STUDIES ON DUNE REHABILITATION TECHNIQUES FOR MINED AREAS AT RICHARDS BAY, NATAL.

THESIS
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by

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ABSTRACT

Rehabilitation is a dynamic process influenced by factors related to more than one field of ecology. It is therefore necessary to consider all these components when assessing the rehabilitation, although in the initial stages the successful revegetation of the disturbed areas is the most important criterion. Richards Bay Minerals, on whose mining site this project was carried out, is dredge mining heavy minerals on the north coast of Natal, where they have rehabilitated mined areas since 1978.

This project has been carried out to establish:

1) The success of their dune forest rehabilitation using quantitative techniques.

2) The available seed bank in their rehabilitation stands.

3) The similarities in the succession taking place in rehabilitation stands compared to the revegetated stands in the vicinity of Richards Bay.

4) The best methods for creating alternative vegetation communities, especially grasslands, with a high species diversity on the mined tailings.

This study reviews only the success of rehabilitation of the natural vegetation but other studies focusing on the insect, reptile, mammal and bird populations are also being undertaken by other researchers.

No particular method of determining the success of vegetation rehabilitation has been chosen by restoration ecologists. Therefore in this study a broad range of quantitative techniques were used to show whether successional changes are occurring in the vegetation and physical environment. The results obtained from sampling the rehabilitated vegetation have shown that both the species richness and diversity are increasing as the returned vegetation matures. Levels of soil properties such as Sodium, Phosphate, Calcium and percentage organic matter have also risen with increasing stand age. Community complexity is also increasing with stand age, and TWINSPAN and DECORANA plots have separated out the differently aged stands based on their differences.

A "pilot" study was done on the seed bank present in the rehabilitation stands. This has shown the presence of large amounts of early successional, mostly herbaceous species.

Seeds of later successional and woody species were scarce which may be a result of the sampling intensity used. However seeds of late successional ground cover species were found in the older stands.

Comparisons between the natural revegetation of disturbed areas in the vicinity of Richards Bay and the rehabilitation stands revealed similarities in both species composition and complexity. Species richness and diversity values are comparatively similar for the younger revegetated and older rehabilitation stands, and TWINSPAN and DECORANA analysis techniques clustered the samples recorded from these areas in close proximity on their relative plots. The oldest revegetated sites contain a number of species found in the rehabilitated vegetation but as *Acacia karroo* has thinned-out in these stands many of these other species are now mature individuals.

Attempts at rehabilitating an area of grassland at Richards Bay Minerals has not produced satisfactory species diversity and experimental manipulations were used to try and increase the diversity of the existing *Eragrostis curvula* dominated community. Of the several treatments used for the manipulation, a combination of burning and further topsoiling was the most successful in reducing *Eragrostis* importance and in increasing the species richness. Grassland topsoil spread directly onto the bare tailings produced an extensive vegetation covering over a short period but species richness was not significantly greater than for the existing *Eragrostis* dominated grassland, and further treatments and management needs to continue if this technique is to be employed.

Only a limited amount of alien infestation of the rehabilitated areas was evident from the sampling undertaken during this research. As the removal of alien plants is an ongoing process and the rehabilitation stands are continuously monitored to identify any new invaders, this is not expected to become a problem.

From the results of work done overseas and the rehabilitation carried out in South Africa it appears that it is possible to return natural vegetation communities on mined areas. That this is a lengthy process is to be expected but by manipulating the vegetation and continuously monitoring the process it may be possible to speed up development.

Areas in need of further research have been identified based on the findings of this

project. This will help to reinforce the undertaking of management proposals that will enhance the vegetation recovery and the success of the rehabilitation programme.

CHAPTER 1

GENERAL INTRODUCTION

Coastal dunes function as barriers protecting inland areas against the extreme winds and high tides occurring during storm conditions. This is especially so along the Zululand coast where slumping is a common feature and the steep dunes are susceptible to undercutting (Tinley,1985; von Maltitz *et al* 1991; Weisser, 1991). The dense cover of vegetation plays an important role in binding the sand particles of the unconsolidated dunes, so maintaining their stability. The process of dune formation is dependent on the vegetation colonizing the dune which in turn undergoes a successionary development as the physical conditions of the dune system change. This inter-dependence between vegetation cover and dune stability develops over a lengthy period and therefore once an extensive disturbance such as mining has taken place artificial manipulation is needed to recreate the balance that existed before. Common dune stabilization techniques used in South Africa as described in Tinley (1985) and Avis (1989) are adequate and viable for these small areas, needing stabilization. However where extensive areas of a few hundred thousand hectares or more are cleared a more efficient and practical adaptation of these methods is required. During the dredge mining process presently in use north of Richards Bay the entire vegetation cover is removed along the mine path. This leads to a potentially dangerous situation requiring both a successful and rapid stabilization of the mine tailings to avoid widespread environmental destruction.

1.1 Process of rehabilitation at Richards Bay

Richards Bay Minerals (RBM), the company responsible for the dune mining, are able to revegetate the mined areas by spreading topsoil and seeds of cover crop species over the tailings. However it is not their intention to merely replace the vegetation but rather to rehabilitate and where possible, restore the original vegetation communities (Camp, 1990). The form of rehabilitation implemented, ie. to either indigenous or commercial communities, is dependent on the landowners, and for the Richards Bay area this is the Kwazulu Forestry

Department. Their present policy is that the section bordering the unmined coastal cordon must be rehabilitated to natural forest while the interior section is returned to commercial plantations of Australian beefwood, *Casuarina equisetifolia*. The mining began in July 1977 and is an opencast operation using dredge ponds which move back and forth along a mine path. The course followed is dependent on the heavy mineral concentrations and the depth of the clay layer which lies under these dunes. The vegetation directly in front of the dredge pond is cleared by bulldozers and either burnt or processed into charcoal. This exposes the topsoil which is removed by scrapers and transported to the mined areas where it is spread evenly over the recontoured dunes. In the dredge pond the sand is loosened from the mining face, sucked up and passed through the concentrator which separates the heavy minerals from the lighter sand by means of gravitational forces. No chemicals or pollutants are added during the mining process. The mined sand or tailings is pumped to the mined - out area behind the mine plant where it is stacked and reshaped by bulldozers to a topography more or less similar to the original. Once this is completed wind barriers are erected at regular intervals on the newly formed dunes. These are placed at right angles to the main wind directions so preventing sand movement and creating initial stability. For the revegetation of commercial plantations no topsoil is added and the young *Casuarina* plants are planted directly into the tailings. It was found that when grown in topsoil the *Casuarina's* seedlings were out - competed for soil moisture by indigenous seedlings which germinated from seeds present in the topsoil, and a higher success rate was achieved by direct planting. To establish natural communities a cover crop of annuals including; *Pennisetum americanum*, *Sorghum spp.* and *Crotalaria juncea* are first sown over the topsoil. This functions to protect the indigenous seeds germinating in the topsoil from the excessive soil temperatures and strong winds prevalent on the exposed dunes (Camp, 1990). Locally - collected indigenous seeds of species such as *Acacia karroo, Chrysanthemoides monilifera, Carissa macrocarpa, Eleusine indica, Cymbopogon validus, Aristida junciformis, Digitaria eriantha, Dactyloctenium germinatum, Panicum maximum* and *Sporobolus africanus* are also added to the topsoil. Depending on the availability, nursery-reared seedlings of *Chrysanthemoides monilifera, Trema orientalis, Carissa macrocarpa, Mimmusops caffra, Acacia karroo, Antidesma venosum* and

other indigenous species may also be randomly planted amongst the rehabilitated stands.

Using this technique RBM have returned once totally destroyed dunes back to a state of stability, able to support and sustain the growth of indigenous forest species. The rehabilitation of disturbed dune vegetation on the scale undertaken by RBM north of Richards Bay is unique to South Africa (Camp,1990). As this is the first major attempt at rehabilitating and finally restoring the original dune vegetation in this country (Avis, 1989) it has necessitated the implementation of techniques developed and experience gained during similar operations in America, the United Kingdom and Australia. In Australia success of rehabilitation and the understanding of the dynamics of frontal dune systems is so advanced that previously mined areas are now included in National Parks (Myers,1987). RBM have applied the same basic methods in their rehabilitation programme at Richards Bay which appears successful to date when viewed subjectively. However doubts have been expressed by prominent scientists and knowledgable persons on whether the rehabilitated vegetation dominated by *Acacia karroo* is indicative of a successful restoration of natural vegetation. This study is an attempt to answer this question by quantitative techniques and to look at the possible adjustments to the present management and rehabilitation process employed in the re-establishment of wetland, grassland and forest communities.

1.2 Rehabilitation, Restoration or Revegetation

During this study the words rehabilitation and restoration are extensively applied in describing the reconstruction of the ecosystems but what exactly do these terms mean? The definitions given by the Oxford Dictionary are as follows: rehabilitation is, " to set up again in a proper condition " whereas restoration is, " to bring back to the original state, by rebuilding, repairing etc " . Bradshaw (1990a) (in figure 1.1) uses the two terms to describe the process whereby ecologists try to build back ecosystems to exactly what was there before the disturbance. Where the return of the complete ecosystem has been successful it is referred to as "restoration", partial success in re - establishing the ecosystem is called "rehabilitation".

Therefore rehabilitation may possibly have been successful in returning a certain component of the ecosystem but not all of them. A third term used by Bradshaw (1990a) namely "replacement " describes the introduction of an ecosystem different from the original.

