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DEVELOPING COMPLETION CRITERIA FOR REHABILITATION AREAS ON ARID AND SEMI-ARID MINE SITES IN WESTERN AUSTRALIA

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ABSTRACT

Continued expansion of the gold and nickel mining industry in Western Australia during recent years has led to disturbance of larger areas and the generation of increasing volumes of waste rock. Mine operators are obligated to rehabilitate all disturbed surfaces and reconstructed landforms, and considerable effort and expense is now applied to the achievement of this objective. Associated with increasing rehabilitation effort is the requirement to accurately judge rehabilitation success through the development of completion criteria. Completion criteria are rehabilitation performance objectives set as conditions of approval for each stage of rehabilitation and for the project as a whole. They provide standards against which the success of rehabilitation can be measured, or more broadly the point at which responsibility for rehabilitation is complete.

The current research project tackles the development of completion criteria by investigating ecosystem function within a variety of rehabilitation trials at four mine sites located in arid and semi-arid Western Australia, and also within surrounding 'natural' vegetation complexes undisturbed by mining, termed analogue sites. Six specific objectives were identified as part of the study:

1. To establish an appropriate end point land use for each mine site where field trials were established;
2. To examine long-term ecosystem development through the assessment of revegetation at a variety of rehabilitation sites;
3. To examine functional components within analogue communities and make appropriate comparisons with rehabilitation trials;
4. To record the potential reproductive capacity of revegetation progeny, and determine how this relates to ecosystem function;
5. To provide a better understanding of ecosystem function by investigating the relationship between state factors, interactive controls, and ecosystem processes at rehabilitation and analogue sites; and
6. To develop a methodology for establishing realistic environmental completion criteria at mine sites situated in arid and semi-arid Western Australia.

Field trials were established at four mine sites located within three subtly different bioclimatic zones that extend through the arid / semi-arid shrubland belt of Western Australia; Northeastern Goldfields (Granny Smith Gold Mine, Sunrise Dam Gold Mine), Eastern Goldfields (Black Swan Nickel Mine), and Northeastern Wheatbelt (Westonia Gold Mine).

1The re-establishment of a self-sustaining vegetation cover integrated with the surrounding ecosystem, was the common end land use objective at the four mine sites selected for this study. For three sites located in the Northeastern Goldfields and Eastern Goldfields of Western Australia, sheep were grazed on surrounding rangeland; the fourth site located in the Northeastern Wheatbelt of Western Australia, and was surrounded by Crown Land.

2To better understand ecosystem function, the dynamic behaviour and interaction of plant biodiversity parameters was monitored regularly at 19 post-mining rehabilitation sites up to 11 years after direct seeding. For functional ecosystems, plant biodiversity parameters changed rapidly during the initial five years after seeding following predictable trends, after which time they remained within a relatively stable range. The stabilising of parameters over time was identified as a key indicator of rehabilitation success, however the point at which the parameters stabilised was influenced by numerous variables and was difficult to accurately predict.

Prolific seed germination resulted in high seedling density during the initial growing season. Plant density then progressively decreased in response to competition, before stabilising within a range approximately five years after seeding. Revegetation cover was typically low during the first growing season, increasing rapidly there after before also stabilising in line with plant density. Maximum species richness was generally achieved during the first and second year when annual *Atriplex* species were prominent. Perennial *Atriplex* species established more slowly during the early stages of revegetation development, but eventually replaced the annual component as the dominant taxa. Perennial *Maireana* species required up to three years before germinating in the field and establishing themselves in the revegetation; in many cases they replaced perennial *Atriplex* as the prominent taxa.

The presence or absence of cyclonic rainfall during the first growing season was a major determinant of the ecosystem trajectory, controlling revegetation structure and composition. The germination and successful establishment of hard seeded species, including *Acacia* and *Senna,* was reliant on heavy summer rainfall during the early stages of ecosystem development to break seed dormancy and extend the length of the first growing season. This provided an important competitive advantage against faster growing *Atriplex* species, which possessed greater drought tolerance. The intensity of summer rainfall was also beneficial in leaching surface salts from the upper profile and hence, reducing salinity within the rooting zone.

In the absence of heavy summer rainfall during the first growing season, the establishment of a low chenopod dominated vegetation cover was favoured, total species richness for the rehabilitation tended to be lower, and the variety of plant life forms was restricted to low and mid stratum shrubs. Increasing water stress resulted in progressively higher rates of local species extinction, with fewer taxa possessing the drought tolerance adaptations required to survive.

For established revegetation, cyclonic rainfall increased productivity (as measured by % foliage ground cover) and stimulated the establishment of new taxa, which in many cases were brought in from adjacent unmined vegetation complexes (analogue sites). While the benefits of summer cyclonic rainfall were undoubtedly important to arid and semi-arid ecosystems, the occurrence of drought was also important in buffering the ecosystem against large-scale change by acting as a negative feedback to constrain cumulative productivity.

Parent waste rock material varied considerably between rehabilitation sites, affecting the soil resource supply and associated functional components. Extreme salinity was a typical limitation of the rehabilitation medium, reducing the variety of salt tolerant species and favouring annual *Atriplex* during the early stages of ecosystem development. The cover of annual species present during early stages of ecosystem development contributed to decreasing salinity in the plant rooting zone, by reducing surface temperature and hence capillary rise of salts during summer months. Annual *Atriplex* species were replaced by perennial *Atriplex* in line with decreasing surface salinity. Fundamental to successful revegetation of the post-mining rehabilitation site was the requirement that reconstruction and contouring focus on maximising water retention and reducing salinity within the upper soil profile.

Once the initial vegetation community established and plant parameters became relatively stable, change continued to occur, albeit slowly. One factor contributing to this change was the immigration rate of biota from adjacent revegetation or more commonly from surrounding analogue complexes. Linking rehabilitation areas to surrounding functional ecosystems ensured the movement of plants and animals, and ultimately increased the rate of recovery. The sustainability of post-mining rehabilitation was enhanced where these links were established early, allowing for the provision of additional seed and the migration of displaced species.

The life cycle pattern of keystone species in the revegetation was found to be an important determinant in long-term sustainability of the plant cover, particularly for chenopod shrublands where one species was typically dominant. The senescence and death of large numbers of a dominant revegetation species together, had the ability to significantly alter the revegetation structure and composition. The impact for rehabilitation where a number of dominant taxa co-exist was less pronounced. Thus it follows that a minimum level of species richness was important to long-term rehabilitation sustainability, as was the development of an age-class structure in the rehabilitation.

The most common disturbances encountered at the rehabilitation trial sites were drought, overgrazing and weed infestation. All three disturbances decreased the plant biodiversity parameters measured. Ecosystem recovery following disturbance was dependent on effective rainfall, but occurred rapidly with plant parameters returning to pre-disturbance levels within one to two growing seasons. The recovery of plant biodiversity parameters followed the same trends identified at functional rehabilitation sites during the initial five years following direct seeding.

3Assessment of plant biodiversity parameters occurred at 15 analogue sites supporting native vegetation undisturbed by mining. It was anticipated that data from analogue sites could be used as a 'reference' against which to compare developing rehabilitation. However, analogue vegetation complexes were less dynamic in comparison to rehabilitation sites. Minor seasonal changes were recorded for plant biodiversity parameters, but overall annual change was minimal. Significant and sudden changes within analogue communities only occurred following disturbance, such as severe overgrazing, and recovery to pre-disturbance levels was rapid following the removal of the disturbance and return of effective rainfall.

A major difference between rehabilitation and analogue sites related to their age. Rehabilitation sites were 'juvenile systems' assessed against a time frame much shorter than had been required for natural processes to achieve the developmental state represented at analogue sites. Hence, it was important not to model one specific analogue site too closely, but instead model the desired revegetation structure and species composition on a variety of local analogue complexes occurring in parent materials 'matched' closely to those of the rehabilitation site.

Data from analogue sites should be utilised extensively during rehabilitation planning, but cautiously when interpreting the rehabilitation outcome. For mine sites in arid and semi-arid Western Australia, the application of specific numeric targets for plant biodiversity parameters as a measure of rehabilitation success was not recommended. A number of factors and controls in the developing ecosystem together determined the rehabilitation outcome. These factors were site and time specific; minor changes in any number of variables led to significantly different rehabilitation outcomes, making them difficult to accurately predict.

4Quality and germination testing confirmed progeny seed from a number of rehabilitation trials was of similar or higher viability than the maternal seed originally sown. This was further confirmed by field responses at trials in the Northeastern Goldfields one year after the 1994 drought, when elevated plant density was recorded following the return of above average rainfall. The ability of rehabilitation to show an immediate response to rainfall following a seven-month drought, and for vegetation parameters to subsequently recover to pre-disturbance levels within one to two years, provided an indication that the revegetation cover was resilient.

The relationship between plant production and rainfall was dependent on a 'carry-over' effect between seasons or following drought years, and 'pulses' mediated, for instance, by the amount of seed in the soil store. The 'reserve' component in arid ecosystems was responsible for both the memory of the system between pulses and for its long-term resilience.

6The analysis of time series data collected from 19 rehabilitation trials emphasized the importance of planning and implementation of best practice techniques to subsequent rehabilitation success, and reinforced the difficulty associated with accurately predicting the final rehabilitation outcome. The large spatial heterogeneity of undisturbed vegetation complexes across the landscape of arid and semi-arid Western Australia, provided the foundation on which site-specific rehabilitation scenarios could be modelled, albeit with caution. The translation of data into useful completion criteria was dependent on the realisation that successful rehabilitation requires the implementation of best practice rehabilitation techniques, as determined by technically prescriptive (design) based standards, as much as the identification of a successful rehabilitation outcome, as determined by performance (outcome) based standards. With this in mind, completion criteria were developed as part of a robust theoretical framework incorporating the larger mine plan, and were not simply based on numbers generated as stand-alone performance standards. The broad methodology generated could be adopted by any mine site across the mining industry, however the criteria and, more specifically, the standards for each criterion should always remain site specific.

The methodology designed for developing completion criteria has been addressed in three stages:

1. Planning,
2. Operational and Monitoring, and
3. Post-Mining Hand-Over.

Within each stage three parameters are addressed:

1. Criteria,
2. Process, and
3. Standard.

'Planning' is the most important stage in the development of completion criteria. It is the stage when an appropriate end land use is determined, analogue sites are assessed, a rehabilitation plan developed along with specified design standards ensuring implementation of best practice techniques, and a process of risk assessment implemented. The 'Operational Monitoring Stage' focuses on rehabilitation success during the period of ecosystem development. This stage is concerned largely with rehabilitation monitoring, from which performance standards can be developed to gauge rehabilitation success for specific periods during revegetation development. The initial task in Stage 2 is to ensure all aspects of the rehabilitation plan have been implemented as specified in Stage 1, and meet agreed design standards. The final stage of the completion criteria process, 'Post Mining Hand Over', is to ensure the rehabilitated site is safe, and able to successfully revert to the end land use.

While plant biodiversity parameters formed the focus of the current study, a variety of other functional ecosystem components may also make sound assessment criteria for determining rehabilitation success. Increasing the knowledge base for other functional components in arid and semi-arid ecosystems would further increase the ability to accurately determine rehabilitation success.

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1 INTRODUCTION

1.1 Background

Approximately 78 percent of Western Australia's land area lies within the arid and semi-arid bio-climatic zones. A variety of minerals including most of the State's gold and nickel, and all of its iron ore, copper, manganese and salt is currently extracted from mines situated within these zones (DME 1996). Mining activities in arid and semi-arid areas of Western Australia have expanded in the past ten years. Companies are exploring over extensive areas and developing operations from lower, previously non-economic ore grades. In addition to the extensive disturbances associated with exploration activities, mines are generating large volumes of waste rock, much of which is relatively soft and subject to weathering.

Mine operators are obligated to rehabilitate both exploration areas and waste rock dumps, and considerable effort and expense is being applied to the achievement of this objective. Prior to the commencement of mining, monetary bonds are determined by the appropriate decision making authority, based on the size of the area to be disturbed and the type of disturbance. Within Western Australia, the decision-making authority is usually the Department of Minerals and Petroleum Resources (DMPR) or, in environmentally and socially sensitive areas, the Environmental Protection Authority (EPA). Environmental bonds are held in trust until it can be determined that the end land use objectives, agreed prior to mining, have been met.

Completion criteria (defined in Section 1.3) need to be formulated so there is an agreed acceptable end point for rehabilitation. Current operations need attainable, measurable rehabilitation goals to demonstrate the required standard, guide rehabilitation programs and facilitate budgeting. Such standards are currently lacking for mining operations in arid and semi-arid Western Australia. The process of removing bonds over rehabilitated sites has been placed into industry hands; "It is the province of the operators to develop and propose completion criteria which are appropriate to their own specific situations" (DME 1996).

Completion criteria indicate clear rehabilitation targets, which are achievable in the short term and allow for a higher level of self-management on the part of mining companies. They provide more equilibrium in respect to the quality of rehabilitation between sites, as goals and expectations become better defined. Rehabilitation goals need to be specific, attainable and measurable. Assessment should include both quantitative measures and qualitative judgement; the satisfaction of regulatory personnel is not a sufficient criterion. Interim goals may be necessary to determine rehabilitation success where ecosystem development occurs slowly over a longer time frame; completion criteria may be set for a particular successional stage of development where climax communities are reasonably predictable (Mills, Chandler and Caporn 1991).

While it is important that completion criteria are specific enough to allow judgement of when they have been met, it is also important that the methodology is sufficiently flexible and robust to accommodate changes in either technical knowledge or community expectations (Tacey and Treloar 1994). Within the constraints imposed by individual sites, the methodology used to develop completion criteria should be applicable to the entire industry, however, individual criterion will always be site specific (Mills, Chandler and Caporn 1991; Gordine 1993).

Mined-out land in arid and semi-arid Western Australia generally reverts to its original land use, which usually implies return to the natural ecosystem that may or may not be used as rangeland. Management of the rehabilitation is generally discontinued once mining ceases. Hence, revegetation should be directed towards maintenance-free and self-perpetuating systems that are integrated with the surrounding natural habitats (Waggitt and McQuade 1994). It is this broad end land use concept on which the current investigations focus.

The problem associated with returning mined areas to their natural land use is that in many cases mining creates a new environment that may not reproduce the same features or functions as the pre-mining conditions (Foster 1986; Dragovich and Patterson 1995). The ability to judge the success or otherwise of rehabilitation is further compromised by a lack of knowledge on basic ecosystem processes and the rate of ecosystem dynamics in many areas of Western Australia (Court, Wright and Guthrie 1996). This is particularly the case in arid and semi-arid environments, which are characterised by unreliable rainfall.

Four mine sites were investigated as part of the current study, with selected parameters associated with ecosystem development in the post-mining environment monitored for periods up to 11 years; databases were subsequently produced for 19 rehabilitation trials. The four mine sites were situated within three distinct bioclimatic zones within the arid and semi-arid zone of Western Australia. It was anticipated that time series data recorded from the trials would allow for a better understanding of ecosystem function, and hence provide the basis for development of environmental completion criteria. Before commencing the rehabilitation trials it was necessary to model ecosystem function in order to understand the relationship between the environmental controls and resultant ecosystem processes.

1.2 Understanding Ecosystem Function

While ecosystems have been described as collections of organisms which respond to their surrounding environment (Engelberg and Boyarsky 1979), results from the current project support the view of Patten and Odum (1981) who see the biotic and abiotic components as being integrated by processes that control and sustain ecosystem traits. Chapin, Torn and Tateno (1996) developed the latter concept further to define a sustainable ecosystem as one that, over the normal cycle of disturbance events, maintains its characteristic diversity of major functional groups, productivity, soil fertility, and rates of biogeochemical cycling.

The point that ecosystems are not static must be emphasised. The composition and structure of plant and animal communities, productivity levels, and nutrient cycling all change in response to stochastic events and successional change. Sustainable ecosystems, however, maintain these traits within stable bounds (Chapin, Torn and Tateno 1996).

Jenny (1941) suggested that five independent state factors determine soil and ecosystem processes; parent material, climate, topography, potential biota, and time. Chapin, Torn and Tateno (1996) elaborated on this model by characterising four interactive controls in addition to the five state factors; local climate, soil resource supply, major functional groups of organisms, and disturbance regime (Figure 1.1). In contrast to state factors, interactive controls both influence and respond to ecosystem characteristics. Interactive controls must be conserved if an ecosystem is to be sustained, with any major changes ultimately leading to a new ecosystem with distinctly different properties. The set of interactive controls operates within bounds that are representative for a particular ecosystem, and form negative feedbacks preventing larger changes in interactive controls.

Negative feedbacks are the key to ecosystem sustainability because strong negative feedbacks provide resistance to changes in interactive controls and maintain the potential for regeneration after disturbance. In sustainable ecosystems, negative feedbacks generated by soil resources, plants, and other interactive controls constrain positive feedbacks (Pimm 1984). The acquisition of water, nutrients and light to support the growth of one plant reduces the availability of these resources for other plants, thereby stabilising community productivity (Tilman 1988). Similarly animal populations cannot sustain an exponential increase in numbers, because of declining food resources and predation (Oksanen 1990).

Positive feedbacks amplify an initial change in conditions and push the ecosystem toward some new state. Examples include resource-based mutualisms of plants with mycorrhizal fungi or nitrogen-fixing bacterium (Allen 1991), where both the plant and soil microbe benefits. Demographic mutualisms such as pollination and seed dispersal enhance population sizes in a community. Population growth acts as a positive feedback as increased population size tends to cause still greater population increase. The establishment of positive feedbacks is common during the early stages of restoration, and is often encouraged by land managers through the implementation of techniques including high legume content in seed mixtures and fungal inoculation of sown seed.

Natural ecosystems are complex networks of interacting positive and negative feedbacks (Post 1991). Both positive and negative feedbacks are important in determining the characteristics of natural ecosystems. Community dynamics, which operate within an ecosystem at any point in time, primarily involve feedbacks among soil resources and functional groups of organisms such as plants. Following disturbance the initial increase in plant biomass enables the vegetation to acquire more resources, which causes a further increase in plant production and potential to acquire resources. These along with other positive feedbacks can promote fast recovery of a degraded ecosystem (Bradshaw 1983; Perry et al. 1989). Over the longer-term, however, negative feedbacks act to constrain increasing productivity and act to form an ecosystem in which the interactive controls are limited within stable bounds.

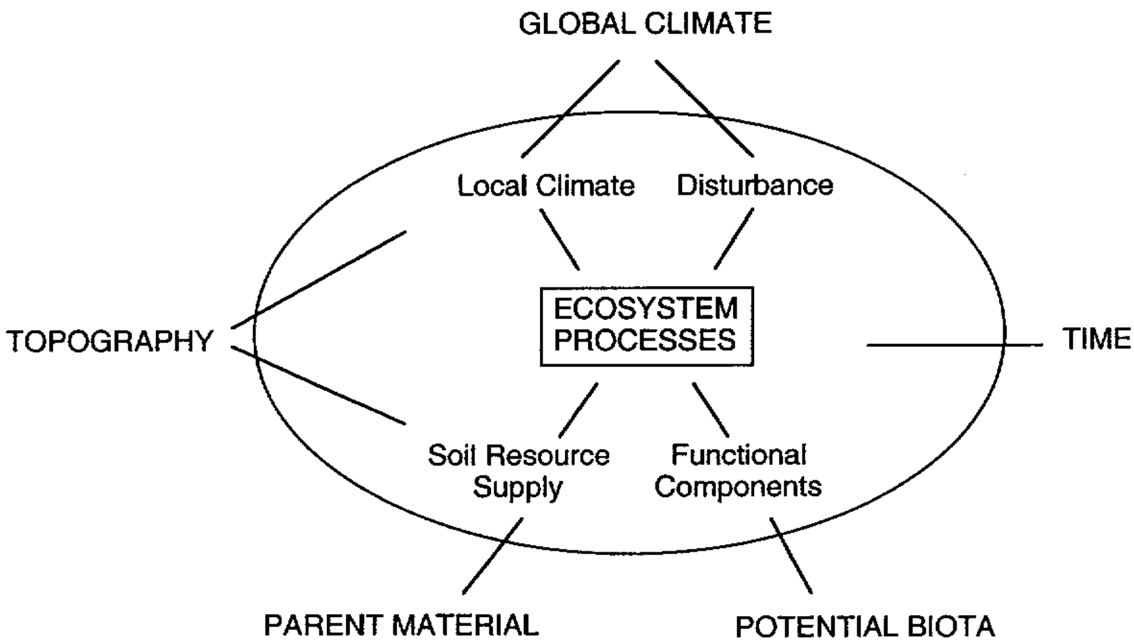


FIGURE 1.1: The relationship between state factors (in capitals), interactive controls, and ecosystem processes (as described by Chapin, Torn and Tateno 1996).

1.3 Completion Criteria

Completion Criteria have been defined in a number of ways.

Mills, Chandler and Caporn (1991) define completion criteria as rehabilitation performance objectives set as conditions of approval for each stage of rehabilitation and for the project as a whole. Their purpose is to guide the rehabilitation towards a preferred land use objective, in terms of its function, productivity, stability and sustainability. Mills, Chandler and Caporn (1991) stress the importance of defining the post mining land use objective prior to establishing specific completion criteria.

Farrell (1993) defines completion criteria as those measures, either qualitative or quantitative, against which the success or otherwise of rehabilitation can be measured, so that the objectives of the decommissioning plan can be achieved and the lease relinquished. A similar definition is given by Gordine (1993) - rehabilitation performance objectives and standards generated on a site-specific basis that enable administrative agencies and mining companies to gauge the success or otherwise of the rehabilitation techniques employed.

Tacey and Treloar (1994) see completion criteria as rehabilitation performance objectives, or more broadly the point at which the rehabilitation responsibility is complete. They feel completion criteria should be site specific, and represent milestones in the biophysical processes that provide a high degree of confidence the rehabilitation will eventually reach the desired sustainable state.

Biggs (1995) emphasized the development of completion criteria based on knowledge of the local environment, constraints of the mining operation, and land use objectives. In Western Australia, the Department of Minerals and Energy feel operators themselves should ultimately be responsible for the development of completion criteria that are appropriate to their own specific situations. The agreed standards form the basis by which compliance with regulatory requirements is determined and financial securities are released (Mohsen 1992).

Tacey and Treloar (1994); believed that the links between rehabilitation techniques, completion criteria and successful long-term ecosystem development have not been well established within Australia. More monitoring and research is required during the after-care period, following decommissioning, to confidently predict whether completion criteria lead to successful ecosystem development on rehabilitated sites over the longer term. Revegetation may take up to 20 years to reach a self-perpetuating state. Many operations have a shorter mine life in comparison, and monitoring usually ceases following mine closure. Hence valuable insight into longer-term ecosystem development is not being recorded.

Revegetation monitoring may highlight specific developmental stages in the rehabilitation process. Completion criteria should be able to predict with confidence whether a system is moving towards a sustainable state at a particular stage in the rehabilitation (Tacey and Treloar 1994). The bond release and condition clearance system requires more rigorous application of quantitative completion criteria. At present it relies too strongly on qualitative criteria (Tacey and Treloar 1994).

1.4 End Land Use

At present in arid and semi-arid regions of Western Australia, mined-out land generally reverts to its original land use. This usually implies return to the natural ecosystem. Management of rehabilitated areas is generally discontinued once mining ceases, thus revegetation must be directed towards self-perpetuating systems that can be integrated with the surrounding natural habitats (Biggs 1995).

The post mining land use objective should preceed the setting of more specific rehabilitation completion criteria (Mills, Chandler and Caporn 1991). The nature of completion criteria will depend on the type of end-use selected, and the significant environmental factors of the project area. Completion criteria may be as diverse as engineering specifications for structures, water quality standards for run-off or leachate, erosion/sedimentation rates, crop or rangeland productivity, the return of specific plants, animals or biotic communities, or the establishment of a self-perpetuating and resilient vegetative cover (Eagle and Higgins 1990; Roe 1990; DME 1996; Elliott et al. 1996).

In arid and semi-arid Western Australia, the re-establishment of self-perpetuating vegetation that is integrated with the surrounding ecosystem, is the most common land use objective. This sounds simple in principle but demonstrating that a sustainable plant cover has been established is in practice a complex matter, which hinges on the monitoring of ecological processes (DME 1996). Understanding the characteristics of the overburden materials (topsoil, subsoil, waste rock) is essential for making informed post-mining land use decisions and for planning landform reconstruction and revegetation (Biggs 1995).

Mine environments should be matched as closely as possible with natural ones, particularly with respect to position in the landform and moisture status. It is important to recognise that rainfall drives the rate of regeneration in arid environments, and progress should always be assessed against rainfall rather than against a time scale. It follows that good rainfall records are necessary to investigate local regeneration cycles and to monitor revegetation (Biggs 1995).

The problem associated with returning mined areas to their natural land use is that most mining creates a new environment, with different features or functions in comparison to the pre-mining conditions. When setting completion criteria for individual waste dumps there may be the requirement to determine limitations of what can be established in the short term, and see the rehabilitation process as a staged series of land uses as site capacity builds up (Mills, Chandler and Caporn 1991). To complicate the matter, different parts of the mine may require different rehabilitation treatments (Hollands 1993).

Rehabilitation monitoring schemes and completion criteria are inextricably linked by the parameters being assessed or measured. Neither can be established without adequate baseline studies, including models of local regeneration cycles. It is not possible to rehabilitate to self-perpetuating vegetation without reference to the surrounding ecosystem on which the constructed one will ultimately depend for stability (DME 1996).

It is vital that the state of the existing environment at the planning stage is documented (Brooks, Hollands and Whitfield 1989). This will focus the rehabilitation plan towards maintaining or improving the status of that existing environment (Mohsen 1992). Draft standards for completion criteria would ideally be derived from consultations between administrative agencies and mining companies, and be based on site-specific environmental parameters quantified at the pre-mining project approval stage (Gordine 1993; DME 1996).

Baseline investigations underpin subsequent stages in environmental management and mined land rehabilitation. They are pivotal in making decisions with respect to post-mining land use, operational site planning, the avoidance of unnecessary secondary impacts, rehabilitation planning, and the development of ecologically based monitoring programs and completion criteria (Biggs 1995). Baseline studies in undisturbed areas prior to mining should concentrate on common critical components such as soil and sub-soil properties, ground and surface water parameters, and flora and fauna surveys (Gordine 1993).

Concepts of ecosystem reconstruction, self-sustaining ecosystems, succession, and critical floral and faunal elements are all relevant when developing completion criteria. However, our ability to judge rehabilitation success when viewed against a background of these concepts is compromised by a lack of knowledge of basic ecosystem processes, and the rate of ecosystem dynamics in many areas of Western Australia. This is of particular relevance for arid and semi-arid climatic zones, which are characterised by unpredictable rainfall (Gordine 1993).

The opportunity exists to build up significant databases on ecosystem function prior to disturbance, through surveys currently required for project approval. This information, combined with retrospective studies of previously rehabilitated sites and baseline studies of undisturbed areas, could indicate key ecosystem elements and provide the basis for draft environmental completion criteria (Gordine 1993).

1.5 Government

In 1992, the National Strategy on Ecologically Sustainable Development (ESD) was finalised after extensive consultation (Commonwealth of Australia 1993). While there is no universally accepted definition of ESD, in 1990 the Commonwealth Government suggested the following definition for ESD in Australia; 'using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased'. Put more simply, ESD is development that aims to meet the needs of Australians today, while conserving our ecosystems for the benefit of future generations. A key component in achieving this goal is developing ways of using those environmental resources in a way that maintains and, where possible, improves their range, variety and quality.

To be successful it is acknowledged that changes are required in the current patterns of decision-making and actions by all groups and individuals. The experience required to make relevant changes can be found in all sectors of private enterprise and the community, and it is these same groups that can help provide practical solutions for the problems.

With respect to the mining sector, a major objective of ESD is to further develop industry in a way that manages the renewable and non-renewable resources on which it depends in an efficient manner. This will be achieved by ensuring exploration and mining activities are conducted in accordance with the principles underlying the Strategy. One objective relevant to the current project is:

To ensure mine sites are rehabilitated to sound environmental and safety standards, and to a level at least consistent with the condition of surrounding land.

To achieve the above objective, Governments will:

- Support the Australian and New Zealand Minerals and Energy Council (ANZMEC) to develop guidelines for the rehabilitation of abandoned mine sites, such as the *Strategic Framework for Mine Closure 2000.*
- Continue to work through ANZMEC to develop a policy framework for rehabilitation of operational mine sites, which is based on ESD principles.

Industry has also responded to changing environmental standards through the development of mechanisms such the Australian Mining Industry (2000) *Code of Environmental Management*, and through the adoption of international environmental performance standards such as ISO 14001. The Code encourages self-regulation by the industry, with mine closure as a key component (ANZMEC 2000).

Several management roles have evolved in State and Territory Government in Australia during the 1990s in the pursuit of ecologically sustainable development for the mining industry. However, the process has been constrained by the absence of accepted standards for rehabilitation success. In assessing compliance with rehabilitation conditions, regulatory agencies make judgements that rehabilitation is complete based on a range of factors such as company monitoring data, post-mining land user approval, and best judgement. But no agreed approach exists. This lack of consistency and lack of sound framework indicates the need for a more structured approach to decide when the miner's responsibility for rehabilitation is complete (Tacey and Treloar 1994; Wilson 1998). Suitably qualified government assessors are necessary to judge completed rehabilitation criteria, not only at the end of the operations but, most importantly, at the design stage and at regular intervals during the mining operation. Do governments have suitably qualified assessors? (Unwin and Karlson 1990).

The *Strategic Framework for Mine Closure* is intended to promote a nationally consistent approach to mine closure management in all Australian jurastrictions. It will not necessarily result in identical legislation in each State and Territory, but it will establish principles for mine closure that are agreed between regulators and the mining industry (ANZMEC 2000).

In Western Australia it is the province of the operators to develop and propose completion criteria, which are appropriate to their own specific situation (DME 1996). However, there are four legislative instruments controlling the impact of mining on the environment; *Mining Act 1978, Environmental Protection Act 1986, Commonwealth Environment Protection and Biodiversity Conservation Act 1999,* and various Agreement Acts. These conditions are expressed under clauses in the Agreement, or occasionally as a condition proposed by the EPA. These are:

- Mining to be conducted to an approved development program with specific environmental protection and management measures,
- Annual environmental reports to be submitted, and

- A bond to ensure adherance to the conditions and provide sufficient funds to undertake rehabilitation on default.

The Department of Minerals and Energy in Western Australia has historically applied three broad criteria when determining success of mine site rehabilitation. These criteria are:

- Is the site safe?
- Are the structures stable and non-erodible?
- Is there a reasonable vegetation cover and plant diversity?

Up until 1991 regulation of mine site rehabilitation in Queensland was covered by the *Mineral Resources Act 1989*. However, a lack of definition in the requirements of this Act lead to the development of a policy contained within the Environmental Management for Mining in Queensland. The policy sets broad goals and establishes a planning framework in which the company prepares an Environmental Management Overview Strategy (EMOS) for the life of the mine, and Plans of Operations for periods of one to five years. The plans detail environmental management and rehabilitation plans and calculate a security bond based on the maximum rehabilitation cost during the period (Wilson 1998). In effect mining companies in Queensland are required to identify the standards and targets against which successful mine rehabilitation are addressed and to demonstrate that these standards and targets have been achieved (Haylock and Macey 1994). Self-certification places the responsibility of meeting completion criteria into the hands of the operator, and therefore requires the support of managers, supervisors and operators for the process to succeed (Elliott *et al.* 1996). For example, completion criteria at the Selwyn Gold/Copper Mine in northwest Queensland were based around the achievement of a stable landform and post mining land use, and maintenance of acceptable downstream water quality (Haylock and Macey 1994). Specific targets were expressed as detailed measurable variables such as soil loss, gully depth, and heavy metal concentration.

In New South Wales it was not until 1993 that completion criteria became an issue, sparked by a shift in community expectations with respect to mining and the rehabilitation of mined land. Associated with increased public demand came progressive tightening of environmental controls placed upon industry (Hollands 1993). It was during this period that Hollands (1993) recognised the need to incorporate rehabilitation as an integral part of any mining operation, starting from the pre-feasibility stage of mine planning. There was also an acknowledgement of the need to address the specific requirements of each individual operation, and determine rehabilitation standards on a site by site basis. The principle statutes covering mining in New South Wales are the *Mining Act 1992, Environmental Planning and Assessment Act 1979,* and the *Pollution Control Act 1970,* with only the first of these prescribing specific requirements for mine site decommissioning (Summerhayes 1998).

The *Mining Act 1995* and the *Mine Management Act 1990* regulate mining in the Northern Territory (NT) for non-uranium minerals. Uranium mining is dealt with under the *Uranium Mining (Environmental Control) Act 1979.* The Department of Lands, Planning and Environment administers the *Mine Management Act* which mandates environmental impact assessment of all new mining projects. Completion criteria developed in the NT are aimed at ensuring responsible environmental outcomes, while applying consistency to the whole of the mining industry (Norris et al. 1997). Completion criteria are general rather than prescriptive, focused on outcomes regardless of the methodology, brief and easily understood by a wide audience, easily audited, and able to be administered using current resources. These developed completion criteria deal with a number of specified areas including sequential land use, physical safety, low risk to biota, stability, rubbish clean-up, revegetation, visual amenity, and heritage and archaeological sites. Guidelines, such as that developed for 'Mine Close-out Criteria' are being developed by government to supplement the progressive legislative direction of self-regulation. These guidelines will encourage best practice environmental management by 'advising current and prospective licensees of the general criteria that will be used, in conjunction with site specific criteria, to determine the success of mine rehabilitation (Department of Mines and Energy 1998).

1.6 Overseas

In the 1960s increased environmental awareness resulted in a number of international developments sponsored by the United Nations: Human Environment (Stockholm 1972); European Commission for Europe Long Range Transport of Air Pollutants Convention (1979); Wastes Transportation Convention (Basel 1989); and Earth Summit (Rio de Janeiro 1992). Although there are currently no credible, comprehensive international environmental performance standards that are recognised for mining (Finlay 2000), many national, state and corporate standards do exist; these are not consistent, measurable or reported against as benchmarks. A significant recent development is publication by the International Organisation for Standardisation of the 'ISO 14001 Environmental Management System' standards. These are being adopted by corporations around the world on a voluntary basis. While they provide valuable guidance on environmental management systems and require that all applicable environmental regulatory requirements be met, ISO 14001 standards are not themselves, measurable environmental performance standards.

Within the United States of America (U.S.A.) there is a variety of government, research, and private organisations that together have generated large quantities of time series data. These data sets may hold the key to developing more specific standards applicable to a variety of land managers. The importance of these long-term ecological data sets has recently been recognised, and there is now a clear focus among government departments to make effective use of the material. It is information gained from such programs that will increase understanding of ecosystem development and function, and may be used as a predictive tool for developing completion criteria.

Regulations governing end point criteria in the U.S.A. are at a similar stage of development to Australia. Currently a Federal Act in the U.S.A. provides broad environmental guidelines, while each State details more specific criteria to individual operations. This leads to a high degree of variability in performance standards across the country. Present changes being formulated for the '3809 Surface Management Regulations' are anticipated to promote better co-operation with, and between, State regulators (Bureau of Land Management 1999).

A major difference between U.S.A. and Australian regulations is in respect to the time period that elapses before sites are inspected for final success evaluation. In areas of the U.S.A. where annual rainfall is less than 660 mm, the proponent must assume responsibility and liability for successful revegetation for at least 10 years after the last reclamation work (Gordine 1993). In Australia there is no stipulated minimum period.

A recent report to the Senate (U.S.A.) by the Committee on Hardrock Mining on Federal Lands favoured the application of performance based standards over technically prescriptive standards (National Research Council 1999). The Committee concluded 'Existing regulations were generally well co-ordinated, although some changes were necessary'. One such required improvement focused on the development of more accurate predictive models and tools, and of more reliable prevention, protection, reclamation, and monitoring strategies at mine sites. The Committee also found the science base was far from complete and environmental protection would require that improvements continue to be devised.

Reclamation performance standards in the U.S.A. have historically placed emphasis on revegetation and hydrology. However, serious concern has been raised over this emphasis, as it is uncertain whether successful revegetation and hydrological restoration are sufficiently reliable indicators of success for soils, overburden and wildlife. In addition, evaluating methodology for both topics has not been agreed upon (Gordine 1993).

The release of 'Guidelines for Ecological Risk Assessment' by the United States Environmental Protection Agency (1998) provides a framework for risk assessment, identifies the roles of the risk assessor and the risk manager, and points out some of the problems (USEPA 1992; USEPA 1996; Wilson 1998). This process places greater importance on value-based management goals and defining what to measure.

The legacy of mining in Canada includes significant economic and social benefits, along with substantial social and ecological costs. Canadian technological, scientific and regulatory capacity for environmental protection has expanded significantly over the past 20 years, to the extent that Canada is viewed as one of the world leaders in these fields (EMCBC 1997). However, recent regulatory and economic trends are seen to be increasing risk to the environment (EMCBC 1997). Areas of environmental concern that have been raised include a reduction in government resources to enforce existing regulations, the current trend towards environmental de-regulation and erosion of public safeguards, limited public capacity for independent participation in development of assessment processes, ongoing uncertainty for dealing with long term toxicity problems, and increased corporate capital mobility for mineral investment resulting in reduced weighting of environmental issues.

In Canada, the Provincial Governments are responsible for mining and associated rehabilitation activities, and the Federal Government is responsible for environmental protection (Wilson 1998). To ensure that rehabilitation occurs, the Canadian Government requires that decommissioning and rehabilitation are integrated with mine development, and financial bonds are sufficient to cover mine closure costs.

Concepts included in the National Strategy on Ecologically Sustainable Development for Australia, are contained in the 1996 Canadian policy document 'The Minerals and Metals Policy of the Government of Canada: Partnerships for Sustainable Development' (Natural Resources Canada 1996). The stated objective of the policy is to attempt to mesh industry competitiveness in a global marketplace with sustainable development fo minerals and metals that respects and protects the needs of future generations. At face value, the policy identifies a number of important sustainability principles (life cycle management, precautionary prevention, polluter pays) and is considered a good first step. However, there is a strong requirement to match the above objectives with solid programs that meet the needs of all stakeholders.

A significant initiative recently developed by the Mining Association of Canada was 'A Guide to the Management of Tailings Facilities' (MAC 1998). These guidelines cover phases of development from design through to decommissioning. Although guidelines are not numerical themselves, they do refer to references and authorities that do include performance standards. There are a number of other initiatives to develop environmental performance standards for the minerals and metals sectors in Canada. The legislative authority for these activities is the federal *Fisheries Act* and *Canadian Environmental Protection Act.* Examples of planned standards include: *Environmental Codes of Practice for Steel Mills (2000); Metal Mining Effluent Regulations (2001); Environmental Code of Practice for Base Metal Smelters (2002);* and *Environmental Code of Practice for Metal Mining (planned 2003).*

1.7 Assessment Techniques

In 1984, the Western Australian Department of Agriculture adopted the Western Australian Rangeland Monitoring System (WARMS) as the primary monitoring tool in rangelands (Burnside and Faithfull 1993). Reassessment of study sites over time (5 yearly intervals) is applied to elucidate any long-term change in the vegetation and soil attributes being monitored, termed trend in range condition. Burnside and Faithfull (1993) found that subjective components in the monitoring system contributed to variation between subjects and hence range trend judgement. It is therefore important that monitoring of rehabilitation success comprise an objective, quantitative and field measurable system if it is to provide the necessary feedback on performance (Biggs 1995).

In Australia, guidelines for the development of completion criteria show only subtle differences between the States and Territory. In general it is left to individual operations to develop and justify their rehabilitation target, and hence associated assessment techniques. For most operations completion standards are outcome based; however, a number of companies are now preferring to develop a mixture of technically prescriptive and performance based standards. The development of technically prescriptive standards is often seen as the most appropriate method of ensuring the implementation of best practice techniques, thus providing the best chance of achieving the desired outcome.

Monitoring is the means by which information gained from rehabilitation experiences is channeled back into the planning phase (Bradley 1994). These data then form the basis for developing standards for completion criteria (Mills, Chandler and Caporn 1991; Haylock and Macey 1994). It is important for mine sites that the criteria and assessment techniques selected to monitor are relatively easy to perform and able to be conducted by either mine site personnel or consultants, at a relatively low cost.

A major obstacle to developing assessment techniques is that at the pre-mining stage it may only be possible to develop quantitative numbers based on surrounding vegetation communities, which establish on materials of similar physical and chemical composition. Site specific standards, e.g. % vegetation cover, will likely require refinement based on experimental trials, monitoring and evaluation. Hence flexibility should be kept within the system to allow for modification of completion criteria during the annual environmental review and operational progress reporting (Mohsen 1992).

1.8 Succession

Key elements within the rehabilitation may act as indicators of success at various stages of ecosystem development (Roe 1990). The question is often asked, "At what stage in the succession can it be determined that the desired vegetation association has been successfully established?" Without waiting for the passing of time of at least two generations of the longest-lived species, all we can do is guess

(Mills, Chandler and Caporn 1991). However, time series monitoring of developing rehabilitation can greatly increase confidence in those estimates.

Evidence suggests that pasture can be re-established in the south west of Western Australia in two seasons, and coastal sand dunes may be stabilised in three years (Gordine 1993). In the arid zone or where forest is being re-established, some twenty years of monitoring data may be required to scientifically define trends (Tacey and Treloar 1994).

Petersen (1985) made the point that in most cases assessment of rehabilitation success has to be made on juvenile systems. Decisions are required on the health of the rehabilitated system as it exists and the prospects for the system to either perpetuate itself, or continue developing along a path that will result in the desired land use being achieved. Rehabilitation success is judged against a time frame much shorter than would be required for natural processes to achieve the same result (Bradshaw 1987).

The state and transition model proposed by Westoby *et al.* (1989) recognises 'multiple stable states' in a developing vegetation system and the transitions between them. This model is relatively new and opposes the succession theory proposed by Clements (1916). The succession theory was based around the concept that a 'climax' vegetation state characterised the final stage in plant succession. If a system was disturbed by grazing, fire, clearing etc, it was said to be dysclimax until the climax species composition returned following a linear pattern after removal of the disturbance pressure.

1.9 Environmental Indicators

Many ecological responses are complex and difficult to measure accurately and reliably. It is tempting to describe such responses in terms of surrogates (indicators) that are more accessible and easier to measure (Hancock and Wolfgang 1996; Murtaugh 1996). Environmental indicators are simple measures that summarise information about complex systems (Statements 1996).

Indicators of rehabilitation success that may have merit for application to mine site rehabilitation are varied and include soil physical factors (infiltration, soil stability), soil chemistry factors (pH, electrical conductivity, nutrient status, toxicities), productivity factors (nutrient accumulation, biomass accumulation, tree growth rates), soil microbial factors (infection by mycorrhiza and rhizobia, microbial biomass and respiration, presence of plant pathogens), and biodiversity factors (species richness, density and cover for plants, abundance and richness of vertebrates and invertebrates). Unfortunately there has been limited research to validate the usefulness of specific indicator groups at rehabilitation sites within Australia.

The most popular indicators for rehabilitation success have historically been based on vegetation and hydrological parameters. In comparison there has been an assumption that other groups, such as vertebrate fauna, will return to a mine site when the revegetation has reached an appropriate stage in the seral succession. Accordingly, the regulatory authorities have made few specific demands concerning fauna (Mills, Chandler and Caporn 1991).

In Australia, ants are considered to be particularly useful bio-indicators in environmental assessment programs. They are of great abundance and functional importance, show a variety of interactions with the rest of the ecosystem; and have the ability to integrate a wide range of ecological variables (Majer 1983; Greenslade and Greenslade 1984; Andersen 1990). As pointed out by Majer (1984) in relation to an earlier study of rehabilitated mine areas in northern Australia, it is likely that the succession of ant species is longer than the sequence of rehabilitation because of the changing resources present (Reddell et al. 1992). Many of the differences in ant species richness and composition between revegetated and control sites can be attributed to differences in canopy cover and litter development (Andersen 1993). For example, revegetated sites at the Ranger uranium mines are initially colonised by species of *Iridomyrmex,* which are then replaced by opportunists and generalised myrmicines as plant cover and litter development increase (Andersen 1993). Studies elsewhere in the region have shown that different fire management regimes have a marked impact on ant communities, due primarily to changes in vegetation structure (Andersen 1991; Andersen 1993).

A procedure called Ecosystem Function Analysis (EFA) is currently being tested as a means of judging rehabilitation success in Western Australia (Kearns and Barnett 1998). The EFA package has 3 components, (1) landscape function analysis (LFA); (2) vegetation development, in which the species composition and growth characteristics are assessed in relation to LFA; and (3) habitat complexity, in which the habitat quality for a range of vertebrate fauna is assessed. The methodology makes use of a range of analogue sites in nearby unmined lands to provide guidance for indicator value to rehabilitation sites. While research is continuing to validate the accuracy of the indicators being measured, time-series data obtained thus far from different aged sites has provided insight into the shape of the expected response curve that indicaties successful rehabilitation. This curve is characterised by a steep initial response followed by a steady increase over time (Tongway *et al.* 1997).

1.10 Planning

The practices that contribute mostly to the long-term success of mine site rehabilitation are undertaken during the planning and establishment phases (Farrell 1993; Elliott et al. 1996). Although criteria may be established in the pre-mining phase, a number of variables about the operation may remain tentative. In reality "you don't know exactly what you can achieve until you try it" (Mills, Chandler and Caporn 1991). Time is a key ingredient. It therefore makes sense to structure completion criteria as a chronological sequence, matching the major stages of rehabilitation: Land forming, water management, vegetation establishment and development, fauna occupation, monitoring and remediation (Mills, Chandler and Caporn 1991).

The assessment of criteria should be made as early as practical, throughout the various stages of rehabilitation operations and during the early years of ecosystem development. This ensures that if corrective actions are required, they occur prior to succeeding operations (Elliott et al. 1996).

Completion criteria should be regularly reviewed as the operation progresses and monitoring data is generated. Standards must be set within a framework that ensures flexibility (Gordine 1993; Tacey and Treloar 1994). While completion criteria may not deliver anticipated ecosystems in a short time frame, this does not reduce their significance as rehabilitation performance objectives (Gordine 1993).

Progressive rehabilitation is particularly important in arid and semi-arid environments characterised by unreliable and low annual rainfall. Revegetation serves to reduce erosion, provides aesthetic value, and facilitates recolonisation by fauna. It also plays a key role in characterising the nominated post-mining land use (Gordine 1993).

1.11 Case Studies from Western Australia

Eneabba Mineral Sands

The Eneabba Mineral Sands Mine operated by Iluka Resources, is located 300 km north of Perth and 30 km inland from the coast. Native vegetation in the area is predominantly low woody heath comprising high species richness, with high conservation value. Although the mine was commissioned in 1976, there was no requirement for completion criteria until the mid-1980s. The establishment of completion criteria in 1985 provided both the mining company and regulatory authorities with an important aid in determining rehabilitation success relative to the pre-mining ecosystem (Gordine 1993).

Interim completion criteria were developed as outcome standards, with quantitative targets established for three vegetation parameters (species richness, plant density, total community canopy protective cover). Standards were generated from the assessment of control sites - adjacent vegetation communities undisturbed by mining.

The interim completion criteria adopted in 1985 were reviewed in 1990 (Table 1.1). No changes were made and they were accepted as being realistic and achievable targets.

TABLE 1.1: Completion criteria developed for the Eneabba Mineral Sands Mine (from Petersen and Herpich 1996).

Criteria	Standard
Species Richness	Mean number of 6 spp. m^{-2}, with a minimum of 70 spp. in areas up to 10 ha (all indigenous perennial spp.)
Plant Density	Mean number of 12 plants m^{-2}, with not more than 10% bare quadrats (all indigenous perennial spp.)
Total Community Canopy Protective Cover	32% ground cover by any indigenous perennial plant canopy (excluding *Acacia blakleyi*)

Minninup Beach Mineral Sands

In 1988 Westralian Sands Ltd and Cable Sands (W.A.) Pty Ltd proposed to mine the primary dune system and beach at Minninup, 10 km south of Bunbury. Rehabilitation was aimed at restoring the landscape to its natural state, but with greater stability of the dune. Interim completion criteria (Table 1.2) defined for the project, were derived from baseline data recorded over stable vegetation on the dune system (Gordine 1993). Completion criteria for vegetation were modified and finalised in late 1988 (Table 1.3). Continued monitoring and the development of a time series database of revegetation parameters has confirmed the progressive attainment of completion criteria within specific areas of rehabilitation, and the subsequent release of company responsibility for those areas.

TABLE 1.2: Interim completion criteria developed for mineral sands mining at Minninup (from Gordine 1993).

Criteria	Standard
Stability	There should be at least three years of stability of land form, stability being attributable to its location, shape and the establishment of stable and self perpetuating vegetation.
Survivorship	Perennial plant species must have survived at least two summer seasons.
Species Composition	The vegetation must have a density of plants which will provide long term stability to the restored landforms. The minimum density required 10 m^{-2} is based on baseline data collected prior to mining from excellent examples of stable stands of vegetation on the dune system.
	a) Foredune: 10 evenly distributed plants, each developing into clumps, of any combination of the species listed in Table 10(A). This includes monostands.
	b) Primary Dune: Any 10 plants from Table 10(B) and at least any 2 plants from Table 10(C), or up to 12 from Table 10(C) and none from Table 10(B). Other species occur naturally and will be in addition to the minimum numbers outlined above.

TABLE 1.3: **Finalised completion criteria for mineral sands mining at Minninup (from Gordine 1993).**

Location	Plant Density	Species Richness
Foredune	1.0 m^{-2}	3 species 25m^{-2}
Seaward slope of primary dune	1.0 m^{-2} (predominantly shrubs)	4 species 10m^{-2}
Crest of primary dune	0.9 m^{-2} (predominantly shrubs)	5 species 25m^{-2}
Inland slope of primary dune	0.5 m^{-2}	4 species 25m^{-2}

Northern Jarrah Forests

Alcoa operates a number of bauxite mines in the northern jarrah forests of the Darling Range, in the south west of Western Australia. Most of these bauxite reserves lie within State Forest, with a range of conflicting land uses including forestry, water supply catchment, conservation and recreation.

A 1995 environmental assessment of the proposed expansion to Alcoa's Wagerup Refinery, gave approval on the condition that environmental completion criteria were developed. A joint working group including personnel from Alcoa of Australia Limited (Alcoa) and the Western Australian Department of Conservation and Land Management (CALM), was formed to identify practical completion criteria and propose achievable standards.

Two sets of completion criteria were developed for Alcoa's bauxite operations in the northern jrrah forest of southwestern Western Australia, pre 1988 and post 1988. The rehabilitation eras reflect step changes in rehabilitation practices. The pre 1988 rehabilitation consists of plantations of either Pine species or Eucalyptus species native to the eastern states of Australia, planted after limited site preparation. The post 1988 rehabilitation has been undertaken by direct seeding indigenous species, with jarrah as the dominant Eucalyptus species.

The completion criteria developed a set of actions that ensure best practice rehabilitation techniques are adopted, combined with measures that determine when the rehabilitated mined areas are complete and Alcoa has no further liability in the management of the area (Elliott et al. 1996). The criteria encompass a range of design standards and outcome standards implemented and assessed at various stages throughout the mining process. Previously completion criteria were based on a narrow set of vegetation indices, usually measured at an establishment or early development stage immediately prior to divestment.

Alcoa defined five broad principles to which rehabilitation had to conform to be considered complete:

1. Meets land use objective.
2. Is integrated into the landscape.
3. Exhibits sustained growth and development.
4. Vegetation is as resilient as the jarrah forest.
5. Can be integrated with forest management.

Criteria which best demonstrated the accomplishment of the above principles were then identified, both quantitative (measurable) and qualitative (observations), along with appropriate standards. The standards set were determined as being realistic and achievable at the current level of knowledge, technology, and community expectation. Numerical targets were modeled on data collected from rehabilitation sites. All standards are being regularly reviewed over time, based on updated information and new technology.

Criteria are assessed under four time categories in a process of staged completion criteria. These categories are Planning, Very Early, Early, Mid and Late. This process ensures any remedial action required for rehabilitation that does not meet the specific standards set, occurs at the earliest possible time.

2 OBJECTIVES, STUDY SITES AND EXPERIMENTAL METHODOLOGY

2.1 Project Objectives

The objective of post-mining rehabilitation is typically to stabilise the surface by establishing a permanent vegetation cover as quickly and cheaply as possible. In reality, however, the rehabilitation of a functional ecosystem requires a thorough understanding about how the stable, mature ecosystem functions and maintains itself. This information is also a pre-requisite to establishing meaningful environmental completion criteria for mine site rehabilitation.

There is general agreement that completion criteria should be quantitative and field measurable. However, it is also acknowledged that at the pre-mining stage it is often not possible to develop quantitative numbers and narrow down site-specific standards, as the appropriate background data are rarely available. Only through the establishment of experimental trials, long-term monitoring, and evaluation can completion criteria and accurate standards be developed.

The current research project tackles the development of completion criteria by investigating ecosystem function within a variety of rehabilitation trials at four mine sites, and conversely within 'natural' vegetation complexes undisturbed by mining (analogue sites). Ecosystem function has been modelled, with the identification of a number of broad state factors, interactive controls, and associated ecosystem processes with both positive and negative feedback linkages (Chapin, Torn and Tateno 1996). The inputs to each rehabilitation trial differ, along with the final rehabilitation outcome as measured by specific soil and plant biodiversity parameters. The databases generated contribute to a better understanding of the ecological relationships occurring within functional ecosystems in arid and semi-arid Western Australia, and the potential impacts mining has on components of those ecosystems. This knowledge base has allowed for the development of realistic environmental completion criteria and accurate performance standards prior to the commencement of mining.

Six specific objectives were identified as part of the study:

1. To establish an appropriate end point land use for each mine site where field trials were established.

2. To examine long-term ecosystem development through the assessment of revegetation (the major functional component) at a variety of rehabilitation sites with specific reference to state factors and interactive controls.
3. To examine functional components within analogue communities ('natural' vegetation communities not impacted by mining), and make appropriate comparisons with rehabilitation trials.
4. To record the potential reproductive capacity of revegetation progeny, and determine how this relates to ecosystem function.
5. To provide a better understanding on the relationship between state factors, interactive controls, and ecosystem processes within rehabilitation at mine sites throughout arid and semi-arid Western Australia.
6. To develop a methodology for establishing realistic environmental completion criteria at mine sites situated in arid and semi-arid Western Australia.

2.2 Location and Description of Study Sites

Field trials were established at four mine sites located within three subtly different bioclimatic zones that extend through the arid / semi-arid shrubland belt of Western Australia (Figure 2.1); Northeastern Goldfields (Granny Smith Gold Mine, Sunrise Dam Gold Mine), Eastern Goldfields (Black Swan Nickel Mine), and Northeastern Wheatbelt (Westonia Gold Mine).

The two mine sites selected in the Northeastern Goldfields were located in close proximity to one another, approximately 20 km south of the Laverton townsite (Figure 2.1). The predominant vegetation type for this region is Mulga Woodland, however a variety of Low Chenopod Shrubland associations occur locally in connection with a large ephemeral salt lake, Lake Carey.

The Eastern Goldfields site was situated approximately 50 km north east of Kalgoorlie (Figure 2.1). Natural vegetation communities at this location include a mixture of Mulga Woodland and Low Chenopod Shrublands more common to the north, along with extensive Tall *Acacia* Shrublands and *Eucalyptus* Woodlands.

The final site was located adjacent to the town site of Westonia approximately 320km east of Perth, in the Northeastern wheatbelt of Western Australia (Figure 2.1). Westonia is a centre for surrounding wheat and sheep farming. The township lies 60 km west of Southern Cross and Marvel Loch, major gold mining and processing centres in the Yilgarn. *Eucalyptus* Woodland is the dominant native vegetation cover in the Westonia district, with *Eucalyptus salubris* (gimlet), *E. salmonophloia* (salmon gum) and *E. longicornis* (morrell) the dominant mallee and tree species. The understorey composition and structure is variable in response to changing soil conditions, however typical associations are low chenopod shrubs or mid-tall *Acacia / Melaleuca* shrubs. Significant clearing of native vegetation has occurred in the local district for cropping.

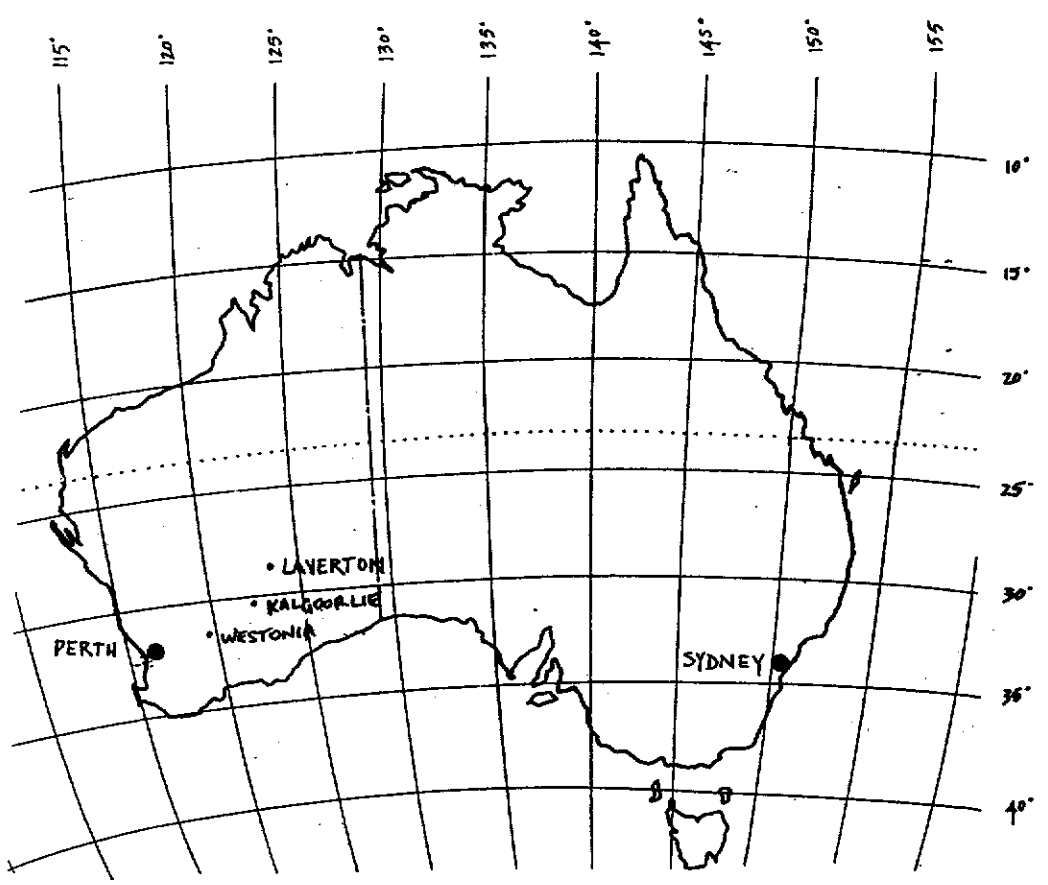


FIGURE 2.1: Location of the four mine sites where field trials were established.

2.3 Climate of the Study Sites

The climate of the bioclimatic zones distinguished has a Mediterranean tendency with hot summers and cool winters. Annual rainfall total increases when moving south from the Northeastern Goldfields (220 mm), into the Eastern Goldfields (260 mm), and down into the Northeastern Wheatbelt (309 mm, see Appendix 1).

The Northeastern Goldfields and Eastern Goldfields are characterised by a low and often unpredictable rainfall pattern. High intensity, short duration rainfall events occur infrequently during summer months (December-April), when large tropical depressions off the north west coast dissipate over inland areas of northern Western Australia. In the ten year period between 1990 and 2000 monthly rainfall exceeded 100 mm on three occasions for Laverton (February 1995, January 2000, March 2000) and four occasions for Kalgoorlie (March 1992, February 1995, March 1999, January 2000, see Appendix 1). The Northeastern Wheatbelt is on the southern boundary of the area influenced by summer cyclonic rainfall. In the ten-year period between 1990 and 2000 monthly rainfall for Westonia exceeded 100mm twice (March 1999, January 2000, see Appendix 1).

Winter rainfall is associated with cold fronts moving in from the Southern Ocean. As a result, the consistency of these falls decreases with increasing distance from the southwest land division. The more consistent winter rainfall received in the Northeastern Wheatbelt contributes to the higher annual rainfall total, when compared to the other two bioclimatic zones, and allows for cropping activities on what is the edge of the wheatbelt zone.

Extremes of temperature are typical for all three bioclimatic zones, with maximum summer temperatures exceeding 42°C and winter minimums down to –1°C (Western Australian Bureau of Meteorology).

Drought is a normal part of the semi-arid environment. It has been estimated that, over any forty-year period in the Goldfields region, there will be one 4-5 year drought, two 3-year droughts, and eight 1-year droughts (Burnside 1985).

2.4 Experimental Methodology

A total of 19 rehabilitation trials and 15 analogue vegetation complexes were monitored at the four mine sites, over periods extending up to 11 years (Table 2.1).

Many of the field trials were initially established to investigate the effect of specific experimental treatments including fertiliser rate, seed rate, and rehabilitation medium. However, it is the long-term assessment of common plant biodiversity and surface soil parameters, aimed at establishing a database of information on ecosystem development for each site, which is the major aim of this project.

The same assessment procedure applied to the rehabilitation trials has been duplicated within rangeland vegetation communities undisturbed by mining (analogue sites). These assessments are aimed at providing a comparison between ecosystem development for post-mining rehabilitation sites and natural analogue sites.

2.4.1 Procedure for vegetation monitoring

The procedure implemented to monitor vegetation was the same for rehabilitation trials and analogue sites, and involved the establishment of permanent belt transects of twenty contiguous one metre square quadrats. The number of assessment transects established was determined by a species area curve; when no new species were recorded along subsequent transects, the level of sampling was deemed adequate. Random numbers determined the commencement point of each transect (Zar 1984), which was orientated at 45° to the riplines.

The twenty 1 m^2 quadrats along each transect line were assessed individually. For each species within a quadrat the number present, percentage ground cover, and maximum plant height were recorded. Summarised data gave mean density values (no. stems m^{-2}), mean percentage ground cover, and mean maximum plant height. An importance value index (IVI, Mueller-Dombois and Ellenberg 1974) which considers frequency, density, and cover was calculated for each species recorded along a transect line. For all species along a transect line the total IVI value was 300. The larger an individual IVI, the greater the dominance of that species.

Statistical comparisons used one-way analysis of variance (ANOVA) and Fisher's testing ($\alpha = 0.05$). Percentage values were transformed to the arcsine of the square root of the proportion for ANOVA testing to normalise distributions. Regression analysis was also used to determine the significance of relationships between the plant biodiversity and soil parameters assessed.

TABLE 2.1: Summary of years in which the 19 rehabilitation trials and 15 analogue sites were formerly assessed.

	Year of Assessment											
REHABILITATION TRIALS	**90**	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**00**	**01**
Northeastern Goldfields												
1992 Oxide			■	■	■	■	■	■	■			
1993 Oxide				■	■	■	■	■	■			
1994 Upper Surfaces							■	■	■			
1992 Circular Ripping			■	■	■	■	■	■	■			
1992 Fertiliser			■	■	■		■	■	■			
1992 Seeding			■		■		■	■	■			
1994 Childe Harold							■	■	■			
1993 Seeding				■	■	■	■	■	■			
1994 Lower Batter							■	■	■			
1994 Top Batter							■	■	■			
1997 Sunrise Dam										■		
1998 Sunrise Dam										■		
Eastern Goldfields												
1996 Sump Hole							■	■	■	■	■	■
1996 Drill Line							■	■	■	■	■	■
1996 General Exploration							■	■	■	■	■	■
1997 Tailings Storage								■	■	■	■	■
1998 Evaporation Pond									■	■	■	■
1997 Crusher Pad									■	■	■	■
Northeastern Wheatbelt												
Waste Dumps 1A-1D	■		■		■	■	■	■	■		■	
ANALOGUE SITES												
Northeastern Goldfields												
Mulga Woodland								■	■			
Mixed *Acacia* Shrub								■				
A. vesicaria Low Shrubland								■				
A. bunburyana Shrubland								■				
M. pyramidata Shrubland								■				
M. triptera Low Shrubland								■				
Frankenia Low Shrubland								■				
Eastern Goldfields												
Eucalyptus Mallee										■		
Acacia Scrub								■	■	■	■	■
A. bunburyana Shrubland								■				
A. vesicaria Low Shrubland A								■		■	■	
A. vesicaria Low Shrubland B										■	■	
Northeastern Wheatbelt												
E. salubris W. over Tall Scrub								■		■		
E. salubris W. over Low Shrub									■	■		
A. vesicaria Low Shrubland									■			

2.4.2 *Procedure for soil monitoring*

Soil samples were collected from the surface 5 cm at three points along each vegetation transect (0 m, 10 m, 20 m) using a trowel. Each sample soil was taken from five points, mixed and then sub-sampled for later analysis.

In the laboratory soil was oven dried at 40°C for 48 hours (Rayment and Higginson 1992), passed through a 2 mm sieve and the resulting soil fraction then analysed for conductivity ($EC_{1:5}$) and pH using a 1:5 soil water extract. Soil pH readings were taken with a Hanna Instruments laboratory micro-processor pH meter (Model No. HI 8521). Electrical conductivity ($EC_{1:5}$) readings were made using an Activon Model 301 conductivity meter.

The $EC_{1:5}$ conductivity reading is an estimate of the amount of soluble salts the soil contains, the value varying with soil texture because of different moisture retention capacities. Conductivity readings were converted to saturation extract values (ECe) which range from a factor of six for a fine clay medium, to sixteen for a coarse sandy soil (George and Wren 1985). For soils collected as part of this project a factor of eight was used (consistent with conversion from previous samplings).

2.4.3 *Procedure for seed quality and germination testing*

Seed quality was determined by examining the 'soundness' of 100 seeds, randomly chosen from each collection, under a dissecting microscope. The number of sound versus unsound seed was recorded, with unsound seed including that which showed visual evidence of insect damage, was immature or malformed, or physically damaged.

Prior to germination testing, 100 sound seeds from each seed collection were selected for germination testing. Hard seeded species, including *Acacia* and *Senna*, received heat pre-treatments of varying strength to break seed dormancy and encourage germination. The pre-treatments were selected with reference to literature of previous germination testing. The pre-treatments involved either pouring water at a specified temperature onto the seeds contained in a test tube and leaving the test tube to cool, or emersing seeds into water at a constant temperature for a specified time. For 'soft' seeded species such as the chenopods no heat pre-treatment was necessary. However, seeds were removed from the fleshy bracteole enclosing them to prevent salts contained within the bracts from influencing final germination.

Following pre-treatment, seeds were surface sterilised with 3% sodium hypochlorite solution for 45 seconds, then rinsed thoroughly with deionised water. Petri dishes were also sterilised before being lined with a shallow layer of vermiculite, on which two filter papers were placed. The vermiculite and filter papers were moistened with a fungicide solution (1 g/L benlate), before 20 seeds of the species being tested were arranged evenly over the upper surface of the filter paper (five replicates for each species tested). The petri dishes were then transferred to temperature controlled cabinets. The incubation temperature for optimum germination of each species was chosen with reference previous testing.

The petri dishes were checked three times weekly, moistened with deionised water as required, and if fungal infection was observed benlate solution (1 g/L) was applied. The number of germinants in each petri dish was recorded on six occasions over a thirty-day period, from which final germination percentages were calculated.

3 REHABILITATION TRIALS

3.1 Northeastern Goldfields

3.1.1 1992 Oxide Trial

Rehabilitation Strategy

Parameter	Technique
Establishment Date	May 1992
Slope of Topography	Flat upper surface of waste dump
Revegetation Medium	Extremely saline oxidised waste removed at depth from an open-cut (mean ECe 40 dS m^{-1})
Surface Treatment	Conventional contour ripping using a grader to 0.5 m depth at 1 m intervals
Experimental Treatments	Two fertiliser treatments 150 kg ha^{-1} ('low') and 300 kg ha^{-1} ('high'). (9.0%N, 3.5%P, 7.4%K, 0.1%Cu, 0.1%Zn, 1.0%Fe, and 100 ppm Mn & Mo)
Seeding Method	Hand Broadcast
Seeding Rate	8.3 kg ha^{-1} with a mixture of 25 salt tolerant species

Results and Comments

The 1992 Oxide Trial was initially established to examine plant establishment in the absence of a topsoil cover resource, with seeding occurring directly into extremely saline oxidised waste mined from depth. For both fertiliser treatments (150 and 300 kg ha^{-1}), surface salinity approximated 40 dS m^{-1} ECe and was alkaline during the initial assessment in September '92. Surface salinity within the 'low' fertiliser treatment decreased over time, averaging 7 dS m^{-1} ECe in October '98 (Figure 3.1.1.1). For the 'high' fertiliser treatment, however, salinity increased in the seven years to October '98 (64 dS m^{-1} ECe). Surface salinity over the high fertiliser treatment was influenced by a haul road, which unknowingly ran through the middle of the experimental plot. The highly compacted surface decreased the potential for salts to leach from the surface profile.

Plant density for the 'low' and 'high' fertiliser treatments responded differently during the initial 28 months following seeding (Figure 3.1.1.2). For the low fertiliser treatment, plant density increased rapidly to average 2.1 stems m^{-2} 17 months after seeding, before decreasing to 0.8 stems m^{-2} eleven months later in response to low rainfall during 1994. During the same period the high fertiliser treatment gave a maximum plant density of 0.4 stems m^{-2}, however the revegetation cover response was similar for both treatments over this period.

For the December '95 assessment made one year after the 1994 drought broke, average plant density increased to approximate 3.0 stems m^{-2} for both fertiliser treatments. Plant density decreased annually over the proceeding period, and in October '98 averaged 1.3 stems m^{-2} for both treatments (Figure 3.1.1.2). Revegetation cover for the low fertiliser treatment ranged between 20 and 32 percent during this period; for the high fertiliser treatment the range for revegetation cover was larger (24 to 50 percent).

Over the six-year period of monitoring, trends in ecosystem development for the fertiliser treatments were categorised into two phases, pre and post 1994 drought. Prior to the 1994 drought the annual *Atriplex* species, *A. codonocarpa* and *A. semibaccata,* established in high numbers over the extremely saline medium and were the dominant revegetation taxa. Low numbers of *Maireana* spp. were recorded on the low fertiliser treatment (Figure 3.1.1.3) but were not recorded from the high fertiliser treatment (Figure 3.1.1.4).

A break in the 1994 drought occurred during December '94, and was followed by Tropical Cyclone Bobby in February '95 (Appendix 1). Rainfall associated with this cyclonic event immediately decreased surface salinity, which produced an increase in species richness for both fertiliser treatments. Perennial *Atriplex* species established, numbers of *Maireana* progressively increased to October '98, as did *Sclerolaena* and 'Other species' (Figures 3.1.1.3 and 3.1.1.4).

Seventeen months after seeding, three direct sown annual species were dominant in the low fertiliser treatment, *Atriplex codonocarpa* (IVI 159.2), *A. semibaccata* (IVI 64.1) and *A. holocarpa* (IVI 34.0). *Atriplex semibaccata* alone provided almost 5 percent ground cover. Seventy-seven months after seeding, three direct sown perennial species were dominant, *Atriplex lentiformis* (IVI 70.2), *Maireana pyramidata* (IVI 34.2) and *A. canescens* (IVI 22.0). These three species provided individual ground coverage of 14 percent, 4 percent and 7 percent respectively in October '98.

For the high fertiliser treatment, *A. semibaccata* (IVI 183.1) and *A. lentiformis* (IVI 70.8) were the dominant revegetation species 17 months after seeding. Seventy-seven months after seeding *A. lentiformis* remained prominent (IVI 104.0) providing 37 percent ground cover. However, the importance of *A. semibaccata* decreased over this period, and in October '98 it was only a minor revegetation component (IVI 5.3).

FIGURE 3.1.1.1: Change in soil salinity and pH between September '92 and October '98, for 150 kg ha^{-1} (low, n=12) and 300 kg ha^{-1} (high, n=9) fertiliser treatments.

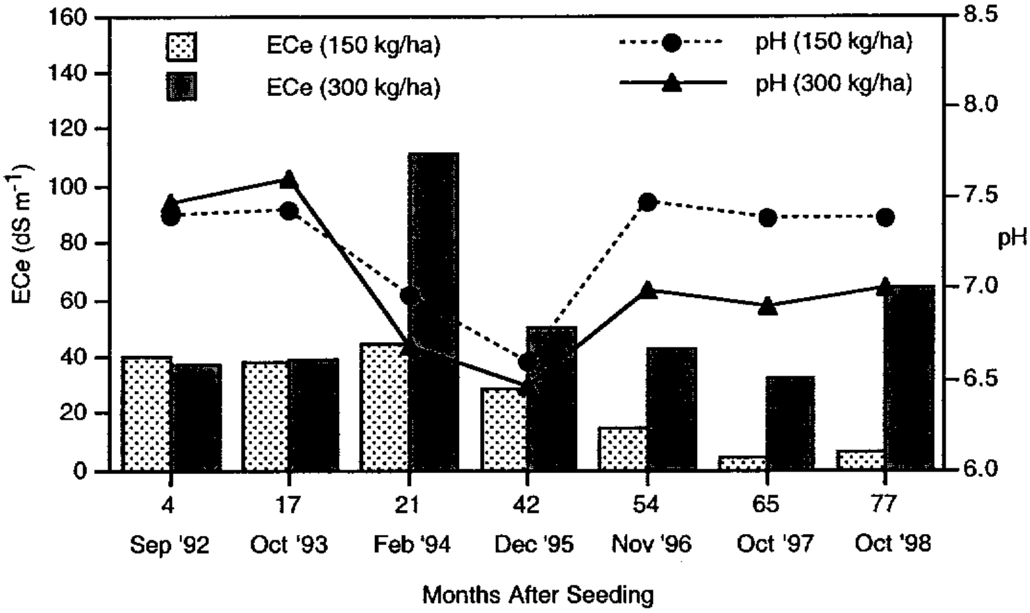


FIGURE 3.1.1.2: Change in plant density and revegetation cover between September '92 and October '98, for the 150 kg ha^{-1} (low, n=4) and 300 kg ha^{-1} (high, n=3) fertiliser treatments.

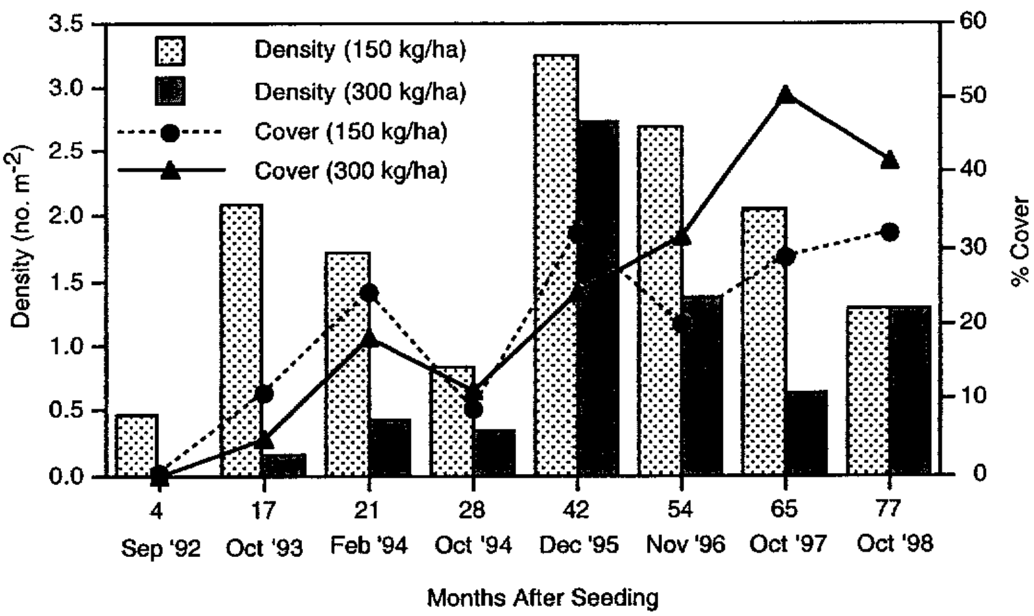


FIGURE 3.1.1.3: **Change in plant density, revegetation cover, and Importance Value Index (IVI) for dominant taxa recorded in the 150 kg ha^{-1} (low, n=4) fertiliser treatment, between September '92 and October '98.**

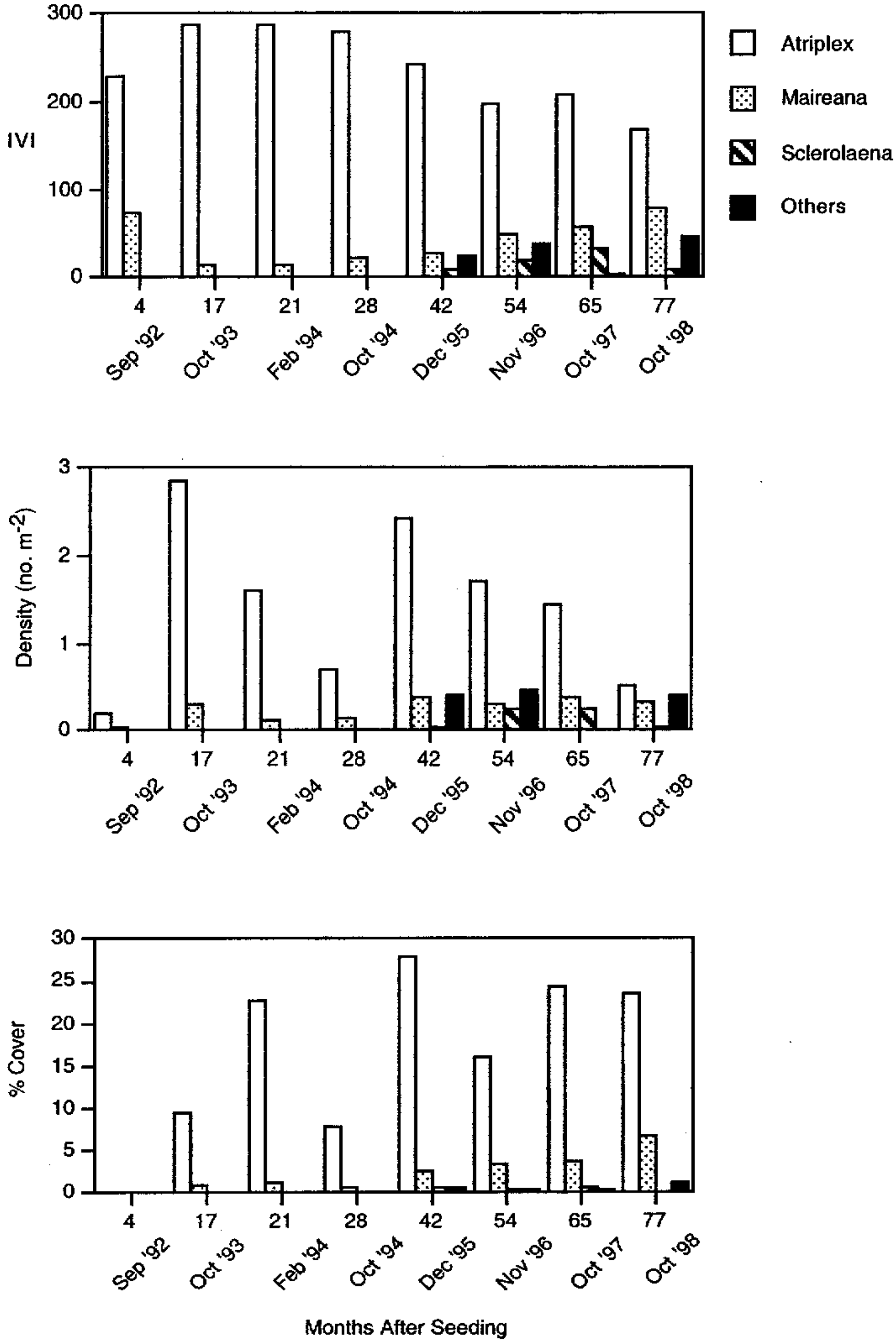
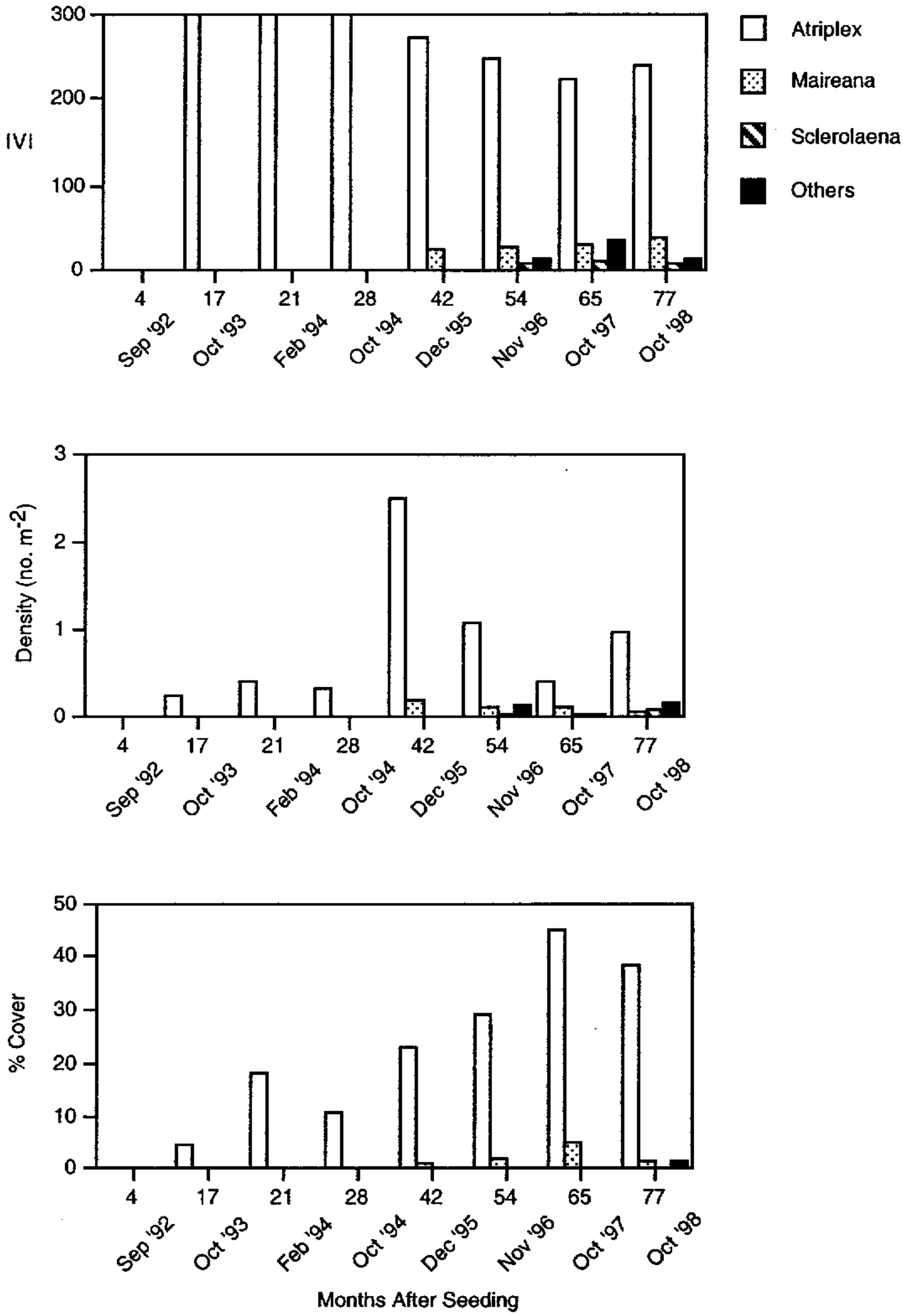


FIGURE 3.1.1.4: Change in plant density, revegetation cover, and Importance Value Index (IVI) for dominant taxa recorded in the 300 kg ha^{-1} (low, n=3) fertiliser treatment, between September '92 and October '98.



3.1.2 1993 Oxide Trial

Rehabilitation Strategy

Parameter	Technique
Establishment Date	April 1993
Slope of Topography	Flat upper surface of waste dump
Revegetation Medium	Extremely saline oxidised waste removed at depth from an open-cut (mean ECe 36 dS m^{-1})
Surface Treatment	Conventional contour ripping using a D6 dozer to 0.5 m depth at 1 m intervals
Experimental Treatments	Two seeding rates, 14 kg ha^{-1} and 20 kg ha^{-1}, with six salt tolerant chenopod species
Seeding Method	Hand broadcast
Fertiliser Rate	300 kg ha^{-1} (9.0%N, 3.5%P, 7.4%K, 0.1%Cu, 0.1%Zn, 1.0%Fe, and 100 ppm Mn & Mo)

Results and Comments

Plant biodiversity and soil parameters were assessed annually between October '93 (6 months after seeding) and October '98 (66 months after seeding). The two seed rate treatments showed similar responses over time for plant density, revegetation ground cover, soil salinity, and soil pH over time (Figure 3.1.2.1 & Figure 3.1.2.2).

The surface medium was initially highly saline (approximating 35 dS m^{-1} ECe) and neutral in reaction (pH 6.7). Salinity peaked during the summer assessment (February '94) ten months after seeding (85 dS m^{-1} ECe), but steadily declined to approximate 33 dS m^{-1} ECe in October '98 (66 months after seeding, Figure 3.1.2.1). Soil pH increased to average 7.4 in October '98 (Figure 3.1.2.1).

For the three assessments made in the initial 17 months following seeding, average plant density for both seed rate treatments remained below 0.8 stems m^{-2} due largely to elevated surface salinity and low rainfall received during 1994 (Figure 3.1.2.2). Following the break of drought in December '94 and Tropical Cyclone Bobby in February '95 (Appendix 1), plant density increased significantly to approximate 2.0 stems m^{-2} for each treatment in December '95 (Figure 3.1.2.2). Thirteen months later plant density increased further to average 3.1 and 3.8 stems

m^{-2} for the low and high seed rate treatments respectively. In the two subsequent assessments, plant density progressively declined to average 2.2 and 2.1 stems m^{-2} in October '98. Revegetation cover increased progressively during the post-drought period in a step-like pattern for both seed rate treatments, averaging between 28 and 30 percent in October '98 (Figure 3.1.2.2).

Changes over time in the importance, density, and ground cover of dominant taxa were similar for both seed rate treatments (Figure 3.1.2.3 and Figure 3.1.2.4). *Atriplex* dominated the rehabilitation during the initial 17 months following seeding, approximating 0.5 stems m^{-2} with 10 percent ground cover (Figure 3.1.2.3 and Figure 3.1.2.4). Six months after seeding the dominant species present in both the low and high seed rate treatments was the annual *Atriplex codonocarpa* (IVI 288.4 and 259.8 respectively), which provided an individual ground cover of 5 percent (Figure 3.1.2.5).

In December '95 (30 months after seeding) there was a change in the pattern of species dominance, with *Maireana* recorded at densities of 0.6 stems m^{-2} (low seed rate) and 0.9 stems m^{-2} (high seed rate) respectively. Thirteen months later (November '96) *Maireana* replaced *Atriplex* as the dominant taxa (Figure 3.1.2.3 and Figure 3.1.2.4). This change was reflected by a sudden increase in *Maireana* density (2.4 and 2.6 stems m^{-2} respectively) and foliage cover (11 and 14 percent). Plant density of this taxa subsequently decreased to approximate 0.5 stems m^{-2} in October '98, while ground cover remained stable averaging between 15 to 20 percent.

In November '96 (43 months after seeding) *Maireana brevifolia* was the dominant species recorded for low and high seed rate treatments (IVI 169.3 and 158.5 respectively). In October '98 (66 months after seeding) *M. brevifolia* remains dominant, providing 17 percent and 14 percent ground cover for the low and high seed rate treatments respectively (Figure 3.1.2.6).

FIGURE 3.1.2.1: Change in soil salinity and pH between October '93 and October '98, for 14 kg ha^{-1} (low, n=24) and 20 kg ha^{-1} (high, n=24) seed rate treatments.

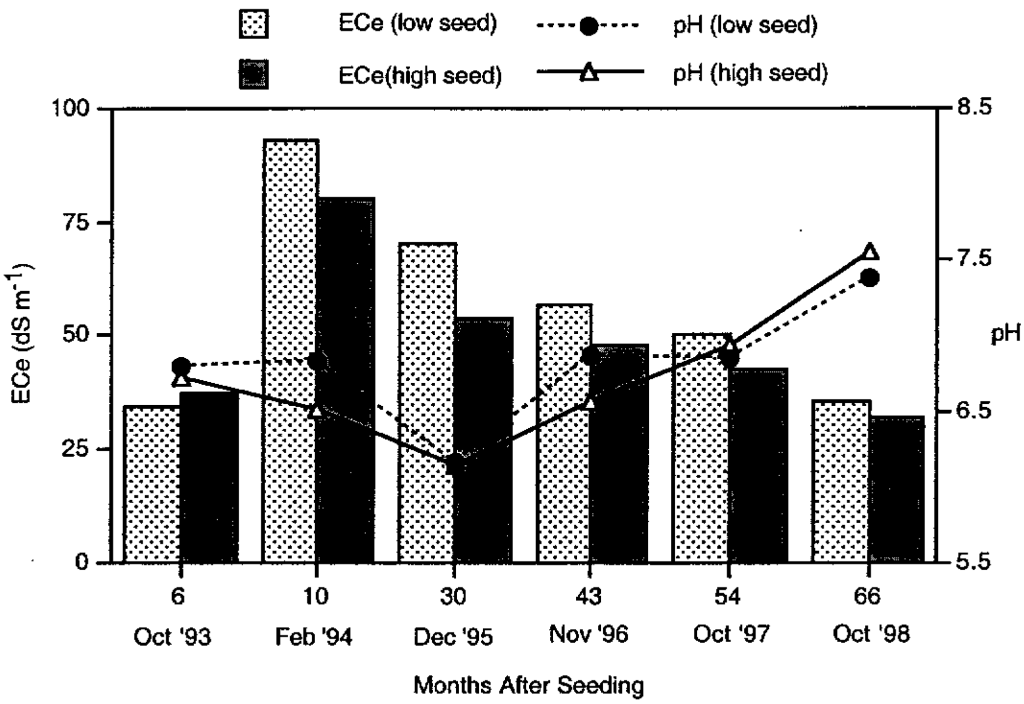


FIGURE 3.1.2.2: Change in plant density and revegetation cover between October '93 and October '98, for 14 kg ha^{-1} (low, n=8) and 20 kg ha^{-1} (high, n=8) seed rate treatments.

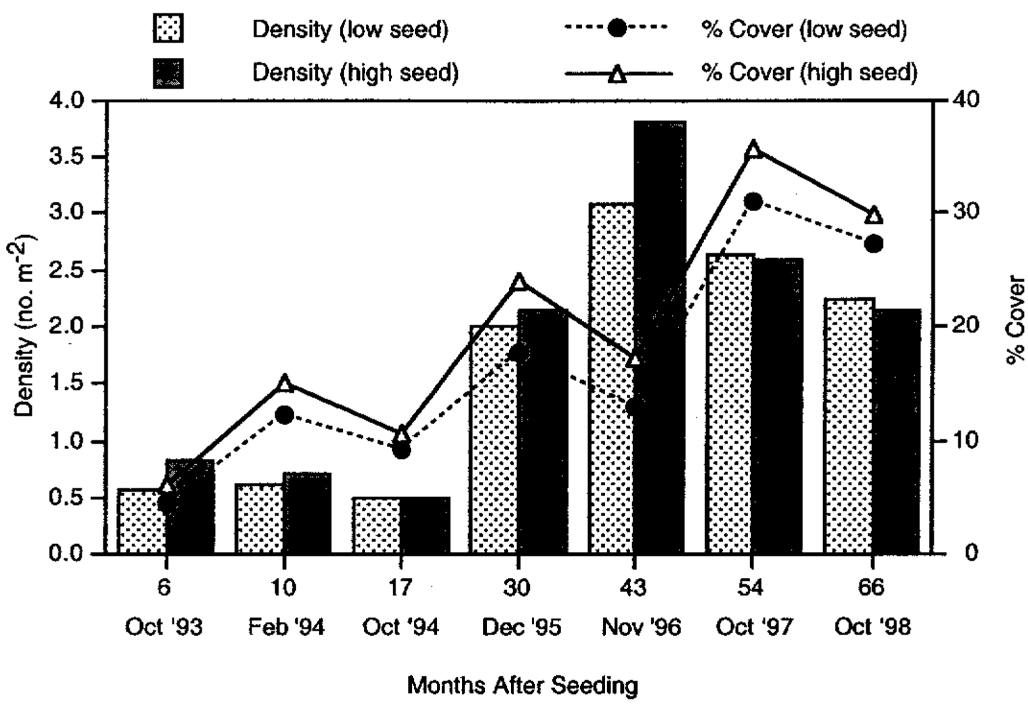


FIGURE 3.1.2.3: Change in Importance Value Index (IVI), plant density, and revegetation cover for dominant taxa recorded in the 14 kg ha^{-1} (low) seed rate treatment, between October '93 and October '98.

