). Many roads in the area are minor rural roads of gravel construction. These roads need periodic maintenance. Gravel road surfaces are usually graded every five years or so (Spooner et al. 2004b). It is common practice to regularly clear vegetation adjacent to gravel roads with a grader to maintain table drains. In 2001, a regional survey of the three study *Acacia* species was carried out, using existing roadside survey reports as a baseline (Bull 1997; Spooner et al. 2004b). Roads were then monitored for grading activities that impacted upon *Acacia* populations and wide road corridors were targeted (> 20 m) so comparisons could be made between graded areas and adjacent, ungraded (control) areas.

In total, four wide road corridors were selected where recent roadworks activities had occurred (table 1). Two road reserves were selected for sampling in 2001 and two further road reserves were selected in 2002; both had similar soils, topography and disturbance from grading activities. In all cases, grading occurred parallel to the road, extending approximately 2.5 m (one angled blade width) into adjacent native vegetation. After grading operations, transects were placed parallel to the road along the edge of the impact area. Transect length varied depending on the extent of grading along each road. Transects were divided into 'populations' and 'gaps.' The number of acacia plants in each population was re-counted and stem densities calculated.

Table 1. Site data for four road reserves impacted by soil disturbance from grading and number of sub-sample acacia populations monitored on each roadside

Road reserve	Date of impact	Road verge width (m)*	Impact length (km)	Populations (n)
Soldier Settlement road	Sep 2001	14	5.76	13
Pat Gleesons road	Sep 2001	17	3.92	7
County Boundary road	Nov 2002	14	2.70	7
The Rock-Lockhart road	Oct 2002	42	3.85	8

* Width of roadside vegetation at one side of roadway. Not entire road reserve width.

Based on the difference between population censuses before and after grading, an estimate of the number of stems that existed prior to disturbance was made and verified by visual inspection of stumps in the impact area. Emergence of basal resprouts, root suckers and seedlings in acacia populations and gaps was monitored three months after impact and then at one-year intervals until September 2003, coinciding with the spring flowering of *Acacia* species. For all sites, the total number of acacia resprouts and seedlings that emerged was recorded. In each shrub zone, a random sample (maximum of 20) of resprouts and seedlings was tagged. Stem heights and plant reproductive outputs were recorded using methods described in Spooner (2005b).

Results

Physical evidence of damage to acacia populations was obvious at all four road reserves, with approximately 100 percent of all above-ground biomass removed by grading and only stumps and damaged roots remaining. Despite the catastrophic nature of this disturbance, resprouts of *Acacia* species emerged almost immediately in September 2001 in two road reserves, often with vigorous growth of basal resprouts and root suckers.

Prior to the grading-disturbance events, the area had experienced below-average monthly rainfall. However, subsequent to resprout and seedling counting, a thunderstorm event resulted in approximately 140-mm rainfall (24-32 percent of yearly average), which may have contributed to resprout establishment and growth. However, monthly rainfall throughout 2002 and early 2003 was well below average, resulting in a declared drought for the summer of 2002/03. Rainfall did not return to average levels until July 2003 (Bureau of Meteorology 2004).

Recovery of acacias to grading was highly variable. However, basal resprouting, root suckering, and seedling emergence led to an overall 6.2 percent population increase for all road reserves combined (table 2). At Soldier Settlement and Pat Gleesons roads, grading resulted in significantly ($P < 0.05$) more resprouting of A. decora populations in the impact areas compared to control areas. However there was no resprouting of *Acacia* species observed at County Boundary and the Rock-Lockhart roads.

Table 2. Number of acacia resprouts and seedlings recorded at four road reserves post-disturbance and net population change

Road Reserve	Number of acacias prior to grading		Resprouts		Seedlings		Net change[2] (%)
	C	I	C	I	C	I	
Soldier Settlement	826	166	0	276	0	0	+ 11.1
Pat Gleesons	274	55	0	88	0	0	+ 10.0
County Boundary	308	45	0	0	0	52	+ 2.0
The Rock-Lockhart	556	27	0	0	0	16	- 1.9
Total	1964	293	0	364	0	68	**+ 6.2**

[1] Where C = control, I = impact areas.
[2] Assumes 100 percent survivorship of resprouts and seedlings.