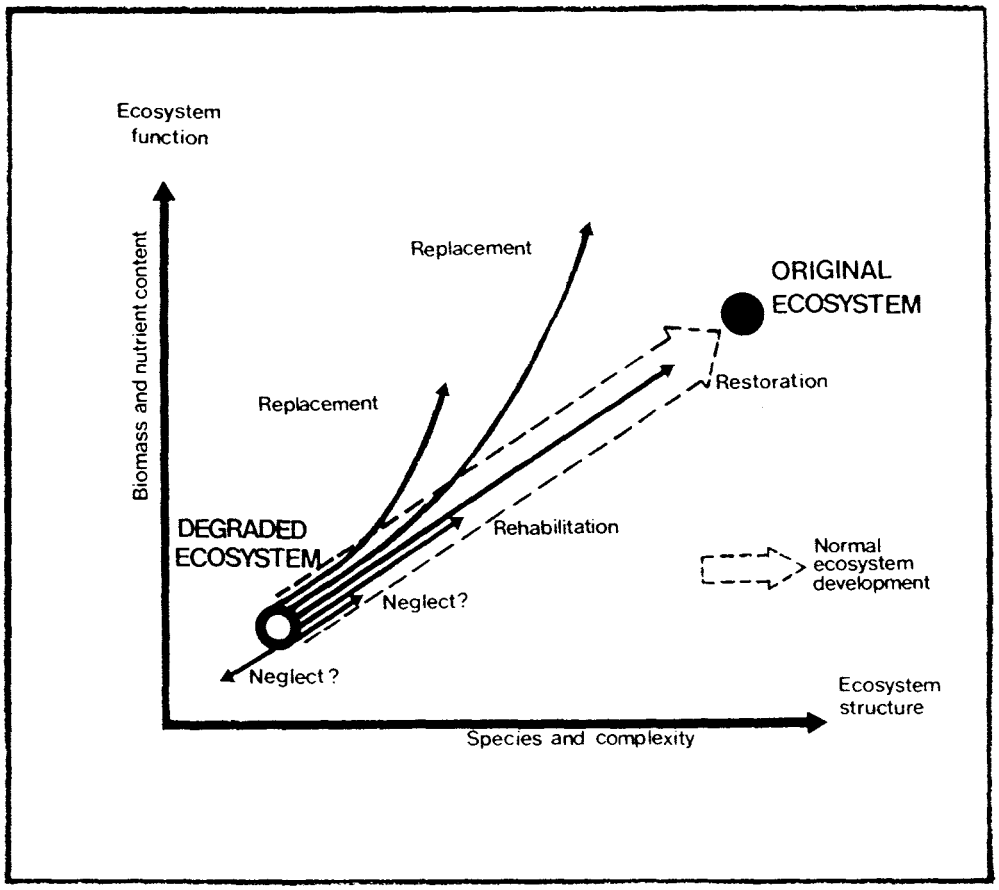

Figure 1.1; Ecosystem development depicted in two dimensions, structure and function. Showing that rehabilitation is only a process that may achieve restoration, the ultimate goal (from Bradshaw, 1990a).

The process whereby indigenous vegetation returns naturally after a disturbance without any human assistance is known as revegetation. Westman (1991) proposes that restoration is the complete return of the ecosytem properties to a pre-determined regional baseline level (Fig 1.2). Therefore a project aimed at restoring the historical plant composition will have

achieved this once all the expected species have demonstrated the ability to colonize and persist for a certain period. Rehabilitation is only the partial achievement of the goal and replacement doesn't set out to recreate the original at all.

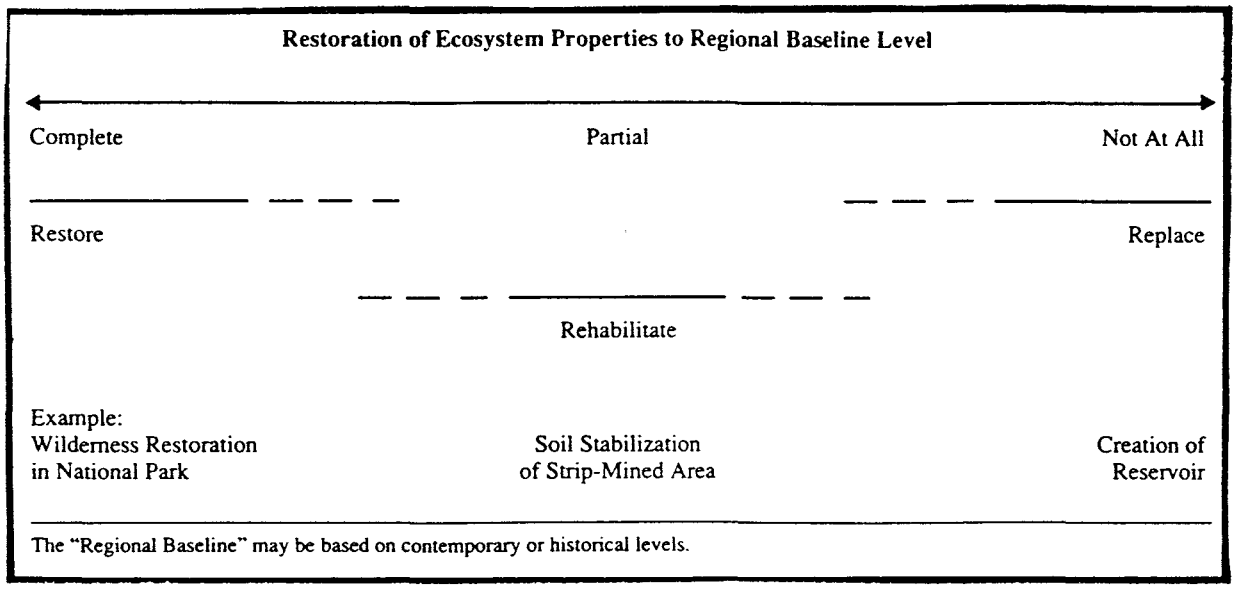

Figure 1.2; A diagram showing the continuum of restoration goals (from Westman,1991).

In the course of this study the term rehabilitation is to be used to describe areas where the soil has been disturbed then replaced, stabilized and then the return of the vegetation is managed. As only the floral component of the returned ecosystem has been studied during this research, the use of the word rehabilitation refers to the return of the vegetation. Other constituents such as animals and insects are being studied separately but their effects on the vegetation are mentioned where necessary.

1.3 Rehabilitation in South Africa and overseas

The stabilization of dune systems along the South African coast started as long ago as 1945. The Department of Forestry used a number of different stabilization methods in their restriction

of drift sand movement where the natural vegetation cover had been damaged. Early stabilization processess include the spreading of city refuse, brushwood and seeds of alien woody species onto the bare sand (Avis, 1989). Once it was realized that the introduction of alien species could pose a threat to indigenous species this practice was discontinued. Now areas are only stabilized when absolutely necessary and then only with indigenous species. The spreading of brushwood which does not contain seeds or fruits, and the erection of barrier fences made of shade cloth is used to create initial stability. Seeds of indigenous species were sowed onto the the stabilized sands and in most cases this had to be repeated quite regularly to promote an extensive cover of natural vegetation. This technique, although it was fairly successful in creating a stable natural vegetation needed some refinement before it could be used on the scale required by RBM in their rehabilitation programme. The spreading of topsoil and the initial sowing of a cover crop are methods that were copied from overseas mining rehabilitation practices and when used in conjunction with the standard stabilization techniques they are successful in creating stable, self-perpetuating natural vegetation.

Camp and Weisser (1991) in an earlier study of the rehabilitated vegetation at Richards Bay showed that succession is taking place and based on this and other evidence declared the rehabilitation process to be a success. In the present study, proof of primary succession has been obtained using quantitative techniques which objectively distinguish variations in the vegetation with increasing age of the rehabilitation stands. This together with changes in the species occurance, richness and diversity and also comparisons with naturally revegetated areas, is presented to quantify the amount of success obtained so far and to help make assumptions on future development of the rehabilitated areas (Harper,1990).

Brooks (1987b) states that post - mining rehabilitation has developed to such an extent in Australia that it is difficult to identify mined areas shortly after mining is completed. This is a subjective assessment but how do we determine from an objective botanical viewpoint whether rehabilitation has been successful or not? Carey and Brooks (1985) surveyed rehabilitation areas in order to quantify the number of potential canopy species. These were

then compared to pre - mined figures for the same area. Results showed that rehabilitated areas of two or more years have attained higher densities of upper canopy species than the pre - mined vegetation and are therefore successful in this aspect.

Brooks (1986) highlights the deficiency of information on the long term seral development of rehabilitated vegetation in Australia, the absence of which makes the assessment of rehabilitation success very subjective. The seral development of rehabilitated vegetation was recorded annually by Carey and Jefferies (unpub.) at Eneabba, Western Australia. The parameters chosen, species richness, density and percentage cover were recorded using an electronic botanical data management system which provides a summation of the factors scored and is capable of selecting out different groupings of plants. This provides a historical data bank which can be used to evaluate changes in the vegetation over the years (Brooks 1987b). Regeneration of the vegetation with distinct seral development from a cover crop to large shrub and tree communities as described by Brooks and Bell (1984) is characteristic of natural succession. As at Richards Bay an *Acacia* species tends to dominate the rehabilitation communities but only for up to 6 years, during which time they provide protection for young seedlings and add nitrogen and organic matter to the soil. After 6 years the *Acacia* species begin to senesce and the tree and large shrub species take over leading to an increase in species richness and diversity. The succession of the rehabilitated stands through similar stages of development as occurs in natural vegetation is an indication that the revegetation is successful. In the long term, successional processes will produce a vegetation that resembles the original in generic composition and physiognomy (Rogers 1982).