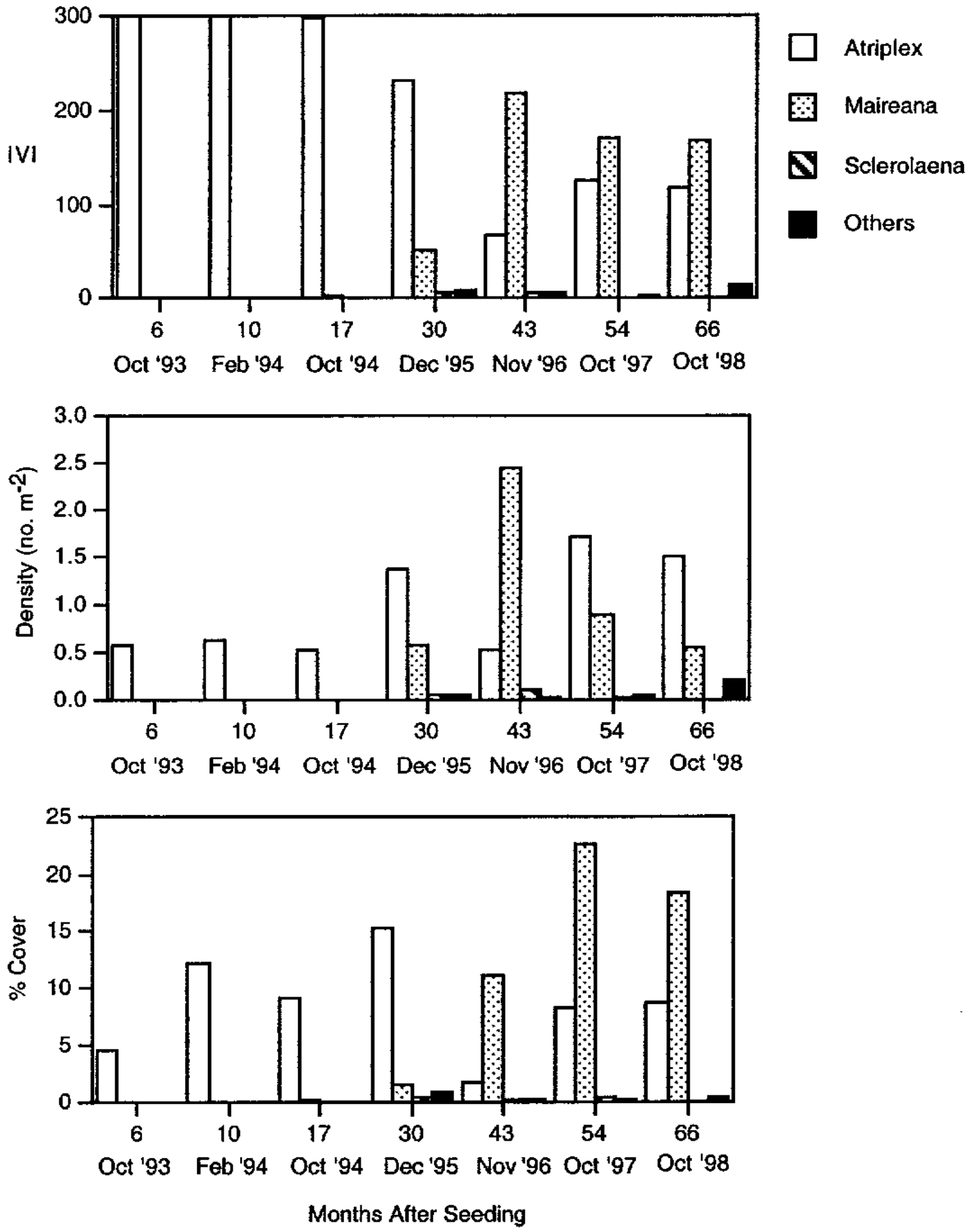


FIGURE 3.1.2.4: Change in Importance Value Index (IVI), plant density, and revegetation cover for dominant taxa recorded in the 20 kg ha^{-1} (high) seed rate treatment, between October '93 and October '98.

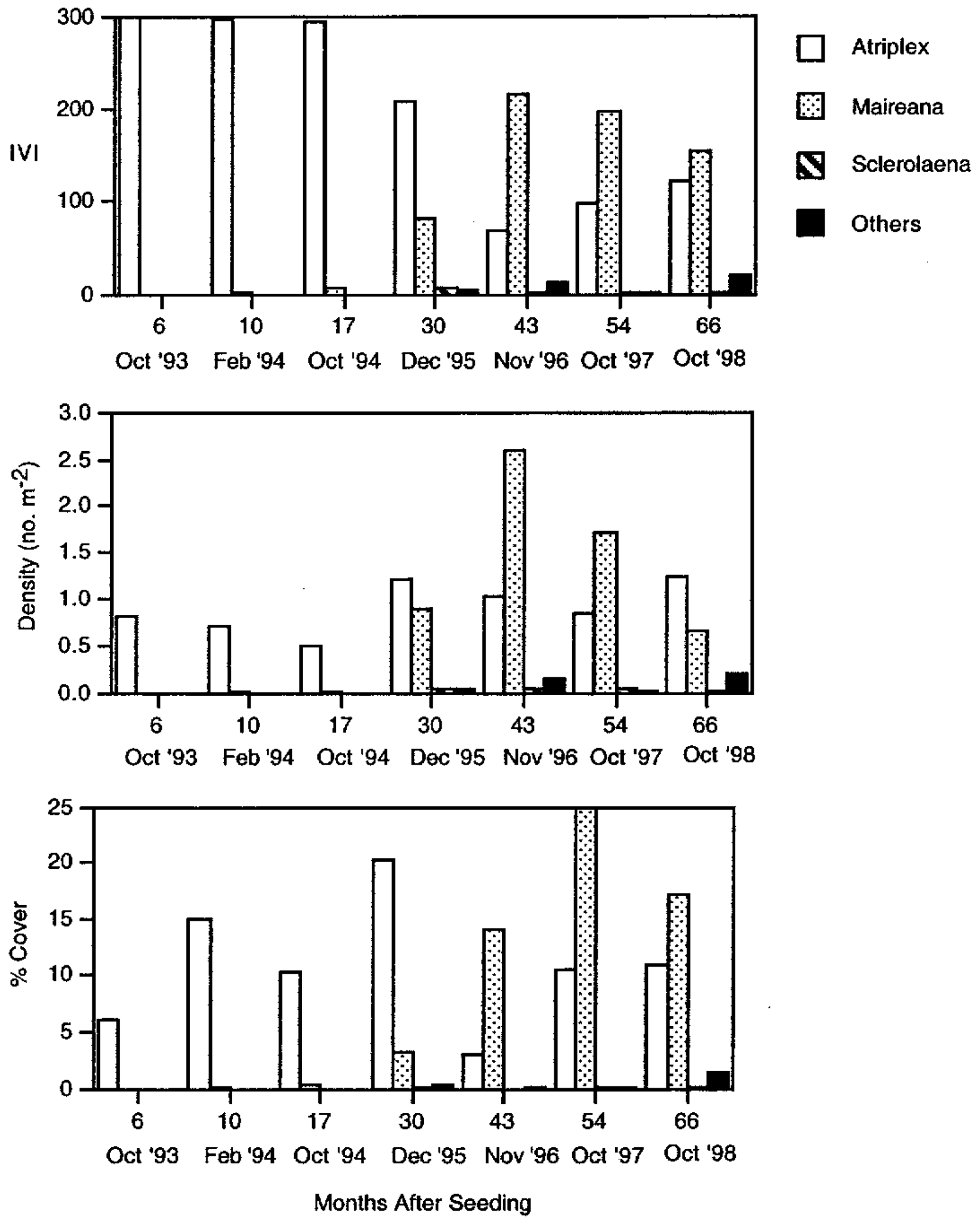


FIGURE 3.1.2.5: **Annual chenopods were prevalent over extremely saline surfaces during the initial growing season.**

FIGURE 3.1.2.6: **In October '98, 66 months after seeding, a number of perennial species have successfully established and the oxidised waste materials continue to be ameliorated.**

3.1.3 1994 Seeding Trial - upper surfaces

Rehabilitation Strategy

Parameter	Technique
Establishment Date	February 1994
Slope of Topography	Flat upper surfaces of the waste dump
Revegetation Medium	Saline oxidised waste, compacted
Surface Treatment	Conventional contour ripping using a D6 dozer to 0.3 m depth at 1 m intervals
Experimental Treatments	none
Seeding Method	Mechanical
Seed / Fertiliser Rate	30 species sown at 10.25 kg ha^{-1}, with fertiliser spread at 100 kg ha^{-1} (super copper zinc molybdenum - 8.3%P, 0.6%Cu, 0.3%Zn, 600ppm Mo, 10%S)

Results and Comments

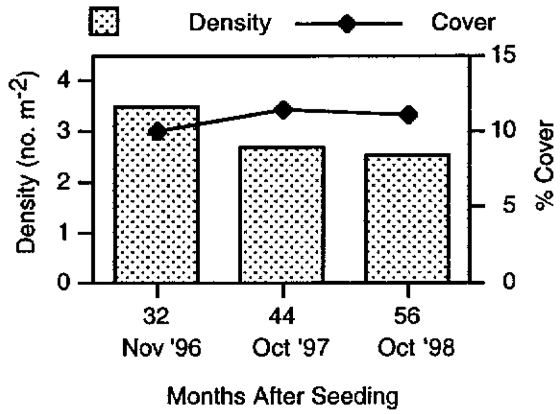
The upper flat waste dump surfaces rehabilitated during 1994 were extremely saline (>40 dS m^{-1} ECe). Subsequently only the most salt tolerant species in the seed mixture established, primarily *Atriplex* and *Maireana* species (Appendix 2). Elevated surface salinity was a major factor restricting the establishment of woody perennial species sown *(Eucalyptus, Senna, Acacia).* Surface salinity remained elevated for the duration of the revegetation assessments, up to 56 months after seeding (Figure 3.1.3.1).

For the three assessments made between November '96 and October '98, average plant density remained relatively high approximating 3.0 stems m^{-2} (Figure 3.1.3.1). Over the same period revegetation cover was relatively low but remained stable, approximating 10 percent.

Atriplex codonocarpa (IVI 81.0) and *A. vesicaria* (IVI 66.2) were important components in the revegetation during the first revegetation assessment 32 months after seeding (Figure 3.1.3.2), recorded at individual densities of 1.72 and 0.59 stems m^{-2} respectively (Figure 3.1.3.3). *Maireana georgei* (IVI 39.6) and *M. pyramidata* (IVI 18.2) provided relatively high individual ground coverage (2.2 and 1.5 percent respectively) (Figure 3.1.3.4).

In October '98, 56 months after seeding, *Atriplex* species were established as the dominant revegetation taxa. The annuals *A. codonocarpa* (IVI 54.5) and *A. holocarpa* (IVI 46.3) were prevalent (0.61 and 0.74 stems m^{-2}), with *A. nummularia* (IVI 43.6) and *A. vesicaria* (IVI 25.6) each providing individual ground coverage greater than one percent. *Maireana georgei* (IVI 28.2) and *M. pyramidata* (IVI 28.8) provided similar ground coverage as in the two previous assessments, ranging between 1 and 3 percent.

FIGURE 3.1.3.1: Change in plant density and % ground cover (n=7), and soil salinity and pH (n=21) for the 1994 Seeding Trial (upper surfaces); 32 - 56 months after seeding.



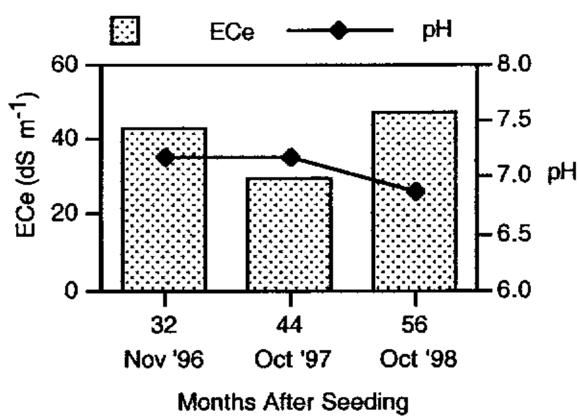


FIGURE 3.1.3.2: Change in Importance Value Index (IVI) for prominent revegetation taxa recorded over the 1994 Seeding Trial (upper surfaces, n=7); 32 - 56 months after seeding.

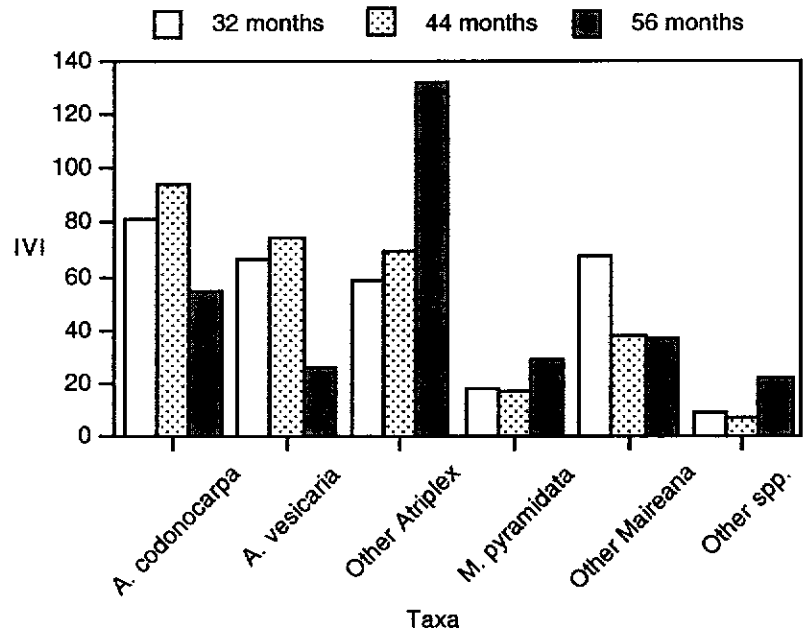


FIGURE 3.1.3.3: Change in plant density for important revegetation taxa recorded over the 1994 Seeding Trial (upper surfaces, n=7); 32 - 56 months after seeding.

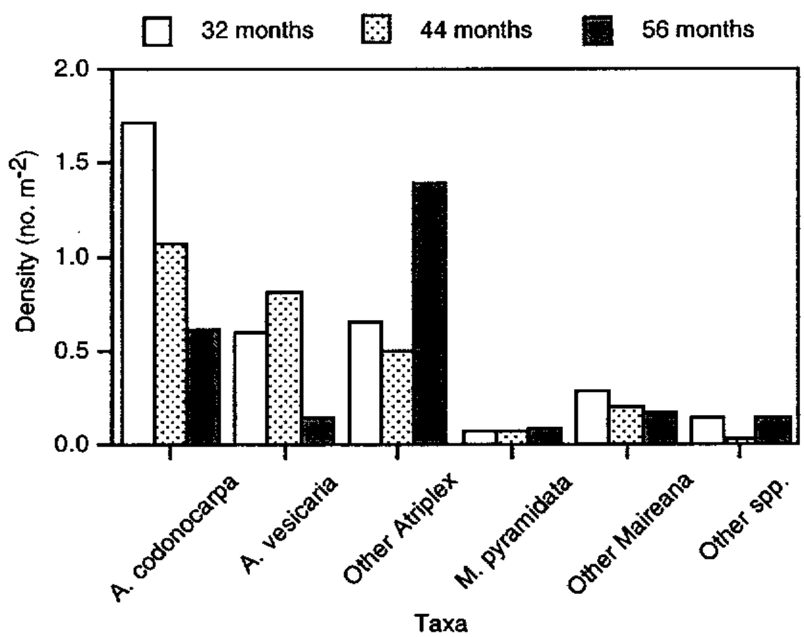
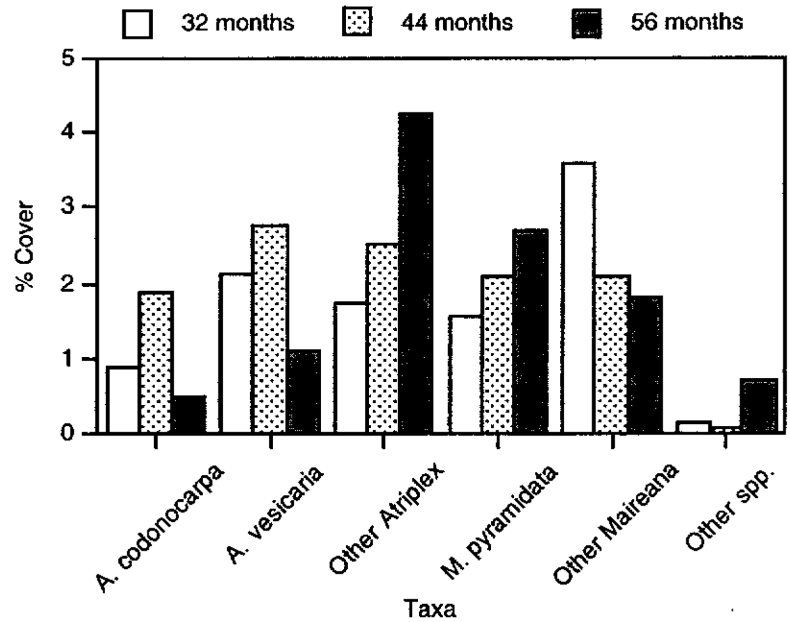


FIGURE 3.1.3.4: Change in % ground cover for important revegetation taxa recorded over the 1994 Seeding Trial (upper surfaces, n=7); 32 - 56 months after seeding.



3.1.4 1992 Circular Ripping Trial

Rehabilitation Strategy

Parameter	Technique
Establishment Date	May 1992
Slope of Topography	Flat upper surfaces of waste dump
Revegetation Medium	0.3 m topsoil cover over extremely saline oxidised waste
Surface Treatment	Circular ripping using a grader to 0.3 m depth and at 1 m intervals
Experimental Treatments	none
Seeding Method	Hand Broadcast
Seeding Rate	8 kg ha^{-1} with a mixture of chenopods, acacias and eucalypts

Results and Comments

Surface salinity increased between the September '92 and November '96 assessments (mean ECe 16.4 dS m^{-1} in November '96), but progressively decreased thereafter averaging 5.7 dS m^{-1} ECe in October '98 (Figure 3.1.4.1). The gradual establishment of a revegetation cover facilitated lower salinity within the plant-rooting zone by decreasing surface temperatures and hence, the potential for capillary rise of salts. Soil pH remained neutral over the seven-year period of monitoring.

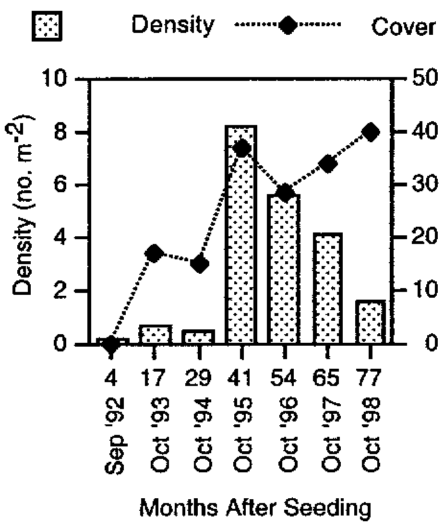
Plant density and revegetation cover remained relatively low during the initial three years following seeding in response to elevated surface salinity. In October '95 (41 months after seeding) both parameters increased significantly in response to heavy summer rainfall from Tropical Cyclone Bobby, to average 8.2 stems m^{-2} and 37 percent respectively. Summer rainfall during 1995 lowered surface salinity, stimulated seed germination for a variety of species not previously recorded and increased revegetation cover. Increased competition over the next three years, resulting from this pulse of production, saw plant density decrease to average 1.6 stems m^{-2} in October '98, and associated foliage cover stabilise at 40 percent (Figure 3.1.4.1).

The revegetation comprised two genera from the Chenopodiaceae, *Atriplex* (saltbush) and *Maireana* (bluebush), for the entire 77 months since direct seeding

(Figure 3.1.4.2). Although a diverse suite of life forms was sown into the topsoil cover, elevated salinity of underlying oxidised waste favoured the establishment of salt tolerant chenopods. Even the establishment of *Atriplex* and *Maireana* species was initially inhibited by extreme salinity, made worse by a seven month drought during 1994 which further stressed establishing vegetation and ultimately reduced plant density and revegetation cover.

Summer rainfall associated with the Tropical Cyclone Bobby in February '95 was an important cue to revegetation development on the 1992 Circular Ripping Trial.

FIGURE 3.1.4.1: Change in plant density and revegetation cover (n=4), and soil salinity and pH (n=12), between September '92 and October '98.



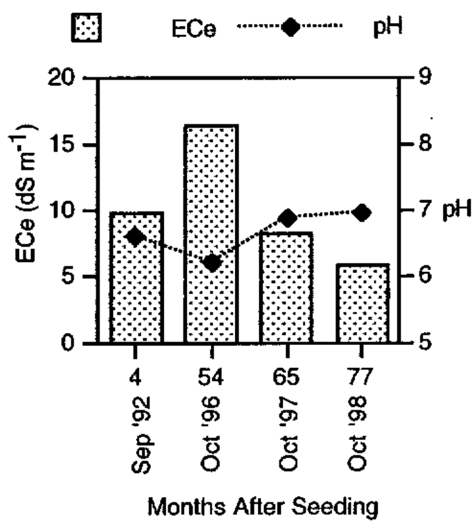
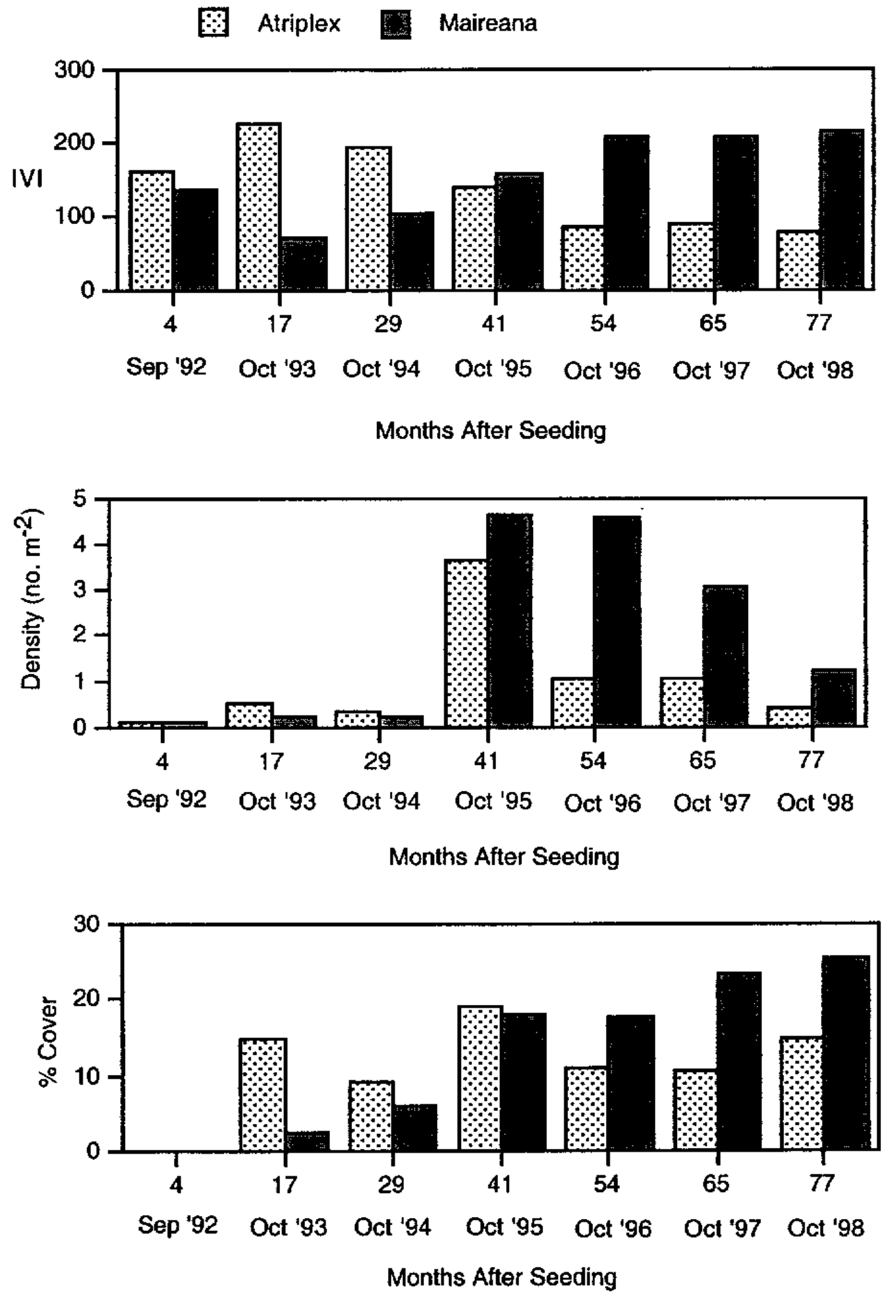


FIGURE 3.1.4.2: Change in Importance Value Index (IVI), plant density and % revegetation cover for the two dominant taxa recorded in the Circular Ripping Trial between September '92 and October '98 (n=4).



3.1.5 1992 Fertiliser Trial

Rehabilitation Strategy

Parameter	Technique
Establishment Date	May 1992
Slope of Topography	20° batters
Revegetation Medium	Topsoil cover up to 1 m deep in places, over extremely saline oxidised waste
Surface Treatment	Conventional contour ripping using a D6 dozer to 1 m depth and at 1-1.5 m intervals
Experimental Treatments	Five fertiliser treatments 0, 50, 100, 150, and 200 kg ha^{-1} (9.0%N, 3.5%P, 7.4%K, 0.1%Cu, 0.1%Zn, 1.0%Fe, and 100 ppm Mn & Mo)
Seeding Method	Hand Broadcast
Seeding Rate	8.3 kg ha^{-1} with a mixture of chenopods, acacias and eucalypts

Results and Comments

The surface revegetation medium was initially mildly saline and slightly acidic. For all five fertiliser treatments there was a trend for soil pH to increase over time (Figures 3.1.5.1-3.1.5.6); in October '98 soil pH ranged from neutral to slightly alkaline. The February '94 assessment confirmed there was capillary rise of salts during the dry summer months, with salinity increasing to average 35 dS m^{-1} ECe for 100 kg ha^{-1} fertiliser treatment. Surface salinity remained below 16 dS m^{-1} ECe for all fertiliser treatments during the remaining spring assessments (Figures 3.1.5.1-3.1.5.6).

Change in plant density and revegetation cover over time follows similar trends for all five fertiliser treatments. Plants established at high density during the initial two growing seasons, accompanied by a rapid increase in revegetation cover during the second growing season. Both parameters declined during October '94, in response to drought conditions experienced for the seven months prior to assessment (Appendix 1).

Following the return of effective rainfall in December '94, revegetation parameters recovered to pre-disturbance levels within two growing seasons for all fertiliser treatments except the control.

For the control treatment revegetation established at high density during the initial two growing seasons (3.1 stems m^{-2}); revegetation cover averaged 29 percent seventeen months after seeding (Figure 3.1.5.1). Both parameters then declined before showing only minor variation between October '94 and October '97, with plant density and ground cover approximating 1.4 stems m^{-2} and 20 percent (Figure 3.1.5.1). In October '98 revegetation density increased significantly to average 3.1 stems m^{-2}; at the same time revegetation cover decreased to average 14 percent.

For the 50 kg ha^{-1} fertiliser treatment average plant density peaked in October '93 (1.6 stems m^{-2}) and October '98 (1.8 stems m^{-2}). During the five year period between these assessments, plant density reached its minimum level of 0.8 stems m^{-2} in October '94, following an extended period of low rainfall (Figure 3.1.5.2). Revegetation cover showed an increasing trend following seeding to average 42 percent in October '97. However, a significant decrease was recorded in the 12 month period to October '98 (18 percent cover, see Figure 3.1.5.2).

The change in plant density for the 100 kg ha^{-1} fertiliser treatment was similar to that recorded for the 50 and 150 kg ha^{-1} treatments. Maximum plant density occurred during the second growing season (2.4 stems m^{-2}), before decreasing in response to low rainfall to average 0.7 stems m^{-2} October '94. The return of effective rainfall stimulated a recovery by October '97 (1.8 stems m^{-2}) and in October '98 plant density averaged 1.6 stems m^{-2}. Revegetation cover was also impacted by the '94 drought, ranging between 19 and 26 percent in the period between October '93 and October '98, with the exception of October '94 when cover decreased to 9 percent (Figure 3.1.5.3).

Change in plant density for the 150 kg ha^{-1} treatment was similar to the trend recorded for the 50 and 100 kg ha^{-1} treatments. Revegetation cover also showed a similar pattern of change between assessments, however total cover was greater. Revegetation cover peaked during February '94 (56 percent), before decreasing to 24 percent over the following seven months in response to low rainfall (Figure 3.1.5.4). In the three proceeding assessments cover ranged between 32 and 45 percent.

The highest plant density for all treatments was recorded 17 months after seeding the 200 kg ha^{-1} fertiliser treatment (4.2 stems m^{-2}). Plant density decreased to its lowest point during October '94 following low rainfall (1.1 stems m^{-2}), recovering during 1995 in response to heavy summer rainfall associated with Tropical Cyclone Bobby (Figure 3.1.5.5). Over the assessment period average revegetation cover ranged between 11 percent (October '94) and 28 percent (October '93).

Atriplex was the dominant taxa recorded in all five fertiliser treatments, approximating 1.0 stem m^{-2} (Figures 3.1.5.6-3.1.5.10). Foliage cover provided by this taxa ranged from 10 percent for the 0 and 200 kg ha^{-1} treatments (Figures 3.1.5.6 and 3.1.5.10), to 20 percent for the 50 and 100 kg ha^{-1} treatments (Figures 3.1.5.6 and 3.1.5.8) and a maximum of 30 percent for the 150 kg ha^{-1} treatment (Figure 3.1.5.9). *Maireana* showed a general increase in dominance 54 months after seeding (November '96). For the five treatments *Maireana* density and foliage cover ranged between 0.3-0.5 stems m^{-2} and 5-7 percent (Figures 3.1.5.6-3.1.5.10). *Acacia* was recorded during the initial assessment, four months after seeding (Figure 3.1.5.7), but was only a minor component of the rehabilitation in proceeding assessments, as were other woody perennial life forms including *Eucalyptus* and *Senna*.

FIGURE 3.1.5.1: **Annual change in plant density and revegetation cover (n=3), and soil salinity and pH (n=9) between September '92 and October '98; 0 kg ha^{-1} fertiliser treatment.**

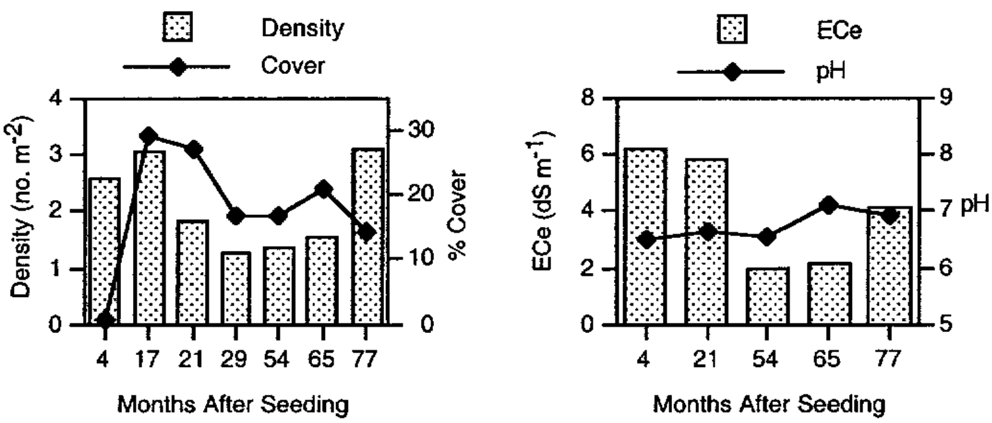


FIGURE 3.1.5.2: **Annual change in plant density and revegetation cover (n=3), and soil salinity and pH (n=9) between September '92 and October '98; 50 kg ha^{-1} fertiliser treatment.**

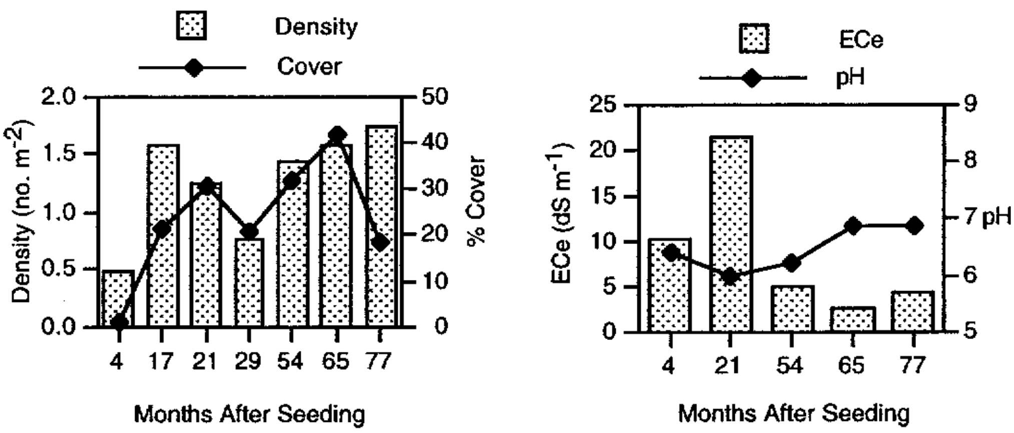


FIGURE 3.1.5.3: Annual change in plant density and revegetation cover (n=3), and soil salinity and pH (n=9) between September '92 and October '98; 100 kg ha^{-1} fertiliser treatment.

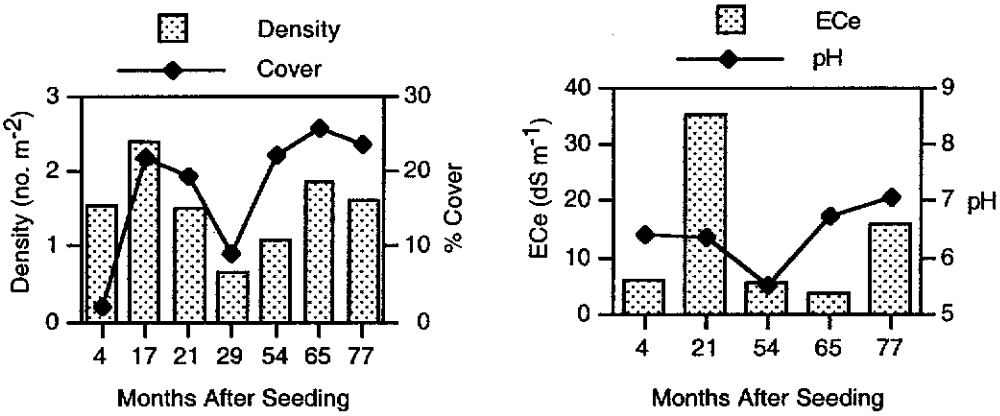


FIGURE 3.1.5.4: Annual change in plant density and revegetation cover (n=3), and soil salinity and pH (n=9) between September '92 and October '98; 150 kg ha^{-1} fertiliser treatment.

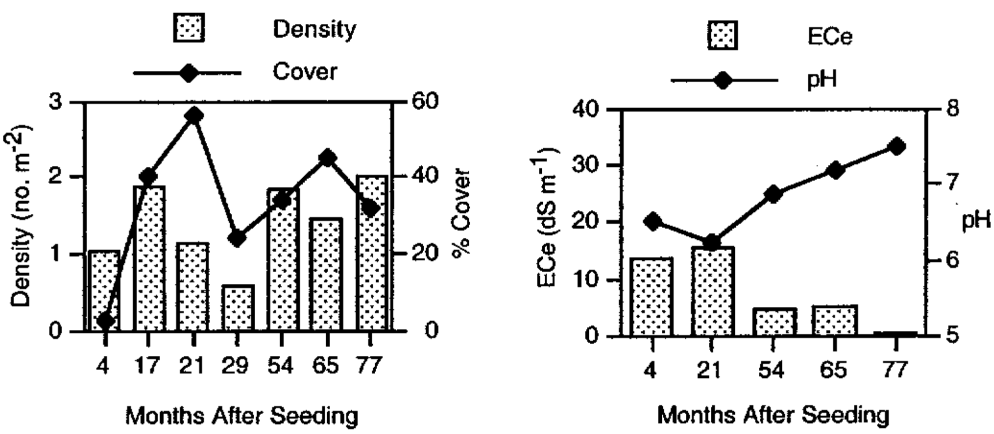


FIGURE 3.1.5.5: Annual change in plant density and revegetation cover (n=3), and soil salinity and pH (n=9) between September '92 and October '98; 200 kg ha^{-1} fertiliser treatment.

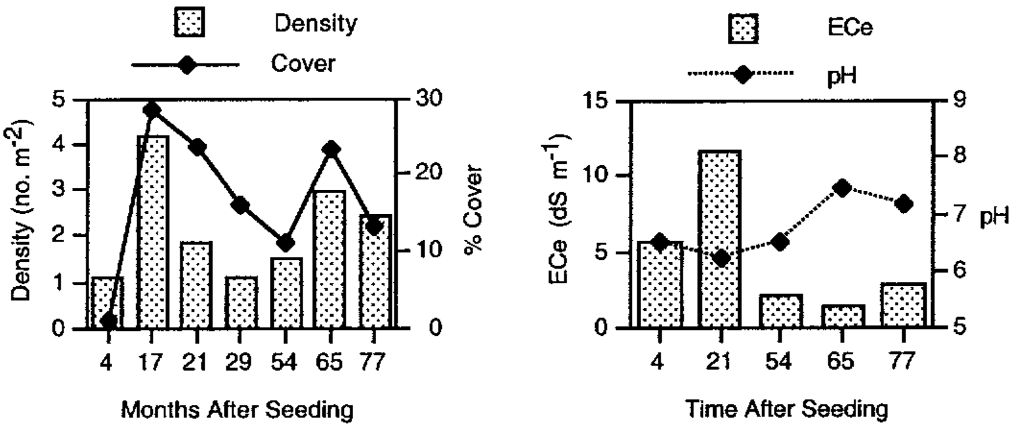


FIGURE 3.1.5.6: **Change in plant density, revegetation cover, and Importance Value Index (IVI) for dominant taxa recorded in the 0 kg ha^{-1} fertiliser treatment between September '92 and October '98.**

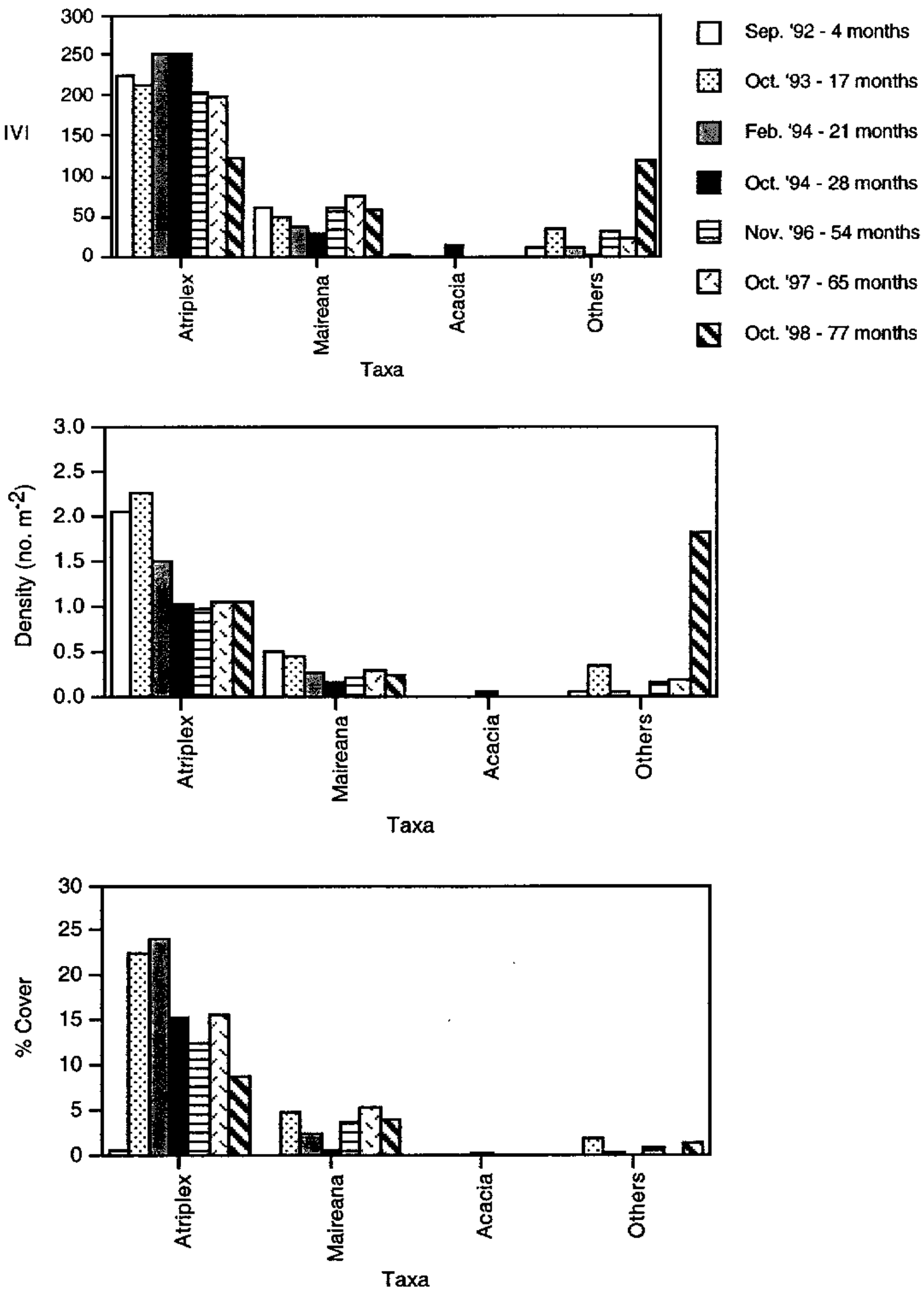


FIGURE 3.1.5.7: Change in plant density, revegetation cover, and Importance Value Index (IVI) for dominant taxa recorded in the 50 kg ha[-1] fertiliser treatment between September '92 and October '98.

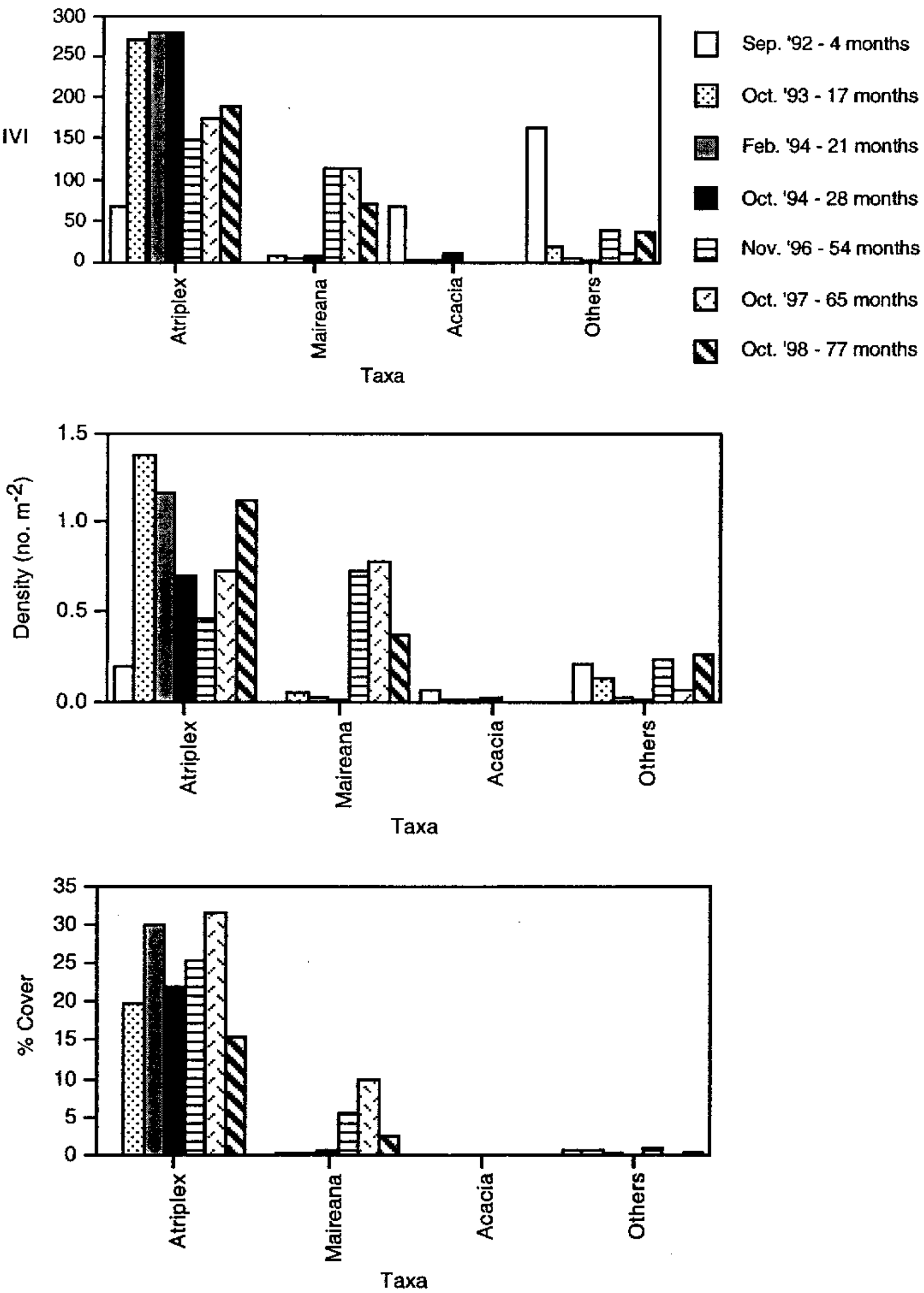


FIGURE 3.1.5.8: **Change in plant density, revegetation cover, and Importance Value Index (IVI) for dominant taxa recorded in the 100 kg ha^{-1} fertiliser treatment between September '92 and October '98.**

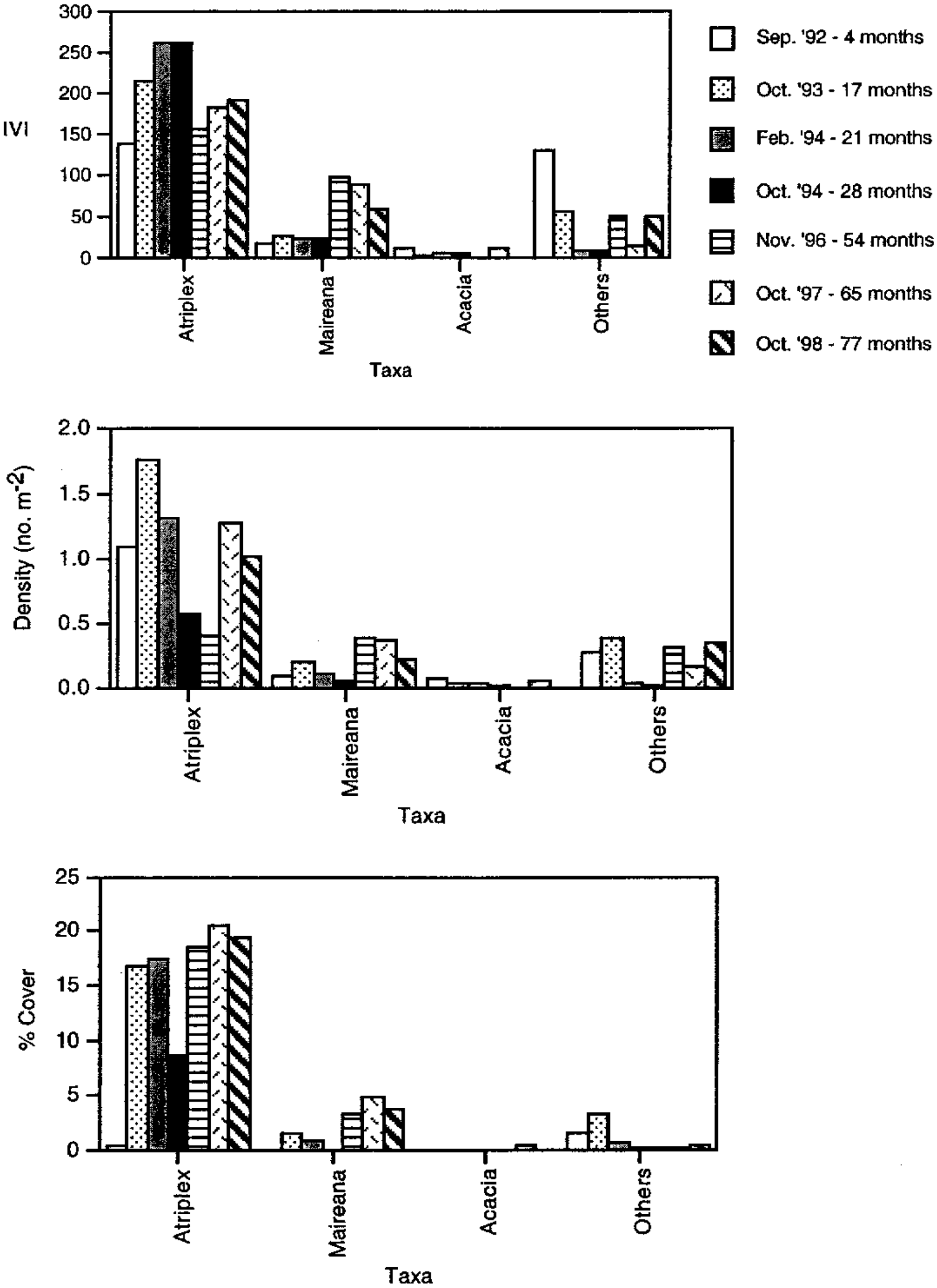


FIGURE 3.1.5.9: Change in plant density, revegetation cover, and Importance Value Index (IVI) for dominant taxa recorded in the 150 kg ha^{-1} fertiliser treatment between September '92 and October '98.

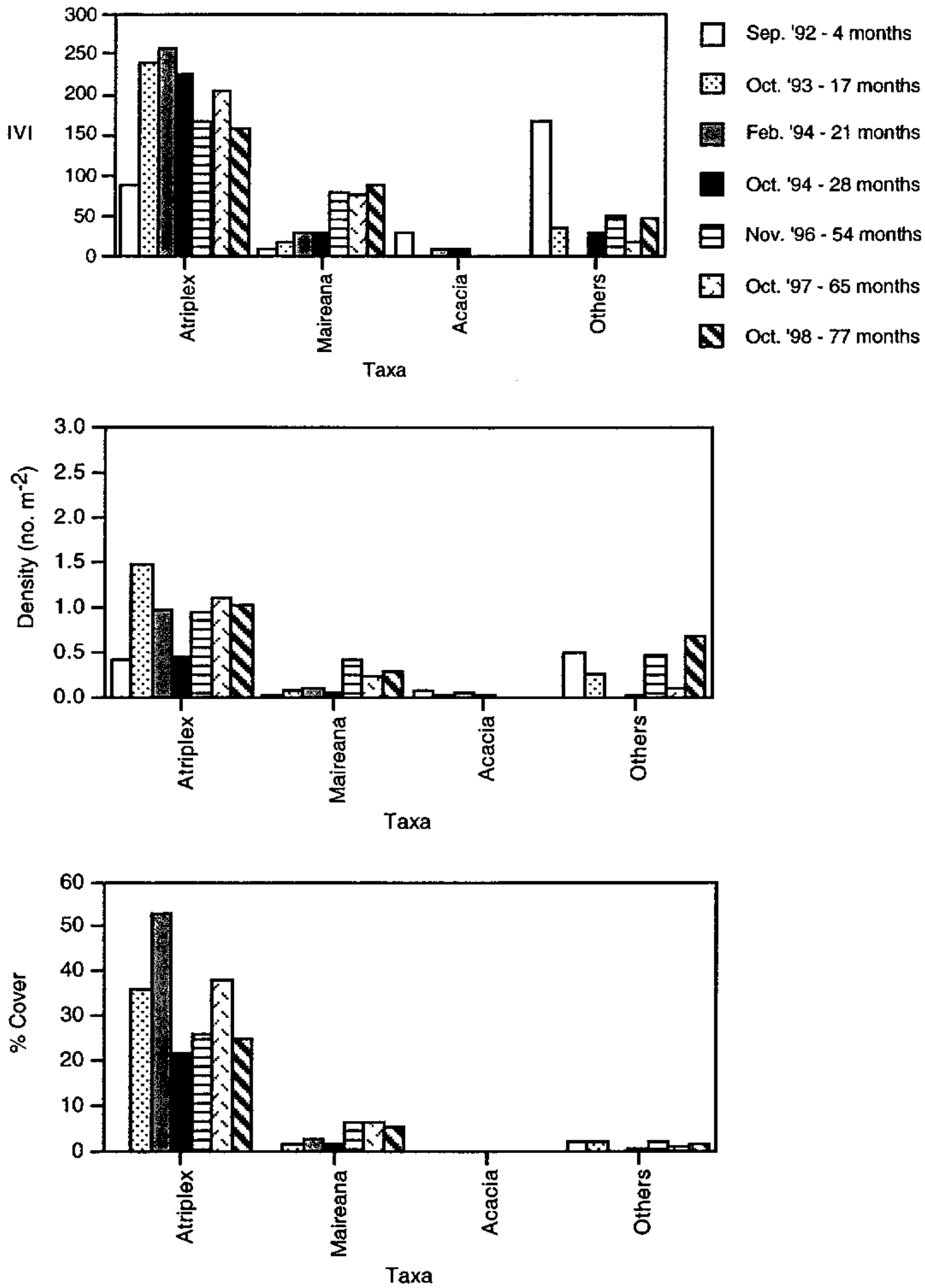
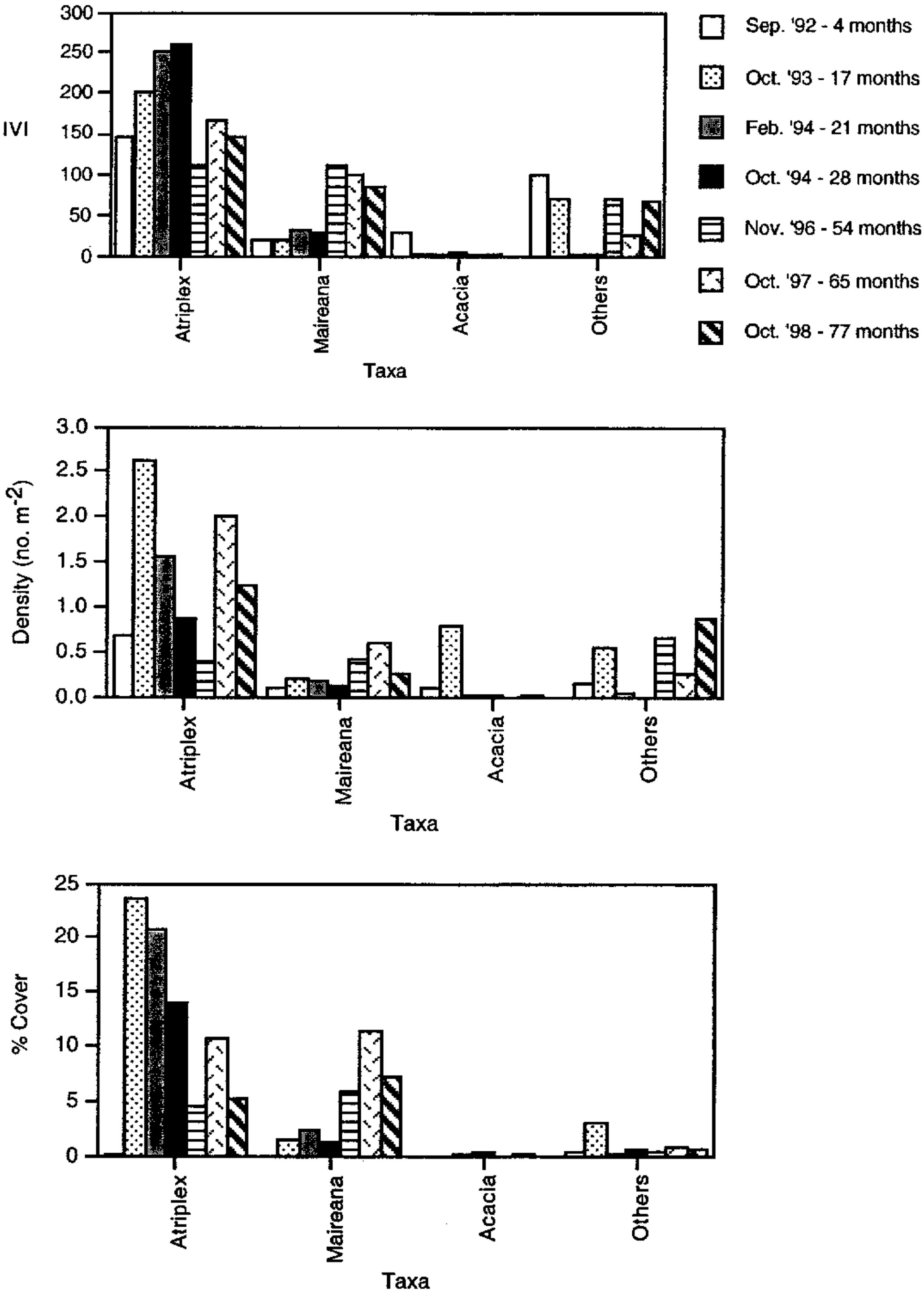


FIGURE 3.1.5.10: Change in plant density, revegetation cover, and Importance Value Index (IVI) for dominant taxa recorded in the 200 kg ha^{-1} fertiliser treatment between September '92 and October '98.



3.1.6 1992 Seeding Trial

Rehabilitation Strategy

Parameter	Technique
Establishment Date	May 1992
Slope of Topography	20° batters
Revegetation Medium	Topsoil cover to 1 m depth in parts, over saline oxidised waste
Surface Treatment	Conventional contour ripping using a D6 dozer to 0.5 m depth at 1 m intervals
Fertiliser Treatment	Fertiliser spread at 150 kg ha^{-1} (9.0%N, 3.5%P, 7.4%K, 0.1%Cu, 0.1%Zn, 1.0%Fe, and 100 ppm Mn & Mo)
Seeding Method	Mechanical
Seeding Rate	8.3 kg ha^{-1} with a mixture of chenopod, acacia and eucalyptus

Results and Comments

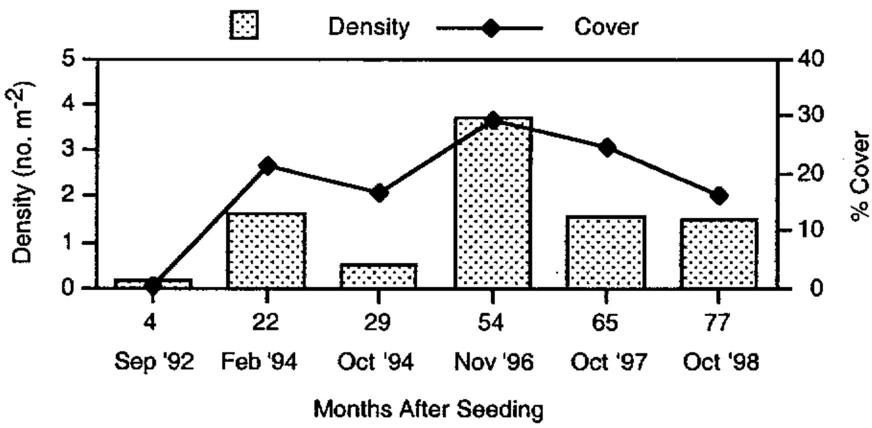
The upper topsoil medium was initially saline (ECe 35 dS m^{-1}) and acidic (pH 5.8), with the topsoil layer contaminated through capillary rise of salts from underlying oxidised waste. However, surface salinity decreased over time to average 12 dS m^{-1} ECe 77 months after seeding (Figure 3.1.6.1). Over the same period pH increased and was neutral in October '98 (mean pH 6.8).

The first assessment occurred just four months following seeding, when much of the revegetation was at a juvenile stage with few plants taller than 10 cm in height. Twenty-two months after seeding (third growing season), plant density averaged 1.6 stems m^{-2} with 21 percent ground cover. Drought conditions experienced during 1994 (Appendix 1) reduced both plant density (0.5 stems m^{-2}) and revegetation cover (17 percent). However, both parameters had recovered to pre-disturbance levels by November '96 (3.7 stems m^{-2} and 29 percent) and remained stabilise in October '97 and October '98 (1.5 stems m^{-2} and 20 percent, Figure 3.1.6.1).

High soil salinity favoured the establishment of chenopods, particularly *Atriplex* and *Maireana* species. *Atriplex* was the dominant taxa recorded to October '98;

however, *Maireana* has progressively increased in dominance over time (Figure 3.1.6.3). Seven years after seeding *Atriplex* approximate 1.0 stem m^{-2} and provide 10-15 percent foliage cover and *Maireana* approximate 0.5 stems m^{-2} with 5 percent ground cover (Figure 3.1.6.2). *Acacia* species were recorded within the rehabilitation during the first growing season, but did not survive in high numbers.

FIGURE 3.1.6.1: Annual change in plant density and revegetation cover (n=8), and soil salinity and pH (n=24) between September '92 and October '98.



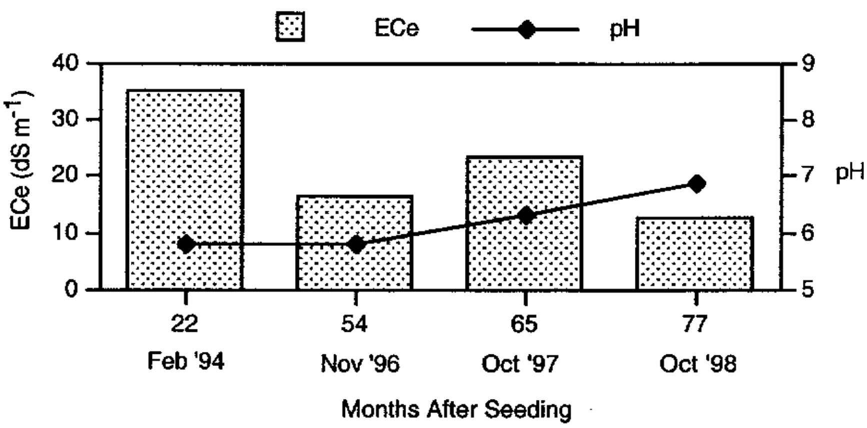
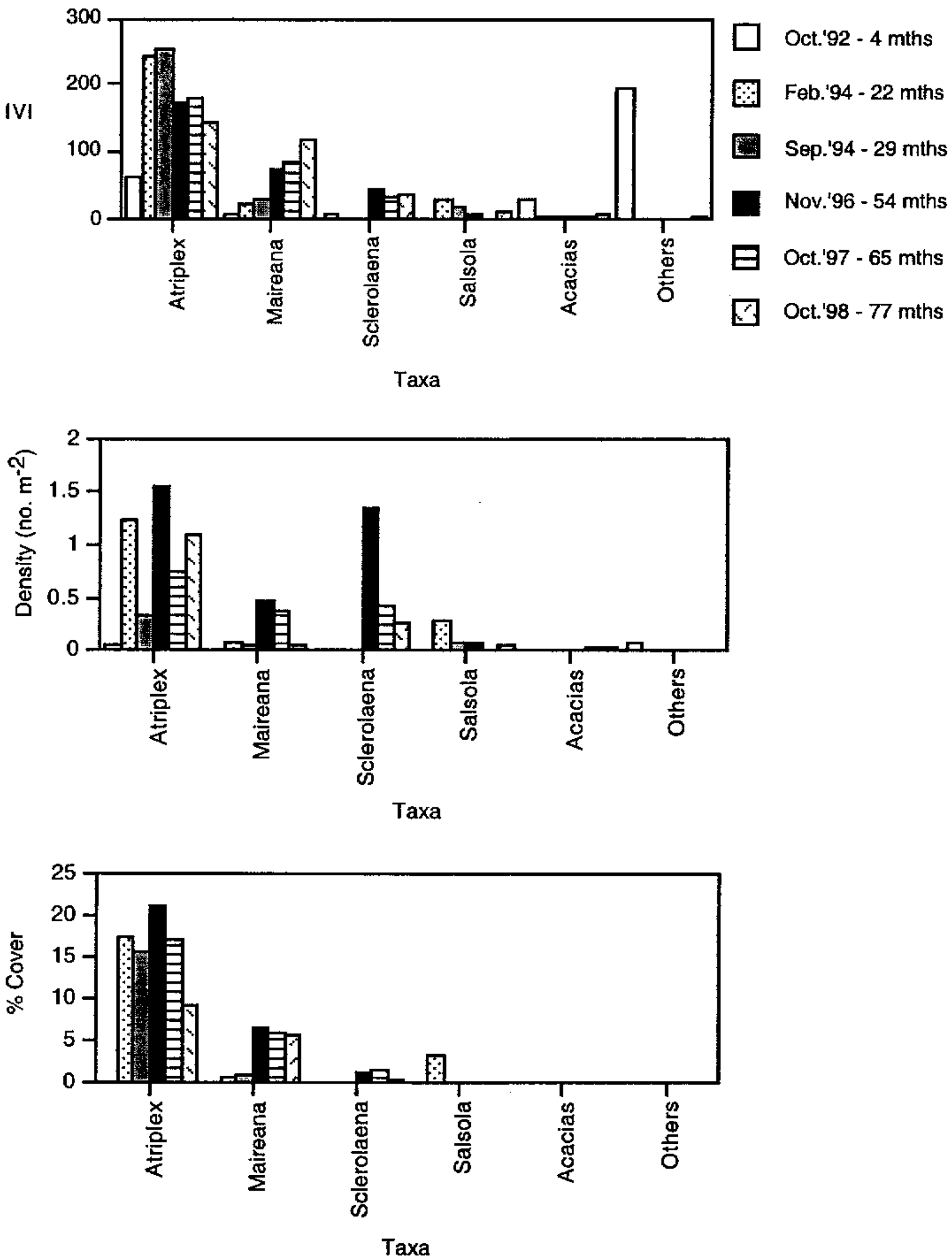


FIGURE 3.1.6.2: Change in Importance Value Index (IVI), plant density, and revegetation cover for dominant taxa recorded in the 1992 Seeding Trial between September '92 and October '98.



3.1.7 1994 Rehabilitation - Childe Harold Waste Dump

Rehabilitation Strategy

Parameter	Technique
Establishment Date	February 1994
Slope of Topography	20° batters
Revegetation Medium	Topsoil spread to 0.5 m depth over saline oxidised waste (high clay content)
Surface Treatment	Conventional contour ripping using a D6 dozer to 0.5 m depth at 1 m intervals
Experimental Treatments	none
Seeding Method	Mechanical
Seeding / Fertiliser Rate	32 species sown at 7.9 kg ha^{-1}, and fertiliser spread at 100 kg ha^{-1} - super copper zinc molybdenum (8.3%P, 0.6%Cu, 0.3%Zn, 600 ppm Mo, 10%S)

Results and Comments

A comprehensive seed mixture (Appendix 2) was sown into mildly saline topsoil (approximating 5 dS m^{-1} ECe) in February '94. Surface salinity remained mildly saline up to 56 months after seeding (October '98, see Figure 3.1.7.1).

The first rehabilitation assessment was made in November '96, 32 months after seeding. A total of 37 revegetation species were recorded at a density of 5.1 stems m^{-2}, with ground coverage approximating 20 percent (Figure 3.1.7.1). *Atriplex* species were initially the important revegetation component (Figure 3.1.7.2), establishing in high numbers (Figure 3.1.7.3) and providing large ground coverage (Figure 3.1.7.4). The annuals *A. codonocarpa* and *A. semilunaris* were recorded at high individual densities of 1.4 and 0.5 stems m^{-2} respectively. Other important taxa represented in the revegetation were *Maireana, Sclerolaena, Acacia, Senna* and *Eucalyptus.* Domestic stock (sheep) were observed grazing the revegetation 32 months after seeding, attracted to the area by a permanent water source situated in close proximity to the north.

By October '97 (44 months after seeding) mean plant density and species richness had decreased to average 1.9 stems m^{-2} and 28 species; revegetation cover remained steady averaging 19 percent (Figure 3.1.7.1). However, the important taxa recorded 12 months earlier were well represented in the revegetation. High numbers of *A. codonocarpa* were again recorded (0.5 stems m^{-2}), and *A. nummularia* provided 7 percent ground cover. *Maireana brevifolia* and *M. triptera* also provided relatively high ground coverage of 4 and 2 percent respectively.

Plant density increased to its highest point during October '98 (56 months after seeding), averaging 3.2 stems m^{-2} (Figure 3.1.7.1). Ground cover again remained stable at 18 percent. The instability in plant density reflected the impact from overgrazing along the northern batter where perennial species had been replaced by a short-lived cover of annuals. The density of *Atriplex codonocarpa, A. holocarpa* and *A. semilunaris* was elevated along the northern batter in October '98 (Figure 3.1.7.3). The southern batter of the Childe Harold Waste Dump however, was situated further from the watering point and had been subjected to lower grazing pressure (Figure 3.1.7.5); this was reflected by higher plant species richness and revegetation cover, and lower plant density. Established species along the southern batter include *Eucalyptus* spp., *A. nummularia* and *Maireana brevifolia.*

Rangeland around the Childe Harold Waste Dump was de-stocked during 1999 and the watering point closed. Remedial earthworks and reseeding has now occurred along the northern batter.

FIGURE 3.1.7.1: Change in plant density and % ground cover (n=11), and soil salinity and pH (n=33) for the 1994 Seeding of Childe Harold Waste Dump; 32 - 56 months after seeding.

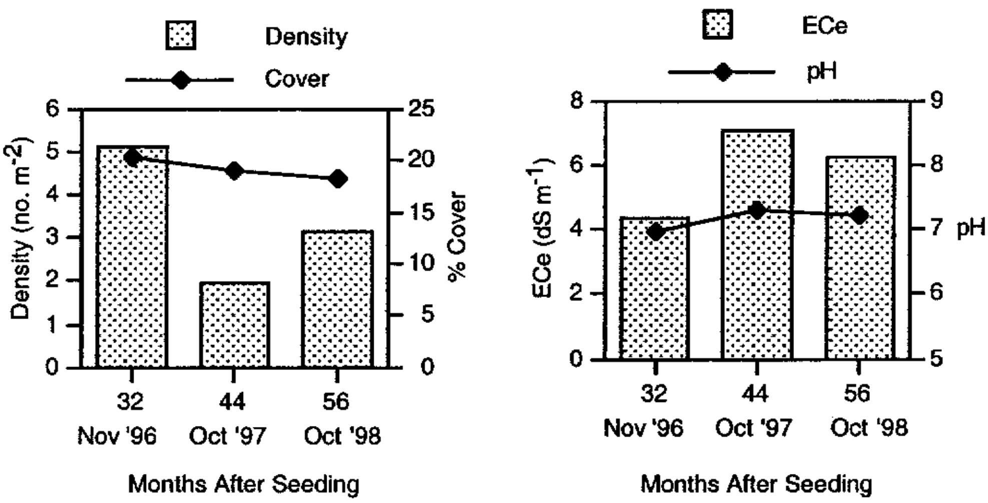


FIGURE 3.1.7.2: Change in Importance Value Index (IVI) for important revegetation taxa recorded over the 1994 Seeding of Childe Harold Waste Dump; 32 - 56 months after seeding.

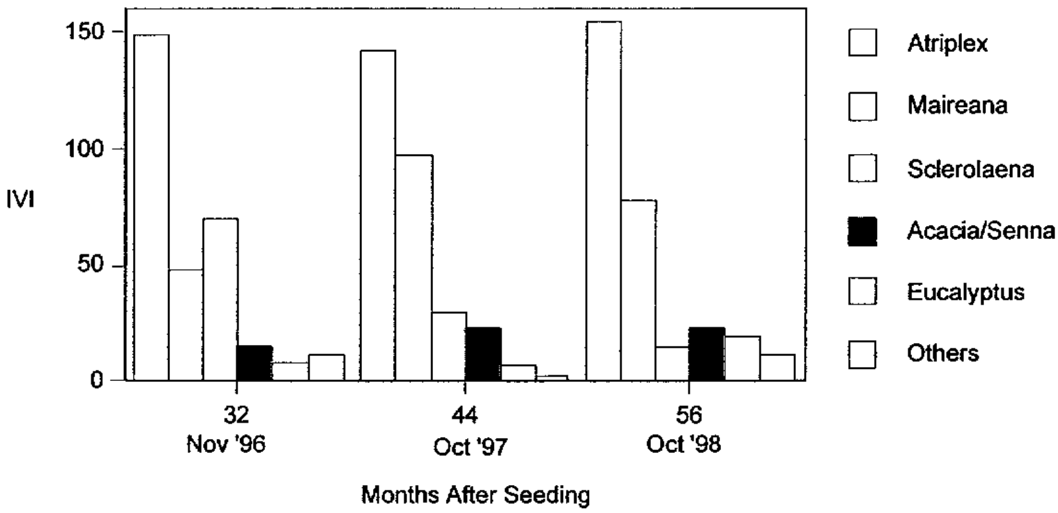


FIGURE 3.1.7.3: Change in plant density for important revegetation taxa recorded over the 1994 Seeding of Childe Harold Waste Dump; 32 - 56 months after seeding.

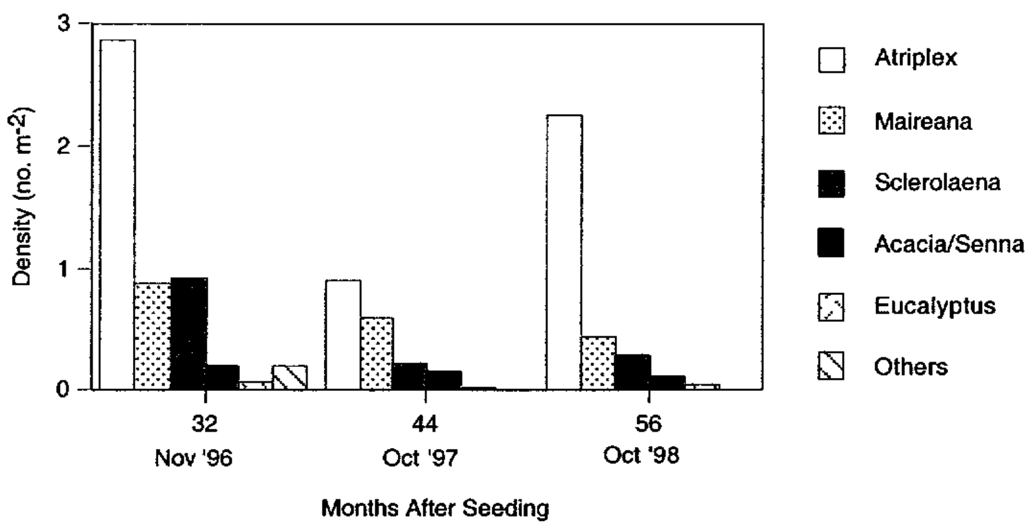


FIGURE 3.1.7.4: Change in % ground cover for important revegetation taxa recorded over the 1994 Seeding of Childe Harold Waste Dump; 32 - 56 months after seeding.

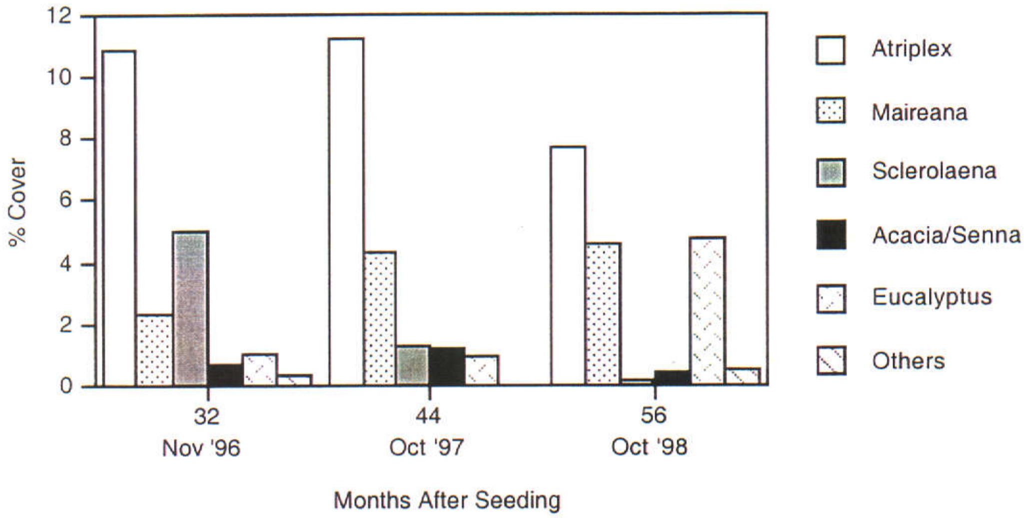


FIGURE 3.1.7.5: Low grazing pressure on the southern side of Childe Harold Waste Dump has had minimal impact on revegetation.

3.1.8 1993 Seeding Trial

Rehabilitation Strategy

Parameter	Technique
Establishment Date	April 1993
Slope of Topography	20° batters
Revegetation Medium	Topsoil and sub-soil caprock to 2 m depth blasted from the advancing face of an open cut was spread to 0.5 m over saline oxidised waste
Surface Treatment	Conventional contour ripping using a D6 dozer to 0.5 m depth at 1m intervals
Experimental Treatments	none
Seeding Method	Hand broadcast
Seeding / Fertiliser Rate	A standard chenopod seed mix including additional hard seeded species was sown at 15.9 kg ha^{-1}, with fertiliser spread at 50 & 100 kg ha^{-1} - super copper zinc molybdenum fertiliser (8.3%P, 0.6%Cu, 0.3%Zn, 600 ppm Mo, 10%S)

Results and Comments

Surface soil salinity is a key factor controlling revegetation development in arid and semi-arid zones. During the first growing season surface salinity over the 1993 rehabilitation surfaces was similar to that recorded at the analogue site of most similar vegetation structure and composition, *Atriplex bunburyana* Shrubland (mean ECe 5 and 8 dS m^{-1} respectively, Figures 3.1.8.1 & 3.1.8.2). Over the proceeding assessment period however, salts were leached from the upper profile of the rehabilitation site and surface salinity progressively decreased (Figure 3.1.8.2).

Elevated plant density recorded during the initial growing season (2.5 stems m^{-2}) decreased over the following two years to average 1.0 stem m^{-2} in October '95, 30 months after seeding (Figure 3.1.8.3). Plant density between October '95 and October '98 remained stable. Revegetation cover responded differently to plant density. During the initial two growing seasons ground cover increased rapidly before stabilising at between 20 to 30 percent (Figure 3.1.8.3).

Large variation in plant biodiversity parameters was recorded at some trials in response to disturbance, however recovery was usually rapid, albeit rainfall dependent. During the 1994 drought (Appendix 1), species richness for the 1993 rehabilitation decreased but overall revegetation cover increased. The continued increase in revegetation cover was due to the drought tolerance of the keystone species *Atriplex bunburyana,* which continued production under the low water regime and showed an increase in individual ground cover (Figure 3.1.8.4 and Figure 3.1.8.5).

Between October '97 (54 months after seeding) and October '98 (66 months after seeding), revegetation cover decreased from 25 to 16 percent, despite high average rainfall in the six months prior to the 1998 assessment (Figure 3.1.8.3). Individual ground cover for *A. bunburyana* decreased from 24 to 15 percent over the same period (Figure 3.1.8.3), with individual species density also decreasing from 0.92 to 0.57 stem m^{-2} (Figure 3.1.8.6). The decrease in density and ground cover occurred in response to the senescence and death of large numbers of maternal *A. bunburyana* plants (Figure 3.1.8.7). Over time an age-class structure is expected to develop within the rehabilitation and prevent large numbers of deaths in the keystone species from occurring together.

The important plant taxa recorded in the 1993 rehabilitation and *Atriplex bunburyana* Low Shrubland analogue complex, show high levels of similarity (Figure 3.1.8.8). *Atriplex bunburyana* is the dominant species in both communities, and appears to strongly influence the establishment of other plant taxa. *Atriplex bunburyana* has been the dominant rehabilitation species from the first growing season (IVI 128.4, 1.0 stems m^{-2}, 6.2 percent) through to the sixth growing season (IVI 240.1, 0.6 stems m^{-2}, 15.1 percent).

The initial establishment of *A. bunburyana* was favoured by a high individual seeding rate (624 g ha^{-1}), light seed weight (high number of seed g^{-1} - 377), and high seed viability (82 percent final germination, Appendices 2 and 3). The dry conditions experienced throughout 1994 also favoured this drought tolerant species, providing a competitive advantage over less tolerant species.

In October '93 *A. bunburyana* occurred with a suite of salt tolerant chenopods including *A. vesicaria* (IVI 68.8), *A. holocarpa* (IVI 39.8) and *A. codonocarpa* (IVI 33.6). In October '98 these chenopods were only minor components of the revegetation (IVI's < 5), occurring with low numbers of woody perennials including *Senna, Eucalyptus* and *Hakea* (Appendix 4).

FIGURE 3.1.8.1: *Atriplex bunburyana* Shrubland Analogue Site.

FIGURE 3.1.8.2: Change in upper soil salinity (ECe in dS m⁻¹, n=48) and pH (n=48) for the 1993 Seeding Trial (over time); *Atriplex bunburyana* analogue community assessed October '97.

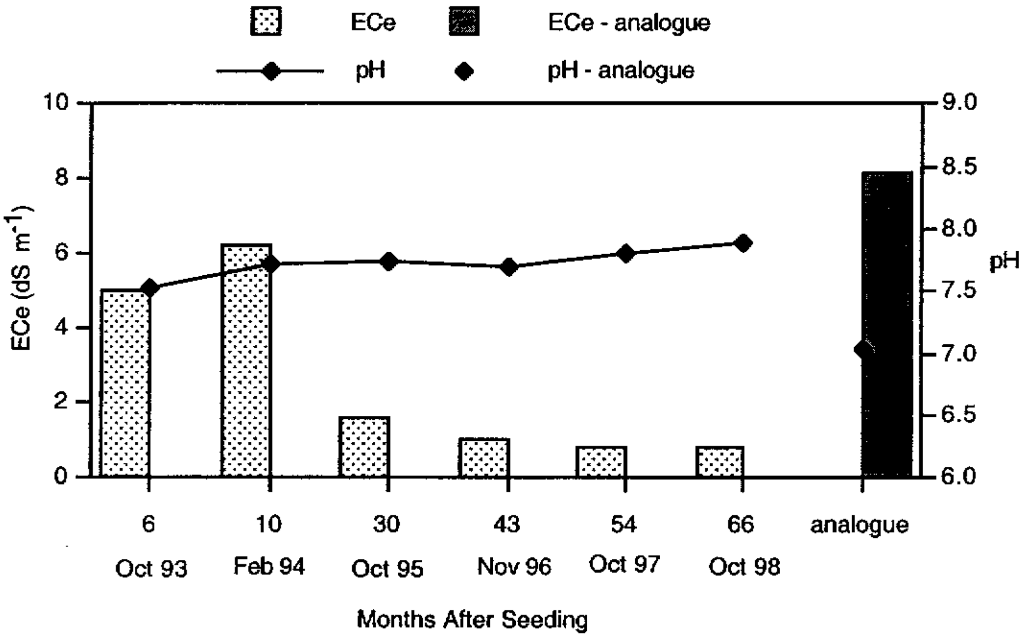


FIGURE 3.1.8.3: Change in plant density and ground cover (n=16) for the 1993 Seeding Trial (over time); *Atriplex bunburyana* analogue community assessed October '97. Mean monthly rainfall for the six month period prior to assessment indicated.

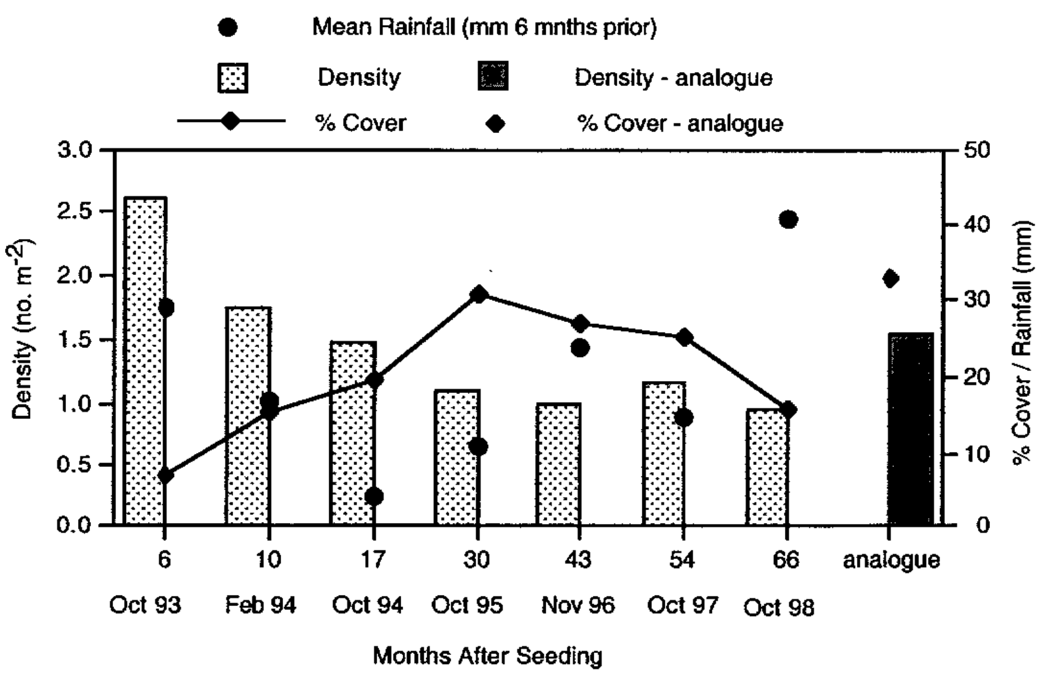


FIGURE 3.1.8.4: Percentage ground cover for important revegetation taxa recorded over the 1993 Seeding Trial (change over time, n=16), and *Atriplex bunburyana* analogue community (assessed October '97). Mean monthly rainfall for the six month period prior to assessment indicated.

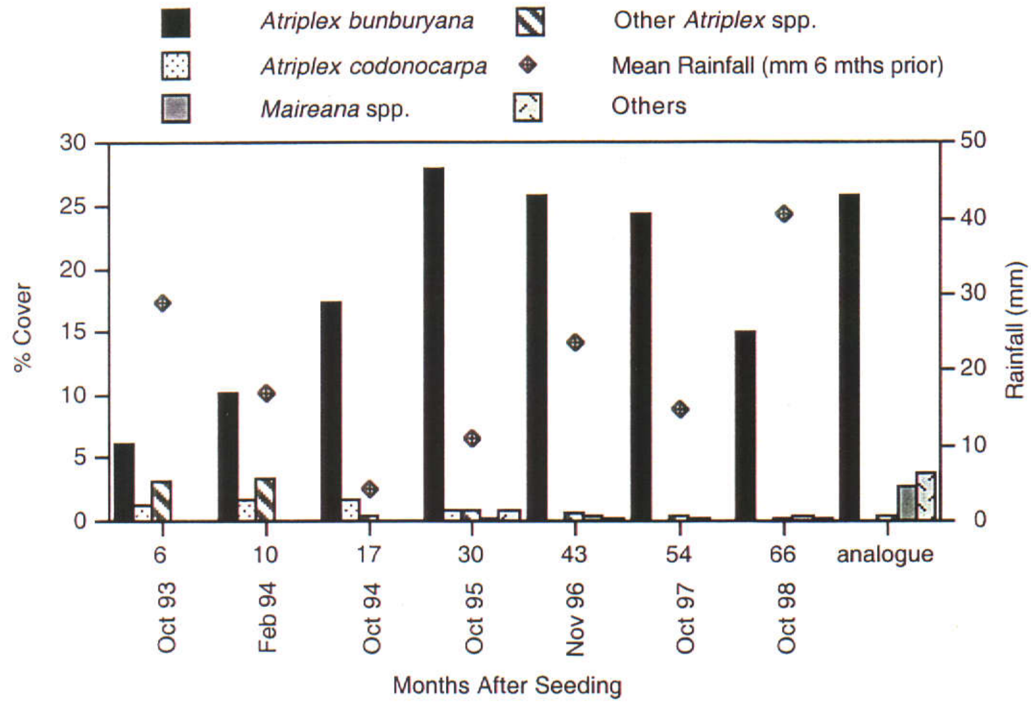


FIGURE 3.1.8.5: The development of *Atriplex bunburyana* was unaffected by the 1994 drought.

FIGURE 3.1.8.6: Plant density of important revegetation taxa recorded over the 1993 Seeding Trial (change over time, n=16), and *Atriplex bunburyana* analogue community (assessed October '97). Mean monthly rainfall for the six month period prior to assessment indicated.

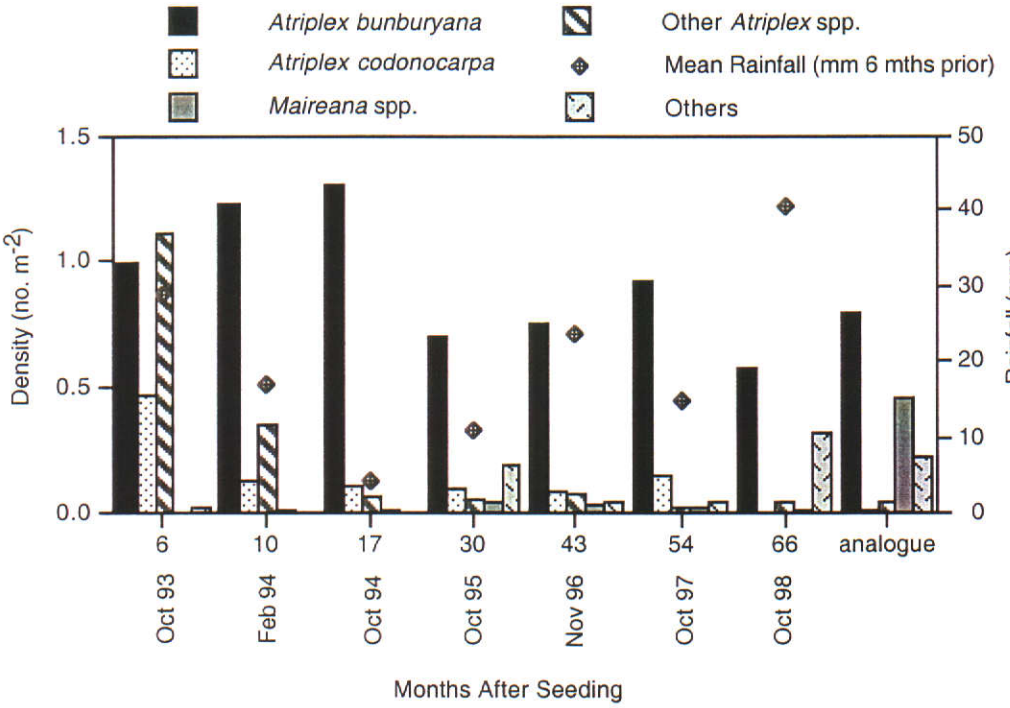


FIGURE 3.1.8.7: In October '98, 66 months after seeding, a decrease in the ground cover of *A. bunburyana* coincided with a large number of mature plant deaths.

