Ecological control of weeds on mine sites across Australia

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Summary  Vegetation development on mine sites is strongly influenced by the initial site conditions, including the media characteristics, moisture availability, propagule sources and competition. Weeds can have a substantial impact on the initial success or failure of vegetation establishment by competing with desired species. In other cases a weedy species may be introduced to provide rapid initial ground cover to control erosion. Controlling weed species with chemical sprays can be expensive and may not be effective if substantial weed populations and weed seedbanks have developed at the site. However, in many cases it is not necessary and an ecological approach to weed control is more effective.

Ecological control of weeds focuses on minimising the build-up of weeds and weed propagules at the mine site. It then relies on establishing a robust vegetation community that minimises excess resource availability and that competes effectively with weeds that do establish. Examples show how resource levels can be controlled so that potential weeds can be used to provide initial cover but are then eliminated from the community. For example, broadleaf weeds may initially build up but can be controlled by the developing community. By following this approach a case can be made for avoiding chemical control of even a major weed like Parthenium hysterophorus L. On the other hand, lack of control of soil disturbance and excess resource availability can rapidly promote a weed problem. Lessons learnt from control of weeds on mine sites are also relevant to weed control on other disturbed land, such as road verges.

Keywords  Establishment, competition, fire, seedbank, rehabilitation success, completion criteria.

INTRODUCTION
Mine rehabilitation has a particular re-vegetation goal. In some cases the target vegetation community is broadly defined, but in other cases it is defined with very specific criteria. The desired species need to be established at the site and then vegetation development needs to be guided towards the target community. A weed can be considered to be any plant species, which interferes with the developing vegetation achieving the desired target. Most mine sites in Australia have a rehabilitation goal of achieving a sustainable native vegetation community but the goal may also be to achieve low or high quality grazing land (Bell 1996).

If the goal is to achieve a native vegetation community then any non-native species can be considered a weed. Native species can also be considered weeds if they are non-local or if they prevent the desired vegetation community from being achieved. Some non-native species may be desired for erosion control or to enable the community to fulfil certain end land uses. For example, non-native species may be required to give greater grazing productivity, to achieve a recreation use or for timber production. Sometimes during the life of a mine the end land use may change and desired species may later become considered as weeds. Examples include radiata pine (Pinus radiata D.Don), which may have been planted for a possible forestry end land use, and grasses such as Rhodes grass (Chloris gayana Kunth.) planted for erosion control. Control has become necessary where the end land use has changed to native wildlife habitat (pers. obs.).

Weeds may need to be controlled to comply with legislation, or the absence of key weed species may be a condition required for lease relinquishment. Weeds may also prevent attainment of rehabilitation success by preventing the establishment of required species or by causing the community not to be sustainable. Weeds may alter fire regimes or prevent continuing recruitment of desired species.

Weed control is expensive and may not always be necessary. However, lack of control at critical stages is also expensive if the rehabilitation fails or, later, more extensive weed control is required. The focus is often on chemical and mechanical control of weeds, however these measures generally need to be undertaken in conjunction with ecological control of the weed. Ecological control is generally more efficient and is more likely to result in a sustainable solution (Blumenthal et al. 2003).

In this paper I look at control of undesirable species through minimising the establishment of weeds, at impacts of weeds on vegetation community development and at vegetation community control of weeds.
MINIMISING WEED ESTABLISHMENT

Weed establishment can be minimised by controlling the presence of weed propagules or by making establishment conditions unfavourable for particular weed species. If vegetation is disturbed and the site is allowed to remain in a disturbed state, a substantial weed population can establish and the density of the weed seedbank can rapidly increase. This then provides a source of weeds to the rehabilitation area.

Unfortunately, mine sites generally involve substantial disturbance to the site as a whole and not just to the area affected by direct mining disturbance. Haul roads, access roads, maintenance areas, pipelines and infrastructure all add to the disturbed area and, unless care is taken, large areas surrounding infrastructure areas are often disturbed. Most weeds are ruderal and so arefavoured by disturbed habitat. A topsoil stockpile can be a valuable source of native seeds but if it remains bare of perennial vegetation a weed seedbank can rapidly develop. Read et al. (2000) found the seed content of a topsoil stockpile to increase from 377 seeds per m$^{-2}$ in 12 month old soil to 4927 seeds m$^{-2}$ after 20 months of stockpiling. This was mostly due to a 43-fold increase in the density of introduced weed seeds, whereas native species increased 6-fold. Also, the native species that increased in density were typically grasses or ruderal taxa such as *Wahlenbergia* species (Read 2002). Thus, unless the extent and duration of disturbance is minimised, seedbanks of weed and native ruderal species at a site can dramatically increase and become a problem.

In the wheat belt of Western Australia broad leaf weeds can grow vigorously if uncontrolled but on mine sites it is possible to control site characteristics to minimise weed growth. A goal of mineral sand mining near Eneabba was to create a vegetation community similar to the surrounding native kwongan shrubland. The soil is low in fertility but the native vegetation is adapted to these soils. After 12 months, seedlings of many species are healthy but have grown only a few centimetres high due to minimal rainfall over summer, low nutrient levels and a tendency to maximise root growth. Vigorous weed growth during the winter rainy season could easily threaten these woody plants.