One basic but important criteria that can be a measure of rehabilitation success is the resistance of the stabilized post - mining surface to soil erosion (Bell 1987). According to Ford and Langkamp (1987) effective rehabilitation creates a stable landform capable of supporting self regenerating vegetation communities. Thus it is vital to establish a complete vegetation cover as soon as possible, but this must not inhibit the germination and growth of late successionary and canopy species. Where native vegetation is re - established the long term

diversity, stability and productivity of the vegetation are significant considerations for assessing success (Bell,1987).

Bradshaw (1990b) expresses the view that the basic principles of land and ecosystem restoration are the same as for ecological succession. This endorses the use of quantitatively obtained successionary evidence as a determinant of rehabilitation success. Furthermore the best evidence for the success of rehabilitation and our understanding of the functioning of ecosystems is when we are able to replace in the correct form and amount all those crucial components of the ecosystem which make it indistinguishable in structure and function from the original. However to justify these findings, restoration must occur over a limited period as given enough time any degraded or destroyed ecosystem will restore itself.

Judging the success of ecosystem restoration simply by the resemblance to the original is the most common approach. However in some circumstances it is a very superficial guage of success and Ewel (1990) proposes the use of more rigorous criteria such as stability, invasibility, productivity, nutrient retention and biotic interactions within the returned vegetation as indicators of the success achieved. As these criteria occur in the natural revegetation of indigenous communities and are part of the successionary process, the fact that they are considered makes the measurement of the rehabilitation success more decisive.

Westman (1991) has produced a protocol for measuring the performance of ecological restoration projects. This defines the restoration goals, selects appropriate criteria for monitoring goal achievement, identifies the performance standards and measures and maps levels of achievement of these standards. Performance is quantitatively measured using resemblance functions (CC values) and remote sensing and geographic information systems. Westman uses ecosystem resilience indices and Markov models, to evaluate the possibility of the current rehabilitation project leading to ultimate recovery. A flexible model using specialized ecological, social and economic evaluation criteria has been developed by Berger (1991) to assist descision makers to rate project effectiveness. Species composition, indicator

species, species abundance, species richness, age distribution and nutrient cycling are all considered under the ecological rating process. The evaluation includes magnitude, probability and importance ratings of ecosystem parameters.

If we are unable to learn from and rectify failures in existing rehabilitation, confirming the success in other rehabilitated areas is of little significance. The successes and failures as well as changes which take place in communities lead to questions on the factors guiding succession (Ashby,1990). von Maltitz (1990) and Weisser (unpub.) mention that information on the structure, function and dynamics of dune vegetation in South Africa is scarce. It is only by studying how communities develop following a disturbance that we will be able to gain an understanding of how these factors interact together (Brooks,1986; Gross,1990).

Experimental studies or manipulations of rehabilitated vegetation offer the best opportunities to discover the forces acting on and produced by changes in the community complexity (Ashby,1990). Gross (1990) endorses the use of experimental manipulation of communities to try to recreate features or events that occur naturally, thereby exposing the mechanisms responsible for maintaining diversity. As forest and wetland communities only show reactions to the modification in the long term ie. (5 - 15 years) it was not possible to undertake any manipulative experiments on these vegetation types during the two years available for this study. Grassland on the other hand consists of fast regenerating species and is ideal for small scale studies involving the change of component parts (Kline and Howell,1990). It is also the vegetation type that encourages the return of animal and bird species which in turn play an important part in the natural succession from secondary grassland through bushclumps and thickets to forest (von Maltitz *et al*, 1989).

An excellent summary of what a good rehabilitation programme sets out to achieve is that given by Bell (1987). The initial objective is to create a self - sustaining land surface which is stable against the erosive forces of water and wind thus preventing localized environmental change. The longer term task is to return mined land to a condition suitable for other forms

of land use. This may involve the return of land to native vegetation for wildlife conservation or recreation, the establishment of agricultural or forest crops or the creation of improved pastures for stock. These are the same principles as practised by Richards Bay Minerals which has led to their investment of large sums of money in the replacement of *Causarina* plantations and the rehabilitation of indigenous dune vegetation. They have sponsored studies undertaken recently and still in progress, to try to quantify the success obtained in their rehabilitation of the dune forest ecosystems and to make proposals for changes where necessary. This commitment of RBM to restoring mined areas to their former state needs to be acknowledged and all assistance possible should be given by concerned ecologists and conservationists to encourage and help them achieve their aim.

1.4 Study area

The area being mined by Richards Bay Minerals is just north of Richards Bay, between the foremost coastal dunes and the interior (Fig 1.3). It forms part of the southern most extension of the Mozambique Coastal Plain which in the south makes a very narrow strip on the continental margin.

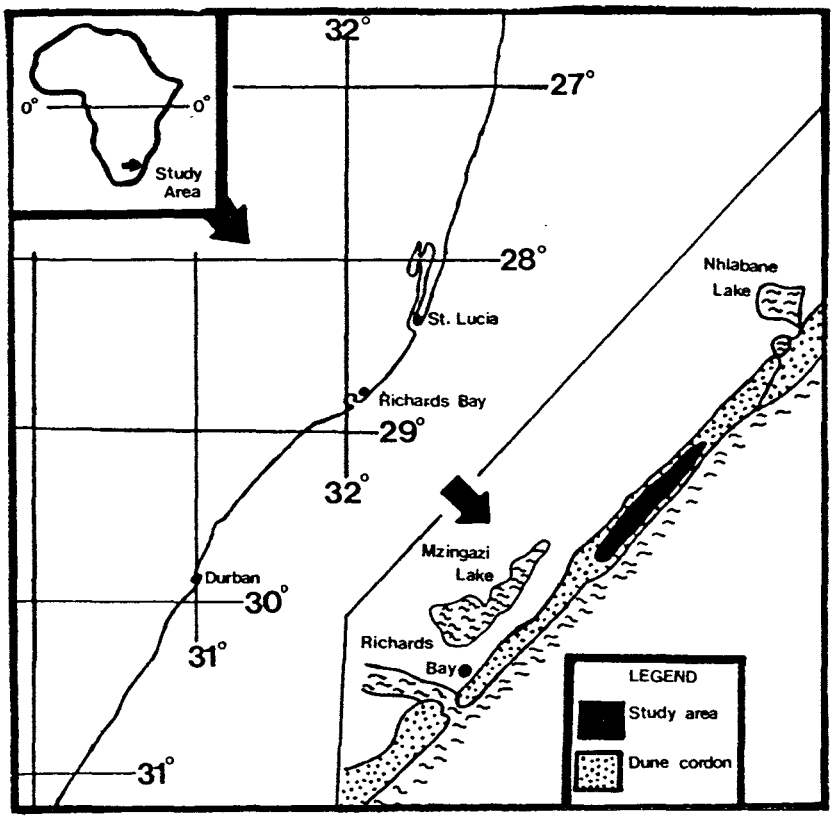

Figure 1.3; Map of Northern Natal showing the location of the Richards Bay Minerals mine site.

The dune systems of the Natal North Coast are formed from deposits left on the coastal plain as a result of climatic changes and sea level movements (Maud,1991). At the time of the last glacial period large areas of the coastal plain were exposed with the receding sea levels after which a period of high wind velocities built up the present dune cordon (Tinley,1985). The Zululand coastal dunes can be regarded as a young formation approximately 9000 years old which have since been modified by parabolic dune forming processes (von Maltitz, etal 1991, Maud,1991). The soils in this area are deep and sandy with clays and nutrients concentrated in the topsoil. The dunes are highly permeable which together with the rapid weathering and leaching of minerals has formed sandy soils of low fertility. Leaching by rainwater and aeolian reworking of weathered sands has removed the clay content from the topsoil to form a clayey sand layer deeper down (Maud,1991).

The climate of Richards Bay is subtropical with a high annual rainfall of 1650mm at the mine site. The daily weather is hot and humid with an average temperature of 21,5°C recorded at the Cape St. Lucia station (Fig 1.4). The main winds are north - easterly which produce hot and dry conditions, while the south - easterly winds are associated with rainy weather (Camp,1990). These climatic conditions are ideally situated for vegetation growth and rapid regeneration of disturbed areas.

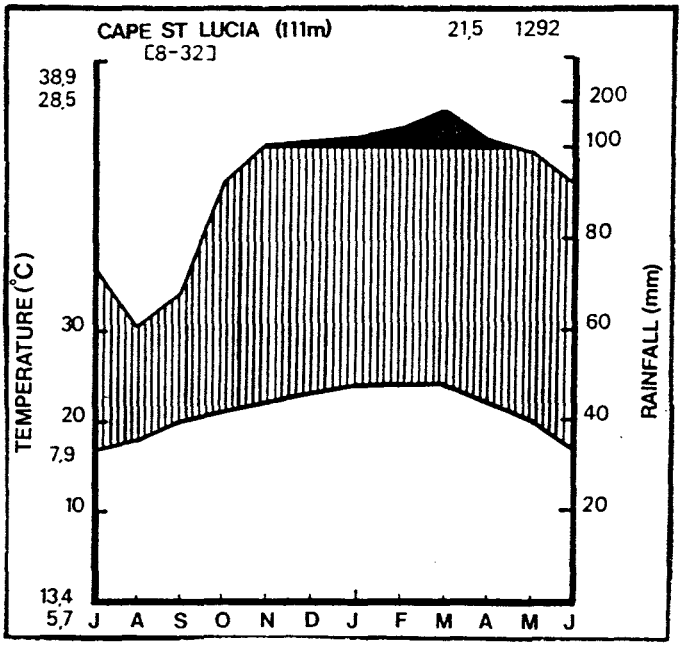

Figure 1.4 Climatic diagram of the data recorded at Cape St Lucia lighthouse (from Camp and Weisser, 1991).