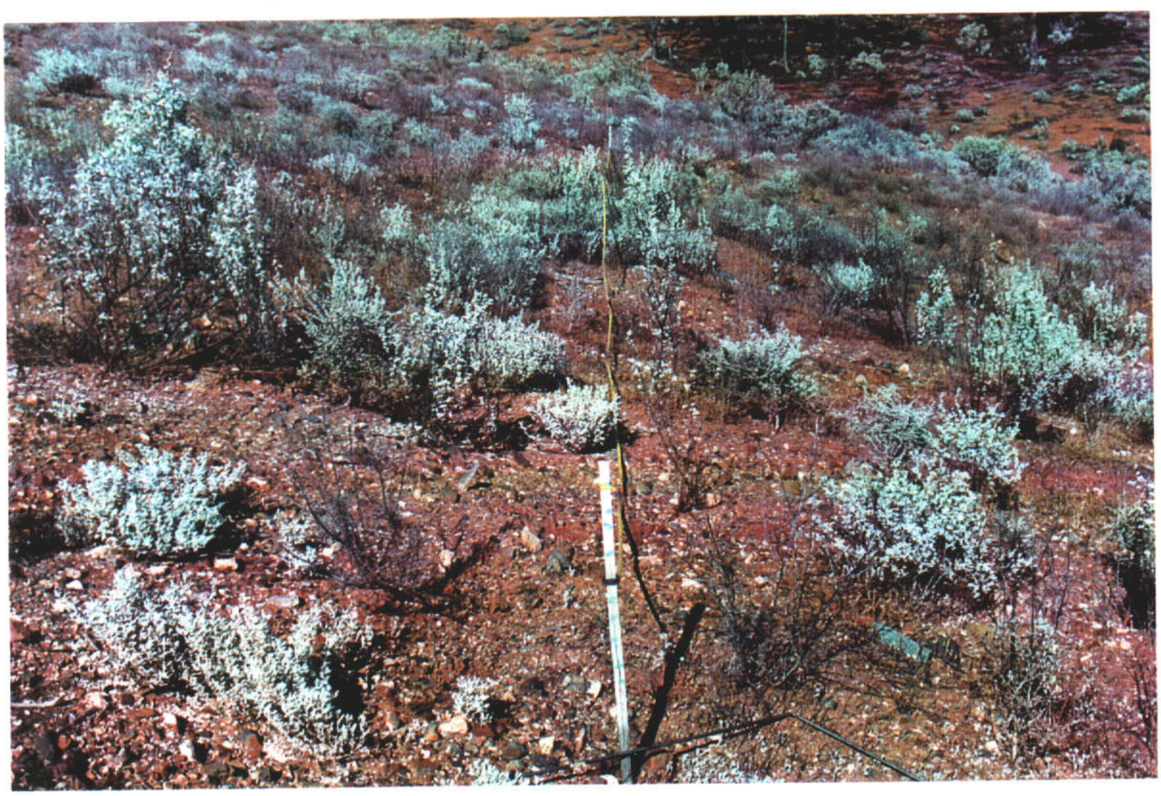
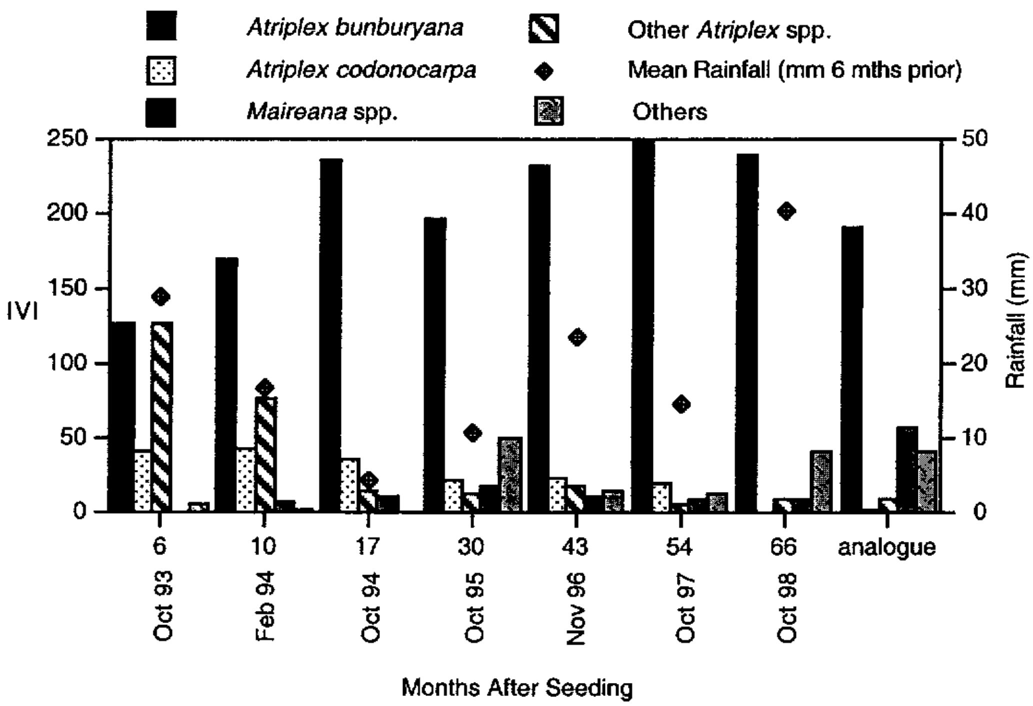


FIGURE 3.1.8.8: Importance Value Index (IVI) for important revegetation taxa recorded over the 1993 Seeding Trial (change over time, n=16), and *Atriplex bunburyana* analogue community (assessed October '97).
Mean monthly rainfall for the six month period prior to assessment indicated.



3.1.9 1994 Seeding - Lower Batter

Rehabilitation Strategy

Parameter	Technique
Establishment Date	February 1994
Slope of Topography	20° batters
Revegetation Medium	Topsoil/caprock mulch (surface 2 m blasted from an advancing open cut) spread to 0.5 m depth over extremely saline oxidised waste
Surface Treatment	Conventional contour ripping using a D6 dozer to 0.5 m depth at 1 m intervals
Experimental Treatments	none
Seeding Method	Hand broadcast
Seeding / Fertiliser Rate	30 species sown at 7.9 kg ha^{-1}, and fertiliser spread at 100 kg ha^{-1} - super copper zinc molybdenum (8.3%P, 0.6%Cu, 0.3%Zn, 600 ppm Mo, 10%S)

Results and Comments

The 1994 rehabilitation (lower batters) was sown in February '94. During the following eight months, rainfall totalled 21.6 mm (Appendix 1) and subsequently no seed germination occurred during the first growing season. In February '95, 197 mm of rainfall associated with Tropical Cyclone Bobby fell over the trial area (Appendix 1). This was preceded by above average rainfall in December '94 (72 mm) and January '95 (46 mm). High-intensity summer rainfall is an important cue to the germination of many hard seeded species occurring in arid regions.

The first revegetation assessment occurred in November '96, 32 months after seeding. The surface revegetation medium was non-saline and alkaline (Figure 3.1.9.1). Plant density averaged 2.29 stems m^{-2} with 27 percent ground cover. Plant density decreased over the proceeding two years to average 1.42 stems m^{-2} in October '98 (56 months after seeding). Revegetation cover remained relatively stable during this same period, averaging 29 percent in October '98 (Figure 3.1.9.1).

Carrichtera annua (Ward's weed) occurred in high numbers during the first assessment, averaging 0.84 stems m^{-2}. The extended period between seeding and the first rains provided an opportunity for a store of *C. annua* seed to become established between the rip lines. However, Ward's weed was rapidly out-competed by desirable local species, and occurred in low numbers during October '98.

The high numbers of annual *Atriplex* species recorded in November '96 increased the relative importance of this taxa (Figure 3.1.9.2). The fast growing annual *Atriplex codonocarpa* (IVI 65.4) was a major component, occurring at an individual density of 0.61 stems m^{-2} during the first growing season; density and cover of this taxa decreased over time in response to increased competition from perennial life forms.

Maireana and *Senna* were recorded in low numbers (Figure 3.1.9.3), but provided high individual ground coverage (Figure 3.1.9.4) in the first assessment. The relative importance of both taxa progressively increased between November '96 and October '98 (Figure 3.1.9.2). *Maireana brevifolia* (IVI 42.9), *M. pyramidata* (IVI 29.6), *Senna helmsii* (IVI 25.0) and *S. filifolia* (IVI 35.6) were important species from both taxa.

The importance of *Acacia* species in the revegetation also increased over time (Figure 3.1.9.2). The non-saline rehabilitation medium, and heavy cyclonic rainfall during the early stages of ecosystem development, were important factors enhancing the establishment of desirable woody perennials e.g. *Senna, Acacia* (Figure 3.1.9.5, Figure 3.1.9.6). High individual seeding rates for both genera was also beneficial to their field establishment (Appendix 2).

FIGURE 3.1.9.1: Change in plant density and % ground cover (n=5), and soil salinity and pH (n=15) for the 1994 Seeding Trial (batters), 32 - 56 months after seeding.

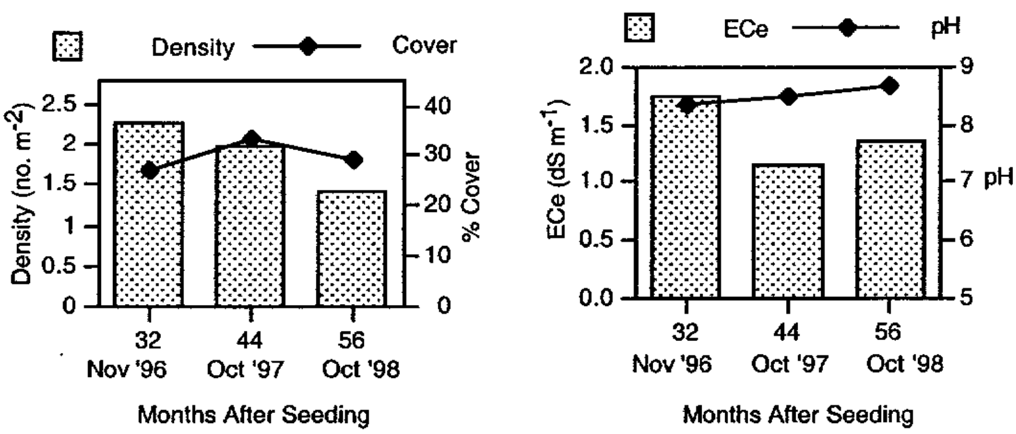


FIGURE 3.1.9.2: Change in Importance Value Index (IVI) for important revegetation taxa recorded over the 1994 Seeding Trial (batters); 32 - 56 months after seeding.

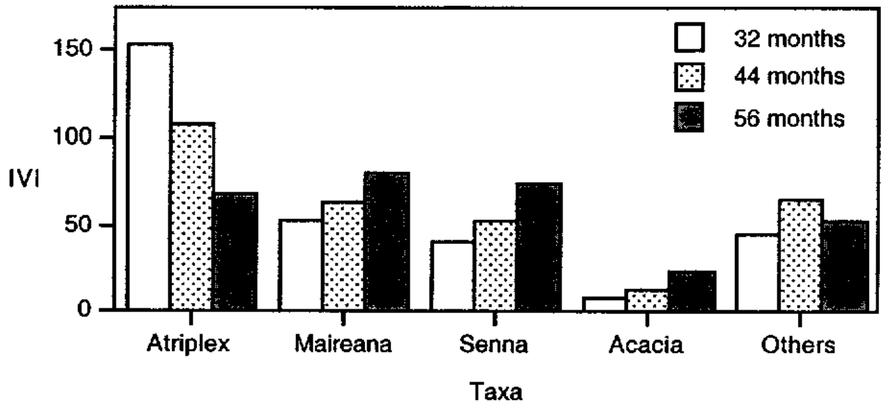


FIGURE 3.1.9.3: Change in plant density for important revegetation taxa recorded over the 1994 Seeding Trial (batters); 32 - 56 months after seeding.

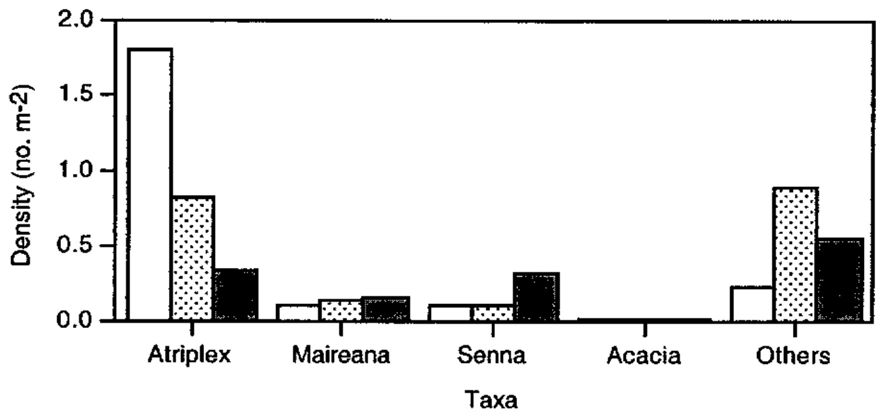


FIGURE 3.1.9.4: Change in % ground cover for important revegetation taxa recorded over the 1994 Seeding Trial (batters); 32 - 56 months after seeding.

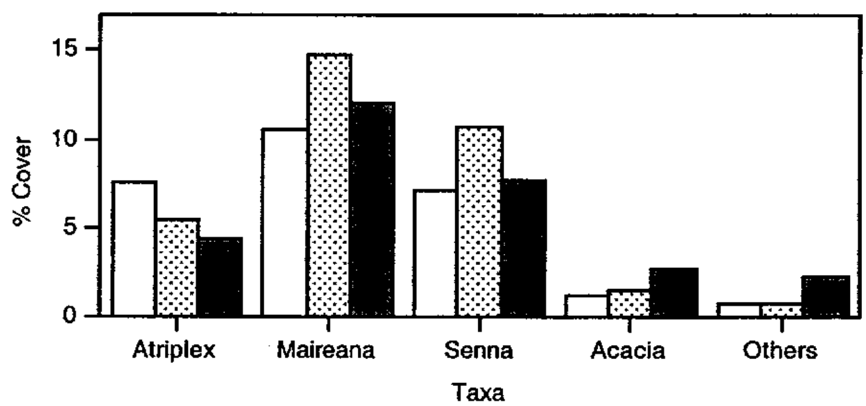


FIGURE 3.1.9.5: **The 1994 rehabilitation along the bottom batter, with adjacent undisturbed Mulga Woodland in the background.**

FIGURE 3.1.9.6: ***Acacia, Senna*** **and** ***Maireana*** **have all established successfully following heavy rainfall associated with Tropical Cyclone Bobby.**

3.1.10 1994 Seeding - Top Batter

Rehabilitation Strategy

Parameter	Technique
Establishment Date	February 1994
Slope of Topography	20° batters
Revegetation Medium	Topsoil/caprock mulch (surface 2 m blasted from an advancing open cut) spread to 0.5 m depth over extremely saline oxidised waste
Surface Treatment	Conventional contour ripping using a D6 dozer to 0.5 m depth at 1m intervals
Experimental Treatments	none
Seeding Method	Mechanical
Seeding / Fertiliser Rate	30 species sown at 7.9 kg ha^{-1}, and fertiliser spread at 100 kg ha^{-1} - super copper zinc molybdenum (8.3%P, 0.6%Cu, 0.3%Zn, 600 ppm Mo, 10%S)

Results and Comments

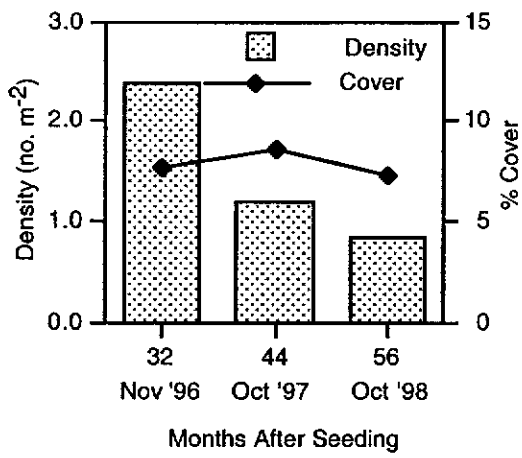
Surface soils remained non-saline and alkaline during the assessment period (Figure 3.1.10.1). In October '94, eight months after sowing, no seed germination was recorded, due to low rainfall; annual falls to October '94 totalled 56 mm (Appendix 1). Drought conditions ended in December '94 and were followed by Tropical Cyclone Bobby in February '95 (197 mm).

The first revegetation assessment was in November '96, 32 months after seeding. There was high plant density (2.4 stems m^{-2}) and relatively low revegetation cover (7.6 percent) (Figure 3.1.10.1). *Atriplex* occurred at elevated density, averaging 2.0 stems m^{-2}, with the annual species *A. codonocarpa* (IVI 108.8) and *A. holocarpa* (IVI 43.7) both significant contributors (1.55 and 0.44 stems m^{-2} respectively). It was *Maireana* spp., however, which provided the greatest revegetation cover of 4.8 percent. *Maireana georgei* (2.9 percent) and *M. triptera* (1.7 percent) were also prominent.

Overall plant density progressively decreased from 2.4 stems m^{-2} in November '96, to 1.2 stems m^{-2} in October '97, and 0.8 stems m^{-2} in October '98 (Figure 3.1.10.1). The numbers of *A. codonocarpa* decreased from 1.55 stems m^{-2} in

November '96 to 0.07 stems m^{-2} in October '98 (Appendix 4). Over the same period overall ground cover remained stable, ranging between 7.3 and 8.6 percent (Figure 3.1.10.1). There was, however, a shift in the taxa contributing to revegetation cover; *Maireana* cover halved in the 12 months between October '97 and October '98, while both *Senna* and *Acacia* exhibited increased ground coverage (Figure 3.1.10.2).

FIGURE 3.1.10.1: Change in plant density and revegetation cover (n=5), and soil salinity and pH (n=15) between November '96 and October '98.



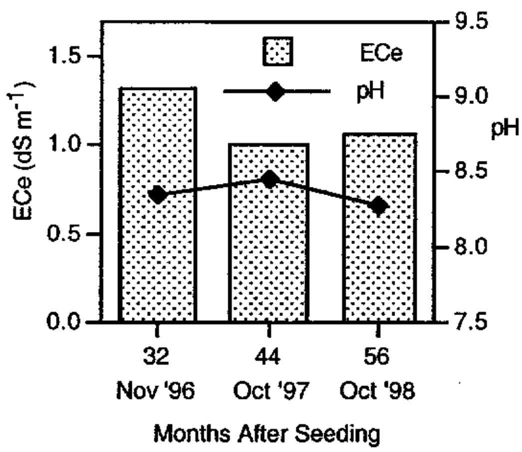
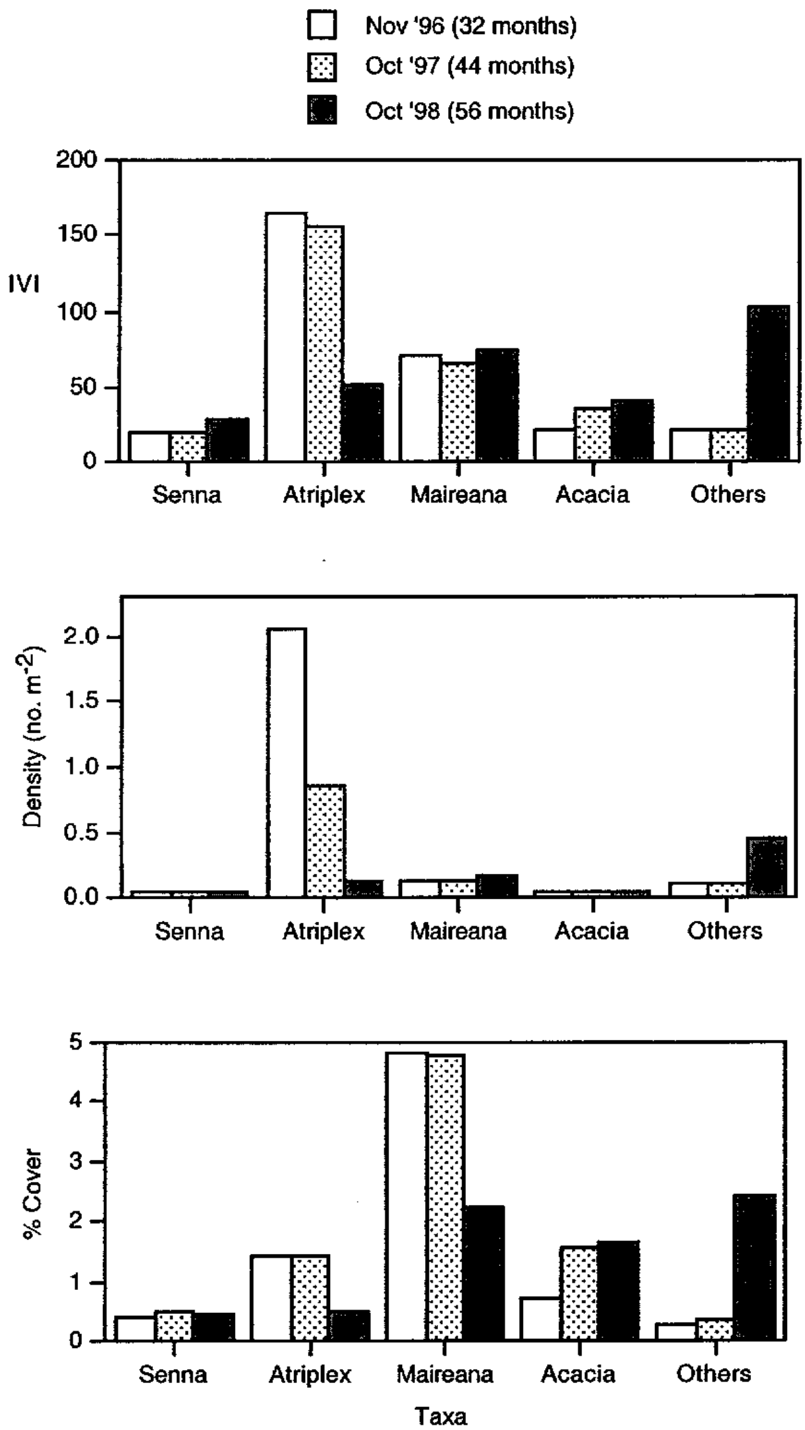


FIGURE 3.1.10.2: Change in Importance Value Index (IVI), plant density, and revegetation cover for dominant taxa recorded between November '96, October '97, and October '98.



3.1.11 Sunrise Dam - 1997 Rehabilitation

Rehabilitation Strategy

Parameter	Technique
Establishment Date	May 1997
Slope of Topography	15° batters
Revegetation Medium	Highly dispersible gypsum and aeolian quartz sands removed from low dunes bordering a large ephemeral salt lake, spread over highly saline waste rock mined from depth
Surface Treatment	Conventional contour ripping using a D9 dozer to 1 m depth and at 1-1.5 m intervals
Experimental Treatments	Two fertiliser treatments 0 and 100 kg ha^{-1} (9.0%N, 3.5%P, 7.4%K, 0.1%Cu, 0.1%Zn, 1.0%Fe, and 100 ppm Mn & Mo)
Seeding Method	Hand Broadcast
Seeding Rate	14.8 kg ha^{-1} with a mixture dominated by chenopods, but including other salt tolerant species collected locally

Results and Comments

Initial soil analysis confirmed that the underlying waste rock was extremely saline (mean ECe 122.1 dS m^{-1}). The gypsum cover was approximately one third the salinity of underlying materials, but was also classified as being extremely saline (mean ECe 43.6 dS m^{-1}). Both soil types were alkaline, with pH ranging from 7.00 to 8.02. Twenty-four months after sowing, the upper gypsiferous surface remained saline and alkaline in reaction for both fertiliser treatments (Table 3.1.11.1).

The application of fertiliser had no significant effect on either plant density or revegetation cover, 24 months after sowing (Table 3.1.11.1). Plant density and revegetation ground cover averaged 1.1 stems m^{-2} and 8.0 percent for the unfertilised treatment, and 1.2 stems m^{-2} and 7.5 percent for the fertilised treatment (Table 3.1.11.1). A total of 18 species was recorded within each treatment, 13 of these being direct seeded varieties (Figure 3.1.11.1, Appendix 4).

The Chenopodiaceae was the dominant family present in the revegetation (17 species). The three direct seeded species *Atriplex codonocarpa, A. vesicaria* and *Maireana georgei* were all prominent, recorded with *Sclerolaena fimbriolata* and *S. densiflora* which likely volunteered from the topsoil resource. Two *Zygophyllum* species had also successfully colonised over the waste dump. Both were sown varieties but are also likely to have germinated from the topsoil seed store.

The analogue vegetation complex, occurring in rangeland surrounding the Sunrise Dam Gold Mine and undisturbed by current mining activities (*Frankenia* Low Shrubland), was assessed to provide a 'benchmark' with which to compare rehabilitation parameters (Appendix 5). Surface soils for the rehabilitation and analogue sites were both saline and alkaline (Table 3.1.11.1).

Species richness was comparable between the two rehabilitation fertiliser treatments (18 species each) and the analogue site (20 species). Importantly, keystone taxa recorded at the analogue site, *Frankenia, Atriplex vesicaria* and *Enneapogon caerulescens* were well represented in the rehabilitation. Plant density and foliage cover were both lower in the rehabilitation treatments in comparison to the analogue site (Table 3.1.11.1), however, revegetation was only 24 months old at the time of assessment. The month of sowing, May '97, was later than is desirable, and therefore revegetation was unable to take full advantage of the more reliable rainfall months experienced during the first growing season.

Comparison between the fertiliser treatments and analogue site with respect to important plant taxa confirmed three taxa, *Disphyma, Frankenia* and grasses, were better represented at the analogue site (Figures 3.1.11.2 - 3.1.11.4). *Sclerolaena* was better represented in the rehabilitation. *Disphyma* was absent from the 1997 Rehabilitation and was not included in the seed mixture. *Frankenia* is a major component of the analogue vegetation complex, providing greater than 5 percent ground cover (Figure 3.1.11.4). In the first two growing seasons *Frankenia* successfully germinated and established over saline waste dump surfaces. Being a long lived but slow growing species, it is anticipated that a number of years will be required before the biodiversity parameters being measured compare with those recorded for the analogue site.

Grasses were more prominent within the analogue community in comparison to the waste dump surfaces. Time of assessment may have influenced this result, with the grasses recorded being annual life forms with seasonal establishment. The *Sclerolaena* species recorded over the waste dump *(S. densiflora, S. fimbriolata)* both volunteered from the topsoil seed store. *Sclerolaena fimbriolata* is a persistent species well suited to the saline surfaces associated with the fringes of salt lakes. It was represented at the analogue community. *Sclerolaena densiflora,* however, is a short lived coloniser which is not expected to persist over the waste dump in the longer term.

TABLE 3.1.11.1: Revegetation and soil parameters recorded for the 1997 Rehabilitation at Sunrise Dam Gold Mine (17-19 May 1999) (n=4 for each fertiliser treatment), and matching analogue community in adjacent rangeland (*Frankenia* Low Shrubland, n=9).

Treatment	Species Richness	Density (no. m^{-2})	% Cover	ECe (dS m^{-1})	pH
+ Fertiliser	18	1.250	7.51	39.80	7.67
- Fertiliser	18	1.100	7.98	39.95	7.70
ANOVA between Fert. treat.'s		F = 0.09, *P* = 0.779, df = 1,6	F = 0.02, *P* = 0.993, df = 1,6	F = 0.02, *P* = 0.985, df = 1,22	F = 0.24, *P* = 0.632, df = 1,22
Analogue	20	2.311	16.45	23.17	7.14
ANOVA between rehab. & analogue		F = 4.52, *P* = 0.031, df = 2,14	F = 8.97, *P* = 0.003, df = 2,14	F = 0.88, *P* = 0.426, df = 2,25	F = 45.22, *P* = 0.001, df = 2,25

FIGURE 3.1.11.1: 1997 Rehabilitation: 24 months after direct seeding.

FIGURE 3.1.11.2: **1997 Rehabilitation, 24 months after seeding: Importance Value Index (IVI) for dominant taxa, with comparison between the waste dump revegetation (two fertiliser treatments) and adjacent analogue community.**

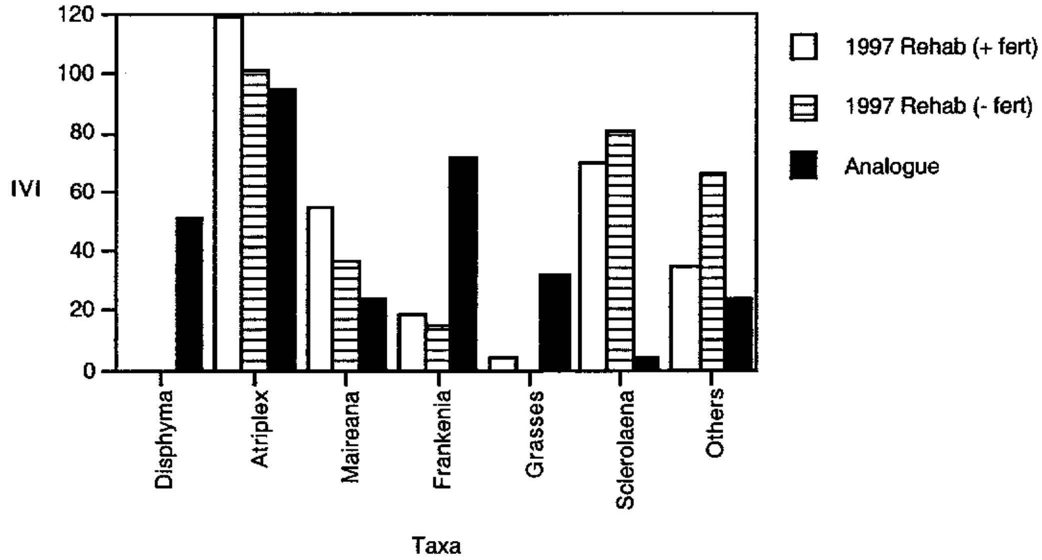


FIGURE 3.1.11.3: **1997 Rehabilitation, 24 months after seeding: Revegetation density of dominant taxa, with comparison between the waste dump revegetation (two fertiliser treatments) and adjacent analogue community.**

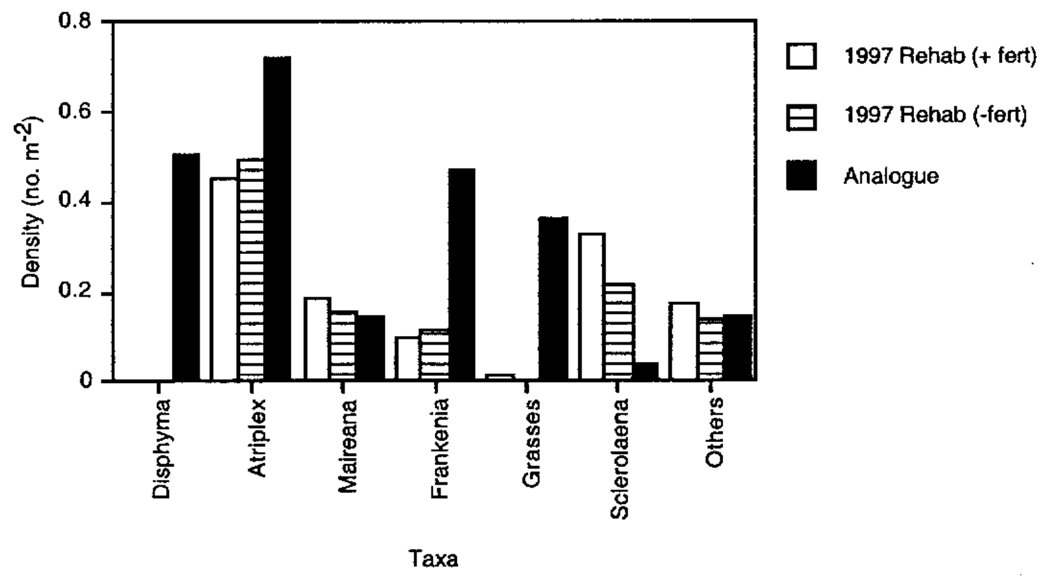
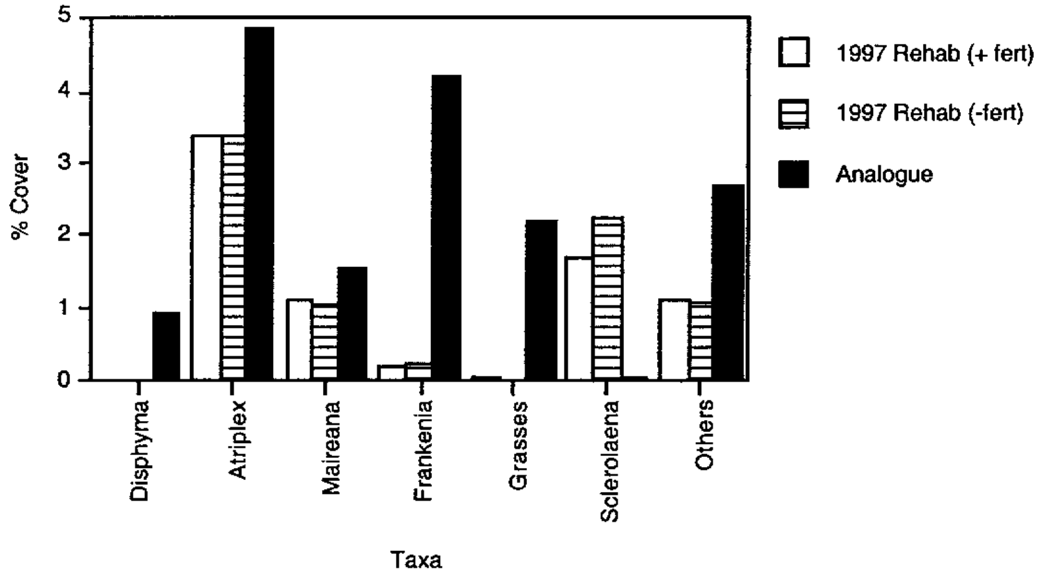


FIGURE 3.1.11.4: **1997 Rehabilitation, 24 months after seeding: Plant cover (%) provided by dominant taxa, with comparison between the waste dump revegetation (two fertiliser treatments) and adjacent analogue community.**



3.1.12 Sunrise Dam - 1998 Rehabilitation

Rehabilitation Strategy

Parameter	Technique
Establishment Date	May 1998
Slope of Topography	15° batters
Revegetation Medium	Highly dispersible gypsum and aeolian quartz sands removed from low dunes bordering a large ephemeral salt lake, spread over highly saline waste rock mined from depth
Surface Treatment	Conventional contour ripping using a D9 dozer to 1 m depth and at 1-1.5 m intervals
Experimental Treatments	Two fertiliser treatments 0 and 100 kg ha^{-1} (9.0%N, 3.5%P, 7.4%K, 0.1%Cu, 0.1%Zn, 1.0%Fe, and 100 ppm Mn & Mo)
Seeding Method	Hand Broadcast
Seeding Rate	9.2 kg ha^{-1} with a mixture dominated by chenopods, but including other salt tolerant species collected locally

Results and Comments

Twelve months after sowing, surface soils over the 1998 rehabilitation area remain saline (ECe 50 - 70 dS m^{-1}) and alkaline for both fertiliser treatments (Table 3.1.12.1). The analogue site was also saline (ECe 23 dS m^{-1}).

Similar to the 1997 Rehabilitation, fertiliser had no significant effect on either plant density or revegetation cover, 12 months after sowing (Table 3.1.12.1). Plant density and revegetation cover averaged 1.50 stems m^{-2} and 5.8 percent for the fertilised treatment, and 1.68 stems m^{-2} and 5.9 percent for the unfertilised treatment. Twenty-six species and 31 species were recorded within each treatment respectively (Appendix 4), compared to 20 species from the analogue community (Appendix 5). Fourteen of the species recorded in the revegetation were direct seeded varieties.

The Chenopodiaceae was the dominant family present in the revegetation (21 species). Within the fertilised treatment dominant species were *Disphyma crassifolium* (IVI 46.2), *Eragrostis dielsii* (IVI 38.1), *Atriplex vesicaria* (IVI 33.5), *Maireana pyramidata* (IVI 30.6), *Frankenia pauciflora* (IVI 28.0), *Atriplex* *codonocarpa* (IVI 29.4) and *Enchylaena tomentosa* (IVI 14.8); the same suite of species were prominent in the unfertilised treatment.

Higher species richness was recorded for the two rehabilitation fertiliser treatments in comparison to the analogue site, but both plant density and foliage cover were lower for the rehabilitation (Table 3.1.12.1, Figure 3.1.12.1).

Important plant taxa at the analogue and rehabilitation sites show high similarity with respect to importance value index (IVI) (Figure 3.1.12.2). Twelve months after sowing *Maireana* showed greater dominance in the rehabilitation compared to the analogue site, and correspondingly *Frankenia* was more dominant at the analogue site. Considering the young age of the rehabilitation, density of important taxa compared favourably with the analogue site (Figure 3.1.12.3). *Atriplex* and *Frankenia* provided significantly greater individual ground cover in the analogue community (range 4-5 percent). In the rehabilitation, corresponding cover was less than 2 percent (Figure 3.1.12.4), however revegetation was only 12 months old at the time of assessment.

TABLE 3.1.12.1: Revegetation and soil parameters recorded for the 1998 Rehabilitation at Sunrise Dam Gold Mine (17-19 May 1999) (n=12 for each fertiliser treatment), and matching analogue community in adjacent rangeland (*Frankenia* Low Shrubland, n=9).

Treatment	Species Richness	Density (no. m^{-2})	% Cover	ECe (dS m^{-1})	pH
+ Fertiliser	26	1.504	5.78	69.53	8.02
- Fertiliser	31	1.683	5.94	49.54	7.82
ANOVA between Fert. treat.'s		F = 0.35, P = 0.558, df = 1,22	F = 0.08, P = 0.777, df = 1,22	F = 3.10, P = 0.082, df = 1,70	F = 0.82, P = 0.369, df = 1,70
Analogue	20	2.311	16.45	23.20	7.14
ANOVA between rehab. & analogue		F = 3.07, P = 0.061, df = 2,30	F = 28.66, P = 0.001, df = 2,30	F = 3.11, P = 0.051, df = 2,68	F = 3.81, P = 0.027, df = 2,68

FIGURE 3.1.12.1: ***Frankenia*** **Low Shrubland (Analogue Site) occurs over the gypsiferous flats between Lake Carey and the 1998 Rehabilitation (lower batter).**

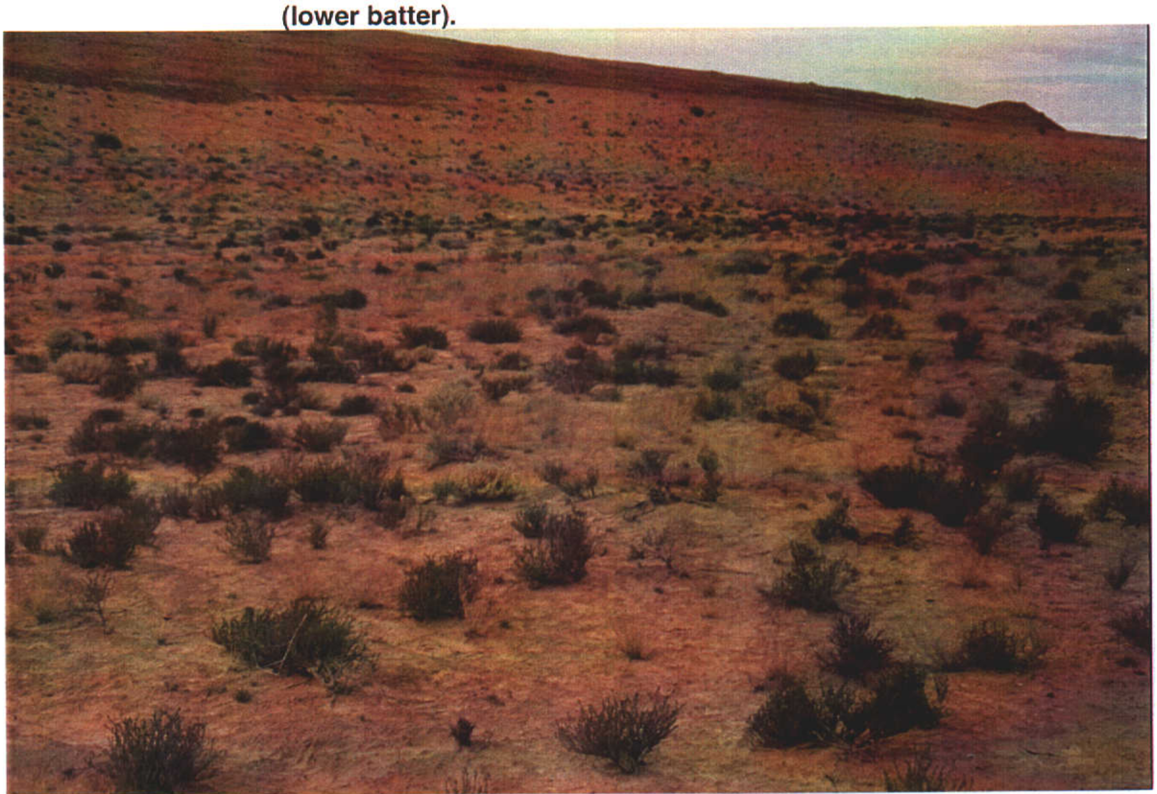


FIGURE 3.1.12.2: 1998 Rehabilitation, 12 months after seeding: Importance Value Index (IVI) for dominant taxa, with comparison between the waste dump revegetation (two fertiliser treatments) and adjacent analogue community.

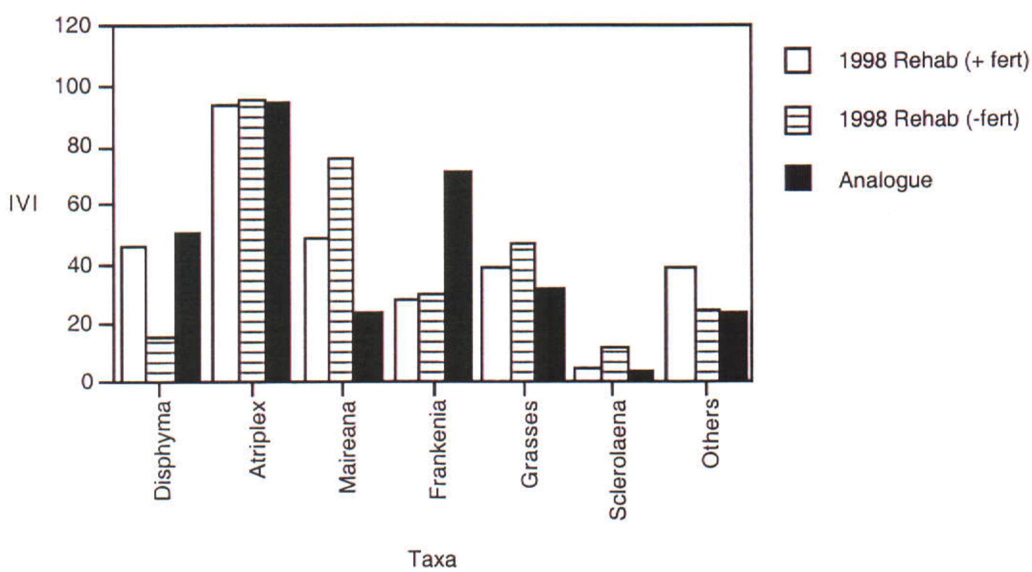


FIGURE 3.1.12.3: 1998 Rehabilitation, 12 months after seeding: Plant density of dominant taxa, with comparison between the waste dump revegetation (two fertiliser treatments) and adjacent analogue community.

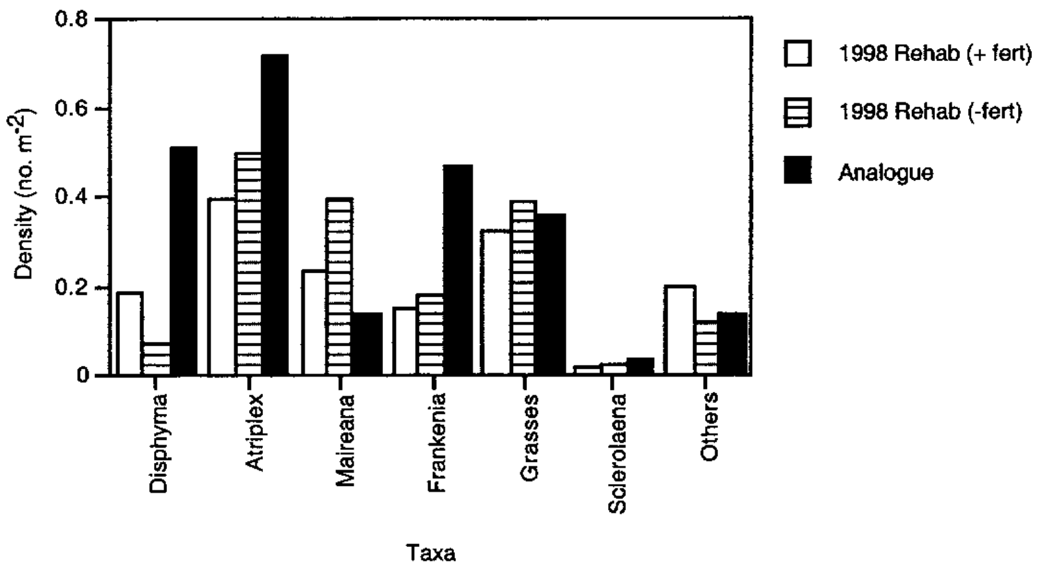
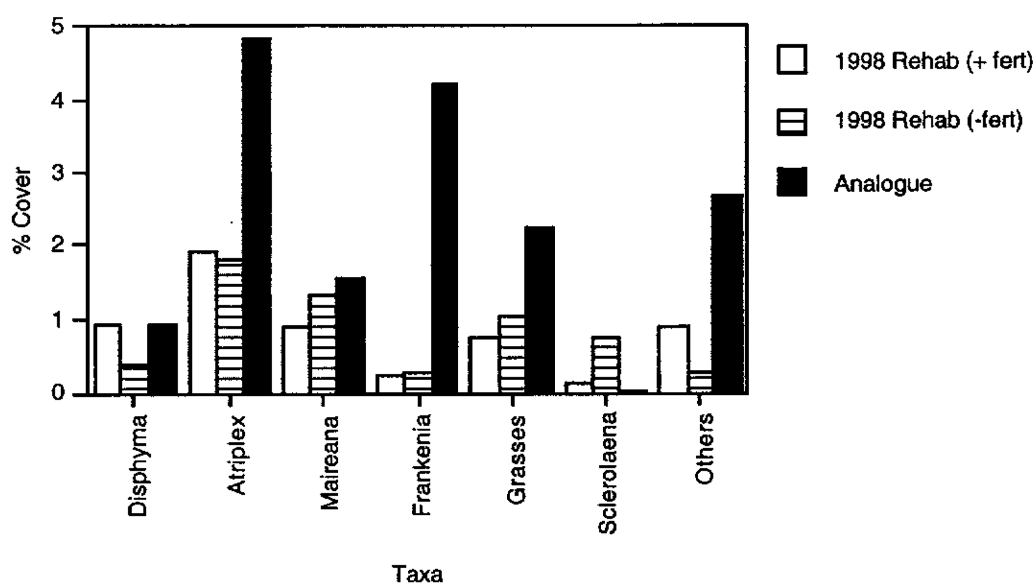


FIGURE 3.1.12.4: 1998 Rehabilitation, 12 months after seeding: Plant cover (%) provided by dominant taxa, with comparison between the waste dump revegetation (two fertiliser treatments) and adjacent analogue community.



3.1.13 Summary of Findings

The 12 rehabilitation trials established and monitored since 1992 at two mine sites in the Northeastern Goldfields can be categorised into four groups based on differences in rehabilitation media:

Group	Rehabilitation Trial	Revegetation Medium
1	1992 Oxide (Upper Flat Surfaces) 1993 Oxide (Upper Flat Surfaces) 1994 Seeding (Upper Flat Surfaces)	Extremely saline oxidised waste lacking a topsoil cover.
2	1992 Circular Ripping (Upper Flat Surfaces) 1992 Fertiliser (Batter) 1992 Seeding (Batter) 1994 Seeding (Childe Harold Batters)	Topsoil over extremely saline oxidised waste.
3	1993 Seeding (Batters) 1994 Seeding (Lower Granny Batter) 1994 Seeding (Top Granny Batter)	Topsoil/caprock mulch over extremely saline oxidised waste.
4	1997 Rehabilitation Sunrise Dam (Batters) 1998 Rehabilitation Sunrise Dam (Batters)	Gypsiferous dune sediments over extremely saline oxidised waste.

Group 1 Rehabilitation Trials

Trials established in extremely saline oxidised waste lacking a topsoil cover were confined to the upper flat surfaces of waste dumps. The upper surfaces of the waste dump were less susceptible to erosion than batter surfaces and more amenable to the leaching of salts from the upper profile. In response to elevated salinities initially present, seed mixtures comprised a large proportion of salt tolerant chenopod species. A number of mildly salt tolerant *Acacia* and *Eucalyptus* species were sown during 1992, but did not establish at high density in the rehabilitation up to six years after seeding.

Ecosystem development on extremely saline materials occurs more slowly in comparison to less hostile rehabilitation surfaces. Short-lived annual *Atriplex* species including *A. codonocarpa, A. holocarpa* and *A. semibaccata* were more prominent than perennial species during the initial three growing seasons, when surface salinity was extreme. The drought conditions experienced during 1994 further retarded revegetation development, reducing species richness and associated plant biodiversity parameters (density and ground cover). However, there was an immediate response to heavy summer rainfall associated with Cyclone Bobby in February '95, with plant parameters increasing above pre-drought levels within one growing season. This event facilitated the establishment of perennial *Atriplex* species, and stimulated the germination of a variety of other taxa including *Maireana* and *Sclerolaena*.

Chenopod species in the seed mixture that were specifically adapted to limiting factors present at the three sites, control ecosystem development up to six years following seeding. Soil or spoil over the trial area was ameliorated over time, and importantly surface salinity decreased rapidly following summer cyclonic rainfall and subsequent perennial plant establishment. There may now be merit in the remedial sowing of local plant varieties initially limited by the waste characteristics. Without remedial sowing the ecosystem is reliant on new propagules being introduced from adjacent natural vegetation complexes. This is likely to be a slow process occurring over an extended period of time.

Group 2 Rehabilitation Trials

Three trials established during 1992 involved direct seeding into a topsoil cover spread directly over oxidised waste of variable salinity to form a duplex. Along the western batter (1992 Seeding Trial) and eastern batter (1992 Fertiliser Trial), topsoil was spread up to a depth of 1 m. The unconsolidated topsoil cover contributed to the resultant instability of the rehabilitation surface, represented by deep erosion channels angled sharply down slope. The application of topsoil reduced initial surface salinity; however, levels remained above the tolerance limit for many hard-seeded species. As a result, halophytic chenopods dominated the resultant revegetation; *Acacia* spp. established in low numbers.

For the 1992 Seeding and 1992 Fertiliser Trials revegetation established rapidly, with high plant density and revegetation cover recorded 1-2 years after seeding. Plant density then declined under increasing competition; revegetation cover remained relatively stable as plants matured. Both parameters decreased during 1994 in response to seven months of very low rainfall, before recovering rapidly to pre-disturbance levels following high summer rainfalls during early 1995.

Recovery of plant biodiversity parameters to pre-disturbance levels followed similar trends to those observed during the first two growing seasons after direct seeding. High plant density was recorded during the first growing season following heavy summer rainfalls in early 1995, but stabilised under increasing competition. Over the same period revegetation cover increased rapidly initially, before stabilising in line with plant density. Rapid recovery of the revegetation following disturbance was seen as an indicator of ecosystem resilience.

The 1992 Circular Ripping Trial was established on the upper flat surface of a waste dump. A thin topsoil layer was spread over extremely saline oxidised waste that was also highly compacted. Revegetation establishment during the initial three growing seasons was limited to a small number of salt tolerant chenopods. Rainfall associated with Tropical Cyclone Bobby in early 1995 produced an immediate and significant revegetation response. Average plant density and revegetation cover increased from 0.6 stems m^{-2} and 15 percent, to 8.2 stems m^{-2} and 37 percent within nine months of the rainfall event. Plant density subsequently decreased under increasing competition, with revegetation cover stabilising as plants matured.

The 1994 seeding of Childe Harold Waste Dump occurred into a non-saline topsoil layer spread to less than 0.3 m deep. A diverse range of life forms successfully established including eucalypts, acacias, sennas and chenopods. The close proximity of a stock watering point resulted in overgrazing of revegetation along one side of the waste dump. This disturbed area was characterised by a decrease in plant density and revegetation cover.

Group 3 Rehabilitation Trials

In 1993 and 1994 an alternative revegetation medium comprising a mixture of topsoil and caprock blasted from the surface 2 m of an advancing open cut pit was trialled. It was anticipated this medium would provide a capillary break between the rehabilitation surface and underlying saline waste, and improve batter stability.

With average rainfall during the four months following seeding in 1993, a diverse suite of sown species germinated. However, the establishment of chenopod species was favoured by a dry 1994 summer. A further seven months of low rainfall during 1994 affected survival and growth of even the chenopod species, with the exception of *Atriplex bunburyana*. The initial establishment of *A. bunburyana* was enhanced by good maternal seed quality. Foliage cover provided by *A. bunburyana* actually increased during and after the 1994 drought period, confirming this species as extremely drought tolerant and emphasising the competitive advantage it has over other species during extended dry periods. The occurrence of similar *A. bunburyana* dominated stands in surrounding rangeland suggests this phenomenon is widespread.

For the 1994 Seeding trial utilising topsoil/caprock mulch as a surface substrate, no seed germination was recorded in the field during the first growing season in response to low rainfall. Between December 1994 and February 1995 however, monthly rainfall ranged from 46mm to 197mm with the passing of Tropical Cyclone Bobby. This event broke the dormancy of many hard-seeded species *(Acacia, Senna)* with the inherent high soil moisture facilitating their establishment. The prominence of chenopods in the revegetation was lower than expected, given the high seeding rate of these taxa. A large proportion of the light chenopod seed was either windblown, or damaged / eaten by insects and gramnivores. The five major revegetation taxa identified in October '98 (56 months after seeding), *Atriplex, Maireana, Acacia, Senna,* Others, show similar levels of relative importance.

Group 4 Rehabilitation Trials

The establishment of rehabilitation trials at Sunrise Dam Gold Mine in 1997 and 1998 coincided with the first rehabilitation work on site. There was only one assessment of the trials during the early stages of ecosystem development (first and second growing seasons respectively). Information from this assessment, however, provided important feedback to enhance the success of future programs.

The two trials established are unique because both utilise gypsiferous dune sediments removed from the fringe of Lake Carey, as a surface rehabilitation medium. Waste dump surfaces were battered to a slope of less than 15° to decrease the potential for surface erosion.

The revegetation medium was extremely saline over both the 1997 Rehabilitation (24 months after sowing) and the 1998 Rehabilitation (12 months after sowing). Species richness in the revegetation was very high considering the salinity level, with both seeded and volunteering plant varieties represented. A number of species restricted to salt lake environments and not commonly available from commercial seed pickers successfully germinated from the topsoil medium. This included the Priority 1 flora *Halosarcia* sp. 'Angel Fish Island'.

After the initial two growing seasons plant density and foliage cover was lower than the surrounding analogue community occurring naturally over the low gypsum dunes, *Frankenia* Low Shrubland. Given the elevated salinity of the revegetation medium, however, initial germination and seedling establishment rates were encouraging. Keystone species recorded at the analogue site were well represented in the rehabilitation. Many of these taxa, such as *Frankenia*, are long-lived varieties that will require a number of growing seasons before reaching maturity. Plant biodiversity parameters will not be comparable between rehabilitation and analogue sites until this stage in the rehabilitation is reached.

3.2 Eastern Goldfields

3.2.1 1996 Sump Hole Trial

Rehabilitation Strategy

Parameter	Technique
Establishment Date	May 1996
Slope of Topography	Gently undulating, generally flat
Revegetation Medium	Highly saline sump holes containing hydrocarbon derivatives from exploration drilling, covered with topsoil to 0.3 m deep
Surface Treatment	Scarification to 0.3 m depth using a grader
Experimental Treatments	1. control (untreated) 2. deep ripping - seeding + fertiliser 3. deep ripping + seeding - fertiliser 4. deep ripping + seeding + fertiliser
Direct Seeding	Seed mixture dominated by local chenopod species, but including a variety of salt tolerant acacias and eucalypts, hand broadcast at a rate of 15 kg ha^{-1} (Appendices 6 & 7)
Fertiliser	Agras No. 1 applied at 100 kg ha^{-1} (17.5%N, 7.6%P and 17.0%S)

Results and Comments

Control sumps (Treatment 1) remained sparsely vegetated 29 months after seeding, with low plant density and revegetation cover recorded for the first three annual assessments (Tables 3.2.1.1-3.2.1.3). Surface soils were extremely saline during this period, with mean ECe greater than 31 dS m^{-1}. The un-ripped medium inhibited leaching of surface salts. In addition, high ground temperatures, facilitated by low revegetation cover, enhanced the capillary rise of salts during summer months. High species richness (16-23 species) confirmed the germination of volunteer seed, however plants failed to survive and persist into the second growing season. *Atriplex* and *Maireana* were common taxa recorded over the control treatment, particularly colonising annual life forms (Figure 3.2.1.2). The likely seed source for these species was exploration rehabilitation that had been completed up to the boundary of sump hole plots during 1996. These topsoiled surfaces were non-saline and supported established plants that were producing viable seed.

In December 1999, 43 months after seeding, mean plant density increased three fold to average 3.67 stems m^{-2} and revegetation cover increased to 13 percent (Figure 3.2.1.1, Table 3.2.1.4). This marked a transition period in revegetation development for the control treatment. In November 2000 plant density decreased to average 1.91 stems m^{-2} and revegetation cover remained stable at 12 percent (Table 3.2.1.5). The trend shown by the above parameters during the 1999 and 2000 assessments was similar to those represented during the initial two growing seasons for the two seeded treatments. The delay in this trend becoming evident in the control treatment was due to the initial absence of a viable seed store (not direct seeded) and absence of the beneficial processes associated with deep ripping (Figure 3.2.1.3). In November '01 plant density averaged 1.50 stems m^{-2} with an increasing revegetation cover of 12 percent (Table 3.2.1.6).

Plots that were deep-ripped but not seeded (Treatment 2), showed a slow but progressive increase in plant density and revegetation cover over the initial two growing seasons (Figure 3.2.1.1). Few plants were recorded during the initial growing season, due to the absence of a viable seed store. However, plant density increased significantly during the second growing season, with seed volunteering from neighbouring seeded treatments being trapped between riplines; revegetation cover also increased at this point. Between October '98 and November '01 mean plant density decreased to approximate 3.18 stems m^{-2}, while revegetation cover continued to increase in line with the seeded treatments (25 percent).

Atriplex and *Maireana* species were the dominant taxa recorded in Treatment 2 (Figure 3.2.1.4). The likely source of the saltbush and bluebush seed was from neighbouring plots where seeding did occur. The decreasing prominance of colonising annual species over time, including *Atriplex semibaccata* and *A. codonocarpa* confirmed that revegetation development was occurring. Prominent perennial life forms recorded in November '01 were *A. bunburyana, A. vesicaria* and *A. nummularia,* all being keystone species at neighbouring analogue sites (Appendices 8 and 9).

A reduction in soil salinity, recorded since October '98 (Figure 3.2.1.1), was enhanced by deep ripping that facilitated the leaching of surface salts within Treatment 2. Deep ripping was also beneficial to seed lodgement and hence, the establishment of a vegetation cover, which in turn reduced ground surface temperatures and the capillary rise of salts (Table 3.2.1.7). A decrease in surface salinity encouraged the establishment of *Acacia* and *Eucalyptus* species; these perennial life forms are expected to continue increasing in dominance over the longer term.

Treatments 3 and 4 were deep ripped and seeded, and Treatment 4 was also fertilised. Both treatments have shown similar time series trends with respect to plant density and revegetation cover, as expected for successfully establishing revegetation (Figure 3.2.1.1). In November '01 plant density and revegetation cover averaged 2.97 stems m^{-2} and 32 percent for Treatment 3, and 2.62 stems m^{-2} and 38 percent for Treatment 4 (Tables 3.2.1.5 & 3.2.1.6).

Direct seeding accelerated plant colonisation for both seeded treatments (Appendix 6). The annuals *Atriplex codonocarpa* (1.34 stems m^{-2}) and *A. semibaccata* (0.59 stems m^{-2}) both occurred in high numbers during the first growing season, and provided 3 and 2 percent ground cover respectively (Figures 3.2.1.5 & 3.2.1.6). In the following three years to December '99, overall density for Treatments 3 and 4 progressively decreased in response to greater competition from maturing plants, producing a negative feedback. At the same time perennial life forms became more prominent at the expense of opportunistic annual life forms. In November '00 and November '01 mean plant density stabilised to approximate 3 stems m^{-2} (Figure 3.2.1.1).

After increasing significantly during the initial two growing seasons (1996 and 1997), revegetation cover for Treatments 3 and 4 remained relatively stable over the proceeding four-year period (Figure 3.2.1.1). For Treatment 3 cover ranged between 23-32 percent, and for Treatment 4 the range was slightly higher, 30-39 percent.

Atriplex species provided the greatest revegetation cover (Figures 3.2.1.5 & 3.2.1.6). Alone, this genus gave greater than 20 percent ground cover in the second growing season and up to 30 percent ground cover during the fifth growing season. In November '00 *A. bunburyana* (IVI 67 & 80), *A. nummularia* (IVI 77 & 64) and *A. vesicaria* (IVI 32 & 28) were dominant *Atriplex* species recorded in Treatments 3 and 4 respectively. *A. bunburyana* and *A. vesicaria* were also dominant within surrounding analogue communities, providing individual ground cover of 15-16 percent. The colonising species *A. codonocarpa* and *A. semibaccata* were only minor components of the revegetation 66 months after seeding, with individual IVI less than 1.0 for Treatments 3 and 4 (Appendix 8).

Fertiliser was trialled to improve the nutrient status of what was initially a hostile rehabilitation medium. Long-term assessment suggests fertiliser application favoured the growth of a few select species, but did not significantly benefit revegetation establishment over saline sump holes. Fertiliser enhanced the density and foliage cover of the vigorous and drought resistant perennial *Atriplex bunburyana*.

There was an emphasis on salt tolerant species (*Atriplex* and *Maireana*) in the seed mixture (Appendix 6), as surface salinity over the sump holes was initially extreme. However, surface salinity decreased rapidly over time in direct relationship with increasing vegetation cover (Table 3.2.1.7). The establishing plant cover reduced surface temperatures and hence capillary rise of salts, while plant roots facilitated leaching of surface salts into the soil profile. Further soil amelioration over time should allow for the establishment of a greater range of plant life forms in the rehabilitation.

TABLE 3.2.1.1: Sump Hole Trial: Mean plant density, % revegetation cover, species richness, soil salinity and pH (n=10). Revegetation age 7 months. NOTE: ANOVA and Fisher's Test between treatments, similar superscript letters indicate no significant difference.

Treatment	Density no. m^{-2}	% Cover	Species Richness	ECe (dS m^{-1})	pH
control (no treatment)	0.810 ^{b}	1.015 ^{b}	23	41.52 ^{a}	6.36 ^{b}
– seed + fertiliser	1.456 ^{b}	3.603 ^{b}	29	52.37 ^{a}	7.17 ^{a}
+ seeding – fertiliser	5.870 ^{a}	8.518 ^{a}	29	52.24 ^{a}	7.43 ^{a}
+ seeding + fertiliser	7.195 ^{a}	13.250 ^{a}	33	29.97 ^{a}	7.53 ^{a}
P - value	0.001	0.001		0.492	0.001

TABLE 3.2.1.2: Sump Hole Trial: Mean plant density, % revegetation cover, species richness, soil salinity and pH (n=10). Revegetation age 19 months.

Treatment	Density no. m^{-2}	% Cover	Species Richness	ECe (dS m^{-1})	pH
control (no treatment)	0.890 ^{c}	2.626 ^{c}	18	32.72 ^{a}	6.75 ^{b}
– seed + fertiliser	3.135 ^{b}	13.580 ^{b}	25	23.49 ^{a}	7.43 ^{a}
+ seeding – fertiliser	4.080 ^{ab}	26.220 ^{a}	19	24.18 ^{a}	7.52 ^{a}
+ seeding + fertiliser	4.870 ^{a}	35.050 ^{a}	23	7.24 ^{a}	7.63 ^{a}
P - value	0.001	0.001		0.221	0.001

TABLE 3.2.1.3: Sump Hole Trial: Mean plant density, % revegetation cover, species richness, soil salinity and pH (n=10). Revegetation age 29 months.

Treatment	Density no. m^{-2}	% Cover	Species Richness	ECe ($dS\ m^{-1}$)	pH
control (no treatment)	1.41 ^{b}	3.41 ^{c}	16	30.93 ^{a}	7.06 ^{b}
– seed + fertiliser	4.27 ^{a}	17.83 ^{b}	23	6.58 ^{b}	8.06 ^{a}
+ seeding – fertiliser	3.68 ^{a}	23.79 ^{a}	21	7.63 ^{b}	7.96 ^{a}
+ seeding + fertiliser	3.94 ^{a}	29.69 ^{a}	20	4.78 ^{b}	8.07 ^{a}
P - value	0.001	0.001		0.006	0.001

TABLE 3.2.1.4: Sump Hole Trial: Mean plant density, % revegetation cover, species richness, soil salinity and pH (n=10). Revegetation age 43 months. NOTE: ANOVA and Fisher's Test between treatments, similar superscript letters indicate no significant difference.

Treatment	Density no. m^{-2}	% Cover	Species Richness	ECe ($dS\ m^{-1}$)	pH
control (no treatment)	4.67 ^{a}	10.77 ^{c}	22	6.42 ^{a}	6.79 ^{b}
– seed + fertiliser	3.21 ^{a}	16.79 ^{b}	21	1.86 ^{b}	7.59 ^{a}
+ seeding – fertiliser	2.80 ^{a}	22.73 ^{b}	19	1.32 ^{b}	7.83 ^{a}
+ seeding + fertiliser	2.82 ^{a}	32.69 ^{a}	18	0.48 ^{b}	7.84 ^{a}
P - value	0.505	0.001		0.008	0.001

TABLE 3.2.1.5: Sump Hole Trial: Mean plant density, % revegetation cover, species richness, soil salinity and pH (n=10). Revegetation age 54 months.

Treatment	Density no. m^{-2}	% Cover	Species Richness	ECe ($dS\ m^{-1}$)	pH
control (no treatment)	1.90 ^{b}	11.68 ^{c}	25	1.83 ^{a}	7.06 ^{b}
– seed + fertiliser	3.87 ^{a}	24.61 ^{b}	22	25.36 ^{a}	7.51 ^{a}
+ seeding – fertiliser	3.43 ^{a}	30.39 ^{b}	22	6.93 ^{a}	7.66 ^{a}
+ seeding + fertiliser	3.48 ^{a}	38.77 ^{a}	22	3.31 ^{a}	7.86 ^{a}
P - value	0.001	0.001		0.224	0.005

TABLE 3.2.1.6: Sump Hole Trial: Mean plant density, % revegetation cover, species richness, soil salinity and pH (n=10). Revegetation age 66 months.

Treatment	Density no. m^{-2}	% Cover	Species Richness	ECe ($dS\ m^{-1}$)	pH
control (no treatment)	1.50 [b]	12.13 [c]	13	21.98 [a]	6.98 [b]
– seed + fertiliser	3.18 [a]	24.71 [b]	23	10.61 [ab]	7.62 [a]
+ seeding – fertiliser	2.97 [a]	31.92 [a]	21	4.98 [b]	7.74 [a]
+ seeding + fertiliser	2.62 [a]	37.98 [a]	25	1.83 [b]	7.71 [a]
P - value	0.001	0.001		0.045	0.002

TABLE 3.2.1.7: Regression analysis showing the correlation coefficient (r) between surface soil salinity (ECe in $dS\ m^{-1}$) and % revegetation cover, for the six assessments between '96 and '01.

Year	*P* - value	r
December 1996	0.170	0.22
December 1997	0.013	0.39
October 1998	0.002	0.47
December 1999	0.002	0.48
November 2000	0.354	0.15
November 2001	0.048	0.32

FIGURE 3.2.1.1: Sump Hole Trial: Change in mean salinity (ECe in dS m^{-1}), pH, plant density, and revegetation cover for the four treatments between December '96 and November '01 (n=10).

Treatments

1:	control	(no treatment)	
2:	deep ripping	- seeding	+ fertiliser
3:	deep ripping	+ seeding	- fertiliser
4:	deep ripping	+ seeding	+ fertiliser

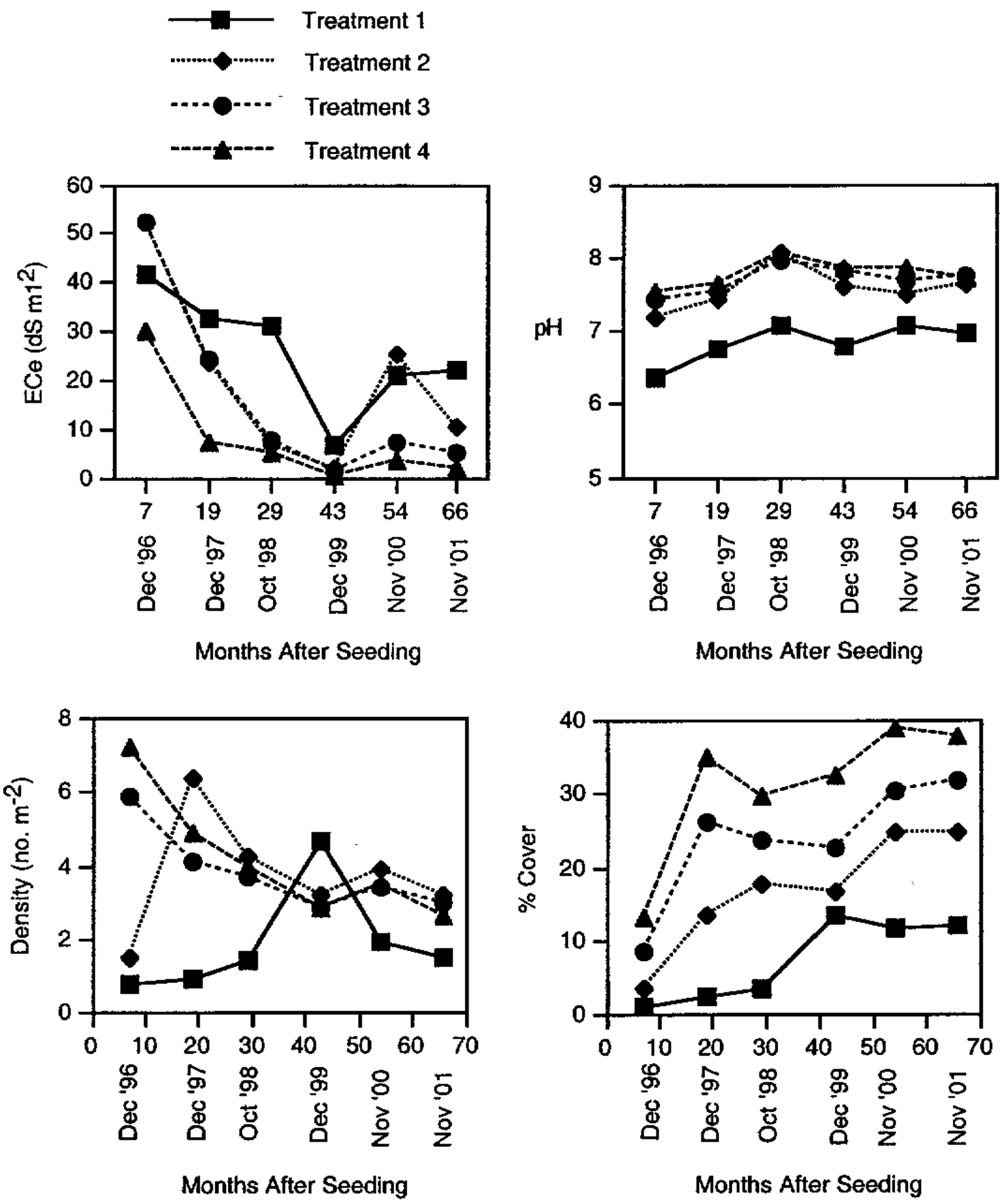


FIGURE 3.2.1.2: Sump Hole Trial: Change in Importance Value Index (IVI), plant density, and % cover for important taxa recorded in Treatment 1 between December '96 and November '01.

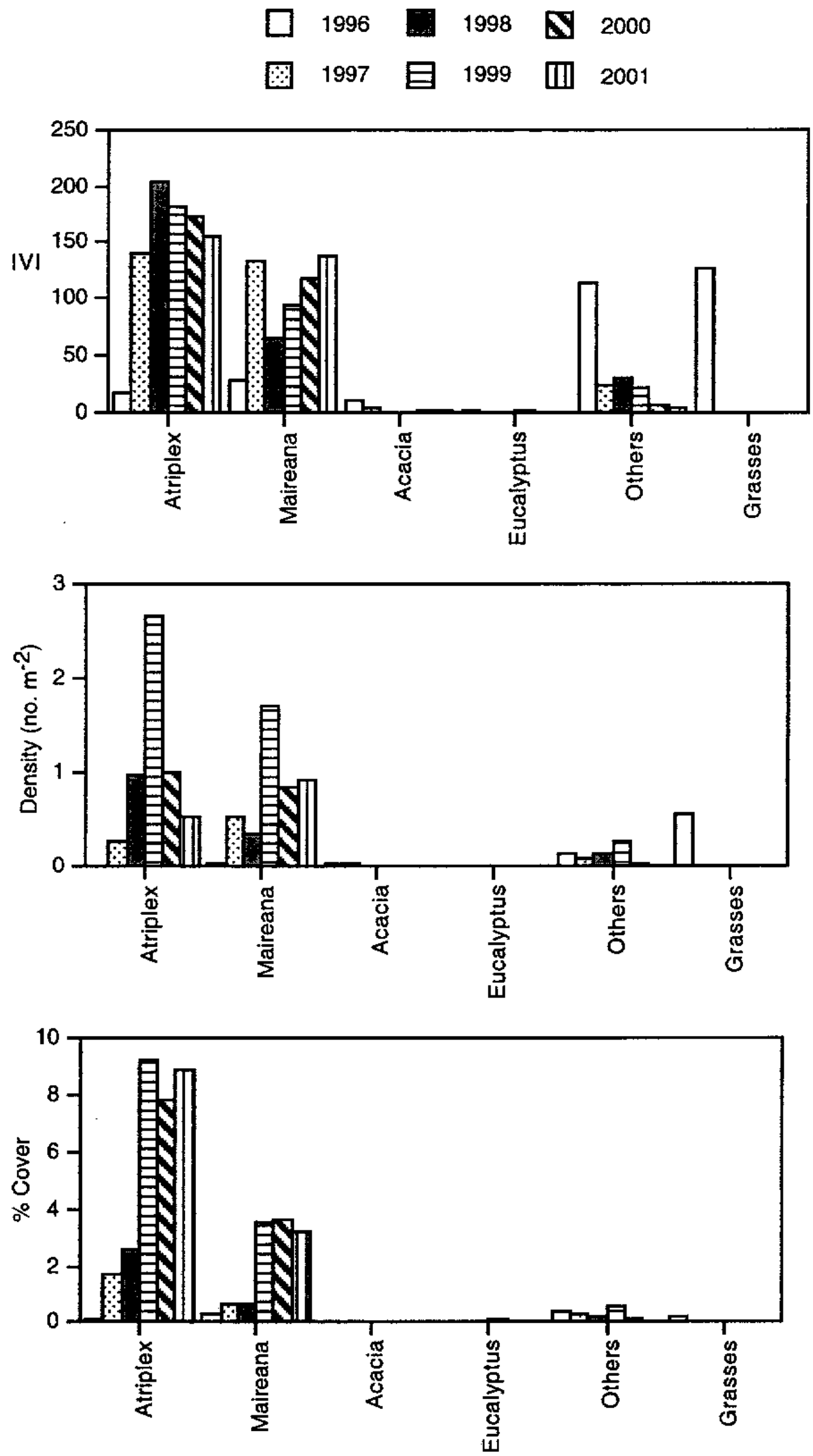


FIGURE 3.2.1.3: **Deep ripping and direct seeding (Treatment 3) significantly improved vegetation establishment over sump holes (top). Control treatments required a longer period for successful plant colonisation (bottom).**

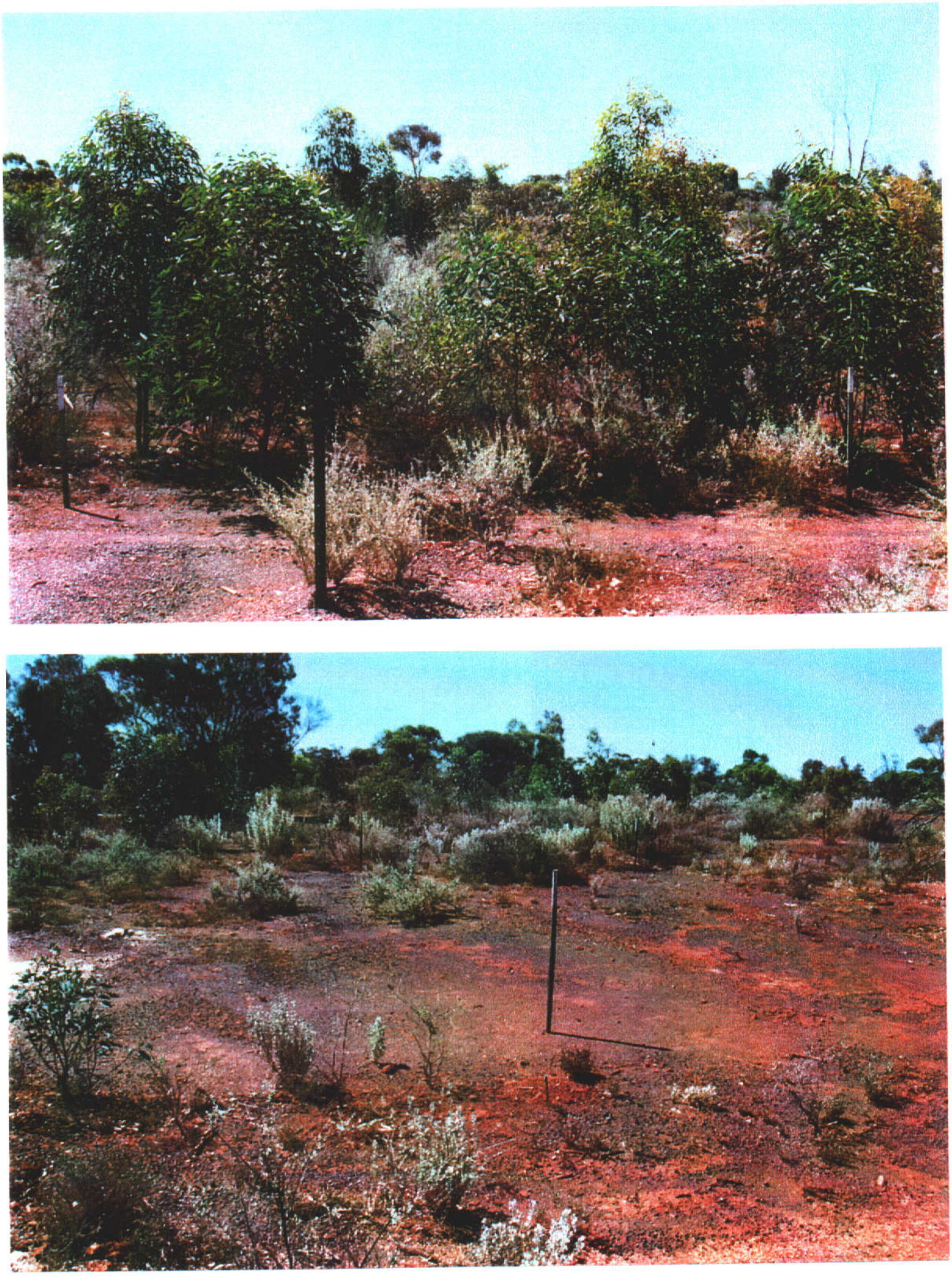


FIGURE 3.2.1.4: Sump Hole Trial: Change in Importance Value Index (IVI), plant density, and % cover for important taxa recorded in Treatment 2 between December '96 and November '01.

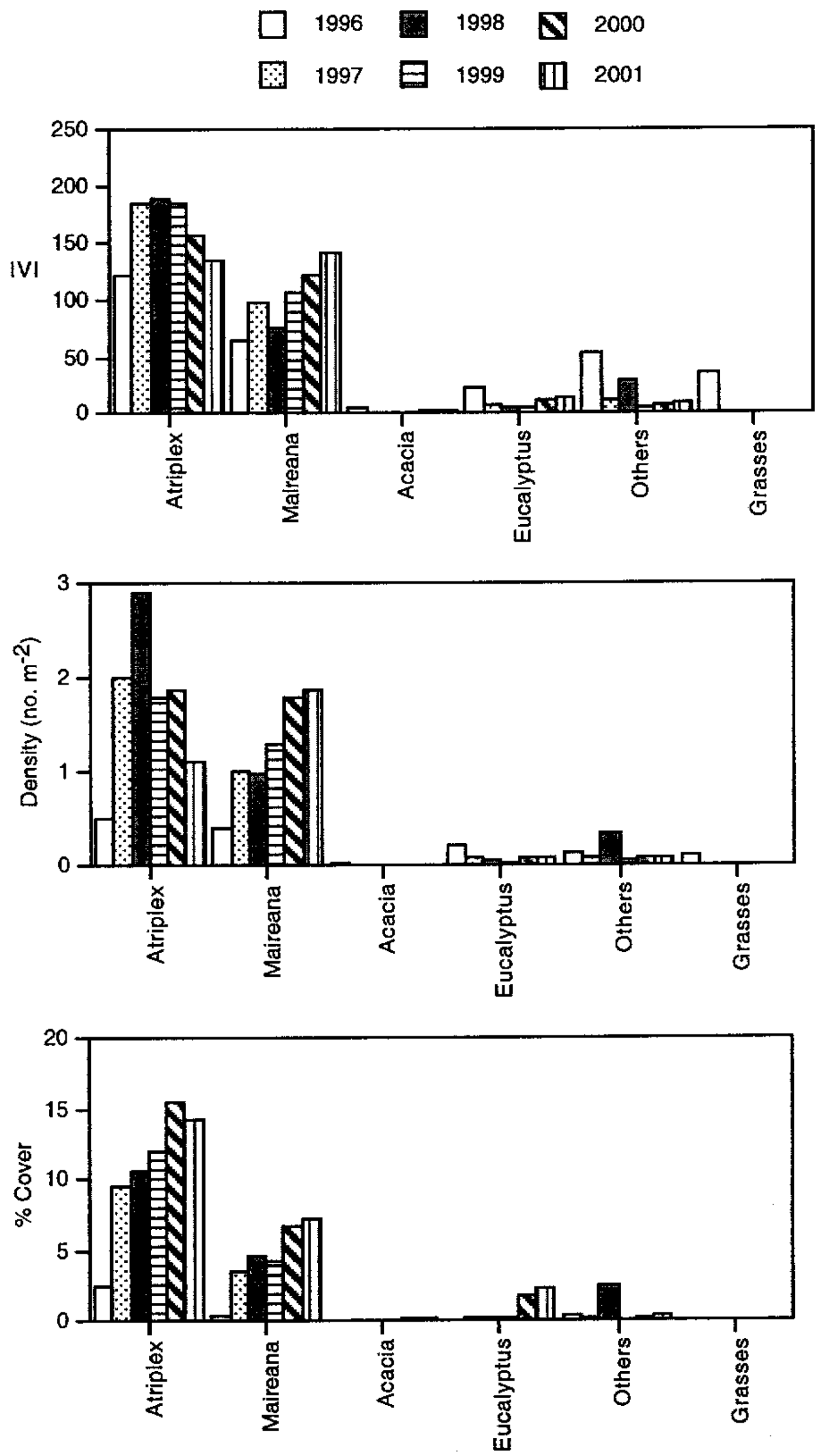


FIGURE 3.2.1.5: Sump Hole Trial: Change in Importance Value Index (IVI), plant density, and % cover for important taxa recorded in Treatment 3 between December '96 and November '01.

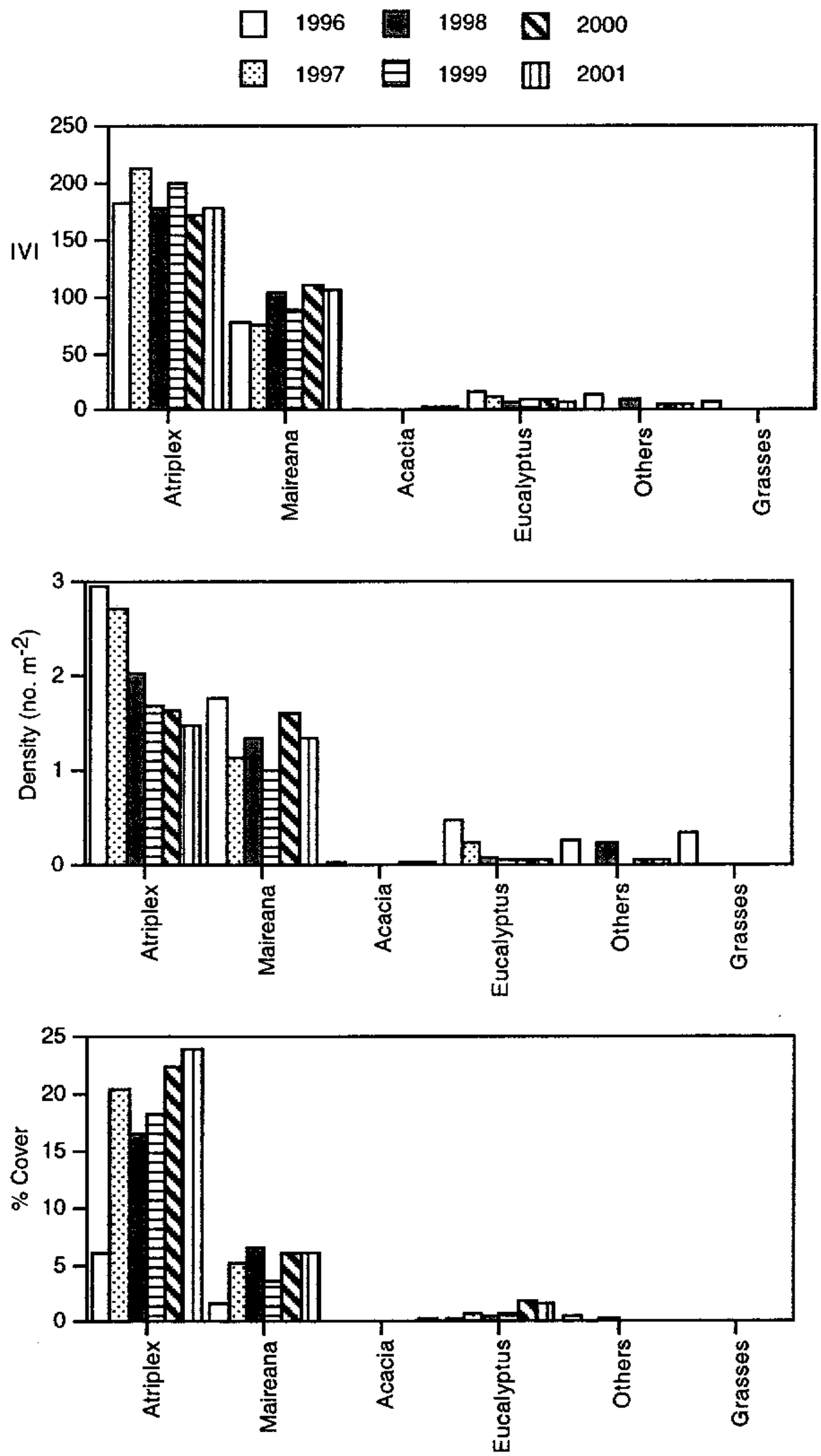
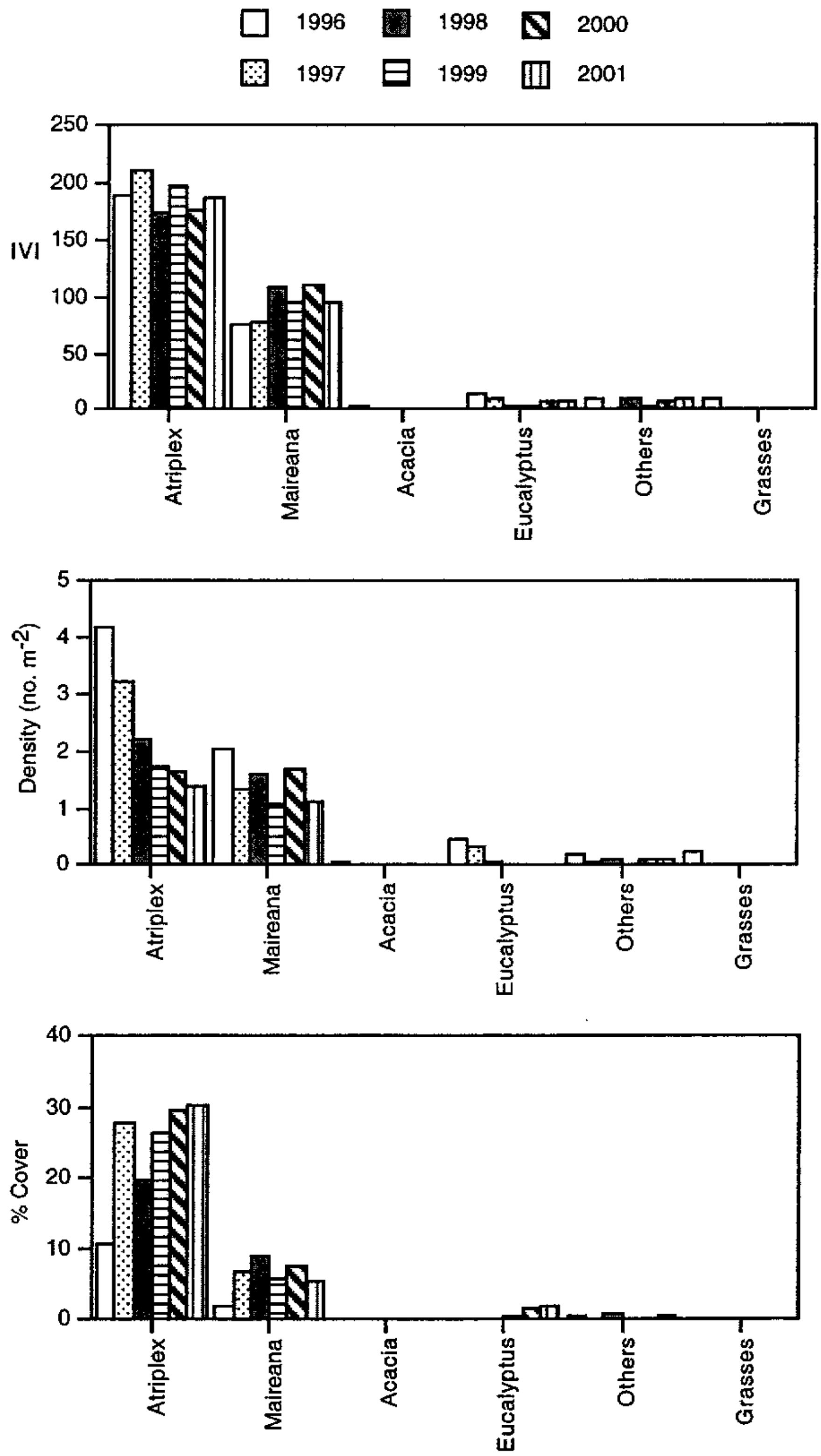


FIGURE 3.2.1.6: Sump Hole Trial: Change in Importance Value Index (IVI), plant density, and % cover for important taxa recorded in Treatment 4 between December '96 and November '01.



3.2.2 1996 Drill Line Trial

Rehabilitation Strategy

Parameter	Response
Establishment Date	May 1996
Slope of Topography	Gently undulating, generally flat
Revegetation Medium	Pre-existing topsoil, highly compacted drill lines
Surface Treatment	Scarification to 0.3 m depth using a grader
Experimental Treatments	1. control (- scarification, -seeding) 2. + scarification – seeding 3. + scarification + seeding
Seeding Method	Hand broadcast
Seeding Rate	28 species at a rate of 6 kg ha^{-1}

Results and Comments

Seven months after seeding there was no significant difference among the three experimental treatments with respect to plant density, revegetation cover, soil salinity and soil pH (Figure 3.2.2.1). However, species richness for Treatment 3 (direct seeded) totalled 28, compared to 16 and 17 species for Treatment 1 and Treatment 2 respectively (neither direct seeded, see Table 3.2.2.1).

During the first growing season Treatments 1 and 2 were characterised by the dominant establishment of grasses, which comprised 80 percent and 67 percent of the total revegetation density for each treatment respectively (Figures 3.2.2.2 & 3.2.2.3). The establishment of ephemeral grasses was stimulated by summer rains, which fell prior to the 1996 assessment. Observation of historical exploration sites in the area confirms grasses continue to dominate disturbed areas in the absence of perennial plant life forms, up to 20 years after clearing activities have ceased.