In two road reserves, *A. decora* resprouts reached respective mean height of 72 and 74 cm two years after the grading event (figure 6). Seedlings only emerged at County Boundary and the Rock-Lockhart roads. By 12-13 months after disturbance, mean seedling heights were 42.0-52.5 cm respectively (figure 6). The tallest seedling had attained a height of 100 cm (*A. pycnantha*). Somewhat surprisingly, 71 percent of *A. decora* resprouts flowered and 49 percent also set viable seed. Similarly, 65 percent of resprouts of the facultative seeder *A. montana* flowered but only 10 percent set viable seed, which appeared to be more affected by prevailing drought conditions. In contrast, there was patchy seedling emergence of the obligate seeder *A. pycnantha* and (to a lesser extent) *A. montana*, and seedlings did not reach reproductive maturity one year after disturbance. Results for seedling emergence were not statistically significant.

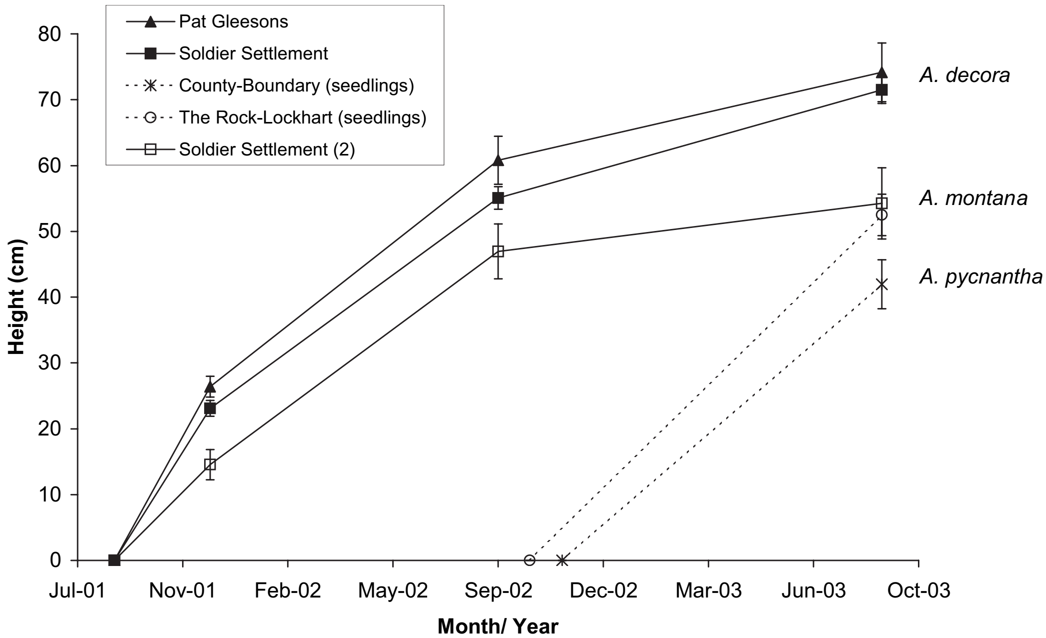

Figure 6. Mean height of acacia resprouts (solid lines) and seedlings (dashed lines) following grading at four road reserves. Species listed on LHS. Bars indicate +/- 1 standard error (SE). SS(2) indicates one population of *A. montana* resprouts at SS.

Discussion

Soil disturbance from grading activities reduces plant biomass by causing its partial or complete destruction and provides a diverse set of new conditions for seedling establishment and plant growth (White and Pickett 1985). It has been commonly accepted that for most *Acacia* species, fire is required to stimulate germination from hard-coated seed and that a lesser proportion of species rely on resprouting ability for recruitment (Hodgkinson 1979; New 1984). However, the results of this study show that for some acacias, soil disturbance from roadworks acts as a surrogate disturbance agent for small-scale natural-soil disturbances and fire, which is now mitigated in most agricultural areas (Hobbs 1987; Benson 1991). Grading activities led to vigorous resprouting of the facultative seeder *Acacia decora* in most populations. Vegetative reproduction from damaged roots greatly aided the ability of this species to colonize a site.