The vegetation includes both tropical species with their southern limit in this area and the common southern dune forest species which begin to reach the northern end of their distribution in this area. According to Weisser and Muller (1983) the original vegetation was mainly Dune Forest and Closed Dune Scrub, however shifting cultivation has destroyed most of the original vegetation. Exotic plantations of *Eucalyptus grandis* also covered large areas of the mine path prior to mining (Camp,1990). The pre - mining vegetation was therefore not pristine at all but in terms of soil structure and topography the area had not been disturbed. Weisser (1987) recorded 285 species in the dune forests between Richards Bay and the Mlalazi Lagoon, and if the rehabilitation is to be completely successful the same number of species and vegetation complexity need to be returned.

1.5. Aims and Objectives

The return of natural vegetation after mining, to a state that resembles and functions the same as the original community, is the aim of rehabilitation ecology. Bearing this in mind, this project was undertaken to investigate just how successful the rehabilitation techniques used by Richards Bay Minerals have been, and based on the results, to make proposals for future management policies. A breakdown of the major aims of this study are as follows:

1) To determine the success of the return of wetland and dune forest communities. The return of the dune forest, now only twelve years old, is assessed according to its progression through initial successionary stages. (Chapter 2)

2) To determine the available seed bank present in the rehabilitation stands. This is only a "pilot" study and more in - depth research is required to distinguish whether a lack of seeds may be limiting the establishment of certain species. (Chapter 3)

3) To study natural revegetation in the vicinity of Richards Bay and to compare this to the rehabilitated stands of similar age. Studying older revegetated areas gives us an indication of what to expect from the rehabilitation stands as they mature. (Chapters 4 & 5)

4) To establish the best means of obtaining diverse grassland communities using economically viable rehabilitation techniques. (Chapter 6)

These aims and objectives have been formulated due to conceptual thinking and hypotheses based on the general successionary ideas of Connell and Slatyer (1977). Firstly the facilitation mechanism which highlights the interactions and need for early and late colonisers, and the futility of trying to establish late successionary species at the outset. If the rehabilitated vegetation is self-perpetuating and creates changes in conditions that favour later-colonising species, then a successful successionary development has been obtained. For this reason sampling was undertaken to expose the changes in species composition, community complexity and edaphic factors from younger to older rehabilitation stands. The absence of seeds of both early and late colonisers in the seed bank can lead to poorly developed communities and may retard the successionary process therefore requiring the input of further indigenous seed. If no knowledge exists on the availability of the seed this makes it impossible to quantify this limiting factor. In the grassland community it appears that *Eragrostis curvula* is preventing the establishment of all but the most robust grassland species due to it's extensive cover. This example of inhibition requires a reduction in the *Eragrostis* cover on a scale that allows replacement with other species but does not reduce stability of rehabilitated areas. Burning and cutting which are temporary measures for reducing the total cover of the swards but do not remove the individual plants were used. These treatments enable other species to germinate and grow at the begining of the summer season while the *Eragrostis curvula* is still recovering and re-sprouting.

CHAPTER 2

ASSESSMENT OF DUNE FOREST REHABILITATION AT RICHARDS BAY FOLLOWING MINING

> *"I think there is a general feeling that the ability to restore communities under various conditions and with confidence of success will turn out to be a test of ecology as a mature science." (Werner 1990)*

2.1 Introduction

At the start of mining at Richards Bay in 1977 no large-scale rehabilitation of dune mined areas and particurly of dune forest vegetation had taken place in South Africa. Drift sand stabilization and the reclamation of cleared dunes has occured along most of the South African coast. However even though this has included large areas of mobile sand it has never been attempted to establish a completely natural community and especially one as complex as dune forest (Avis 1989). Similarly the rehabilitation of the Witwatersrand mine dumps was aimed at simply revegetating and stabilizing these stacked tailings. The grassland communities produced on the mine dumps have a low species diversity and are composed largely of palatable species cultivated for grazing purposes. When RBM started their rehabilitation of dunes, they could have used the methods of dune stabilization practiced in this country, but as they wanted to return natural dune forest they had to base their rehabilitation techniques on those employed overseas. Hannan and Brooks (1987) warn against the use of techniques developed in other countries, as factors such as climate, geology and soil types vary so much from site to site. Fortunately environmental conditions in Australia, where extensive successful rehabilitation of natural vegetation has taken place, are very similar to those in Zululand. This enabled RBM to utilize the knowledge and experience gained in Australia but adapted to local conditions in the rehabilitation of the dune forest ecosystem (Brooks,1987b). The rehabilitation process as described in the first chapter

has been refined over the years and with stands of 12 year old rehabilitated vegetation it is now possible to quantify the initial success and make further adjustments based on these findings. Cairns(1990) feels that the opportunity offered by rehabilitated areas for the study of ecological processes and functioning cannot be stressed enough. This research can have positive contributions to the mining company as it provides useful information for the long term maintenance of rehabilitated areas so reducing the overall cost of restoration (Bell,1987; Bradshaw,1990a).

Research aimed at confirming the success of rehabilitation is very rare and mostly presented in the form of a descriptive review. As a result no particular method of objectively determining success has been formed but a number of suggestions are made in the relevant literature. The most popular of measures for deciding on the success of a rehabilitation project is whether or not the reconstructed community resembles the original (Ewel,1990). This approach is very subjective and not suited to making future management policies, therefore it was decided to rather use another measure. Succession is the natural process whereby the vegetation returns after a disturbance to its former stable state (Clements,1916). If it can be quantitatively shown that this is taking place, as expected, with all the constituent parts present, then the rehabilitation should be successful. Gross (1990) supports this with the statement that an "understanding of how communities develop following a disturbance, which is the process of succession, is fundamental to developing an understanding of the maintenance and restoration of diversity in plant communities". The advantage of using succession as a gauge of success is that it is an ongoing process enabling us to make predictions on future vegetation development. As succession takes place changes in the species richness, diversity and species compositions are to be expected. Thus these factors, together with soil properties, structure of the vegetation and complexity, have been investigated for the progressively older rehabilitation stands. The continous progress of the mining and the subsequent rehabilitation provides according to Cairns (1990) an unequalled supply of ecosystems of known age since disturbance. If the environmental factors such as aspect, slope and macroclimate are virtually the same for all the stands it makes comparison

between stands of different ages possible. Further influences on the development of rehabilitated vegetation such as the origin and quality of the topsoil spread on tailings, the distance from an available seed source (MacMahon, 1990) and the related boundary shape of the rehabilitated site which effects the colonization pattern (Hardt and Forman, 1989) need to be considered. The period that topsoil is stockpiled and the date of sowing of additional seeds is believed to have an effect on the later successional species (Brooks and Bell, 1984). The inability of late successional woody species to survive the disturbance caused by mining and transport to the tailings as mentioned in chapter 3 is cause for concern. Most species are prompted to germinate by disturbance of the soil and it may be the early growth or stimulation of these species while unfavourable conditions prevail that prevents them from establishing in the rehabilitated sites (Brooks and Bell, 1984).

One of the aims of rehabilitation is to create a highly diverse community as soon as possible. However environmental conditions at the start of rehabilitation are often not able to sustain late successionary species, and the different seral stages of early colonisers must be allowed to proceed. This is described in Connell and Slatyer's (1977) facilitation mechanism of succession, whereby early colonisers create conditions that favour (or facilitate) the return of other species that cannot re-establish in their absence. The complete dominance of the rehabilitated sites at Richards Bay by *Acacia karroo* has caused concern among some environmentalists who believe this species is inhibiting the establishment of other woody plants (Camp, pers. com.). Although this is thought to be affecting the diversity in the rehabilitation community at present it is possibly a very important stage in the succession of the dune forests. It was noted before mining started that *Acacia karroo* was always present and dominated the natural succession occuring on disturbed ground in the Richards Bay area (Camp, 1990). Therefore this species was seeded into the topsoil and left to grow into a canopy under which other forest species could germinate.

Weisser (1987), in a study of the vegetation between Richards Bay and the Mlalazi Lagoon, identified 285 species from a range of habitats. It is not expected that anywhere near this

number of species will be found in the rehabilitated stands, not only due to the lack of habitat diversity created but also the time elapsed since the rehabilitation process began. From Weisser's work and that of other ecologists including Moll (1972), Venter (1972), Weisser and Muller (1983), Tinley (1985), von Maltitz *et al* (1991) and Weisser (unpub) it was possible to determine which species are missing from the rehabilitation stands, and also the key species that play a major role in the succession pathways. The presence or absence of certain key species can act as indicators of the stage of maturity that the rehabilitated communities have reached, especially where these species require specific growing conditions. Richards Bay Minerals' rehabilitation of indigenous vegetation has not only been restricted to dune forest although this community does cover by far the largest area. Attempts at reconstructing both grassland and wetland communities are now receiving greater attention (Plate 6), and Chapter 5 of this study focuses on experimental manipulation carried out on the rehabilitated grassland.

This chapter looks at the success that has been achieved so far in the return of indigenous dune forest species to the rehabilitated stands. Also the development of the rehabilitation stands through expected seral stages of vegetation succession has been highlighted. The changes occuring in the physical properties such as soil nutrients and pH are also reviewed.