A greater range of life forms was present in the seeded treatment (Treatment 3) during December '96. Annual grasses had volunteered, but were recorded at lower density (18 percent of total density) in comparison to Treatments 1 and 2 (Figures 3.2.2.1-3.2.2.4). Eleven chenopod species provided 59 percent of the total revegetation density within Treatment 3, with *Maireana georgei* the dominant species (0.24 plants m^{-2}). Long-lived perennials included four *Acacia*'s at a density of 0.08 plants m^{-2}, and four *Eucalyptus* species at 0.26 plants m^{-2}.

Nineteen months after seeding both plant density and revegetation cover was significantly greater for the scarified and seeded plots (Treatment 3). Two species were recorded over the control treatment, *Ptilotus obovatus* and *Senna filifolia*, together averaging 0.02 stems m^{-2}. Only one species was recorded over Treatment 2 (scarified but not seeded) at a density of 0.03 plants m^{-2}. However, a total of 16 species were recorded over Treatment 3, of which 14 were seed mixture varieties. Total revegetation density for Treatment 3 averaged 1.18 plants m^{-2}: eucalypts 0.46 stems m^{-2} and acacias 0.06 stems m^{-2} (Figure 3.2.2.4). The most prevalent chenopods were *Atriplex bunburyana*, *A. nummularia*, *A. vesicaria* and *Maireana georgei* with individual densities in the order of 1.1 - 1.3 plants m^{-2}.

In October 1998, 29 months after seeding, plant density and revegetation cover for Treatments 1 and 2 (not seeded) remained below 0.25 stems m^{-2} and 1.5 percent respectively (Table 3.2.2.1, Figure 3.2.2.5). Only three perennial species were recorded, *Ptilotus obovatus*, *Senna filifolia* and *Eremophila granitica*. In contrast, Treatment 3 showed significantly higher plant density, revegetation cover, and species richness (Figure 3.2.2.6). Eleven of the 16 species recorded were perennial life forms, with *Eucalyptus* and *Atriplex* each providing 1-2 percent ground cover, and *Maireana* and *Acacia* approximating 0.5 percent cover (Figure 3.2.2.4).

Forty-three months after seeding plant density and revegetation cover for Treatments 1 and 2 remained low averaging 0.14 and 0.08 stems m^{-2}, and 0.8 and 0.7 percent respectively (Table 3.2.2.1). Species richness for Treatment 1 had increased to 9 species (8 perennial) compared to 4 species for Treatment 2. Time series data confirmed plant density for Treatment 3 stabilised in December '99 at 0.61 stems m^{-2}, revegetation cover continued to increase averaging 7 percent (Figure 3.2.2.1).

Similar trends were evident during 2000 and 2001 assessments as were recorded for the 1999 assessment (Table 3.2.2.1). Plant density, revegetation cover, and species richness for Treatments 1 and 2 remained low. In comparison Treatment 3 recorded relatively high values, 20 species at 0.78 stems m^{-2} and 9 percent respectively. In November 2001, 66 months after seeding, woody perennial taxa common to surrounding vegetation complexes were showing increased dominance within Treatment 3, including *Eucalyptus* and *Acacia.*

TABLE 3.2.2.1: Mean plant density, species richness, % revegetation cover, and soil salinity and pH for six assessments of three experimental treatments between December 1996 (7 months after seeding) and November '01 (66 months after seeding). NOTE: ANOVA and Fisher's Test between treatments, similar superscript letters indicate no significant difference.

Months After Seeding	n	Density no. m^{-2}	Species Richness	% Cover	ECe ($dS\ m^{-1}$)	pH
Treatment 1 – Control						
7	10	1.840 ^{a}	16	0.72 ^{a}	0.49 ^{b}	6.34 ^{c}
19	10	0.015 ^{b}	2	0.12 ^{b}	0.32 ^{b}	7.28 ^{ab}
29	10	0.115 ^{b}	6	0.29 ^{ab}	0.24 ^{b}	7.09 ^{ab}
43	10	0.140 ^{b}	9	0.77 ^{a}	0.21 ^{b}	6.95 ^{b}
54	10	0.110 ^{b}	5	0.86 ^{a}	0.73 ^{b}	7.21 ^{ab}
66	10	0.000 ^{b}	0	0.00 ^{b}	3.93 ^{a}	7.58 ^{a}
P - value		0.000		0.002	0.000	0.000
Treatment 2 – Scarified, Not Seeded						
7	10	0.900 ^{a}	17	0.44 ^{a}	0.83 ^{a}	6.39 ^{a}
19	6	0.025 ^{b}	1	0.01 ^{a}	0.24 ^{b}	7.32 ^{a}
29	6	0.250 ^{b}	5	1.54 ^{a}	0.52 ^{ab}	7.27 ^{a}
43	6	0.080 ^{b}	4	0.72 ^{a}	0.05 ^{b}	6.70 ^{a}
54	6	0.190 ^{b}	6	1.07 ^{a}	0.50 ^{ab}	7.05 ^{a}
66	6	0.160 ^{b}	5	0.83 ^{a}	0.80 ^{a}	7.01 ^{a}
P - value		0.003		0.381	0.018	0.058
Treatment 3 – Scarified, Seeded						
7	10	2.013 ^{a}	28	0.97 ^{a}	1.04 ^{a}	6.35 ^{c}
19	6	1.183 ^{a}	16	4.88 ^{a}	0.48 ^{a}	7.40 ^{a}
29	6	0.830 ^{a}	16	4.55 ^{a}	2.55 ^{a}	7.25 ^{ab}
43	6	0.610 ^{a}	17	6.84 ^{a}	0.06 ^{a}	6.53 ^{c}
54	6	0.570 ^{a}	15	7.63 ^{a}	1.79 ^{a}	6.74 ^{bc}
66	6	0.780 ^{a}	20	9.40 ^{a}	2.72 ^{a}	6.82 ^{ac}
P - value		0.081		0.175	0.551	0.004

FIGURE 3.2.2.1: Change in mean values for soil salinity and pH, and plant density and % ground cover for each of the three treatments (n=10, 6, 6) between December '96 and November '01.

Treatments

1:	control	(no treatment)
2:	+ scarification	- seeding
3:	+ scarification	+ seeding

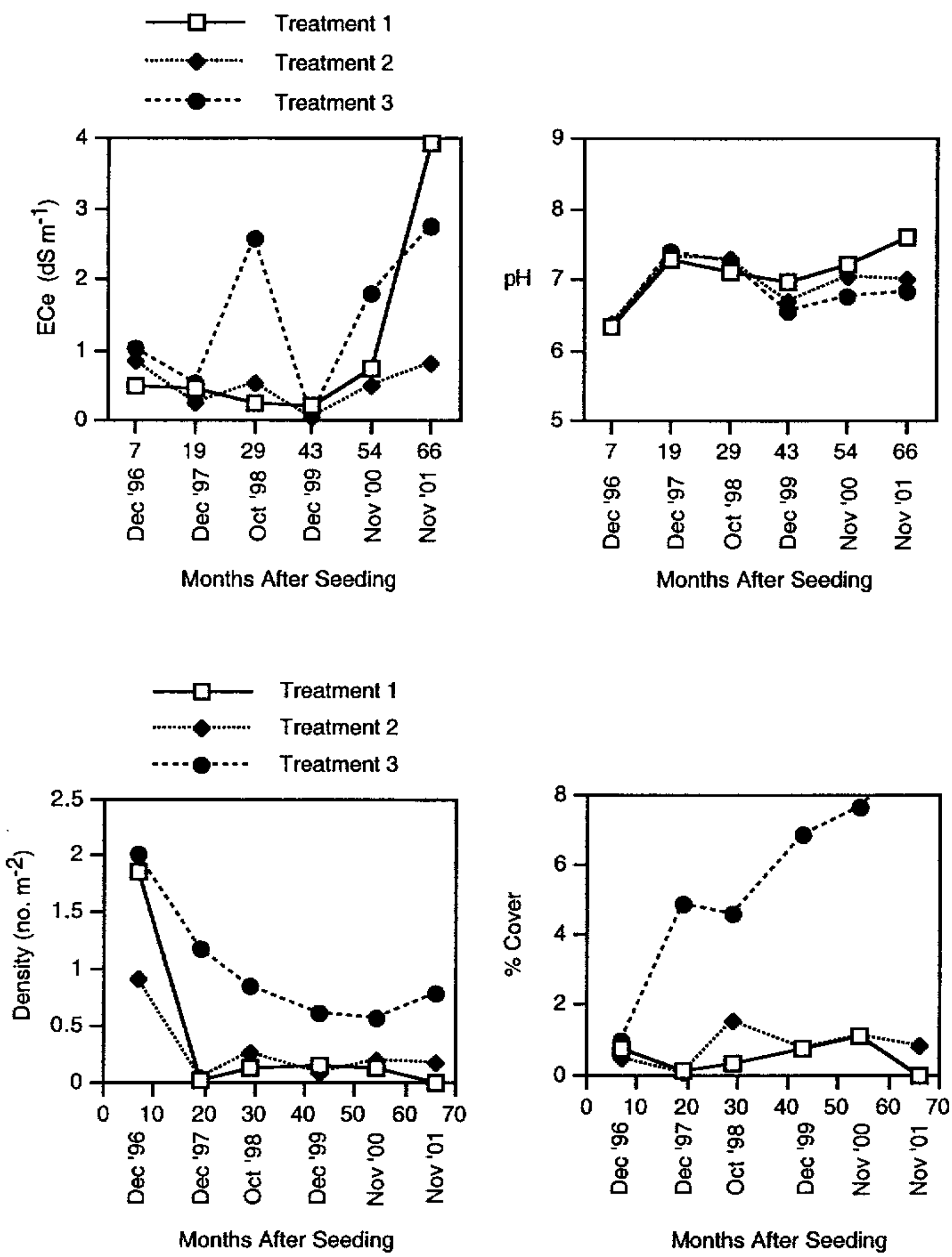


FIGURE 3.2.2.2: Change in importance value index (IVI), plant density, and % ground cover for important taxa recorded in Treatment 1 between December '96 and November '01.

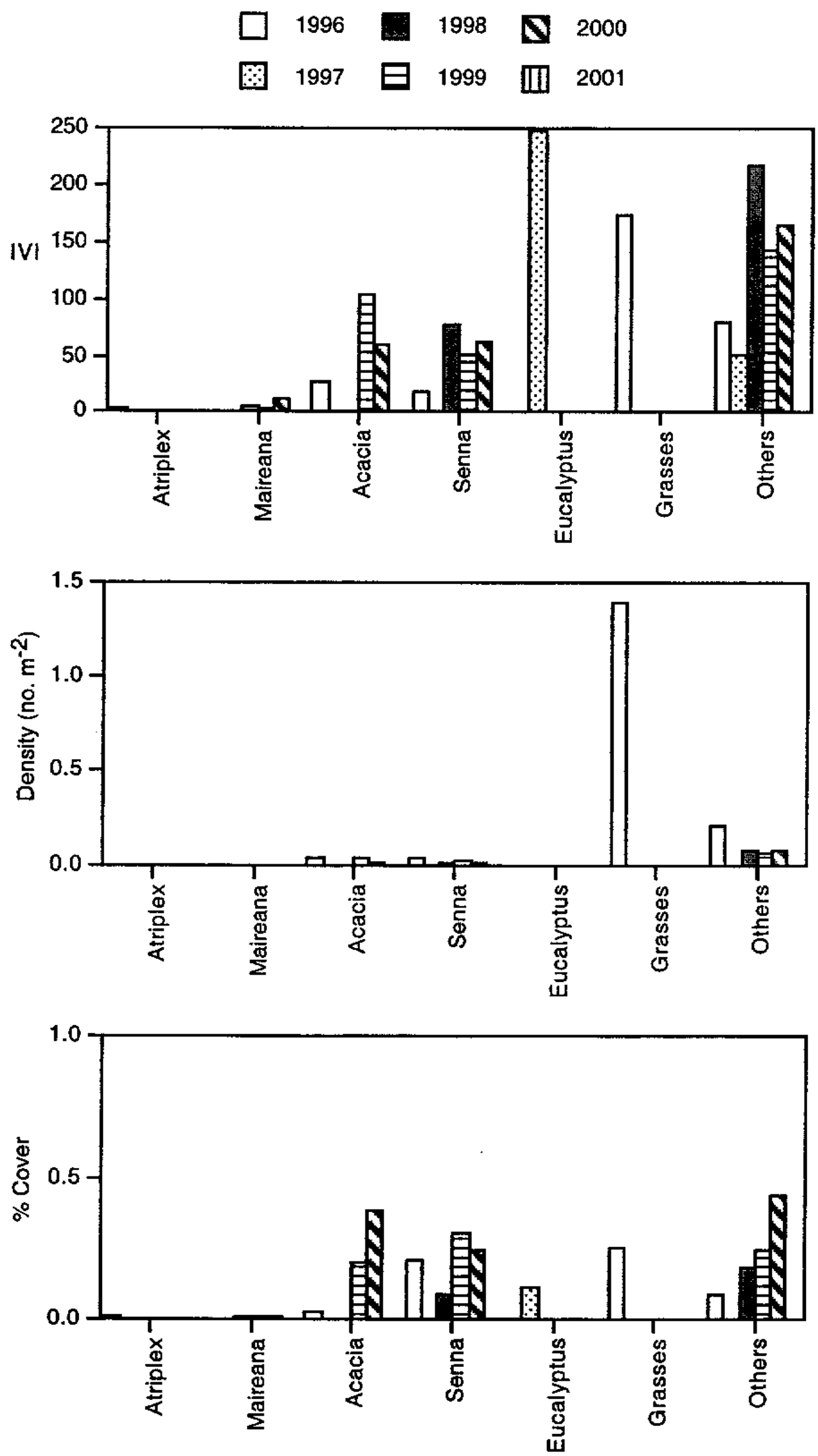


FIGURE 3.2.2.3: **Change in importance value index (IVI), plant density, and % ground cover for important taxa recorded in Treatment 2 between December '96 and November '01.**

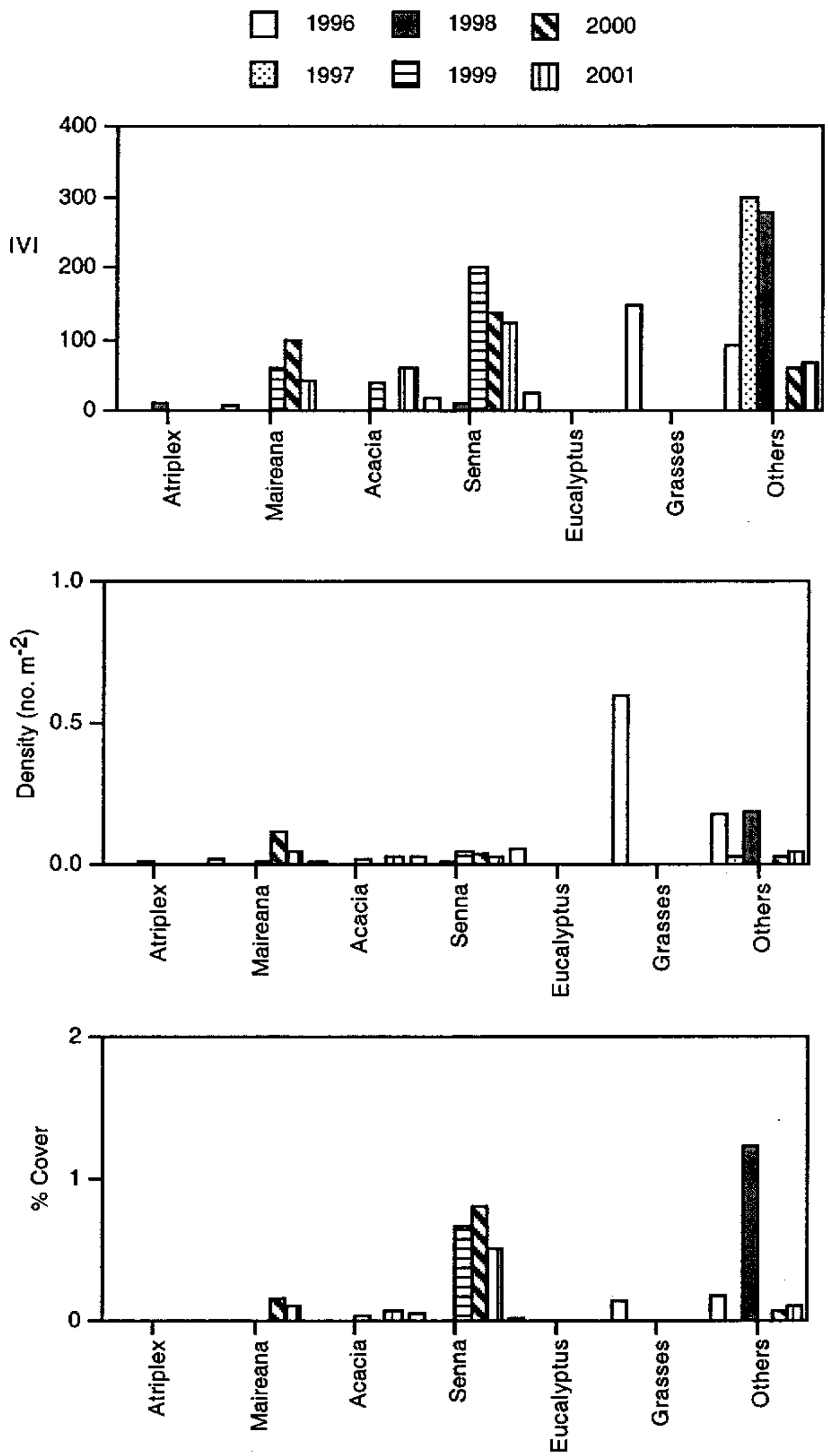


FIGURE 3.2.2.4: Change in importance value index (IVI), plant density, and % ground cover for important taxa recorded in Treatment 3 between December '96 and November '01.

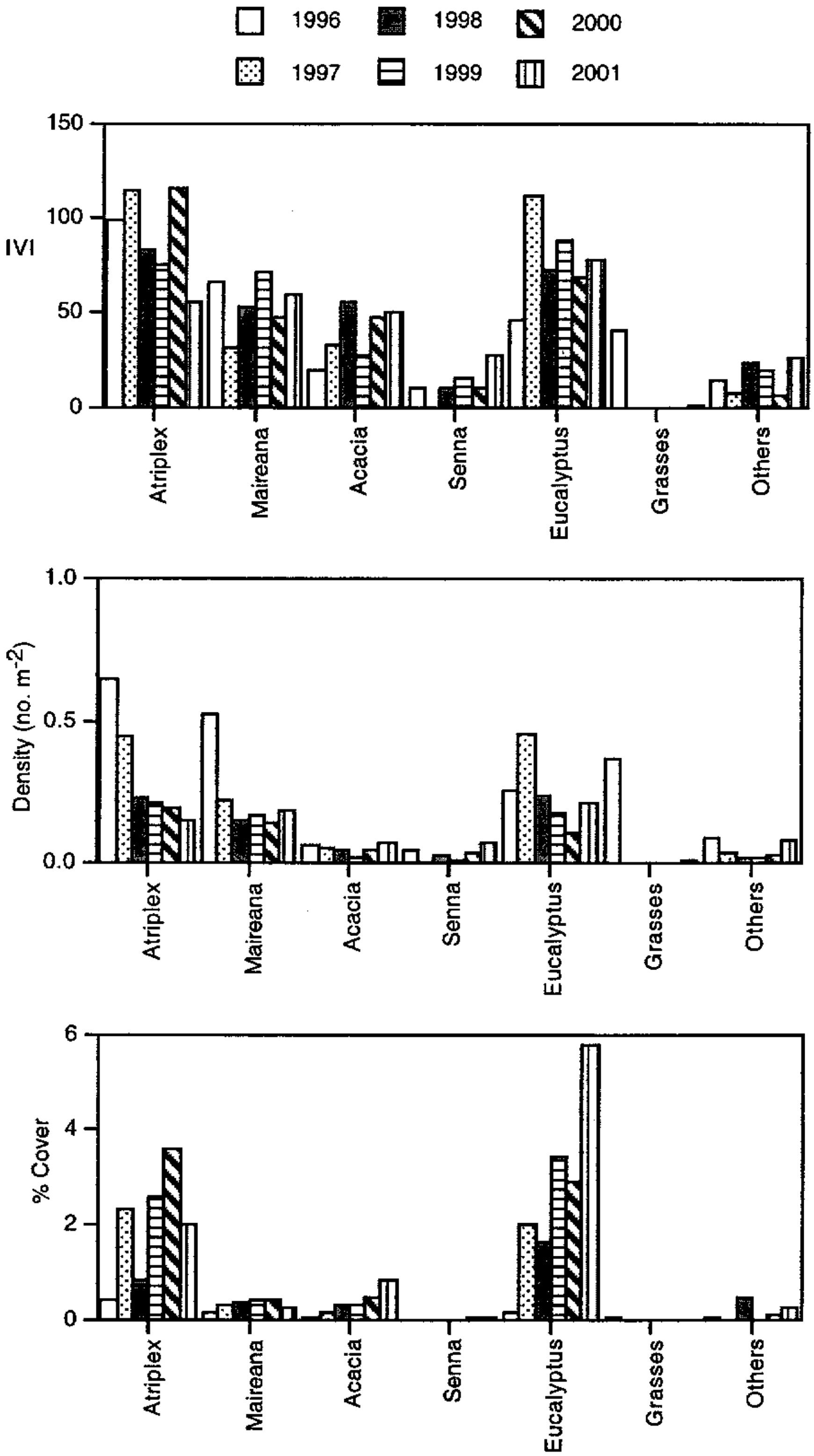


FIGURE 3.2.2.5: **Perennial plants occur in low numbers over Control plots (Treatment 1) which were not scarified or direct seeded.**

FIGURE 3.2.2.6: **A perennial cover is establishing in Treatment 3 plots (scarified and seeded).**

3.2.3 1996 General Exploration Rehabilitation

Rehabilitation Strategy

Parameter	Technique
Establishment Date	May 1996
Slope of Topography	Gently undulating, generally flat
Revegetation Medium	Pre-existing topsoil cover respread
Surface Treatment	Conventional contour ripping using a grader to 0.3 m depth and at 1 m intervals
Experimental Treatments	none
Seeding Method	Hand broadcast
Seeding Rate	28 species at a rate of 8.6 kg ha^{-1}

Results and Comments

Surface soils over the exploration area were saline seven months after seeding (ECe 10.7 dS m^{-1}), however values progressively decreased over the period of assessment to be non-saline (<1 dS m^{-1} ECe) from December '99 to November '01 (Table 3.2.3.1). Soil pH was slightly alkaline up to December '99, neutral in November '01.

Average plant density progressively decreased from 6.93 stems m^{-2} seven months after seeding, down to 2.78 stems m^{-2} 29 months after seeding (Table 3.2.3.1). In the following three growing seasons up to 66 months after seeding, mean plant density has remained relatively stable, ranging between 2.50 and 2.98 stems m^{-2}. Revegetation cover increased rapidly during the second growing season to average 24 percent, 19 months after seeding. Over the subsequent four years mean revegetation cover remained relatively stable, ranging between 18 to 27 percent (Table 3.2.3.1).

With the exception of the acacia's, all major taxa in the revegetation have exhibited decreasing plant density over the 66 months following seeding in response to increased competition (Figures 3.2.3.1-3.2.3.3). Acacia's require weathering of the hard seed coat before seed dormancy is broken. It is this feature, along with initial salinity levels, that has likely delayed field establishment. The faster growing *Atriplex* and *Maireana* species were the dominant taxa initially recorded, with annual chenopods of particular prominence during the initial two growing seasons. Revegetation cover provided by these taxa has stabilised over time as perennial life forms have become established.

In November '01 *Atriplex* (IVI 105) and *Maireana* (IVI 84) species approximated 11 and 4 percent ground cover respectively (Figure 3.2.3.1). In comparison the slower growing taller perennial taxa, *Acacia* (IVI 30) and *Eucalyptus* (IVI 55), show revegetation cover progressively increasing over the 6-year period of assessment to average 2 and 9 percent respectively (Appendix 8). The ground cover provided by these species will continue to increase until they reach maximum height. In November '01, *Acacia* and *Eucalyptus* averaged 1.0 m and 2.6 m in height respectively.

TABLE 3.2.3.1: Change in mean plant density, % revegetation cover and species richness, and soil salinity and pH (n=7) between December '96 and November '01. ANOVA and Fisher's Test between years, same superscript letters indicate no significant difference.

Year Assessed	Density no. m^{-2}	Cover %	Species Richness	ECe ($dS\ m^{-1}$)	pH
1996 (December)	6.936^{a}	7.46^{c}	28	10.70^{a}	7.29^{a}
1997 (December)	4.107^{b}	23.53^{ab}	29	3.51^{a}	7.16^{a}
1998 (October)	2.779^{b}	18.42^{b}	22	2.95^{a}	7.57^{a}
1999 (December)	2.980^{b}	22.04^{ab}	21	0.67^{a}	7.36^{a}
2000 (November)	2.940^{b}	25.79^{ab}	20	0.47^{a}	7.02^{a}
2001 (November)	2.500^{b}	26.70^{a}	19	0.89^{a}	7.11^{a}
P - value	0.001	0.001		0.312	0.836

FIGURE 3.2.3.1: Change in Importance Value Index (IVI), plant density and revegetation cover for important taxa, between December '96 and November '01.

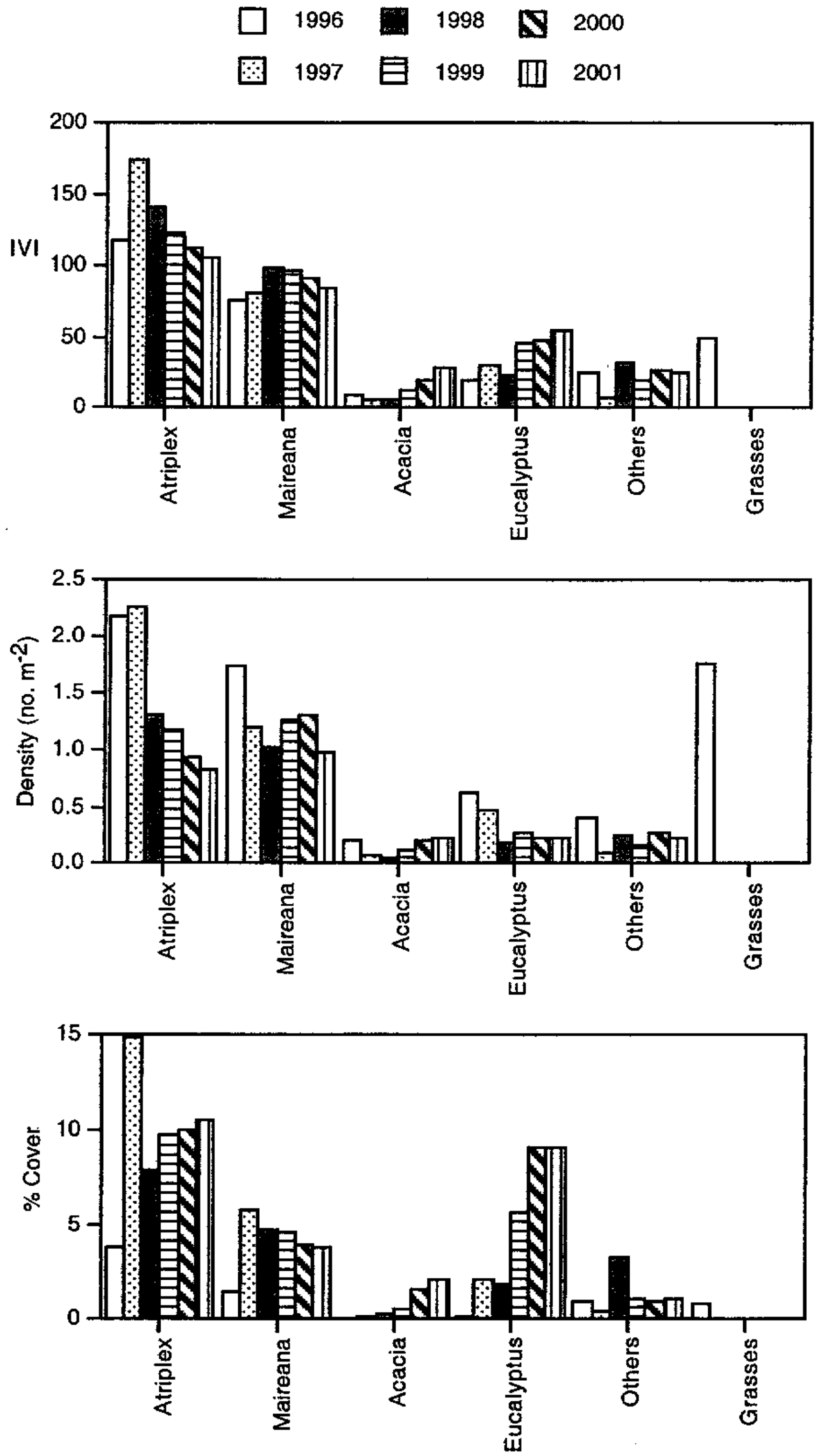


FIGURE 3.2.3.2: Elevated plant density was recorded during the first two growing seasons following direct seeding.

FIGURE 3.2.3.3: In November '01, 66 months after direct seeding, a diverse suite of local taxa had successfully established in the revegetation.

3.2.4 1997 Tailings Storage Facility

Rehabilitation Strategy

Parameter	Technique
Establishment Date	May 1997
Slope of Topography	15° batter
Revegetation Medium	Topsoil cover to 0.5 m depth over batters of the tailings storage facility
Surface Treatment	Conventional contour ripping using a D9 dozer to 0.5 m depth at 1 m intervals
Experimental Treatments	none
Seeding Method	Hand broadcast
Seeding Rate	Shallow rooting species at a rate of 8.0 kg ha^{-1}

Results and Comments

The composition of the seed mixture was limited to low shrubs with shallow root systems in order to maintain stability in the tailings wall (Appendix 6). Local chenopods were the obvious revegetation choice being prevalent in the surrounding rangeland, and well suited to later revegetation activities over the saline upper surfaces of the tailings storage facility.

Surface salinity remained non-saline and alkaline over the 66 month monitoring period (<2.5 dS m^{-1} ECe and <8.6 pH). Average plant density decreased over the period following seeding from 8.30 stems m^{-2} in December '97 (7 months after seeding) to 2.40 stems m^{-2} in November '01 (66 months after seeding, see Table 3.2.4.1). Revegetation cover increased significantly during the second growing season (from 13 to 46 percent) in response to prolific establishment by the annual weed *Carrichtera annua* (Ward's Weed), which alone provided 16 percent cover. In the absence of *C. annua* during the following year, revegetation cover decreased to average 25 percent. In November '00, cover increased to 41 percent due largely to a suite of perennial chenopods; high revegetation cover was maintained to November '01 (31 percent) under relatively low annual rainfall.

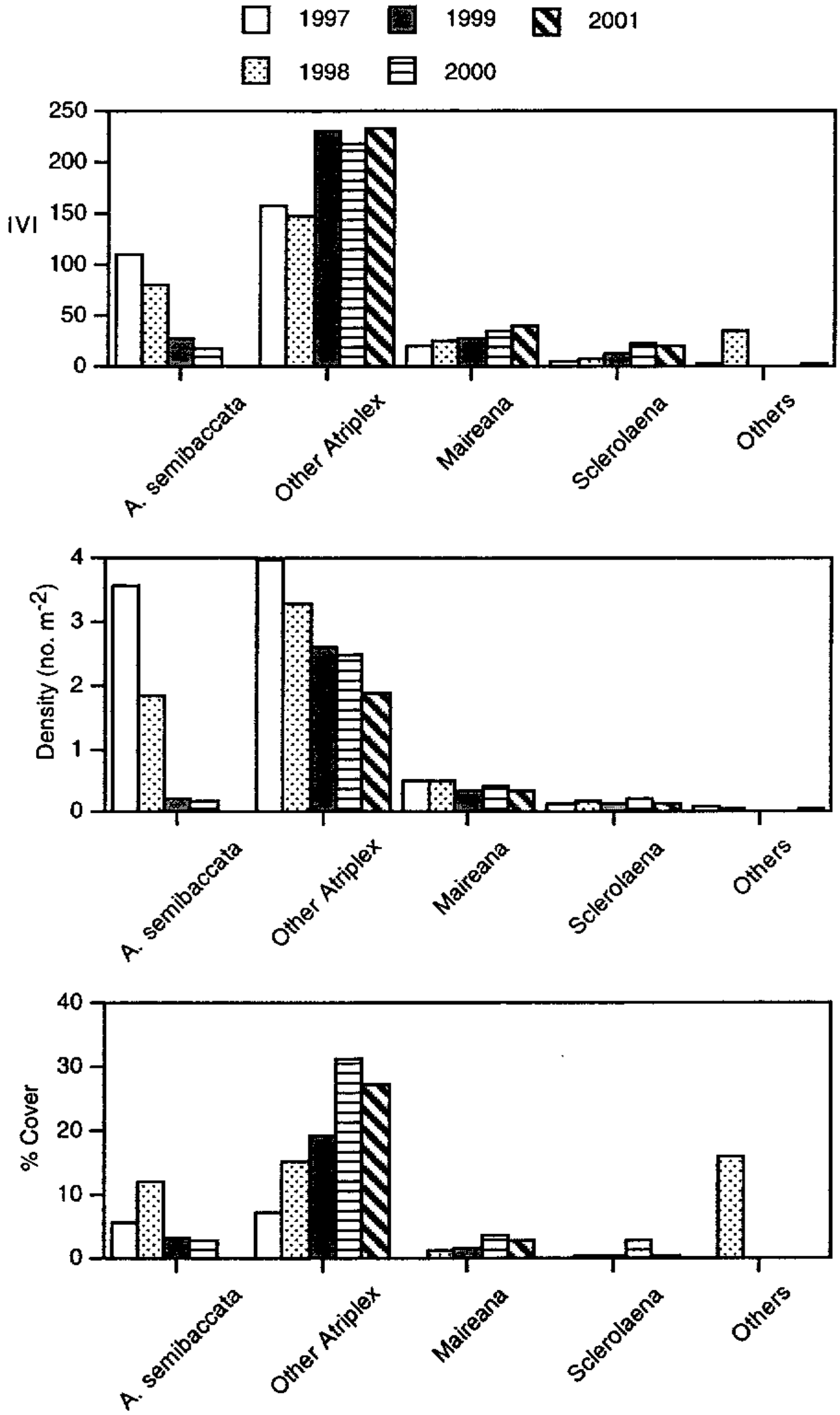
During the first growing season a high density of *Atriplex* species was recorded over the tailings wall (Figure 3.2.4.1). *Atriplex semibaccata* (creeping saltbush) recorded an individual density of 3.50 stems m^{-2}. This short-lived perennial was specifically included into the seed mixture to increase the initial revegetation cover. A fast growing revegetation cover plays an important role in developing ecosystems by stabilising topsoil, reducing surface temperatures and hence soil moisture loss, and preventing the capillary rise of salts. Creeping saltbush has a prostrate habit and short life expectancy, thus does not compete with more desirable but slower growing species important to longer-term revegetation success. Between December '97 and October '98, *A. semibaccata* ground cover increased from 6 to 12 percent. However, under increased competition from perennial species, the cover of *A. semibaccata* progressively diminished over time and in November '01 it was not recorded in the revegetation (Appendix 8).

The ground cover provided by the 'Other *Atriplex*' taxa increased between December '97 and November '01, ranging from 7 to 32 percent (Figure 3.2.4.1). Sixty-six months after seeding *Atriplex vesicaria* (IVI 147) is the keystone species in the rehabilitation, providing an individual cover of 19 percent. Other prominent species include *A. nummularia* (IVI 48, 3 percent), *Maireana* triptera (IVI 31, 3 percent), *A. amnicola* (IVI 20, 2 percent) and *A. bunburyana* (IVI 18, 2 percent).

TABLE 3.2.4.1: Change in mean plant density, % revegetation cover and species richness, and soil salinity and pH between December '97 and November '01. Seeded in May '97 (n=5).

Year Seeded Year Assessed	**Density no. m^{-2}**	**Cover %**	**Species Richness**	**ECe ($dS\ m^{-1}$)**	**pH**
1997 (December)	8.300 ^{a}	13.36 ^{c}	20	1.55 ^{b}	8.30 ^{b}
1998 (October)	5.860 ^{b}	45.50 ^{a}	20	1.74 ^{b}	8.63 ^{a}
1999 (December)	3.320 ^{c}	24.96 ^{b}	17	2.53 ^{a}	8.13 ^{c}
2000 (November)	3.290 ^{c}	40.98 ^{a}	17	1.95 ^{ab}	8.07 ^{c}
2001 (November)	2.400 ^{c}	31.01 ^{b}	13	2.64 ^{a}	7.91 ^{d}
P - value	0.001	0.001		0.026	0.001

FIGURE 3.2.4.1: Change in Importance Value Index (IVI), plant density and % revegetation cover for important taxa between December '97 and November '01.



3.2.5 1998 Evaporation Pond

Rehabilitation Strategy

Parameter	Technique
Establishment Date	May 1998
Slope of Topography	15° batter
Revegetation Medium	Topsoil cover to 0.5 m depth over walls of the evaporation pond
Surface Treatment	Conventional contour ripping using a D9 dozer to 0.5 m depth and at 1 m intervals
Experimental Treatments	none
Seeding Method	Hand broadcast
Seeding Rate	Shallow rooting species at a rate of 8.0 kg ha^{-1}

Results and Comments

A similar seed mixture composition and sowing rate was applied over the tailings storage facility batter in May '97 and evaporation pond batter in May '98 (Appendix 6). Soil salinity and pH was also similar for both areas, non-saline and alkaline. The resultant revegetation composition approximately seven months after seeding, however, was very different.

Overall plant density and revegetation cover 7 months after seeding averaged 8.30 stems m^{-2} and 13 percent for the 1997 seeding (Table 3.2.4.1). At the same revegetation age, these parameters over the 1998 seeding averaged 4.46 stems m^{-2} and 31 percent (Table 3.2.5.1). Plant density and ground cover provided by the *Atriplex* and *Maireana* taxa was much lower for the 1998 seeding in comparison to the 1997 seeding at a similar age.

Surface preparation of the 1998 rehabilitation was completed six months prior to seeding. Rainfall during this period subjected the surface to wetting drying cycles and resulted in the formation of a surface crust, which inhibited the lodgement and germination of seed following direct sowing. The extended period between surface preparation and sowing also favoured the build-up of wind blown weed species seed between rip lines. *Carrichtera annua* (Ward's Weed) was one such species that established a seed bank during this period, and subsequently established in high numbers during the first growing season (represented in the 'others' taxa, see

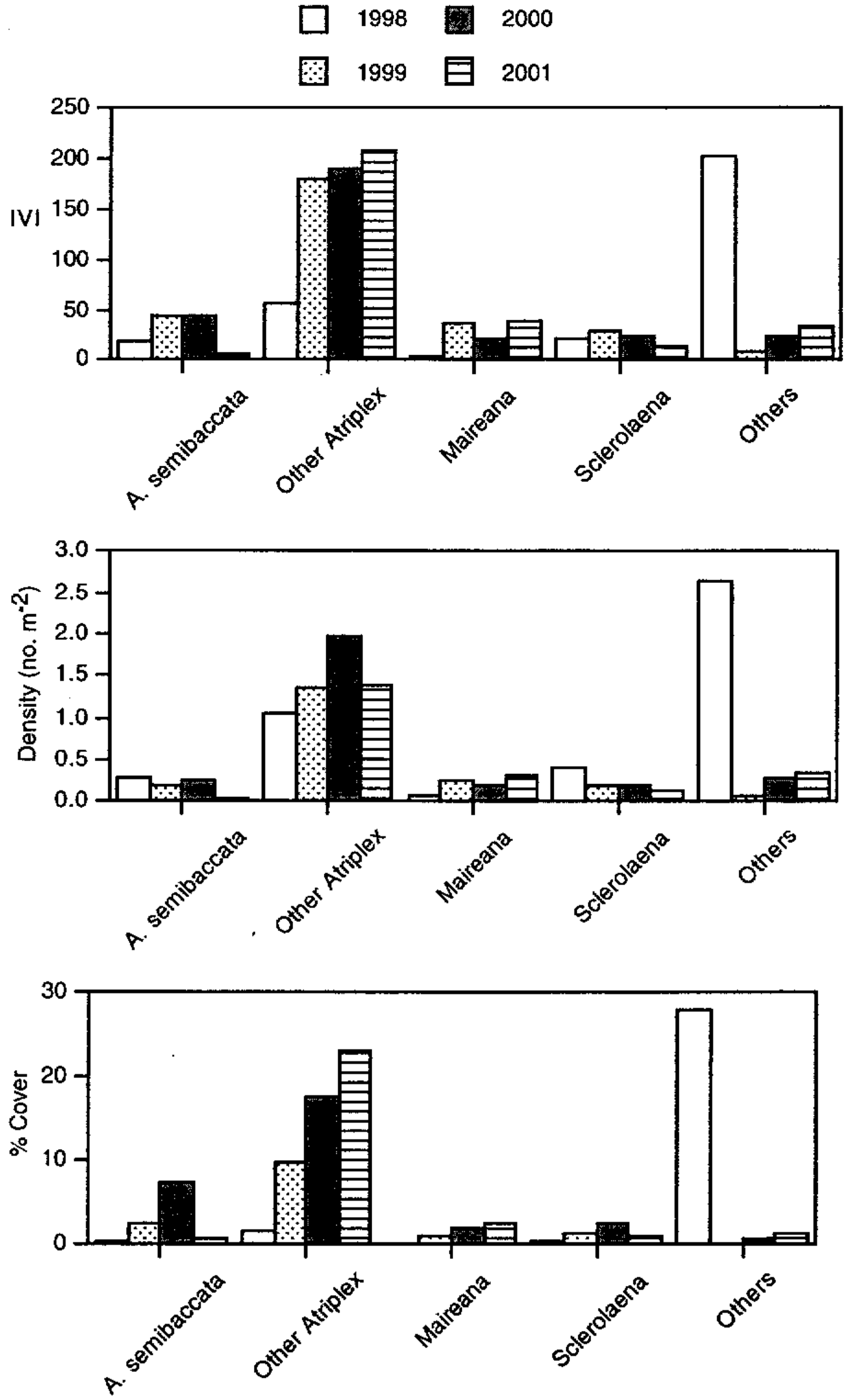
Figure 3.2.5.2). The prominence of Ward's Weed during the first growing season limited the initial establishment of seeded species, and subsequently slowed revegetation development.

Between December '99 and November '01, *C. annua* was either absent or represented as only a minor component of the revegetation. Over this period seeded species became established in the revegetation at progressively higher numbers, and during the 2000 and 2001 assessments plant biodiversity parameters began to stabilise (Table 3.2.5.1). In November '01 the prominent revegetation species were *Atriplex vesicaria* (IVI 139, 18 percent), *A. nummularia* (IVI 29), *A. codonocarpa* (IVI 15), *Senna filifolia* (IVI 15) and *E. tomentosa* (IVI 15).

TABLE 3.2.5.1: Evaporation Pond (Batters): Mean plant densities (no. stems m^{-2}) and % cover, and salinity (ECe in dS m^{-1}) and pH. Seeded in May '98 (n=5).

Year Seeded Year Assessed	**Density** **no. m^{-2}**	**Cover** **%**	**Species Richness**	**ECe** **(dS m^{-1})**	**pH**
1998 (October)	4.460 [a]	30.96 [a]	21	1.33 [b]	8.46 [a]
1999 (December)	2.100 [b]	15.04 [b]	19	1.89 [a]	8.04 [b]
2000 (November)	2.950 [b]	30.00 [a]	25	2.22 [a]	8.01 [b]
2001 (November)	2.210 [b]	28.54 [a]	22	2.04 [a]	7.92 [b]
P - value	0.014	0.003		0.010	0.001

FIGURE 3.2.5.1: Change in Importance Value Index (IVI), plant density and % ground cover for important taxa between October '98 and November '01.



3.2.6 1997 Crusher Pad Rehabilitation

Rehabilitation Strategy

Parameter	Technique
Establishment Date	May 1997
Slope of Topography	20° batter
Revegetation Medium	0.3 m topsoil cover over competent fresh rock
Surface Treatment	Conventional contour ripping using a D9 dozer to 1 m depth and at 1-1.5 m intervals
Experimental Treatments	none
Seeding Method	Hand broadcast
Seeding Rate	28 species at a rate of 8.6 kg ha^{-1}

Results and Comments

Surface soil condition remained non-saline and alkaline for the five rehabilitation assessments (Table 3.2.6.1). High plant density recorded during the initial growing season (4.26 stems m^{-2}) represented successful germination of direct seeded species, and was accompanied by typically low revegetation cover (7 percent). Plant density decreased during the second growing season (2.39 stems m^{-2}) under increased competition (20 percent cover), but again increased 14 months later (3.40 stems m^{-2} and 18 percent cover). In November '00 (43 months after seeding), average plant density again decreased to 1.35 stems m^{-2} (25 percent), only to increase again 12 months later (4.06 stems m^{-2} and 25 percent cover).

Atriplex semibaccata was an important colonising species recorded during the initial growing season (Figure 3.2.6.1). Numbers and cover decreased during the second growing season under increased competition from 'Other *Atriplex*' and *Carrichtera annua* (Ward's Weed). As was recorded for neighbouring rehabilitation, *C. annua* established prolifically during 1998 under favourable seasonal conditions. Although only a short lived annual species, the competitive effects of Ward's Weed early in the growing season was detrimental to the establishment and growth of the more desirable rehabilitation species direct seeded. A higher ground cover was expected from the 'Other *Atriplex*' and '*Maireana*' taxa during the second growing season. This 'disturbance' event was likely responsible for the increase in plant density and slight decrease in revegetation cover recorded during the following year (December '99).

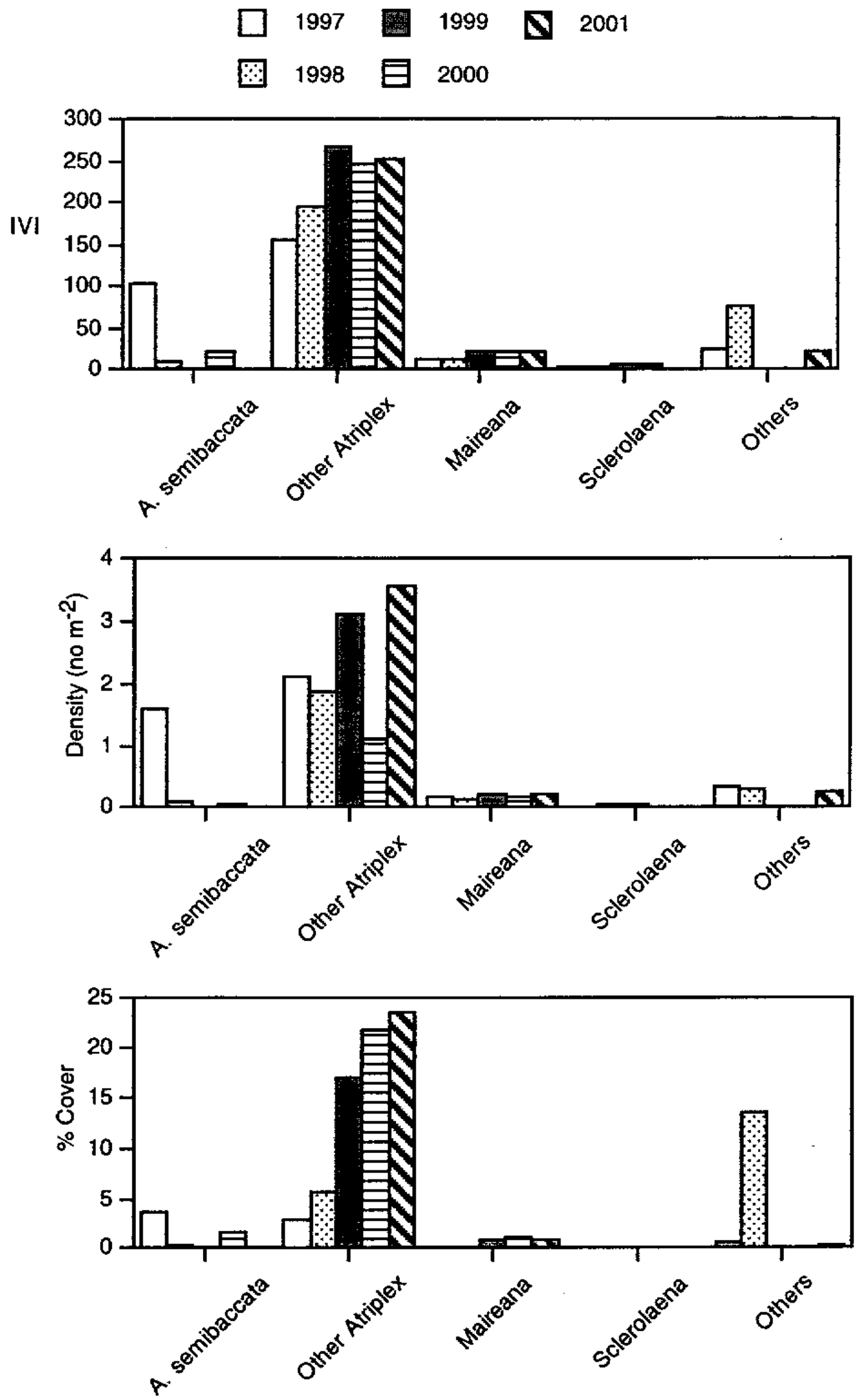
In November '01 (55 months after seeding) important rehabilitation species included the perennial species *Atriplex vesicaria* (IVI 61), *A. nummularia* (IVI 60) and *A. bunburyana* (IVI 41), and the annual *A. codonocarpa* (IVI 60, Figure 3.2.6.1). Although included in the seed mixture (Appendix 6), taller perennial species were absent from the crusher pad rehabilitation (acacia, eucalyptus, eremophila and senna). Within the exploration rehabilitation these taxa appeared during the first growing season and established successfully to become dominant components in the revegetation.

The crusher pad rehabilitation is currently not self-sustaining, as evidenced by large fluctuations in the plant biodiversity parameters being measured, and continued dominance of annual life forms. Water is likely to be the factor limiting ecosystem development over the crusher pad. Underlying the thin topsoil layer is a high proportion of competent rock, which has a low capacity to hold water following rainfall. Future rehabilitation of similar structures should aim to increase the proportion of sub-surface fines in an effort to maximise water retention in the upper profile following rainfall.

TABLE 3.2.6.1: Crusher Pad (Batters): Mean plant densities (no. stems m^{-2}) and % cover, and salinity (ECe in dS m^{-1}) and pH. Seeded in May '97 (n=5).

Time of Assessment	Density no. m^{-2}	Cover %	Species Richness	ECe (dS m^{-1})	pH
1997 (December)	4.260 ^{a}	7.32 ^{b}	13	1.56 ^{a}	7.84 ^{c}
1998 (October)	2.390 ^{a}	19.57 ^{a}	14	3.17 ^{a}	8.22 ^{a}
1999 (December)	3.400 ^{a}	18.13 ^{a}	14	2.19 ^{a}	7.95 ^{bc}
2000 (November)	1.350 ^{a}	24.73 ^{a}	13	3.19 ^{a}	8.13 ^{ab}
2001 (November)	4.060 ^{a}	25.06 ^{a}	16	2.16 ^{a}	8.05 ^{abc}
P - value	0.087	0.040		0.226	0.017

FIGURE 3.2.6.1: Change in Importance Value Index (IVI), plant density and revegetation cover for important taxa between December '97 and November '01.



3.2.7 Summary of Findings

A variety of plant taxa have been successfully reintroduced over a variety of mining and exploration sites in the Eastern Goldfields including *Eucalyptus, Acacia, Eremophila, Dodonaea, Atriplex* and *Maireana.*

For sump hole areas where substrates were initially extremely saline, local chenopod species have successfully established. A relatively high seeding rate (15 kg ha^{-1}) was applied in response to elevated salinity. Fertiliser application (100 kg ha^{-1}) favoured the establishment and growth of specific revegetation species, particularly *Atriplex bunburyana,* but overall did not produce a significant revegetation response. Deep ripping facilitated the leaching of surface salts. The establishment of a vegetation cover was also important in decreasing surface temperatures and facilitating the leaching of surface salts.

Disturbance over the 'General Exploration Area' and 'Drill Lines' was less intensive in comparison to the 'Sump Hole' sites, and although still saline, topsoil salinity was significantly lower at the time of seeding. In response to lower soil salinity a wider range of plant life forms were included into the seed mixture, at a reduced seeding rate (6 kg ha^{-1}). All of the major plant taxa sown were represented in the revegetation during the six assessments made up to 66 months after seeding.

The batters of the tailings storage facility and evaporation pond were sown with a mixture of local shallow rooted chenopod species, unlikely to interfere with the stability of the underlying structure. Seeding occurred during May '97 and May '98 respectively at a rate approximating 8 kg ha^{-1}. In November '01, vegetation composition and structure of both rehabilitation sites reflected that of the neighbouring analogue community, *Atriplex vesicaria* Low Shrubland.

The composition of the seed mixture sown over batters of the 'Crusher Pad' was similar to that used for the 'General Exploration Area' and 'Drill Lines'. The resultant revegetation, however, was dominated by chenopod species, and characterised by the absence of *Acacia, Senna* and *Eucalyptus* species. The revegetation outcome has likely been influenced by the limitation of water in the upper rehabilitation medium. Topsoil was spread to a maximum depth of 0.3 m over competent rock. Following rainfall a large proportion of the moisture input is lost through the competent rock layer, and revegetation usage is limited to moisture stored within the thin upper topsoil layer. As a result, only drought tolerant chenopod species have been able to establish and survive.

3.3 Northeastern Wheatbelt

3.3.1 Waste Dumps 1A-1D

Rehabilitation Strategy

Parameter	Technique
Establishment Date	May 1990
Slope of Topography	Flat upper surfaces, and 20° batters
Revegetation Medium	Topsoil cover to >0.3 m depth over saline oxidised waste
Surface Treatment	Deep ripping to 1 m depth and at 1.5 m intervals using a D9 dozer
Experimental Treatments	none
Direct Seeding	*Waste Dumps 1A and 1B* A mixture of 15 species including salt tolerant chenopods, acacias and eucalypts, hand broadcast at a rate of 3.7 kg ha^{-1} (Appendix 10) *Waste Dump 1C – upper surfaces* A mixture of 15 species including salt tolerant chenopods, acacias and eucalypts, hand broadcast at a rate of 4.5 kg ha^{-1} *Waste Dump 1C – batters* A mixture of 16 species including salt tolerant chenopods, acacias and eucalypts, hand broadcast at a rate of 4.9 kg ha^{-1} *Waste Dump 1D* A mixture of 12 species including salt tolerant chenopods, acacias and eucalypts, hand broadcast at a rate of 4.0 kg ha^{-1}
Fertiliser	Agras No. 1 applied at 100 kg ha^{-1} (17.5%N, 7.6%P and 17.0%S)

Results and Comments

The upper and batter surfaces of the four waste dumps showed similar change with respect to soil salinity and pH over the 11 year assessment period (Figures 3.3.1-3.3.4). Initially soils were very saline (25 dS m^{-1} ECe) and alkaline (pH 8.2). However, salinity decreased over time averaging less than 2.1 dS m^{-1} ECe in September '00 for all surfaces, with the exception of the batters on Waste Dump

1C (8.4 dS m^{-1} ECe). Soil pH remained alkaline in September '00, averaging between 8.1 and 8.8 for the four waste dumps.

Four seed mixtures, differing only slightly in species composition and sowing rate, were used over the four waste dumps with overall seeding rates ranging between 3.67 kg ha^{-1} and 4.94 kg ha^{-1} (Table 3.3.1, Appendix 10). The largest proportion of the four seed mixtures (approximately 50 percent by weight) comprised between four and six chenopod species adapted to tolerate high salinity, provide an initial revegetation cover and increase surface stability during the early stages of ecosystem development. *Acacia* (3) and *Eucalyptus* (4) species were included at similar proportions into each of the four seed mixtures (Table 3.3.1), comprising between 8 and 19 percent of the total weight. The remainder of each seed mixture comprised a variety of woody perennials making up between 19 and 26 percent of the total seed mixture weight. This group included *Senna, Melaleuca, Pittosporum, Hakea* and *Dodonaea.*

TABLE 3.3.1: Seed mixture composition for the four waste dumps at Westonia Gold Mine, showing the breakdown of major taxa with respect to seed rate and as a percentage of the total seed rate.

Taxa	Seed Rate (kg ha^{-1}) and % of Total Weight							
	1A, 1B entire		1C upper		1C batters		1D upper	
Chenopods	1.896	52	2.200	48	3.044	62	1.888	47
Acacia	0.456	12	0.580	13	0.400	8	0.456	11
Eucalyptus	0.608	17	0.600	13	0.400	8	0.752	19
Others	0.708	19	1.162	26	1.100	22	0.924	23
TOTAL	**3.668**	**100**	**4.542**	**100**	**4.944**	**100**	**4.020**	**100**

In September '00, 125 months after seeding, three distinct structural layers were distinguishable in the revegetation over Waste Dumps 1A, 1B, 1C and 1D. A developing upperstorey layer comprised a variety of *Eucalyptus* species, the most common being *E. salubris*. This stratum was best developed on the upper surfaces of Waste Dumps 1B and 1C (foliage cover >20 percent) where it formed Low Woodland. Over the remaining surfaces the eucalypts provided less than 10 percent cover (Open Low Woodland), and were absent from the upper surfaces of Waste Dump 1A.

The composition of the understorey strata varied between waste dumps, however the dominant taxa for batter and upper surfaces of each waste dump were relatively similar. Waste Dump 1A and Waste Dump 1D had an established cover of *Atriplex* shrubs to 2 m tall, with *A. nummularia* and *A. vesicaria* the dominant species represented. Over Waste Dump 1D *A. nummularia* was particularly well established, alone providing 25 percent ground cover. *Atriplex* species provided lower ground coverage over Waste Dump 1B, occurring with two local *Acacia* species, *A. hemiteles* and *A. merrallii.* For Waste Dump 1C both *Atriplex* and *Acacia* were represented in the revegetation, along with a variety of local species represented as minor components *(Dodonaea, Melaleuca)* but increasing overall species richness.

The ground cover common to all rehabilitation surfaces was provided by introduced annual grasses. This was best represented over the upper surfaces of Waste Dump 1A, where grasses recorded 17 percent foliage cover in September '00.

Species richness for Waste Dump 1A was relatively low over both batter and upper surfaces for the entire period of monitoring, totalling nine and five species respectively in September '00 (10.5 years after seeding). Taller woody species such as *Eucalyptus salubris* (IVI 13) were established over the batters of Waste Dump 1A (Figure 3.3.5). In comparison, revegetation on flat upper surfaces was limited to a sparse cover of salt bush (*A. nummularia* IVI 226, *A. vesicaria* IVI 19) and annual grass species (IVI 18) (Figure 3.3.6).

Very high plant density was recorded for both surfaces of Waste Dump 1A during the initial growing season of 1990 (up to 80 germinants m^{-2}), confirming successful seed germination (Figure 3.3.1). However, during the third year following seeding mean plant density decreased to average less than 5 stems m^{-2} and has since stabilised within a range less than 2 stems m^{-2} (Appendix 11).

Revegetation cover for Waste Dump 1A was typically 15 percent higher for upper surfaces, in comparison to the batters (Figure 3.3.1), owing to the dominance of annual grasses in the absence of an established cover of perennial shrubs. Ground cover increased rapidly during the initial five years following seeding for both surfaces, before fluctuating within a range of 27-50 percent and 18-34 percent for upper and batter surfaces respectively.

The variability of plant biodiversity parameters over time for Waste Dump 1A, particularly on upper surfaces, was a response to the dominance of annual life forms and the relative sparseness of established perennial species (Figures 3.3.5 & 3.3.6). Variability of the parameters measured was highlighted during periods of low annual rainfall as was evidenced during '95, '96 and '00.

For Waste Dumps 1B and 1C plant biodiversity parameters showed less variation between the two surfaces (upper and batters) in comparison to Waste Dump 1A (Figure 3.3.2 & 3.3.3 respectively). After increasing rapidly during the initial growing seasons, plant density decreased under increasing competition to average 0.18 and 0.33 stems m^{-2} in September '00 for upper and batter surfaces of Waste Dump 1B (Figure 3.3.2), and 0.47 and 0.76 stems m^{-2} for corresponding surfaces of Waste Dump 1C (Figure 3.3.3). In September '00 revegetation cover averaged between 33 and 37 percent for the above surfaces, with the exception of Waste Dump 1C batters (20 percent).

For Waste Dump 1B species richness for both surfaces (upper and batter) remained relatively stable during the period of assessment, approximating 10 species (range 8-14 species). The variation recorded was due largely to seasonal fluctuations and the emergence of annual life forms during spring assessments.

Species richness for Waste Dump 1C increased from six species five months after seeding, to 15 species 125 months after seeding. A number of local perennial shrubs established approximately six years after seeding including *Eremophila, Dodonaea* and *Melaleuca.*

Plant biodiversity parameters over Waste Dump 1D showed similar trends to those of the other waste dumps, even though the structure and composition of revegetation was different; characterised by the dominance of *Atriplex nummularia* (oldman saltbush) as a tall shrub providing 25 percent cover. High plant density recorded during the first growing season (4.8 stems m^{-2} in September '90) decreased exponentially over the 11 year monitoring period to average 0.80 stems m^{-2} in September '00 (Figure 3.3.4). Revegetation cover increased over the same period to average 53 percent in September '98, before decreasing to 37 percent in September '00.

The dominance of *Atriplex nummularia* over Waste Dump 1D contributed to the relatively low but stable species richness recorded. During 1997 and 1998 assessments the upperstorey species *Eucalyptus salubris* was recorded for the first time, and in September '00 species richness totalled seven.

Atriplex semibaccata (creeping-saltbush) was an important coloniser species recorded in high numbers during the early stages of ecosystem development for all waste dump surfaces. The prostrate spreading habit of this species increased surface stability during the early stages, before being easily outcompeted by more desirable longer-lived species during later stages of ecosystem development (Figures 3.3.5 - 3.3.11). Sixty months after seeding *A. semibaccata* was only recorded in very low numbers, and by September '00 (125 months after seeding) it was restricted to the upper surfaces of Waste Dumps 1A and 1C.

Perennial *Atriplex* species established gradually to replace *A. semibaccata* in the revegetation by mid '95 (60 months after seeding). *A. nummularia* and *A. vesicaria* were dominant saltbushes recorded over all four waste dumps, with *A. nummularia* alone providing 25 percent ground cover over Waste Dump 1D in September '00 (Figures 3.3.11 & 3.3.12). *A. nummularia* also established well over Waste Dump 1A, approximating 7 and 19 percent cover for upper and batter surfaces during the most recent assessment. For Waste Dumps 1B and 1C, where taller eucalypts and acacias have successfully established, *Atriplex* was less prominent approximating 8 percent and 4 percent ground cover respectively.

Maireana was a minor component of the revegetation over all four waste dumps. In September '98 *Maireana* approximated 2 percent ground cover for the upper and batter surfaces of Waste Dump 1C. For the other surfaces assessed, it provides less than 0.6 percent cover.

Grasses began volunteering 29 months after seeding, when surface salinity had decreased to tolerable levels. Although seasonally variable, grasses persisted over the course of the assessments and in September '00 average ground coverage ranges between 4 and 17 percent for all waste dump surfaces.

Mid stratum and upper storey species including *Acacia* and *Eucalyptus* were first recorded in the revegetation 29 months after seeding (September '92). Both taxa displayed slow initial development, but in September '97 ground cover increased significantly. The sudden increase in productivity coincided with the first flowering by many species, and subsequent production of seed (Figure 3.3.13). *Acacia* and *Eucalyptus* were present on the batter surfaces of Waste Dump 1A (1 and 3 percent ground cover respectively, see Figure 3.3.5), but were absent from the upper surfaces of the same waste dump. For Waste Dumps 1B and 1C, *Eucalyptus* spp. were better established over the upper flat surfaces (18 and 22 percent cover respectively), in comparison to batters (2 and 4 percent cover respectively). *Acacia* spp. have successfully established over upper and batter surfaces of Waste Dump 1B (8 and 13 percent cover), but have been less successful on Waste Dump 1C (3 and 2 percent cover respectively).

The differences in rehabilitation development observed between the four waste dumps have resulted from a number of factors including initial salinity of the surface rooting medium, quality and depth of respread topsoil, slope angle and length of slope for waste dump batters, and seed mixture composition and seeding rate.

FIGURE 3.3.1: Change in plant density and revegetation cover (n=5), and soil salinity and pH (n=15), between September '90 and September '00 for Waste Dump 1A.

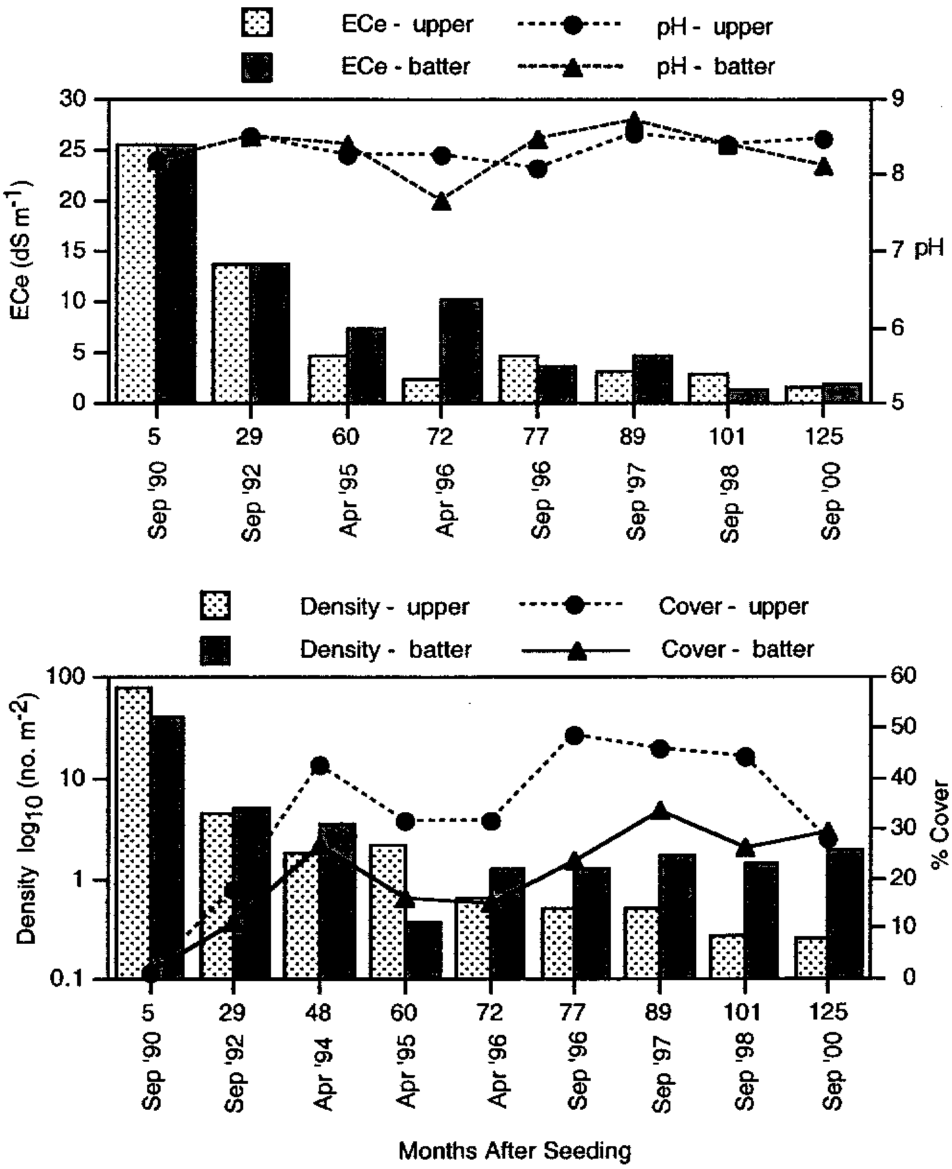


FIGURE 3.3.2: **Change in plant density and revegetation cover (n=5), and soil salinity and pH (n=15), between September '90 and September '00 for Waste Dump 1B.**

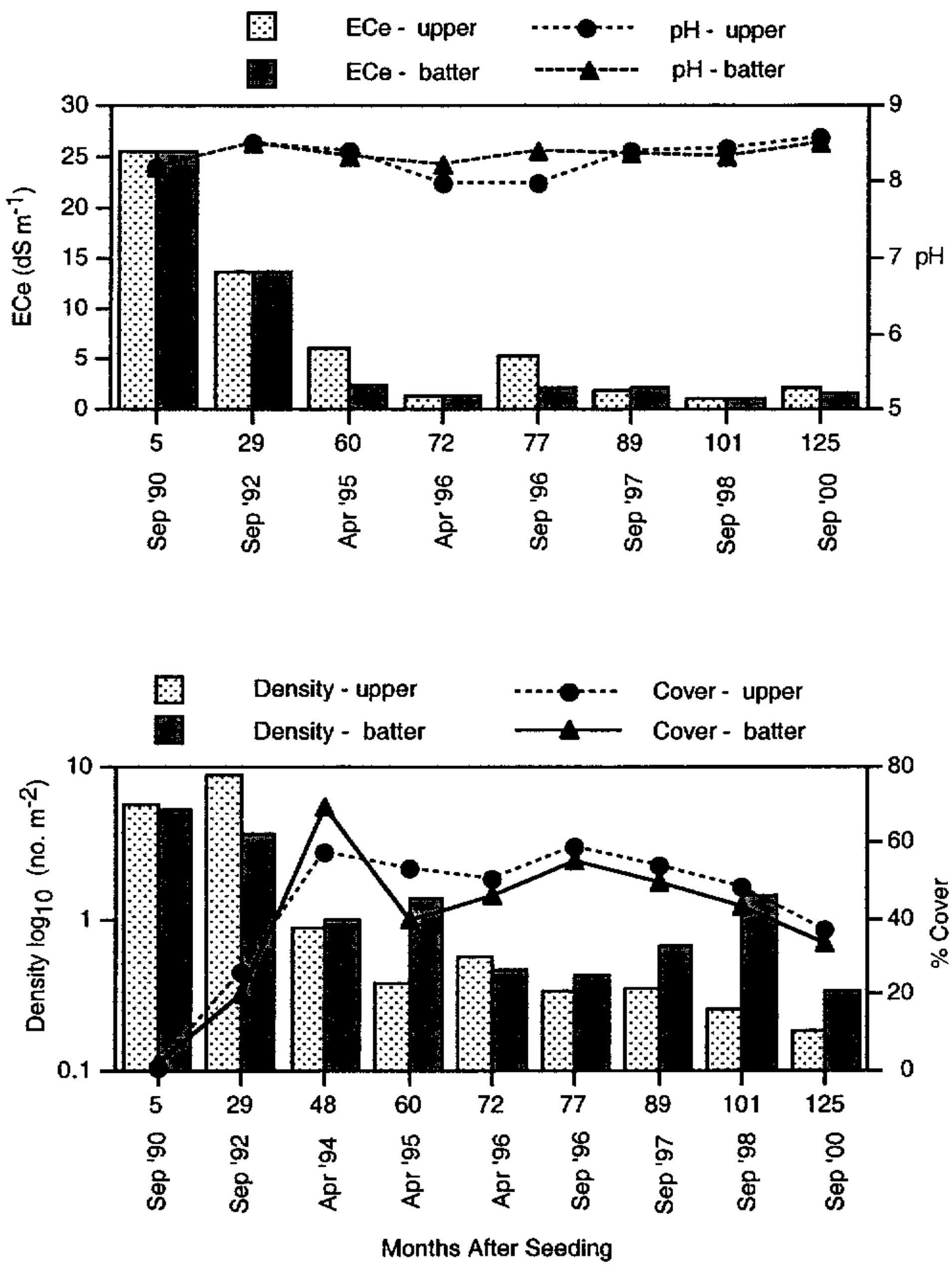


FIGURE 3.3.3: Change in plant density and revegetation cover (n=5), and soil salinity and pH (n=15), between September '90 and September '00 for Waste Dump 1C.

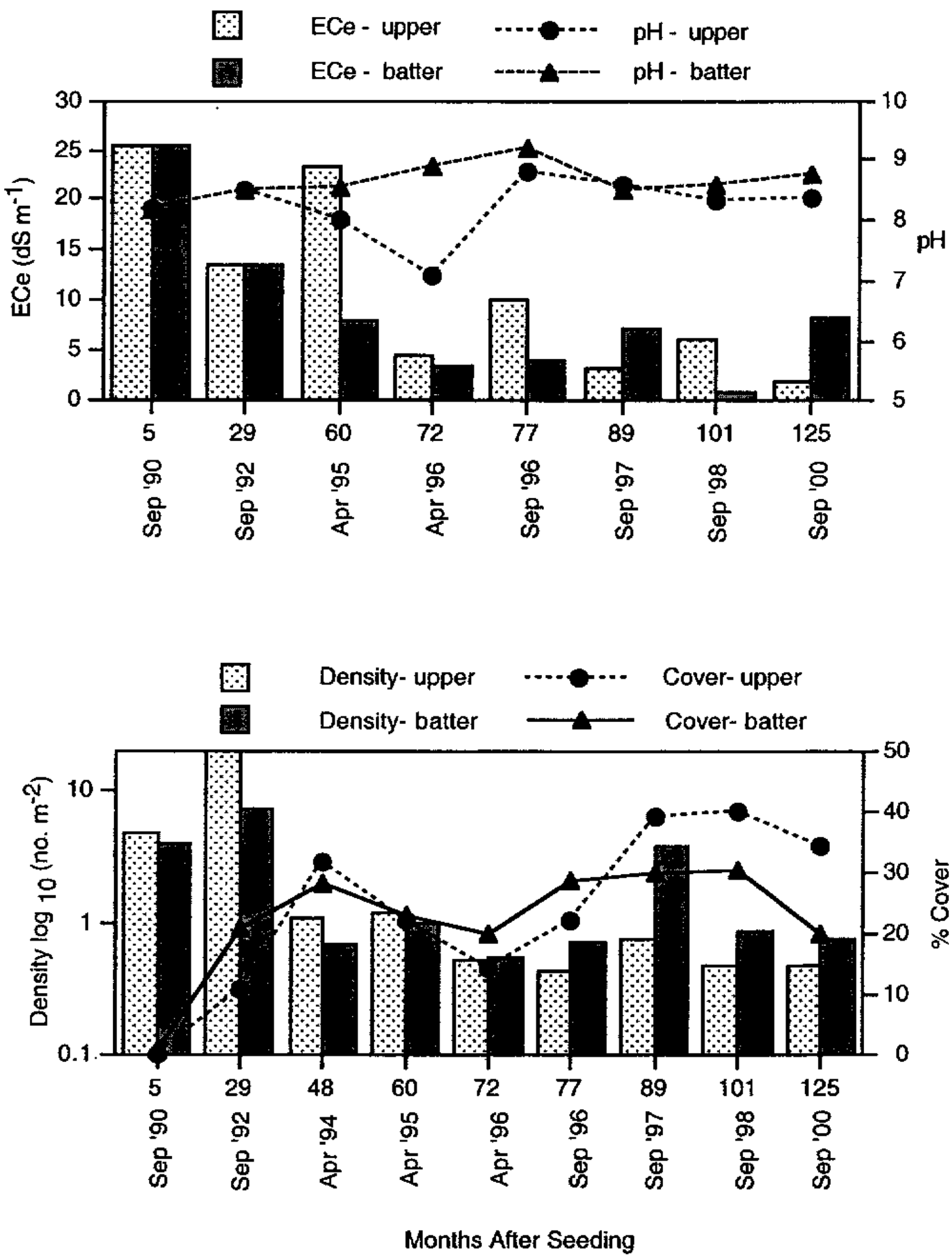
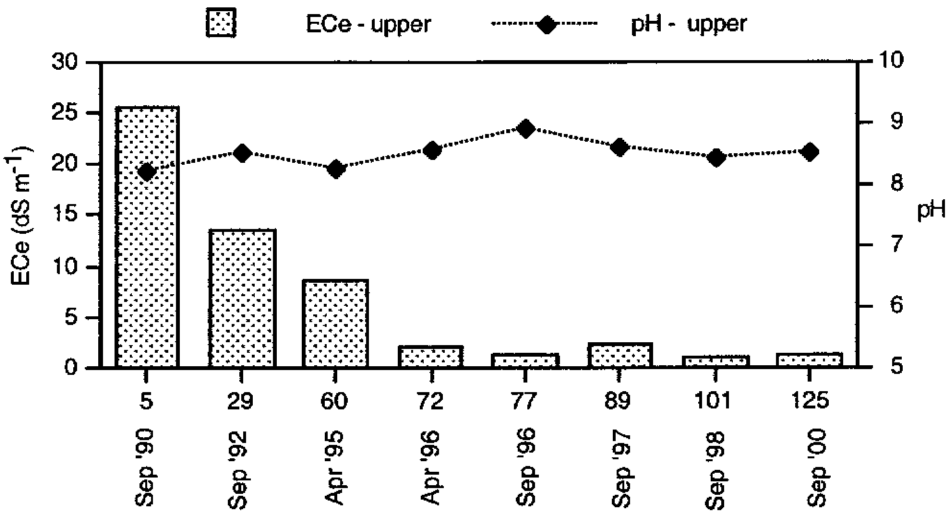


FIGURE 3.3.4: Change in plant density and revegetation cover (n=5), and soil salinity and pH (n=15), between September '90 and September '00 for Waste Dump 1D.



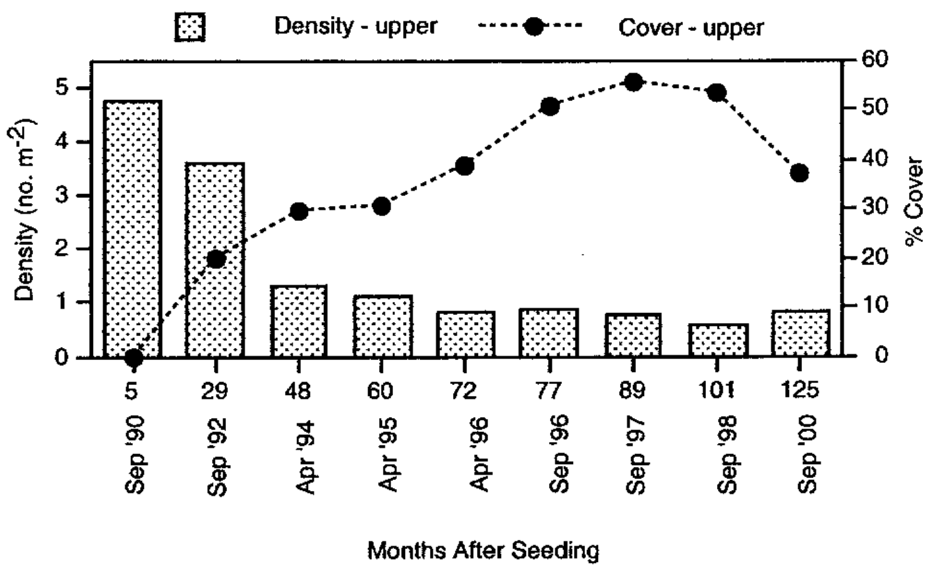


FIGURE 3.3.5: Change in Importance Value Index (IVI), plant density, and revegetation cover for dominant taxa recorded over Waste Dump 1A batter between September '90 and September '00 (n=5).

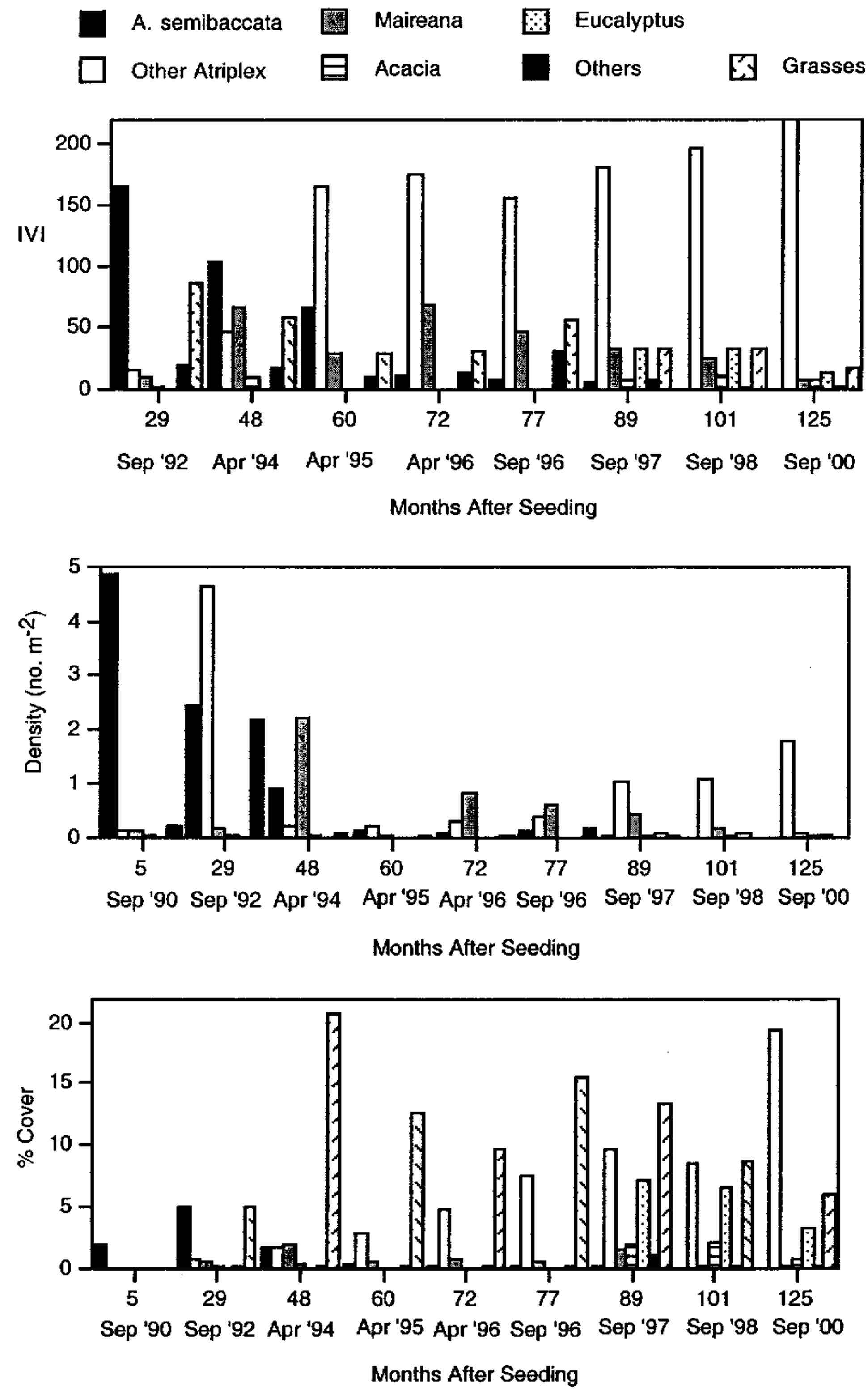


FIGURE 3.3.6: Change in Importance Value Index (IVI), plant density, and revegetation cover for dominant taxa recorded over Waste Dump 1A upper between September '90 and September '00 (n=5).

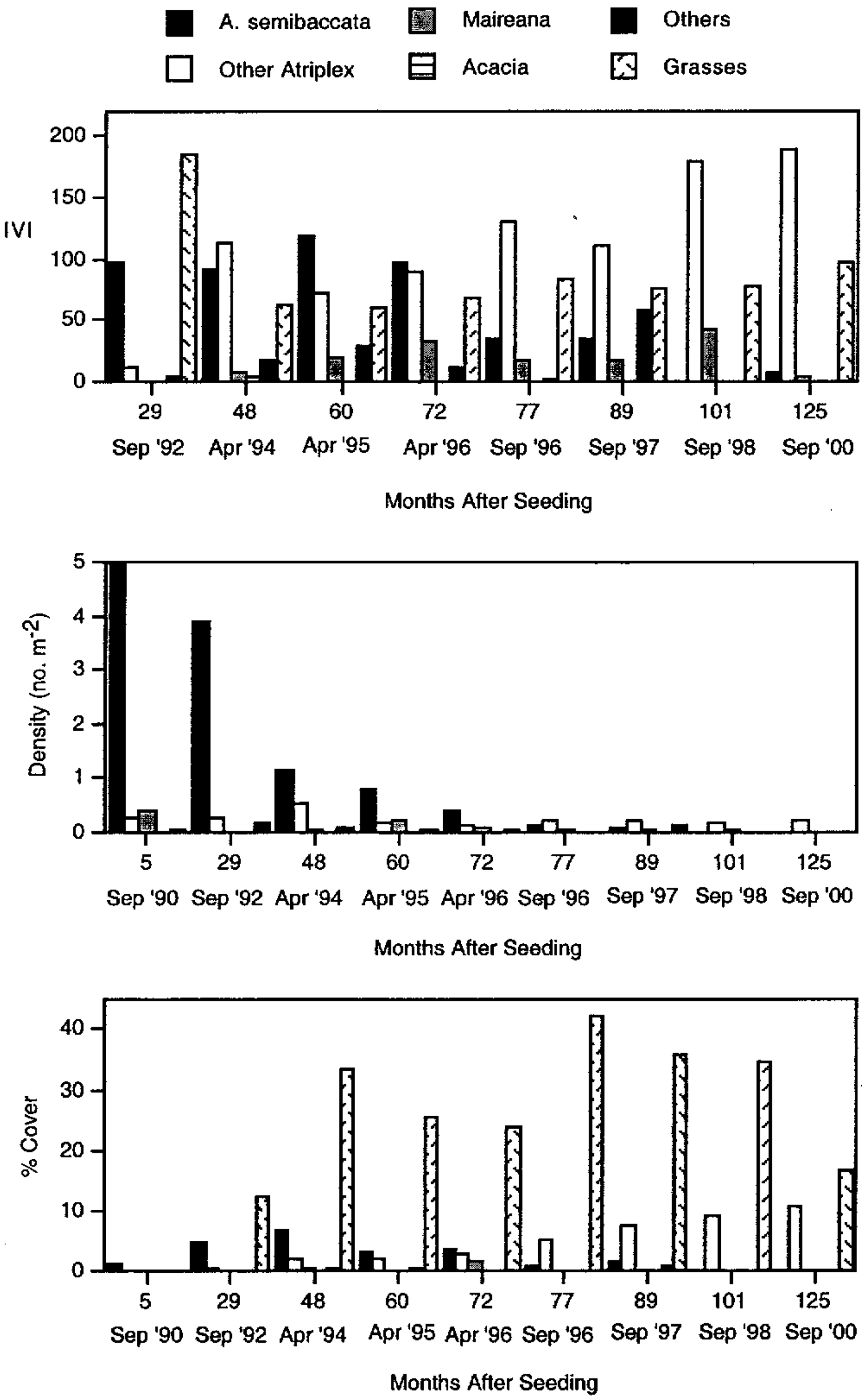


FIGURE 3.3.7: **Change in Importance Value Index (IVI), plant density, and revegetation cover for dominant taxa recorded over Waste Dump 1B batter between September '90 and September '00 (n=5).**

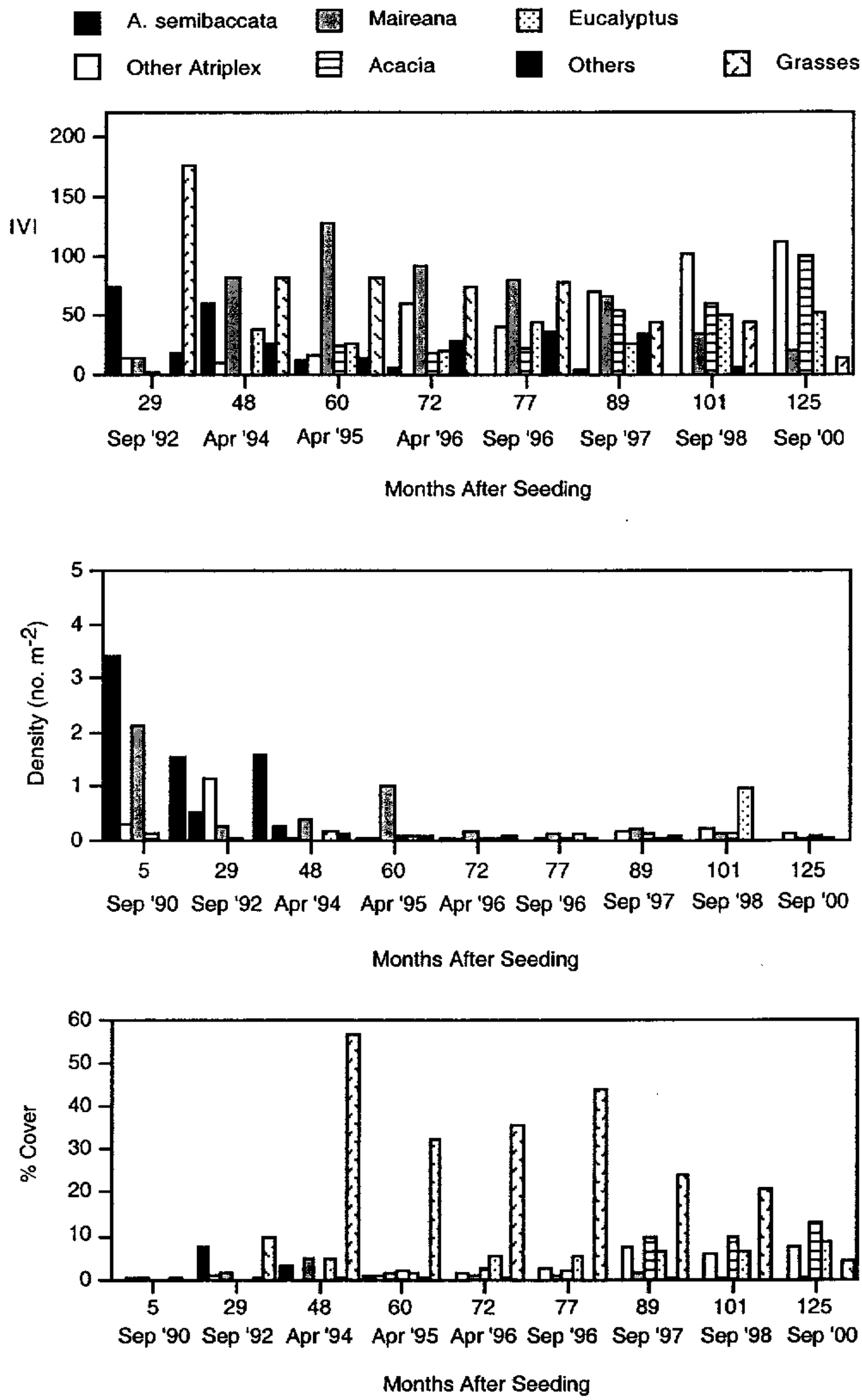


FIGURE 3.3.8: **Change in Importance Value Index (IVI), plant density, and revegetation cover for dominant taxa recorded over Waste Dump 1B upper between September '90 and September '00 (n=5).**

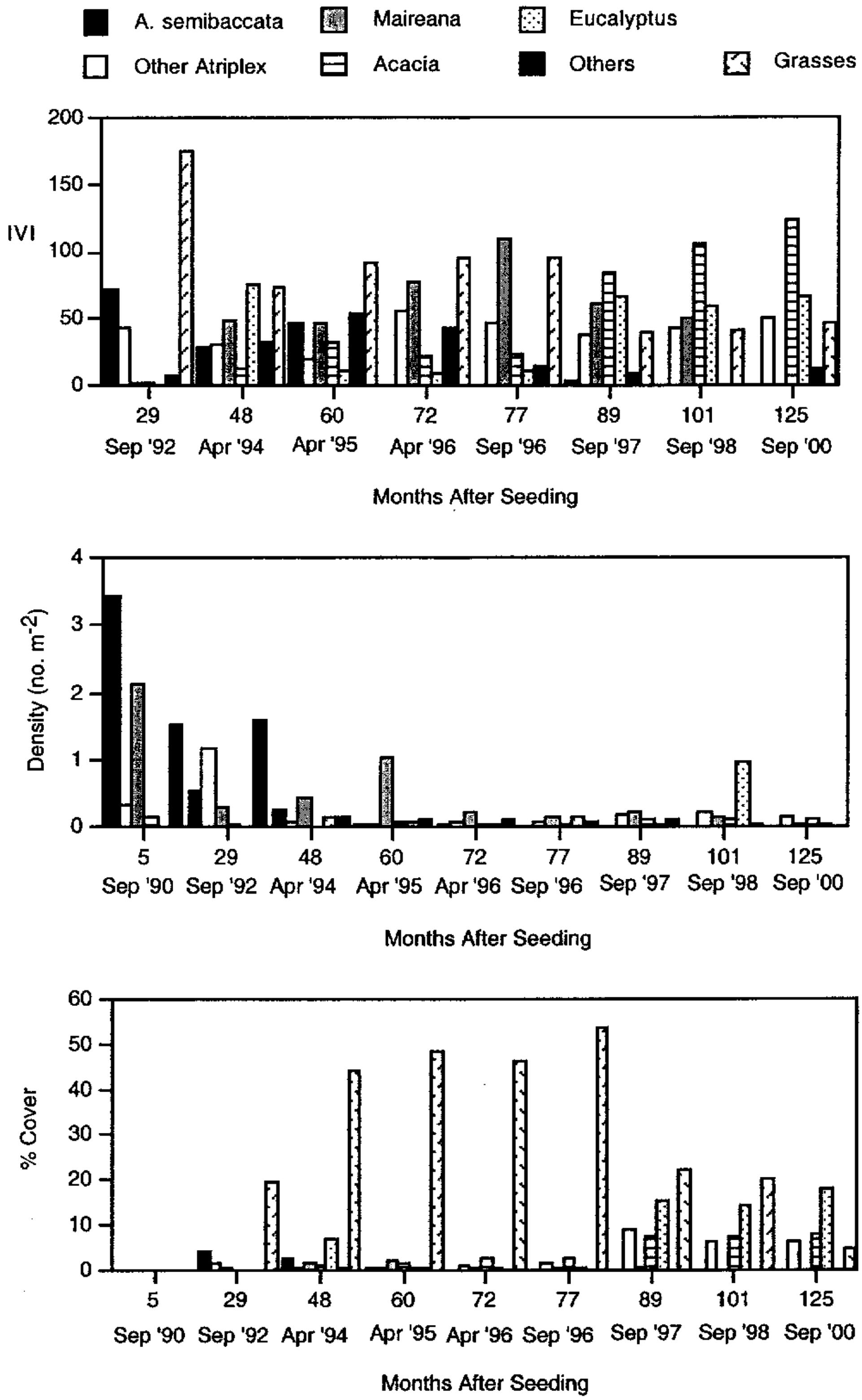


FIGURE 3.3.9: Change in Importance Value Index (IVI), plant density, and revegetation cover for dominant taxa recorded over Waste Dump 1C batter between September '90 and September '00 (n=5).