Bellairs (1992) investigated native plant and introduced weed establishment and survival on a minerals sand mine rehabilitation area that was sown in April 1988. Weed control across the site was good but a low level of weed establishment occurred on the rehabilitation site in the first year (Figure 1). These plants grew large and seeded and a greater than 70-fold increase in the population of broad leaf weeds occurred in the second winter. However, these weeds were small and produced few seeds (personal observation) and the weed population then declined with the weeds having little effect on native plant establishment or survival.

A key to controlling the dynamics of the weed population at the Eneabba site was managing the available nutrient levels. The native vegetation was adapted to low nutrient levels whereas ruderal weed species require higher nutrient levels to thrive (Grime 1979). By minimising fertiliser application so that nutrient levels were just sufficient to establish the native vegetation and weakly establish an erosion control cover crop, then weed growth could be controlled. By the second year, most of the nutrients in the initial fertiliser application had presumably been taken up by the native vegetation. In subsequent years, the
well-established native vegetation was of a density and size such that nutrients and moisture would be taken up by the perennial plants and weeds visually appeared to be under both water and nutrient stress.

**IMPACTS OF WEEDS ON VEGETATION COMMUNITY DEVELOPMENT**
A key aim of mining rehabilitation is generally to establish perennial vegetation, including species that will dictate the structure of the final community and often species that are required to achieve the end land use. Grass weed competition can have a major impact on growth and survival of trees and shrubs. Forster (1995) investigated the impact of kikuyu grass (*Pennisetum clandestinum* Hochst. ex Chiov.) and Rhodes grass (*Chloris gayana* Kunth.) on *Eucalyptus* and *Acacia* spp. growth and survival at an open cut coal mine in south-eastern Queensland. *Corymbia maculata* (Hook.) K.D.Hill & L.A.S.Johnson and *Acacia blakei* Pedley plants growing in one year old rehabilitation in dense grass (as high as the trees and >75% cover) patches, moderate grass (lower than the sapling and 20–60% grass cover) and on bare ground (no grass rooted within 50 cm) patches had their height and survival monitored between 15 and 32 weeks post-seeding. Leaf production by the trees was greatest for those growing on the bare soil patches. Initially the trees grew tallest in the dense grass patches but by 32 weeks they had declined in height and had been overtaken by growth in height of the trees growing in the moderate grass patches. All the trees in the bare and moderately grassed patches survived but by 32 weeks trees were dying in the dense grass patches. The level of grass growth during early tree establishment can determine whether a forest community establishes or whether a grassland with scattered slow growing trees results (Forster 1995).

At the Nabarlek mine in the Top End of Australia, grass weeds have become established across the site. This site was sown in 1995 but in 2004 grass weeds still dominated the vegetation across the site (Bayliss *et al.* 2004a, 2004b). A high weed density was preventing woody plant recruitment and creating a high fuel load, therefore likely to result in hotter fires that would damage woody plants that did establish (Bayliss *et al.* 2006). Thus, once grass weeds are well established on a mine site they can persist and may cause ecological functional problems as well as failure to achieve the end land use.

**USING VEGETATION COMMUNITY DEVELOPMENT TO CONTROL WEEDS**
The most sustainable means of weed control is to utilise the target vegetation community to control resources and manipulate site characteristics to favour those species and disadvantage weed species (Blumenthal *et al.* 2003). Ruderal weed species require greater resource levels than most native species so if native species can lower available resource levels then they can effectively eliminate weeds. It is more difficult for weeds that have a similar resource use strategy to the end land use target species. However, weed species that have plants adapted to be effective at competing for resources or tolerating environmental stress have reduced reproductive capacity (Grime 1979). Thus, for these latter species chemical or mechanical weed management strategies are more likely to be effective at controlling establishment as seedling production rates are not as high.

*Parthenium hysterophorus* L. is a major problem weed in rangelands and summer cropping areas of Queensland. This annual weed can produce up to 100,000 seeds per plant and build up a soil seedbank of 340 million seeds per hectare (Anon. 2003). It commonly occurs on disturbed land in central Queensland, including on mine sites. Gravina and Bellairs (1999) investigated the establishment of this weed on open cut coal mine rehabilitation areas in central Queensland. Few plants of *P. hysterophorus* emerged in the wet season of the first year from the soil seedbank. However, at maturity these plants produced many seeds, which germinated the next wet season and *P. hysterophorus* was then the most abundant species on the newly rehabilitated site. However, as perennial grasses and *Acacia* spp. were well established, subsequent mortality of the *P. hysterophorus* seedlings was high, few plants survived to maturity and produced few seeds. Long-term research at the site showed that *P. hysterophorus* was controlled by the establishment of native trees and shrubs and by native and exotic perennial grasses (Gravina and Bellairs 1999).

**CONCLUSION**
Weed management on mine sites should commence when initial disturbance of the site begins. Hygiene controls, minimising disturbance and minimising available nutrients can result in weeds being a minimal issue for management. Even at sites with an established weed population, control can be much less expensive if disturbance is reduced in extent and duration. Then, optimising site conditions that favour desired species over weed species can result in the vegetation community being able to control the build-up of weeds without the need for spraying. Failure to consider weed management until after rehabilitation commences can result in an expensive problem. However, failure to control weeds during rehabilitation can result in failure to meet rehabilitation goals or, if the desired
species are established, an unstable and unsustainable vegetation community.

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REFERENCES