2.2 Materials and Methods

An almost continuous rehabilitation of indigenous dune forests has taken place at Richards Bay since 1978 and the ages of the vegetation stands are clearly marked. Five random 10m x 10m quadrats were sampled for vascular plants during 1990 in each rehabilitation stand of ages 4, 5, 7, 8, 9, 10, 11 and 12 years (Table 2.1). No rehabilitation of indigenous dune forests was undertaken in 1984 and therefore no data of six year old stands is included in the results. The same plot size and sampling technique were used in each rehabilitation stand to enable direct comparison of data from the various communities. Sampling was not done in the stands less than four years old due to the still visible presence of cover crop species and artificial wind breaks. The vegetation of the stands 4 years and slightly older is very homogenous and therefore only 5 quadrats were used to account for variability. Carey and Brooks (1985) felt that four 100m^2 plots and six 100m^2 plots per year respectively in their studies at Amity and Enterprise minesites in Australia were adequate. Camp and Weisser (1991) used 10m x 10m quadrats in their study of the rehabilitated vegetation at Richards Bay. Every species found was recorded, the unknown individuals were collected and later identified at the Rhodes University Herbarium where voucher specimens are deposited. The abundance data recorded for each quadrat included species density and cover, the height and cover of the different strata as well as aspect and slope. Physical conditions of the rehabilitated stands and the biotic influences were noted.

Table 2.1; Quadrat numbers associated with age of stands in which they were sampled.

QUADRAT NUMBERS	AGE OF STAND (YEARS)	YEAR REHABILITATED
1,2,3,4,5	4	1986
6,7,8,9,10	5	1985
11,12,13,14,15	7	1983
16,17,18,19,20	8	1982
21,22,23,24,25	9	1981
26,27,28,29,30	10	1980
31,32,33,34,35	11	1979
36,37,38,39,40	12	1978

Cover data from all the 40 quadrats were used for multivariate analysis. The data was analysed by Two Way Indicator Species Analysis (TWINSPAN). This produces a two-way table from which a dendrogram expressing the affinities between samples can be constructed. Twinspan has been used successfully in a number of studies on succession in vegetation (Avis, *et al*,in prep). In the same way Detrended Correspondence Analysis (DECORANA) has ordinated the 40 samples showing changes in the vegetation from younger to older rehabilitation stands. The importance values of certain key species in stands of different age were calculated, with the relative cover, relative frequency and relative density acting as parameters of importance, were then summed to give a maximum importance of 300 (Mueller-Dombois and Ellenberg, 1974; Lubke, 1985). Total and mean species richness (Brower and Zar, 1984) as well as the total cover values of the three strata have been calculated for each rehabilitation stand.

Species diversity which is at its maximum when the individuals are distributed evenly amongst the species was also determined. A number of methods were used to calculate the intra-community or alpha-diversity; Simpson's dominance index (ℓ) estimates dominance within communities, the inverse of ℓ (ds) is a measure of diversity (Table 2.2). Brower and Zar (1984) explain the diversity index as an expression of the number of times needed to collect two individuals randomly before finding the same species. Shannon's diversity index (H) is not affected by the lack of data on rare species. It was applied as rare species can be a problem in rehabilitated communities. Beta diversity which highlights the species turnover in a community is expressed by Sorenson's (1948) co-efficient of community (CC). This is a measure of the resemblance between communities, high CC values indicate a greater similarity in species composition. Westman (1991) supports the use of CC values for pairwise comparisons between rehabilitated areas as has been done in this study.

Soil samples collected from the surface of the rehabilitation stands, the pre-mined indigenous forests (topsoil and subsoil) and the mined tailings were analyzed by the Rhodes University Plant Nutrition Reaserch Unit, Grahamstown. Percentage organic matter, pH, calcium,

phosphate and sodium were measured to determine if changes in some of the nutrients and soil properties are taking place throughout the ageing rehabilitation stands. It is hoped that with all this quantitative data the succession occurring in the rehabilitation stands can be proved beyond a doubt. The results presented are the means of three, separately collected samples and their replicates. However after measuring a higher percentage organic matter in the tailings compared to the topsoil of the rehabilitated stands more replicates were collected. The final results being obtained from eight separately collected samples which when meaned gave a lower organic content for the tailings compared to the rehabilitated stands.

Sampling of the grasslands was in the form of a number of 1m x 1m plots which is described in Chapter 5. The wetland formed at an old turning of the dredge path does not contain many characteristic species which were not recorded in the grasslands, however two 5m x 5m quadrats were sampled in this vegetation type (Plate 6).

2.3 Results

In recent times the study of vegetation succession using numerical techniques has become more common, and these are now accepted as valuable contributions to the field of ecology (Avis,etal, in prep.). By separating sample sites according to their species composition, these techniques are able to bring into perspective the changing complexity of the rehabilitated vegetation.

2.3.1 Classification and Ordination:

The TWINSPAN dendogram (Fig 2.1) produced from the two-way indicator table shows a clear seperation of the older (1978, 1979 and 1980) and younger (1985 and 1986) rehabilitated stands at the third level of division. This is due to changes in the sub-dominant species, as *Acacia karroo* has remained the dominant species throughout the rehabilitation stands (Plates 1,2 and 3). The position of samples not found in the place they would be expected, may be accounted for by the presence of some early successionary species in the older vegetation. Likewise the early germination and colonization by late successionary species in immature stands is also possible. These two factors, causing minor differences in the vegetation composition, diversity and complexity, are most likely responsible for the mixture of the intermediate stands in an undifferentiated group.

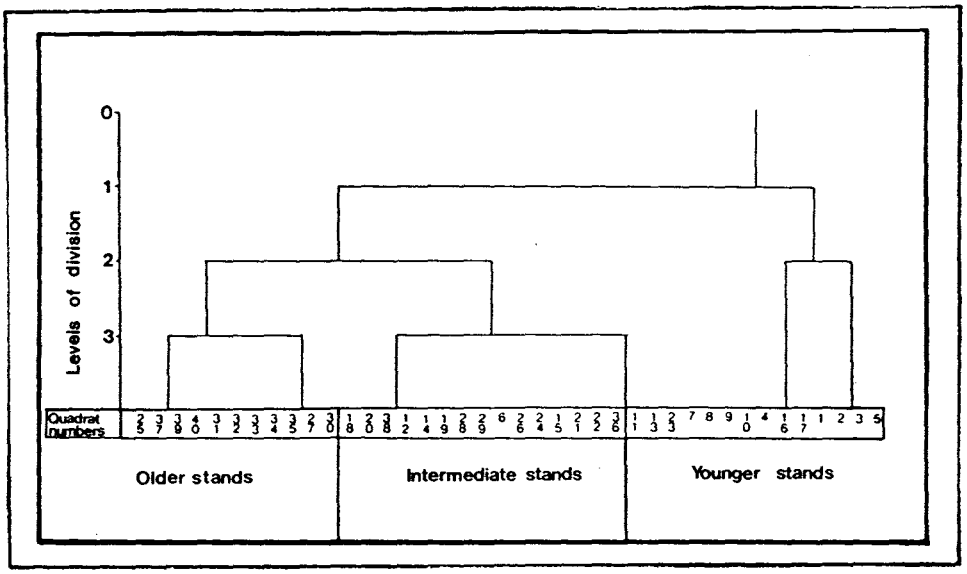

Figure 2.1; TWINSPAN dendrogram shows the seperation of stands, based on species content and stand complexity that change according to their age since rehabilitation.

DECORANA (Fig 2.2) a technique complimentary to TWINSPAN has produced a similar distinction between the oldest and youngest stands. A loose arrangement of the samples along axis 2, depicting a gradient of increasing community complexity with age was obtained.