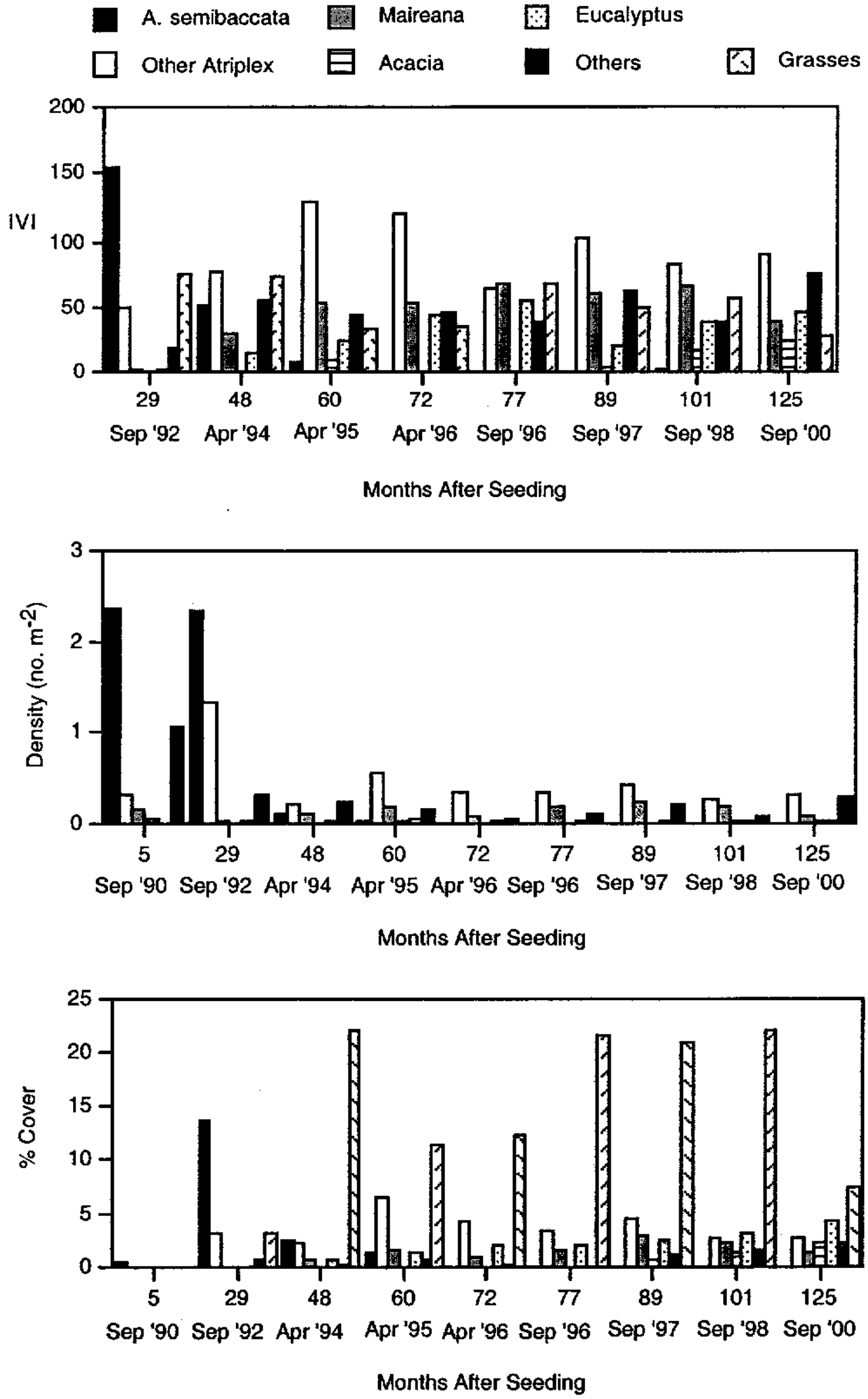


FIGURE 3.3.10: Change in Importance Value Index (IVI), plant density, and revegetation cover for dominant taxa recorded over Waste Dump 1C <u>upper</u> between September '90 and September '00 (n=5).

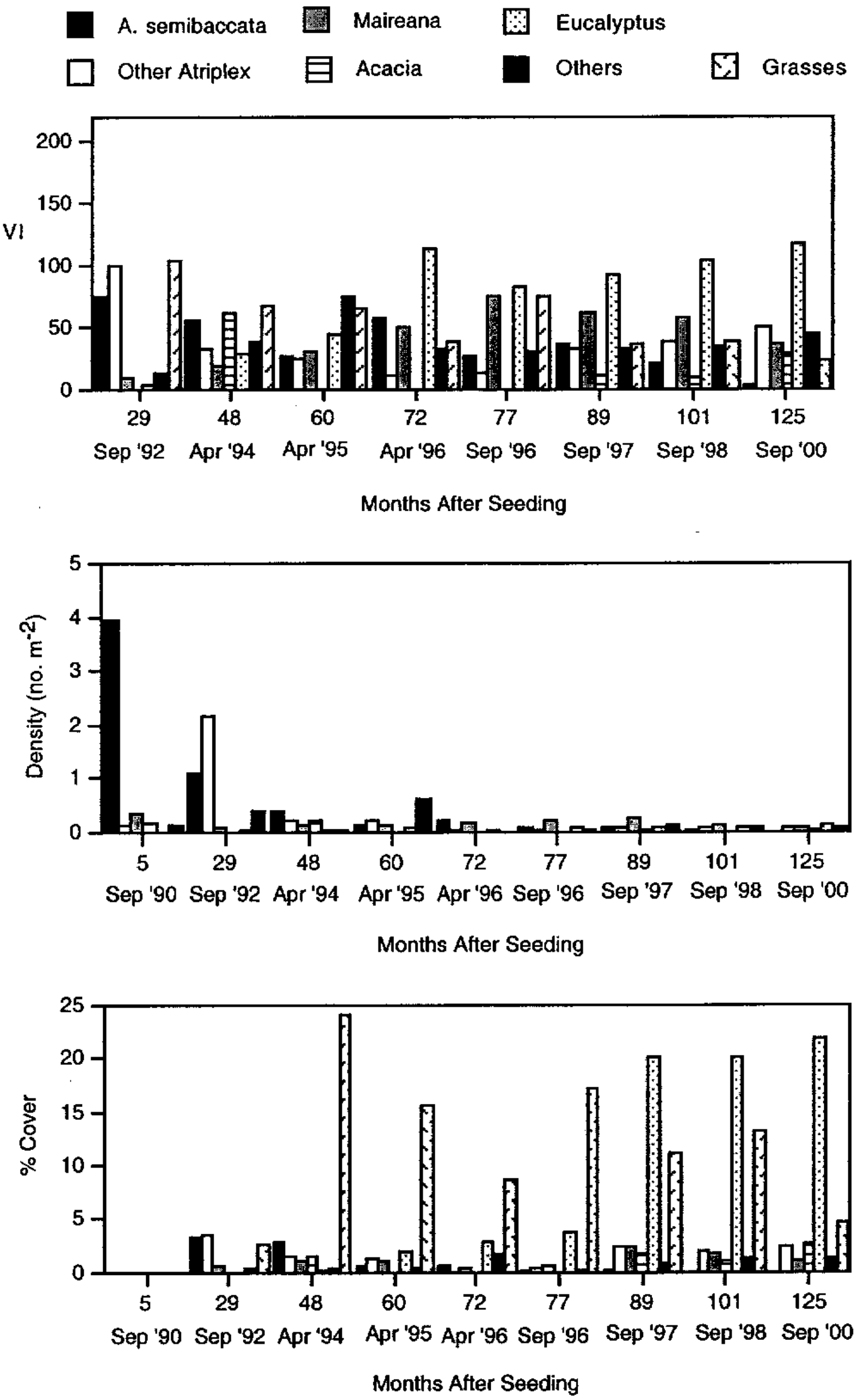


FIGURE 3.3.11: Change in Importance Value Index (IVI), plant density, and revegetation cover for dominant taxa recorded over Waste Dump 1D upper between September '90 and September '00 (n=5).

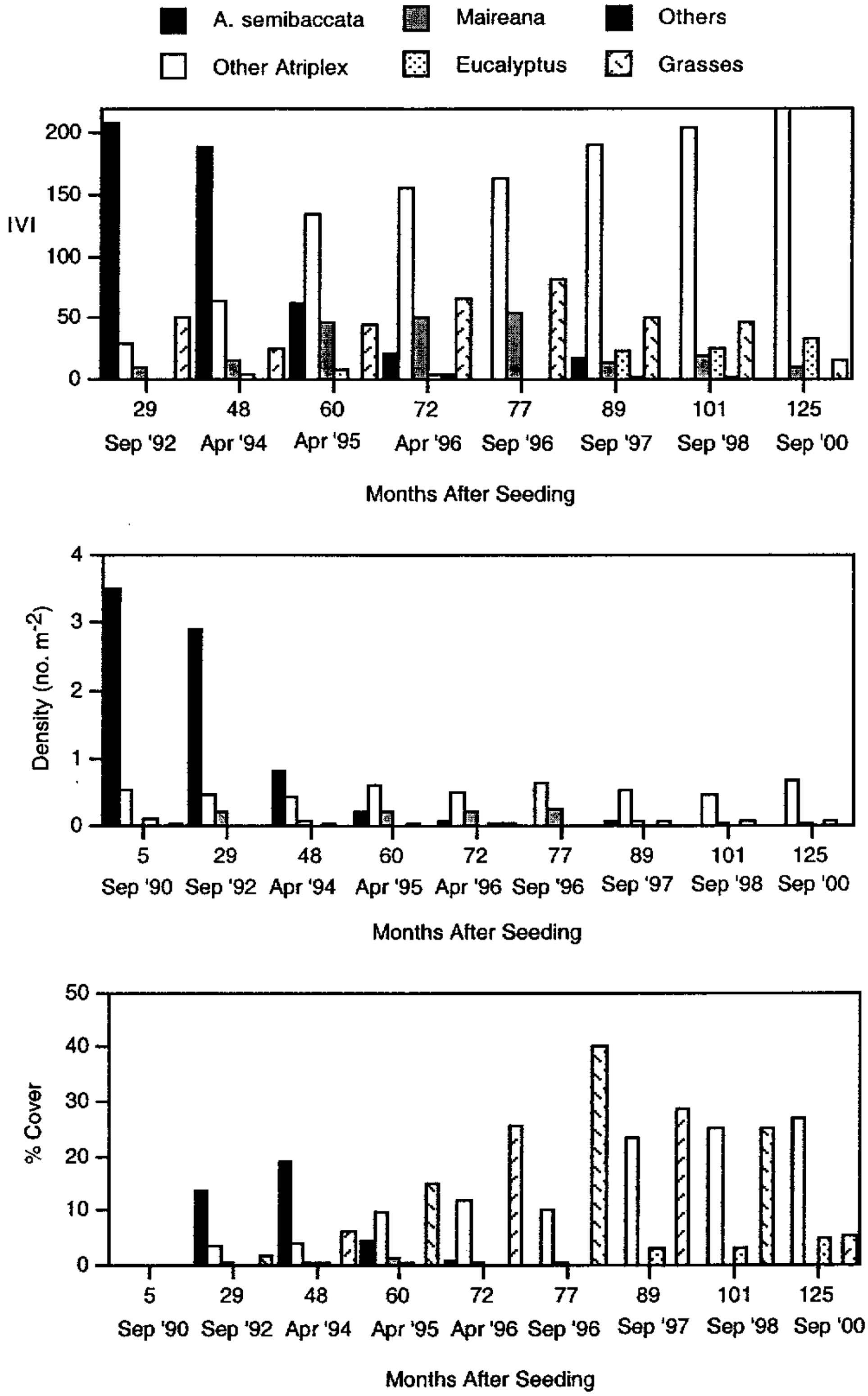


FIGURE 3.3.12: *Atriplex nummularia* is the dominant species over Waste Dump 1D, however *Eucalyptus salubris* is establishing in localised areas over the upper surface.

FIGURE 3.3.13: Waste Dump 1B, upper surfaces: An upperstorey cover of *Eucalyptus* spp. is establishing above a mid-level layer of chenopods and *Acacia* spp., with volunteering grasses providing a ground cover.

3.3.2 Summary of Findings

A number of trends in revegetation development were common among the waste dumps.

- The broad composition and structure of vegetation over Waste Dumps 1A, 1B and 1C (*Eucalyptus* overstorey, mixed acacia / chenopod understorey) differed from Waste Dump 1D (*Atriplex nummularia* tall shrubland).

- During the first and second growing seasons very high plant density was recorded, with *Atriplex semibaccata* the dominant colonising species. Revegetation cover was low during the first growing season, but increased rapidly thereafter (2-5 years).

- Fast-growing colonising species were important components in the developing ecosystem. The prostrate life form of *Atriplex semibaccata* was particularly beneficial in providing surface stability and forming a microclimate by reducing surface temperature.

- By the fifth growing season plant biodiversity parameters being monitored (density and ground cover) had stabilised within a range.

  For Waste Dumps 1A, 1B and 1C variability in plant density and ground cover was recorded during the April '95 assessment (60 months after seeding) in response to low rainfall experienced during the previous year. Plant density and cover both decreased at this time, but recovered to pre-disturbance levels by September '96 (77 months after seeding).

  In comparison, revegetation over Waste Dump 1D remained unaffected by low rainfall during 1994, due to the drought tolerance of the keystone species *Atriplex nummularia*.

- Surface salinity over the waste dumps was initially extremely saline and limited revegetation establishment to salt tolerant chenopods. Within 5-6 years after seeding however, salts had been leached, and surfaces were non-saline (ECe < 4 dS m^{-1}). In response to decreasing salinity the variety of life forms recorded in the revegetation increased to include *Eucalyptus, Acacia, Senna, Dodonaea, Melaleuca, Hakea* and *Eremophila*. These species originated from either the soil seed store (hard seeded species), bradysporous wind-blown seed from adjacent Crown Land (eucalypts), or native animal droppings (eremophilas).

- In September '97 (89 months after seeding) the *Acacia* species flowered and successfully set seed for the first time. A number of the *Eucalyptus* species were also observed to flower for the first time.

4 ANALOGUE SITES

4.1 Northeastern Goldfields

Seven analogue communities occurring in rangeland 20-50 km south of Laverton were assessed in October '97, with one site also assessed during October '98 (Table 4.1.1, Appendix 5). *Acacia aneura* (Mulga) Woodland is the most widespread vegetation community in the Northeastern Goldfields, occurring over gently sloping hardpan plains. It was selected for assessment, along with a more open community dominated by tall Acacia and Senna shrubs (Mixed Acacia Shrubland) occurring in skeletal soils over low hills. The remaining analogue communities were Low Shrublands dominated by halophytes, commonly found on heavier saline soils in areas receiving run-on, or around the margin of the large ephemeral salt lake, Lake Carey. The vegetation associated with these communities was well matched to a variety of rehabilitation mediums on which experimental trials had been established.

TABLE 4.1.1: Species richness, plant density (no. stems m^{-1}), % ground cover, soil salinity (ECe dSm^{-1}) and soil pH for the seven Northeastern Goldfields analogue sites; assessments made September '97 and October '98.

Analogue Community	Spp. Richness	Density (no./m^{-2})	% Cover	ECe (dS m^{-1})	pH
Woodland					
Mulga Woodland Oct. 1997	49	2.08	53.31	0.84	5.83
Mulga Woodland Oct. 1998	37	2.31	44.68	0.68	5.16
Tall Shrubland					
Mixed *Acacia* Shrubland	13	0.36	23.67	0.56	7.19
Low Shrubland					
Atriplex vesicaria Low Shrubland	20	1.73	11.05	3.04	6.74
Atriplex bunburyana Shrubland	14	1.54	32.84	8.16	7.03
Maireana pyramidata Shrubland	21	3.12	22.70	4.11	6.59
Maireana triptera Low Shrubland	15	2.50	16.57	21.68	6.20
Frankenia Low Shrubland	20	2.31	16.45	23.20	7.14

4.1.1 *Acacia aneura* (Mulga) Woodland

In contrast to the halophytic shrubland communities, the Mulga Woodland analogue site occurred on non-saline, acidic soils (Table 4.1.1). Plant density averaged 2.08 stems m^{-2} in September '97 and 2.31 stems m^{-2} thirteen months later (October '98). Vegetation cover decreased from 53.3 percent to 44.7 percent over the same period (Table 4.1.1). The variation in plant biodiversity parameters was likely related to rainfall frequency, season, and length of growing period (Beard 1990).

The same eight taxa gave the highest individual ground covers for both assessments. *Acacia aneura* (mulga) provided the highest foliage cover of 19.5 percent in '98, compared with 22.2 percent in '97. Annual grasses covered 8.2 percent of the surveyed area in '98, compared to 10 percent in '97. Other prominent taxa in '98 were *Sida calyxhymenia* (2.2 percent), *Ptilotus obovatus* (2.1 percent), *Acacia ramulosa* (2.5 percent) and *Acacia tetragonophylla* (1.9 percent).

The Chenopodiaceae showed highest species richness in '98, represented by 12 species from 5 genera; *Atriplex* and *Enchylaena* (saltbushes), *Maireana* (bluebushes), *Sclerolaena* (copperburrs) and *Rhagodia.* Together the chenopods averaged 0.82 plants m^{-2} and covered 3.3 percent of the area sampled (Figure 4.1.1). *Acacia aneura* was the dominant upperstorey species (IVI 54.8) recorded at a density of 0.06 plants m^{-2} (Figure 4.1.2). *Ptilotus obovatus* (IVI 35.8) was prominent at ground level, averaging 0.28 plants m^{-2}.

Variation in species richness between the two assessments can be contributed to differences in the annual rainfall pattern. In October '97, 49 species were recorded from 14 families. In October '98 species richness decreased to 37 species from 13 families. Years in which effective rainfall occurs over longer periods (summer and winter rainfalls) generally leads to the establishment of a greater variety of plant species. Annual life forms in particular may be absent from the vegetation during dry rainfall years.

The Chenopodiaceae (12 species), Mimosaceae (6 acacias), Myoporaceae (4 eremophilas), and Amaranthaceae (3 *Ptilotus* species) were well represented at the rangeland site during '98 (Figure 4.1.1). A number of the annual species recorded during '97 however, were absent from the '98 assessment. The establishment of ephemeral grasses, including *Aristida contorta, Eragrostis dielsii, Enneapogon caerulescens* and *Stipa* sp., is favoured by heavy summer rainfalls such as those experienced during 1997. Other ephemerals, such as the wildflowers *Cephalipterum, Erodium, Helipterum* and *Brachycome,* respond better to winter rainfalls, which often lead to high productivity over a short period. Annual chenopods respond to either summer or winter rainfalls, but remain absent under dry conditions. In '98 the diversity of annual species including *Atriplex* (saltbushes) and *Sclerolaena* (copperburrs) declined in response to low rainfall during the months preceding assessment.

FIGURE 4.1.1: *Acacia aneura* (Mulga) Woodland analogue site: Change in importance value index (IVI), plant density and % ground cover for important taxa between September '97 and October '98 (n=10).

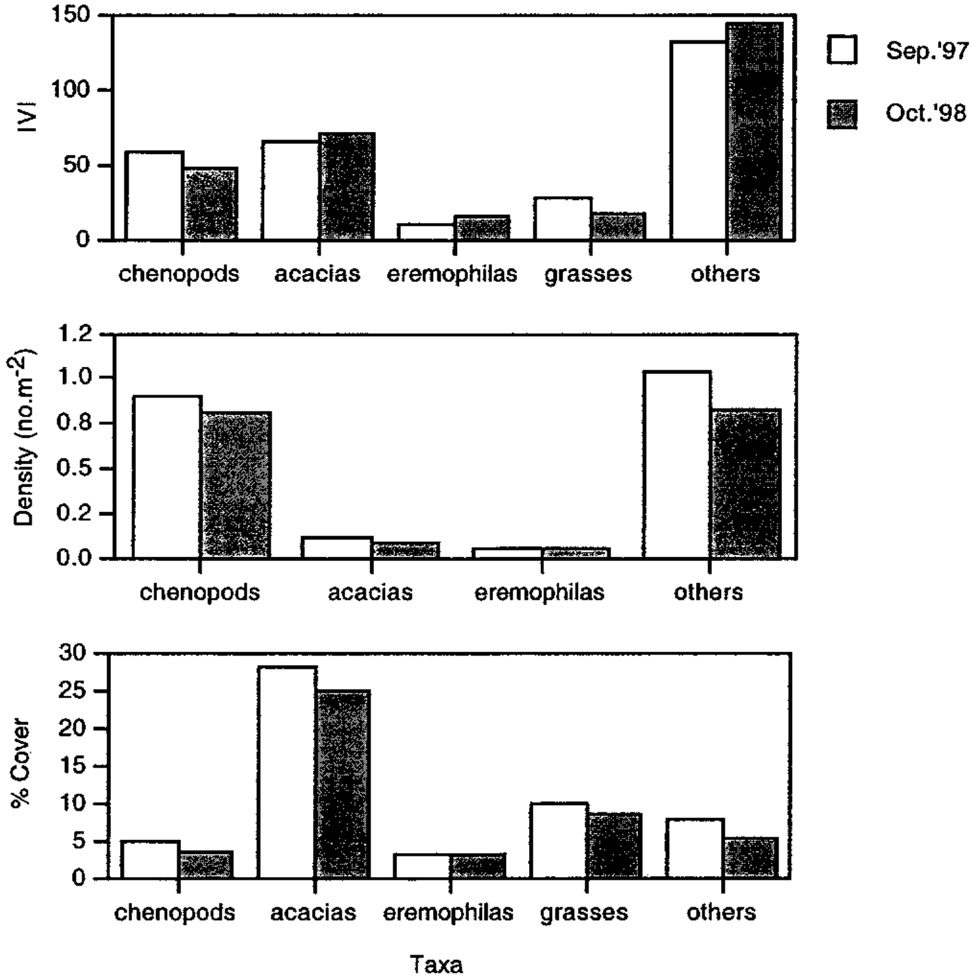


FIGURE 4.1.2: ***Acacia aneura* (Mulga) Woodland analogue site.**

4.1.2 Mixed *Acacia* Shrubland

Mixed *Acacia* Shrubland occurred on non-saline neutral soils, over low rocky hills. Total plant density was relatively low (0.36 stems m^{-2}), however foliage cover was comparable to that of the Low Halophytic Shrublands (23.7 percent, Table 4.1.1).

A total of 13 plant species from seven families was recorded, with mid-shrubs to 1.5 m tall the dominant life form, particularly *Senna, Dodonaea* and *Acacia* (Figures 4.1.3 & 4.1.4). *Senna filifolia* (IVI 100.8) occurred at an individual density of 0.11 stems m^{-2} and provided the highest individual ground cover of 8.8 percent. *Dodonaea lobulata* (IVI 99.3) occurred at similar density (0.12 stems m^{-2}) and provided high foliage cover (6.4 percent). *Acacia resinomarginea* (4.2 percent), *A. ramulosa* (1.3 percent) and *Eremophila oldfieldii* (1.0 percent) all provided greater than one percent ground coverage.

FIGURE 4.1.3: Mixed *Acacia* Shrubland analogue site: Importance Value Index (IVI), plant density and % ground cover for important taxa in September '97 (n=10).

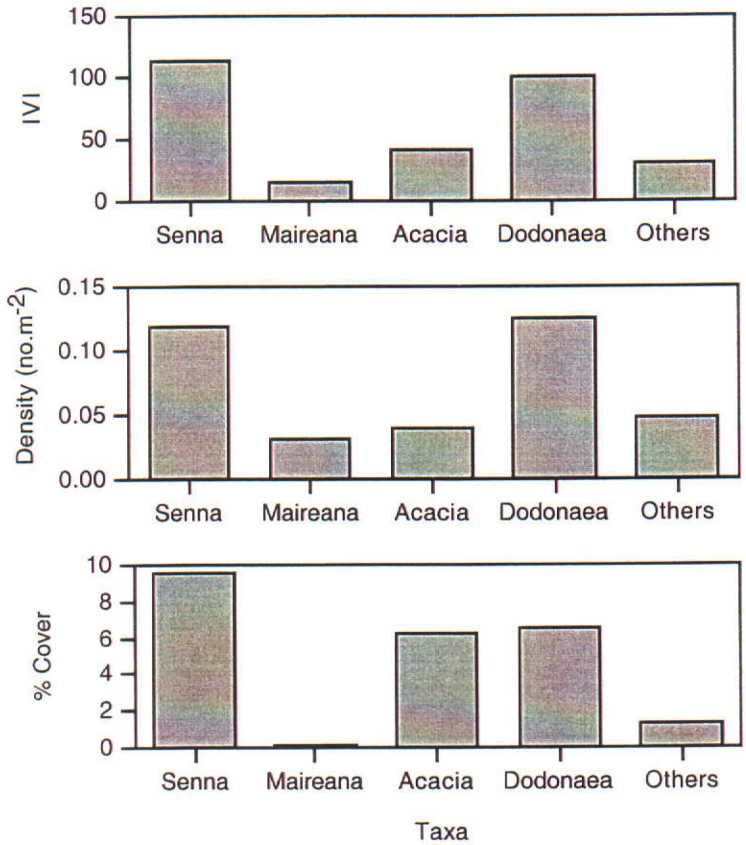
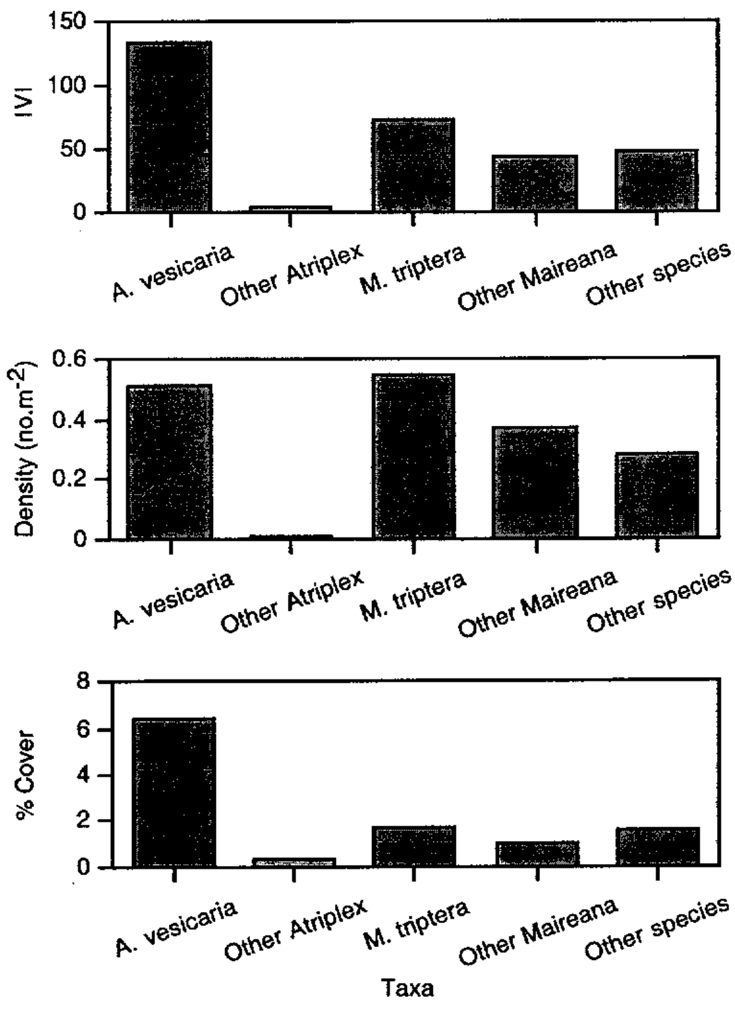


FIGURE 4.1.4: Mixed *Acacia* Shrubland analogue site.

4.1.3 *Atriplex vesicaria* Low Shrubland

Twenty species from 11 plant families were recorded in the *Atriplex vesicaria* Low Shrubland at an average density of 1.73 stems m^{-2} and providing 11.0 percent ground cover (Table 4.1.1). *Atriplex vesicaria* (IVI 133.8) was the keystone species in the vegetation, with an individual density of 0.51 stems m^{-2} and ground cover approximating 6.4 percent (Figure 4.1.5). Other *Atriplex* species were almost absent from the site. *Maireana triptera* was the only other species recorded with a foliage cover greater than one percent, also occurring at high density (0.55 stems m^{-2}). The remaining species were relatively minor components in the vegetation, with species IVI scores less than 29.

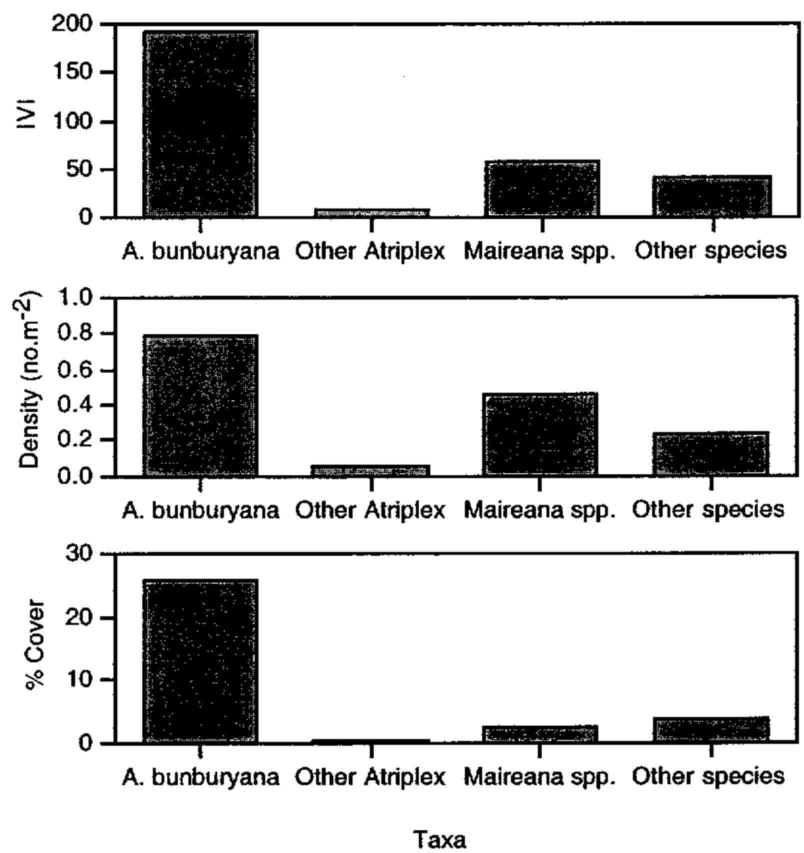
FIGURE 4.1.5: *Atriplex vesicaria* Low Shrubland analogue site: Importance value index (IVI), plant density and % ground cover for important taxa in September '97 (n=10).



4.1.4 *Atriplex bunburyana* Shrubland

Atriplex bunburyana Shrubland occurred on saline soils (8.2 dSm^{-1} ECe) at an overall density of 1.54 stems m^{-2} and with revegetation cover of 32.8 percent (Table 4.1.1). Fourteen species from six families were recorded, nine of which were members of the Chenopodiaceae. *Atriplex bunburyana* was the keystone species (IVI 191.6), occurring in high numbers (0.79 stems m^{-2}) and providing large foliage cover (25.9 percent, see Figure 4.1.6). Only four other species gave greater than 1 percent foliage cover; *Ptilotus obovatus* (1.6 percent), *Maireana triptera* (1.1 percent), *M. pyramidata* (1.6 percent) and *Hakea preissii* (1.9 percent). *Atriplex* species other than *A. bunburyana* were largely absent from the site (Figure 4.1.6).

FIGURE 4.1.6: *Atriplex bunburyana* Shrubland analogue site: Importance value index (IVI), plant density and % ground cover for important taxa in September '97 (n=10).



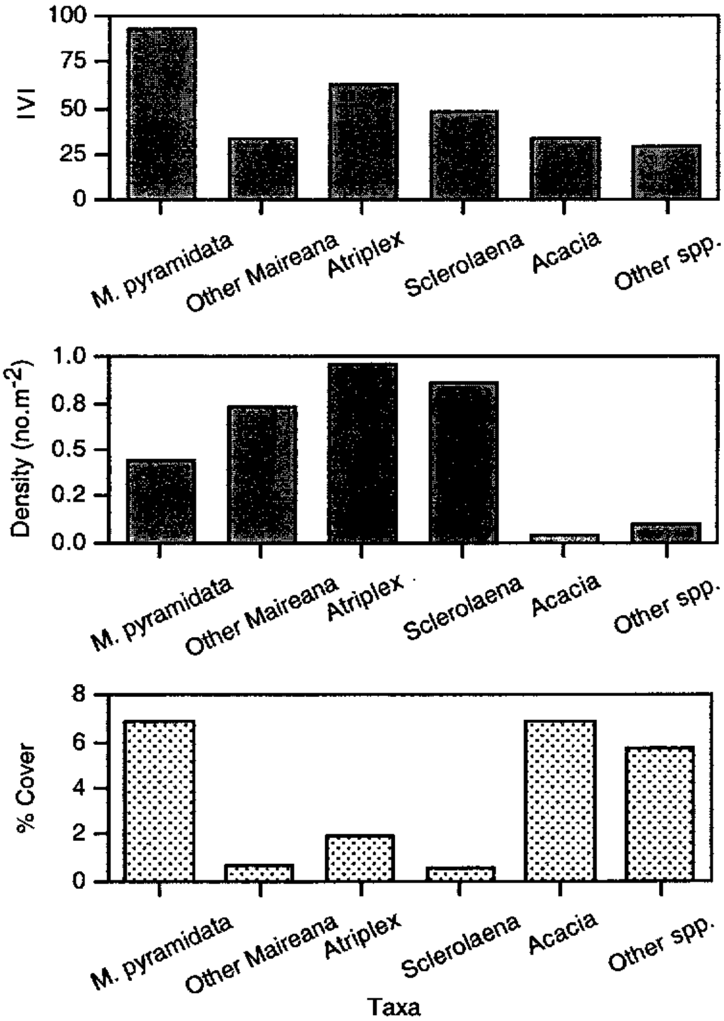
4.1.5 *Maireana pyramidata* Shrubland

Surface salinity for the *Maireana pyramidata* Shrubland analogue site was variable, with ECe ranging from 0.5 dS m^{-1} on raised sandy banks, up to 28.7 dS m^{-1} on heavier clay soils (mean 4.1 dS m^{-1}, Table 4.1.1). Twenty-one species from eight families were recorded at this site. The dominant plant family, Chenopodiaceae, was represented by six *Maireana* species, two *Atriplex* species, four *Sclerolaena* species and one *Halosarcia* species. Other species represented in the understorey were *Sida* sp. (Malvaceae), *Stipa nitida* (Poaceae), and *Solanum lasiophyllum* (Solanaceae). Upperstorey woody perennials included two *Acacia* species (Mimosaceae), *Pittosporum phylliraeoides* (Pittosporaceae), *Hakea arida* (Proteaceae) and *Eremophila granitica* (Myoporaceae).

Plant density averaged 3.12 individuals m^{-2} with a revegetation cover of 23 percent (Table 4.1.1). High numbers of annuals, *Atriplex codonocarpa* (0.87 stems m^{-2}) and *Maireana carnosa* (0.46 stems m^{-2}), contributed to the relatively high plant density. *Maireana pyramidata* (sago bush) was the keystone species (IVI 93.8), recorded at an individual density of 0.44 stems m^{-2} and with 6.9 percent ground cover (Figure 4.1.7).

Thirteen chenopod species represented 96 percent of the total plant density (2.99 plants m^{-2}), and 46 percent of the total revegetation cover. *Acacia aneura* (mulga) gave foliage cover of 5.6 percent and was the dominant upperstorey species (IVI 29.5). Mulga was the tallest plant sampled in the revegetation, approaching 2 m in height. *Acacia tetragonophylla* and *Pittosporum phylliraeoides* were the only other two species to provide ground cover greater than one percent.

FIGURE 4.1.7: ***Maireana pyramidata* Shrubland analogue site: Importance value index (IVI), plant density and % ground cover for important taxa in September '97 (n=10).**

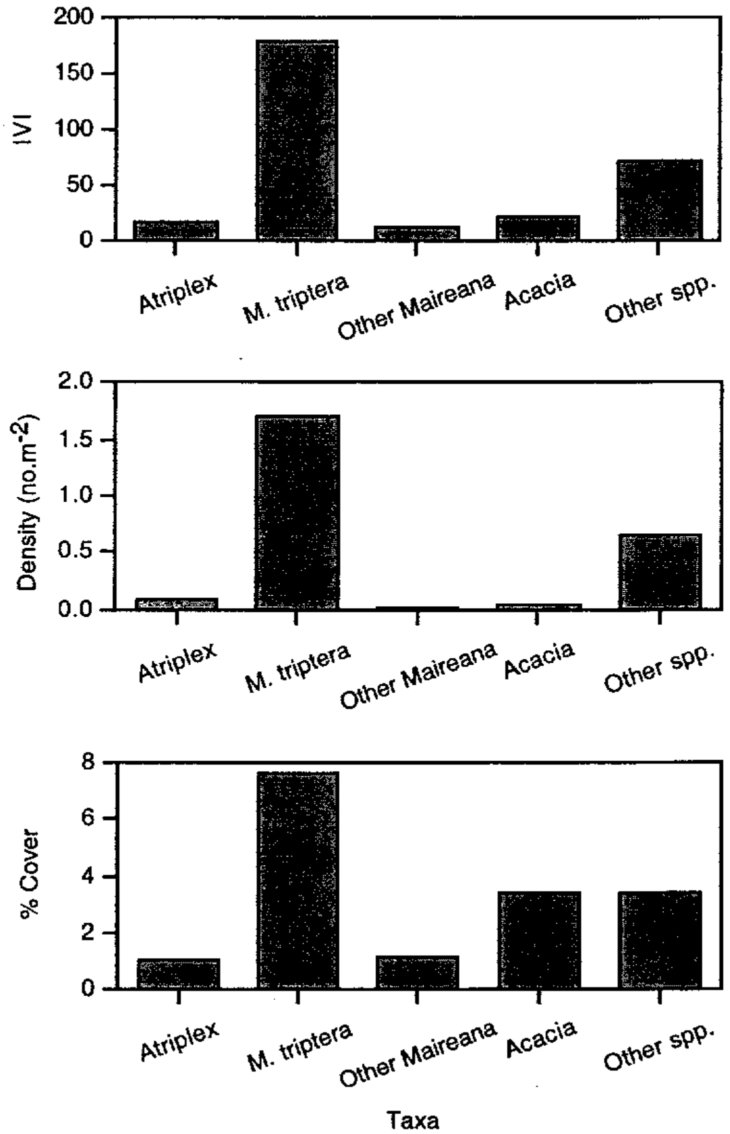


4.1.6 *Maireana triptera* Low Shrubland

Maireana triptera Low Shrubland occurred on very saline and acidic shallow red earths (Table 4.1.1). This analogue site was situated close to a permanent watering point, and had been under prolonged grazing pressure from domestic stock. Fifteen species from six families were recorded at a density of 2.50 stems m^{-2} and with a total ground cover of 16.6 percent (Table 4.1.1).

The low shrub *Maireana triptera* (IVI 179.4) was the keystone species, occurring at an individual density of 1.70 stems m^{-2} with 7.6 percent foliage cover (Figure 4.1.8). A very open stratum of tall shrubs included *Acacia aneura* (2.1 percent), *A. tetragonophylla* (1.2 percent) and *Eremophila scoparia* (1.8 percent). *Maireana* *pyramidata* was the only other species to provide greater than 1.0 percent ground cover. Palatable species either had been removed through grazing, or occurred only in low numbers.

FIGURE 4.1.8: *Maireana triptera* Low Shrubland analogue site: Importance value index (IVI), plant density and % ground cover for important taxa in September '97 (n=10).

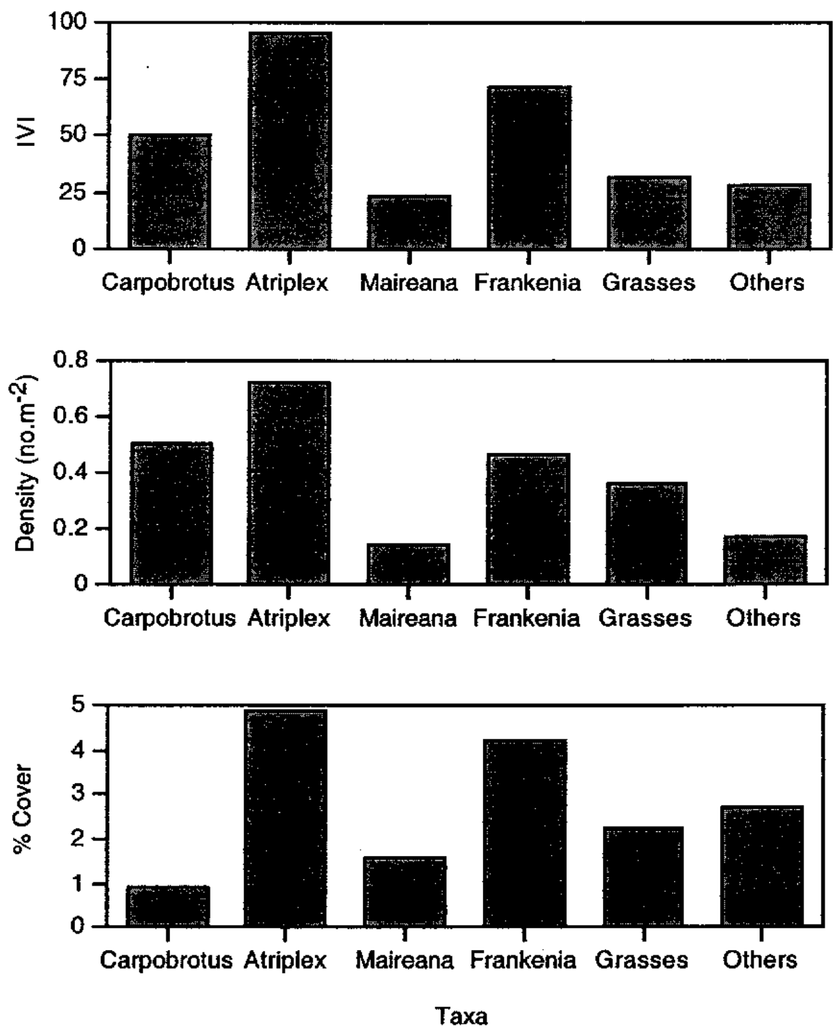


4.1.7 *Frankenia* Low Shrubland

Frankenia Low Shrubland occurred on gypsiferous saline soils (mean ECe 23.2 dS m^{-1}) fringing a large ephemeral salt lake. Twenty plant species from seven families were recorded, with Chenopodiaceae (8 species), Poaceae (4 species) and Frankeniaceae (3 species) all prominent. Total plant density averaged 2.31 plants m^{-2}, with a revegetation cover of 16.4 percent (Table 4.1.1).

The three *Frankenia* species recorded in the Low Shrubland complex together averaged 0.47 stems m^{-2} with 4.2 percent foliage cover (Figure 4.1.9). *Atriplex vesicaria* (IVI 81.6) was prominent (0.62 stems m^{-2}) providing 4.3 percent ground cover (Figure 4.1.7). Other important components in the vegetation included *Disphyma crassifolium* (0.51 stems m^{-2}) and the grasses *Aristida contorta* (1.3 percent cover), *Enneapogon caerulescens* (0.23 stems m^{-2}) and *Eragrostis dielsii* (0.11 stems m^{-2}).

FIGURE 4.1.9: *Frankenia* Low Shrubland analogue site: Importance value index (IVI), plant density and % ground cover for important taxa in September '97 (n=10).



4.2 Eastern Goldfields Analogue Sites

In rangeland surrounding the Black Swan Nickel Mine, 50 km north east of Kalgoorlie, five analogue vegetation complexes were chosen as reference sites; *Eucalyptus* Mallee Woodland, *Acacia* Tall Scrub, and three Low Chenopod Shrublands (Appendix 9). While the analogue communities remained unaffected by mining activities, they were susceptible to disturbance from other land users, including pastoralists. Areas of rangeland monitored were subject to grazing by domestic stock. Another infrequent disturbance in the past has been fire; in 1974 a severe wildfire swept through the study area, removing many of the larger trees (P. Carter pers. com. 1996). The dead stems are evident today, 27 years after the event. Much of the more productive grazing land (low chenopod shrublands) did not recover from this disturbance event (P. Carter pers. comm. 1996) and has since been replaced by dense *Acacia* scrub. Data from the five analogue sites are summarised in Table 4.2.1.

TABLE 4.2.1: Species richness, plant density, % ground cover, soil salinity and pH for five analogue sites in rangeland north east of Kalgoorlie.

Analogue Community	Assess. Date	Spp. Rich.	Density (no. m^{-2})	% Cover	ECe (dS m^{-1})	pH
Mallee Woodland						
Eucalyptus Mallee over Scrub	Jun '99	14	0.83	47.00	0.29	6.28
Tall Scrub						
Acacia Scrub above *A. vesicaria*	Dec '97	21	1.54	31.00	0.81	7.33
	Oct '98	30	1.50	26.80	0.92	7.58
	Jun '99	23	1.36	31.70	1.04	6.97
	Dec '99	21	1.23	25.90	1.10	7.89
	Nov '00	20	1.18	30.59	0.75	7.10
	Nov '01	18	1.40	31.93	0.83	7.14
Shrublands						
A. bunburyana Shrubland	Dec '97	23	1.49	24.30	0.80	7.36
A. vesicaria Low Shrubland A	Dec '97	19	1.24	20.10	5.84	7.65
	Jun '99	13	1.65	6.70	6.38	7.82
	Nov '00	14	2.34	11.26	3.22	8.00
A. vesicaria Low Shrubland B	Jun '99	10	1.54	23.90	6.15	7.88
	Nov '00	11	1.82	24.00	1.72	8.18

4.2.1 Mixed *Acacia* Scrub above *Atriplex vesicaria* Low Shrubland

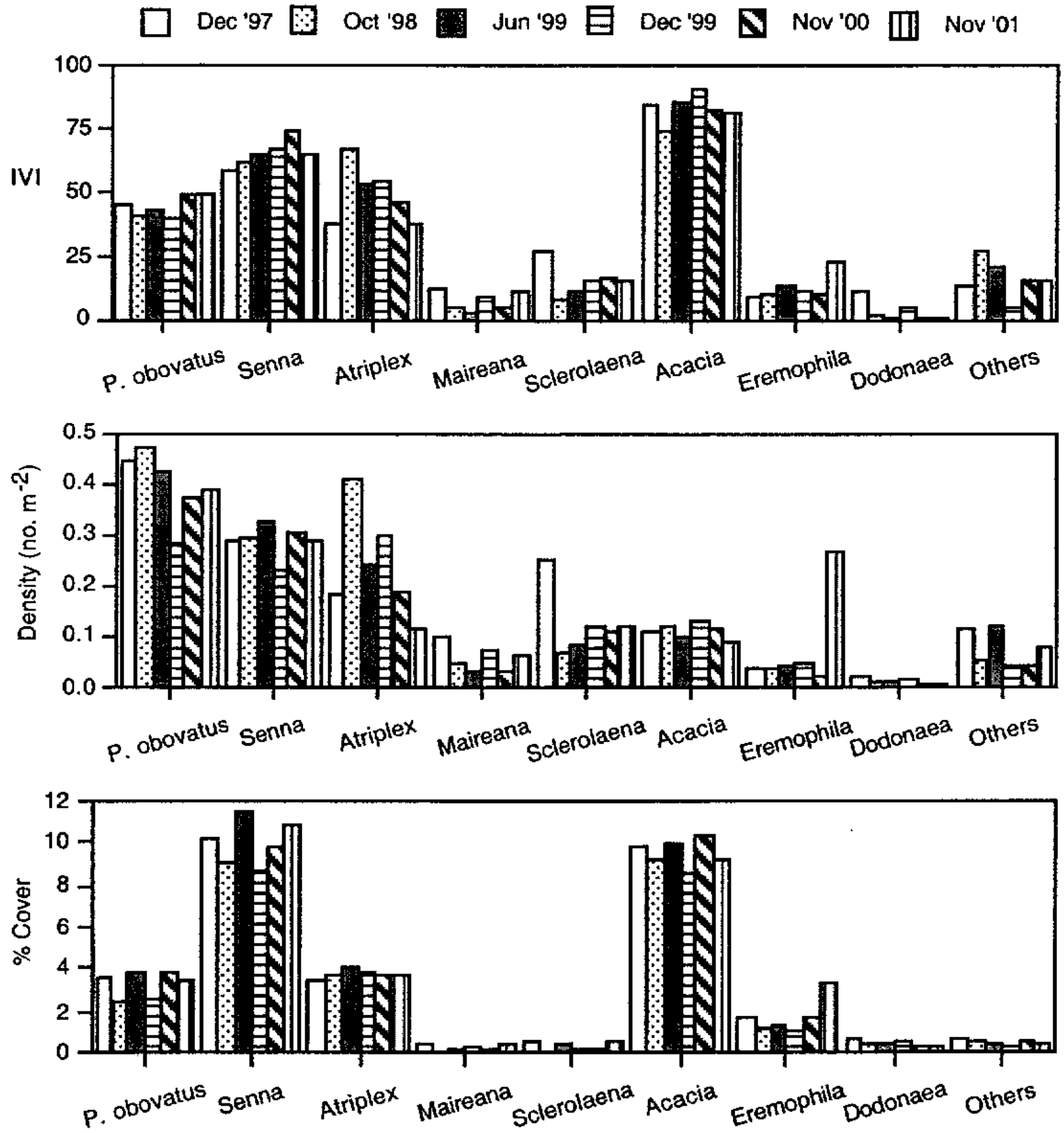
There have been six assessments of the Mixed *Acacia* Scrub above *Atriplex vesicaria* Low Shrubland analogue site (Figure 4.2.1) between December '97 and November '01. Analysis of plant density and revegetation cover, and surface soil salinity and pH shows no significant change in either the plant biodiversity or soil parameters during this period (Table 4.2.1). Over the four-year period of assessment, average plant density ranged from 1.18-1.54 stems m^{-2} and revegetation cover from 26 to 32 percent. Surface soil salinity remained non-saline (<1 dS m^{-1}) and soil pH neutral (Table 4.2.1).

Species richness for the six assessments ranged between 18 and 30 species, with annual life forms accounting for the variation in response to seasonal rainfall. Of the nine dominant taxanomic groups defined, elevated density of *Sclerolaena, Atriplex,* and 'Other species' was recorded during December '97, October '98, and June '99 respectively (Figure 4.2.2). Revegetation cover for each taxa was relatively stable over the period of assessment, with less than 3 percent variation.

FIGURE 4.2.1: Mixed *Acacia* Scrub above *Atriplex vesicaria* analogue site.

Dominant species showed only minor variation in the parameters being measured between assessments (Figure 4.2.2). In November '01 keystone species at the site were *Senna filifolia* (IVI 65, 11 percent cover), *Ptilotus obovatus* (IVI 49, 4 percent cover), *Acacia aneura* (IVI 47, 5 percent cover) and *Atriplex vesicaria* (IVI 36, 4 percent cover).

FIGURE 4.2.2: Mixed *Acacia* Scrub above *Atriplex vesicaria* analogue site: Change in Importance Value Index (IVI), plant density and % cover for important taxa, between December '97 and November '01 (n=10).



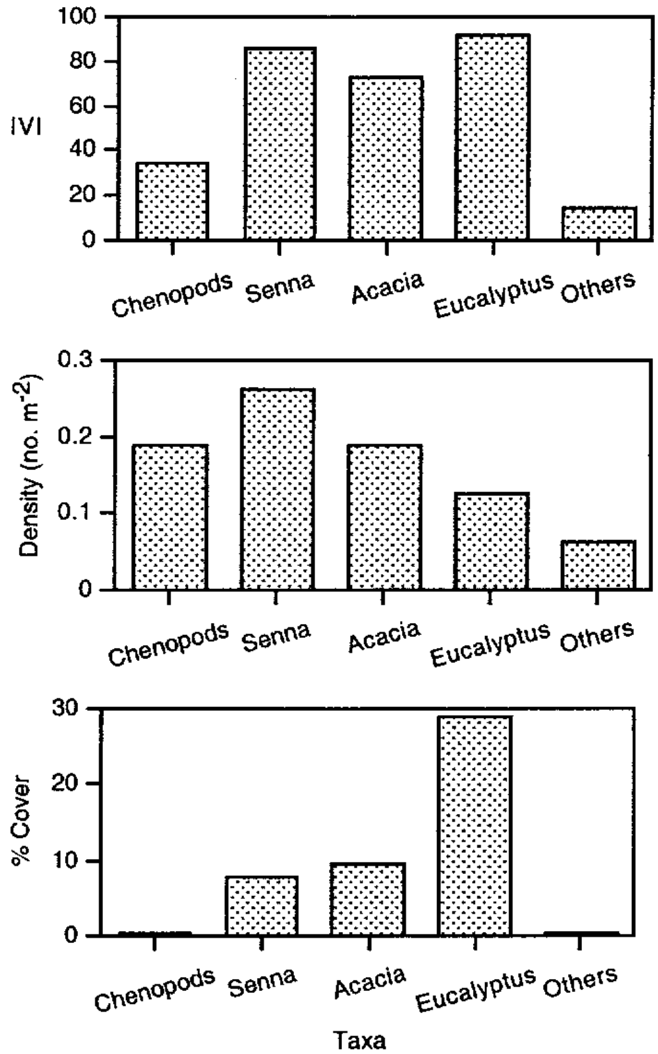
4.2.2 *Eucalyptus* Mallee over Mixed Species Scrub

The *Eucalyptus* Mallee over Mixed Species Scrub analogue site occurs on non-saline acidic soils (ECe 0.29 dS m^{-1}, pH 6.28) adjacent to the Silver Swan exploration site. The vegetation is characterised by a low *Eucalyptus* canopy and mid-strata layer of *Senna* and *Acacia* shrubs (Figure 4.2.3). This site was assessed once, in June '99.

Plant density averaged 0.83 stems m^{-2} with a ground cover of 47 percent (Table 4.2.1). Fourteen species from seven families were recorded, with *Eucalyptus* (IVI 92), *Senna* (IVI 85) and *Acacia* (IVI 73) the dominant taxa, and chenopods (IVI 35) less prominent (Figure 4.2.4). Numbers of plants representing the four dominant taxa were relatively even, ranging from 0.12 stems m^{-2} for *Eucalyptus* to 0.26 stems m^{-2} for *Senna.* The larger size of the *Eucalyptus* trees contributed to the high individual ground cover of 29 percent, compared to less than 19 percent for the remaining three taxa combined (Figure 4.2.4).

FIGURE 4.2.3: Exploration has occurred throughout the *Eucalyptus* Mallee over Mixed Species Scrub analogue site.

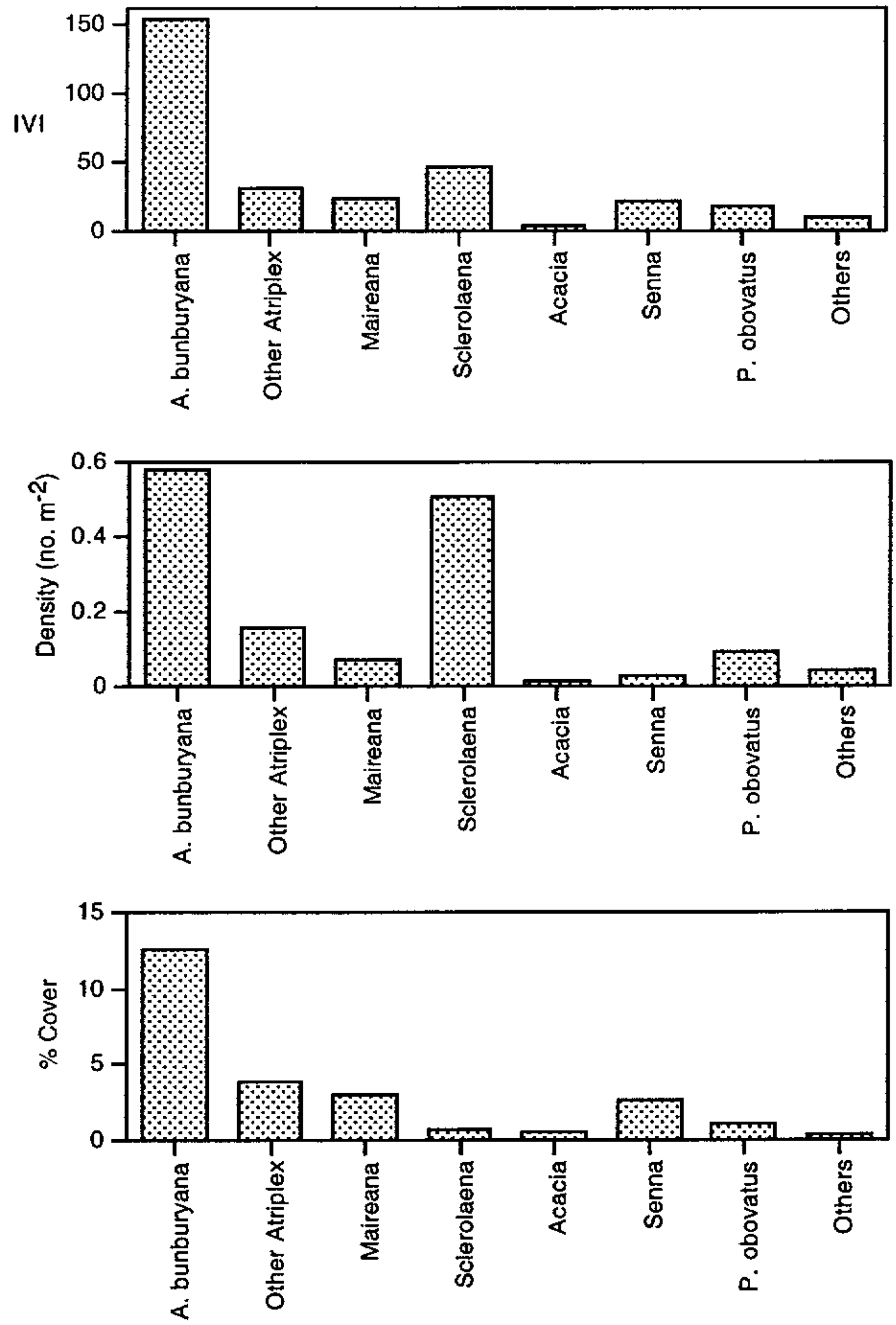
FIGURE 4.2.4: ***Eucalyptus* Mallee over Mixed Species Scrub analogue site: Importance Value Index (IVI), plant density and % cover for important taxa in June '99 (n=4).**



4.2.3 *Atriplex bunburyana* Shrubland

The *Atriplex bunburyana* Shrubland analogue site occurred on non-saline alkaline soils. Twenty-three species from six families were recorded during December '97, of which 16 were members of the Chenopodiaceae. Overall plant density and revegetation cover averaged 1.49 stems m^{-2} and 24 percent respectively (Table 4.2.1). The density and ground cover provided by the keystone species, *A. bunburyana,* was 0.60 stems m^{-2} and 12 percent (Figure 4.2.5). Other *Atriplex, Maireana, Sclerolaena, Senna* and *Ptilotus obovatus* were less significant taxa represented at the analogue site.

FIGURE 4.2.5: ***Atriplex bunburyana*** **Low Shrubland: Importance Value Index (IVI), plant density, and revegetation cover for important taxa in December '97 (n=5).**



4.2.4 *Atriplex vesicaria* Low Shrubland A

The *Atriplex vesicaria* Low Shrubland analogue site occurred in a local drainage depression between two low hills (Figure 4.2.6). Vegetation and soil parameters were assessed on three occasions, December '97, June '99 and November '00. During this period soil remained mildly saline and alkaline. Plant density, however, increased progressively from 1.24 stems m^{-2} to 2.34 stems m^{-2} between the first and third assessments (Table 4.2.1). Vegetation ground cover and species richness decreased from 20 percent and 19 species in December '97 to 7 percent and 13 species in June '99, before again increasing to 11 percent and 14 species in November '00 (Table 4.2.1).

Change to species richness, plant density and revegetation cover resulted from prolonged overgrazing by domestic stock (sheep) during early '99. The keystone species, *A. vesicaria,* was affected most significantly. The density of *Atriplex vesicaria* halved in the 19 month period between the first two assessments, from 0.70 to 0.36 stems m^{-2}, and foliage cover decreased from 14 percent to 1 percent (Figure 4.2.7). Over the same period the density of three other prominent taxa increased, 'Other Chenopods', '*Maireana*' and '*Ptilotus obovatus*'. There was, however, no corresponding increase to foliage ground cover for these three taxa (Figure 4.2.7).

FIGURE 4.2.6: *Atriplex vesicaria* Low Shrubland A analogue site.

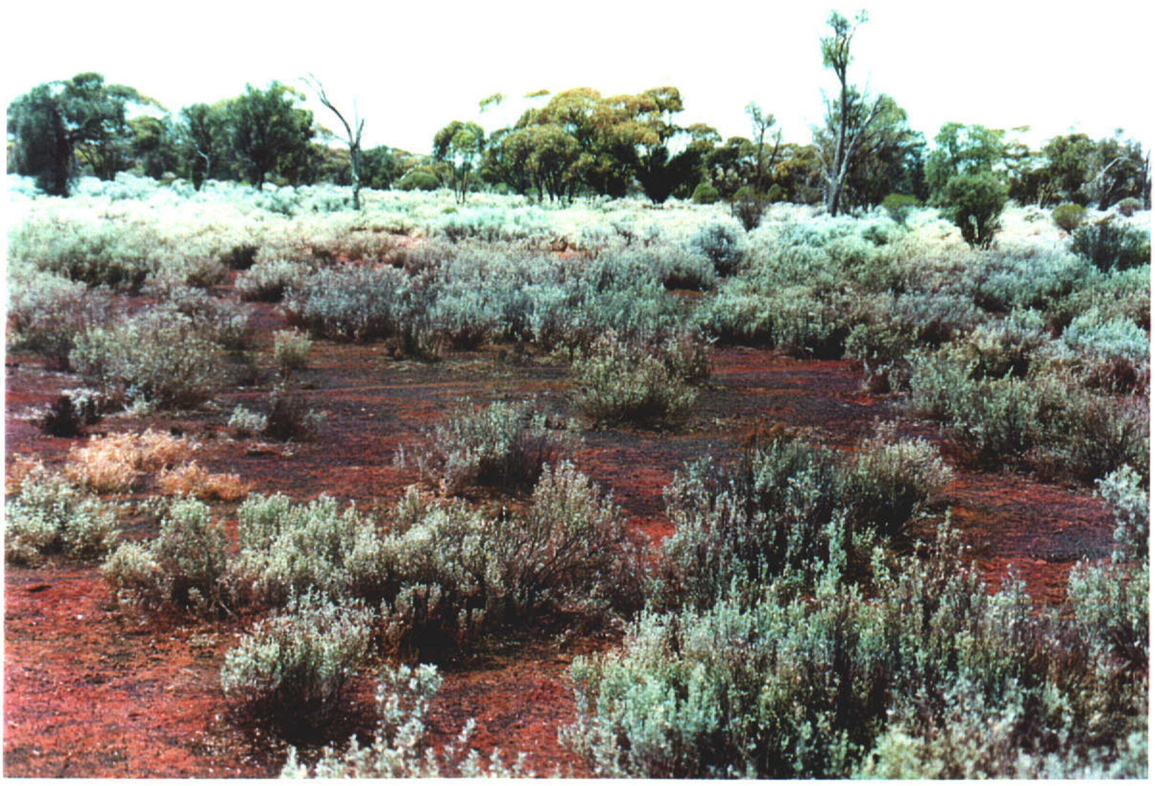
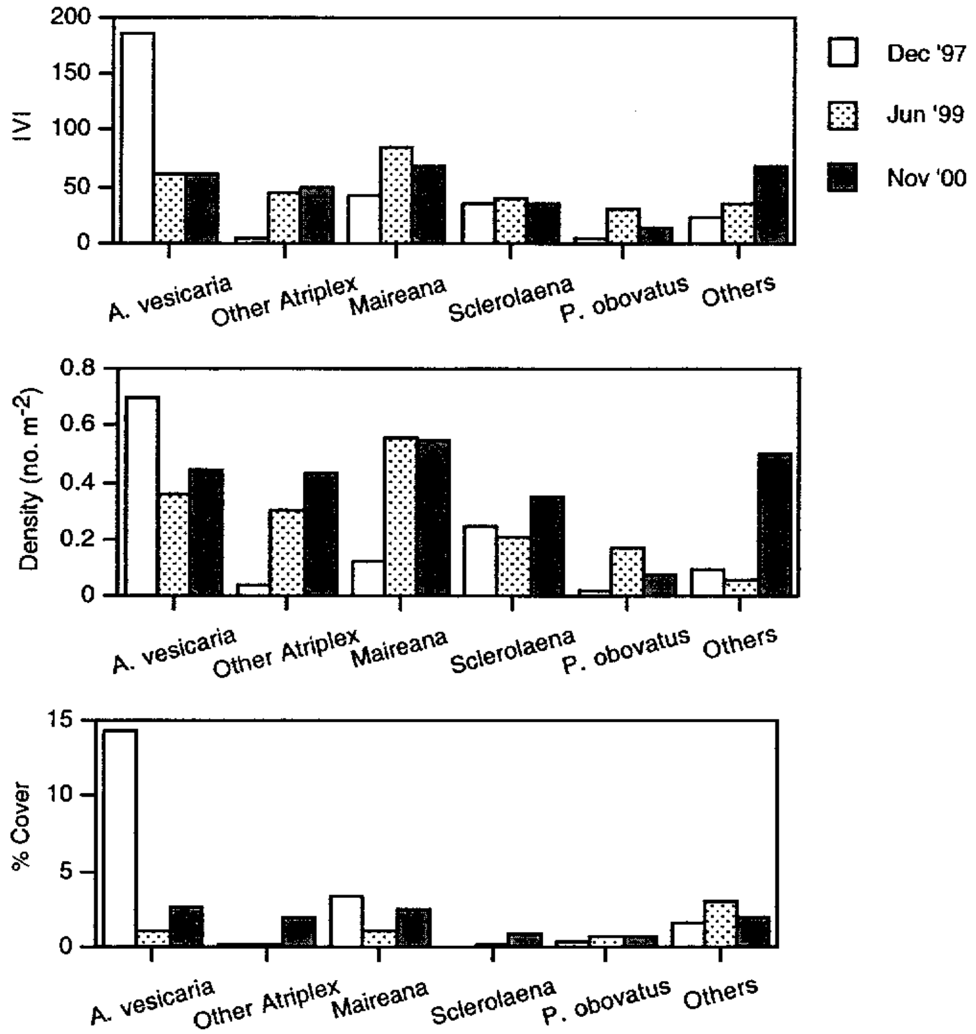


FIGURE 4.2.7: ***Atriplex vesicaria* Low Shrubland A analogue site: Change in Importance Value Index (IVI), plant density, revegetation cover for important taxa between December '97 and June '99 (n=5).**



4.2.5 *Atriplex vesicaria* Low Shrubland B

A second *Atriplex vesicaria* Low Shrubland site was assessed during June '99 and November '00, following overgrazing of the initial analogue site. This site was not subject to grazing by domestic stock, occurring inside the fenced mining lease (Figure 4.2.8). Surface soil was saline and alkaline during the 1999 assessment (ECe 6.15 dS m^{-1}, pH 7.88), however salinity decreased to 1.7 dS m^{-1} in November '00 (Table 4.2.1).

Plant density and vegetation ground cover remained relatively stable between assessments averaging 1.53 stems m^{-2} and 24 percent and 1.82 stems m^{-2} and

24 percent for 1999 and 2000 respectively. These values reflect those recorded from the *Atriplex vesicaria* Low Shrubland A analogue site prior to overgrazing (Table 4.2.1).

Ten and 11 species were recorded within *Atriplex vesicaria* Low Shrubland B for the two assessments, all members of the Chenopodiaceae. Higher species richness was inhibited by elevated soil salinity and the prominence of *A. vesicaria*. *Atriplex vesicaria* was the dominant plant taxa (IVI 206), recorded at an individual density of 0.86 stems m^{-2} with 21 percent foliage cover in June '99 (Figure 4.2.9). The 'Other *Atriplex*' and '*Sclerolaena*' taxa occurred at relatively high density (approximating 0.30 stems m^{-2}), but together contributed less than 3 percent foliage cover.

FIGURE 4.2.8: ***Atriplex vesicaria*** **Low Shrubland B analogue site.**

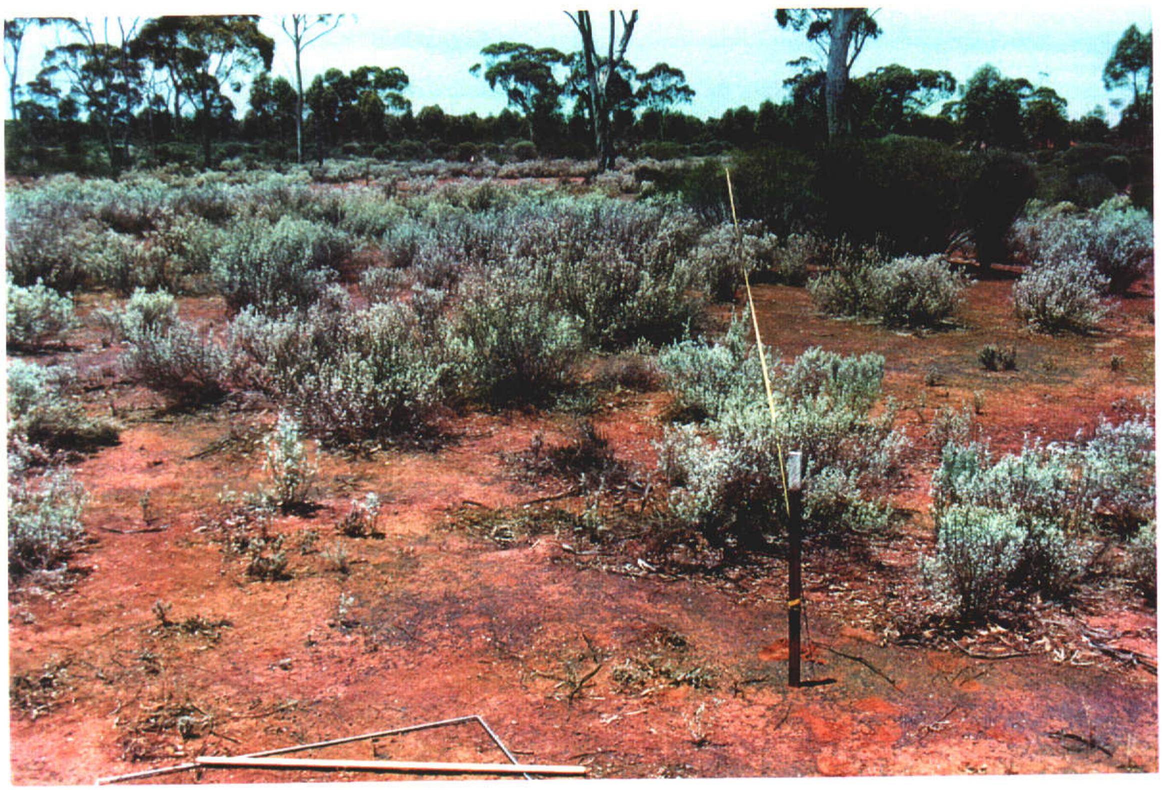
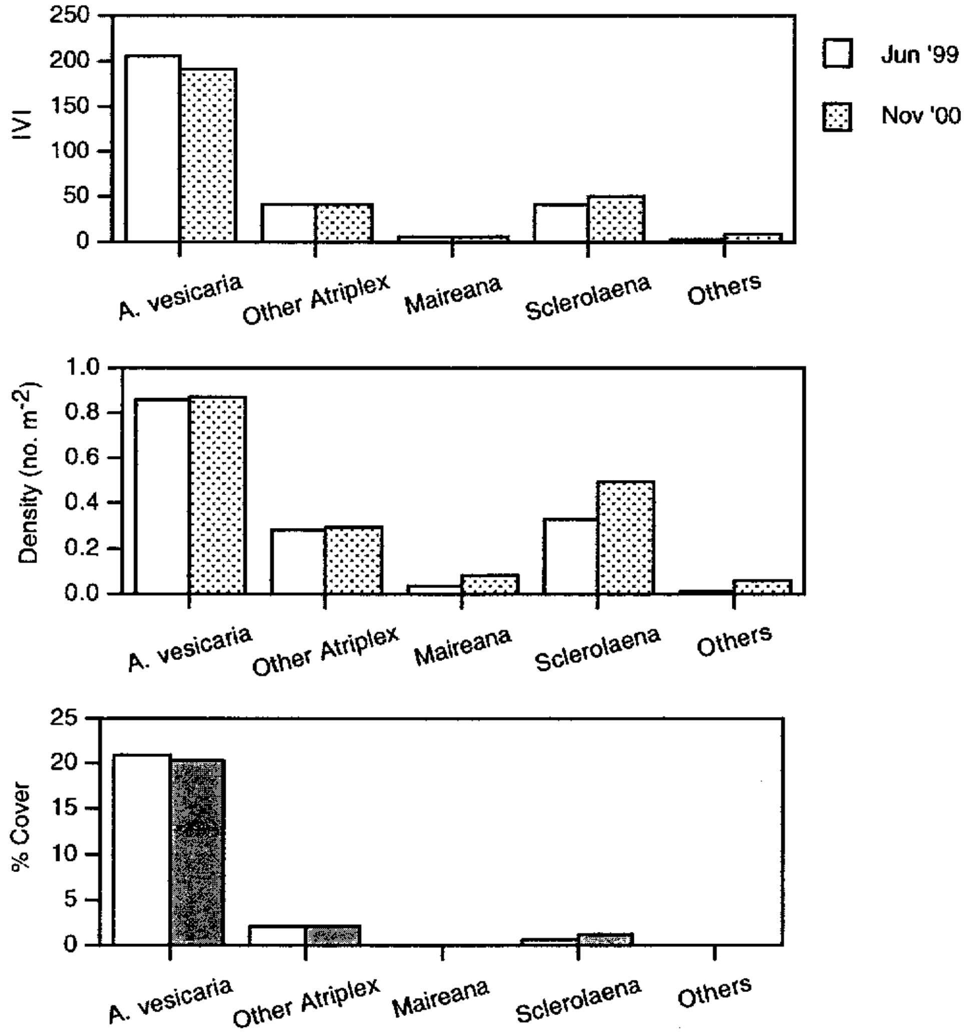


FIGURE 4.2.9: ***Atriplex vesicaria*** **Low Shrubland B analogue site: Plant density, revegetation cover, and importance value indices (IVI) for important taxa recorded in June '99 (n=5).**



4.3 Northeastern Wheatbelt Analogue Sites

Vegetation and soil parameters from the assessment of three analogue vegetation communities in the Westonia locale are summarised in Table 4.3.1 and Appendix 12.

TABLE 4.3.1: Species richness, plant density, % ground cover, soil salinity and pH for the three analogue sites at Westonia, assessments made October '97, October '98 and April '99.

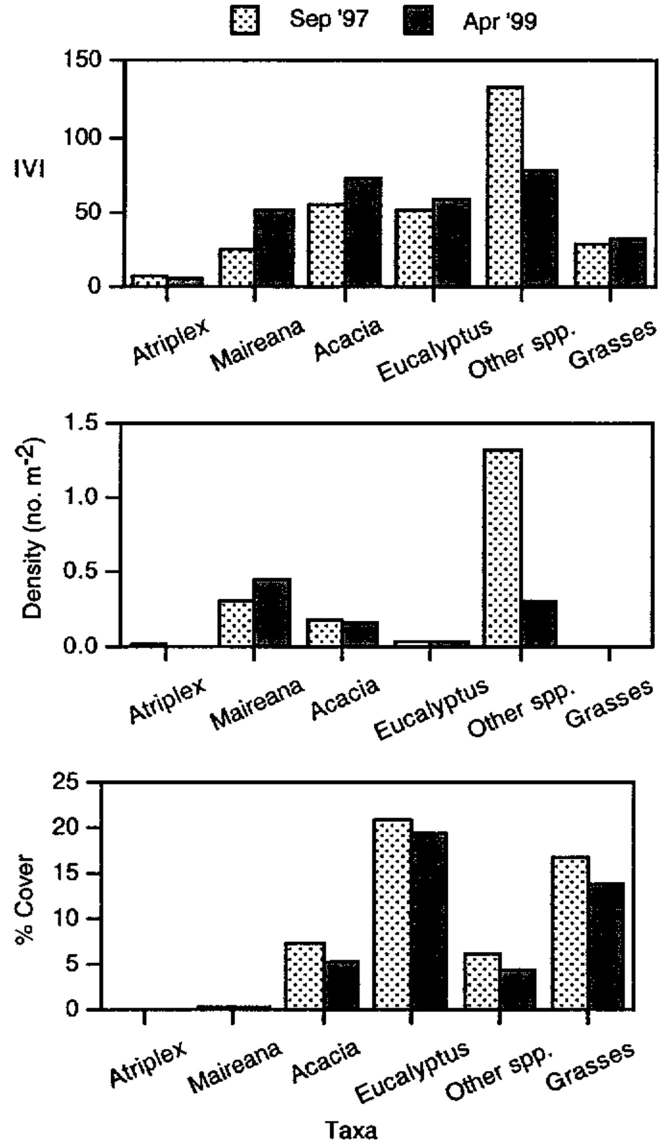
Analogue Community	Spp. Richness	Density (no. m^{-2})	% Cover	ECe ($dS\ m^{-1}$)	pH
***Eucalyptus* Woodland**					
E. salubris Woodland above	24	1.88	51.89	0.96	7.32
Tall Scrub	21	0.98	43.67	0.95	7.74
E. salubris Woodland above	14	3.48	31.30	0.78	7.28
Low Shrubland	9	4.40	24.90	1.86	7.81
Shrubland					
Atriplex vesicaria Low Shrubland	10	1.98	17.50	1.10	8.20

4.3.1 *Eucalyptus* Woodland above Tall Scrub

The *Eucalyptus* Woodland over Tall Scrub analogue community occurred immediately north east of the waste dumps. Soils were non-saline (1.0 dS m^{-1} ECe) and alkaline (pH range 7.3 - 7.8). Species richness was high for both assessments, 24 species in September '97 and 21 species in April '99. The total ground coverage of vegetation within this community averaged 44 percent and 52 percent respectively for the two assessments (Table 4.3.1). The dominant upperstorey eucalypts (20 percent) were the greatest contributors to overall ground coverage, along with grasses (15 percent) and acacias (5 percent, see Figure 4.3.1).

The openness of the understorey was reflected by relatively low total plant density, which ranged from 1.90 stems m^{-2} in September '97 down to 0.90 stems m^{-2} in April '99. The elevated density recorded during September '97 resulted from an abundance of the short-lived annual *Ptilotus exaltatus* (grouped into the 'other spp.' taxa), which established in high numbers following late unseasonal rainfall during '97 (Figure 4.3.1).

FIGURE 4.3.1: **Change in Importance Value Index (IVI), plant density, and revegetation cover between September '97 and April '99 (n=10) for dominant taxa recorded in the *Eucalyptus* Woodland over Tall Scrub analogue site.**



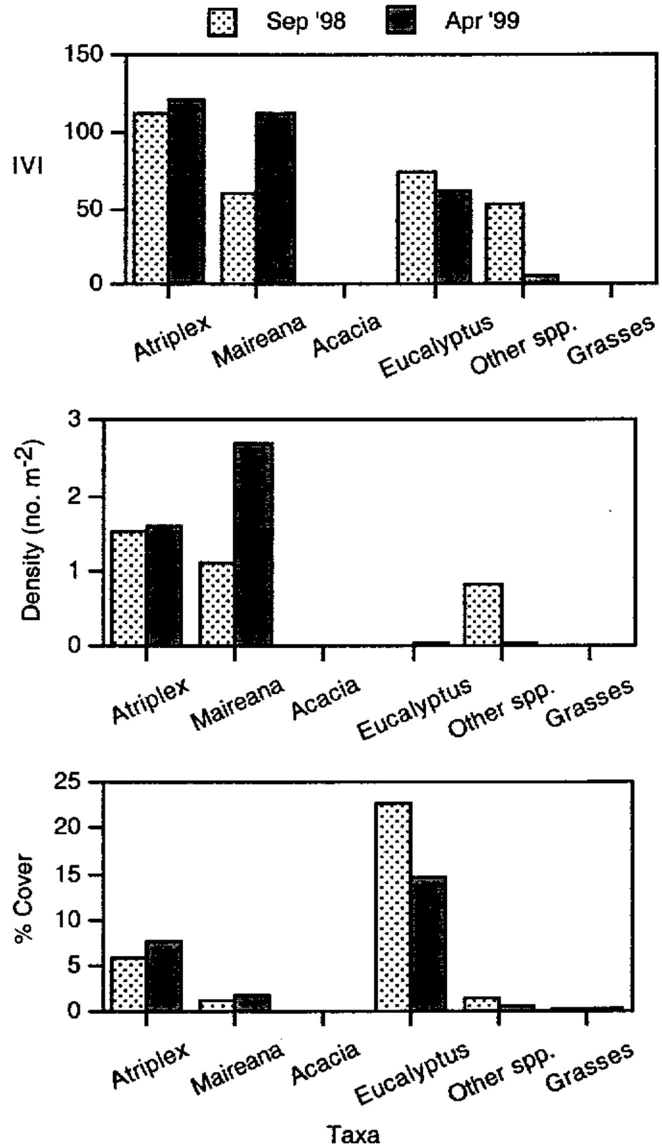
4.3.2 *Eucalyptus* Woodland over *Atriplex stipitata* Low Shrubland

Soils were non-saline (range 0.8-1.9 dS m^{-1} ECe) and alkaline (pH range 7.3 - 7.8) during the period of assessment (Table 4.3.1) for the *Eucalyptus* Woodland over *Atriplex stipitata* Low Shrubland site, situated immediately south west of the Westonia Gold Mine waste dumps. This site recorded the highest plant density of the three Northeastern Wheatbelt analogue communities assessed; 3.50 stems m^{-2} in September '98, and 4.40 stems m^{-2} in April '99 (Table 4.3.1). Higher numbers of *Maireana* were responsible for the increase in density between assessments (Figure 4.3.2).

Total ground cover decreased from 31 to 25 percent between September '98 and April '99, with the major decrease recorded by *Eucalyptus* species (23 to 18 percent, Figures 4.3.2 & 4.3.3). A greater number of annual life forms recorded during September '98 (14 species from 8 families) were responsible for increased species richness, in comparison to the May '99 assessment (9 species from 6 families).

FIGURE 4.3.2: *Eucalyptus* Woodland over *Atriplex stipitata* Low Shrubland analogue site.

FIGURE 4.3.3: **Change in Importance Value Index (IVI), plant density, and revegetation cover between September '98 and April '99 (n=4) for dominant plant taxa recorded at the *Eucalyptus* Woodland over *Atriplex stipitata* Low Shrubland analogue site.**

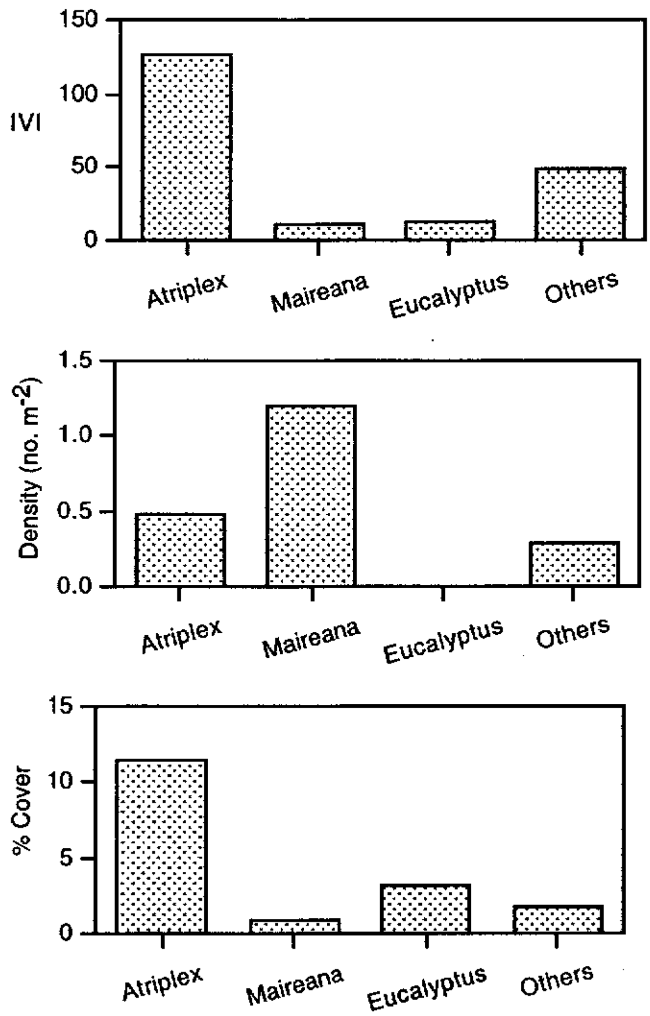


4.3.3 *Atriplex vesicaria* Low Shrubland

The *Atriplex vesicaria* Low Shrubland analogue site was assessed during September '98. Ten plant species from 6 families were recorded at an average density of 1.98 stems m^{-2} and with 18 percent ground cover (Table 4.3.1). Soil was non-saline (1.1 dS m^{-1} ECe) and alkaline (pH 8.2).

A. vesicaria (IVI 94.8) and *A. nummularia* (IVI 24.1) provided highest individual ground coverage of 6 and 5 percent respectively, occurring as low and mid level shrubs (Figure 4.3.4). *Eucalyptus salubris* (IVI 14.1) provided an open upperstorey cover averaging 3 percent.

FIGURE 4.3.4: Importance Value Index (IVI), plant density, and revegetation cover for dominant plant taxa recorded at the *Atriplex vesicaria* Low Shrubland analogue site.



5 QUALITY AND GERMINATION OF PROGENY SEED

5.1 Northeastern Goldfields

Seed was collected from eight revegetation species represented within rehabilitation trials at the Granny Smith Gold Mine, and fruiting at the time of assessment in October '98. Testing for seed quality in the laboratory confirmed a high proportion of seed for all species was sound; greater than 83 percent for seven of the eight collections, and 60 percent for *Atriplex bunburyana* (Table 5.1.1). Seed had successfully matured on plants over the rehabilitation trials, and evidence of subsequent insect attack on seed was low.

Seed germinability was variable for the eight collections, with final germination rates ranging from 35 percent for *Senna filifolia* up to 94 percent for *Atriplex codonocarpa*. The lower seed germination recorded for *S. filifolia* (35 percent) and *Maireana georgei* (52 percent), was however, compared favourably with that recorded for maternal seed included in the original seed mixture (21 and 19 percent respectively, see Appendix 3). Final germination for progeny seed of the other six species ranged between 74 and 94 percent, and was again relative when compared to the viability of maternal seed (Table 5.1.1).

TABLE 5.1.1: Seed quality and germination characteristics of rehabilitation species fruiting on rehabilitation trials at Granny Smith Gold Mine during the October '98 assessment (n=5, with standard deviation in brackets). Final % germination of maternal seed direct seeded shown for comparison.

FAMILY Species	**Collection**	**% Sound Seed**	**% Final Germ. (sd)**	**% Final Germ. - Maternal**
CAESALPINIACEAE				
Senna filifolia	'94 Seeding	85	35.0 (1.6)	21.3
CHENOPODIACEAE				
Atriplex bunburyana	'93 Seeding	60	82.0 (5.4)	82.0
Atriplex codonocarpa	'93 Oxide	87	94.0 (1.9)	66.0
Atriplex nummularia	'94 Seeding	83	74.0 (7.0)	74.2
Atriplex semibaccata	'92 Oxide	87	89.0 (5.6)	92.0
Atriplex vesicaria	'94 Seeding	95	76.0 (5.6)	95.8
Maireana georgei	'94 Seeding	100	52.0 (13.1)	18.8
Maireana triptera	'93 Oxide	100	87.0 (6.2)	8.0

Seed was collected from revegetation species fruiting on the 1997 (4 species) and 1998 (4 species) rehabilitation trials at Sunrise Dam Gold Mine during May 1999 and tested in the laboratory for seed quality and germination potential. Data from the 1997 trial however, was unable to be compared with that of maternal seed, as the direct sown seed was not tested.

Seed of all four *Atriplex* species collected from the 1997 rehabilitation trial was found to be of sound quality, with seed soundness ranging from 70 to 79 percent. Final germination was greater than 81 percent for *A. holocarpa, A. lindleyi* and *A. vesicaria,* and lower for *A. nana* (67 percent, see Table 5.1.2). Visual inspection confirmed polymorphism with two seed types present, brown and black seeds. The significance of polymorphism in regard to seed dormancy and germination has not been fully examined, however it has been suggested that black seed may remain dormant for extended periods and only germinate under optimum environmental conditions (Mott and Groves 1981). This may be the case for *A. nana,* with 100 percent of the seed recorded as being black.

Atriplex nana occurs in close proximity to the 1997 rehabilitation trial plot, growing on extremely saline gypsiferous sediments around the margin of a large ephemeral salt lake. The production of dark seeds, and hence dormancy, may be a mechanism by which this species tolerates the elevated salinities encountered. The lower final seed germination recorded in the laboratory may reflect this pattern of dormancy.

TABLE 5.1.2: Seed quality and germination characteristics of rehabilitation species fruiting on the 1997 Rehabilitation at Sunrise Dam Gold Mine during the May '99 assessment (n=3, with standard deviation in brackets). Final % germination of maternal seed direct sown shown for comparison. NA - not tested, NS - not direct sown.

Species	Progeny Seed (collected May '99)			Maternal Seed
	% Seed Soundness	% Black Seeds	% Final Germ.	% Final Germ.
Atriplex holocarpa	79.4	11.8	81.0 (6.0)	NA
Atriplex lindleyi	69.8	2.3	90.7 (8.1)	NS
Atriplex nana	71.2	100.0	67.3 (11.5)	NS
Atriplex vesicaria	79.2	16.7	92.3 (0.6)	NA

Seed of the 1998 rehabilitation species was germination tested prior to direct seeding (Appendix 5). Results confirmed that four taxa were more likely to establish in the field; the saltbushes represented by *Atriplex codonocarpa, A. semibaccata, A. semilunaris, A. vesicaria* and *Enchylaena tomentosa;* the bluebushes *Maireana georgei, M. pyramidata* and *M. triptera;* pre-treated *Acacia tysonii;* and the grass *Eragrostis dielsii* under optimum conditions. In the field trial 12 months after seeding the dominant sown varieties to establish were from these four groups. A number of taxa including *Maireana* and untreated *Acacia tysonii* seed will require an after ripening period before maximum germination occurs, hence field densities for these taxa are likely to increase over time.