Resprouting is a common response in woody plants subject to disturbance regimes of high severity, which destroy most or all above-ground biomass (Hodgkinson 1998; Bellingham and Sparrow 2000). Similar studies have shown how plants can resprout after repeated damage from heavy machinery (Gibson et al., 2004). These results suggest that in areas affected by roadwork activities, known as the ‘road-effect zone’ (Forman et al. 2003), soil disturbance by grading is an important process impacting roadside acacia populations. The scale of response from resprouting species is dependent on a number of factors, including: (1) the frequency of grading events; (2) the timing of events e.g., season; (3) the intensity of grading e.g., depth of cut; (4) individual carbohydrate (starch) reserves prior to disturbance, which is related to past disturbances and seasonal factors; and (4) prevailing climatic conditions.

Soil disturbance is also known to promote the germination of *Acacia* species from seed (Farrell and Ashton 1978). Acacias produce hard-coated seed that is ejected out of seedpods in hot conditions, which then falls to the ground where it maybe further dispersed by wind, water or animals. Ants harvest the seed and bury it in soil seed-banks (Buckley 1982; New 1984). Germination of acacia seed is normally triggered by heat shock from fire (Mott and Groves 1981), and manual scarification of the seed coat is a common seed treatment of acacia seed (Cavanagh, 1987). Spooner et al. (2004b) suggested that soil disturbance by grading may assist establishment of *Acacia* species by disturbing soil seedbanks, scarifying the hard seed coat, and providing an ideal substrate for establishment. Although this could not be supported conclusively in this study, seedling emergence of *A. pycnantha* and *A. montana* only occurred in areas disturbed by grading.

Conclusions

Most studies of transportation corridors have usually focused on their deleterious effects. As this study has shown, frequent and intensive soil disturbance regimes appears to favor acacias with strong resprouting ability, whereas acacias that are obligate seeders may be eliminated from roadside environments. Future colonization, stability or decline of roadside acacia populations will depend on the timing of soil disturbances from grading operations in relation to species life-history attributes (Noble and Slatyer 1980; Clarke 1991).

For *Acacia* species, it could be argued that disturbances from road management activities are really no different to periodic natural disturbances, but in reality there are significant differences in extent, frequency, and severity (Lugo and Gucinski 2000). In contrast with natural disturbances, soil disturbance from grading may reach intensities rivaling the most severe natural disturbances and lead to local extinctions (Foster et al. 1998). As ecosystems may take centuries to recover after this form of soil disturbances (Webb et al. 1983; Olander et al. 1998), grading effectively maintains the road-effect zone of roadsides in a simplified transitional state. It is only the ability of acacias to quickly grow and reproduce which allows this species to persist in environments with disturbances regimes which may be catastrophic to most other plants.

Given that roadsides are graded every five years or so and that a roadworks disturbance regime can have a strong controlling influence on acacia structural dynamics (Spooner et al. 2004b, c), it is reasonable to predict that plants that persist in regularly maintained environments would possess strong resprouting ability or be able to rapidly establish and set seed (e.g., exotic weeds) (McIntyre et al. 1995). Further studies of plant life-history attributes in relation to human disturbance regimes can only better our understanding of plant dynamics in transportation corridors and assist in formulating appropriate management actions.

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Biographical Sketch: Peter Spooner is a lecturer in plant ecology at Charles Sturt University, Albury New South Wales, Australia. Peter recently completed his Ph.D. which investigated the effects of roadworks on roadside vegetation, with a specific focus on *Acacia* species. His research interests include disturbance, historical, and restoration ecology. He has published widely in the scientific literature. In conjunction with state environment agencies and NGOs, Peter is presently involved in several research projects relating to conservation grazing and historical legacies of European settlement on native woodland vegetation in Australia.

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