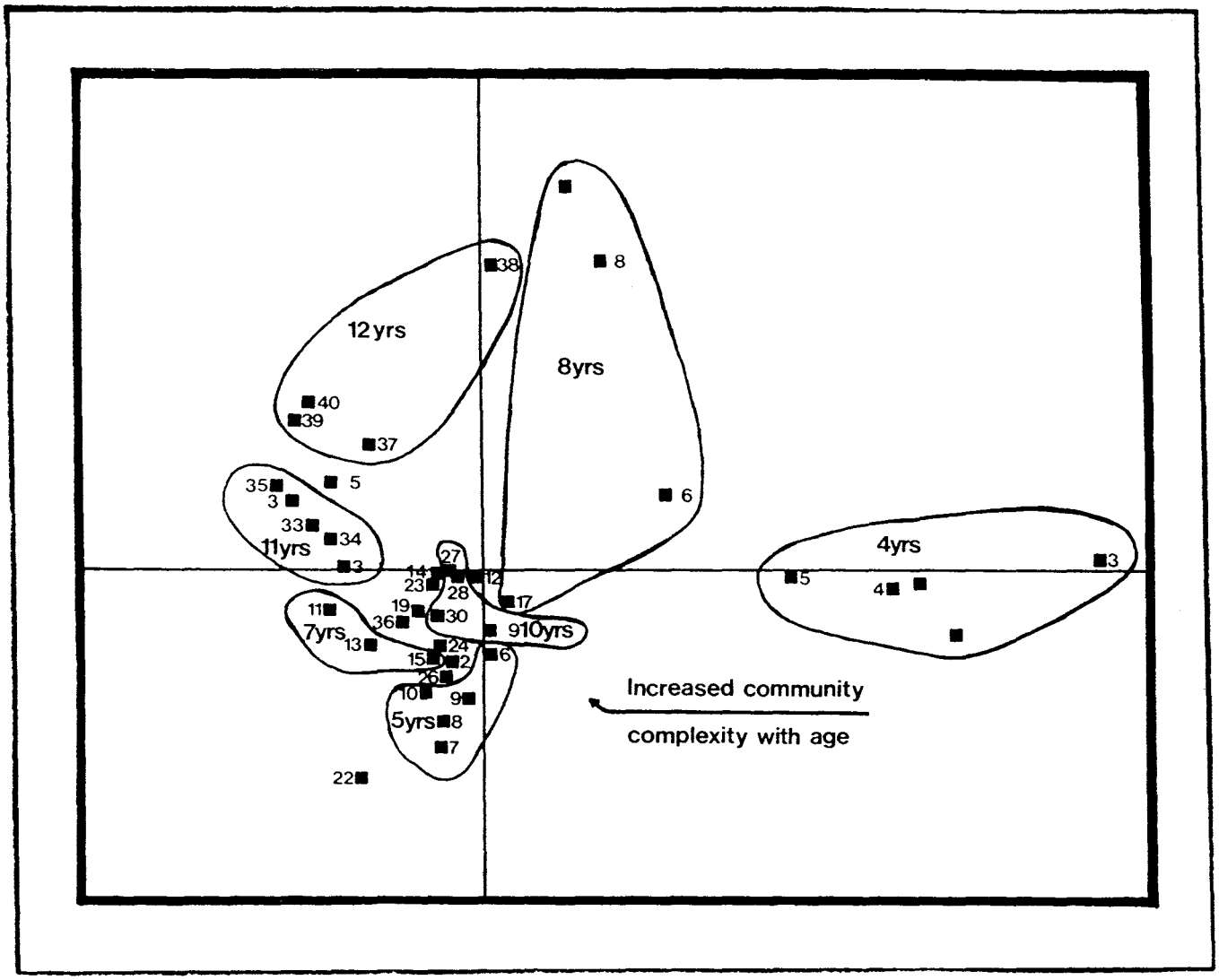

Figure 2.2; DECORANA plot with increased community complexity with age since rehabilitation. Groupings are similar to those obtained by TWINSPAN.

The distribution of samples on axis 1 shows greater plant diversity with ageing of the vegetation. The grouping of samples according to age are clearly distinguished by DECORANA.

2.3.2 Changes in Species Importance and Total Cover of Strata:

Importance values (Figures 2.3 and 2.4) calculated for eleven key species have shown that woody species and climbers are present in greater numbers in the older rehabilitated stands. *Canthium inerme* and *Carissa bispinosa* are only found in stands older than eight years since rehabilitation when the shrub layer starts to establish. *Tricalysia sonderiana* and *Brachylaena discolor* which appear to play leading roles in the succession of rehabilitated stands occur throughout but increase in importance in older stands. Weisser (unpub.) listed both as key species based on their spacial and temporal dominance in this study of vegetation dynamics on the Zululand dunes. The climbers *Secamone filiformis* and *Cynanchum natalitium* are found in nearly every sample but become more common in the older stands, as competition for light begins to play a role in the community structure. *Vigna unguiculata* and *Hibiscus surattensis* which also have climbing habitats are only found in the younger stands. Both species do not show a rank type of growth but creep along the forest floor and appear to be outcompeted by fast growing ground cover species in the older rehabilitated stands. *Cheilanthes viridus,* suited to open grassy habitats, is found in the younger stands, whereas *Microsorium scolopendrium* the other fern is more suited to bushclump and forest communities (Moll 1972, Pammenter *et al*,1985) and occurs throughout the range of rehabilitation stands. *Acacia karroo,* although remaining the most dominant woody species in all the rehabilitation stands, declines slightly in importance with age. This may be due to the reduction in the number of individuals of this species, or the invasion by other species of the older rehabilitated stands.

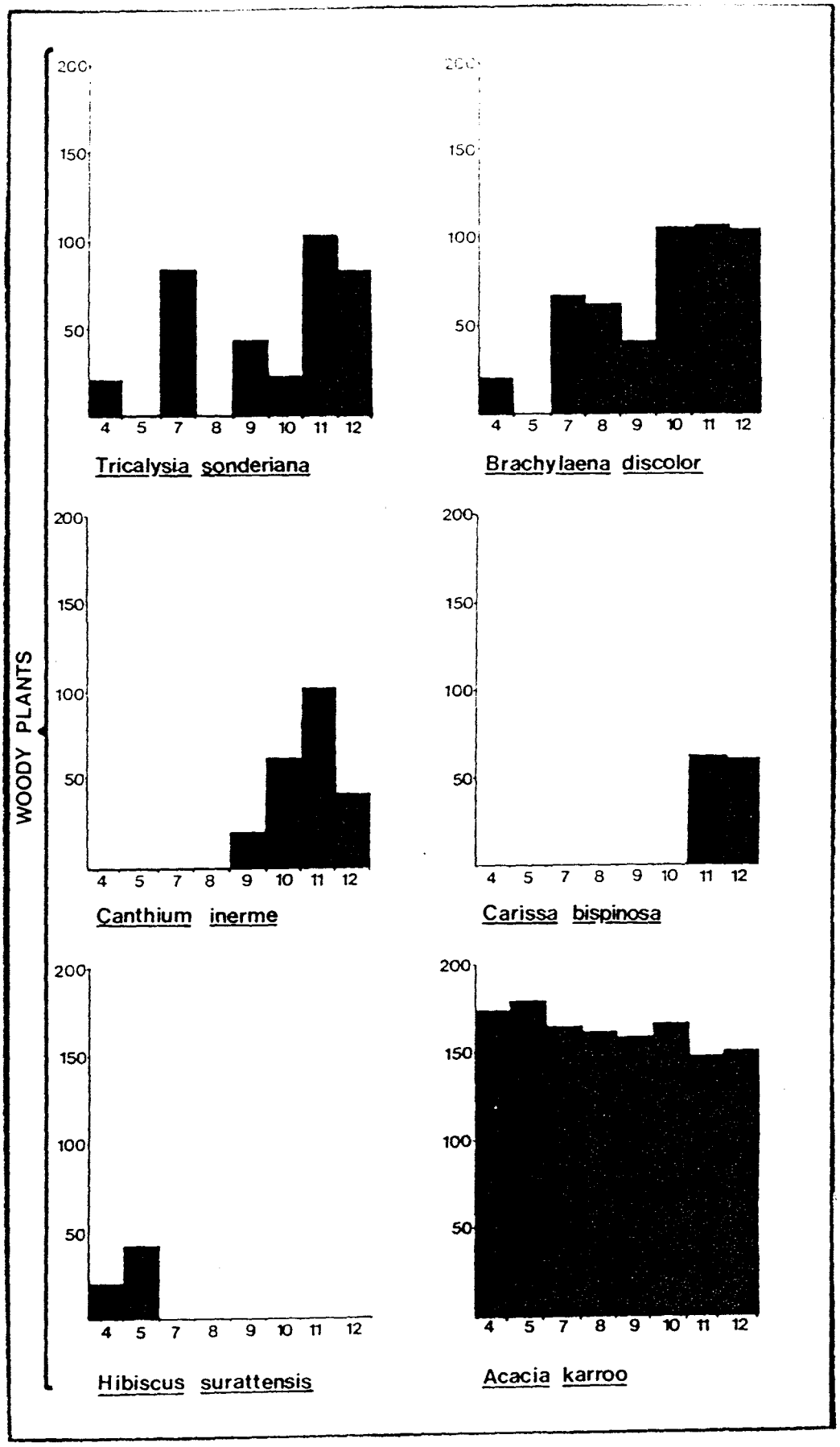

Figure 2.3; The change in the Importance values of some of the dominant woody plants as the rehabilitation increase with age since mining.