Progeny seed collected from four species fruiting on the 1998 rehabilitation trial in May '99 was of good quality. Final germination for all species was greater than 91 percent (Table 5.1.3). Seed soundness was high for three species (greater than 86 percent); *Atriplex vesicaria* gave a lower value of 49 percent with a large proportion of seed immature when dissected from the bracteole. Two of the four species from which seed was collected were direct sown varieties, *Atriplex vesicaria* and *Enchylaena tomentosa.* Final germination percentage of the progeny seed was higher for both species in comparison to the maternal seed sown (Table 5.1.3).

TABLE 5.1.3: Seed quality and germination characteristics of rehabilitation species fruiting on the 1998 Rehabilitation at Sunrise Dam Gold Mine during the May '99 assessment (n=3, with standard deviation in brackets). Final % germination of maternal seed direct sown shown for comparison. NA - not tested, NS - not direct sown.

	Progeny Seed (collected May '99)			Maternal Seed
Species	**% Seed Soundness**	**% Black Seeds**	**% Final Germ.**	**% Final Germ.**
Atriplex lindleyi	86.1	5.1	90.3 (9.1)	NS
Atriplex vesicaria	49.3	0.0	94.3 (5.5)	65.0
Enchylaena tomentosa	100.0	0.0	100.0 (0.0)	45.0
Maireana tomentosa	96.0	0.0	91.0 (9.0)	NS

5.2 Eastern Goldfields

Seed was collected in October '98 from four revegetation species fruiting over the Sump Hole Trial at Black Swan Nickel Mine, *Atriplex codonocarpa, Maireana georgei, M. pentatropis,* and *M. tomentosa.* For all species a high proportion of the progeny seed collected was sound (>95 percent), and for the three *Maireana* species collected final germination was greater than 80 percent (Table 5.2.1). Final germination for *Atriplex codonocarpa* was lower (17 percent), however, a high proportion of the seed was dark in colour (79 percent).

Atriplex codonocarpa is one of the annual species which occurred in high numbers during the early stages of revegetation development over the Sump Hole Trial, but became less prevalent as the perennial vegetation cover established. In the case of disturbance, such as fire, drought or overgrazing, this 'coloniser species' has been shown to reappear at high density. The production of large proportions of 'dark' seeds may be a survival mechanism allowing *A. codonocarpa* to remain dormant for extended periods until a disturbance event provides the opportunity for reestablishment (Mott *et al.* 1981).

TABLE 5.2.1: **Seed quality and germination characteristics of rehabilitation species fruiting on the Sump Hole Trial at Black Swan Nickel Mine in early October '98 (n=3, with standard deviation in brackets). Final % germination of maternal seed direct sown shown for comparison.** NA - not tested, NS - not direct sown.

Species	**Progeny Seed (collected May '99)**			**Maternal Seed**
	% Seed Soundness	**% Black Seeds**	**% Final Germ.**	**% Final Germ.**
Atriplex codonocarpa	95.8	78.9	16.6	NA
Maireana georgei	100.0	0.0	90.0	NA
Maireana pentatropis	95.1	0.0	79.7	73.3
Maireana tomentosa	98.0	0.0	79.4	NA

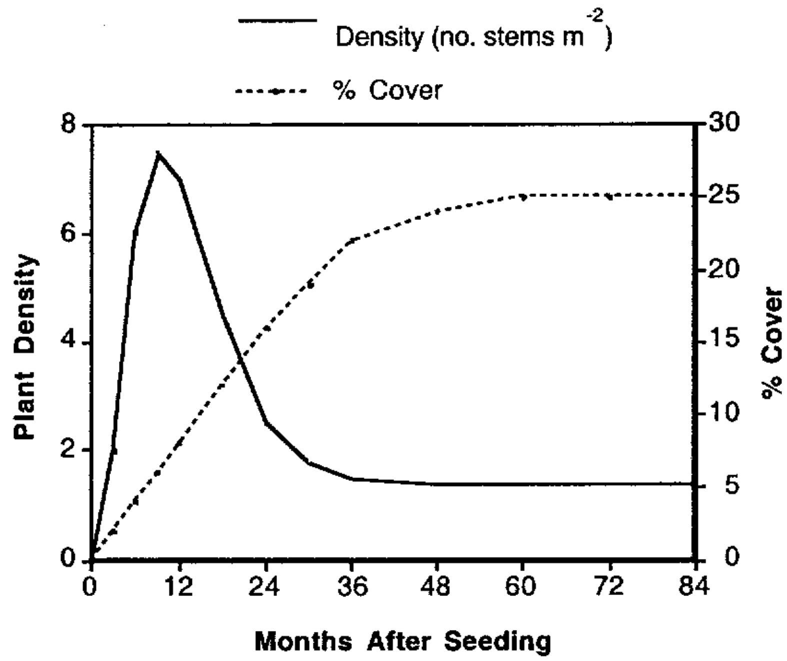
6 DISCUSSION

The establishment of a 'green' rehabilitation surface once subscribed to by most operators is no longer acceptable (Bradshaw 1994). Operators are now realising that successful rehabilitation relies on a thorough risk-based approach to planning, an understanding of local ecosystem function, and the implementation of best rehabilitation practice. While the short-term cost is often higher, the long-term benefits are much greater; by acting as a responsible caretaker of the environment, the working relationship with both the regulatory and public communities at large is enhanced.

To better understand ecosystem function, observations on the dynamic behaviour and interaction of associated components over at least a few years is required for both stable mature ecosystems (analogues) and developing rehabilitation sites. Time series monitoring of selected plant biodiversity parameters shows the occurrence of characteristic response curves, similar to those depicted in Figure 6.1. Parameters were observed to change rapidly during the early stages of rehabilitation development, before reaching a relatively stable state. It is this stable state that was identified as an indicator of successful rehabilitation progress. However, change continued to occur in both directions, albeit more slowly and with less variation. Positive variation occurred in response to cyclonic rainfall, and negative variation followed disturbances such as overgrazing and drought. Recovery of the parameters being measured was an indicator of ecosystem reslience, however, often the rehabilitation was pushed towards a new state.

These 'stable' states are similar to those proposed by Westoby *et al.* (1989) in the state and transition model; this model recognises 'multiple stable states' in a developing vegetation system and the transitions between them. Tongway *et al.* (1997) discusses predictable rehabilitation trajectories expected from time series monitoring of soil parameters, and the identification of critical threshold ranges below which the ecosystem would not be self-sustainable. Tongway *et al.* (1997) suggests the appropriate trajectory shape of a response curve for all indicators of rehabilitation success, is characterised by a steep initial response followed by a steady increase over time. This is similar to the response curve observed for % revegetation cover in the current project, but differs markedly from the response observed for plant density (Figure 6.1).

FIGURE 6.1: A characteristic response curve recorded for plant density and ground cover parameters; rehabilitation site supporting a low chenopod shrubland vegetation complex.



To better understand specific results from the project, time series monitoring of rehabilitation sites is discussed below in terms of state factors and interactive controls.

6.1 State Factors

Global Climate

Annual rainfall for study sites in the Northeastern Goldfields, Eastern Goldfields, and Northeastern Wheatbelt averages 220 mm, 260 mm and 309 mm respectively. The Mediterranean climate of the above regions is characterised by hot summers and cool winters. In southern parts, most effective rainfall occurs during winter months, with the probability of summer rainfall increasing to the north.

Moisture is the primary limiting resource in arid and semi-arid Western Australia, with most biological processes occurring in 'pulses' induced by rainfall events (Westoby 1972; Bridges et al. 1972). The quantity of available water is not only affected by precipitation inputs, but also by soil characteristics and position of the ecosystem in the landscape (Ludwig and Tongway 1996). The construction and contouring of waste dumps and other rehabilitation sites should always focus on the retention of water within the upper soil profile. Lowering batter angles to 15° and deep ripping, back sloping berms and bunding the perimeter around the upper surface of the rehabilitation landform, and ensuring an adequate proportion of fine materials in the upper profile were all measures used to enhance water retention. Neglecting any one of the above design features detrimentally affected the revegetation outcome at all rehabilitation sites monitored.

For the 1997 Crusher Pad Rehabilitation in the Eastern Goldfields, topsoil was spread too thinly (<0.1 m deep) and subsurface material comprised a large proportion of competent rock. As a result, rainfall readily infiltrated through the rooting zone and was rapidly lost from the thin topsoil cover; subsequently only drought tolerant chenopods were able to successfully establish. In neighbouring exploration rehabilitation sites, the same seed mixture sown over flat mediums comprising deeper topsoil over hardpan, resulted in a more diverse range of taller plant life forms similar to the pre-disturbance vegetation complex; *Acacia, Senna* and *Eucalyptus.*

Most biological processes in arid and semi-arid ecosystems are rainfall dependent (Noy-Meir 1981). The water holding capacity of the upper soil profile in the reconstructed landscape is a major determinant of revegetation structure and composition, and subsequent ecosystem function. The season of precipitation input also affects both the growth and reproductive responses of different species in the revegetation. Winter rains are of lower intensity but more reliable in comparison to summer rainfall. Summer rainfall stimulates a more pronounced response from revegetation, however, winter rainfall remains important to revegetation maintenance. Revegetation condition for a majority of the rehabilitation trials was affected by an extended period of low winter rainfall during 1994, however, recovery occurred rapidly following the return of effective rainfall.

Climate is the factor that most strongly governs the structure, productivity, and biogeochemistry of ecosystems (Woodward 1987). Long term change in climatic conditions has the potential to alter the structure, productivity, and biogeochemistry of any given ecosystem. The increased frequency of El nino years (years in which cool ocean currents extend down the west coast of Western Australia) is changing the long-term rainfall pattern for arid and semi-arid regions of Western Australia by increasing the potential for summer cyclonic rainfall (Nicholls 1988).

Arid and semi-arid bioclimatic regions of Western Australia are characterised by low and often unpredictable rainfall patterns. High intensity, short duration rainfall events occur infrequently during summer months (November - April), when large tropical depressions off the northwest coast dissipate over inland areas of northern Western Australia. In the 11-year period between 1990 and 2000 there have been two periods when monthly rainfall exceeded 100 mm for the town site of Laverton in the Northeastern Goldfields of Western Australia, February 1995 and January-March 2000. On both occasions, high rainfall was associated with tropical cyclone activity. In comparison to summer rainfall, winter rains are generally lower but more consistent. They are important to revegetation maintenance, their absence producing an immediate negative response from the revegetation when proceeding periods of low summer rainfall.

Time series data collected from a variety of rehabilitation treatments confirm the positive influence that summer rainfall events have on revegetation development over post mining rehabilitation surfaces. These events are of increasing importance to ecosystem development and function from the Northeastern Wheatbelt into the Eastern Goldfields and the Northeastern Goldfields, as rainfall consistency and annual totals decrease. The presence or absence of cyclonic rainfall during the first growing season is a major factor determining ecosystem trajectory. Rainfall pattern during the initial growing season was found to be of particular importance in controlling revegetation structure and composition for many years to follow. The germination and successful establishment of hard seeded species (*Acacia, Senna*) and a number of the bluebushes (*Maireana* species) was reliant on heavy summer rainfall during the early stages of ecosystem development. Summer rainfall not only acted to break seed dormancy, but also extended the length of the first growing season, which was important to the establishment of slower growing perennial life forms. In the absence of summer rainfall during the first growing season the establishment of low chenopod dominated vegetation covers was favoured, total species richness for the rehabilitation tended to be lower, and the variety of plant life forms was restricted to low and mid strata shrubs.

For established revegetation, cyclonic rainfall increased productivity and stimulated the establishment of new taxa, which in many cases were brought in from the surrounding undisturbed ecosystems. The deposition of *Eremophila* seeds by browsing emus was a common example at mine site rehabilitation in all three bioclimatic zones.

The relationship between plant production and rainfall was dependent on a 'carry-over' effect between seasons or following drought years and 'pulses' mediated, for instance, by the amount of seed in the soil store (Ludwig and Whitford 1981). This 'reserve' component in arid ecosystems is responsible for both the memory of the system between pulses and for its long-term resilience (Noy-Meir 1981). The 'carry-over' response was observed in a number of rehabilitation trials in the Northeastern Goldfields following the 1994 drought. High summer rainfall in early 1995 (Tropical Cyclone Bobby) evoked an immediate revegetation response and the viable soil resource supply was an important determinant of this response. The lack of a response following heavy summer rains was a good indicator that some part of the rehabilitated ecosystem was dysfunctional, and hence remedial strategies were required. While the benefits of rainfall and summer cyclonic rainfall are undoubtedly important to arid and semi-arid ecosystems, the occurrence of drought may also be important in buffering the ecosystem against large changes. In effect, drought acts as a negative feedback to ecosystem function and constrains cumulative productivity and eventual large-scale change.

Two broad revegetation outcomes were achieved over rehabilitation trials in the Northeastern Goldfields, low chenopod shrublands, and tall *Acacia/Senna* shrublands. The establishment of low chenopod dominated vegetation covers was favoured over rehabilitation mediums that were initially highly saline, and/or in the absence of effective summer rainfall during the initial growing season. The successful establishment of tall *Acacia/Senna* shrublands was restricted to years when rehabilitation programs were followed by heavy cyclonic rainfall.

The number of species supported within a rehabilitated vegetation community was determined largely by the abundance of the limiting resource, which was typically water. Increasing levels of water stress, particularly during the first growing season, resulted in progressively higher rates of local species extinction, with fewer species possessing the drought tolerance adaptations required to survive. This was observed in the 1993 Seeding at Granny Smith Gold Mine, where species richness decreased from 17 to 11 species following the 1994 drought. Winter rainfall was important to the maintenance of revegetation throughout arid and semi-arid regions of Western Australia. The absence of winter rains generally resulted in a negative response from all plant biodiversity parameters measured. However, in some circumstances these conditions favoured the establishment of a single specifically adapted species, such as was observed with *Atriplex bunburyana* in the 1993 rehabilitation at Granny Smith Gold Mine.

Methods of predicting long term climatic patterns and, in particular, the occurrence of tropical cyclone activity for northern Western Australia, are becoming increasingly accurate. The Southern Oscillation Index (SOI) is a measure that allows determination of the strength of El Nino and La Nina climatic events (Konnen et al. 1998). Long-term analysis suggests there is a tendency for tropical cyclones to be more common when El Nino events break down, as was experienced during late 1994 and early 1995 (Cyclone Bobby). The timing of these climatic events should be incorporated as a routine part of any rehabilitation program used by mining companies in the Northeastern Goldfields of Western Australia. Seed mixture composition and time of sowing should reflect the likelihood of receiving heavy summer rainfall during the first growing season.

Parent Material

Parent material encompasses the surface substrate as well as any underlying media that may influence surface substrates or the plant-rooting zone. Parent materials at analogue sites show distinct changes, largely in response to geology and associated weathering processes. Naturally occurring changes in the parent material are usually accompanied by changes in the functional components, such as vegetation. The parent material at a particular site is dynamic, and the present condition is often the result of processes operating over very long time periods.

The parent material at reconstructed post-mining rehabilitation sites may vary considerably to those present in the pre-mining environment. As a result, the soil resource supply and associated functional components are also likely to differ. This is an important point when attempting to predict rehabilitation outcomes based on the assessment of analogue sites. This was recognised at rehabilitation sites in the U.S.A. during the early 1990s by Chambers and Wade (1990). They identified the physical and chemical characterisation of spoil materials as an essential requirement in the reconstruction of a sustainable ecosystem.

Salinity of the upper rehabilitation medium was identified as a major factor limiting plant establishment during the early stages following seeding. A limited variety of salt tolerant species were able to successfully establish on extremely saline surfaces, and the rate of revegetation development was typically slowed. Although surface salinity declined rapidly through leaching, the composition and structure of the initial vegetation cover persisted for many years. Annual *Atriplex* species colonised saline surfaces in high numbers, but were replaced by halophytic perennials in line with decreasing surface salinity. The cover of annual species present during early stages of ecosystem development contributed to decreasing salinity in the plant rooting zone, by reducing surface temperature and hence the capillary rise of salts during summer months.

The availability of water for plant function limited plant establishment over all of the trial sites. Often the vegetation cover was restricted to drought tolerant varieties, which were able to colonise surfaces under a low soil moisture regime. Reducing the slope of topography, ensuring a high proportion of fines in the upper profile, and deep ripping were all important design criteria implemented to increase water holding potential of the surface substrate. The dumping of competent rock close to the rehabilitation surface was a common fault reducing water holding capacity in the plant rooting zone and hence limiting the variety of life forms that were able to establish.

Correct topsoil handling was paramount to the rehabilitation outcome. The physical, chemical and biological benefits of this resource have been well documented (Howard and Samuel 1979; Bellairs and Bell 1993; Brearley 1995). However, it is the available seed store contained within this layer that arguably provides the greatest benefit to rehabilitation. The direct return of the surface topsoil layer was in some instances found to render direct seeding unnecessary, providing a significant cost saving and ultimately increasing biodiversity. A surface rehabilitation substrate was also important in providing a buffer between germinating seed and hostile materials deeper in the rooting profile.

A number of trials examined the application of fertiliser supplements into a variety of rehabilitation mediums. Fertiliser had the affect of eliciting a positive plant response as measured by foliage cover. However, this response was typically observed from one or two species, which became dominant and reduced total species richness. For inhospitable materials fertiliser did not provide any significant benefit to long-term plant establishment; the plant community at these sites developed slowly over time and showed clear successional patterns.

Slope of Topography

The slope of topography is a major factor affecting soil resource supply, particularly in arid ecosystems where overland flow following rainfall is an important landscape process. Mine rehabilitation sites are often large dumps of waste rock, battered down to form anywhere up to a 20 degree slope. Initially surface parent materials are relatively unstable, and often susceptible to erosion. Increasing the slope can dramatically alter soil resource supply and hence, impact the functional components capable of being supported.

Reducing the slope of a rehabilitation medium increases stability of the reconstructed soil profile, and provides direct benefits to the establishment of vegetation by reducing potential losses from the soil resource supply. There is typically lower retention of resources on steeper slopes. Slopes up to 20 degrees however, remained stable and were able to support a sustainable vegetation cover when surfaces were consolidated with large fragments of blasted caprock mixed with a proportion of topsoil fines. Slopes covered with topsoil or gypsum alone were more prone to erosion when slope angles were increased.

Time

Time must be considered when interpreting ecosystem function, as the degree of change within ecosystems differs significantly over the short and longer term (Goodall 1981; Friedel 1990, 1994). Temporal variation occurred at four levels in data collected from rehabilitation trials and analogue sites; seasonal, cyclical, successional, and in response to disturbance.

Seasonal change was represented by the rapid response of annual plant taxa to rainfall. For the majority of analogue sites this was the only temporal variation recorded during the relatively short assessment duration. The vegetation response to heavy summer rainfall events was apparent at all Goldfields sites. Long-term climatic records suggest this cyclical variation is the result of an increasing frequency of El nino events, and hence greater number of cyclones passing across the region. The longer-term impact of this temporal change on ecosystem structure and function may be significant.

Successional variation was clearly evidenced through trends in revegetation development. Investigation of vegetation as a functional component of the ecosystem found a number of plant biodiversity parameters to behave in a predictable manner over relatively short time intervals.

Finally, disturbance events resulted in variation to the plant biodiversity parameters being monitored. Recovery of functional ecosystems occurred rapidly following removal of the disturbance and following the same successional trends outlined above.

Potential Biota

What occurs early in the rehabilitation process controls revegetation development for many years to follow. Indeed revegetation development during the initial two growing seasons provides an accurate indication of the longer-term revegetation structure and composition. Once the initial vegetation community has established, change continues to occur, albeit very slowly. One factor controlling this change is the immigration rate of biota from adjacent revegetation or more commonly from surrounding analogue communities. A common example in the rehabilitation trials was the visitation by browsing species such as emus, which deposited a variety of seeds through their scats *(Eremophila, Santalum)* and in doing so increased plant diversity. Similarly birds commonly dispersed plant species that produced berry-like fruits, such as *Enchylaena tomentosa*.

Ensuring that rehabilitation areas are linked to surrounding functional ecosystems ensures the movement of plants and animals, water, energy and biogeochemical cycles (Turner 1989) and ultimately increases the rate of recovery. The sustainability of post-mining rehabilitation is enhanced where these links are established early, allowing for the provision of additional seed and the migration of displaced species (Tilman and Downing 1994).

6.2 Interactive Controls

Four interactive controls were identified by Chapin, Torn and Tateno (1996); local climate, soil resource supply, functional components and disturbance. As previously mentioned interactive controls both control and respond to ecosystem characteristics unlike state factors, which predominantly have a control function.

Local Climate

Local climate is influenced by factors including regional location and topography, but may also be influenced by the ecosystem itself. A number of design criteria play an important role in establishing the local climatic condition. Riplines for example, act to trap seed and harvest water, and hence promote a microclimate to support seed germination and seedling growth. The establishment of a vegetation cover further alters local environmental conditions by decreasing surface temperature and hence reducing soil moisture loss and preventing the capillary rise of salts. Salt may even be acticely exported from the site following uptake by halophytes and subsequent grazing. The pronounced growth response of annual life forms during the initial growing seasons, as evidenced in the field trials, may benefit the establishment of slower growing perennial life forms over the longer term, by altering the local climate.

Soil Resource Supply

Soil resource supply is the determining factor of vegetation productivity and structural diversity (Chapin 1993). The uptake of nutrients from the soil supports plant productivity, with transpirational water loss occurring as part of the photosynthetic process (Field et al. 1992). Thus productivity, nutrient cycling and water loss are all linked to the availability of soil resources.

Loss of soil through erosional processes reduces associated nutrient supplies, and therefore productivity and rates of nutrient cycling. Soil resource supply is the major link between state factors and other interactive controls, particularly the functional components of an ecosystem. While the composition of functional components is highly dependent on the state of the soil resource supply, the maintenance of the soil resource supply is also highly dependent on the functional components.

Reconstruction of the landscape such that scarce resources are not lost from the site, and in fact may be concentrated at catchment points, is important in accelerating ecosystem development for arid and semi-arid Western Australia. This is commonly achieved through deep ripping of slopes on the contour, reducing batter angles for waste dumps, and back sloping waste dump berms. As demonstrated by Whisenant, Thurow and Maranz (1995), microcatchments can increase plant productivity by up to ten-fold in arid and semi-arid ecosystems by enhancing the collection of surface run-off.

For rehabilitation sites in the arid and semi-arid zone there is a carry-over of resources held in the soil store between growing seasons, which allows for an immediate response following the first effective rainfall. Decomposition of vegetative matter by soil organisms and the production of viable seed from mature plants are both important components that are likely to mediate the carry-over response.

Quality and germination testing confirmed progeny seed from a number of trials was of similar or higher viability than the maternal seed originally sown. This was confirmed by field responses at trials in the Northeastern Goldfields one year after the 1994 drought, when very high plant densities were recorded following the return of above average rainfall. The ability of the rehabilitation to show an immediate response to rainfall following a seven-month drought, and for vegetation parameters to subsequently recover to pre-disturbance levels within 1-2 years, provided an indication that the revegetation cover was resilient.

Functional Components

Functional components are defined as groups of species that have similar effects on ecosystem processes, *e.g.* plants, animals, insects. The most common functional components in an ecosystem are higher plants and animals. The presence and success of these groups is highly regulated by the soil resource supply, which in turn is dependent on feedbacks from the functional components.

Competition for limiting resources generates a negative feedback at the ecosystem level. Competition is detrimental to one species, but will have less of an effect on another species, or even a positive effect because of release from competition for the shared resource. It is the level of the shared resource that constrains productivity, and hence buffers the community against large changes in productivity (Pimm 1993). Conversely, if there is only one species capable of using a resource, changes in the abundance of that species can effect other parts of the ecosystem. Biodiversity within a group of species that are limited by the same resource provides insurance against radical ecosystem change in response to extreme events that might eliminate a species (Tilman and Downing 1994). Kareiva (1996) suggests that ecosystems with higher biological diversity are better able to utilise and retain nutrients. In fact ecosystem productivity, sustainability and stability may all be influenced by biodiversity (Tilman, Wedin and Knops 1996).

Terrestrial vegetation is the most common functional component for which data have historically been collected from rehabilitation at arid and semi-arid mine sites. Importantly it is also an area of the rehabilitation program over which there is a high degree of control; for example, by manipulating species in the seed mixture and their individual sowing rates.

Revegetation species must be selected to tolerate constraints of the rehabilitation medium. This is most accurately determined with reference to surrounding analogue communities. Importantly the final species composition of the seed mixture must be broad enough to allow for a number of potential ecosystem trajectories, and not limited to one specific outcome. Chenopod dominated communities are suited to establishment on saline rehabilitation mediums, of which there are many successful examples throughout the arid and semi-arid zones. However, leaching of salts from the surface profile does occur rapidly to provide an opportunity for the establishment of a much wider variety of plant life forms. An opportunity for the most desirable rehabilitation trajectory to occur given the site-specific constraints should be accommodated as part of the rehabilitation strategy.

Successful revegetation development can be determined by monitoring a group of plant biodiversity parameters and identifying trends in the data over time. Successful seed germination resulted in high seedling density during the initial growing season. Density then progressively decreased in response to competition, before stabilising within a range approximately five years after seeding. Revegetation cover was typically low during the first growing season, increasing rapidly there after before also stabilising in line with plant density. Maximum species richness was generally achieved during the first and second year following seeding when annual *Atriplex* species were prominent. Perennial *Atriplex* species established more slowly during the early stages of revegetation development, but eventually replaced the annual component as the dominant taxa. Perennial *Maireana* species required up to three years before germinating in the field, before also establishing themselves as a prominent taxa in revegetation. As discuseed under 'Global Climate' above, the establishment of taller woody taxa such as *Acacia* and *Senna* was reliant on heavy summer rainfall during the early stages of ecosystem development. Heavy summer rainfall was a pre-cursor to seed germination and also extended the length of the first growing season. In the absence of summer rainfall during the first growing season the establishment of chenopod shrubland complexes was favoured and total species richness for the rehabilitation tended to be lower.

Undisturbed analogue vegetation complexes are less dynamic in comparison to developing rehabilitation sites. Plant biodiversity parameters in rehabilitated areas show a relatively high degree of change within the initial five years following seeding, after which time they fluctuate within a stable range for a functional ecosystem. For analogue sites minor seasonal changes occur, but overall annual change is minimal. Significant and sudden change to vegetation parameters within stable rehabilitation sites and analogue communities, occurred only following disturbances such as drought and overgrazing. In functional ecosystems, recovery to pre-disturbance levels occurred rapidly once the disturbance was removed and following the return of effective rainfall.

The desired revegetation structure and species composition should be modelled on local analogue communities occurring in parent materials 'matched' to those of the rehabilitation site. It is, however, important not to model one specific analogue community too closely, as in reality, there are always a number of equally possible ecosystem trajectories. This was observed for two trials in the Northeastern Goldfields, 1993 Seeding Trial and 1994 Seeding Trial. For both trials the revegetation medium, ground preparation techniques, seed mixture composition and sowing rates were similar, but the resulting revegetation composition and structure differed markedly.

For the 1993 Seeding Trial, above average rainfall during the three months following sowing facilitated the germination of a variety of taxa including salt tolerant chenopods and taller woody perennials. However, drier conditions over the summer months followed by drought conditions during eight months of 1994, significantly changed the resulting revegetation structure and composition. The juvenile woody perennials succumbed rapidly to moisture stress, followed later by a majority of the chenopods. Only one species, the drought tolerant *Atriplex bunburyana,* was able to tolerate the extended dry period and subsequently became the keystone revegetation species.

For the 1994 Seeding Trial in comparison, drought conditions throughout the first growing season inhibited seed germination for all taxa. Seed germination for a variety of taxa was stimulated one year after direct sowing by high summer rainfall in December '94, January '95, and from Tropical Cyclone Bobby in February '95. Follow-up rainfall during winter months extended the growing season and further benefited plant establishment, particularly for woody perennial species (acacias and sennas). In October '98 all of the major taxa direct sown were relatively evenly represented in the revegetation.

Rangeland assessments by Ludwig and Tongway (1996) found annual life forms to be fast growing, reaching maximum production within two months following significant rainfall. Annuals also established at higher density in more open areas. Perennial species in comparison responded more slowly and over a longer period to rainfall, with maximum production after four months (Ludwig and Tongway 1996). Similar trends were observed for the rehabilitation trials, with annual *Atriplex* species establishing at high density during the early stages of rehabilitation. Annual life forms were particularly prominent and also persistent when surface salinity was extreme, *e.g. Atriplex semibaccata* at Westonia, *A. codonocarpa* at Laverton. With the establishment of a perennial vegetation cover, the annual component within the rehabilitation became less significant. However, annuals readily recolonised in high density immediately following disturbance of the perennial plant cover, suggesting longevity of seed in the soil store and presence of associated dormancy mechanisms. Dormancy was confirmed through seed quality and germination testing of progeny seed collected from three mine sites. Progeny seed generally showed high viability, with *Atriplex codonocarpa* and *A. nana* both exhibiting polymorphism.

The life cycle pattern of keystone species in the revegetation was an important determinant in long-term sustainability of the plant cover, particularly for chenopod shrublands complexes where one species was typically dominant. Because seed is sown at the same time, a majority of the maternal plants for each species establish together during the initial growing seasons, and hence have a similar life expectancy. The senescence and death of large numbers of a dominant revegetation species together, can significantly alter the revegetation structure and composition. In revegetation dominated by *Atriplex bunburyana,* for example, senescence and death occurred approximately five years after seeding. This severely impacted the structure and composition of the revegetation. The same phenomenon may be expected to occur in revegetation where other *Atriplex* occur as single species dominants, e.g. *A. vesicaria, A. nummularia.* Changes related to life cycle patterns will occur over different time frames depending on the life expectancy of the dominant species in a site-specific rehabilitation medium. The impact for rehabilitation where a number of dominant taxa co-exist is expected to be less pronounced. Thus it follows that a minimum level of species richness is important to long-term rehabilitation sustainability, as is the development of an age-class structure in the rehabilitation.

Disturbance

Landscape scale disturbance is critical to sustaining the natural structure and rates of processes in ecosystems (Sousa 1985). For example, fire is critical to the long-term maintenance of fire-prone ecosystems such as the spinifex grasslands in northern Western Australia. Change in either the intensity or frequency of disturbance can cause long term ecosystem change. Invasive species may be given the chance to establish where fire frequency is decreased, fuel loads may build to levels which increase the potential intensity of fire and thus endanger keystone tree species, or alternatively a higher frequency of fires may prevent keystone species from renewing soil seed store reserves.

The most common disturbances encountered at the rehabilitation trial sites were drought, overgrazing and weed infestation. All three disturbance had a similar effect on the rehabilitation, resulting in a decrease to the plant biodiversity parameters measured (density, foliage cover, species richness). Grazing not only impacted the vegetation component directly by removing foliage, but indirectly affected the soil resource supply by reducing the maintenance of a viable topsoil seed store and impacting physical soil properties e.g. compaction, capillary rise of salts. Increasing the period of overgrazing reduced the ability of the revegetation to recover. Long-term monitoring of a sagebrush steppe in semi-arid North America found that increases in plant species diversity and heterogeneity were largely the result of a recovery of vegetation from drought and grazing (Anderson and Inouye 2001). Plots with higher species richness showed greater vegetation cover and less variation in cover, and an adequate cover of native species appeared to render these semi-arid communities more resistant to invasion by exotics (Anderson and Inouye 2001).

The sustainable utilisation of any ecosystem requires careful management. The *Atriplex vesicaria* Low Shrubland analogue site in rangeland surrounding the Black Swan Nickel Mine was impacted by prolonged overgrazing during 1997, with the perennial vegetation cover effectively removed. For many mine sites, the management of domestic stock is primarily the responsibility of the pastoralist, however, there is usually close liaison with the mining company for areas surrounding mining leases. Management options introduced to enhance rehabilitation success include fencing waste dumps or mining leases, destocking susceptible areas, closing down watering points close to rehabilitation, and introducing feral animal control programs, e.g. goats.

A number of the rehabilitation trials monitored were subjected to differing levels of grazing by domestic stock and native fauna. There was, however, only one case where revegetation did not recover from grazing. The Childe Harold waste dump at Granny Smith Gold Mine was located adjacent to a permanent source of potable water, and hence subjected to prolonged overgrazing. Rehabilitation along the northwestern side of the waste dump, closest to the watering hole, was severely impacted and did not recover after stock were relocated. This area required remedial inputs including site works (deep ripping) and direct seeding. It follows that it is the responsibility of the mining company to ensure both rangeland and rehabilitation within their mining lease are not impacted during their tenure, just as it is the responsibility of the pre- and post-mining land manager to ensure the same. Without good management principles both rehabilitation and analogue sites are vulnerable to degradation.

Disturbed ecosystems can be restored through practices that enhance positive feedbacks to bring the ecosystem to a state where the interactive controls are commensurate with desired ecosystem characteristics. Recovery of the ecosystem following drought or overgrazing was dependent on effective rainfall, but occurred rapidly with plant parameters returning to pre-disturbance levels within 1-2 growing seasons. The recovery of plant biodiversity parameters followed the same trends identified at functional rehabilitation sites during the initial five years following direct seeding, however the rate of recovery was influenced by the severity of the disturbance. It should be recognised that disturbance regimes interact strongly with climate and the soil resource supply.

7 COMPLETION CRITERIA

7.1 Development of Completion Criteria

Completion criteria developed prior to mining should be outlined for discrete stages of the mining and rehabilitation program, but considered preliminary during the early stages. The number of criteria selected to judge rehabilitation success, and the detail of associated standards, should be determined by the cumulative knowledge of the ecosystem on which the end land use is based. More often than not appropriate information has to be generated during the operational stage of the project. Hence it is important that there is scope to continually update completion criteria, as data becomes available throughout the mine life. This encourages mining companies to aim for the highest possible rehabilitation target at the commencement of operations, but provides scope to make changes to these targets as a knowledge base is developed over time.

Standards developed for completion criteria can be categorised into two groups; performance (outcome) based standards and technically prescriptive (design) standards. Performance based standards specify the desired outcome for each criterion, whereas technically prescriptive standards prescribe specific design techniques required to achieve the desired outcome. Performance based standards are recommended as the predominant regulatory tool. However, as outlined above the depth of knowledge required to develop specific performance standards is rarely available during the early stages of mining. Design standards are a practical substitute that can be effectively applied during these early stages to ensure the 'building blocks' for successful rehabilitation are laid. The importance of design and construction considerations to establishing sustainable ecosystems over rehabilitated landscapes is recognised by the Commonwealth of Australia Environment Protection Agency (1995). As has been suggested by Mills, Chandler and Caporn (1991) in Western Australia, completion criteria are not always represented as such but appear under the guise of the various conditions of project approval. This is particularly the case for a variety of design standards.

There are countless processes occurring within a functional ecosystem at any one time, many of which we may be totally unaware. These processes are often difficult to measure and quantify, unlike the outcomes from these processes, which are commonly represented by a number, weight, cover or concentration. For mine site rehabilitation, vegetation is a major functional component of the ecosystem for which a variety of associated parameters can make logical assessment criteria. Examples include; biodiversity parameters (plant density, % ground cover and species richness), production (growth rates, biomass accumulation), successional patterns (changes in keystone taxa over time), reproductive capacity (flowering and seed production, soil seed bank), resilience (survival during and reestablishment following disturbances such as drought and fire, presence of weeds), and nutrient accumulation (litter fall, infection by root symbionts). For the above parameters, data are easily and efficiently recorded from both rehabilitation and analogue sites, performance can be visually observed and photographically recorded, and importantly information can be accurately related back to the rehabilitation plan so appropriate changes can be put in place immediately.

A variety of other ecosystem components may also make sound assessment criteria for rehabilitation success including soils (stability, nutrient status and cycling, microbial biomass and respiration), vertebrate and invertebrate fauna (species richness, density), and water (quality, infiltration). While water quality standards are used extensively by industry, the application of many other criteria are seen to be expensive, laborious, or require monitoring over too long a period. The development of indicators of success for such parameters may allow for their incorporation into regular monitoring programs, and hence provide a more extensive assessment of the developing ecosystem. Mine sites should be encouraged by regulatory authorities to monitor a greater variety of ecosystem parameters that may be relevant to their site-specific situation, in an effort to reclaim bonds and relinquish rehabilitation sooner.

Biological surveys throughout the arid interior of Western Australia indicate the recurrence of distinct vegetation complexes, which have evolved in association with the underlying geology and soils. Although plant species richness within each community is typically low, overall diversity is increased by the large spatial heterogeneity throughout the rangeland. It is this diverse range of undisturbed vegetation communities, termed analogue sites, on which site-specific rehabilitation scenarios can be modeled, albeit with caution. Pickett and Parker (1994) advise against using analogue sites on which to compare rehabilitation development, due to their dynamic nature making them unpredictable over time. White and Walker (1997) acknowledge the potential role that analogue sites may play in evaluating rehabilitation success, but stress the need to understand temporal and spatial variation in nature before selecting and applying information from such sites.

Fifteen analogue sites were assessed during the current project over a period of four years. Plant biodiversity parameters within these communities remained relatively stable during the sampling period, with minor seasonal changes between assessments resulting from fluctuation in annual life forms. Major changes, although uncommon, did occur in response to disturbances such as overgrazing by domestic stock.

The mining process alters a number of components in the reconstructed ecosystem when compared against undisturbed analogue sites. Rehabilitation is effectively an attempt to artificially overcome these factors that could potentially restrict ecosystem development. The actual rehabilitation operations are often dominated by engineering or financial considerations, but their underlying logic must remain ecological (Bradshaw 1994). A comparison between 14-year old rehabilitation at a mine site in Idaho and an undisturbed analogue site situated nearby, confirmed low similarity with respect to species richness (Chambers, Brown and Williams 1994). Such differences are typical for other sites in western U.S.A. (Australian Minerals Industry Research Association 1996). The current project found that reference to a single analogue site was inadequate for use in rehabilitation planning and evaluation of rehabilitation success, owing to heterogeneity in the natural environment and significant alteration of the post-mining environment. Instead there should be detailed assessment of multiple analogue sites within the area of disturbance and across the surrounding landscape.

The assessment of 19 rehabilitation trials over periods up to 11 years after seeding was important in understanding patterns in revegetation development, with respect to plant biodiversity parameters. Trends were usually apparent within five years of direct seeding, depending on the timing of effective rainfall in relation to sowing. During the first and second growing seasons high plant density and the prominence of annual life forms in the revegetation was characteristic. During the following three years plant density decreased and stabilised under increasing competition, revegetation cover increased, stabilised, and perennial species replaced annuals as the dominant life form.

For rehabilitation sites supporting chenopod shrubland complexes, the point at which plant density and revegetation cover parameters stabilised was comparable, within a range, to analogue communities of similar structure and composition. For rehabilitation sites supporting upperstorey vegetation strata, time series trends for plant biodiversity parameter were evident, however periods of sampling up to 11 years was not long enough for parameters to be directly comparable with analogue sites of similar composition and structure.

The assessment of 15 analogue vegetation communities of varying composition and structure provided a range of values with which to compare revegetation at rehabilitation sites. For mine sites in arid and semi-arid Western Australia, however, the application of specific numeric targets for these parameters as a measure of rehabilitation success, is not recommended. A number of state factors and interactive controls together determine any rehabilitation outcome. These factors are site and time specific; minor changes in any number of variables can lead to significantly different rehabilitation outcomes, making them impossible to accurately predict. A similar finding was made by Brown and Lugo (1994) when looking at the rehabilitation of tropical ecosystems. They recommend a more flexible approach to the rehabilitation process whereby the land manager facilitates ecosystem development through the strategic input of materials into an organised landscape, but otherwise accepts the final outcome shaped by natural ecosystem processes. This approach provides a greater reliance on design standards.

7.2 Theoretical Framework for Developing Completion Criteria

The analysis of time series data collected from nineteen rehabilitation trials emphasized the importance of planning and implementation of best practice techniques to subsequent rehabilitation success, and reinforced the difficulty associated with accurately predicting the final rehabilitation outcome. The high degree of variability between rehabilitation surfaces combined with the unpredictability of rainfall in arid and semi-arid zones of Western Australia were significant factors influencing the rehabilitation outcome.

Completion criteria have been developed as part of a robust theoretical framework (Table 7.1) incorporating the larger mine plan, and are not simply based on numbers generated as stand-alone performance standards. The broad methodology generated could be adopted by any mine site across the mining industry, however the criteria and more specifically the standards for each criterion should always remain site specific (Table 7.2).

The methodology designed for developing completion criteria has been addressed in three stages:

1. Planning,
2. Operational and Monitoring, and
3. Post-Mining Hand-Over.

Within each stage three parameters are addressed:

1. Criteria,
2. Process, and
3. Standard.

STAGE 1 Planning - prior to mining

Planning is the most important stage in the development of completion criteria, and ultimately to rehabilitation success. It is the stage in which an end land use is determined in collaboration with government and community groups. The end land use chosen should take into account the concerns of all interested parties, but above all else be based on what is realistically achievable given the constraints of the mining operation and knowledge of local ecosystem function.

Quantitative assessment of multiple analogue sites provides a broad understanding of the surrounding ecosystem/s on the rehabilitated site will ultimately depend for stability. The parameters measured as part of the monitoring program should reflect the criteria likely to be developed as part of the rehabilitation process. There should be flexibility in any performance standards developed, with review periods allowing for updating of targets based on long-term data recorded from developing rehabilitation sites.

A rehabilitation plan should be developed outlining the range of specific rehabilitation techniques to be implemented. Critical aspects of the rehabilitation plan should be incorporated as completion criteria, with specified design standards ensuring the implementation of best practice techniques and hence the most successful rehabilitation outcome possible. While many ecosystem processes and outcomes are determined largely by environmental variables such as rainfall, a number of aspects associated with the rehabilitation plan can be controlled, including waste characterisation and dumping pattern, batter angles, depth of topsoil cover, and ripping technique. A factor that was found to control ecosystem development for many years was the seed mixture composition and individual species sowing rates. Seed mixtures can be tailored to suit different environmental constraints, and are easily manipulated from one year to the next in response to field performance.

Finally, there should be a process of risk assessment implemented to determine risk management priorities, by evaluating and comparing the level of risk against pre-determined standards (Farrell 1998). A risk is the chance of something happening that will impact on the rehabilitation objectives. As defined in the completion criteria process, the simplified yet robust methodology for risk assessment includes a management phase. Risk assessment should be completed for the rehabilitation site, and separately for surrounding land use/s.

STAGE 2 Operational Monitoring - during mining and up to a minimum of five years following rehabilitation activities

Following implementation of the rehabilitation plan, the Operational Monitoring Stage focuses on rehabilitation success during the period of ecosystem development. This stage is concerned largely with rehabilitation monitoring, from which performance standards can be developed to gauge rehabilitation success for specific periods during revegetation development. The initial task in Stage 2 is to ensure all aspects of the rehabilitation plan have been implemented as specified in Stage 1, and meet agreed design standards.

Specific revegetation outcomes are difficult to predict due to the high degree of variability between rehabilitation surfaces; this is further complicated in arid and semi-arid environments by the high degree of climatic variability. It is therefore important that any performance standards generated are broad enough to encompass this variability. For the above reasons, rehabilitation success was most accurately determined by identifying trends in revegetation development for the plant biodiversity parameters monitored, rather than by setting specific numeric targets.

Annual rehabilitation assessment should occur at regular intervals during the early stages of ecosystem development (1-5 years). Permanent monitoring points should be randomly established at the time of seeding, to reduce sampling bias. Specific trends for plant biodiversity parameters (plant density, % ground cover, and species richness) should become evident within five years following direct seeding. A longer period of sampling may be required to confirm patterns of sustainability and resilience in the form of viable seed banks, and the ability of the ecosystem to recover following disturbances such as drought.

STAGE 3 Post Mining Hand Over - at the conclusion of mining, with a minimum of five years since rehabilitation commenced

The final stage of the completion criteria process is to ensure the rehabilitated site is safe, and able to successfully revert to the end land use. It is important the post-mining land user is familiarised with specific management practices required to ensure the rehabilitation remains sustainable.

TABLE 7.1: The processes involved with establishing staged completion criteria for arid and semi-arid minesites, and associated standards.

CRITERIA	PROCESS	STANDARD
1. PLANNING		
1.1 Baseline studies of the existing environment.	Implement appropriate baseline studies as required to provide knowledge of the existing ecosystem/s, and determine conservation values and the potential impact of mining: - terrestrial flora and fauna - aquatic flora and fauna - surface hydrology - groundwater hydrology - anthropology / archaeology	All specified baseline studies completed to a level required by the relevant regulatory authorities.
1.2 End land use.	Based on what is realistically achievable given the constraints of the mining operation, and knowledge of local ecosystem function. Made in collaboration with all interested groups (previous land user, government, indigenous people, wider public) with a regional perspective. Determine what infrastructure, if any, the mining operation can contribute over the duration of operations to benefit the end land use.	Agreed end land use defined prior to mining.
1.3 Rehabilitated landform, natural landscape, and existing roads / tracks.	The shape and nature of the post-mining landform should compliment the surrounding landscape, and at the same time be compatible with the end land use. Existing access roads/tracks should remain open or safe alternatives be established.	Approved by the relevant government body.

CRITERIA	PROCESS	STANDARD
1.4 Rehabilitation plan.	Quantitative assessment of distinct analogue communities around the project area. Formulation of a rehabilitation plan tailored to the achievement of a defined vegetation composition and structure.	Quantitative data from a range of local analogue sites recorded. A detailed rehabilitation plan developed and passed by the relevant regulatory body.
1.5 Risk assessment a) From the mine site	1 Analyse potential failures at the site 2 Assess the release scenarios (to the environment) 3 Evaluate potential environmental impacts of 2 4 Evaluate the risks (presented as a 'risk register') 5 Provide management options for the risks	Risk assessment process completed and passed by the relevant regulatory body.
b) From surrounding land use/s.	As above.	As above.
2. OPERATIONAL MONITORING		
2.1 Rehabilitation plan implemented.	Ground assessment to ensure all aspects of the rehabilitation plan have been implemented to best practice standards, agreed prior to the commencement of mining.	All areas of the rehabilitation plan meet the criteria established for best practice.
2.2 Revegetation development	Annual assessment of plant biodiversity parameters in the rehabilitation.	The identification of time series trends in revegetation development. 1 - 2 years following seeding: High plant density during the first two growing seasons, with annuals and short-lived perennial life forms prominent. Low revegetation cover during the first year, increasing during the second growing season.

CRITERIA	PROCESS	STANDARD
2.2 Revegetation development (cont'd)		3 - 5 years following seeding: Plant density decreases under increasing competition, stabilising within a range. Revegetation cover stabilises within a range, in line with plant density.
2.3 Resilience	Monitor rehabilitation following a disturbance.	Ecosystem disturbance caused by disturbance results in decreased plant density and revegetation cover, and a change to species dominance. During ecosystem recovery plant biodiversity parameters follow similar trends in revegetation development to those identified during the first five years following direct seeding. Recovery is characterised by an initial increase in plant density, which decreases and plateau's in line with increasing revegetation cover.
	Seed quality and germination test progeny seed from the rehabilitation, and compare to maternal seed characteristics.	Progeny seed in the rehabilitation shows similar or higher viability and germination to that of the maternal seed direct sown.
2.4 Risk assessment	Monitoring of areas where there are perceived impacts.	No significant change in the parameters being measured over time.

CRITERIA	PROCESS	STANDARD
3 POST MINING HAND OVER		
3.1 Health and safety	Ground assessment to ensure all hazards and potential for the generation of hazards, have been removed.	All areas are deemed safe by the relevant government authority.
3.2 Revert to the end land use	The manager of the new land use is familiarised with the rehabilitated landscape, and management techniques required for it to remain sustainable over the longer term.	The rehabilitated area is capable of supporting the end land use. Rehabilitation remains functional and resilient under the end land use.

TABLE 7.2: A hypothetical example showing the application of staged completion criteria.

CRITERIA	PROCESS (COMPANY ACTION)	STANDARD
1. PLANNING		
1.1 Baseline studies of the existing environment		
Terrestrial flora	Twelve broad vegetation types identified over the study area: 3 types associated with hardpan plains 2 types associated with deep sandy soils 4 types associated with depositional plains 3 types associated with salt lake margins salt pans. No DRF, but one Priority 3 Flora identified from the study area.	Long term monitoring of selected control plots established during the baseline survey. Priority 3 Flora will only be removed from one of the five populations mapped over the study area. There will be long term monitoring of vegetation health within the remaining four populations, to ensure they are not indirectly impacted by mining activities.
Terrestrial fauna	A total of 63 spp. of vertebrate fauna, including 10 mammal spp., 17 spp. of reptiles, and 36 bird spp. One Schedule 1 species from the study area has conservation significance.	Liaise with CALM (Land Management Nature Conservation Division) to develop a management strategy to address the presence of, and potential impacts on, the Schedule 1 fauna species.
Aquatic flora and fauna	Sampling of aquatic flora and fauna, and associated water quality, has occurred at wetland sites over the study area. The diatom flora was identified as a potential bioindicator of the undisturbed nature of the lake system.	Biomonitoring of important aquatic biota within the wetland will occur annually during June, and following summer cyclonic events which produce greater than 50 mm of rainfall. There will be no significant change to the aquatic biota in the wetland system.
Surface hydrology	Surface water flow over the study area occurs from north to south emptying into a large ephemeral salt lake (Lake Friday) 5 km from the current exploration site.	There will be no uncontrolled surface water run-off or erosion from the mine site.

	CRITERIA	PROCESS (COMPANY ACTION)	STANDARD
	Groundwater hydrology	The natural groundwater gradient is from north of the study area towards Lake Friday in the south.	There will be no unexpected change to vegetation health, groundwater levels, or groundwater quality, including the area around the tailings storage facility and production bores.
	Anthropology / archaeology	No recorded sites of significance	There will be no disturbance of sites with archaeological or anthropological significance, and immediate reporting of any sites unearthed during mining.
1.2	Determine the end land use	As determined through stakeholder consultation, the mined area will revert back to the current land use following rehabilitation, which is pastoral.	The end land use is pastoral.
1.3	Rehabilitated landform, natural landscape; and existing roads / tracks.	A series of low rocky hills are orientated in an east-west direction in the northern section of the study area, with a series of low aeolian sand dunes (2 m in height) fringing Lake Friday to the south. The exploration site occurs over a large depositional plain, with surface water movement occurring from north to south. There are no existing tracks through the study area.	The final rehabilitated landform will not exceed 30 m in height, with all slopes battered to less than 15 degrees. The main road established into the mine site will be the only road/track not rehabilitated at the conclusion of mining.

	CRITERIA	PROCESS (COMPANY ACTION)	STANDARD
1.4	Development of a rehabilitation plan.		
	Seed collection prior to clearing.	All seed collections will be from local provenance sources using experienced contractors. Seed collection will coincide with the various seed-fall periods of local species. Seed will be germination and quality tested, and appropriate germination pre-treatments determined.	Seed will be collected from a total of 35 species recorded within the study area.
	Removal and storage of habitat logs.	The return of habitat logs will aim to speed up the return of ground dwelling fauna to the post-mining environment.	All potential habitat logs identified in the upperstorey of the pre-mining vegetation cover, will be stockpiled and returned to the post-mining landscape.
	Topsoil stripping and storage.	Topsoil is an important rehabilitation resource comprising many beneficial physical, chemical and biological properties. Topsoil handling and storage will aim to maximise these properties in the final rehabilitation landscape.	The surface 100 mm of topsoil will be stripped using scrapers, and stockpiled in paddock mounds less than 1 m in height.
	Overburden removal and storage.	Sufficient quantities of overburden will be removed prior to mining to ensure the desired rehabilitation landforms can be restored.	
	Recontouring of the landscape using overburden, subsoil and topsoil.	Waste rock has been characterised prior to mining to ensure less desirable materials (high salinity) are dumped below the plant rooting zone. Topsoil will be spread to less than 0.3 m depth over the recontoured surface.	Topsoil to be spread over a minimum of 80% of the final rehabilitation surface area.
	Nursery propagation and planting.	Seed, cuttings and rootstock material removed prior to mining will be used in the propagation of potted seedlings.	A total of 6 species will be utilised as nursery raised seedlings or cuttings, and planted into the post-mining landscape.

	CRITERIA	PROCESS (COMPANY ACTION)	STANDARD
1.5	Risk Assessment a) From the mine site		
	Vegetation clearing.	Temporary loss of vegetation resulting from clearing.	
	Loss of fauna habitat due to clearing.	Temporary loss of habitat area, with low numbers of animal deaths expected during clearing.	A maximum area of 300 ha will be cleared.
	Aquatic biota affected by changes to surface water quality.	No impact is expected to wetlands.	There will be no significant change over time in water quality or composition of aquatic flora and fauna in the ephemeral salt lake.
	Increased surface water flow from the rehabilitation.	Increased surface water flow from the rehabilitation has the potential to impact aquatic and terrestrial ecosystems downstream.	There will be no uncontrolled surface run-off from the rehabilitation.
	Interference to the natural groundwater gradient, and groundwater quality.	Mining operations are not expected to impact on groundwater condition or water quality.	There will be no unexpected change to vegetation health, groundwater levels, or groundwater quality at monitoring sites.
1.5	b) From surrounding landuse/s		
	Dieback	Approximately 10% of the study area was found to be dieback infected.	Dieback Hygiene Program implemented.
	Exotic weeds	Few exotic weeds are currently established within the vegetation communities identified.	Weed species will occur at lower density than was recorded from pre-mining vegetation community types.
	Wildfire	Currently managed by CALM.	Fire protection plan agreed with CALM
	Pastoral	Ensure all stock watering points close to the rehabilitation are shut down, and stock are relocated prior to the commencement of rehabilitation.	No overgrazing of the rehabilitation.

CRITERIA	PROCESS (COMPANY ACTION)	STANDARD
2 OPERATIONAL MONITORING		
2.1 Rehabilitation plan implemented	Ground assessment to ensure all aspects of the rehabilitation plan are implemented to best practice standards.	Best practice rehabilitation techniques will be implemented as defined in the rehabilitation plan.
	Establishment of vegetation monitoring transects over the rehabilitation.	Permanent vegetation monitoring transects will be established within 3 months following the conclusion of rehabilitation activities.
2.2 Revegetation development	Frequent visual qualitative checks of vegetation establishment and surface stability during the first year following rehabilitation.	Seed germination and seedling establishment will be evident during the first growing season. There will be no uncontrolled surface water run off from the rehabilitation.
	Quantitative assessment of rehabilitation following the first growing season, and at 12 month intervals from there on.	Revegetation assessment will occur during the first September following the conclusion of rehabilitation activities, and at 12 month intervals there-after.
		Expected trends in plant density and revegetation cover will be evident within 5 years.
		Revegetation will comprise at least 80 percent of the number of native species recorded at analogue sites of similar vegetation structure and composition.

CRITERIA	COMPANY ACTION	STANDARD
2.3 Resilience	There will be long term monitoring of vegetation parameters from analogue sites.	The vegetation parameters being measured will remain stable over time: species richness, perennial plant density, perennial plant ground cover. There will be a recovery for vegetation parameters, to pre-disturbance levels within 2 years following drought.
	Progeny seed from rehabilitation trials will be quality and germination tested.	Seed produced by keystone revegetation species will be viable.
2.4 Risk assessment	Ensure continued sampling and data analysis from all monitoring programs implemented prior to mining, to determine potential impacts from mining outlined at Stage 1.5.	There will be no significant change in the parameters being monitored over time. If changes do become evident, an appropriate management plan will be developed and implemented.

CRITERIA	COMPANY ACTION	STANDARD
3 POST MINING HAND-OVER		
3.1 Health and safety	Analysis of long term quantitative data sets, and qualitative ground assessment to ensure all hazards, and potential for the generation of hazards, has been removed.	All areas deemed safe by the relevant government authorities.
3.2 Revert to the end land use	The manager of the new land use is familiarised with the rehabilitated landscape, and management techniques required for it to remain sustainable over the longer term.	The rehabilitation area is capable of supporting the end land use. Rehabilitation remains functional and resilient under the end land use.

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APPENDICES

DEVELOPING COMPLETION CRITERIA FOR REHABILITATION AREAS ON ARID AND SEMI-ARID MINE SITES IN WESTERN AUSTRALIA

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Presented as part of the requirements for the award of the Degree of Doctor of Philosophy of the Curtin University of Technology

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APPENDIX 1: Rainfall summaries for Laverton (Northeastern Goldfields), Kalgoorlie (Eastern Goldfields), and Westonia (Northeastern Wheatbelt).

Laverton (Figure A1.1)

Annual rainfall for 1992 totalled 338mm, with significant falls recorded for the months of February, March, April, August and October.

Rainfall during 1993 totalled 251mm with the highest proportion recorded during the winter months of May to September.

December was the only month of 1994 in which rainfall exceeded the long term monthly average. In the first 11 months of 1994 rainfall totalled just 66mm, and was considered a drought by local pastoralists.

Consistent summer rains were recorded during early 1995, with Tropical Cyclone Bobby increasing the February rainfall total to 197mm. Above average rainfall was recorded for April and July, lifting the annual total to 354mm.

In 1996 rainfall was more consistent, with all months between March and July (with the exception of May) receiving more than 50mm, and 33mm falling during February. Rainfall was spread between late summer, autumn and winter. Annual rainfall for 1996 totalled 350mm.

Rainfall totalled 272mm during 1997. Significant falls were concentrated during the first quarter of the year, however less prominent rainfall occurred during every month and reflected long term averages.

In 1998 annual rainfall was the lowest since 1994, averaging 197mm. Falls were concentrated during four winter months (April-July), when 88 percent of the total rainfall was received.

Although vegetation was not assessed later than September '98, annual rainfall recorded for 1999 and 2000 totalled 222mm and 526mm respectively. Cyclonic rainfall during January and March 2000 was responsible for the above average annual total.

FIGURE A1.1: **Monthly rainfall (mm) recorded for Laverton between 1992 and 2000, with long term averages (from WA Bureau of Meteorology).**

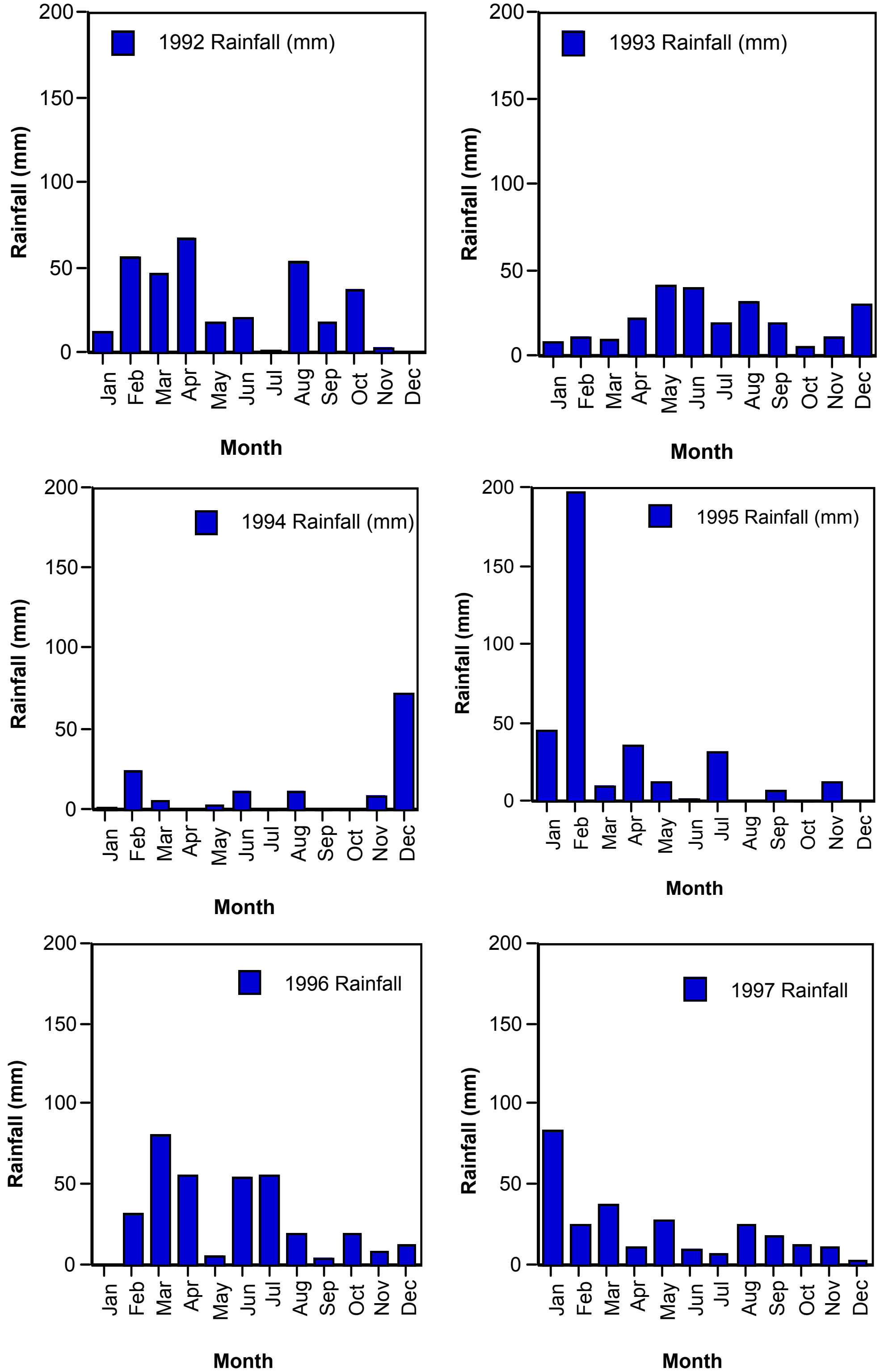
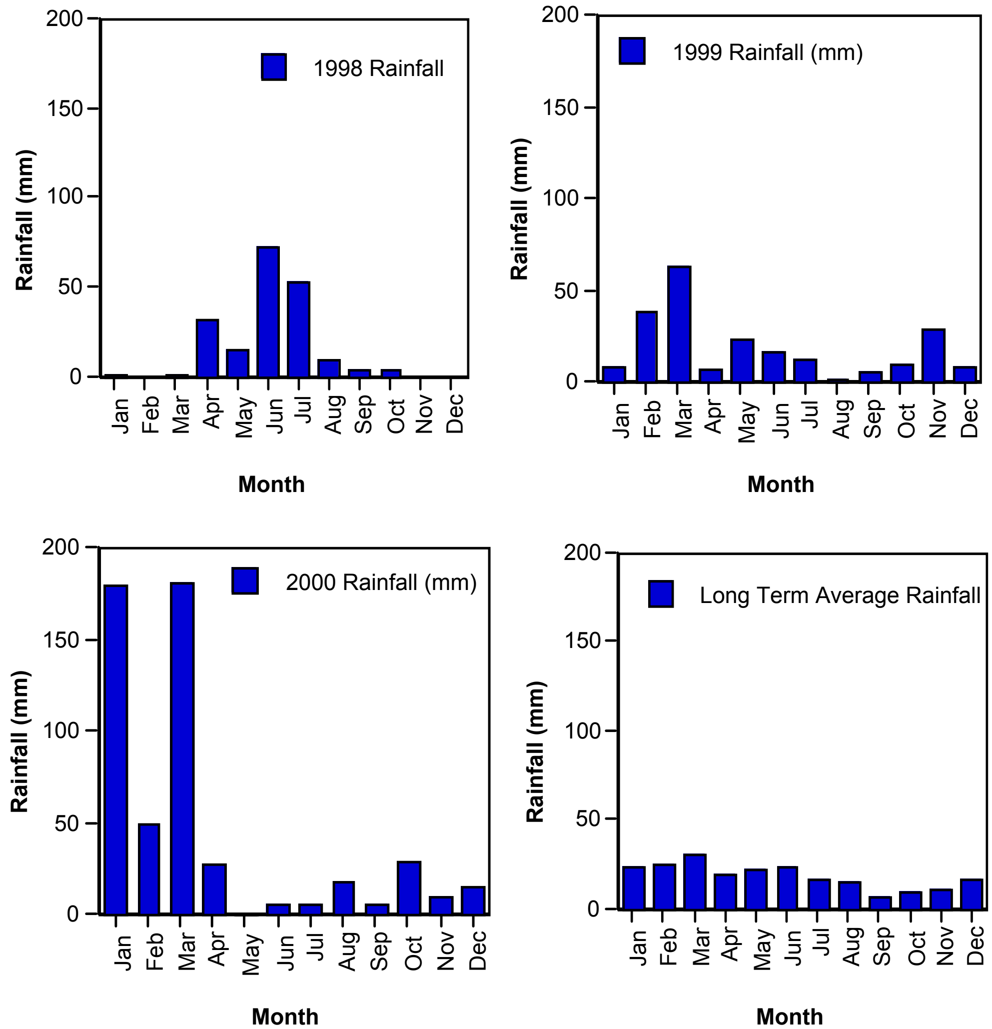


FIGURE A1.1: **cont'd Monthly rainfall (mm) recorded for Laverton between 1992 and 2000, with long term averages (from WA Bureau of Meteorology).**



Kalgoorlie (Figure A1.2)

The long term rainfall average for Kalgoorlie is 265mm. Mean monthly rainfall gives the impression of a relatively even rainfall distribution throughout the year, however long term median data confirms higher more consistent falls during the winter months of April to August. Mean rainfall values for summer months are elevated in response to infrequent but high intensity tropical cyclonic activity.

In 1995 rainfall from Cyclone Bobby contributed to a February total of 197mm, almost 7 times the long term monthly average. Significant follow up rains occurred during April (68mm), June (36mm) and July (49mm). Annual rainfall totalled 480mm.

Annual rainfall for 1996 (235mm) was below the long term average. Less than 5mm fell during the months of January, February, May and October, with average rainfall recorded during the remaining months.

Monthly rainfall totals for six months of 1997 ranged between 21mm and 42mm (February-May, August, November). June (7mm) and July (17mm) were uncharacteristically dry months which contributed to the below average annual total of 241mm.

Consistent falls between April and September (monthly totals 22-60mm), and a summer rainfall event during December (58mm), contributed to an above average annual total for 1998 (314mm).

Summer cyclonic rainfall during March 1999 (197mm), and January (169mm) and March (115mm) 2000, significantly increased annual totals for both years (386mm and 446mm respectively). Monthly rainfall totals outside of the summer months were relatively low during 1999 and 2000.

Below average rainfall occurred during 2001 (226mm), with February (93mm) alone accounting for 41 percent of the annual total.

FIGURE A1.2: Monthly rainfall (mm) recorded for Kalgoorlie between 1995 and 1998, with long term averages (from WA Bureau of Meteorology).

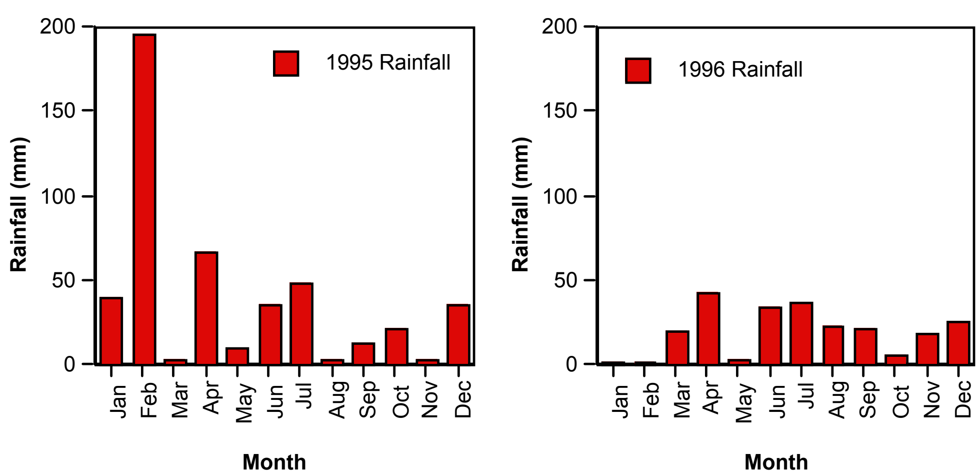
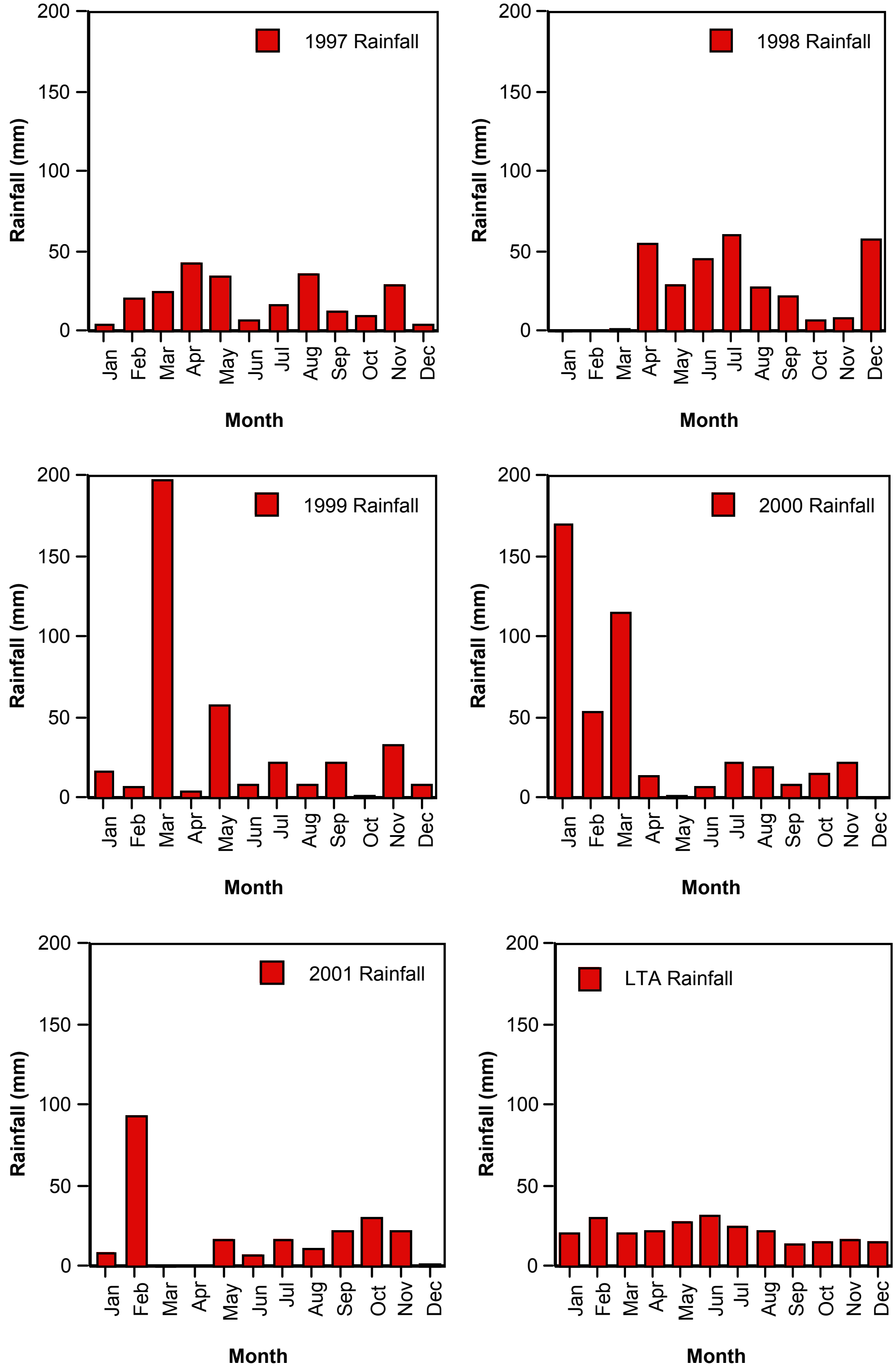


FIGURE A1.2: **cont'd Monthly rainfall (mm) recorded for Kalgoorlie between 1995 and 1998, with long term averages (from WA Bureau of Meteorology).**



Westonia (Figure A1.3)

Long term rainfall for Westonia averages 309mm, with mean monthly totals peaking during June and progressively decreasing either side of this month (forming a bell-shaped curve). Between 1990 and 1998 monthly rainfall did not exceed 100mm. High intensity cyclonic rainfall experienced during summer months in the Eastern Goldfields and Northeastern Goldfields regions did not impact on the Westonia region to the same degree. The climate of the Westonia District supports broadacre wheat/sheep farming.

In 1990 annual rainfall totalled 329mm. Higher than expected falls occurred during January, March and April, with the highest monthly total recorded in July.

Rainfall distribution during 1991 was similar to the long-term average, however no rain fell in February or March. The annual total was 268mm.

Two very wet months, June (74mm) and August (94mm), were recorded in 1992. As with 1991, no rain fell during two months of the first quarter, however the annual total (318mm) remained above average.

Rainfall during 1993 was concentrated between May and August (236mm in 4 months), however a significant monthly total was also recorded for November (52mm). Summer rainfall was very low, with 7mm recorded in the 4 months between December and March.

Annual rainfall for 1994 (193mm) was well below the long term average, however monthly totals greater than 25mm did occur between May to August (149mm).

The rainfall pattern during 1995 was atypical with high monthly totals during February, March and December, average falls during May and June, and above average falls in July. Annual rainfall was well above average (406mm).

The 1996 and 1998 rainfall patterns followed similar trends to those recorded over the long term, however monthly totals during summer months (December-March) were lower than expected. Annual rainfall totalled 321mm in 1996, and 313mm in 1998. In 1997 high average monthly rainfall occurred between February and September, ranging from 21-57mm. The annual rainfall total was 337mm.

FIGURE A1.3: **Monthly rainfall (mm) recorded for Merredin between 1990 and 1998, with long-term averages (from WA Bureau of Meteorology for Merredin).**

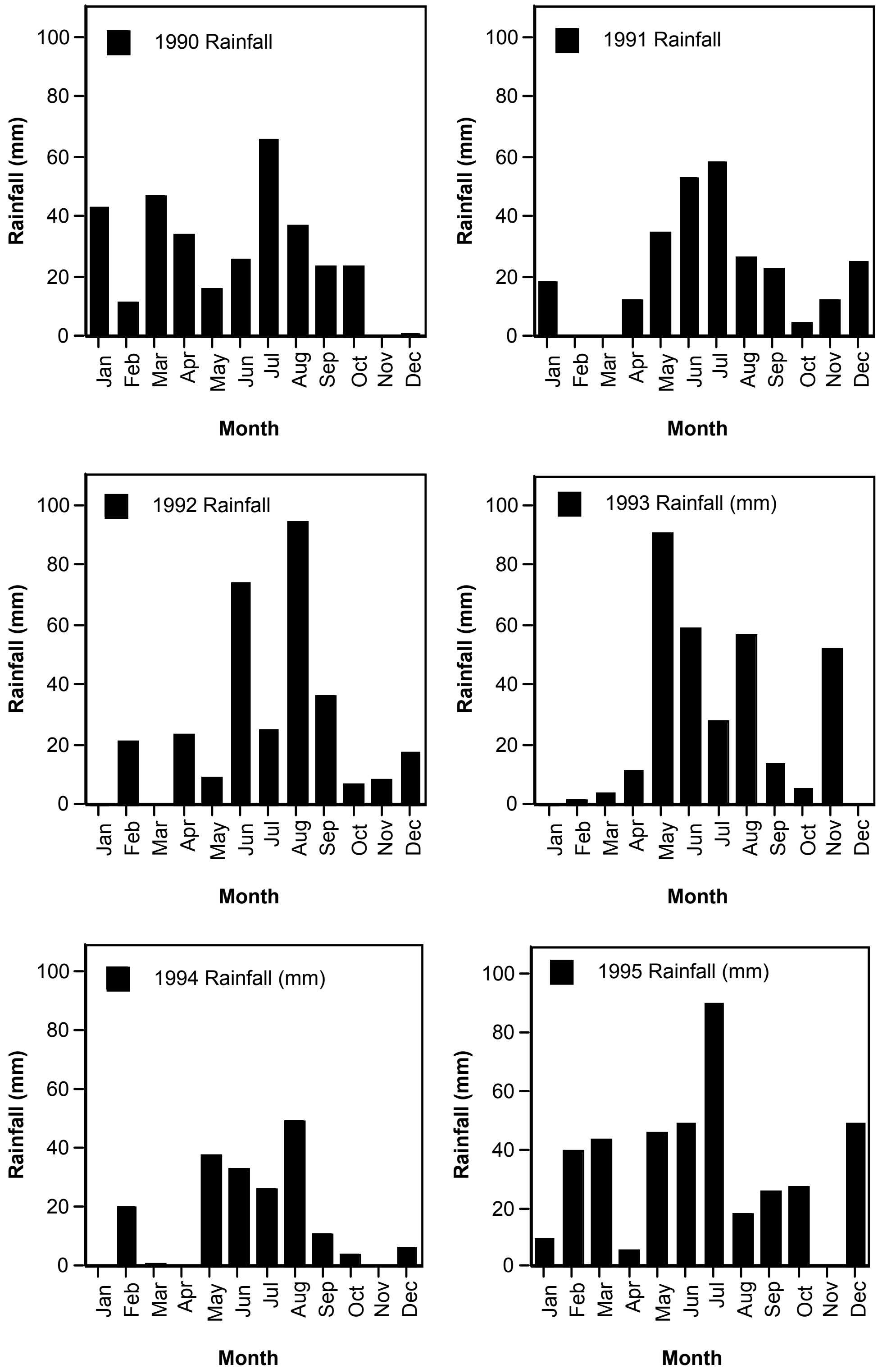
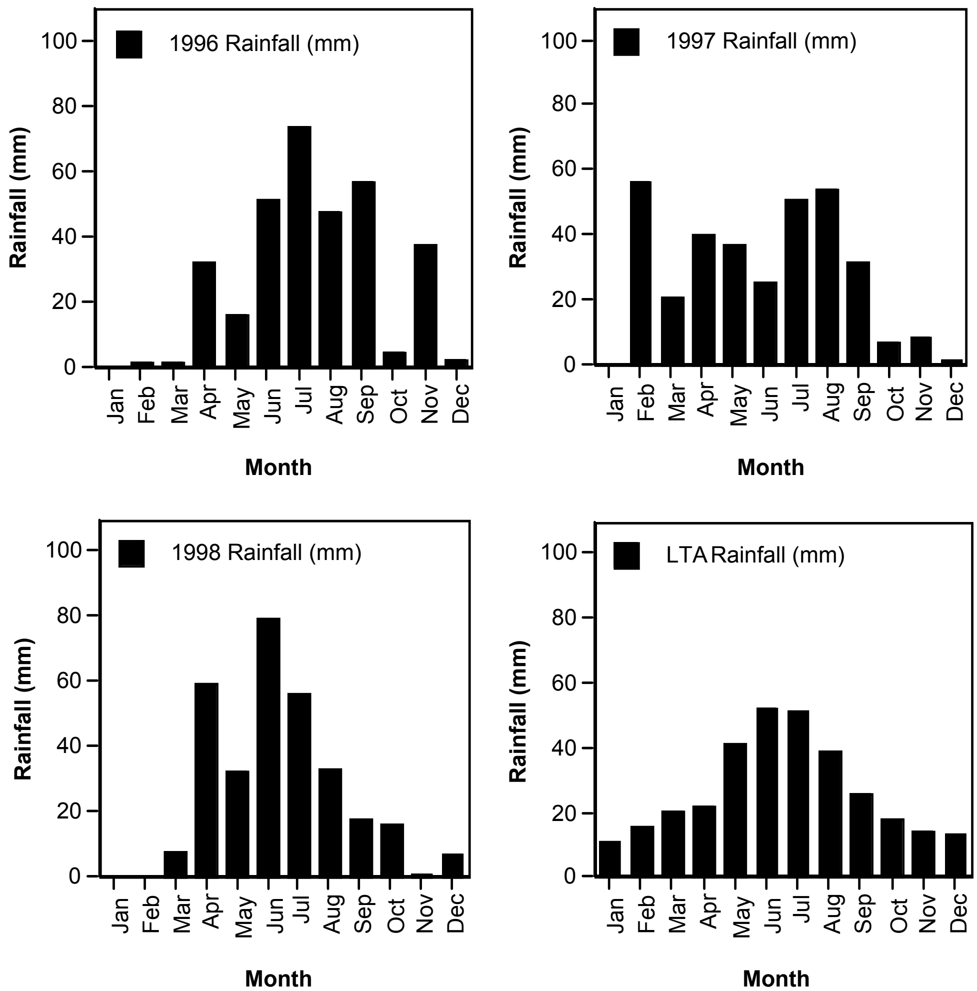


FIGURE A1.3: **cont'd Monthly rainfall (mm) recorded for Merredin between 1990 and 1998, with long term averages (from WA Bureau of Meteorology for Merredin).**



APPENDIX 2.0: Species sown over rehabilitation trials in the Northeastern Goldfields between 1992 and 1994.

1992 Seeding, 1992 Fertiliser Trial, 1992 Oxide Trial - Species direct seeded in May 1992.

FAMILY Species	**Seed Rate**	**Final Germ.%**	**FAMILY** Species	**Seed Rate**	**Final Germ.%**
AIZOACEAE			**MIMOSACEAE**		
Carpobrotus edulis	0.100	58	*Acacia hemiteles*	0.300	96
CHENOPODIACEAE			*Acacia linophylla*	0.300	74
Atriplex canescens	0.546	40	*Acacia ramulosa*	0.180	80
Atriplex codonocarpa	0.090	66	*Acacia tetragonophylla*	0.118	48
Atriplex holocarpa	0.409	50	*Acacia victoriae*	0.300	na
Atriplex lentiformis	0.454	76	*Cassia pleurocarpa*	0.300	96
Atriplex nummularia	0.500	32	*Dodonaea lobulata*	0.300	16
Atriplex semibaccata	1.000	92	**MYRTACEAE**		
Atriplex vesicaria	0.500	24	*Eucalyptus griffithsii*	0.150	100
Enchylaena tomentosa	0.036	0	*Eucalyptus leptopoda*	0.077	100
Halosarcia spp. (chaff)	0.400	0	*Eucalyptus salicola*	0.150	82
Maireana aphylla	0.500	56	*Eucalyptus salmonophloia*	0.073	86
Maireana pyramidata	0.500	48	*Eucalyptus salubris*	0.150	100
Maireana triptera	0.500	0	ground mix	0.364	na
			TOTAL	**8.297**	

1992 Circular Ripping Trial: *Acacia* spp. and chenopod seed mixture sown May 1992.

FAMILY Species	**Seed Rate**	**Final Germ.%**	**FAMILY** Species	**Seed Rate**	**Final Germ.%**
MIMOSACEAE			**CHENOPODIACEAE**		
Acacia hemiteles	0.712	96	*Atriplex canescens*	1.000	40
Acacia linophylla	0.712	74	*Atriplex holocarpa*	1.000	50
Acacia ramulosa	0.712	80	*Atriplex nummularia*	1.000	32
Acacia tetragonophylla	0.150	48	*Atriplex semibaccata*	1.000	92
Acacia victoriae	0.712	na	*Atriplex semilunaris*	0.300	na
	3.000		*Atriplex vesicaria*	1.000	24
MYRTACEAE			*Maireana aphylla*	0.700	56
Eucalyptus griffithsii	0.300		*Maireana brevifolia*	1.000	44
Eucalyptus longicornis	0.300		*Maireana pyramidata*	1.000	48
Euc. salmonophloia	0.300			**8.000**	
Eucalyptus salubris	0.300				
Eucalyptus striaticalyx	0.300				
	1.500		**TOTAL**	**12.500**	

1993 Oxide Trial: Species sown at 14 kg ha^{-1} (low) and 20 kg ha^{-1} (high) rates in late April 1993.

Species	**Seed Rate**	**Final Germ.%**	**Species**	**Seed Rate**	**Final Germ.%**
Low rate – 14 kg ha^{-1}			High rate – 20 kg ha^{-1}		
Atriplex codonocarpa	1.56	66	*Atriplex codonocarpa*	2.34	66
Atriplex holocarpa	1.30	50	*Atriplex holocarpa*	1.94	50
Atriplex nummularia	1.30	24	*Atriplex nummularia*	1.94	32
Maireana georgei	2.08	2 & 4	*Maireana georgei*	2.60	2 & 4
Maireana triptera	0.91	8 & 0	*Maireana triptera*	1.13	8 & 0
Maireana pyramidata	2.60	0	*Maireana pyramidata*	3.90	0
local salt/bluebush	3.90	na	local salt/bluebush	5.84	na
local mixes acacias	0.37	na	local mixes acacias	0.47	na
TOTAL	**14.00**		**TOTAL**	**20.00**	

1993 Batter Seeding - Species seeded in late April 1993.

FAMILY Species	**Seed Rate**	**Final Germ.%**	**FAMILY** Species	**Seed Rate**	**Final Germ.%**
CHENOPODIACEAE			**SOLANACEAE**		
Atriplex acutibractea	0.184	2	*Solanum lasiophyllum*	0.06	na
Atriplex bunburyana	0.624	82		**0.06**	
Atriplex codonocarpa	0.624	66	**MIMOSACEAE**		
Atriplex holocarpa	0.312	58	*Acacia aneura*	0.55	82
Atriplex nummularia	0.936	24	*Acacia craspedocarpa*	0.55	58
Atriplex vesicaria	1.248	34	*Acacia linophylla*	0.55	14
Chenopodium spp.	0.160	na	*Acacia murrayana*	0.55	na
Maireana appressa	0.120	0	*Acacia pruinocarpa*	0.55	100
Maireana carnosa	0.936	22	*Acacia quadrimarginea*	0.55	82
Maireana georgei	0.624	2	*Acacia tetragonophylla*	0.55	10
Maireana pyramidata	1.000	0		**3.85**	
Maireana triptera	1.000	8	**MYOPORACEAE**		
extra salt/blue bush	4.200	na	*Eremophila duttonii*	0.90	0
bluebush mix	3.120	na	*Eremophila freelingii*	2.00	0
	15.088		*Eremophila gilesii*	0.80	0
CAESALPINIACEAE			*Eremophila longifolia*	2.00	0
Senna artemisioides	0.187	42	*Eremophila maculata*	2.00	4
Senna helmsii	0.312	48		**7.70**	
Senna filifolia	0.250	44			
	0.749				

1994 Batters (Top and Bottom) and Upper Surfaces of Granny Waste Dump, and Childe Harold Waste Dump - Direct sown in February '94.

FAMILY Species	**Seed Rate**	**Final Germ.%**	**FAMILY** Species	**Seed Rate**	**Final Germ.%**
CHENOPODIACEAE			**MIMOSACEAE**		
Atriplex bunburyana	0.269	92	*Acacia aneura*	0.129	88
Atriplex codonocarpa	0.697	74	*Acacia craspedocarpa*	0.129	88
Atriplex holocarpa	0.548	57	*Acacia linophylla*	0.129	85
Atriplex nummularia	3.538	74	*Acacia murrayana*	0.025	67
Atriplex semibaccata	0.118	54	*Acacia pruinocarpa*	0.011	61
Atriplex semilunaris	0.097	43	*Acacia quadrimarginea*	0.129	91
Atriplex vesicaria	0.118	96	*Acacia ramulosa*	0.129	91
	5.385		*Acacia tetragonophylla*	0.129	48
Maireana brevifolia	0.452	6	*Acacia victoriae*	0.043	18
Maireana carnosa	0.086	5		**0.853**	
Maireana pyramidata	0.280	98	**MYRTACEAE**		
	0.818		*Eucalyptus brockwayi*	0.016	100
CAESALPINIACEAE			*Eucalyptus griffithsii*	0.016	100
Senna artemisioides	0.081	89		**0.032**	
Senna filifolia	0.118	89	**POACEAE**		
Senna helmsii	0.150	100	*Stipa nitida*	0.484	na
	0.349			**0.484**	

Additional species sown at Placer (Granny Smith) in February '94. These were locally collected or remaining from previous years sowing.

FAMILY Species	**Seed Rate**	**Final Germ.%**	**FAMILY** Species	**Seed Rate**	**Final Germ.%**
CHENOPODIACEAE			**MIMOSACEAE**		
Atriplex acutibractea	0.011	8	*Acacia burkittii*	0.002	92
Atriplex bunburyana	0.011	92	*Acacia linophylla*	0.011	48
Atriplex holocarpa	0.003	41	*Acacia murrayana*	0.002	na
Atriplex nummularia	0.043	32		**0.015**	
Atriplex vesicaria	1.398	64	**AMARANTHACEAE**		
Maireana carnosa	0.001	10	*Ptilotus exaltatus*	0.022	na
Maireana georgei	0.022	19	*Ptilotus obovatus*	0.075	4
Maireana pyramidata	0.003	0	*Ptilotus polystachyus*	0.075	0
	1.492			**0.172**	
additional seed	**0.570**		**CAESALPINIACEAE**		
			Senna artemisioides	0.054	52
			Senna filifolia	0.054	21
				0.108	

1997 and 1998 Rehabilitation Trial Areas at Sunrise Dam Gold Mine: Individual seeding rates (kg ha^{-1}) for plant species sown during May '97 and May '98.

FAMILY Species	**1997** **kg ha^{-1}**	**1998** **kg ha^{-1}**
AMARANTHACEAE		
Ptilotus obovatus		0.250
CHENOPODIACEAE		
Atriplex amnicola	0.850	
Atriplex bunburyana		0.080
Atriplex codonocarpa	1.250	1.000
Atriplex holocarpa	1.250	
Atriplex nummularia	1.250	1.000
Atriplex semibaccata	1.725	0.100
Atriplex semilunaris		0.250
Atriplex vesicaria	1.250	1.300
Enchylaena tomentosa		0.100
Halosarcia sp. nov aff *undulata*		1.200
Maireana appressa	0.700	
Maireana brevifolia	0.100	
Maireana georgei	1.000	1.000
Maireana pentatropis	1.300	
Maireana pyramidata	1.500	0.450
Maireana tomentosa	0.600	
Maireana triptera	1.500	1.250
FRANKENIACEAE		
Frankenia sp.		0.150
MALVACEAE		
Lawrencia squamata		0.100
Lawrencia sp.		0.100
MIMOSACEAE		
Acacia tysonii		0.500
POACEAE		
Eragrostis dielsii		0.100
SOLANACEAE		
Solanum lasiophyllum		0.250
ZYGOPHYLLACEAE		
Zygophyllum spp.	0.500	
TOTAL	**14.775**	**9.180**

APPENDIX 3.0: **Seed quality and germination results for species sown over rehabilitation trials at Northeastern Goldfields sites between 1992 and 1998.**

Species sown during 1992: final germination %, days to first germinant, days to 50% germination, days to final germination, and no. seed g^{-1}.

FAMILY Species	**Final %**	**Days - First**	**Days - 50 %**	**Days- Final**	**no. seed g^{-1}**
AIZOACEAE					
Carpobrotus edulis	58	4	25.8	33	na
CAESALPINIACEAE					na
Senna pleurocarpa	96	2	3.0	12	na
CHENOPODIACEAE					
Atriplex canescens	40	2		28	394
Atriplex codonocarpa	66	1	5.0	12	na
Atriplex holocarpa	50	2	19.0	19	37
Atriplex lentiformis	76	5	9.1	26	na
Atriplex nummularia	32	5		28	154
Atriplex semibaccata	92	1	2.5	9	188
Atriplex semilunaris	30	3		14	na
Atriplex vesicaria	24	2		12	54
Maireana aphylla	56	2	9.5	12	220
Maireana brevifolia	44	2		14	812
Maireana pyramidata	48	1		9	133
MIMOSACEAE					
Acacia hemiteles	96	1	3.8	9	27
Acacia linophylla	74	1	3.8	11	18
Acacia ramulosa	80	1	3.7	12	na
Acacia tetragonophylla	48	2		12	39
MYRTACEAE					
Eucalyptus griffithsii	100	1	2.9	11	955
Eucalyptus leptopoda	100	2	6.1	12	na
Eucalyptus longicornis	100	3	5.8	12	na
Eucalyptus salicola	82	4	6.8	14	na
Eucalyptus salmonophloia	86	3	5.5	9	5,357
Eucalyptus salubris	100	2	4.4	12	2,609
Eucalyptus striaticalyx	94	3	4.8	12	1,282
PAPILIONACEAE					
Medicago minima	76	2	3.4	9	na
POACEAE					
Hordeum leporinum	14	3		9	na
SAPINDACEAE					
Dodonaea lobulata	16	3		19	na

Species sown during 1993: final germination %, days to first germinant, days to 50% germination, days to final germination, no. seed g^{-1}, and % sound seed.

FAMILY Species	**Temp. tested ˚C**	**Final %**	**Days - First**	**Days - 50 %**	**Days- Final**	**no. seed g^{-1}**	**% sound seed**
CAESALPINIACEAE							
Senna artemisioides	25	8	4	4	36	69.1	98
Senna artemisioides	25	42	4	6	18	70.6	94
Senna helmsii	20	48	4	8	39	41.6	96
Senna helmsii	25	38	4	8	36		
Senna filifolia	20	44	4	4	40	60.6	88
Senna filifolia	20	12	4	4	20	45.6	90
CHENOPODIACEAE							
Atriplex acutibractea	15	2	8	8	8	524.1	88
Atriplex acutibractea	20	2	4	4	4		
Atriplex bunburyana	20	82	4	4	4	377.4	96
Atriplex codonocarpa	20	66	4	4	27	74.2	96
Atriplex holocarpa	15	50	4	6	32	39.7	90
Atriplex holocarpa	20	58	4	11	36		
Atriplex nummularia	15	24	6	8	18	155.0	92
Atriplex vesicaria	15	34	6	15	34	66.4	100
Maireana appressa	15	0				177.4	96
Maireana appressa	20	0					
Maireana appressa	25	0					
Maireana carnosa	15	22	5	7	12	211.8	92
Maireana carnosa	20	22	5	10	19		
Maireana carnosa	25	18	5	10	17		
Maireana georgei	15	2	7	7	7	59.9	100
Maireana georgei	15	4	7	7	10	40.9	92
Maireana pyramidata	25	0				200.1	100
Maireana triptera	25	8	5	5	12	86.7	100
Maireana triptera	25	0				88.8	100

cont'd Species sown during 1993: final germination %, days to first germinant, days to 50% germination, days to final germination, no. seed g^{-1}, and % sound seed.

FAMILY Species	**Temp. ˚C**	**Final %**	**Days - First**	**Days - 50 %**	**Days- Final**	**# seed g^{-1}**	**% sound**
MIMOSACEAE							
Acacia aneura	25	82	4	4	8	121.1	100
Acacia craspedocarpa	25	58	4	6	36	10.9	98
Acacia linophylla						7.9	96
1. No pre-treatment	20	14	6	8	25		
2. Hot water	20	22	6	11	40		
Acacia murrayana (i)	20	78	4	4	27	25.9	96
Acacia murrayana (ii)	20	84	4	4	15	26.0	100
Acacia pruinocarpa	25	100	4	6	18	64.0	100
Acacia quadrimarginea	25	82	4	13	39	8.8	100
Acacia tetragonophylla	20	10	8	15	32	48.6	92
MYOPORACEAE							
Eremophila duttonii							
1. Un-scarified	15	-	-	-	-	12.2	100
	20	-	-	-	-		
2. Scarified	15	-	-	-	-	16.7	100
	20	-	-	-	-		
Eremophila freelingii							
1. Un-scarified	15	-	-	-	-	3.6	100
	20	-	-	-	-		
2. Scarified	15	-	-	-	-	5.1	100
	20	-	-	-	-		
Eremophila gilesii							
1. Un-scarified	15	-	-	-	-	6.8	98
	20	-	-	-	-		
2. Scarified	15	-	-	-	-	6.6	100
	20	-	-	-	-		
Eremophila longifolia							
1. Un-scarified	15	-	-	-	-	6.6	100
	20	-	-	-	-		
1. Scarified	15	-	-	-	-	6.2	100
	20	-	-	-	-		
Eremophila maculata							
1. Un-scarified	15	2	12	12	12	2.0	100
	20	-	-	-	-		
2. Scarified	15	4	31	31	35	3.0	98
	20	2	19	19	19		

Species sown during 1994: final germination %, days to first germinant, days to final germination and no. seed g^{-1}.

FAMILY Species	**Treatment**	**Temp. ˚C**	**Final %**	**Days - First**	**Days- Final**	**# seed g^{-1}**
AMARANTHACEAE						
Ptilotus obovatus	untreated	25	2.5	13.0	13.0	544.0
Ptilotus obovatus	untreated	25	3.8	16.5	18.5	444.7
Ptilotus polystachyus	untreated	25	0.0			447.0
CAESALPINIACEAE						
Senna artemisioides NS 11082	boiling water	25	1.1	27.0	31.0	80.0
Senna artemisioides NS 11048	scarified	25	89.0	3.0	11.8	67.7
	boiling water	25	4.5	14.0	16.0	
Senna artemisioides GS	boiling water	25	52.5	4.0	8.0	66.7
Senna filifolia NS 11035	scarified	25	88.9	3.0	8.7	62.0
	boiling water	25	53.4	5.3	26.3	
Senna filifolia GS	untreated	25	8.8	19.3	22.8	47.8
	boiling water	25	21.3	4.0	7.8	
Senna helmsii NS	scarified	25	100.0	3.0	7.2	45.4
	boiling water	25	50.0	3.8	22.0	
CHENOPODIACEAE						
Atriplex acutibractea GS	fruits	20	7.5	8.7	11.0	653.5
Atriplex bunburyana NS 9892	fruits	20	92.5	4.0	9.5	420.6
Atriplex codonocarpa NS 11274	fruits	20	74.2	1.3	6.5	66.9
	seeds	20	62.5	5.3	12.7	
Atriplex holocarpa NS 11260	fruits	20	37.5	6.3	30.3	42.7
Atriplex holocarpa NS 9538	fruits	20	15.0	9.8	21.8	104.7
	seeds	20	56.7	2.0	18.2	
Atriplex holocarpa NS 9524	fruits	20	41.3	5.0	25.0	51.7
Atriplex nummularia NS 11263	fruits	15	52.5	6.0	14.3	101.6
	seeds	15	74.2	2.5	8.3	
Atriplex nummularia NS 10921	fruits	15	55.0	7.0	23.2	223.1
	seeds	15	71.7	6.5	19.3	
Atriplex nummularia NS 9200	fruits	15	32.5	8.0	16.0	166.3
Atriplex semibaccata NS 10434	fruits	20	54.2	5.2	22.5	227.3
	seeds	20	48.3	3.3	19.7	
Atriplex semilunaris NS 11265	fruits	20	29.2	4.0	11.0	733.8
	seeds	20	43.3	2.0	8.5	
Atriplex vesicaria NS 9916	fruits	20	62.5	8.3	20.2	66.9
	seeds	20	95.8	2.8	7.8	
Atriplex vesicaria GS i	fruits	20	63.8	5.0	16.5	106.7
Atriplex vesicaria GS ii	fruits	20	43.8	7.0	13.0	54.5

cont'd Species sown during 1994: final germination %, days to first germinant, days to final germination and no. seed g^{-1}.

FAMILY Species	**Treatment**	**Temp. ˚C**	**Final %**	**Days - First**	**Days- Final**	**# seed g^{-1}**
Maireana brevifolia NS 9993	fruits	20	5.8	5.8	7.8	1137.2
	seeds	20	1.7	13.0	13.0	
Maireana carnosa NS 11275	fruits	20	0.0			193.8
	seeds	20	5.0	8.8	8.8	
Maireana carnosa NS 9888	fruits	20	10.0	9.0	10.0	157.9
Maireana georgei NS 9525	fruits	20	18.8	9.8	19.0	68.7
Maireana pyramidata NS 11258	fruits	25	95.0	5.2	9.5	103.0
	seeds	25	98.3	1.7	5.8	
MIMOSACEAE						
Acacia aneura NS 10920	scarified	25	87.5	3.0	8.0	48.0
	untreated	25	36.3	4.0	15.5	
Acacia aneura NS 11071	untreated	25	2.5	4.0	4.0	62.0
Acacia burkittii GS	boiling water	25	92.5	4.3	11.5	41.3
Acacia craspedocarpa NS10327	scarified	25	87.5	3.5	7.3	16.1
Acacia craspedocarpa NS10422	scarified	25	53.8	4.0	23.8	14.0
Acacia craspedocarpa NS11154	boiling water	25	60.0	5.5	22.5	15.0
Acacia linophylla NS 9527	untreated	25	45.0	7.0	18.8	8.3
Acacia linophylla NS 11156	untreated	25	28.8	5.3	21.0	8.7
	scarified	25	85.0	3.0	19.0	
Acacia linophylla NS GS	boiling water	25	47.5	4.0	20.8	8.4
Acacia murrayana NS 10421	untreated	20	36.7	7.8	26.8	39.3
	scarified	20	67.0	3.0	31.8	
Acacia pruinocarpa NS 10030	untreated	25	8.8	7.5	10.0	27.0
	scarified	25	61.3	3.0	12.5	
Acacia quadrimarginea NS11155	untreated	25	68.3	7.0	25.8	
	scarified	25	90.8	5.5	24.8	
Acacia ramulosa NS10167	untreated	20	75.0	10.0	24.5	9.6
	scarified	20	91.1	7.0	15.0	
Acacia tetragonophylla	untreated	25	38.8	3.0	11.3	60.0
NS 10918	scarified	25	47.5	3.0	16.0	
Acacia victoriae NS 10621	untreated	30	6.3	4.3	7.7	37.3
	scarified	30	17.5	5.0	13.0	
MYRTACEAE						
Eucalyptus brockwayi NS 8154	untreated	15	100.0	6.0	11.5	2766.7
Eucalyptus griffithsii NS 5961	untreated	15	100.0	8.0	15.7	1320.5

Seed quality and final germination percentage of species sown on the 1998 Rehabilitation Trial at Sunrise Dam Gold Mine.

FAMILY Species	**Purity**	**% Sound Seed**	**Final Germ. %**
AMARANTHACEAE			
Ptilotus obovatus	60.5	5.0	5
CHENOPODIACEAE			
Atriplex bunburyana	20.4	51.1	5
Atriplex codonocarpa	96.1	92.6	90
Atriplex nummularia	35.5	46.2	70
Atriplex semibaccata	99.0	79.3	100
Atriplex semilunaris	89.2	77.8	65
Atriplex vesicaria	69.2	62.5	65
Enchylaena tomentosa	96.0	71.9	45
Halosarcia sp. (wet)	82.0	-	-
Halosarcia sp. (dry)	83.4	-	-
Maireana georgei	82.1	83.0	100
Maireana pyramidata	54.1	92.3	100
Maireana triptera	67.5	100.0	70
FRANKENIACEAE			
Frankenia sp.	35.0	-	-
MALVACEAE			
Lawrencia squamata	73.1	34.9	5
Lawrencia sp.	30.0	100.0	0
MIMOSACEAE			
Acacia tysonii (untreated)	100.0	91.0	12
(boiled)			96
POACEAE			
Eragrostis dielsii	78.0	100.0	0
SOLANACEAE			
Solanum lasiophyllum	-	100.0	5

APPENDIX 4.0: **NORTHEASTERN GOLDFIELDS - REHABILITATION TRIALS: SUMMARY OF REVEGETATION PARAMETERS FOR ASSESSMENTS BETWEEN SEPTEMBER '92 AND OCTOBER '98.**

APPENDIX 4.1: **1992 Oxide Trial - Mean density, percentage cover, Importance Value Index and plant height for species recorded on the 150 kg ha^{-1} (low, n=4) and 300 kg ha^{-1} (high, n=3) fertiliser treatments (constant 8.3 kg ha^{-1} seed rate). Eight assessments between September '92 and October '98.**

Oxide Trial 1992 - 150 kg ha^{-1} fertiliser treatment assessed September 1992.

FAMILY Species	**Mean No. m^{-2}**	**Mean % Cover**	**Mean IVI**	**Mean Ht. cm**
CHENOPODIACEAE				
Atriplex semibaccata	0.01	0.001	10.50	6
Atriplex spp.(juveniles)	0.17	0.070	217.80	2
Maireana spp.	0.05	0.013	71.70	2
TOTAL	**0.23**	**0.084**	**300.00**	

Oxide Trial 1992 - 300 kg ha^{-1} fertiliser treatment assessed September 1992: No species sampled over the two assessment transects.

Oxide Trial 1992 –150 kg ha^{-1} fertiliser assessed late October 1993.

FAMILY Species	**Mean No. m^{-2}**	**Mean % Cover**	**Mean IVI**	**Mean Ht. cm**
CHENOPODIACEAE				
Atriplex canescens	0.03	0.25	2.63	25
Atriplex codonocarpa	0.25	0.52	159.15	26
Atriplex holocarpa	1.15	1.30	33.97	11
Atriplex lentiformis	0.07	2.25	14.05	78
Atriplex nummularia	0.10	0.45	7.86	28
Atriplex semibaccata	1.18	4.74	64.12	11
Atriplex vesicaria	0.05	0.10	3.32	10
Maireana aphylla	0.13	0.39	4.88	20
Maireana carnosa	0.03	0.05	1.67	10
Maireana pyramidata	0.15	0.52	7.96	25
Maireana villosa	0.00	0.09	0.40	18
TOTAL	**3.14**	**10.66**	**300.00**	

Oxide Trial 1992 – 300 kg ha^{-1} fertiliser assessed late October 1993.

FAMILY Species	**Mean No. m^{-2}**	**Mean % Cover**	**Mean IVI**	**Mean Ht. cm**
CHENOPODIACEAE				
Atriplex holocarpa	0.05	0.14	44.88	5
Atriplex lentiformis	0.03	3.25	70.75	165
Atriplex semibaccata	0.18	1.32	183.10	13
Maireana pyramidata		0.09	1.18	
TOTAL	**0.26**	**4.80**	**300.00**	

Oxide Trial 1992 - 150 kg ha^{-1} fertiliser treatment assessed late February 1994.

FAMILY Species	**Mean No. m^{-2}**	**Mean % Cover**	**Mean IVI**	**Mean Ht. cm**
CHENOPODIACEAE				
Atriplex canescens	0.01	0.19	2.32	25
Atriplex codonocarpa	0.03	0.06	29.76	10
Atriplex holocarpa	0.08	0.36	31.37	11
Atriplex lentiformis	0.06	6.34	22.06	110
Atriplex nummularia	0.09	0.66	8.20	27
Atriplex semibaccata	1.32	15.58	166.90	12
Atriplex vesicaria	0.01	0.08	25.30	8
Maireana aphylla	0.10	0.74	11.84	33
Maireana pyramidata	0.01	0.75	1.44	8
TOTAL	**1.71**	**24.10**	**300.00**	

Oxide Trial 1992 - 300 kg ha^{-1} fertiliser treatment assessed late February 1994.

FAMILY Species	**Mean No. m^{-2}**	**Mean % Cover**	**Mean IVI**	**Mean Ht. cm**
CHENOPODIACEAE				
Atriplex codonocarpa	0.02	0.05	11.82	5
Atriplex holocarpa	0.05	0.17	21.11	8
Atriplex lentiformis	0.02	5.25	34.19	155
Atriplex nummularia	0.03	3.42	27.29	90
Atriplex semibaccata	0.30	9.20	205.30	17
Maireana aphylla		0.08	0.34	
TOTAL	**0.42**	**18.17**	**300.00**	

Oxide Trial 1992 - 150 kg ha^{-1} fertiliser treatment assessed September 1994.

FAMILY Species	**Mean No.** m^{-2}	**Mean** **% Cover**	**Mean** **IVI**	**Mean** **Ht. cm**
CHENOPODIACEAE				
Atriplex canescens	0.03	0.14	5.08	18
Atriplex codonocarpa		0.06	6.25	
Atriplex holocarpa	0.01	0.09	13.02	10
Atriplex nummularia	0.12	4.41	49.49	48
Atriplex semibaccata	0.40	2.81	115.34	7
Atriplex vesicaria	0.15	0.48	88.89	21
Maireana aphylla	0.10	0.68	16.73	33
Maireana triptera	0.03	0.15	5.15	20
TOTAL	**0.84**	**8.82**	**300.00**	

Oxide Trial 1992 - 300 kg ha^{-1} fertiliser treatment assessed September 1994.

FAMILY Species	**Mean No.** m^{-2}	**Mean** **% Cover**	**Mean** **IVI**	**Mean** **Ht. cm**
CHENOPODIACEAE				
Atriplex holocarpa	0.02	0.17	7.18	10
Atriplex lentiformis		2.25	23.32	
Atriplex nummularia	0.05	4.62	41.72	114
Atriplex semibaccata	0.15	3.02	160.70	9
Atriplex stipitata	0.02	0.08	6.77	28
Atriplex vesicaria	0.10	0.78	59.50	13
Maireana aphylla		0.07	0.82	
TOTAL	**0.33**	**10.98**	**300.00**	

Oxide Trial 1992 - 150 kg ha^{-1} fertiliser treatment assessed October 1995.

FAMILY Species	**Mean No. m^{-2}**	**Mean % Cover**	**Mean IVI**	**Mean Ht. cm**
CHENOPODIACEAE				
Atriplex canescens	0.025	0.563	3.18	84
Atriplex codonocarpa	0.463	0.535	47.38	11
Atriplex holocarpa	0.338	2.958	25.03	20
Atriplex lentiformis	0.113	12.940	36.98	150
Atriplex nummularia	0.088	3.013	13.98	82
Atriplex semibaccata	1.025	5.483	68.35	8
Atriplex vesicaria	0.363	2.413	45.58	30
Maireana aphylla	0.050	1.038	6.80	48
Maireana carnosa	0.013	0.013	1.19	18
Maireana pyramidata	0.075	1.188	7.75	58
Maireana triptera	0.238	0.358	11.20	11
Sclerolaena diacantha	0.038	0.575	8.08	21
Salsola kali	0.013	0.088	4.85	34
POLYGONACEAE				
Rumex vesicarius	0.400	0.895	19.49	37
TOTAL	**3.238**	**32.050**	**300.00**	

Oxide Trial 1992 - 300 kg ha^{-1} fertiliser treatment assessed October 1995.

FAMILY Species	**Mean No. m^{-2}**	**Mean % Cover**	**Mean IVI**	**Mean Ht. cm**
AIZOACEAE				
Carpobrotus edulis	0.017	0.167	1.76	11
CHENOPODIACEAE				
Atriplex acutibractea	0.067	0.027	6.17	8
Atriplex codonocarpa	0.083	0.173	13.70	11
Atriplex holocarpa	0.017	0.067	2.86	16
Atriplex lentiformis	0.467	8.547	73.57	61
Atriplex nummularia	0.883	9.533	56.70	43
Atriplex semibaccata	0.567	2.220	94.43	11
Atriplex vesicaria	0.417	2.317	25.75	23
Maireana aphylla	0.017	0.800	12.51	84
Maireana georgei	0.017	0.010	1.36	16
Maireana pyramidata	0.083	0.120	6.00	21
Maireana triptera	0.083	0.203	5.20	23
TOTAL	**2.717**	**24.180**	**300.00**	

Oxide Trial 1992 - 150 kg ha^{-1} fertiliser treatment assessed November '96.

FAMILY Species	**Mean No. m^{-2}**	**Mean % Cover**	**Mean IVI**	**Mean Ht. cm**
AIZOACEAE				
Carpobrotus sp.	0.438	0.255	34.80	6
CHENOPODIACEAE				
Atriplex canescens	0.038	0.798	7.29	62
Atriplex codonocarpa	0.175	0.070	14.05	10
Atriplex holocarpa	0.075	0.038	5.20	13
Atriplex lentiformis	0.113	10.510	45.45	87
Atriplex nummularia	0.038	1.753	8.93	92
Atriplex quadrivalvata	0.113	0.040	7.16	10
Atriplex semibaccata	0.425	0.740	39.03	12
Atriplex vesicaria	0.725	2.023	68.73	25
Maireana aphylla	0.063	0.708	9.52	35
Maireana pyramidata	0.075	2.150	20.70	67
Maireana tomentosa	0.013	0.188	1.91	65
Maireana triptera	0.138	0.423	17.17	18
Sclerolaena cuneata	0.050	0.303	4.96	23
Sclerolaena eriacantha	0.138	0.020	7.30	5
Sclerolaena sp.1	0.038	0.083	4.54	8
Sclerolaena sp.2	0.013	0.003	1.81	8
POLYGONACEAE				
Rumex vesicarius	0.013	0.013	2.08	17
TOTAL	**2.681**	**20.118**	**300.00**	

Oxide Trial 1992 - 300 kg ha^{-1} fertiliser treatment assessed November '96.

FAMILY Species	**Mean No. m^{-2}**	**Mean % Cover**	**Mean IVI**	**Mean Ht. cm**
AIZOACEAE				
Carpobrotus sp.	0.117	0.153	8.67	6
CHENOPODIACEAE				
Atriplex canescens	0.033	10.600	41.53	185
Atriplex codonocarpa	0.167	0.103	11.23	9
Atriplex holocarpa	0.050	0.050	15.90	18
Atriplex lentiformis	0.100	14.680	65.38	128
Atriplex nummularia	0.067	0.187	12.53	42
Atriplex quadrivalvata	0.067	0.067	4.60	8
Atriplex quinnii	0.133	0.060	7.03	8
Atriplex semibaccata	0.250	3.193	52.17	12
Atriplex vesicaria	0.200	0.377	36.67	18
Maireana aphylla		0.367	1.57	
Maireana pyramidata	0.033	1.450	12.97	53
Maireana triptera	0.083	0.190	13.93	28
Salsola kali	0.017	0.017	6.40	17
Sclerolaena densiflora	0.017	0.017	1.61	6
Sclerolaena eriacantha	0.033	0.013	7.95	8
TOTAL	**1.367**	**31.524**	**300.00**	

Oxide Trial 1992 - 150 kg ha^{-1} fertiliser treatment assessed October '97.

FAMILY Species	**Mean No.** **m^{-2}**	**Mean** **% Cover**	**Mean** **IVI**	**Mean** **Ht. cm**
AIZOACEAE				
Mesembryanthemum nodiflorum		0.300	4.15	
CHENOPODIACEAE				
Atriplex canescens	0.013	1.088	7.62	69
Atriplex codonocarpa	0.175	0.180	17.73	12
Atriplex holocarpa	0.013	0.063	1.56	15
Atriplex lentiformis	0.075	16.690	47.98	116
Atriplex lindleyi	0.475	0.863	32.05	16
Atriplex nummularia	0.088	2.663	18.08	116
Atriplex quadrivalvata	0.013	0.025	1.28	11
Atriplex semibaccata	0.275	0.638	27.68	8
Atriplex vesicaria	0.300	2.025	52.28	21
Maireana aphylla	0.063	0.788	10.28	44
Maireana brevifolia	0.025	0.363	6.22	48
Maireana pyramidata	0.088	1.963	17.40	60
Maireana triptera	0.188	0.550	19.64	22
Maireana villosa	0.025	0.088	2.72	20
Sclerolaena cuneata	0.063	0.400	7.75	10
Sclerolaena densiflora	0.050	0.075	6.70	8
Sclerolaena eriacantha	0.113	0.125	15.73	8
Sclerolaena patenticuspis	0.013	0.025	3.02	13
TOTAL	**2.055**	**28.912**	**300.00**	

Oxide Trial 1992 - 300 kg ha^{-1} fertiliser treatment assessed October '97.

FAMILY Species	**Mean No. m^{-2}**	**Mean % Cover**	**Mean IVI**	**Mean Ht. cm**
CHENOPODIACEAE				
Atriplex canescens	0.033	3.367	13.13	67
Atriplex lentiformis	0.100	39.120	126.70	200
Atriplex lindleyi	0.100	0.400	14.83	22
Atriplex nummularia	0.033	0.333	6.51	88
Atriplex semibaccata	0.150	1.967	60.07	11
Maireana brevifolia		0.083	0.20	
Maireana pyramidata	0.100	3.567	24.97	58
Maireana triptera	0.017	1.217	6.10	72
Salsola kali	0.050	0.087	34.78	14
Sclerolaena densiflora	0.033	0.100	12.61	14
TOTAL	**0.616**	**50.241**	**300.00**	

Oxide Trial 1992 - 150 kg ha^{-1} fertiliser treatment assessed October '98.

FAMILY Species	**Mean No. m^{-2}**	**Mean % Cover**	**Mean IVI**	**Mean Ht. cm**
AIZOACEAE				
Mesembryanthemum nodiflorum		0.875	12.590	
CHENOPODIACEAE				
Atriplex canescens	0.025	7.063	21.970	200
Atriplex codonocarpa	0.125	0.225	37.970	14
Atriplex holocarpa	0.125	0.175	12.130	23
Atriplex lentiformis	0.113	13.740	70.200	164
Atriplex lindleyi	0.013	0.188	3.883	25
Atriplex nummularia	0.088	1.950	17.550	111
Atriplex vesicaria	0.025	0.138	3.535	26
Maireana aphylla	0.075	1.363	12.780	59
Maireana brevifolia	0.025	0.188	9.900	53
Maireana pyramidata	0.138	3.813	34.500	63
Maireana triptera	0.063	1.388	14.240	29
Maireana villosa	0.038	0.288	6.940	37
Sasola kali	0.013	0.075	1.783	40
Sclerolaena densiflora	0.025	0.013	9.308	3
POLYGONACEAE				
Rumex vesicarius	0.400	0.400	30.740	31
TOTAL	**1.288**	**31.880**	**300.000**	

Oxide Trial 1992 - 300 kg ha^{-1} fertiliser treatment assessed October '98.

FAMILY Species	**Mean No.** m^{-2}	**Mean** **% Cover**	**Mean** **IVI**	**Mean** **Ht. cm**
AIZOACEAE				
Mesembryanthemum nodiflorum		1.367	2.930	
CHENOPODIACEAE				
Atriplex codonocarpa	0.217	0.217	39.640	10
Atriplex holocarapa	0.133	0.097	12.800	7
Atriplex lentiformis	0.100	36.620	104.000	307
Atriplex lindleyi	0.050	0.100	9.910	14
Atriplex nummularia	0.083	0.610	24.530	34
Atriplex quadrivalvata	0.117	0.033	7.013	4
Atriplex quinnii	0.017	0.033	5.323	8
Atriplex semibaccata	0.017	0.017	5.287	5
Atriplex vescaria	0.150	0.617	22.790	22
Enchylaena tomentosa	0.017	0.083	5.430	60
Maireana aphylla	0.017	0.250	5.787	65
Maireana pyramidata	0.017	0.917	14.370	63
Maireana tomentosa	0.017	0.017	1.933	13
Maireana triptera	0.067	0.167	16.470	14
Salsola kali	0.033	0.017	2.563	6
Sclerolaena cuneata	0.083	0.117	7.983	5
Sclerolaena densiflora	0.017	0.017	1.933	12
POLYGONACEAE				
Rumex vesicarius	0.133	0.150	9.257	28
TOTAL	**1.283**	**41.440**	**300.000**	

APPENDIX 4.2: **1993 Oxide Trial - Mean density, percentage cover, Importance Value Index and plant height for species recorded on the 14 kg ha^{-1} (low, n=8) and 20 kg ha^{-1} (high, n=8) seed rate treatments (constant 300 kg ha^{-1} fertiliser rate). Seven assessments between October '93 and October '98.**

Oxide Trial 1993 - 14 kg ha^{-1} seed rate treatment assessed late October 1993.

FAMILY Species	**Mean No. m^{-2}**	**Mean % Cover**	**Mean IVI**	**Mean Ht. cm**
CHENOPODIACEAE				
Atriplex acutibractea	0.01	0.01	5.43	6
Atriplex codonocarpa	0.55	4.50	288.38	14
Atriplex holocarpa	0.02	0.04	6.19	5
TOTAL	**0.58**	**4.55**	**300.00**	

Oxide Trial 1993 - 20 kg ha^{-1} seed rate treatment assessed late October 1993.

FAMILY Species	**Mean No. m^{-2}**	**Mean % Cover**	**Mean IVI**	**Mean Ht. cm**
CHENOPODIACEAE				
Atriplex codonocarpa	0.650	5.01	259.85	16
Atriplex holocarpa	0.175	1.10	40.15	15
TOTAL	**0.825**	**6.11**	**300.00**	

Oxide Trial 1993 - 14 kg ha^{-1} seed rate treatment assessed late February 1994.

FAMILY Species	**Mean No. m^{-2}**	**Mean % Cover**	**Mean IVI**	**Mean Ht. cm**
CHENOPODIACEAE				
Atriplex codonocarpa	0.45	9.97	233.70	22
Atriplex holocarpa	0.16	2.21	62.94	15
Atriplex vesicaria	0.01	0.13	3.39	15
TOTAL	**0.62**	**12.31**	**300.00**	

Oxide Trial 1993 - 20 kg ha^{-1} seed rate treatment assessed late February 1994.

FAMILY Species	**Mean No. m^{-2}**	**Mean % Cover**	**Mean IVI**	**Mean Ht. cm**
CHENOPODIACEAE				
Atriplex codonocarpa	0.34	7.97	157.10	23
Atriplex holocarpa	0.35	6.88	137.80	23
Atriplex nummularia	0.01	0.04	1.60	15
Atriplex vesicaria	0.01	0.02	1.47	10
Maireana carnosa		0.01	0.05	
Maireana pyramidata	0.01	0.12	1.99	60
TOTAL	**0.72**	**15.04**	**300.00**	

Oxide Trial 1993 - 14 kg ha^{-1} seed rate treatment assessed September 1994.

FAMILY Species	**Mean No. m^{-2}**	**Mean % Cover**	**Mean IVI**	**Mean Ht. cm**
CHENOPODIACEAE				
Atriplex acutibractea	0.01	0.17	4.55	20
Atriplex codonocarpa	0.36	7.29	237.70	21
Atriplex holocarpa	0.13	1.59	52.48	19
Atriplex vesicaria	0.01	0.04	1.71	26
Maireana pyramidata		0.16	3.55	
TOTAL	**0.51**	**9.24**	**300.00**	

Oxide Trial 1993 - 20 kg ha^{-1} seed rate treatment assessed September 1994.

FAMILY Species	**Mean No. m^{-2}**	**Mean % Cover**	**Mean IVI**	**Mean Ht. cm**
CHENOPODIACEAE				
Atriplex acutibractea	0.01	0.09	2.35	22
Atriplex codonocarpa	0.29	7.84	198.60	25
Atriplex holocarpa	0.16	2.31	72.24	23
Atriplex nummularia	0.01	0.03	1.70	45
Atriplex vesicaria	0.04	0.08	19.45	26
Maireana pyramidata	0.01	0.19	3.90	36
Maireana triptera	0.01	0.19	1.74	6
TOTAL	**0.51**	**10.75**	**300.00**	

Oxide Trial 1993 - 14 kg ha^{-1} seed rate treatment assessed October 1995.

FAMILY Species	**Mean No. m^{-2}**	**Mean % Cover**	**Mean IVI**	**Mean Ht. (cm)**
CHENOPODIACEAE				
Atriplex codonocarpa	1.08	10.22	182.13	23
Atriplex holocarpa	0.16	3.56	29.85	22
Atriplex nummularia	0.01	0.11	1.46	17
Atriplex semibaccata	0.01	0.01	0.54	5
Atriplex semilunaris	0.03	0.54	7.69	21
Atriplex vesicaria	0.09	0.83	9.45	27
Maireana brevifolia	0.31	0.73	27.58	29
Maireana georgei	0.05	0.04	3.59	10
Maireana pyramidata	0.03	0.06	3.78	23
Maireana triptera	0.18	0.59	17.39	19
Sclerolaena densiflora	0.01	0.02	1.44	12
Sclerolaena diacantha	0.01	0.20	4.02	34
Sclerolaena obliquicuspis	0.01	0.03	0.96	13
POACEAE				
grass	0.01	0.00	0.48	9
POLYGONACEAE				
Rumex vesicarius	0.03	0.64	8.06	58
ZYGOPHYLLACEAE				
Zygophyllum aurantiacum	0.01	0.14	1.57	30
TOTAL	**1.99**	**17.73**	**300.00**	

Oxide Trial 1993 - 20 kg ha^{-1} seed rate treatment assessed October 1995.

FAMILY Species	**Mean No. m^{-2}**	**Mean % Cover**	**Mean IVI**	**Mean Ht. (cm)**
AIZOACEAE				
Tetragonia sp.	0.01	0.19	1.15	8
CHENOPODIACEAE				
Atriplex codonocarpa	0.73	9.23	121.85	23
Atriplex holocarpa	0.36	10.11	66.41	25
Atriplex nummularia	0.01	0.09	2.60	110
Atriplex vesicaria	0.11	0.77	17.99	26
Maireana brevifolia	0.50	2.07	32.49	40
Maireana carnosa	0.02	0.04	3.57	14
Maireana georgei	0.06	0.05	7.08	10
Maireana pyramidata	0.06	0.11	9.54	31
Maireana triptera	0.23	0.97	28.54	21
Sclerolaena densiflora	0.02	0.02	2.46	16
Sclerolaena diacantha	0.01	0.01	3.30	16
Salsola kali	0.01	0.01	0.80	20
POLYGONACEAE				
Rumex vesicarius	0.01	0.20	1.36	52
ZYGOPHYLLACEAE				
Zygophyllum aurantiacum	0.01	0.04	0.74	18
TOTAL	**2.14**	**23.92**	**300.00**	

Oxide Trial 1993 - 14 kg ha^{-1} seed rate treatment assessed November '96.

FAMILY Species	**Mean No. m^{-2}**	**Mean % Cover**	**Mean IVI**	**Mean Ht. (cm)**
CHENOPODIACEAE				
Atriplex acutibractea		0.001	0.01	
Atriplex bunburyana	0.006	0.125	1.10	36
Atriplex codonocarpa	0.325	0.143	31.95	8
Atriplex holocarpa	0.038	0.038	5.84	18
Atriplex lentiformis	0.019	0.385	8.21	58
Atriplex nummularia	0.006	0.489	3.09	32
Atriplex semibaccata	0.013	0.138	4.19	9
Atriplex vesicaria	0.113	0.295	13.03	25
Maireana brevifolia	2.138	5.950	169.30	40
Maireana carnosa	0.006	0.003	0.55	8
Maireana georgei	0.006	0.014	1.78	5
Maireana triptera	0.288	5.188	46.96	56
Salsola kali	0.025	0.219	7.66	24
Sclerolaena eriacantha	0.094	0.014	3.11	14
Sclerolaena sp.	0.006	0.004	3.40	8
TOTAL	**3.083**	**13.006**	**300.00**	

Oxide Trial 1993 - 20 kg ha^{-1} seed rate treatment assessed November '96.

FAMILY Species	**Mean No. m^{-2}**	**Mean % Cover**	**Mean IVI**	**Mean Ht. (cm)**
AIZOACEAE				
M. nodiflorum	0.013	0.069	2.66	11
Carpobrotus sp.	0.106	0.058	4.98	7
CHENOPODIACEAE				
Atriplex codonocarpa	0.894	0.418	41.73	9
Atriplex holocarpa	0.069	0.015	5.71	4
Atriplex lentiformis	0.019	2.294	12.70	116
Atriplex nummularia	0.013	0.020	2.60	30
Atriplex vesicaria	0.031	0.205	5.81	28
Maireana brevifolia	2.419	8.668	158.50	37
Maireana tomentosa	0.006	0.019	1.02	41
Maireana triptera	0.181	5.514	56.88	50
Maireana germ.	0.006	0.001	0.95	2
Salsola kali	0.019	0.031	3.80	17
Sclerolaena eriacantha	0.031	0.001	1.50	4
POLYGONACEAE				
Rumex vesicarius	0.006	0.019	1.06	24
TOTAL	**3.813**	**17.332**	**300.00**	

Oxide Trial 1993 - 14 kg ha^{-1} seed rate treatment assessed October '97.

FAMILY Species	**Mean No. m^{-2}**	**Mean % Cover**	**Mean IVI**	**Mean Ht. (cm)**
CHENOPODIACEAE				
Atriplex bunburyana	0.006	0.304	1.41	46
Atriplex codonocarpa	1.338	3.126	87.86	15
Atriplex holocarpa	0.131	0.275	9.02	16
Atriplex lindleyi	0.063	0.209	5.56	25
Atriplex nummularia	0.038	3.725	12.60	76
Atriplex semibaccata	0.013	0.113	1.04	8
Atriplex semilunaris	0.038	0.029	3.44	22
Atriplex vesicaria	0.069	0.406	5.48	27
Maireana brevifolia	0.756	15.490	139.50	64
Maireana carnosa	0.013	0.031	1.08	5
Maireana triptera	0.119	7.050	27.48	53
Maireana villosa	0.006	0.013	0.72	18
Salsola kali	0.025	0.063	2.92	20
Sclerolaena cuneata		0.144	0.36	
Sclerolaena densiflora	0.013	0.169	1.63	15
TOTAL	**2.628**	**31.147**	**300.00**	

Oxide Trial 1993 - 20 kg ha^{-1} seed rate treatment assessed October '97.

FAMILY Species	**Mean No. m^{-2}**	**Mean % Cover**	**Mean IVI**	**Mean Ht. (cm)**
AIZOACEAE				
M. nodiflorum		0.038	0.17	
CHENOPODIACEAE				
Atriplex bunburyana	0.01	0.219	1.23	77
Atriplex codonocarpa	0.59	1.339	49.70	11
Atriplex holocarpa	0.13	0.285	10.80	11
Atriplex lentiformis	0.02	5.706	16.00	185
Atriplex lindleyi	0.04	0.075	3.10	19
Atriplex nummularia	0.03	2.850	13.40	72
Atriplex semibaccata	0.01	0.004	0.48	6
Atriplex semilunaris		0.004	0.01	
Atriplex vesicaria	0.03	0.050	3.64	16
Maireana brevifolia	1.55	16.812	154.00	58
Maireana triptera	0.16	8.412	44.00	55
Salsola kali	0.01	0.012	1.12	10
Sclerolaena densiflora	0.01	0.012	0.50	4
Sclerolaena diacantha	0.02	0.006	2.15	3
TOTAL	**2.61**	**35.824**	**300.00**	

Oxide Trial 1993 - 14 kg ha^{-1} seed rate treatment assessed October '98.

FAMILY Species	**Mean No. m^{-2}**	**Mean % Cover**	**Mean IVI**	**Mean Ht. (cm)**
CHENOPODIACEAE				
Atriplex codonocarpa	1.075	1.575	70.630	11
Atriplex holocarpa	0.225	0.738	16.080	13
Atriplex lentiformis		0.038	0.082	
Atriplex nummularia	0.038	5.475	15.450	126
Atriplex semilunaris	0.025	0.025	4.125	14
Atriplex vesicaria	0.125	0.825	12.090	24
Maireana brevifolia	0.413	16.650	152.200	71
Maireana triptera	0.138	1.713	14.400	65
Salsola kali	0.013	0.006	0.980	12
POLYGONACEAE				
Rumex vesicarius	0.188	0.338	13.990	24
TOTAL	**2.240**	**27.400**	**300.000**	

Oxide Trial 1993 - 20 kg ha^{-1} seed rate treatment assessed October '98 .

FAMILY Species	**Mean No. m^{-2}**	**Mean % Cover**	**Mean IVI**	**Mean Ht. (cm)**
AIZOACEAE				
M. nodiflorum		0.862	3.520	
Tetrogonia sp.	0.013	0.088	2.227	5
CHENOPODIACEAE				
Atriplex codonocarpa	0.788	1.140	54.380	8
Atriplex holocarpa	0.375	0.568	35.430	10
Atriplex lentiformis	0.013	7.600	17.300	320
Atriplex nummularia	0.038	1.738	12.790	98
Atriplex semilunaris	0.038	0.038	2.900	19
Maireana brevifolia	0.513	14.025	122.300	64
Maireana pyramidata	0.013	0.050	2.512	54
Maireana triptera	0.138	3.188	30.480	59
Sclerolaena densiflora	0.013	0.012	1.212	14
POLYGONACEAE				
Rumex vesicarius	0.200	0.462	15.350	29
TOTAL	**2.140**	**29.771**	**300.000**	

APPENDIX 4.3: **'94 Seeding, Upper Surfaces of Granny Waste Dump - Mean density, percentage cover, Importance Value Index and plant height for species recorded (n=7). Three assessments between November '96 and October '98.**

'94 Seeding, Upper Surfaces of Granny Waste Dump - assessed mid-November '96, 32 months after seeding.

FAMILY Species	**IVI**	**Density (m^{-2})**	**Cover (%)**	**Ht (cm)**
CHENOPODIACEAE				
Atriplex canescens	1.61		0.321	
Atriplex codonocarpa	80.96	1.721	0.869	12
Atriplex holocarpa	10.82	0.143	0.080	12
Atriplex nummularia	23.73	0.114	0.896	32
Atriplex semibaccata	5.47	0.050	0.236	8
Atriplex semilunaris	16.43	0.343	0.191	15
Atriplex vesicaria	66.20	0.593	2.137	27
Maireana brevifolia	12.48	0.150	0.566	23
Maireana carnosa	1.71	0.014	0.014	9
Maireana georgei	39.64	0.093	2.207	46
Maireana pyramidata	18.18	0.071	1.547	48
Maireana triptera	1.52	0.014	0.006	8
Maireana sp.2	12.10	0.014	0.783	68
Sclerolaena cuneata	0.97	0.007	0.064	19
Sclerolaena densiflora	4.43	0.107	0.029	11
Sclerolaena eriacantha	1.17	0.014	0.004	4
POACEAE				
Stipa nitida	2.46	0.014	0.043	6
TOTAL	**300.00**	**3.462**	**9.993**	

'94 Seeding, Upper Surfaces - assessed October '97, 44 months after seeding.

FAMILY Species	**IVI**	**Density (no. m^{-2})**	**% Cover**	**Ht (cm)**
CHENOPODIACEAE				
Atriplex bunburyana	5.68	0.014	0.564	64
Atriplex codonocarpa	94.41	1.071	1.870	15
Atriplex holocarpa	4.15	0.029	0.086	8
Atriplex lentiformis	0.77		0.050	
Atriplex lindleyi	14.68	0.157	0.436	21
Atriplex nummularia	16.82	0.071	0.450	34
Atriplex semibaccata	8.24	0.050	0.426	10
Atriplex semilunaris	19.54	0.179	0.511	21
Atriplex vesicaria	74.64	0.807	2.751	23
Maireana brevifolia	13.83	0.143	0.807	29
Maireana convexa	6.74	0.014	0.036	20
Maireana georgei	12.56	0.036	0.647	31
Maireana pyramidata	16.38	0.064	2.086	58
Maireana turbinata	4.60	0.007	0.607	136
Salsola kali	0.82	0.007	0.029	22
Sclerolaena eriacantha	1.96	0.007	0.021	11
POLYGONACEAE				
Rumex vesicarius	4.09	0.014	0.004	4
TOTAL	**300.00**	**2.670**	**11.381**	

'94 Seeding, Upper Surfaces - assessed October '98, 56 months after seeding.

FAMILY Species	**IVI**	**Density (no. m^{-2})**	**% Cover**	**Ht (cm)**
CHENOPODIACEAE				
Atriplex bunburyana	0.12		0.014	
Atriplex canescens	2.77	0.007	0.543	125
Atriplex codonocarpa	54.48	0.607	0.496	9
Atriplex holocarpa	46.31	0.743	1.400	13
Atriplex lindleyi	15.13	0.179	0.457	18
Atriplex nummularia	43.58	0.121	2.141	51
Atriplex quinnii	7.55	0.050	0.011	7
Atriplex semilunaris	19.75	0.300	0.243	16
Atriplex vesicaria	25.56	0.136	1.100	27
Maireana brevifolia	8.67	0.079	0.536	28
Maireana georgei	28.17	0.086	1.239	35
Maireana pyramidata	28.82	0.086	2.963	55
Maireana triptera	0.19		0.021	
Rhagodia eremaea	0.27		0.029	
Salsola kali	0.90	0.014	0.029	42
POLYGONACEAE				
Rumex vesicarius	17.74	0.212	0.107	16
TOTAL	**300.00**	**2.529**	**11.061**	

APPENDIX 4.4: '92 Circular Ripping Trial - Mean density, percentage cover, Importance Value Index and plant height for species recorded (n=4). Seven assessments assessments between September '92 and October '98.

'92 Circular Ripping Trial - assessed September '92, 4 months after seeding.

FAMILY Species	**IVI**	**Density (no. m^{-2})**	**Cover (%)**	**Ht (cm)**
CHENOPODIACEAE				
Atriplex juveniles	161.34	0.140	0.020	-
Maireana juveniles	138.66	0.118	0.025	-
TOTAL	**300.00**	**0.258**	**0.045**	

'92 Circular Ripping Trial - assessed October '93, 17 months after seeding.

FAMILY Species	**IVI**	**Density (no. m^{-2})**	**Cover (%)**	**Ht (cm)**
CHENOPODIACEAE				
Atriplex canescens	0.21		0.063	
Atriplex holocarpa	18.85	0.050	0.463	20
Atriplex nummularia	41.02	0.100	1.825	62
Atriplex semibaccata	161.32	0.363	12.163	22
Atriplex vesicaria	4.47	0.013	0.188	35
Maireana aphylla	12.43	0.038	0.313	20
Maireana brevifolia	35.28	0.100	1.250	35
Maireana pyramidata	26.42	0.075	0.838	48
TOTAL	**300.00**	**0.739**	**17.103**	

'92 Circular Ripping Trial - assessed September '94, 29 months after seeding.

FAMILY Species	**IVI**	**Density (no. m^{-2})**	**Cover (%)**	**Ht (cm)**
CHENOPODIACEAE				
Atriplex holocarpa	4.90	0.013	0.063	10
Atriplex nummularia	28.23	0.063	1.538	58
Atriplex semibaccata	147.21	0.263	6.838	12
Atriplex vesicaria	12.73	0.025	0.588	35
Maireana aphylla	97.95	0.188	5.300	38
Maireana brevifolia	8.98	0.013	0.688	70
TOTAL	**300.00**	**0.565**	**15.015**	

'92 Circular Ripping Trial - assessed October '95, 41 months after seeding.

FAMILY Species	**IVI**	**Density (no. m^{-2})**	**Cover (%)**	**Ht (cm)**
CHENOPODIACEAE				
Atriplex acutibractea	14.53	0.750	1.520	28
Atriplex canescens	7.41	0.025	2.400	85
Atriplex codonocarpa	1.69	0.025	0.015	10
Atriplex holocarpa	9.45	0.175	0.520	20
Atriplex lentiformis	2.44	0.025	0.050	35
Atriplex nummularia	19.57	0.150	4.025	75
Atriplex semibaccata	70.03	2.313	6.525	11
Atriplex vesicaria	15.63	0.163	4.025	45
Maireana aphylla	3.99	0.025	0.613	52
Maireana brevifolia	131.52	4.400	13.103	41
Maireana pyramidata	23.74	0.175	4.458	45
TOTAL	**300.00**	**8.226**	**37.254**	

'92 Circular Ripping Trial - assessed mid-November '96, 54 months after seeding.

FAMILY Species	**IVI**	**Density (no. m^{-2})**	**Cover (%)**	**Ht (cm)**
AIZOACEAE				
Carpobrotus edulis	1.99	0.025	0.038	3
CHENOPODIACEAE				
Atriplex canescens	1.13	0.013	0.050	65
Atriplex codonocarpa	1.54	0.013	0.003	5
Atriplex holocarpa	5.43	0.100	0.075	19
Atriplex lentiformis	1.02	0.013	0.025	50
Atriplex nummularia	26.01	0.050	6.625	111
Atriplex semibaccata	25.33	0.350	1.198	12
Atriplex quinnii	1.92	0.025	0.013	8
Atriplex vesicaria	24.43	0.475	2.958	22
Maireana aphylla	2.73	0.013	0.563	68
Maireana brevifolia	140.78	3.650	11.863	41
Maireana pyramidata	33.49	0.200	4.663	49
Maireana triptera	33.00	0.713	0.465	25
Sclerolaena diacantha	1.20	0.013	0.013	5
TOTAL	**300.00**	**5.653**	**28.552**	

'92 Circular Ripping Trial - assessed October '97, 65 months after seeding.

FAMILY Species	**IVI**	**Density (no. m^{-2})**	**% Cover**	**Ht (cm)**
CHENOPODIACEAE				
Atriplex canescens	2.67	0.025	0.163	54
Atriplex lentiformis	3.37	0.025	0.350	71
Atriplex nummularia	33.92	0.300	7.825	82
Atriplex semibaccata	23.10	0.363	0.558	9
Atriplex semilunaris	9.16	0.138	0.148	10
Atriplex vesicaria	19.31	0.213	1.678	26
Maireana aphylla	2.68	0.013	0.550	57
Maireana brevifolia	161.40	2.788	15.050	54
Maireana pyramidata	40.26	0.200	7.008	66
Maireana turbinata	4.30	0.038	0.763	67
TOTAL	**300.00**	**4.103**	**34.093**	

'92 Circular Ripping Trial - assessed October '98, 77 months after seeding.

FAMILY Species	**IVI**	**Density (no. m^{-2})**	**% Cover**	**Ht (cm)**
CHENOPODIACEAE				
Atriplex canescens	11.44	0.013	4.100	200
Atriplex codonocarpa	1.88	0.013	0.013	5
Atriplex holocarpa	9.73	0.063	0.030	5
Atriplex lentiformis	1.02		0.300	
Atriplex nummularia	37.77	0.113	9.613	90
Atriplex semilunaris	1.56	0.013	0.050	12
Atriplex vesicaria	18.75	0.163	0.575	24
Maireana aphylla	5.31	0.025	0.663	39
Maireana brevifolia	140.95	0.900	13.650	62
Maireana pyramidata	71.58	0.288	11.100	64
TOTAL	**300.00**	**1.588**	**40.093**	

APPENDIX 4.5: **1992 Batter Seeding - Mean density, percentage cover, Importance Value Index (IVI) and plant height for species recorded (n=8). Six assessments between October '92 and October '98.**

1992 Batter Seeding - assessed September '92, 4 months after seeding.

FAMILY Species	Density (no. m^{-2})	% Cover	Mean IVI	Height (cm)
CHENOPODIACEAE				
Atriplex semilunaris	0.004	0.002	16.00	6
Atriplex spp. (juveniles)	0.038	0.122	43.90	3
Dysphania kalpari	0.004	0.004	4.30	6
Sclerolaena cuneata	0.004	0.013	6.70	20
Maireana spp. (juveniles)	0.004	0.001	5.00	1
MIMOSACEAE				
Acacia sp.	0.008	0.021	28.40	19
GERANIACEAE				
Erodium botrys	0.045	0.061	119.90	6
ASTERACEAE				
Cephalipterum drummondii	0.025	0.027	52.80	10
Helichrysum ayersii	0.008	0.008	20.90	8
AIZOACEAE				
Tetragonia tetragonoides		0.004	2.10	
TOTAL	**0.140**	**0.263**	**300.00**	

1992 Batter Seeding - assessed February '94, 22 months after seeding.

FAMILY Species	Density (no. m^{-2})	% Cover	Mean IVI	Height (cm)
CHENOPODIACEAE				
Atriplex canescens	0.006	0.131	2.83	60
Atriplex bunburyana	0.069	1.519	33.79	20
Atriplex holocarpa	0.094	0.425	16.54	19
Atriplex nummularia	0.025	4.100	20.05	147
Atriplex semibaccata	0.933	10.800	114.42	14
Atriplex vesicaria	0.100	0.481	55.54	15
Maireana aphylla	0.025	0.394	7.60	22
Maireana brevifolia	0.013	0.025	3.19	18
Maireana carnosa	0.025	0.125	7.68	8
Maireana pyramidata	0.013	0.106	3.62	28
Salsola kali	0.281	3.206	30.89	48
MIMOSACEAE				
Acacia aneura	0.013	0.138	3.32	50
TOTAL	**1.597**	**21.450**	**300.00**	

1992 Batter Seeding - assessed September '94, 29 months after seeding.

FAMILY Species	**Density (no. m^{-2})**	**% Cover**	**Mean IVI**	**Height (cm)**
CHENOPODIACEAE				
Atriplex acutibractea	0.019	0.319	9.19	25
Atriplex canescens		0.006	0.03	
Atriplex codonocarpa		0.019	0.16	
Atriplex holocarpa	0.019	0.119	7.86	22
Atriplex lentiformis	0.031	6.460	32.88	158
Atriplex nummularia	0.006	1.062	10.51	120
Atriplex semibaccata	0.231	7.394	146.62	12
Atriplex vesicaria	0.019	0.188	46.00	18
Maireana aphylla	0.044	0.500	20.19	27
Maireana carnosa	0.006	0.019	2.40	10
Maireana georgei	0.012	0.469	6.91	43
Salsola kali	0.088	0.256	14.68	26
MIMOSACEAE				
Acacia aneura	0.006	0.031	2.55	20
TOTAL	**0.481**	**16.842**	**300.00**	

1992 Batter Seeding - assessed mid-November '96, 54 months after seeding.

FAMILY Species	**Density (no. m^{-2})**	**% Cover**	**Mean IVI**	**Height (cm)**
AIZOACEAE				
Carpobrotus edulis	0.238	0.019	7.73	6
CHENOPODIACEAE				
Atriplex bunburyana	0.006	0.029	0.76	29
Atriplex canescens		0.100	0.30	
Atriplex codonocarpa	0.063	0.038	5.94	10
Atriplex holocarpa	0.025	0.056	2.20	15
Atriplex lentiformis	0.019	12.363	34.25	34
Atriplex nummularia	0.019	2.459	13.44	7
Atriplex semibaccata	0.781	5.119	76.34	14
Atriplex semilunaris	0.013	0.001	1.24	5
Atriplex quadrivalvata	0.350	0.051	10.79	6
Atriplex vesicaria	0.263	0.981	26.34	20
Enchylaena tomentosa	0.006	0.004	0.30	10
Maireana aphylla	0.025	1.031	9.57	78
Maireana carnosa	0.006	0.006	0.31	6
Maireana convexa	0.013	0.013	0.40	26
Maireana georgei	0.094	0.263	7.08	19
Maireana pyramidata	0.006	0.044	0.49	28
Maireana triptera	0.306	5.036	52.29	44
Maireana villosa	0.013	0.013	0.63	23
Salsola kali	0.081	0.055	5.29	14
Sclerolaena cuneata	0.006	0.013	0.77	6
Sclerolaena diacantha	1.056	0.304	22.86	8
Sclerolaena eriacantha	0.275	0.398	16.38	14
Sclerolaena sp.	0.006	0.638	2.89	15
MIMOSACEAE				
Acacia aneura	0.013	0.014	1.36	26
TOTAL	**3.681**	**29.044**	**300.00**	

1992 Batter Seeding - assessed October '97, 65 months after seeding.

FAMILY Species	**Density (no. m^{-2})**	**% Cover**	**Mean IVI**	**Height (cm)**
AMARANTHACEAE				
Ptilotus obovatus		0.025	0.11	
CHENOPODIACEAE				
Atriplex bunburyana	0.006	0.150	1.58	59
Atriplex canescens	0.013	1.256	8.20	115
Atriplex codonocarpa	0.019	0.041	3.29	13
Atriplex lentiformis	0.038	8.656	39.40	75
Atriplex lindleyi	0.038	0.131	10.20	18
Atriplex nummularia	0.019	3.050	20.40	95
Atriplex quadrivalvata	0.019	0.031	3.23	9
Atriplex quinnii	0.069	0.129	14.06	12
Atriplex semibaccata	0.400	2.423	53.46	12
Atriplex semilunaris		0.006	0.03	
Atriplex vesicaria	0.113	1.013	20.98	21
Enchylaena tomentosa	0.019	0.150	4.21	44
Maireana aphylla	0.013	1.138	6.43	78
Maireana carnosa	0.013	0.019	1.45	5
Maireana georgei	0.094	0.481	10.04	22
Maireana pyramidata	0.006	0.256	2.07	37
Maireana triptera	0.231	3.990	62.33	33
Maireana villosa	0.013	0.031	1.04	25
Sclerolaena cuneata	0.006	0.419	2.35	22
Sclerolaena densiflora	0.394	1.025	26.15	17
Sclerolaena diacantha	0.006	0.006	1.39	9
Sclerolaena eriacantha	0.019	0.031	3.93	11
MIMOSACEAE				
Acacia aneura	0.019	0.094	2.68	21
Acacia linophylla	0.006	0.019	0.99	35
TOTAL	**1.573**	**24.570**	**300.00**	

1992 Batter Seeding - assessed October '98, 77 months after seeding.

FAMILY Species	**Density (no. m^{-2})**	**% Cover**	**IVI**	**Ht (cm)**
AMARANTHACEAE				
Ptilotus obovatus	0.006	0.044	1.56	50
CHENOPODIACEAE				
Atriplex bunburyana	0.006	0.294	2.33	74
Atriplex canescens		0.094	0.40	
Atriplex codonocarpa	0.050	0.027	7.00	7
Atriplex holocarpa	0.206	0.197	23.04	8
Atriplex lentiformis	0.013	5.538	32.73	107
Atriplex lindleyi	0.025	0.050	6.39	14
Atriplex nummularia	0.013	2.313	18.08	65
Atriplex semibaccata	0.025	0.038	4.15	10
Atriplex quinnii	0.131	0.079	21.01	6
Atriplex vesicaria	0.056	0.469	14.39	16
Enchylaena tomentosa	0.013	0.075	2.52	30
Maireana aphylla	0.013	1.138	7.11	90
Maireana georgei	0.088	0.256	7.95	23
Maireana planifolia	0.013	0.013	1.68	27
Maireana pyramidata	0.025	0.363	6.60	30
Maireana triptera	0.475	4.023	91.72	34
Maireana villosa	0.006	0.006	1.17	13
Salsola kali	0.056	0.056	7.93	17
Sclerolaena cuneata	0.013	0.231	4.60	12
Sclerolaena densiflora	0.250	0.304	32.66	10
MIMOSACEAE				
Acacia aneura	0.025	0.081	5.00	20
TOTAL	**1.506**	**15.687**	**300.00**	

APPENDIX 4.6: **Childe Harold Waste Dump revegetation, seeded February '94 - Mean density, percentage cover, Importance Value Index (IVI) and plant height for species recorded (n=11). Three assessments between November '96 and October '98.**

Childe Harold Waste Dump revegetation - assessed November '96, 32 months after seeding.

FAMILY Species	**IVI**	**Density (no. m^{-2})**	**Cover (%)**	**Ht (cm)**
AIZOACEAE				
Disphyma crassifolium	0.93	0.020	0.010	18
Tetragonia tetragonoides	3.54	0.080	0.110	10
AMARANTHACEAE				
Ptilotus polystachyus	0.27	0.001	0.001	40
CHENOPODIACEAE				
Atriplex bunburyana	4.38	0.010	0.850	56
Atriplex codonocarpa	65.80	1.450	2.870	18
Atriplex holocarpa	7.69	0.140	0.380	20
Atriplex nummularia	21.00	0.110	3.680	66
Atriplex semibaccata	5.69	0.040	0.380	12
Atriplex semilunaris	26.30	0.490	0.800	28
Atriplex quadrivalvata	16.90	0.390	0.330	14
Atriplex quinnii	2.67	0.080	0.100	18
Atriplex vesicaria	2.29	0.030	0.100	15
Maireana brevifolia	42.90	1.640	1.650	22
Maireana georgei	2.61		0.110	46
Maireana pyramidata	1.73	0.010	0.300	33
Maireana triptera	8.79	0.050	1.330	48
Maireana germ.s	0.93	0.030		12
Salsola kali	0.57	0.010		12
Sclerolaena cuneata	16.70	0.090	2.050	31
Sclerolaena densiflora	8.35	0.080	0.290	18
Sclerolaena diacantha	27.90	0.450	0.970	15
Sclerolaena eriacantha	5.23	0.100	0.170	14
Sclerolaena recurvicuspis	4.27	0.050	0.330	30
CAESALPINIACEAE				
Senna artemisioides	2.66	0.050	0.090	26
Senna helmsii	0.14		0.010	
Senna filifolia	0.64	0.010	0.010	14

cont'd Childe Harold Waste Dump revegetation - assessed November '96, 32 months after seeding.

FAMILY Species	**IVI**	**Density (no. m^{-2})**	**Cover (%)**	**Ht (cm)**
MALVACEAE				
Sida sp.	1.25	0.011	0.011	7
MIMOSACEAE				
Acacia aneura	3.89	0.050	0.270	22
Acacia linophylla	0.29		0.010	26
Acacia tetragonophylla	1.33	0.010	0.080	21
Acacia victoriae	0.50	0.010	0.010	13
Acacia sp.	2.52	0.040	0.040	9
MYRTACEAE				
Eucalyptus griffithsii	5.68	0.050	0.740	54
POACEAE				
Stipa nitida	1.91	0.050	0.020	12
SOLANACEAE				
Solanum lasiophyllum	1.55	0.010	0.160	48
ZYGOPHYLLACEAE				
Zygophyllum aurantiacum	0.32	0.001	0.001	15
TOTAL	**300.00**	**5.643**	**18.263**	

Childe Harold Waste Dump revegetation - assessed October '97, 44 months after seeding.

FAMILY Species	IVI	Density (no. m^{-2})	% Cover	Ht (cm)
AMARANTHACEAE				
Ptilotus aervoides	0.557	0.006	0.003	5
CAESALPINIACEAE				
Senna artemisiodies	3.033	0.017	0.194	14
Senna helmsii	0.524	0.006	0.017	5
Senna filifolia	0.016		0.006	
CHENOPODIACEAE				
Atriplex bunburyana	17.330	0.028	1.300	39
Atriplex codonocarpa	45.170	0.467	0.440	58
Atriplex nummularia	44.170	0.133	6.905	66
Atriplex quadrivalvata	7.544	0.022	0.009	68
Atriplex quinnii	4.244	0.017	0.017	19
Atriplex semibaccata	1.351	0.011	0.061	3
Atriplex semilunaris	9.343	0.078	0.088	17
Atriplex vesicaria	4.032	0.011	0.096	9
Enchylaena tomentosa	7.933	0.006	0.072	71
Maireana brevifolia	81.590	0.689	3.773	92
Maireana carnosa	0.849	0.017	0.011	8
Maireana georgei	0.008		0.003	
Maireana pyramidata	1.800	0.006	0.211	16
Maireana triptera	27.610	0.061	1.581	50
Sclerolaena cuneata	1.173	0.011	0.014	5
Sclerolaena diacantha	9.220	0.100	0.087	21
Sclerolaena eriacantha	1.330	0.022	0.017	12
Sclerolaena obliquicuspis	11.430	0.039	0.900	51
MALVACEAE				
Abutilon fraseri	0.852	0.006	0.017	8
MIMOSACEAE				
Acacia aneura	9.362	0.083	0.140	21
Acacia tetrogonophylla	0.687	0.006	0.006	6
Acacia victoriae	3.467	0.006	0.628	31
MYTRACEAE				
Eucalyptus griffithsii	5.366	0.022	0.737	16
SOLANACEAE				
Solanum lasiophyllum	0.071		0.017	
TOTAL	**300.000**	**1.867**	**17.350**	

Childe Harold Waste Dump revegetation - seeded February '94, assessed October '98, 56 months after seeding.

FAMILY Species	**IVI**	**Density (no. m^{-2})**	**% Cover**	**Ht (cm)**
BRASSICACEAE				
Carrichtera annua	9.274		0.475	16
CAESALPINIACEAE				
Senna filifolia	4.676	0.014	0.057	32
CHENOPODIACEAE				
Atriplex bunburyana	5.354	0.007	0.943	12
Atriplex codonocarpa	47.270	0.614	0.500	55
Atriplex holocarpa	32.140	0.693	1.139	37
Atriplex nummularia	33.130	0.114	4.183	46
Atriplex semibaccata	0.698	0.007	0.071	5
Atriplex semilunaris	35.780	0.807	0.770	63
Maireana brevifolia	56.820	0.421	3.807	66
Maireana triptera	21.700	0.036	0.779	38
Sclerolaena diacantha	14.070	0.293	0.227	33
MIMOSACEAE				
Acacia aneura	14.710	0.086	0.214	26
Acacia tetrogonophylla	3.519	0.014	0.114	12
Acacia victoriae	0.124		0.057	1
MYTRACEAE				
Eucalyptus griffithsii	19.110	0.050	4.743	134
SOLANACEAE				
Solanum lasiophyllum	1.604	0.007	0.107	11
TOTAL	**300.000**	**3.164**	**18.190**	

APPENDIX 4.7: 1993 Seeding (Granny Waste Dump) - Mean density, percentage cover, Importance Value Index (IVI) and plant height for species recorded. Six assessments between October '92 and October '98.

1993 Seeding (Granny Waste Dump) - Revegetation taxa recorded in October '93, 6 months after sowing (n=32).

FAMILY Species	**Denity (no. m^{-2})**	**% Cover**	**IVI**	**Mean Ht. cm**
AIZOACEAE				
Tetragonia tetragonoides	0.003	0.006	0.89	8
ASTERACEAE				
Carthamus lanatus	0.003	0.015	3.16	30
BRASSICACEAE				
Lepidium oxytrichum	0.008	0.020	3.26	16
CHENOPODIACEAE				
Atriplex acutibractea	0.005	0.034	2.65	20
Atriplex bunburyana	0.997	6.252	128.36	26
Atriplex canescens	0.002	0.003	0.15	10
Atriplex codonocarpa	0.467	1.261	33.62	17
Atriplex holocarpa	0.331	0.905	39.77	21
Atriplex nummularia	0.064	0.374	7.79	21
Atriplex quinii	0.050	0.159	6.40	25
Atriplex semibaccata	0.006	0.040	2.73	15
Atriplex vesicaria	0.656	1.633	68.76	20
Dysphania kalpari	0.002	0.005	0.44	10
Enchylaena tomentosa	0.003	0.016	0.38	5
Maireana carnosa	0.005	0.010	0.72	12
Sclerolaena cuneata	0.003	0.015	0.44	15
GERANIACEAE				
Erodium crinitum	0.002	0.005	0.17	25
POACEAE				
grass	0.001	0.003	0.31	5
TOTAL	**2.608**	**10.756**	**300.00**	

1993 Seeding (Granny Waste Dump) - Revegetation taxa recorded in February '94, 10 months after sowing (n=32).

FAMILY Species	**Density (no. m^{-2})**	**% Cover**	**IVI**	**Mean Ht. cm**
BRASSICACEAE				
Lepidium oxytrichum	0.003		0.38	10
CHENOPODIACEAE				
Atriplex acutibractea	0.006	0.05	2.35	20
Atriplex bunburyana	1.227	10.11	170.92	40
Atriplex canescens	0.003	0.02	1.46	4
Atriplex codonocarpa	0.126	1.80	42.51	21
Atriplex holocarpa	0.154	1.78	31.92	36
Atriplex nummularia	0.024	0.14	4.57	25
Atriplex quinii	0.084	0.62	17.69	22
Atriplex semibaccata	0.016	0.40	9.44	21
Atriplex vesicaria	0.068	0.47	9.44	33
Chenopodium pumilio	0.001	0.02	0.24	5
Dysphania kalpari	0.001		0.49	5
Maireana carnosa	0.008	0.03	6.76	22
Maireana platycarpa	0.001		0.30	20
Maireana pyramidata	0.003	0.01	0.54	20
Sclerolaena cuneata	0.001	0.02	0.49	30
PRIMULACEAE				
Anagallis arvensis	0.001	0.01	0.22	5
TOTAL	**1.727**	**15.48**	**300.00**	

1993 Seeding (Granny Waste Dump) - Revegetation taxa recorded in September '94, 17 months after sowing (n=32).

FAMILY Species	**Density (no. m^{-2})**	**% Cover**	**IVI**	**Ht (cm)**
CHENOPODIACEAE				
Atriplex acutibractea	0.002	0.03	0.820	24
Atriplex bunburyana	1.298	17.45	235.560	48
Atriplex codonocarpa	0.111	1.63	36.680	48
Atriplex holocarpa	0.006	0.04	0.930	25
Atriplex nummularia	0.036	0.17	5.130	31
Atriplex quinii	0.000	0.01	0.091	
Atriplex semibaccata	0.003	0.07	3.687	9
Atriplex vesicaria	0.019	0.08	3.970	25
Maireana pyramidata	0.002		8.372	35
Maireana triptera	0.009	0.01	2.966	18
Sclerolaena diacantha	0.002	0.05	0.894	30
TOTAL	**1.488**	**19.54**	**300.000**	

1993 Seeding (Granny Waste Dump) - Revegetation taxa recorded during October 1995, 30 months after sowing (n=32).

FAMILY Species	**Density (no. m^{-2})**	**% Cover**	**IVI**	**Ht (cm)**
AIZOACEAE				
Tetragonia sp.	0.028	0.449	9.92	10
AMARANTHACEAE				
Ptilotus aervoides		0.011	0.13	
Ptilotus exaltatus	0.005	0.050	1.25	32
Ptilotus obovatus	0.002	0.001	0.31	12
ASTERACEAE				
Ursinia anthemoides	0.005	0.005	0.46	28
Waitzia acuminata	0.006	0.034	6.26	22
CAESALPINIACEAE				
Senna artemisioides	0.002	0.001	0.34	3
Senna filifolia	0.003	0.011	0.64	24
CHENOPODIACEAE				
Atriplex amnicola	0.003	0.058	0.60	81
Atriplex bunburyana	0.694	28.039	197.04	72

cont'd 1993 Seeding (Granny Waste Dump) - Revegetation taxa recorded during October 1995, 30 months after sowing (n=32).

FAMILY Species	Density (no. m^{-2})	% Cover	IVI	Ht (cm)
CHENOPOIACEAE				
Atriplex codonocarpa	0.103	0.851	21.72	21
Atriplex holocarpa	0.023	0.244	5.37	23
Atriplex nummularia	0.014	0.148	2.37	81
Atriplex semibaccata	0.002	0.012	0.53	17
Atriplex vesicaria	0.012	0.336	3.41	49
Dysphania kalpari	0.002	0.011	0.24	10
Enchylaena tomentosa	0.005	0.212	1.55	66
Maireana brevifolia	0.005	0.012	0.68	8
Maireana carnosa	0.011	0.052	2.65	17
Maireana georgei	0.002	0.008	0.52	22
Maireana triptera	0.027	0.161	13.61	24
Sclerolaena diacantha	0.003	0.047	1.33	23
Sclerolaena sp.	0.002	0.047	1.33	23
MALVACEAE				
Sida sp.	0.002	0.002	1.18	5
MIMOSACEAE				
Acacia linophylla	0.002	0.001	0.30	3
Acacia pruinocarpa	0.011	0.005	4.79	13
Acacia tetragonophylla	0.005	0.004	1.36	14
Acacia sp.	0.002	0.001	0.30	3
MYRTACEAE				
Eucalyptus sp.	0.014	0.002	1.49	10
PAPILIONACEAE				
Glycine sp.	0.002	0.016	0.32	32
POACEAE				
Stipa scabra	0.002	0.008	0.52	50
grass	0.092	0.058	14.31	14
POLYGONACEAE				
Rumex vesicarius	0.005	0.139	2.74	46
PROTEACEAE				
Hakea sp.	0.002	0.001	0.31	8
SOLANACEAE				
Solanum lasiophyllum	0.005	0.006	1.01	9
TOTAL	**1.097**	**31.035**	**300.00**	

1993 Seeding (Granny Waste Dump) - Revegetation taxa recorded in mid-November '96, 43 months after seeding (n=16).

FAMILY Species	**Density** **(no. m^{-2})**	**% Cover**	**IVI**	**Ht** **(cm)**
AMARANTHACEAE				
Ptilotus obovatus		0.006	0.03	
CAESALPINIACEAE				
Senna filifolia	0.003	0.001	1.81	8
Senna helmsii	0.003	0.002	0.65	13
CHENOPODIACEAE				
Atriplex bunburyana	0.753	25.830	233.10	72
Atriplex codonocarpa	0.086	0.041	23.04	8
Atriplex holocarpa	0.036	0.013	5.06	8
Atriplex nummularia	0.011	0.243	3.89	131
Atriplex semibaccata	0.003	0.006	0.66	10
Atriplex vesicaria	0.028	0.433	8.62	32
Enchylaena tomentosa		0.002	0.01	
Maireana sp. 1	0.003	0.022	0.74	43
Maireana georgei	0.003	0.061	2.14	80
Maireana pyramidata	0.006	0.024	1.90	50
Maireana tomentosa		0.003	0.01	
Maireana triptera	0.025	0.231	6.59	38
Salsola kali	0.006	0.008	1.52	23
Sclerolaena diacantha	0.006	0.017	1.03	20
Sclerolaena eriacantha	0.006	0.033	2.74	14
MALVACEAE				
Abutilon sp.	0.003	0.002	0.58	7
MYRTACEAE				
Eucalyptus salicola	0.008	0.007	1.57	12
POACEAE				
Stipa nitida	0.003	0.137	1.67	8
POLYGONACEAE				
Rumex vesicaria	0.003	0.003	0.76	54
PROTEACEAE				
Hakea sp.	0.003	0.002	0.57	8
SOLANACEAE				
Solanum lasiophyllum	0.006	0.025	1.34	39
TOTAL	**1.000**	**27.151**	**300.00**	

1993 Seeding (Granny Waste Dump) - Revegetation taxa recorded during October '97, 54 months after seeding (n=16).

FAMILY Species	**Density (no. m^{-2})**	**% Cover**	**IVI**	**Ht (cm)**
AMARANTHACEAE				
Ptilotus exaltatus	0.003	0.002	0.54	10
CAESALPINIACEAE				
Senna helmsii	0.003	0.003	0.54	5
Senna filifolia	0.003	0.003	0.55	5
CHENOPODIACEAE				
Atriplex bunburyana	0.918	24.406	252.47	68
Atriplex codonocarpa	0.150	0.105	20.05	9
Atriplex lindleyi	0.003	0.003	0.54	12
Atriplex nummularia	0.006	0.041	1.72	68
Atriplex semibaccata	0.006	0.074	0.86	7
Atriplex vesicaria	0.009	0.318	3.23	54
Enchylaena tomentosa	0.003	0.024	0.62	87
Maireana appressa	0.003	0.006	0.55	33
Maireana georgei	0.006	0.147	2.55	28
Maireana pyramidata	0.003	0.024	0.70	38
Maireana triptera	0.015	0.138	5.00	38
Sclerolaena eriacantha	0.009	0.006	1.28	10
MIMOSACEAE				
Acacia linophylla	0.003	0.002	1.98	13
MYRTACEAE				
Eucalyptus sp.	0.003	0.002	0.54	9
POACEAE				
Enneapogon caerulescens	0.003	0.002	0.54	10
POLYGONACEAE				
Rumex vesicarius	0.012	0.005	4.09	5
PROTEACEAE				
Hakea preissii	0.003	0.009	0.59	14
SOLANACEAE				
Solanum lasiophyllum	0.006	0.012	1.09	42
TOTAL	**1.170**	**25.332**	**300.00**	

1993 Seeding (Granny Waste Dump) - Revegetation taxa recorded during October '98, 60 months after seeding (n=16).

FAMILY Species	**Density (no. m^{-2})**	**% Cover**	**IVI**	**Ht (cm)**
BRASSICACEAE				
Carichtera annua	0.006	0.056	0.88	15
CAESALPINIACEAE				
Senna helmsii	0.003	0.003	1.05	7
CHENOPODIACEAE				
Atriplex bunburyana	0.569	15.104	240.14	66
Atriplex holocarpa	0.025	0.022	4.48	10
Atriplex nummularia	0.013	0.031	2.20	68
Atriplex vesicaria	0.003	0.063	2.10	40
Enchylaena tomentosa	0.003	0.022	0.86	31
Maireana georgei	0.006	0.178	5.01	57
Maireana pyramidata	0.003	0.019	0.50	32
Maireana triptera	0.009	0.191	3.05	42
MYRTACEAE				
Eucalyptus sp.	0.009	0.016	1.15	15
POACEAE				
Stipa sp.	0.006	0.001	0.93	24
POLYGONACEAE				
Rumex vesicarius	0.294	0.237	35.67	18
PROTEACEAE				
Hakea preissii	0.003	0.002	0.48	7
SOLANACEAE				
Solanum lasiophyllum	0.006	0.028	1.52	32
TOTAL	**0.953**	**15.915**	**300.00**	

APPENDIX 4.8: **'94 Seeding, Lower Batter Granny Waste Dump - Mean density, percentage cover, Importance Value Index (IVI), and plant height for species recorded (n=5). Three assessments between November '96 and October '98.**

'94 Seeding, Lower Batter Granny Waste Dump - assessed mid-November '96, 32 months after seeding.

FAMILY Species	**IVI**	**Density (no. m^{-2})**	**% Cover**	**Ht (cm)**
AMARANTHACEAE				
Ptilotus obovatus	2.22	0.010	0.010	18
BRASSICACEAE				
Carrichtera annua	57.28	0.840	0.658	9
CAESALPINIACEAE				
Senna artemisioides	19.97	0.040	4.750	161
Senna filifolia	16.68	0.040	3.190	78
Senna helmsii	15.56	0.030	2.710	95
CHENOPODIACEAE				
Atriplex bunburyana	0.02		0.010	
Atriplex codonocarpa	65.36	0.610	1.166	11
Atriplex holocarpa	6.66	0.040	0.072	10
Atriplex nummularia	5.65	0.010	1.210	92
Atriplex semilunaris	18.34	0.120	1.320	18
Atriplex vesicaria	11.19	0.040	1.714	58
Maireana brevifolia	15.46	0.090	2.250	64
Maireana georgei	27.78	0.030	6.730	71
Maireana pyramidata	20.08	0.030	5.770	124
Sclerolaena densiflora	3.36	0.010	0.070	35
MIMOSACEAE				
Acacia acuminata	0.14		0.040	
Acacia aneura	3.82	0.010	0.200	100
Acacia linophylla	2.26	0.002	0.040	55
Acacia murrayana	5.60	0.010	1.120	200
Acacia tetragonophylla	0.37		0.150	
POLYGONACEAE				
Rumex vesicarius	2.06	0.020	0.004	3
TOTAL	**300.00**	**1.982**	**33.184**	

'94 Seeding, Lower Batter Granny Waste Dump - assessed October '97, 44 months after seeding.

FAMILY Species	**IVI**	**Density (no. m^{-2})**	**Cover (%)**	**Ht (cm)**
AMARANTHACEAE				
Ptilotus polystachyus	2.56	0.020	0.004	32
BRASSICACEAE				
Carrichtera annua	19.65	0.110	0.616	25
CAESALPINIACEAE				
Senna filifolia	28.53	0.080	5.100	85
Senna helmsii	12.24	0.030	2.000	81
CHENOPODIACEAE				
Atriplex codonocarpa	80.30	1.230	2.378	22
Atriplex holocarpa	28.37	0.350	0.744	18
Atriplex nummularia	7.01	0.020	0.646	16
Atriplex semilunaris	6.28	0.060	0.072	28
Atriplex vesicaria	32.05	0.150	3.698	41
Maireana brevifolia	6.63	0.040	0.090	28
Maireana georgei	25.96	0.040	5.830	69
Maireana pyramidata	19.46	0.030	4.560	102
GERANIACEAE				
Erodium crinitum	1.28	0.010	0.002	22
MALVACEAE				
Sida sp.	0.24		0.040	
MIMOSACEAE				
Acacia aneura	2.70	0.010	0.030	56
Acacia linophylla	0.17		0.050	
Acacia murrayana	5.00	0.010	1.150	126
POACEAE				
Stipa nitida	18.33	0.080	0.090	13
POLYGONACEAE				
Rumex vesicaria	3.31	0.020	0.070	50
TOTAL	**300.00**	**2.290**	**27.170**	

'94 Seeding, Lower Batter Granny Waste Dump - assessed October '98, 56 months after seeding.

FAMILY Species	**IVI**	**Density (no. m^{-2})**	**% Cover**	**Ht (cm)**
AMARANTHACEAE				
Ptilotus obovatus	7.47	0.02	0.05	25
BRASSICACEAE				
Carrichtera annua	6.58		1.69	
CAESALPINIACEAE				
Senna artemisiodes	12.34	0.04	1.97	143
Senna chatelainiana	1.16		0.25	
Senna filifolia	35.59	0.26	2.87	93
Senna helmsii	24.99	0.03	2.59	98
CHENOPODIACEAE				
Atriplex bunburyana	3.79	0.01	1.05	120
Atriplex codonocarpa	5.83	0.02	0.31	6
Atriplex holocarpa	22.08	0.13	0.06	8
Atriplex nummularia	7.14	0.01	1.49	127
Atriplex quinnii	2.80	0.01	0.01	5
Atriplex semilunaris	11.83	0.14	0.08	10
Atriplex vesicaria	14.98	0.02	1.61	65
Maireana brevifolia	42.88	0.10	5.18	57
Maireana georgei	7.72	0.03	1.06	32
Maireana pyramidata	29.65	0.03	5.79	145
MIMOSACEAE				
Acacia acuminata	0.88		0.22	
Acacia aneura	9.03	0.01	0.15	110
Acacia murrayana	11.66	0.01	2.00	240
Acacia tetragonophylla	2.59	0.01	0.45	79
POLYGONACEAE				
Rumex vesicarius	39.01	0.54	0.28	18
TOTAL	**300.00**	**1.42**	**29.16**	

APPENDIX 4.9: **'94 Seeding, Top Batter Granny Waste Dump - Mean density, percentage cover, Importance Value Index (IVI), and plant height for species recorded (n=5). Three assessments between November '96 and October '98.**

'94 Seeding, Top Batter Granny Waste Dump - assessed mid-November '96, 32 months after seeding.

FAMILY Species	**IVI**	**Density (no. m^{-2})**	**% Cover**	**Ht (cm)**
AMARANTHACEAE				
Ptilotus exaltatus	2.02	0.010	0.002	23
Ptilotus obovatus	3.84	0.010	0.120	40
CAESALPINIACEAE				
Senna helmsii	15.04	0.020	0.360	53
Senna filifolia	5.06	0.020	0.070	32
CHENOPODIACEAE				
Atriplex codonocarpa	108.82	1.550	0.578	11
Atriplex holocarpa	43.72	0.440	0.778	19
Atriplex semilunaris	7.54	0.040	0.034	14
Atriplex vesicaria	4.71	0.020	0.036	19
Maireana brevifolia	10.58	0.070	0.016	14
Maireana georgei	35.36	0.050	2.860	59
Maireana pyramidata	1.13		0.036	
Maireana triptera	17.24	0.010	1.700	67
Maireana sp. 3	7.20	0.010	0.180	17
MIMOSACEAE				
Acacia aneura	2.98	0.010	0.030	17
Acacia tetragonophylla	5.24	0.020	0.200	32
Acacia victoriae	13.88	0.020	0.500	79
POACEAE				
Stipa nitida	15.66	0.080	0.148	13
TOTAL	**300.00**	**2.380**	**7.648**	

'94 Seeding, Top Batter Granny Waste Dump - assessed October '97, 44 months after seeding.

FAMILY Species	**IVI**	**Density (no. m^{-2})**	**% Cover**	**Ht (cm)**
AMARANTHACEAE				
Ptilotus obovatus	5.18	0.010	0.230	38
BRASSICACEAE				
Carrichtera annua	9.84	0.080	0.052	12
CAESALPINIACEAE				
Senna helmsii	13.26	0.020	0.290	53
Senna nemophila	7.44	0.020	0.200	35
CHENOPODIACEAE				
Atriplex codonocarpa	132.38	0.790	0.936	10
Atriplex holocarpa	7.98	0.040	0.050	15
Atriplex semilunaris	0.08		0.010	
Atriplex vesicaria	4.90	0.020	0.070	15
Enchylaena tomentosa	10.62	0.010	0.370	32
Maireana brevifolia	9.74	0.070	0.090	19
Maireana georgei	37.04	0.050	2.840	64
Maireana pyramidata	4.88	0.010	0.100	30
Maireana triptera	14.01	0.010	1.756	70
Salsola kali	2.08	0.010	0.010	16
MIMOSACEAE				
Acacia aneura	4.82	0.010	0.030	16
Acacia tetragonophylla	9.40	0.020	0.290	48
Acacia victoriae	22.36	0.020	1.240	107
POLYGONACEAE				
Rumex vesicarius	2.04	0.010	0.002	14
POACEAE				
Enneapogon caerulescens	1.56		0.060	
TOTAL	**300.00**	**1.200**	**8.626**	

'94 Seeding, Top Batter Granny Waste Dump - assessed October '98, 56 months after seeding.

FAMILY Species	**IVI**	**Density (no. m^{-2})**	**% Cover**	**Ht (cm)**
AMARANTHACEAE				
Ptilotus obovatus	13.11	0.020	0.212	22
BRASSICACEAE				
Carrichtera annua	27.60		2.020	
CAESALPINIACEAE				
Senna helmsii	11.79	0.020	0.260	52
Senna filifolia	17.02	0.020	0.220	36
CHENOPODIACEAE				
Atriplex codonocarpa	27.58	0.070	0.205	8
Atriplex holocarpa	7.51	0.030	0.033	7
Atriplex vesicaria	8.17	0.010	0.010	10
Enchylaena tomentosa	9.09	0.010	0.250	23
Maireana brevifolia	17.25	0.110	0.095	26
Maireana georgei	51.54	0.050	1.900	53
Maireana pyramidata	1.00		0.050	
Maireana triptera	4.39	0.010	0.180	42
MIMOSACEAE				
Acacia aneura	2.09	0.010	0.020	101
Acacia tetragonophylla	15.90	0.020	0.380	42
Acacia victoriae	23.07	0.020	1.270	113
POLYGONACEAE				
Rumex vesicarius	62.86	0.440	0.192	17
TOTAL	**300.00**	**0.840**	**7.297**	

APPENDIX 4.10: Sunrise Dam Gold Mine, 1997 Rehabilitation: Importance Value Index (IVI), plant density, % ground cover, and mean maximum plant height for revegetation species recorded 17-19 May 1999 (n=4).

Unfertilised treatment

FAMILY Species	**IVI**	**Density (no. m^{-2})**	**% Cover**	**Height (cm)**
AMARANTHACEAE				
Hemichroa diandra	5.24	0.025	0.075	30
CHENOPODIACEAE				
Atriplex amnicola	1.79	0.013	0.088	66
Atriplex codonocarpa	42.90	0.125	1.700	23
Atriplex holocarpa	3.98	0.025	0.063	12
Atriplex nummularia	1.28	0.013	0.013	13
Atriplex semibaccata	14.72	0.075	0.775	10
Atriplex vesicaria	36.70	0.238	0.756	23
Dissocarpos paradoxus	1.28	0.013	0.013	10
Maireana georgei	4.34	0.038	0.113	18
Maireana pentatropis	4.85	0.025	0.163	46
Maireana pyramidata	5.81	0.013	0.010	18
Maireana tomentosa	14.98	0.050	0.500	39
Maireana triptera	7.08	0.025	0.250	32
Sclerolaena densiflora	37.71	0.113	1.113	14
Sclerolaena fimbriolata	42.70	0.100	1.163	31
FRANKENIACEAE				
Frankenia pauciflora	15.14	0.113	0.213	14
ZYGOPHYLLACEAE				
Zygophyllum aurantiacum	54.65	0.075	0.800	20
Zygophyllum compressum	4.85	0.025	0.175	16
TOTAL	**300.00**	**1.104**	**7.983**	

100 kg ha^{-1} fertiliser treatment

FAMILY Species	**IVI**	**Density (no. m^{-2})**	**% Cover**	**Height (cm)**
CHENOPODIACEAE				
Atriplex codonocarpa	48.17	0.175	1.306	20
Atriplex holocarpa	12.21	0.125	0.163	15
Atriplex lindleyi	25.79	0.050	0.988	32
Atriplex nana	9.10	0.013	0.500	32
Atriplex semibaccata	7.12	0.025	0.125	12
Atriplex vesicaria	16.04	0.063	0.294	27
Halosarcia thin leaf	2.03	0.013	0.038	24
Maireana georgei	30.48	0.100	0.645	33
Maireana pentatropis	9.10	0.038	0.144	39
Maireana pyramidata	8.21	0.025	0.225	48
Maireana tomentosa	2.90	0.013	0.063	35
Maireana triptera	3.83	0.013	0.025	15
Sclerolaena densiflora	27.39	0.163	0.719	12
Sclerolaena fimbriolata	42.27	0.163	0.994	21
FRANKENIACEAE				
Frankenia pauciflora	18.55	0.100	0.188	15
POACEAE				
Enneapogon caerulescens	4.02	0.013	0.038	23
ZYGOPHYLLACEAE				
Zygophyllum aurantiacum	10.59	0.025	0.725	29
Zygophyllum compressum	22.19	0.138	0.338	14
TOTAL	**300.00**	**1.255**	**7.518**	

APPENDIX 4.11: Sunrise Dam Gold Mine, 1998 Rehabilitation: IVI, plant density, % cover, and height for revegetation species; May 1999 (n=4).

Unfertilised treatment

FAMILY Species	**IVI**	**Density (no. m^{-2})**	**% Cover**	**Height (cm)**
AIZOACEAE				
Disphyma crassifolium	15.62	0.075	0.401	9
AMARANTHACEAE				
Hemichroa diandra	1.23	0.004	0.038	43
BRASSICACEAE				
Carrichtera annua	0.53	0.004	0.001	2
CHENOPODIACEAE				
Atriplex bunburyana	6.96	0.038	0.140	26
Atriplex codonocarpa	19.63	0.088	0.278	11
Atriplex holocarpa	1.66	0.012	0.037	10
Atriplex lindleyi	17.04	0.067	0.327	18
Atriplex nummularia	3.65	0.017	0.023	11
Atriplex semibaccata	0.58	0.004	0.004	20
Atriplex semilunaris	0.40	0.004	0.004	13
Atriplex vesicaria	22.92	0.138	0.398	20
Dissocarpos paradoxus	0.61	0.004	0.021	22
Enchylaena tomentosa	22.28	0.125	0.585	24
Halosarcia 'Angel Fish Is.'	6.77	0.033	0.062	12
Maireana georgei	11.84	0.058	0.120	11
Maireana pyramidata	56.38	0.312	1.004	28
Maireana tomentosa	3.84	0.008	0.171	50
Maireana triptera	2.42	0.012	0.038	14
Maireana villosa	1.08	0.004	0.021	19
Salsola kali	0.59		0.042	
Sclerolaena densiflora	6.29	0.012	0.429	16
Sclerolaena fimbriolata	5.83	0.012	0.304	37
FRANKENIACEAE				
Frankenia pauciflora	29.56	0.183	0.297	15
MALVACEAE				
Lawrencia sp.	0.80	0.004	0.017	29
MIMOSACEAE				
Acacia tysonii	1.71	0.012	0.008	9
PAPILIONACEAE				
Swainsona rostellifera	4.26	0.021	0.048	16
POACEAE				
Enneapogon caerulescens	0.54	0.004	0.004	28
Eragrostis dielsii	41.22	0.362	0.969	9
Stipa sp.	5.05	0.021	0.058	30
ZYGOPHYLLACEAE				
Zygophyllum aurantiacum	1.05	0.008	0.010	8
Zygophyllum compressum	7.66	0.033	0.055	11
TOTAL	**300.00**	**1.679**	**5.914**	

100 kg ha^{-1} fertiliser treatment

FAMILY Species	**IVI**	**Density (no. m^{-2})**	**% Cover**	**Height (cm)**
AIZOACEAE				
Disphyma crassifolium	46.22	0.188	0.932	8
AMARANTHACEAE				
Hemichroa diandra	3.14	0.021	0.121	38
CHENOPODIACEAE				
Atriplex bunburyana	2.40	0.008	0.017	18
Atriplex codonocarpa	29.35	0.088	0.341	13
Atriplex holocarpa	0.92	0.004	0.033	24
Atriplex lindleyi	6.98	0.029	0.238	20
Atriplex nummularia	2.06	0.017	0.042	18
Atriplex semibaccata	4.24	0.004	0.100	5
Atriplex vesicaria	33.51	0.179	0.644	19
Enchylaena tomentosa	14.82	0.067	0.508	30
Halosarcia 'Angel Fish Is.'	14.75	0.033	0.123	15
Maireana georgei	11.18	0.050	0.297	15
Maireana pentatropis	4.81	0.008	0.071	47
Maireana pyramidata	30.60	0.162	0.509	28
Maireana triptera	1.97	0.012	0.029	12
Salsola kali	7.94	0.042	0.308	31
Sclerolaena cuneata	1.11	0.004	0.029	15
Sclerolaena fimbriolata	3.46	0.012	0.112	27
FRANKENIACEAE				
Frankenia pauciflora	28.01	0.154	0.243	15
MALVACEAE				
Lawrencia sp.	0.69	0.004	0.042	33
MIMOSACEAE				
Acacia tysonii	1.87	0.017	0.050	22
PAPILIONACEAE				
Swainsona rostellifera	4.67	0.029	0.096	17
POACEAE				
Enneapogon caerulescens	0.68	0.004	0.004	18
Eragrostis dielsii	38.08	0.312	0.716	8
Stipa sp.	0.55	0.004	0.012	16
ZYGOPHYLLACEAE				
Zygophyllum aurantiacum	2.12	0.033	0.021	5
Zygophyllum compressum	3.87	0.017	0.138	15
TOTAL	**300.00**	**1.502**	**5.776**	

APPENDIX 5.0: Analogue Communities in the Northeastern Goldfields - Mean plant density, percentage cover, plant height and Importance Value Index (IVI) for species recorded from seven analogue sites.