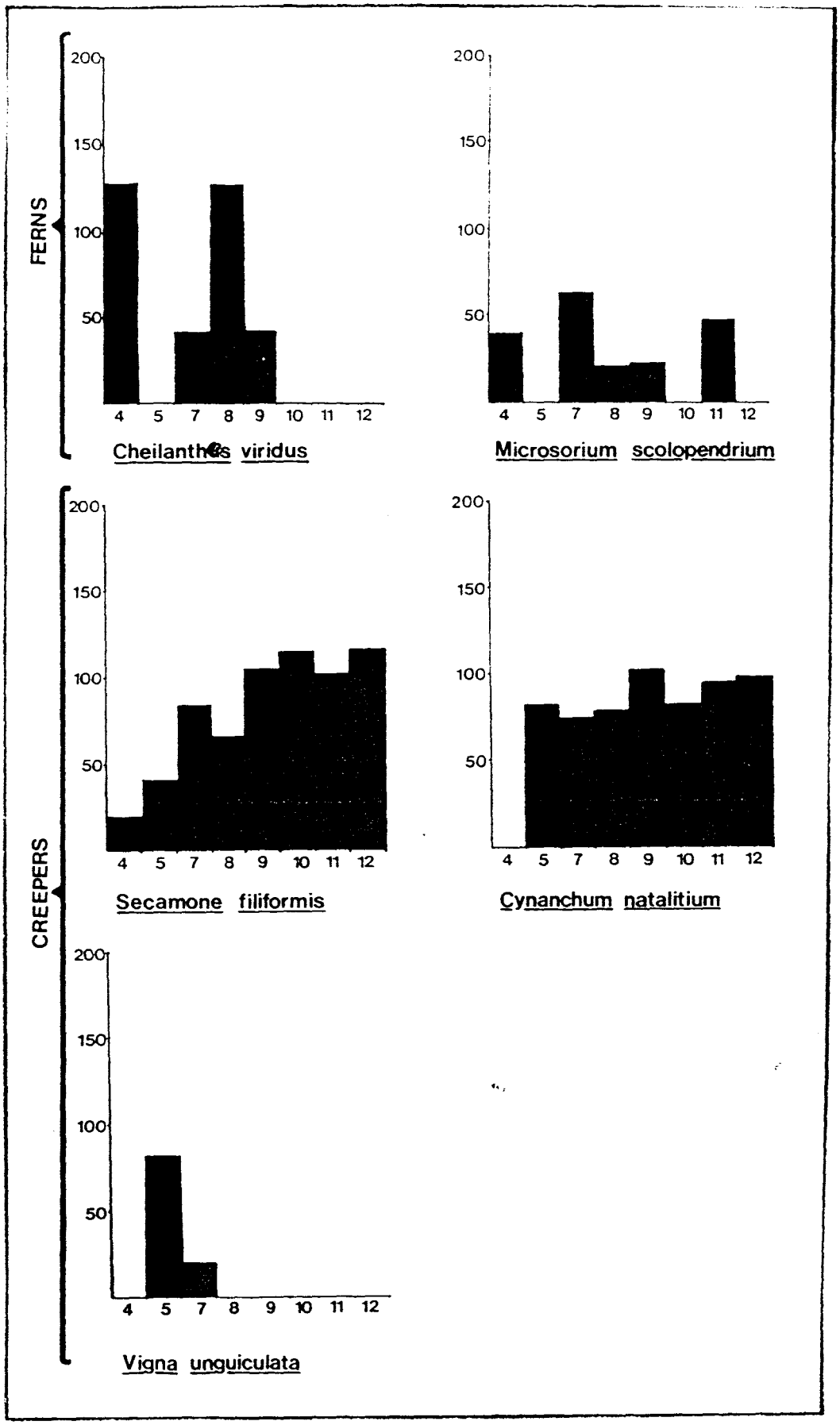

Figure 2.4; The change in the Importance values of fern and creeper species with increasing stand age.

The total percentage cover values for each vegetation strata in the rehabilitation stands have been calculated (Fig 2.5) using the mean cover from the five samples recorded. The total cover starts off high then decreases until the ten year old stand after which it increases again. The lowest total cover is for the nine and ten year old stands which is in accordance with other results such as the species richness and diversity (Fig 2.6 and Table 2.2) that also show reduced values for these two stands.

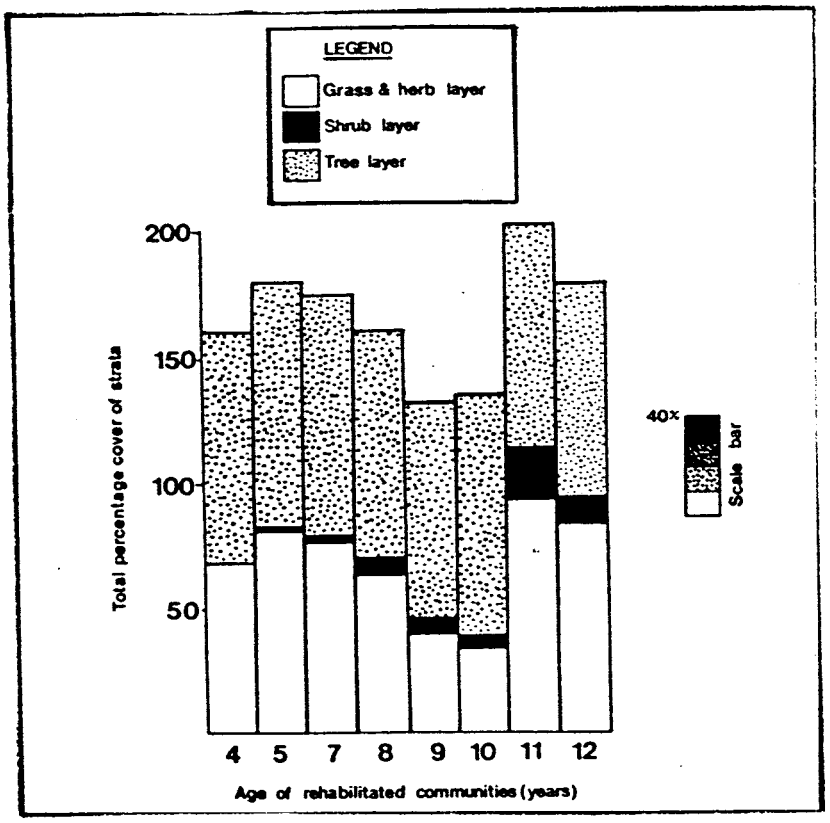

Figure 2.5; Total percentage cover of the strata combined together and of individual strata for the rehabilitation stands of different ages.

From the graph it is noticeable that the tree layer composed almost entirely of *Acacia karroo* maintains a relatively constant cover of about 85 to 90% . However covers of 98% and 100% for the nine and ten year old stands respectively, with higher densities of *Acacia karroo* trees compared to the surrounding years may be an explanation for the reduced total cover value. The shrub layer increases from almost non-existent in the youngest stands (Plate 1) to about 10 - 20% in the 11 and 12 year old stands (Plate 3). The highest cover of shrubs occurs in the 11 year old stand which borders on a fairly extensive area of natural vegetation from

Plate 1 Dense *Acacia karroo* thicket rehabilitated six years ago. The ground layer is composed mostly of dead *Eragrostis curvula* and *Panicum maximum*.

Plate 2 Nine year old rehabilitated *Acacia karroo* woodland with a limited grass and herb layer. Rotting *Acacia* branches litter the open floor inbetween which the young seedlings and creepers grow.

Plate 3 *Acacia karroo* woodland rehabilitated twelve years ago. Showing extensive ground cover of *Laportea peduncularis* and *Asyatasia gangetica*. Shrubs such as the *Trema orientalis* shown in the centre of this photograph are also establishing themselves.

which many indigenous species have colonised. It is also very moist and supports a lush growth of ground cover species. Lowest cover values for the grass and herb species and a lower cover of shrubs is found in the nine and ten year old stands (Plate 2). This may be due to either growth suppression by the dense canopy which restricts light penetration or other unfavourable microclimate conditions that promote *Acacia karroo* dominance. From the graph it can be seen that a definite change in the structure of the vegetation is occuring with increased age of rehabilitation stands as would be expected if primary succession is taking place.

2.3.3 Species richness and Species checklist:

Further changes in the rehabilitated vegetation were revealed in terms of the species richness (Fig. 2.6), and a complete checklist has been produced (Appendix 1) of the 109 species collected in the rehabilitated dune forest. Slight increases in both the mean and total species richness were found against the progressive age of rehabilitation stands which is similar to findings made by Brooks (1989). Total species richness started off at 26 species in 4 year old stands and increased to 48 species in the most diverse 11 year old stands. Once again the species richness shows a reduction in the ten year old stand, therefore a repeat sample of this year and the surrounding years was undertaken to determine whether this was indeed so or because of unrepresentative sampling. The results show an increase in total species richness value of the ten year old rehabilitation stand, but these are still lower than the surrounding stands. However the mean species richness of each quadrat sampled in the 10 year old stand did increase in the second sample. This could be an indication that edaphic conditions in this stand are in a state of flux or otherwise are not suitable for rare species which results in a lower total species richness.