Atriplex bunburyana **Shrubland, assessed October '97 (n=7).**

FAMILY Species	**IVI**	**Density (no. m^{-2})**	**% Cover**	**Ht (cm)**
AMARANTHACEAE				
Ptilotus obovatus	18.90	0.114	1.614	65
CAESALPINIACEAE				
Senna filifolia	1.07	0.007	0.021	52
CHENOPODIACEAE				
Atriplex bunburyana	191.57	0.793	25.857	73
Atriplex codonocarpa	1.38	0.014	0.011	6
Atriplex vesicaria	2.36	0.007	0.157	43
Enchylaena tomentosa	5.89	0.043	0.236	44
Maireana aphylla	1.09	0.007	0.029	33
Maireana appressa	1.19	0.007	0.021	42
Maireana triptera	39.64	0.386	1.130	26
Maireana pyramidata	16.19	0.064	1.600	57
Sclerolaena cuneata	2.19	0.014	0.064	28
MIMOSACEAE				
Acacia aneura	2.20	0.007	0.093	100
PROTEACEAE				
Hakea preissii	10.00	0.036	1.861	103
SOLANACEAE				
Solanum lasiophyllum	6.41	0.043	0.143	20
TOTAL	**300.00**	**1.542**	**32.837**	

***Maireana pyramidata* Shrubland, assessed October '97 (n=6).**

FAMILY Species	**IVI**	**Density (no. m^{-2})**	**% Cover**	**Ht (cm)**
CHENOPODIACEAE				
Atriplex bunburyana	19.20	0.083	1.717	59
Atriplex codonocarpa	42.95	0.867	0.182	8
Atriplex germinants	0.68	0.017	0.002	4
Halosarcia sp.	2.52	0.008	0.358	14
Maireana carnosa	13.18	0.458	0.213	8
Maireana convexa	3.82	0.008	0.008	20
Maireana pyramidata	93.75	0.442	6.883	45
Maireana tomentosa	1.37	0.008	0.008	19
Maireana triptera	9.45	0.142	0.443	17
Maireana germinants	4.98	0.100	0.017	4
Maireana sp.	0.56	0.008	0.008	20
Sclerolaena cuneata	12.28	0.242	0.400	8
Sclerolaena densiflora	9.66	0.208	0.063	6
Sclerolaena diacantha	4.39	0.067	0.020	6
Sclerolaena eriacantha	17.83	0.283	0.087	7
Sclerolaena sp.	3.90	0.058	0.003	3
MALVACEAE				
Sida sp.	1.19	0.017	0.002	5
MIMOSACEAE				
Acacia aneura	29.45	0.033	5.633	191
Acacia tetragonophylla	4.27		1.300	
MYOPORACEAE				
Eremophila sp.	1.39		0.292	
PITTOSPORACEAE				
Pittosporum phylliraeoides	6.42	0.017	1.138	22
POACEAE				
Stipa nitida	2.10	0.042	0.002	2
annual grasses	12.35		3.572	
PROTEACEAE				
Hakea arida	1.18		0.358	
SOLANACEAE				
Solanum lasiophyllum	1.20	0.008	0.002	3
TOTAL	**300.00**	**3.117**	**22.712**	

Atriplex vesicaria **Low Shrubland, assessed October '97 (n=7).**

FAMILY Species	**IVI**	**Density (no. m^{-2})**	**Cover (%)**	**Ht (cm)**
AMARANTHACEAE				
Ptilotus obovatus	1.11	0.007	0.029	23
ASTERACEAE				
Cratystylis subspinescens	2.56	0.007	0.129	48
CAESALPINIACEAE				
Senna chatelainiana	2.00	0.007	0.014	11
Senna glaucifolia	4.44	0.007	0.571	95
CHENOPODIACEAE				
Atriplex bunburyana	3.49	0.007	0.293	45
Atriplex vesicaria	133.80	0.514	6.393	33
Maireana appressa	28.59	0.329	0.241	5
Maireana glomerifolia	2.02	0.007	0.133	21
Maireana triptera	72.19	0.550	1.681	20
Maireana pyramidata	12.93	0.036	0.664	44
Sclerolaena obliquicuspis	7.16	0.043	0.060	13
FRANKENIACEAE				
Frankenia cinerea	1.81	0.007	0.071	20
MALVACEAE				
Sida calyxhymenia	2.46	0.014	0.033	49
Sida corrugata	0.50	0.007	0.007	5
MIMOSACEAE				
Acacia aneura	2.87	0.000	0.307	
MYOPORACEAE				
Eremophila granitica	5.11	0.007	0.314	56
POACEAE				
Aristida contorta	2.00	0.021	0.004	3
Enneapogon caerulescens	10.75	0.129	0.044	10
PROTEACEAE				
Hakea preissii	0.90	0.007	0.014	6
SOLANACEAE				
Solanum lasiophyllum	3.20	0.021	0.043	18
TOTAL	**300.00**	**1.727**	**11.045**	

***Maireana triptera* Low Shrubland, assessed October '97 (n=5).**

FAMILY Species	**IVI**	**Density (m^2)**	**Cover (%)**	**Ht (cm)**
AMARANTHACEAE				
Ptilotus exaltatus	0.90	0.010	0.002	1
Ptilotus obovatus	11.71	0.060	0.590	40
CHENOPODIACEAE				
Atriplex bunburyana	7.88	0.020	0.680	109
Enchylaena tomentosa	8.19	0.070	0.360	42
Maireana georgei	1.68	0.010	0.050	37
Maireana triptera	179.40	1.700	7.606	30
Maireana pyramidata	9.88	0.010	1.100	90
Sclerolaena cuneata	2.44	0.020	0.016	14
Sclerolaena diacantha	1.49	0.010	0.010	7
Sclerolaena obliquicuspis	16.90	0.140	0.230	8
MIMOSACEAE				
Acacia aneura	14.34	0.020	2.130	199
Acacia tetragonophylla	7.38	0.010	1.250	175
MYOPORACEAE				
Eremophila scoparia	10.00	0.010	1.780	265
POACEAE				
Enneapogon caerulescens	18.60	0.350	0.330	20
SOLANACEAE				
Solanum lasiophyllum	9.54	0.060	0.440	36
TOTAL	**300.00**	**2.500**	**16.574**	

Mixed *Acacia* Shrubland, assessed October '97 (n=8).

FAMILY Species	**IVI**	**Density (no. m^{-2})**	**Cover (%)**	**Ht (cm)**
AMARANTHACEAE				
Ptilotus obovatus	16.29	0.038	0.248	93
CAESALPINIACEAE				
Senna cardiosperma	6.72	0.006	0.381	115
Senna filifolia	100.75	0.106	8.756	159
Senna sturtii	6.65	0.006	0.400	123
CHENOPODIACEAE				
Enchylaena tomentosa	5.08	0.006	0.019	63
Maireana georgei	5.68	0.013	0.044	20
Maireana triptera	9.61	0.019	0.119	18
MIMOSACEAE				
Acacia aneura	3.43		0.719	
Acacia ramulosa	3.24		1.300	
Acacia resinomarginea	35.19	0.038	4.206	139
MYOPORACEAE				
Eremophila oldfieldii	4.11		1.000	
SAPINDACEAE				
Dodonaea lobulata	99.31	0.125	6.444	108
SOLANACEAE				
Solanum lasiophyllum	3.99	0.006	0.031	42
TOTAL	**300.00**	**0.363**	**23.667**	

***Frankenia* Low Shrubland, assessed October '97 (n=9).**

FAMILY Species	**IVI**	**Density (no. m^{-2})**	**Cover (%)**	**Ht (cm)**
AIZOACEAE				
Disphyma crassifolium	50.72	0.506	0.907	7
Gunniopsis quadrifida	8.98	0.033	0.761	35
CHENOPODIACEAE				
Atriplex nana	13.12	0.094	0.561	32
Atriplex vesicaria	81.58	0.622	4.291	32
Halosarcia pergranulata	3.94	0.011	0.561	64
Maireana amoena	15.99	0.078	1.333	19
Maireana appressa	0.75	0.006	0.022	18
Maireana tomentosa	7.33	0.061	0.194	24
Sclerolaena eurotioides	0.46	0.006	0.006	23
Sclerolaena fimbriolata	3.48	0.028	0.031	10
FRANKENIACEAE				
Frankenia sp. A	5.24	0.044	0.272	34
Frankenia sp. B	13.29	0.067	1.600	28
Frankenia pauciflora	52.68	0.361	2.328	30
MALVACEAE				
Lawrencia helmsii	1.23	0.006	0.094	36
MYOPORACEAE				
Eremophila miniata	5.71	0.017	0.767	110
POACEAE				
Aristida contorta	7.78		1.322	
Enneapogon caerulescens	14.86	0.233	0.594	25
Eragrostis dielsii	6.50	0.106	0.200	20
Eragrostis eriopoda	2.23	0.022	0.094	42
SOLANACEAE				
Solanum orbiculatum	4.19	0.011	0.506	43
TOTAL	**300.00**	**2.312**	**16.444**	

Mulga Woodland, assessed September '97 (n=15).

FAMILY Species	**IVI**	**Density (no. m^{-2})**	**Cover (%)**	**Ht (cm)**
AMARANTHACEAE				
Ptilotus aervoides	4.66		0.384	
Ptilotus exaltatus	3.25		0.141	
Ptilotus helipteroides	17.96	0.040	0.164	8
Ptilotus obovatus	33.20	0.361	2.119	44
ASTERACEAE				
Sonchus oleraceus	0.94		0.011	
CHENOPODIACEAE				
Atriplex quadrivalvata	2.36	0.071	0.023	9
Atriplex quinnii	0.55	0.004	0.014	24
Atriplex semibaccata	1.06	0.007	0.009	21
Atriplex semilunaris	0.92	0.011	0.182	36
Enchylaena tomentosa	13.04	0.150	1.634	42
Maireana appressa	3.79	0.050	0.114	29
Maireana convexa	3.80	0.068	0.518	59
Maireana georgei	3.86	0.054	0.314	32
*M. georgei * E. tomentosa*	0.55	0.004	0.125	55
Maireana planifolia	5.86	0.139	0.047	19
Maireana pyramidata	0.91	0.004	0.446	88
Maireana sedifolia	0.71	0.004	0.286	85
Maireana triptera	0.42	0.004	0.032	28
Rhagodia eremaea	3.24	0.014	0.800	77
Salsola kali	0.46	0.007	0.029	24
Sclerolaena cuneata	3.22	0.057	0.124	9
Sclerolaena densiflora	2.63	0.089	0.054	12
Sclerolaena diacantha	7.11	0.061	0.049	7
Sclerolaena eriacantha	5.01	0.086	0.038	9
Sclerolaena eurotioides	0.84	0.011	0.009	8
CHLOANTHACEAE				
Spartothamnella teucriiflora	1.86	0.018	0.139	59
GOODENIACEAE				
Scaevola spinescens	1.98	0.014	0.465	79

cont'd Mulga Woodland, assessed September '97 (n=15).

FAMILY Species	**IVI**	**Density (no. m^{-2})**	**Cover (%)**	**Ht (cm)**
MALVACEAE				
Abutilon cryptopetalum	8.44		0.161	
Sida calyxhymenia	41.89	0.418	2.884	43
Sida corrugata	0.30	0.007	0.018	4
MIMOSACEAE				
Acacia acuminata	1.38		0.650	
Acacia aneura	49.14	0.061	22.193	347
Acacia coolgardiensis	2.02	0.004	1.021	215
Acacia linophylla	6.12	0.011	1.954	112
Acacia tetragonophylla	7.13	0.036	2.177	159
MYOPORACEAE				
Eremophila latrobei	3.58	0.025	0.384	88
Eremophila oldfieldii ssp. *angustifolia*	4.55	0.011	1.596	328
Eremophila platycalyx	1.36	0.004	0.596	175
Eremophila serrulata	1.69	0.007	0.393	145
POACEAE				
annual grasses	29.64		9.950	
POLYGONACEAE				
Rumex vesicarius	0.28	0.004	0.004	14
PROTEACEAE				
Hakea arida	0.75		0.339	
SALVINIACEAE				
Salvinia molesta	0.34	0.007	0.002	4
SOLANACEAE				
Solanum lasiophyllum	12.00	0.096	0.454	29
Solanum nigrum	2.79	0.029	0.021	9
Solanum sp.	1.59	0.018	0.296	76
ZYGOPHYLLACEAE				
Zygophyllum aurantiacum	0.79	0.014	0.004	4
TOTAL	**300.00**	**2.040**	**53.367**	

Mulga Woodland, assessed October '98 (n=15).

FAMILY Species	**Density** **no. m^{-2}**	**Mean** **% cover**	**Mean** **IVI**	**Mean** **ht. (cm)**
ADIANTACEAE				
Cheilanthes austrotenuifolia	0.057	0.050	6.894	10
AIZOACEAE				
Tetragonia tetragonoides	0.004	0.002	0.178	6
AMARANTHACEAE				
Ptilotus exaltatus	0.018	0.005	1.049	8
Ptilotus helipteroides	0.071	0.029	12.850	15
Ptilotus obovatus	0.282	2.106	35.776	52
CHENOPODIACEAE				
Atriplex quadrivalvata	0.189	0.054	5.779	10
Atriplex semilunaris	0.086	0.074	2.100	20
Enchylaena tomentosa	0.139	1.032	14.467	60
Maireana georgei	0.118	0.604	10.236	46
Maireana planifolia	0.011	0.011	0.404	30
Maireana pyramidata	0.004	0.507	1.436	86
Maireana sedifolia	0.004	0.339	1.071	82
Maireana triptera	0.007	0.029	0.936	45
Rhagodia eremaea	0.032	0.599	4.845	91
Sclerolaena cuneata	0.011	0.002	0.496	6
Sclerolaena diacantha	0.139	0.029	3.643	9
Sclerolaena eriacantha	0.075	0.026	3.384	6
CHLOANTHACEAE				
Spartothamnella teucriiflora	0.011	0.029	1.285	73
GOODENIACEAE				
Scaevola spinescens	0.007	0.275	1.079	57
MALVACEAE				
Abutilon sp.	0.382	0.099	13.664	10
Sida calyxhymenia	0.414	2.154	52.426	39

contd Mulga Woodland, assessed October '98 (n=15).

FAMILY Species	**Mean** **no. m^{-2}**	**Mean** **% cover**	**Mean** **IVI**	**Mean** **ht. (cm)**
MIMOSACEAE				
Acacia acuminata		0.507	1.229	
Acacia aneura	0.057	19.254	54.836	429
Acacia coolgardiensis		0.554	1.064	
Acacia linophylla		0.018	0.053	
Acacia ramulosa		2.543	6.609	
Acacia tetragonophylla	0.032	1.889	8.719	148
MYOPORACEAE				
Eremophila latrobei	0.025	0.239	4.798	67
Eremophila oldfieldii ssp. *angustifolia*	0.011	1.789	7.086	322
Eremophila platycalyx	0.007	0.782	2.639	198
Eremophila serrulata	0.007	0.343	1.629	134
POACEAE				
annual grasses		8.252	18.323	
PROTEACEAE				
Hakea preissii		0.246	0.730	
SALVINIACEAE				
Salvinia molesta	0.011	0.004	0.249	7
SOLANACEAE				
Solanum lasiophyllum	0.071	0.202	13.846	23
Solanum orbiculatum	0.021	0.039	2.909	58
ZYGOPHYLLACEAE				
Zygophyllum aurantiacum	0.007	0.003	1.227	8
TOTAL	**2.310**	**44.719**	**300.000**	

APPENDIX 6.0: Seed mixture composition and individual seeding rates applied over rehabilitation areas in the Eastern Goldfields between 1996 and 1998.

General Exploration Rehabilitation and Drill Line Trial, and Sump Hole Trial: seeded 6 May 1996.

FAMILY Species	**Explor. / Drill Line seed rate (kg ha^{-1})**	**Sump Hole Trial seed rate (kg ha^{-1})**	**Actual Germ. %**
AMARANTHACEAE			
Ptilotus obovatus	0.18		na
CAESALPINIACEAE			
Senna artemisioides	0.18		74.0
Senna filifolia	0.36		57.5
CHENOPODIACEAE			
Atriplex bunburyana	0.12	0.35	57.6
Atriplex codonocarpa	0.21	1.15	40.0
Atriplex nummularia	0.27	1.10	67.5
Atriplex semibaccata	0.15	0.75	78.6
Atriplex vesicaria	0.27	1.30	77.5
Enchylaena tomentosa	0.21	1.25	29.0
Maireana brevifolia	0.15	0.75	3.8
Maireana convexa	0.34		80.8
Maireana georgei	0.36	1.25	75.0
Maireana pentatropis	0.02	1.10	53.9
Maireana sedifolia	0.02	1.10	7.8
Maireana tomentosa	0.21	1.10	66.2
Maireana triptera	0.27	1.25	50.0
MIMOSACEAE			
Acacia acuminata	0.39	1.20	3.8
Acacia aneura	0.33		35.4
Acacia hemiteles	0.21	0.55	33.8
Acacia colletioides	0.39		9.5
MYOPORACEAE			
Eremophila glabra	0.15		0.0
Eremophila maculata	0.33		0.0
MYRTACEAE			
Eucalyptus lesouefii	0.21		78.7
Eucalyptus salicola	0.03	0.25	92.4
Eucalyptus salmonophloia	0.06		86.3
Eucalyptus salubris	0.06	0.55	85.0
Eucalyptus straticalyx	0.06		83.8
PITTOSPORACEAE			
Pittosporum phylliraeoides	0.18		72.9
SAPINDACEAE			
Dodonaea lobulata	0.12		45.3
Dodonaea viscosa	0.09		50.6
TOTAL	**5.93**	**15.00**	

Crusher Pad batter: seeded 7 May 1997.

FAMILY Species	**Seed Rate** **(kg ha^{-1})**	**Actual Germ.** **%**
CAESALPINIACEAE		
Senna artemisioides	0.20	34.1
Senna filifolia	0.28	42.5
CASUARINACEAE		
Casuarina cristata	0.30	66.3
CHENOPODIACEAE		
Atriplex bunburyana	0.10	53.6
Atriplex codonocarpa	0.75	80.0
Atriplex nummularia	0.60	64.0
Atriplex semibaccata	0.15	87.0
Atriplex vesicaria	0.40	86.6
Enchylaena tomentosa	0.50	72.9
Maireana brevifolia	0.10	18.4
Maireana carnosa	0.15	65.8
Maireana georgei	0.40	86.2
Maireana pentatropis	0.40	86.5
Maireana triptera	0.40	86.7
MIMOSACEAE		
Acacia burkittii	0.30	78.8
Acacia aneura	0.30	56.2
Acacia hemiteles	0.30	59.5
Acacia tetragonophylla	0.30	55.0
MYOPORACEAE		
Eremophila scoparia	0.40	2.1
Eremophila spectabilis	0.40	18.0
MYRTACEAE		
Eucalyptus lesouefii	0.20	97.5
Eucalyptus salmonophloia	0.10	87.5
Eucalyptus salubris	0.10	89.3
Eucalyptus striaticalyx	0.10	81.8
PITTOSPORACEAE		
Pittosporum phylliraeoides	0.50	57.3
SAPINDACEAE		
Dodonaea lobulata	0.25	31.4
Dodonaea viscosa	0.25	39.4
TOTAL	**8.23**	

Tailings Storage Facility batter: seeded 7 May 1997.

FAMILY Species	**Seed Rate** **(kg ha^{-1})**	**Actual Germ.** **%**
CHENOPODIACEAE		
Atriplex bunburyana	0.10	53.6
Atriplex codonocarpa	0.80	80.0
Atriplex nummularia	0.70	64.0
Atriplex semibaccata	0.60	87.0
Atriplex vesicaria	0.70	86.6
Enchylaena tomentosa	0.50	72.9
Maireana brevifolia	0.10	18.4
Maireana carnosa	0.40	65.8
Maireana georgei	0.70	86.2
Maireana pentatropis	0.70	86.5
Maireana triptera	0.70	86.7
MIMOSACEAE		
Acacia hemiteles	0.60	59.5
MYOPORACEAE		
Eremophila spectabilis	1.00	18.0
TOTAL	**7.60**	

Evaporation Pond batter - seeded 22 April 1998.

FAMILY Species	**Seed Rate** **(kg ha^{-1})**	**Actual Germ.** **%**
CHENOPODIACEAE		
Atriplex bunburyana	0.10	9.0
Atriplex codonocarpa	0.80	41.0
Atriplex nummularia	0.70	93.0
Atriplex semibaccata	0.60	53.0
Atriplex semilunaris	0.10	70.0
Atriplex vesicaria	0.70	78.0
Enchylaena tomentosa	0.50	32.0
Maireana brevifolia	0.10	5.0
Maireana georgei	0.70	100.0
Maireana pentatropis	0.70	100.0
Maireana pyramidata	0.40	75.0
Maireana tomentosa	0.30	0.0
Maireana triptera	0.70	62.0
MIMOSACEAE		
Acacia hemiteles	0.60	77.0
MYOPORACEAE		
Eremophila scoparia	0.50	0.0
Eremophila spectabilis	0.50	0.0
TOTAL	**8.00**	

APPENDIX 7.0: Eastern Goldfields: Seed quality and viability for species sown on rehabilitation areas between 1996 and 1998.

1996 SEED MIXTURE Listed are purity of the seed sample, % of sound seeds, final germination % and actual germination % (% sound seeds x final germ % / 100).

FAMILY Species	**seed / fruit**	**% Purity**	**% Sound Seeds**	**% Final Germ.**	**% Actual Germ.**
AMARANTHACEAE					
Ptilotus obovatus KS9638	fruits	77.0	4.8	na	
CAESALPINACEAE					
Senna filifolia NS11036	seeds	100.0	100.0	74.0	74.0
Senna filifolia KS 8951					
(scarified)	seeds	100.0	93.0	42.5	39.5
(untreated)	seeds	98.0	100.0	57.5	57.5
CHENOPODIACEAE					
Atriplex bunburyana	fruits	37.6	66.8	66.0	57.6
	seeds			86.3	
Atriplex nummularia	fruits	93.8	72.0	66.3	67.5
NS13939	seeds			93.8	
Atriplex semibaccata	fruits	100.0	98.3	53.8	78.6
KS 8669	seeds			80.0	
Atriplex vesicaria	fruits	78.0	81.6	62.5	77.5
KS 7728	seeds			95.0	
Enchylaena tomentosa	fruits	100.0	97.0	0.0	0.0
NS12957	seeds			0.0	
Enchylaena tomentosa	fruits	100.0	89.9	1.3	29.2
NS11969	seeds			32.5	
Maireana brevifolia	fruits	92.8	43.6	11.3	3.8
NS13343	seeds			8.8	
Maireana convexa	fruits	87.0	98.0	40.0	80.8
KS 8948	seeds			82.5	
Maireana pentatropis	fruits	80.0	73.6	28.8	53.9
	seeds			73.3	
Maireana sedifolia	fruits	84.8	41.4	6.3	7.8
KS 8630	seeds			18.8	
MIMOSACEAE					
Acacia acuminata NS11033	seeds	100.0	100.0	3.8	3.8
Acacia aneura NS14213	seeds	100.0	94.4	37.5	35.4
Acacia colletioides NS9546	seeds	100.0	83.7	11.3	9.5
Acacia hemiteles NS11411	seeds	100.0	95.0	33.8	

cont'd 1996 SEED MIXTURE Listed are purity of the seed sample, % of sound seeds, final germination % and actual germination % (% sound seeds x final germ % / 100).

FAMILY Species	**seed / fruit**	**% Purity**	**% Sound Seeds**	**% Final Germ.**	**% Actual Germ.**
MYOPORACEAE					
Eremophila glabra KS 9243	fruits	100.0		0.0	0.0
Eremophila maculata	fruits	100.0	25.0	0.0	0.0
MYRTACEAE					
Eucalyptus lesouefii NS13766	seeds	20.5	98.4	80.0	78.7
Eucalyptus salicola KS 4018	seeds	37.4	92.4	100.0	92.4
E.salmonophloia NS13983	seeds	7.9	90.8	95.0	86.3
Eucalyptus salubris KS-8301	seeds	31.9	97.2	87.5	85.0
E. striaticalyx NS8305	seeds	14.2	90.6	92.5	83.8
PITTOSPORACEAE					
Pittosporum phylliraeoides KS-9188	seeds	100.0	85.8	85.0	72.9
SAPINDACEAE					
Dodonaea lobulata NS11435	seeds	97.0	77.1	58.8	45.3
Dodonaea viscosa NS14270	seeds	98.0	67.5	75.0	50.6

1997 SEED MIXTURE Listed are the purity of the seed sample, % of sound seeds, final germination %, and actual germination % (% sound seeds x final germ % / 100).

FAMILY Species	**Code / Supplier**	**% Purity**	**% Sound Seeds**	**% Final Germ.**	**% Actual Germ.**
CAESALPINIACEAE					
Senna artemisioides	NS-15315	92.6	88.0	38.8	34.1
Senna filifolia	Kimseed	99.9	97.0	43.8	42.5
	NS-11449	98.6			
CASUARINACEAE					
Casuarina cristata	NS-12839	96.3	98.2	67.5	66.3
	Kimseed	96.5	100.0	38.8	38.8
CHENOPODIACEAE					
Atriplex bunburyana	Kimseed	40.0	95.3	56.3	53.6
Atriplex codonocarpa	NS-15102		100.0	80.0	80.0
	Kimseed	88.8	87.0	61.6	53.6
Atriplex nummularia	Kimseed	96.0	68.2	93.8	64.0
Atriplex semibaccata	Kimseed	99.0	95.3	91.3	87.0
Atriplex vesicaria	Kimseed	50.0	89.9	96.3	86.6
Enchylaena tomentosa	NS-13218	100.0	98.8	73.8	72.9
Maireana brevifolia	Kimseed	63.9	27.3	67.5	18.4
Maireana carnosa	NS-15335	51.0	90.8	72.5	65.8
Maireana georgei	NS-15420	99.5	89.5	96.3	86.2
	Kimseed	79.6	97.0	81.3	78.9
Maireana pentatropis	NS-1149	99.9	83.2	92.5	77.0
	Kimseed	89.3	88.7	97.5	86.5
Maireana triptera	NS-15313	98.2	96.3	90.0	86.7
	Kimseed	96.4	91.3	93.3	85.2

cont'd 1997 SEED MIXTURE Listed are the purity of the seed sample, % of sound seeds, final germination %, and actual germination % (% sound seeds x final germ % / 100).

FAMILY Species	**Code/ Supplier**	**% Purity**	**% Sound Seeds**	**% Final Germ.**	**% Actual Germ.**
MIMOSACEAE					
Acacia aneura	Kimseed				
(1) no pre-treatment		92.3	84.4	25.0	21.0
(2) scarified		85.2	62.4	90.0	56.2
Acacia burkittii	Kimseed				
(1) no pre-treatment		98.0	100.0	42.5	42.5
(2) scarified		100.0	100.0	78.8	78.8
Acacia hemiteles	Kimseed				
(1) no pre-treatment		100.0	90.8	22.5	20.4
(2) scarified		97.5	91.5	65.0	59.5
Acacia tetragonophylla					
(1) no pre-treatment	NS-13751	100.0	100.0	55.0	55.0
MYOPORACEAE					
Eremophila scoparia	Kimseed	99.9	4.3		2.1
Eremophila spectabilis	Kimseed	92.0	16.0		18.0
MYRTACEAE					
Eucalyptus lesouefii	Kimseed	13.9	100.0	97.5	97.5
Eucalyptus salmonophloia	NS-15106	7.0	100.0	87.5	87.5
Eucalyptus salubris	NS-15483	2.8	95.2	93.8	89.3
Eucalyptus striaticalyx	NS-8305	5.0	97.6	83.8	81.8
	Kimseed	13.9	96.4	65.0	62.7
PITTOSPORACEAE					
Pittosporum phylliraeoides	NS-13465	98.7	89.8	63.8	57.3
SAPINDACEAE					
Dodonaea lobulata	NS-11435	100.0	71.7	43.8	31.4
Dodonaea viscosa	NS-14773	99.1	97.0	40.0	38.8
	Kimseed	88.5	80.7	48.8	39.4

1998 SEED MIXTURE Listed are the purity of the seed sample, % of sound seeds, final germination %, and actual germination % (% sound seeds x final germ % / 100).

FAMILY Species		**%** **Purity**	**% Sound** **Seeds**	**% Final** **Germ.**	**% Actual** **Germ.**
CAESALPINIACEAE					
Senna artemisioides		99.0	100.0	100	100.0
	boiled			0	0.0
Senna filifolia		100.0	90.0	59	53.1
	boiled			8	7.2
CHENOPODIACEAE					
Atriplex bunburyana		20.0	60.0	15	9.0
Atriplex codonocarpa		98.0	87.0	47	40.9
Atriplex nummularia		84.7	92.6	100	92.6
Atriplex semibaccata		92.6	87.0	61	53.1
Atriplex semilunaris		96.6	87.5	80	70.0
Atriplex vesicaria		87.6	91.7	85	77.9
Enchylaena tomentosa		96.0	71.9	45	32.4
Maireana brevifolia		68.4	100.0	5	5.0
Maireana georgei		92.8	100.0	100	100.0
Maireana pentatropis		100.0	100.0	100	100.0
Maireana pyramidata		98.0	100.0	75	75.0
Maireana tomentosa		70.0	100.0	na	na
Maireana triptera		98.2	95.2	65	61.9
MIMOSACEAE					
Acacia aneura	scarified	99.0	75.0	83	62.2
	unscarified	100.0	96.0	94	90.2
Acacia burkittii	scarified	89.0	80.0	90	72.0
	unscarified	98.0	94.0	95	89.3
Acacia hemiteles	scarified	95.0	90.0	86	77.4
	unscarified	100.0	90.0	17	15.3
Acacia linophylla	scarified	100.0	100.0	32	32.0
	unscarified	100.0	100.0	100	100.0
Acacia murrayana	scarified	98.0	95.0	72	68.4
	unscarified	95.0	100.0	43	43.0
A. tetragonophylla	scarified	100.0	100.0	80	80.0
	unscarified	100.0	99.0	35	34.6
MYRTACEAE					
Eucalyptus lesouefii		na	100.0	25	25.0
Eucalyptus salmonophloia		na	100.0	10	10.0
Eucalyptus salubris		na	100.0	35	35.0
PITTOSPORACEAE					
Pittosporum phylliraeoides		100.0	100.0	100	100.0
SAPINDACEAE					
Dodonaea augustissima		100.0	100.0	25	25.0

APPENDIX 8.0: **Eastern Goldfields: Summarised data (plant density, % cover, Importance Value Index IVI, and plant height) for species recorded within rehabilitation trials; December 1996 to November '01.**

1996 ASSESSMENTS

Drill Line Trial, Treatment 1 (control): December 1996, revegetation age seven months (n=10).

FAMILY Species	**Density (no. m^{-2})**	**% Cover**	**IVI**	**Height (cm)**
AMARANTHACEAE				
Ptilotus obovatus	0.11	0.12	26.11	16
ASTERACEAE				
Waitzia acuminata	0.01	0.01	3.66	10
CAESALPINIACEAE				
Senna artemisioides	0.01	0.00	0.81	3
Senna filifolia	0.04	0.21	17.09	26
CHENOPODIACEAE				
Atriplex sp.	0.01	0.01	2.16	16
Maireana convexa	0.01	0.00	0.93	15
Salsola kali	0.12	0.04	11.10	14
Sclerolaena diacantha	0.01	0.00	1.25	6
Sclerolaena sp.	0.02	0.01	1.87	5
MALVACEAE				
Sida calyxhymenia	0.07	0.03	17.93	8
MIMOSACEAE				
Acacia acuminata	0.01	0.02	7.65	10
Acacia aneura	0.04	0.01	18.79	5
MYOPORACEAE				
Eremophila sp.	0.02	0.02	14.33	13
POACEAE				
grasses	1.40	0.26	173.70	12
ZYGOPHYLLACEAE				
Zygophyllum sp.	0.01	0.00	3.53	4
TOTAL	**1.89**	**0.74**	**300.00**	

Drill Line Trial, Treatment 2 (scarified, not seeded): December 1996, revegetation age seven months (n=10).

FAMILY Species	**Density (no. m^{-2})**	**% Cover**	**IVI**	**Height (cm)**
BRASSICACEAE				
Carrichtera annua	0.03	0.08	15.73	23
CAESALPINIACEAE				
Senna artemisioides	0.01	0.00	3.75	4
Senna filifolia	0.01	0.06	15.08	21
CHENOPODIACEAE				
Atriplex nummularia	0.01	0.00	2.29	4
Maireana georgei	0.01	0.01	2.28	18
Maireana tomentosa	0.01	0.00	5.11	5
Sclerolaena sp.	0.01	0.00	4.53	5
MALVACEAE				
Abutilon sp.	0.01	0.00	2.10	6
MIMOSACEAE				
Acacia aneura	0.01	0.00	1.33	7
Acacia tetragonophylla	0.01	0.00	1.41	4
MYRTACEAE				
Eucalyptus sp. 1	0.03	0.01	6.95	6
Eucalyptus sp. 4	0.03	0.01	20.00	7
POACEAE				
grass sp.	0.60	0.14	150.30	5
SAPINDACEAE				
Heterodendrum sp.	0.01	0.00	1.23	7
SOLANACEAE				
Solanum lasiophyllum	0.02	0.02	4.18	7
Solanum orbiculatum	0.01	0.01	8.06	8
ZYGOPHYLLACEAE				
Zygophyllum sp.	0.11	0.07	55.65	9
TOTAL	**0.90**	**0.44**	**300.00**	

Drill Line Trial, Treatment 3 (scarified, seeded): December '96, revegetation age 7 months (n=10).

FAMILY Species	**Density (no. m^{-2})**	**% Cover**	**IVI**	**Height (cm)**
BRASSICACEAE				
Carrichtera annua	0.02	0.01	1.65	10
CAESALPINIACEAE				
Senna artemisioides	0.04	0.01	7.29	4
Senna filifolia	0.01	0.01	3.60	6
CHENOPODIACEAE				
Atriplex bunburyana	0.18	0.14	28.81	12
Atriplex codonocarpa	0.17	0.19	28.81	6
Atriplex holocarpa	0.02	0.02	4.30	6
Atriplex semibaccata	0.09	0.04	8.90	4
Atriplex vesicaria	0.19	0.05	28.54	6
Maireana convexa	0.09	0.03	6.94	8
Maireana georgei	0.24	0.07	22.23	9
Maireana pentatropis	0.01	0.00	1.52	6
Maireana tomentosa	0.12	0.03	20.23	5
Maireana triptera	0.06	0.01	15.08	6
Salsola kali	0.02	0.07	3.01	17
MALVACEAE				
Abutilon sp.	0.01	0.00	0.99	3
MIMOSACEAE				
Acacia acuminata	0.03	0.02	8.23	6
Acacia aneura	0.02	0.01	3.48	3
Acacia hemiteles	0.01	0.00	2.01	2
Acacia pruinocarpa	0.01	0.01	4.51	17
Acacia sp. 1	0.01	0.01	2.48	11
MYRTACEAE				
Eucalyptus sp. 1	0.17	0.11	24.23	5
Eucalyptus sp. 2	0.01	0.01	3.66	6
Eucalyptus sp. 3	0.06	0.03	13.63	6
Eucalyptus sp. 4	0.02	0.01	5.20	4
POACEAE				
grasses	0.37	0.08	41.14	5
SAPINDACEAE				
Dodonaea sp.	0.01	0.00	1.19	2
SOLANACEAE				
Solanum lasiophyllum	0.01	0.00	2.01	2
ZYGOPHYLLACEAE				
Zygophyllum sp.	0.03	0.01	6.41	8
TOTAL	**2.02**	**0.98**	**300.00**	

Sump Hole Trial, Treatment 1 (control): December 1996, revegetation age seven months (n=10).

FAMILY Species	**Density (no. m^{-2})**	**% Cover**	**IVI**	**Height (cm)**
AMARANTHACEAE				
Ptilotus exaltatus	0.01	0.01	5.16	31
ASTERACEAE				
annual daisies	0.02	0.14	34.80	12
CAESALPINIACEAE				
Senna filifolia	0.05	0.02	18.10	14
CHENOPODIACEAE				
Atriplex bunburyana	0.01	0.10	10.20	69
Atriplex semibaccata	0.01	0.01	4.62	10
Atriplex vesicaria	0.01	0.01	2.04	20
Maireana brevifolia	0.01	0.23	14.30	7
Maireana georgei	0.01	0.01	6.94	17
Maireana tomentosa	0.02	0.02	7.57	14
Sclerolaena cuneata	0.01	0.08	9.20	9
GOODENIACEAE				
Goodenia sp.1	0.02	0.01	4.02	10
Goodenia sp. 2	0.02	0.01	19.00	10
Scaevola spinescens	0.01	0.03	5.90	28
MALVACEAE				
Sida sp.	0.01	0.01	2.67	7
MIMOSACEAE				
Acacia acuminata	0.01	0.00	1.40	7
Acacia hemiteles	0.03	0.02	6.09	7
Acacia germinants	0.01	0.00	4.27	4
MYOPORACEAE				
Eremophila sp.	0.01	0.00	0.96	6
MYRTACEAE				
Eucalyptus sp. 1	0.01	0.00	1.26	4
POACEAE				
grasses	0.57	0.21	128.00	17
SAPINDACEAE				
Dodonaea lobulata	0.02	0.09	9.04	12
SOLANACEAE				
Solanum lasiophyllum	0.01	0.00	4.74	4
TOTAL	**0.89**	**1.01**	**300.00**	

Sump Hole Trial, Treatment 2 (scarified, not seeded): December '96, reveg. age 7 months (n=10).

FAMILY Species	**Density (no. m^{-2})**	**% Cover**	**IVI**	**Height (cm)**
AIZOACEAE				
Tetragonia tetragonoides	0.02	0.01	4.43	7
ASTERACEAE				
annual daisies	0.03	0.06	18.90	11
CAESALPINIACEAE				
Senna filifolia	0.01	0.00	0.74	8
CHENOPODIACEAE				
Atriplex bunburyana	0.15	0.53	35.66	30
Atriplex codonocarpa	0.15	0.83	27.34	18
Atriplex semibaccata	0.20	1.12	56.59	22
Atriplex vesicaria	0.02	0.01	1.36	9
Maireana brevifolia	0.06	0.09	16.45	20
Maireana georgei	0.17	0.19	27.09	23
Maireana sedifolia	0.01	0.01	0.49	16
Maireana tomentosa	0.18	0.18	19.73	10
Salsola kali	0.01	0.15	1.84	40
Sclerolaena obliquicuspis	0.01	0.01	2.35	17
GERANIACEAE				
Erodium crinitum	0.01	0.01	1.79	5
GOODENIACEAE				
Goodenia sp.1	0.01	0.00	5.29	5
Goodenia sp. 2	0.02	0.01	1.14	9
MIMOSACEAE				
Acacia acuminata	0.03	0.01	1.33	7
Acacia aneura	0.00	0.05	3.79	-
Acacia hemiteles	0.01	0.01	0.43	27
Acacia sp.	0.01	0.00	0.33	3
MYRTACEAE				
Eucalyptus salicola	0.11	0.02	3.13	7
Eucalyptus salubris	0.11	0.03	17.38	7
Eucalyptus sp. 2	0.01	0.01	1.30	14
POACEAE				
grasses	0.12	0.07	35.15	13
SAPINDACEAE				
Dodonaea lobulata	0.01	0.00	6.43	6
ZYGOPHYLLACEAE				
Zygophyllum aurantiacum	0.07	0.21	9.58	16
TOTAL	**1.54**	**3.62**	**300.00**	

Sump Hole Trial, Treatment 3 (scarified, seeded): December 1996, revegetation age seven months (n=10).

FAMILY Species	**Density (no. m^{-2})**	**% Cover**	**IVI**	**Height (cm)**
ASTERACEAE				
annual daisies	0.08	0.10	3.34	9
CHENOPODIACEAE				
Atriplex bunburyana	0.59	0.90	33.10	23
Atriplex codonocarpa	1.34	2.69	82.80	13
Atriplex nummularia	0.02	0.08	1.32	4
Atriplex semibaccata	0.59	1.83	43.40	14
Atriplex vesicaria	0.45	0.51	22.70	12
Maireana amoena	0.01	0.00	0.23	8
Maireana brevifolia	0.24	0.34	13.20	18
Maireana georgei	0.62	0.45	23.90	18
Maireana pentatropis	0.05	0.03	1.67	23
Maireana sedifolia	0.01	0.00	0.25	7
Maireana tomentosa	0.83	0.79	36.90	11
Maireana triptera	0.02	0.02	1.56	12
Sclerolaena cuneata	0.01	0.08	1.23	10
GOODENIACEAE				
Goodenia sp.1	0.01	0.01	0.20	13
Goodenia sp. 2	0.02	0.01	0.75	8
MIMOSACEAE				
Acacia acuminata	0.02	0.01	0.68	8
Acacia hemiteles	0.01	0.01	0.38	11
Acacia sp.	0.01	0.00	0.38	3
MYRTACEAE				
Eucalyptus salicola	0.20	0.18	7.81	7
Eucalyptus salubris	0.28	0.09	7.90	7
Eucalyptus spp.	0.01	0.00	0.16	3
PITTOSPORACEAE				
Pittosporum phylliraeoides	0.02	0.00	0.36	8
POACEAE				
grasses	0.34	0.10	8.16	7
SAPINDACEAE				
Dodonaea lobulata	0.01	0.08	1.03	10
ZYGOPHYLLACEAE				
Zygophyllum aurantiacum	0.17	0.22	6.69	10
TOTAL	**5.96**	**8.53**	**300.00**	

Sump Hole Trial, Treatment 4 (seeded, fertilised): December '96, reveg. age 7 months (n=10).

FAMILY Species	**Density** **(no. m^{-2})**	**% Cover**	**IVI**	**Height** **(cm)**
ASTERACEAE				
annual daisies	0.04	0.11	1.61	31
BRASSICACEAE				
Carrichtera annua	0.01	0.10	0.80	35
CHENOPODIACEAE				
Atriplex bunburyana	0.96	2.03	38.40	29
Atriplex codonocarpa	1.71	3.80	72.00	15
Atriplex semibaccata	1.00	3.82	54.80	19
Atriplex vesicaria	0.54	0.90	23.40	13
Atriplex sp.	0.01	0.00	0.26	3
Maireana brevifolia	0.35	0.44	15.40	19
Maireana georgei	0.51	0.40	17.40	20
Maireana pentatropis	0.03	0.01	1.15	13
Maireana sedifolia	0.05	0.03	1.83	8
Maireana tomentosa	1.06	1.00	37.60	12
Maireana triptera	0.04	0.03	1.69	10
Salsola kali	0.01	0.13	1.12	23
Sclerolaena cuneata	0.01	0.01	0.48	10
Sclerolaena diacantha	0.01	0.01	0.22	9
Sclerolaena patenticuspis	0.01	0.02	0.33	12
GOODENIACEAE				
Goodenia sp.1	0.01	0.00	0.23	8
Scaevola spinescens	0.01	0.01	0.40	23
Velleia rosea	0.01	0.00	0.22	5
MIMOSACEAE				
Acacia acuminata	0.05	0.01	1.84	7
Acacia hemiteles	0.01	0.01	0.41	8
Acacia sp.	0.03	0.00	0.83	4
MYRTACEAE				
Eucalyptus salicola	0.18	0.05	4.94	6
Eucalyptus salubris	0.30	0.10	9.15	7
Eucalyptus sp. 1	0.01	0.00	0.23	3
POACEAE				
grass	0.24	0.15	9.11	6
SAPINDACEAE				
Dodonaea lobulata	0.01	0.01	0.39	6
ZYGOPHYLLACEAE				
Zygophyllum aurantiacum	0.09	0.09	3.85	11
TOTAL	**7.30**	**13.27**	**300.00**	

General Exploration Area: December 1996, revegetation age seven months (n=7).

FAMILY Species	**Density (no. m^{-2})**	**% Cover**	**IVI**	**Height (cm)**
AMARANTHACEAE				
Ptilotus obovatus	0.01	0.02	0.49	15
ASTERACEAE				
annual daisies	0.03	0.04	2.30	7
CAESALPINIACEAE				
Senna filifolia	0.01	0.01	0.39	9
CHENOPODIACEAE				
Atriplex bunburyana	0.51	0.74	25.70	24
Atriplex codonocarpa	0.78	1.68	50.50	12
Atriplex holocarpa	0.01	0.02	0.49	13
Atriplex nummularia	0.40	0.21	10.40	11
Atriplex semibaccata	0.64	1.00	32.30	13
Atriplex vesicaria	0.34	0.19	11.60	7
Maireana brevifolia	0.21	0.14	9.31	14
Maireana georgei	0.63	0.47	27.40	19
Maireana tomentosa	1.11	0.76	41.70	11
Maireana triptera	0.05	0.04	2.01	16
Salsola kali	0.03	0.18	2.50	30
Sclerolaena diacantha	0.01	0.01	0.39	15
GOODENIACEAE				
Scaevola spinescens	0.01	0.00	0.51	4
MIMOSACEAE				
Acacia acuminata	0.15	0.04	6.66	8
Acacia hemiteles	0.03	0.03	1.73	8
Acacia sp.	0.10	0.02	3.59	6
MYRTACEAE				
Eucalyptus sp. 1	0.74	0.29	26.00	7
Eucalyptus sp. 2	0.12	0.05	2.32	8
PITTOSPORACEAE				
Pittosporum sp.	0.10	0.03	3.66	8
POACEAE				
grasses	1.10	0.21	22.60	6
SAPINDACEAE				
Dodonaea lobulata	0.14	0.04	5.95	7
ZYGOPHYLLACEAE				
Zygophyllum aurantiacum	0.17	0.28	9.11	16
Zygophyllum sp.	0.01	0.01	0.61	10
TOTAL	**7.43**	**6.51**	**300.00**	

1997 ASSESSMENTS

Drill Line Trial, Treatment 1 (control): December 1997, revegetation age 19 months (n=8).

FAMILY Species	**IVI**	**Density** **no. m^{-2}**	**Cover %**	**Height** **cm**
AMARANTHACEAE				
Ptilotus obovatus	50.50	0.01	0.00	20
CAESALPINIACEAE				
Senna filifolia	249.50	0.01	0.12	40
TOTAL	**300.00**	**0.02**	**0.12**	

Drill Line Trial, Treatment 2 (scarified, not seeded): December 1997, age 19 months (n=6).

FAMILY Species	**IVI**	**Density** **no. m^{-2}**	**Cover %**	**Height** **cm**
CHENOPODIACEAE				
Sclerolaena obliquicuspis	300.00	0.03	0.01	3
TOTAL	**300.00**	**0.03**	**0.01**	

Drill Line Trial, Treatment 3 (scarified, seeded): December 1997, age 19 months (n=6).

FAMILY Species	**IVI**	**Density** **no. m^{-2}**	**Cover %**	**Height** **cm**
CHENOPODIACEAE				
Atriplex bunburyana	45.77	0.13	1.30	28
Atriplex codonocarpa	12.00	0.07	0.47	8
Atriplex nummularia	12.93	0.11	0.41	24
Atriplex semibaccata	3.20	0.03	0.07	14
Atriplex vesicaria	41.02	0.11	0.10	9
Maireana brevifolia	7.23	0.02	0.03	16
Maireana georgei	10.82	0.12	0.15	20
Maireana pentatropis	1.26	0.02	0.01	4
Maireana tomentosa	12.62	0.06	0.13	9
Sclerolaena diacantha	7.12	0.02	0.01	9
Sclerolaena obliquicuspis	1.31	0.02	0.01	7
MIMOSACEAE				
Acacia hemiteles	18.88	0.03	0.18	26
Acacia sp.	14.03	0.03	0.01	4
MYRTACEAE				
Eucalyptus sp.1	18.77	0.10	0.23	19
Eucalyptus sp.2	51.44	0.18	1.13	21
Eucalyptus sp.3	41.85	0.18	0.66	25
TOTAL	**300.00**	**1.23**	**4.90**	

Sump Hole Trial, Treatment 1 (control): December 1997, revegetation age nineteen months (n=10).

FAMILY Species	**IVI**	**Density** **no. m^{-2}**	**Cover %**	**Height** **cm**
CHENOPODIACEAE				
Atriplex bunburyana	10.60	0.01	0.65	75
Atriplex codonocarpa	21.92	0.05	0.14	11
Atriplex semibaccata	83.86	0.19	0.22	6
Atriplex vesicaria	17.78	0.02	0.61	21
Enchylaena tomentosa	5.47	0.01	0.05	20
Maireana brevifolia	116.10	0.50	0.39	11
Maireana convexa	0.23		0.01	
Maireana georgei	1.36		0.02	
Maireana polypterygia	2.27	0.01	0.01	16
Maireana tomentosa	11.12	0.02	0.21	20
Maireana triptera	1.86	0.01	0.01	10
Sclerolaena obliquicuspis	17.79	0.07	0.30	7
GOODENIACEAE				
Scaevola spinescens	2.04	0.01	0.02	18
MIMOSACEAE				
Acacia aneura	0.91	0.01	0.00	5
Acacia linophylla	1.59	0.01	0.00	7
Acacia sp.	0.97	0.01	0.00	4
SOLANACEAE				
Solanum lasiophyllum	1.59	0.01	0.00	5
ZYGOPHYLLACEAE				
Zygophyllum aurantiacum	2.53	0.01	0.01	8
TOTAL	**300.00**	**0.95**	**2.64**	

Sump Hole Trial, Treatment 2 (scarified, not seeded): December 1997, revegetation age nineteen months (n=10).

FAMILY Species	**IVI**	**Density no. m^{-2}**	**Cover %**	**Height cm**
AMARANTHACEAE				
Ptilotus exaltatus	0.38	0.01	0.02	33
CAESALPINIACEAE				
Senna filifolia	0.33	0.01	0.00	5
CHENOPODIACEAE				
Atriplex bunburyana	17.50	0.12	1.37	46
Atriplex codonocarpa	32.79	0.26	1.85	18
Atriplex lindleyi	10.13	0.28	0.39	25
Atriplex nummularia	5.23	0.07	0.36	32
Atriplex semibaccata	104.90	1.10	4.75	11
Atriplex vesicaria	11.28	0.16	0.67	17
Enchylaena tomentosa	3.08	0.01	0.08	55
Maireana brevifolia	63.58	0.68	1.11	19
Maireana convexa	9.07	0.08	0.49	69
Maireana georgei	8.69	0.10	0.57	40
Maireana pentatropis	1.38	0.01	0.11	57
Maireana sedifolia	0.46	0.01	0.04	28
Maireana tomentosa	13.12	0.11	1.19	21
Maireana triptera	0.35	0.01	0.01	21
Salsola kali	1.17	0.01	0.03	34
Sclerolaena diacantha	3.23	0.02	0.06	11
Sclerolaena obliquicuspis	3.69	0.03	0.08	9
MIMOSACEAE				
Acacia acuminata	0.66	0.01	0.01	26
Acacia hemiteles	0.43	0.01	0.04	49
MYRTACEAE				
Eucalyptus sp.1	2.77	0.03	0.11	30
Eucalyptus sp.2	1.52	0.03	0.08	29
Eucalyptus sp.3	2.04	0.03	0.13	56
ZYGOPHYLLACEAE				
Zygophyllum aurantiacum	2.32	0.02	0.04	8
TOTAL	**300.00**	**3.21**	**13.59**	

Sump Hole Trial, Treatment 3 (scarified, seeded): December 1997, revegetation age nineteen months (n=10).

FAMILY Species	**IVI**	**Density** **no m^{-2}**	**Cover %**	**Height** **cm**
AMARANTHACEAE				
Ptilotus exaltatus	0.28	0.01	0.01	18
CHENOPODIACEAE				
Atriplex bunburyana	49.65	0.59	6.20	48
Atriplex codonocarpa	46.05	0.51	4.59	22
Atriplex nummularia	39.47	0.72	1.72	30
Atriplex semibaccata	49.31	0.62	4.79	12
Atriplex vesicaria	25.20	0.24	2.95	21
Dissocarpos paradoxus	0.27	0.01	0.01	4
Enchylaena tomentosa	2.88	0.04	0.13	22
Maireana brevifolia	12.48	0.21	0.64	28
Maireana convexa	7.53	0.12	0.34	49
Maireana georgei	17.66	0.26	1.44	41
Maireana pentatropis	1.64	0.04	0.05	51
Maireana sedifolia	0.53	0.01	0.01	16
Maireana tomentosa	33.49	0.47	2.56	20
Maireana triptera	1.57	0.02	0.05	22
Sclerolaena diacantha	0.43	0.01	0.05	9
MIMOSACEAE				
Acacia hemiteles	0.29	0.01	0.02	27
MYRTACEAE				
Eucalyptus sp.1	4.91	0.12	0.28	28
Eucalyptus sp.2	6.37	0.13	0.40	25
TOTAL	**300.00**	**4.14**	**26.24**	

Sump Hole Trial, Treatment 4 (scarified, seeded, fertilised): December 1997, revegetation age nineteen months (n=10).

FAMILY Species	**IVI**	**Density** **no. m^{-2}**	**Cover %**	**Height** **cm**
AMARANTHACEAE				
Ptilotus exaltatus	0.24	0.01	0.00	32
CHENOPODIACEAE				
Atriplex bunburyana	54.74	0.81	9.06	51
Atriplex codonocarpa	45.12	0.69	5.23	24
Atriplex nummularia	31.96	0.66	1.77	29
Atriplex semibaccata	51.54	0.67	8.23	14
Atriplex vesicaria	26.56	0.37	3.62	21
Dissocarpos paradoxus	0.36	0.01	0.03	19
Enchylaena tomentosa	0.70	0.01	0.04	33
Maireana brevifolia	14.70	0.27	0.95	33
Maireana convexa	6.45	0.12	0.38	43
Maireana georgei	15.51	0.26	1.35	44
Maireana pentatropis	1.26	0.02	0.07	44
Maireana sedifolia	1.60	0.03	0.08	21
Maireana tomentosa	35.41	0.60	3.80	19
Maireana triptera	1.93	0.03	0.13	25
Sclerolaena diacantha	1.20	0.03	0.04	6
MIMOSACEAE				
Acacia acuminata	0.25	0.01	0.01	18
Acacia sp.	0.34	0.01	0.01	16
MYRTACEAE				
Eucalyptus sp.1	7.27	0.26	0.11	27
Eucalyptus sp.2	1.50	0.03	0.12	25
Eucalyptus sp.3	0.74	0.01	0.05	56
Eucalyptus sp.4	0.27	0.01	0.01	14
ZYGOPHYLLACEAE				
Zygophyllum aurantiacum	0.33	0.01	0.01	11
TOTAL	**300.00**	**4.93**	**35.10**	

General Exploration Rehabilitation: December 1997, revegetation age nineteen months (n=7).

FAMILY Species	**IVI**	**Density** **no. m^{-2}**	**Cover %**	**Height** **cm**
AMARANTHACEAE				
Ptilotus exaltatus	0.42	0.007	0.007	40
CAESALPINIACEAE				
Senna nemophila	0.51	0.007	0.021	28
CHENOPODIACEAE				
Atriplex bunburyana	43.89	0.436	4.711	41
Atriplex codonocarpa	52.43	0.664	4.976	20
Atriplex lindleyi	3.21	0.043	0.429	28
Atriplex nummularia	36.77	0.643	1.686	28
Atriplex quinnii	0.88		0.179	
Atriplex semibaccata	17.73	0.236	1.594	10
Atriplex vesicaria	18.78	0.236	1.307	21
Maireana brevifolia	12.61	0.229	0.423	25
Maireana convexa	7.67	0.107	0.386	55
Maireana georgei	17.32	0.236	1.386	45
Maireana tomentosa	40.64	0.579	3.426	20
Maireana triptera	3.20	0.036	0.150	28
Maireana villosa	0.46	0.007	0.036	32
Rhagodia drummondii	0.63	0.007	0.007	20
Sclerolaena diacantha	0.81	0.007	0.004	8
GYROSTEMONACEAE				
Codonocarpos continifolius	1.85		0.343	
MIMOSACEAE				
Acacia acuminata	2.23	0.036	0.079	38
Acacia aneura	0.40	0.007	0.003	2
Acacia colletioides	0.55	0.007	0.036	27
Acacia hemiteles	1.10	0.014	0.057	28
Acacia sp.	0.81	0.014	0.007	6
MYRTACEAE				
Eucalyptus sp.1	3.89	0.057	0.207	32
Eucalyptus sp.2	1.51	0.036	0.071	37
Eucalyptus sp.3	25.39	0.379	1.897	42
SAPINDACEAE				
Dodonaea viscosa	2.84	0.057	0.057	15
SOLANACEAE				
Soalanum sp.	0.50	0.007	0.007	10
ZYGOPHYLLACEAE				
Zygophyllum aurantiacum	1.03	0.014	0.043	13
TOTAL	**300.00**	**4.107**	**23.534**	

Crusher Pad Rehabilitation: December 1997, revegetation age eight months (n=5).

FAMILY Species	**IVI**	**Density no. m^{-2}**	**Cover %**	**Height cm**
CHENOPODIACEAE				
Atriplex bunburyana	32.40	0.430	0.616	19
Atriplex codonocarpa	46.06	0.430	1.214	17
Atriplex nummularia	43.78	0.850	0.430	14
Atriplex semibaccata	105.36	1.590	3.688	11
Atriplex stipitata	2.92	0.030	0.070	19
Atriplex vesicaria	29.44	0.380	0.446	14
Maireana brevifolia	5.30	0.090	0.068	15
Maireana georgei	2.27	0.020	0.020	19
Maireana pentatropis	4.20	0.080	0.062	12
Salsola kali	3.59	0.040	0.080	19
Sclerolaena diacantha	2.53	0.020	0.024	10
Sclerolaena obliquicuspis	0.82	0.010	0.010	12
ZYGOPHYLLACEAE				
Zygophyllum aurantiacum	21.22	0.290	0.596	15
TOTAL	**300.00**	**4.260**	**7.324**	

Tailings Storage Facility batter: December 1997, revegetation age eight months (n=5).

FAMILY Species	**IVI**	**Density** **no. m^{-2}**	**Cover %**	**Height** **cm**
CAESALPINIACEAE				
Senna filifolia	0.40	0.010	0.006	7
CHENOPODIACEAE				
Atriplex bunburyana	41.92	1.150	1.464	14
Atriplex codonocarpa	44.60	0.990	2.306	13
Atriplex nummularia	43.92	1.120	2.632	14
Atriplex semibaccata	110.50	3.580	5.554	13
Atriplex semilunaris	1.73	0.020	0.080	33
Atriplex stipitata	0.92	0.010	0.070	21
Atriplex vesicaria	24.18	0.680	0.650	12
Enchylaena tomentosa	0.44	0.010	0.010	9
Maireana brevifolia	5.49	0.150	0.072	17
Maireana georgei	0.46	0.010	0.010	14
Maireana pentatropis	3.27	0.080	0.050	12
Maireana tomentosa	1.64	0.040	0.014	5
Maireana triptera	8.45	0.190	0.136	11
Maireana villosa	1.33	0.030	0.026	14
Salsola kali	1.35	0.030	0.036	12
Sclerolaena diacantha	5.14	0.110	0.114	10
Sclerolaena obliquicuspis	0.39	0.010	0.004	4
Sclerolaena sp.	1.17	0.030	0.040	17
ZYGOPHYLLACEAE				
Zygophyllum aurantiacum	2.83	0.050	0.084	9
TOTAL	**300.00**	**8.300**	**13.358**	

1998 ASSESSMENTS

Drill Line Trial, Treatment 1 (control): October 1998, revegetation age twenty-nine months (n=8).

FAMILY Species	**IVI**	**Density no. m^{-2}**	**Cover %**	**Height cm**
AMARANTHACEAE				
Ptilotus obovatus	127.61	0.05	0.16	22
CAESALPINIACEAE				
Senna filifolia	77.14	0.02	0.09	46
CHENOPODIACEAE				
Maireana carnosa	5.36	0.01	0.01	10
Sclerolaena diacantha	11.94	0.01		5
MYOPORACEAE				
Eremophila granitica	42.86	0.01	0.01	22
ZYGOPHYLLACEAE				
Zygophllum aurantiacum	35.09	0.03	0.02	12
TOTAL	**300.00**	**0.11**	**0.29**	

Drill Line Trial, Treatment 2 (scarified, not seeded): October 1998, revegetation age twenty-nine months (n=6).

FAMILY Species	**IVI**	**Density no. m^{-2}**	**Cover %**	**Height cm**
AMARANTHACEAE				
Ptilotus helipteroides	100.00	0.01	0.01	22
BRASSICACEAE				
Carrichtera annua	103.33	0.01	1.41	
CAESALPINIACEAE				
Senna filifolia	10.34	0.01	0.01	11
CHENOPODIACEAE				
Atriplex acutibractea	10.34	0.01	0.01	18
SOLANACEAE				
Solanum lasiophyllum	76.00	0.21	0.07	5
TOTAL	**300.00**	**0.25**	**1.51**	

Drill Line Trial, Treatment 3 (scarified, seeded): October 1998, revegetation age twenty-nine months (n=6).

FAMILY Species	**IVI**	**Density no. m^{-2}**	**Cover %**	**Height cm**
AMARANTHACEAE				
Ptilotus helipteroides	1.49	0.01	0.01	11
BRASSICACEAE				
Carrichtera annua	21.42		0.55	
CAESALPINIACEAE				
Senna filifolia	11.42	0.03	0.01	7
CHENOPODIACEAE				
Atriplex bunburyana	72.15	0.18	0.89	31
Atriplex codonocarpa	2.08	0.02	0.01	10
Atriplex nummularia	8.97	0.07	0.16	23
Maireana brevifolia	1.40	0.01	0.01	10
Maireana georgei	39.85	0.10	0.25	21
Maireana tomentosa	10.23	0.06	0.19	11
Maireana triptera	1.81	0.01	0.04	27
Sclerolaena obliquicuspis	1.46	0.01	0.01	10
MIMOSACEAE				
Acacia hemiteles	51.51	0.05	0.43	39
Acacia seedling	3.73	0.01		3
MYRTACEAE				
Eucalyptus sp.1	6.38	0.04	0.08	36
Eucalyptus sp.2	29.46	0.15	1.04	38
Eucalyptus sp.3	36.62	0.09	0.88	46
TOTAL	**300.00**	**0.83**	**4.54**	

Sump Hole Trial, Treatment 1 (control): October 1998, revegetation age twenty-nine months (n=10).

FAMILY Species	**IVI**	**Density no. m^{-2}**	**Cover %**	**Height cm**
AMARANTHACEAE				
Ptilotus exaltatus	10.62	0.06	0.08	14
BRASSICACEAE				
Carrichtera annua	5.50		0.08	
CHENOPODIACEAE				
Atriplex bunburyana	68.10	0.34	0.87	17
Atriplex codonocarpa	62.31	0.38	0.46	8
Atriplex nummularia	4.26	0.01	0.01	10
Atriplex semibaccata	58.77	0.23	0.44	8
Atriplex vesicaria	8.38	0.01	0.71	54
Enchylaena tomentosa	2.71	0.01	0.08	23
Maireana brevifolia	21.98	0.08	0.21	21
Maireana georgei	3.03	0.01	0.01	9
Maireana tomentosa	38.76	0.24	0.40	10
Maireana triptera	1.07	0.01	0.01	13
Salsola kali	1.12	0.01	0.01	10
Sclerolaena cuneata	8.24	0.04	0.01	3
Sclerolaena obliquicuspis	3.13	0.01	0.01	6
GOODENIACEAE				
Scaevola spinescens	2.01	0.01	0.02	32
TOTAL	**300.00**	**1.41**	**3.41**	

Sump Hole Trial, Treatment 2 (scarified, not seeded): October 1998, revegetation age twenty-nine months (n=10).

FAMILY Species	**IVI**	**Density** **no. m^{-2}**	**Cover %**	**Height** **cm**
AMARANTHACEAE				
Ptilotus exaltatus	1.30	0.03	0.03	30
BRASSICACEAE				
Carrichtera annua	9.48		1.83	
CHENOPODIACEAE				
Atriplex bunburyana	28.02	0.27	2.86	28
Atriplex codonocarpa	53.52	1.19	1.90	10
Atriplex nummularia	5.78	0.05	0.70	50
Atriplex semibaccata	86.71	1.22	4.09	9
Atriplex vesicaria	15.68	0.17	0.93	17
Chenopodium gaudichaudianum	0.37	0.01	0.01	20
Enchylaena tomentosa	0.15		0.02	
Maireana brevifolia	22.46	0.25	1.15	36
Maireana georgei	15.11	0.19	1.36	52
Maireana pentatropis	1.59	0.02	0.10	19
Maireana sedifolia	0.45	0.01	0.04	36
Maireana tomentosa	34.23	0.49	1.83	11
Maireana triptera	1.53	0.02	0.06	25
Sclerolaena diacantha	3.49	0.04	0.07	7
Sclerolaena obliquicuspis	2.21	0.02	0.13	13
LAMIACEAE				
Westringia rigida	0.55	0.01	0.03	34
MIMOSACEAE				
Acacia acuminata	0.37	0.01	0.02	40
Acacia hemiteles	0.51	0.01	0.06	32
MYRTACEAE				
Eucalyptus sp.2	4.97	0.06	0.28	49
Eucalyptus sp.3	0.06		0.01	
ZYGOPHYLLACEAE				
Zygophyllum aurantiacum	11.45	0.25	0.36	10
TOTAL	**300.00**	**4.27**	**17.83**	

Sump Hole Trial, Treatment 3 (scarified, seeded): October 1998, revegetation age twenty-nine months (n=10).

FAMILY Species	**IVI**	**Density** **no. m^{-2}**	**Cover %**	**Height** **cm**
AMARANTHACEAE				
Ptilotus exaltatus	1.22	0.02	0.01	12
BRASSICACEAE				
Carrichtera annua	0.28		0.08	
CHENOPODIACEAE				
Atriplex bunburyana	65.54	0.56	8.18	44
Atriplex codonocarpa	12.26	0.24	0.19	8
Atriplex nummularia	50.21	0.68	2.86	37
Atriplex semibaccata	24.11	0.28	2.24	9
Atriplex vesicaria	26.28	0.27	3.02	19
Enchylaena tomentosa	0.55	0.01	0.04	24
Maireana brevifolia	8.94	0.11	0.67	34
Maireana georgei	31.28	0.41	2.19	44
Maireana pentatropis	1.47	0.02	0.04	52
Maireana sedifolia	0.73	0.01	0.02	9
Maireana tomentosa	60.63	0.77	3.54	14
Maireana triptera	1.25	0.02	0.06	26
Sclerolaena diacantha	1.42	0.02	0.04	6
MIMOSACEAE				
Acacia hemiteles	0.32	0.01	0.02	32
Acacia sp.	0.35	0.01		5
MYRTACEAE				
Eucalyptus sp.1	1.13	0.01	0.05	50
Eucalyptus sp.2	2.52	0.04	0.18	46
Eucalyptus sp.3	3.13	0.04	0.27	35
ZYGOPHYLLACEAE				
Zygophyllum aurantiacum	6.28	0.20	0.13	10
TOTAL	**300.00**	**3.68**	**23.79**	

Sump Hole Trial, Treatment 4 (scarified, seeded, fertilised): October 1998, revegetation age twenty-nine months (n=10).

FAMILY Species	**IVI**	**Density** **no. m^{-2}**	**Cover %**	**Height** **cm**
AMARANTHACEAE				
Ptilotus exaltatus	0.67	0.01	0.01	18
BRASSICACEAE				
Carrichtera annua	2.96		0.76	
CHENOPODIACEAE				
Atriplex bunburyana	82.15	0.87	12.72	51
Atriplex codonocarpa	6.24	0.13	0.11	6
Atriplex nummularia	41.48	0.67	2.36	35
Atriplex semibaccata	19.27	0.27	1.62	10
Atriplex vesicaria	23.97	0.26	2.75	17
Enchylaena tomentosa	0.82	0.01	0.07	36
Maireana brevifolia	18.12	0.25	1.40	39
Maireana georgei	32.27	0.42	2.77	51
Maireana pentatropis	1.91	0.03	0.14	47
Maireana sedifolia	1.20	0.01	0.13	22
Maireana tomentosa	54.48	0.82	4.29	16
Maireana triptera	3.79	0.05	0.14	21
Sclerolaena diacantha	3.30	0.06	0.05	8
Sclerolaena obliquicuspis	0.33	0.01	0.02	19
MYRTACEAE				
Eucalyptus sp.1	1.02	0.02	0.03	30
Eucalyptus sp.2	1.57	0.02	0.11	64
Eucalyptus sp.3	1.09	0.01	0.16	65
ZYGOPHYLLACEAE				
Zygophyllum aurantiacum	3.05	0.06	0.06	9
TOTAL	**300.00**	**3.94**	**29.69**	

General Exploration Rehabilitation: October 1998, revegetation age twenty-nine months (n=7).

FAMILY Species	**IVI**	**Density no. m^{-2}**	**Cover %**	**Height cm**
AMARANTHACEAE				
Ptilotus exaltatus	2.41	0.03	0.02	16
Ptilotus obovatus	0.56	0.01	0.03	18
BRASSICACEAE				
Carrichtera annua	13.09		2.19	
CAESALPINIACEAE				
Senna filifolia	1.14	0.01	0.02	21
CHENOPODIACEAE				
Atriplex acutibractea	1.51	0.04	0.05	31
Atriplex bunburyana	65.68	0.51	4.80	36
Atriplex codonocarpa	5.61	0.09	0.18	6
Atriplex nummularia	54.26	0.54	2.12	30
Atriplex semibaccata	3.67	0.03	0.31	7
Atriplex vesicaria	9.84	0.09	0.51	15
Maireana brevifolia	9.76	0.07	0.45	44
Maireana georgei	39.80	0.44	1.69	50
Maireana tomentosa	49.03	0.51	2.70	17
Sclerolaena diacantha	1.33	0.01	0.01	14
Sclerolaena obliquicuspis	2.01	0.01	0.06	17
GYROSTEMONACEAE				
Codonocarpus cotinifolius	4.79	0.01	0.88	165
MIMOSACEAE				
Acacia acuminata	3.33	0.04	0.14	52
Acacia hemiteles	1.11	0.01	0.02	58
Acacia ligulata	0.89	0.01	0.09	59
MYRTACEAE				
Eucalyptus sp.2	21.39	0.17	1.79	69
Eucalyptus sp.3	1.39	0.01	0.13	46
ZYGOPHYLLACEAE				
Zygophyllum aurantiacum	7.41	0.16	0.15	11
TOTAL	**300.00**	**2.779**	**18.42**	

Crusher Pad Rehabilitation: October 1998, revegetation age eighteen months (n=5).

FAMILY Species	**IVI**	**Density** **no. m^{-2}**	**Cover %**	**Height** **cm**
BRASSICACEAE				
Carrichtera annua	56.12		13.07	
CHENOPODIACEAE				
Atriplex acutibractea	2.77	0.02	0.05	21
Atriplex bunburyana	45.96	0.39	1.64	26
Atriplex codonocarpa	88.20	0.95	2.59	19
Atriplex nummularia	22.69	0.22	0.36	27
Atriplex semibaccata	10.47	0.09	0.28	11
Atriplex vesicaria	28.81	0.22	0.95	20
Enchylaena tomentosa	6.16	0.06	0.12	20
Maireana brevifolia	1.37	0.01	0.02	35
Maireana georgei	1.94	0.02	0.03	20
Maireana pentatropis	3.55	0.03	0.01	8
Maireana triptera	5.34	0.06	0.09	11
Sclerolaena diacantha	5.13	0.04	0.04	11
ZYGOPHYLLACEAE				
Zygophyllum aurantiacum	21.51	0.28	0.32	13
TOTAL	**300.00**	**2.39**	**19.57**	

Tailings Storage Facility batter: October 1998, revegetation age eighteen months (n=5).

FAMILY Species	**IVI**	**Density** **no. m^{-2}**	**Cover %**	**Height** **cm**
BRASSICACEAE				
Carrichtera annua	34.88		16.17	
CHENOPODIACEAE				
Atriplex acutibractea	2.47	0.04	0.28	26
Atriplex amnicola	0.47	0.01	0.03	22
Atriplex bunburyana	42.34	1.03	3.97	24
Atriplex codonocarpa	38.50	0.63	6.52	21
Atriplex nummularia	30.38	0.85	1.20	32
Atriplex semibaccata	82.07	1.83	12.16	11
Atriplex semilunaris	1.10	0.01	0.24	40
Atriplex vesicaria	28.39	0.65	2.72	25
Enchylaena tomentosa	4.21	0.08	0.28	24
Maireana brevifolia	3.58	0.07	0.19	38
Maireana carnosa	1.77	0.03	0.10	13
Maireana georgei	0.59	0.01	0.08	34
Maireana pentatropis	1.39	0.03	0.07	35
Maireana tomentosa	3.15	0.07	0.21	41
Maireana triptera	12.68	0.26	0.70	19
Maireana villosa	2.22	0.05	0.09	30
Sclerolaena diacantha	4.64	0.09	0.29	19
Sclerolaena obliquicuspis	3.72	0.08	0.17	21
ZYGOPHYLLACEAE				
Zygophyllum aurantiacum	1.45	0.04	0.03	14
TOTAL	**300.00**	**5.860**	**45.49**	

Evaporation Pond Batter: October 1998, revegetation age five months (n=5).

FAMILY Species	**IVI**	**Density no. m^{-2}**	**Cover %**	**Height cm**
AIZOACEAE				
Tetrogonia tetragonoides	23.92	0.40	2.65	7
AMARANTHACEAE				
Ptilotus aervoides	0.89	0.01	0.05	3
Ptilotus exaltatus	0.52	0.01	0.04	431
ASTERACEAE				
Waitzia acuminata	26.63	0.44	1.79	20
BRASSICACEAE				
Carrichtera annua	52.04		16.17	
CHENOPODIACEAE				
Atriplex acutibractea	8.86	0.14	0.25	22
Atriplex bunburyana	4.65	0.12	0.10	12
Atriplex codonocarpa	18.86	0.31	0.75	11
Atriplex nummularia	1.54	0.04	0.05	18
Atriplex semibaccata	17.79	0.29	0.55	11
Atriplex semilunaris	3.44	0.05	0.22	34
Atriplex vesicaria	18.36	0.39	0.39	15
Maireana pentatropis	2.80	0.05	0.07	23
Maireana triptera	0.49	0.01	0.01	11
Salsola kali	0.48	0.01	0.03	34
Sclerolaena cuneata	0.99	0.02	0.07	17
Sclerolaena diacantha	19.94	0.39	0.45	14
Sclerolaena obliquicuspis	2.12	0.02	0.02	13
GERANIACEAE				
Erodium crinitum	1.19	0.02	0.13	26
POACEAE				
Stipa scabra	6.79		1.91	
ZYGOPHYLLACEAE				
Zygophyllum aurantiacum	87.67	1.74	5.25	14
TOTAL	**300.00**	**4.46**	**30.96**	

1999 ASSESSMENTS

Drill Line Trial, Treatment 1 (control): December 1999, revegetation age forty-three months (n=10).

FAMILY Species	**IVI**	**Density no. m^{-2}**	**Cover %**	**Height cm**
AMARANTHACEAE				
Ptilotus obovatus	84.57	0.045	0.125	30
CAESALPINIACEAE				
Senna filifolia	50.89	0.025	0.310	48
CHENOPODIACEAE				
Maireana georgei	3.38	0.005	0.010	26
GOODENIACEAE				
Scaevola spinescens	17.51	0.010	0.080	42
MIMOSACEAE				
Acacia burkittii	31.11	0.010	0.120	54
Acacia hemiteles	62.11	0.025	0.055	17
Acacia tetragonophylla	10.19	0.005	0.030	30
MYOPORACEAE				
Eremophila metallicorum	33.33	0.005	0.030	25
ZYGOPHYLLACEAE				
Zygophyllum aurantiacum	6.94	0.005	0.005	14
TOTAL	**300.03**	**0.140**	**0.770**	

Drill Line Trial, Treatment 2 (scarified, not seeded): December 1999, revegetation age forty-three months (n=6).

FAMILY Species	**IVI**	**Density no. m^{-2}**	**Cover %**	**Height cm**
CAESALPINIACEAE				
Senna artemisioides	80.60	0.030	0.020	5
Senna filifolia	120.00	0.020	0.650	46
CHENOPODIACEAE				
Maireana georgei	60.00	0.010	0.010	12
MIMOSACEAE				
Acacia burkittii	39.40	0.020	0.040	26
TOTAL	**300.00**	**0.080**	**0.720**	

Drill Line Trial, Treatment 3 (scarified and seeded): December 1999, revegetation age forty-three months (n=6).

FAMILY Species	**IVI**	**Density no. m^{-2}**	**Cover %**	**Height cm**
AMARANTHACEAE				
Ptilotus obovatus	1.82	0.010	0.010	20
CAESALPINIACEAE				
Senna filifolia	16.20	0.010	0.010	5
CHENOPODIACEAE				
Atriplex bunburyana	27.90	0.080	2.070	57
Atriplex codonocarpa	1.82	0.010	0.010	5
Atriplex nummularia	17.37	0.090	0.460	27
Atriplex vesicaria	28.50	0.030	0.065	21
Maireana georgei	38.00	0.100	0.277	21
Maireana sedifolia	1.83	0.010	0.010	12
Maireana tomentosa	7.85	0.040	0.110	9
Maireana triptera	24.10	0.020	0.030	12
Sclerolaena diacantha	19.04	0.010	0.020	8
MIMOSACEAE				
Acacia burkittii	1.91	0.010	0.020	38
Acacia hemiteles	25.64	0.010	0.290	52
MYRTACEAE				
Eucalyptus salicola	44.82	0.060	1.700	77
Eucalyptus sp 1	24.24	0.080	1.550	113
Eucalyptus sp 2	11.42	0.030	0.150	50
Eucalyptus sp 3	7.60	0.010	0.060	25
TOTAL	**300.00**	**0.610**	**6.840**	

Sump Hole Trial, Treatment 1 (control): December 1999, revegetation age forty-three months (n=10).

FAMILY Species	**IVI**	**Density** **no. m^{-2}**	**Cover %**	**Height** **cm**
AMARANTHACEAE				
Ptilotus exaltatus	1.93	0.025	0.038	15
ASTERACEAE				
Asteraceae sp	0.66	0.025	0.006	30
CAESALPINIACEAE				
Senna filifolia	2.13	0.006	0.256	4
CHENOPODIACEAE				
Atriplex bunburyana	93.08	1.119	5.631	34
Atriplex codonocarpa	54.59	0.938	2.194	15
Atriplex nummularia	0.24		0.031	
Atriplex semibaccata	31.35	0.594	0.991	10
Enchylaena tomentosa	3.38	0.006	0.406	50
Maireana brevifolia	7.55	0.088	0.310	30
Maireana georgei	1.96	0.038	0.041	19
Maireana sedifolia	0.77	0.006	0.063	30
Maireana tomentosa	80.06	1.563	3.016	18
Maireana triptera	2.84	0.031	0.048	10
Salsola kali	0.98	0.013	0.022	6
Sclerolaena cuneata	12.82	0.150	0.213	8
Sclerolaena diacantha	0.55	0.006	0.006	8
Sclerolaena obliquicuspis	2.53	0.031	0.088	30
MIMOSACEAE				
Acacia acuminata	0.37	0.006	0.006	4
MYRTACEAE				
Eucalyptus salubris	0.89	0.006	0.063	90
Eucalytptus 1	0.46	0.006	0.019	25
SAPINDACEAE				
Dodonaea viscosa	0.42	0.006	0.013	12
SOLONACEAE				
Solanum lasiophyllum	0.45	0.006	0.006	7
TOTAL	**300.00**	**4.670**	**13.460**	

Sump Hole Trial, Treatment 2 (scarified, not seeded): December 1999, revegetation age forty-three months (n=10).

FAMILY Species	**IVI**	**Density** **no. m^{-2}**	**Cover %**	**Height** **cm**
CAESALPINIACEAE				
Senna filifolia	1.83	0.020	0.035	24
CHENOPODIACEAE				
Atriplex acutibractea	0.48	0.005	0.015	20
Atriplex bunburyana	70.26	0.675	5.493	48
Atriplex codonocarpa	17.74	0.205	0.571	15
Atriplex lindleyi	6.31	0.080	0.300	25
Atriplex nummularia	15.55	0.080	1.625	80
Atriplex semibaccata	48.72	0.530	2.178	12
Atriplex vesicaria	24.24	0.215	1.715	28
Enchylaena tomentosa	0.66	0.005	0.010	15
Maireana brevifolia	13.27	0.125	0.468	37
Maireana convexa	7.39	0.060	0.490	95
Maireana georgei	28.27	0.345	0.858	36
Maireana sedifolia	0.54	0.005	0.050	53
Maireana tomentosa	55.29	0.770	2.425	17
Maireana triptera	0.47	0.005	0.015	27
Sclerolaena diacantha	2.82	0.030	0.088	9
MIMOSACEAE				
Acacia burkittii	0.73	0.010	0.030	105
Acacia hemiteles	0.89	0.005	0.100	65
MYRTACEAE				
Eucalyptus salicola	1.56	0.015	0.060	31
Eucalyptus sp 2	1.22	0.010	0.125	105
Eucalyptus sp 3	1.71	0.010	0.140	78
TOTAL	**300.00**	**3.210**	**16.790**	

Sump Hole Trial, Treatment 3 (scarified, seeded): December 1999, revegetation age forty-three months (n=10).

FAMILY Species	**IVI**	**Density** **no. m^{-2}**	**Cover %**	**Height** **cm**
CAESALPINIACEAE				
Senna filifolia	0.79	0.010	0.015	14
CHENOPODIACEAE				
Atriplex bunburyana	76.00	0.525	9.083	60
Atriplex codonocarpa	2.18	0.025	0.050	14
Atriplex nummularia	73.17	0.680	5.275	59
Atriplex semibaccata	7.91	0.120	0.290	13
Atriplex vesicaria	40.53	0.340	3.560	26
Enchylaena tomentosa	0.86	0.010	0.010	20
Maireana brevifolia	4.07	0.045	0.118	36
Maireana convexa	8.34	0.095	0.320	77
Maireana georgei	23.48	0.235	1.028	46
Maireana pentatropis	0.44	0.005	0.010	65
Maireana sedifolia	1.41	0.015	0.025	17
Maireana tomentosa	46.87	0.560	2.000	18
Maireana triptera	3.65	0.050	0.090	19
Sclerolaena diacantha	0.99	0.010	0.020	9
MIMOSACEAE				
Acacia hemiteles	0.66	0.005	0.045	38
MYRTACEAE				
Eucalyptus salicola	4.94	0.040	0.485	68
Eucalyptus sp 2	1.01	0.010	0.105	100
Eucalyptus sp 3	2.70	0.020	0.205	73
TOTAL	**300.00**	**2.800**	**22.730**	

Sump Hole Trial, Treatment 4 (scarified, seeded, fertilised): December 1999, revegetation age forty-three months (n=10).

FAMILY Species	**IVI**	**Density no. m^{-2}**	**Cover %**	**Height cm**
CAESALPINIACEAE				
Senna filifolia	1.20	0.010	0.013	12
CHENOPODIACEAE				
Atriplex bunburyana	100.68	0.670	18.120	75
Atriplex nummularia	61.58	0.675	4.980	63
Atriplex semibaccata	6.76	0.090	0.230	9
Atriplex vesicaria	29.49	0.275	3.050	24
Enchylaena tomentosa	0.41	0.005	0.010	28
Maireana brevifolia	12.80	0.115	0.770	58
Maireana convexa	10.32	0.095	0.715	82
Maireana georgei	26.12	0.310	1.408	62
Maireana pentatropis	0.49	0.005	0.015	61
Maireana sedifolia	2.43	0.015	0.285	45
Maireana tomentosa	38.67	0.465	2.533	19
Maireana triptera	4.48	0.050	0.138	25
Sclerolaena diacantha	0.79	0.010	0.015	16
MIMOSACEAE				
Acacia burkittii	0.88	0.010	0.010	28
MYRTACEAE				
Eucalyptus salicola	1.52	0.005	0.225	110
Eucalyptus sp 2	0.81	0.005	0.115	105
Eucalyptus sp 3	0.56	0.005	0.055	73
TOTAL	**300.00**	**2.820**	**32.690**	

General Exploration Rehabilitation: December 1999, revegetation age forty-three months (n=5).

FAMILY Species	**IVI**	**Density** **no. m^{-2}**	**Cover %**	**Height** **cm**
AMARANTHACEAE				
Ptilotus obovatus	1.46	0.013	0.050	40
CAESALPINIACEAE				
Senna filifolia	5.56	0.063	0.075	19
Senna pleurocarpa	4.54	0.013	0.550	142
CHENOPODIACEAE				
Atriplex acutibractea	5.40	0.088	0.238	35
Atriplex bunburyana	49.82	0.375	4.788	50
Atriplex codonocarpa	0.89	0.013	0.013	5
Atriplex nummularia	42.71	0.450	2.900	47
Atriplex vesicaria	21.74	0.213	1.738	23
Dissocarpus paradoxus	1.69	0.013	0.088	21
Enchylaena tomentosa	0.93	0.013	0.025	38
Maireana brevifolia	1.16	0.013	0.088	46
Maireana convexa	12.95	0.125	0.838	82
Maireana georgei	28.15	0.363	0.918	40
Maireana tomentosa	54.04	0.738	2.844	20
Maireana triptera	1.20	0.013	0.025	18
GYROSTEMONACEAE				
Codonocarpus continifolius	2.59	0.013	275.00	275
MIMOSACEAE				
Acacia burkittii	9.81	0.100	0.575	71
Acacia hemiteles	2.59	0.025	0.038	16
MYRTACEAE				
Eucalyptus sp 2	41.62	0.238	5.400	148
Eucalyptus sp 3	5.04	0.038	0.363	100
SAPINDACEAE				
Dodonaea lobulata	6.14	0.063	0.176	55
TOTAL	**300.00**	**2.980**	**22.040**	

1996 Boxcut Rehabilitation: December 1999, revegetation age forty-three months (n=2).

FAMILY Species	**IVI**	**Density no. m^{-2}**	**Cover %**	**Height cm**
CAESALPINIACEAE				
Senna filifolia	2.53	0.025	0.075	20
CHENOPODIACEAE				
Atriplex bunburyana	72.95	0.550	11.625	43
Atriplex codonocarpa	5.00	0.125	0.100	10
Atriplex nummularia	44.05	0.325	4.875	50
Atriplex semibaccata	24.28	0.325	0.665	18
Atriplex vesicaria	3.36	0.025	0.150	33
Maireana brevifolia	37.30	0.400	3.390	50
Maireana georgei	48.05	0.650	1.600	37
Maireana tomentosa	47.05	0.875	1.065	14
Maireana triptera	4.07	0.025	0.625	80
Sclerolaena obliquicuspis	4.58	0.075	0.050	15
MIMOSACEAE				
Acacia sp.	6.83	0.150	0.115	10
TOTAL	**300.00**	**3.550**	**24.340**	

Tailings Storage Facility batter: December 1999, revegetation age thirty-two months (n=5).

FAMILY Species	**IVI**	**Density no. m^{-2}**	**Cover %**	**Height cm**
CHENOPODIACEAE				
Atriplex acutibractea	0.16		0.030	
Atriplex amnicola	12.68	0.140	1.610	27
Atriplex bunburyana	41.44	0.460	3.630	45
Atriplex codonocarpa	4.77	0.090	0.120	14
Atriplex nummularia	56.65	0.750	2.740	56
Atriplex quinnii	2.67	0.020	0.410	48
Atriplex semibaccata	28.08	0.220	3.540	18
Atriplex vesicaria	105.44	1.080	10.4	41
Dissocarpos paradoxus	0.76	0.010	0.030	15
Enchylaena tomentosa	6.24	0.070	0.360	27
Maireana brevifolia	7.63	0.080	0.350	53
Maireana pentatropis	2.86	0.040	0.070	26
Maireana tomentosa	1.94	0.020	0.130	24
Maireana triptera	16.24	0.200	1.050	35
Sclerolaena diacantha	7.68	0.090	0.280	15
Sclerolaena obliquicuspis	1.94	0.020	0.090	20
Sclerolaena patenticuspis	2.83	0.030	0.120	34
TOTAL	**300.00**	**3.320**	**24.960**	

Evaporation Pond Batter: December 1999, revegetation age twenty months (n=5).

FAMILY Species	**IVI**	**Density no. m^{-2}**	**Cover %**	**Height cm**
AMARANTHACEAE				
Ptilotus obovatus	1.56	0.010	0.030	22
CAESALPINIACEAE				
Senna filifolia	7.77	0.060	0.080	21
CHENOPODIACEAE				
Atriplex acutibractea	31.56	0.160	3.030	39
Atriplex bunburyana	0.36	0	0.030	
Atriplex codonocarpa	7.37	0.050	0.610	40
Atriplex nummularia	37.71	0.300	1.450	40
Atriplex semibaccata	44.08	0.200	2.440	15
Atriplex vesicaria	60.58	0.550	2.890	36
Dissocarpus paradoxus	33.63	0.260	1.470	28
Enchylaena tomentosa	9.54	0.050	0.430	31
Maireana brevifolia	2.45	0.020	0.060	56
Maireana georgei	14.81	0.110	0.380	41
Maireana pentatropis	4.04	0.030	0.240	52
Maireana pyramidata	4.38	0.030	0.060	16
Maireana tomentosa	2.67	0.020	0.090	43
Maireana triptera	8.21	0.050	0.330	45
Sclerolaena diacantha	26.04	0.180	1.190	18
Sclerolaena oblliquicuspis	1.40	0.010	0.020	11
Sclerolaena patenticuspis	1.82	0.010	0.210	46
TOTAL	**300.00**	**2.100**	**15.040**	

Crusher Pad Rehabilitation: December 1999, revegetation age thirty-two months (n=5).

FAMILY Species	**IVI**	**Density no. m^{-2}**	**Cover %**	**Height cm**
CAESALPINIACEAE				
Senna filifolia	0.95	0.010	0.010	9
CHENOPODIACEAE				
Atriplex acutibractea	1.12	0.010	0.030	29
Atriplex bunburyana	88.98	0.540	7.880	39
Atriplex codonocarpa	71.21	1.820	1.375	19
Atriplex nummularia	40.78	0.380	2.610	53
Atriplex semibaccata	1.06	0.010	0.020	15
Atriplex vesicaria	55.78	0.290	4.370	29
Dissocarpos paradoxus	1.11	0.010	0.040	20
Enchylaena tomentosa	9.66	0.070	0.680	20
Maireana brevifolia	3.22	0.030	0.110	28
Maireana georgei	4.48	0.040	0.170	29
Maireana pentatropis	7.39	0.070	0.205	18
Maireana triptera	7.40	0.060	0.420	31
Sclerolaena diacantha	6.82	0.060	0.210	13
TOTAL	**300.00**	**3.400**	**18.130**	

2000 ASSESSMENTS

Drill Line Trial, Treatment 1 (control): November 2000, revegetation age fifty-four months (n=10).

FAMILY Species	**IVI**	**Density no.** m^{-2}	**Cover %**	**Height cm**
AMARANTHACEAE				
Ptilotus obovatus	166.00	0.080	0.440	34
CAESALPINIACEAE				
Senna filifolia	62.20	0.020	0.250	57
CHENOPODIACEAE				
Maireana triptera	12.60	0.010	0.010	15
MIMOSACEAE				
Acacia acuminata	43.90	0.010	0.350	95
Acacia aneura	15.40	0.010	0.040	35
TOTAL	**300.00**	**0.110**	**1.090**	

Drill Line Trial, Treatment 2 (scarified, not seeded): November 2000, revegetation age fifty-four months (n=6).

FAMILY Species	**IVI**	**Density no.** m^{-2}	**Cover %**	**Height cm**
AMARANTHACEAE				
Ptilotus obovatus	50.00	0.020	0.060	22
CAESALPINIACEAE				
Senna artemisioides	12.50	0.010	0.040	19
Senna filifolia	124.78	0.030	0.780	39
CHENOPODIACEAE				
Maireana georgei	20.40	0.020	0.040	21
Maireana triptera	80.00	0.100	0.130	10
SAPINDACEAE				
Dodonaea lobulata	12.28	0.010	0.020	15
TOTAL	**300.00**	**0.190**	**1.070**	

Drill Line Trial, Treatment 3 (scarified, seeded): November 2000, revegetation age fifty-four months (n=6).

FAMILY Species	**IVI**	**Density** **no. m^{-2}**	**Cover %**	**Height** **cm**
AMARANTHACEAE				
Ptilotus obovatus	2.13	0.010	0.020	12
CAESALPINIACEAE				
Senna filifolia	11.50	0.040	0.070	16
CHENOPODIACEAE				
Atriplex bunburyana	94.73	0.110	2.670	51
Atriplex nummularia	22.09	0.090	0.950	34
Maireana georgei	20.78	0.050	0.080	32
Maireana tomentosa	12.04	0.060	0.200	10
Maireana triptera	15.45	0.030	0.170	25
GOODENIACEAE				
Scaevola spinescens	2.05	0.010	0.010	5
MIMOSACEAE				
Acacia acuminata	12.43	0.020	0.030	21
Acacia aneura	2.08	0.010	0.020	21
Acacia hemiteles	33.71	0.020	0.430	45
MYOPORACEAE				
Eremophila alternifolia	2.36	0.010	0.070	42
MYRTACEAE				
Eucalyptus salicola	37.76	0.040	1.200	111