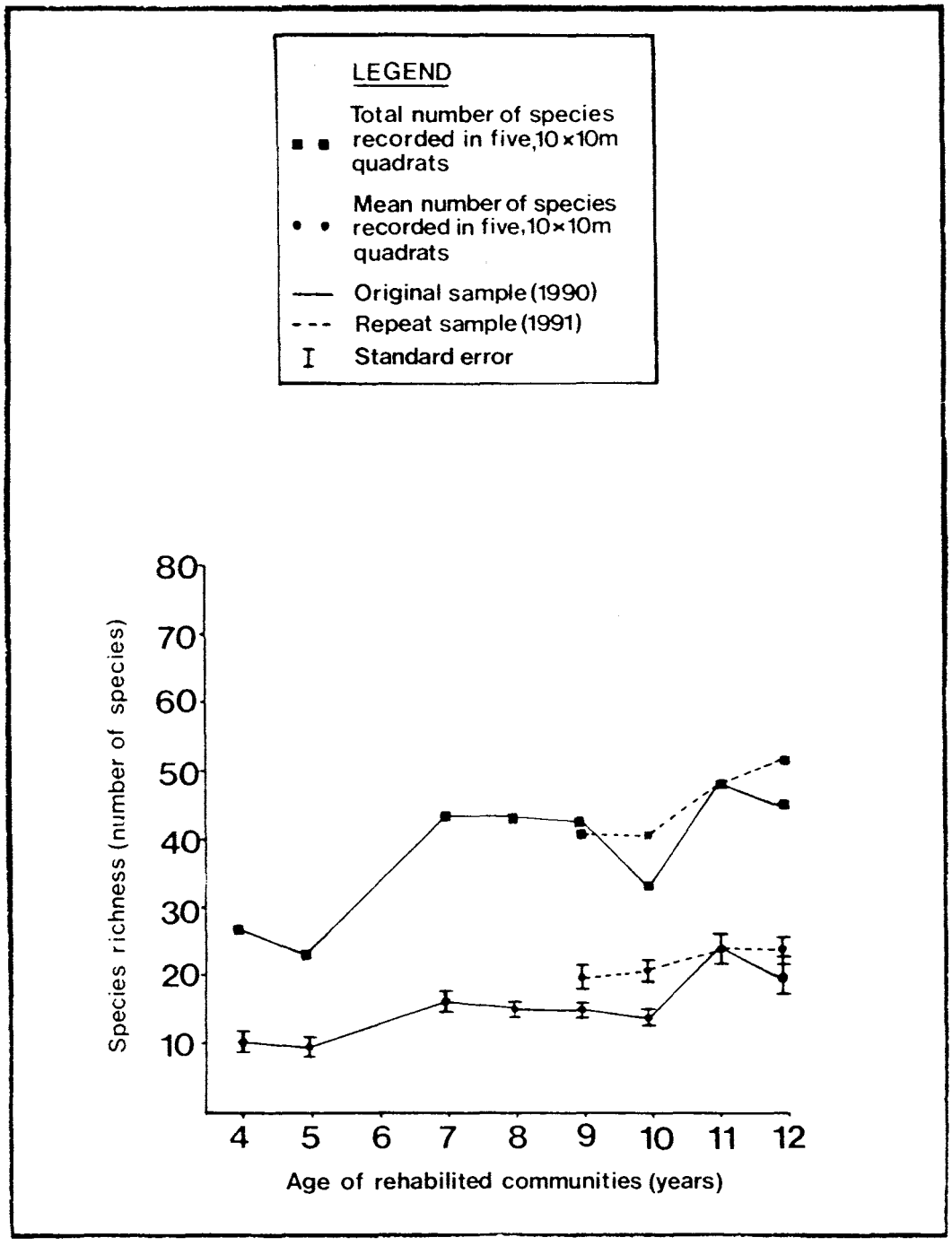

Figure 2.6; Species richness values plotted against age of rehabilitation stands.

2.3.4 Species diversity:

According to Whittaker (1975) species diversity (Table 2.2) can be expected to increase over time in successional communities. The inverse of L (ds) and Shannon's diversity (H') both show a general increase in diversity with growing maturity of the rehabilitated

Table 2.2; Species diversity and dominance values for the rehabilitation stands of different age. The two species richness values for some stands include the initial value recorded (above the line) then the repeat sample taken at a latter date.

YEARS SINCE REHAB.	MEAN SPECIES RICHNESS	TOTAL SPECIES RICHNESS	SIMPSON'S DIVERSITY (Ds)	INVERSE OF L (ds)	SIMPSON'S DOMINANCE	SHANNON DIVERSITY (base E)
4	10	28	0,859	7,098	0,149	0,298
5	9	25	0,868	7,607	0,131	0,371
7	17	44	0,891	9,167	0,109	0,677
8	15	43	0,911	11,262	0,089	0,892
9	20 / 15	41 / 43	0,901	10,131	0,099	0,755
10	21 / 14	41 / 32	0,912	11,394	0,087	0,803
11	24 / 24	47 / 47	0,902	10,263	0,097	0,778
12	24 / 20	52 / 46	0,930	14,248	0,070	0,928

vegetation. The nine and ten year old stands don't conform to this pattern but still have a much greater diversity than the younger rehabilitation stands (4, 5 and 7 years old). These irregularities may be accounted for by the total dominance of the lower strata by a single species such as *Laportea peduncularis, Asystasia gangetica* or *Isoglossa woodii*. This reasoning is supported by the values of Simpson's dominance index (I) which decreases with increasing stand age except the nine and eleven year old stands. These two stands deviate from the decreasing values with higher values showing the dominance by one or more species. Sorenson's co-efficient of community similarity (CC) was calculated to determine the beta diversity (species turnover) between stands (Table 2.3). When the CC values are low, the two communities are dissimilar and the species

Table 2.3; Community similarity (CC) values (above shading) and shared species (below shading) between the different ages of rehabilitated *Acacia* woodland. Total species richness (shaded) in the diagonal.

YEARS SINCE REHABILITATION BEGAN								
YEARS SINCE REHABILITATION BEGAN	4	5	7	8	9	10	11	12
4	28	0,26	0,38	0,37	0,34	0,30	0,27	0,16
5	7	25	0,41	0,35	0,47	0,35	0,31	0,34
7	14	14	44	0,53	0,60	0,45	0,26	0,42
8	13	12	23	43	0,49	0,48	0,40	0,40
9	12	16	26	21	43	0,48	0,60	0,56
10	9	10	17	18	18	32	0,51	0,49
11	10	11	12	18	27	20	47	0,47
12	6	12	19	18	25	19	22	46

turnover (beta diversity) is high. As expected the similarities between the old and young stands are low. Higher similarities occur amongst the younger stands (4,5 and 7 years old) and the older stands (10, 11 and 12 years old). The highest similarities are found between the 7 and 9 year old stands and the 9 and 11 year old rehabilitated stands. The number of shared species shows similar relations between the stands. The highest number of shared species also being between 7 and 9 year old and 9 and 11 year old stands.

2.3.5 Soil Factors:

The analysis of the soil (Figures 2.7, 2.8 and 2.9) has produced data which depicts an increase with stand age of the base elements, a minor increase in percentage organic matter and a relatively constant pH.

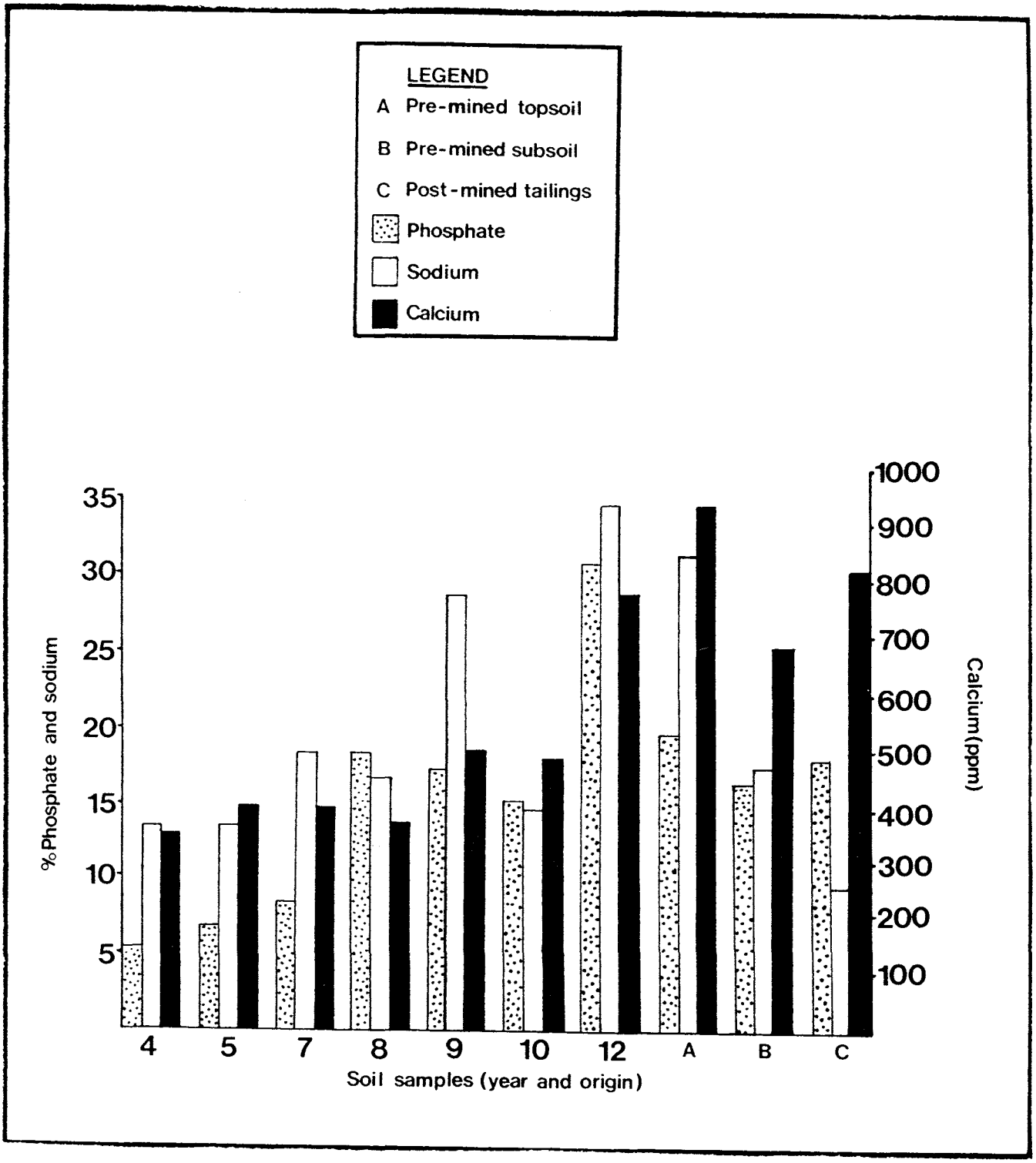

Figure 2.7; Phosphate, Sodium and Calcium content in soils of rehabilitation stands of different ages, tailings and pre-mined topsoil and subsoil.

Comparison of data obtained from the topsoil and subsoil of the pre-mined indigenous dune forest and post-mined tailings has shown similarities with the base elements measured in the soil of older rehabilitated areas (Fig 2.7). Organic matter content is much higher in the topsoil and subsoil of the indigenous dune forest but this is to be expected as it has accumulated over hundreds of years (Fig 2.8). The immaturity of the soils, lack of burrowing animals and invertebrates and the rapid conversion and leaching of organic matter due to the loss of soil profile could all be responsible for the low levels obtained in the rehabilitated vegetation.

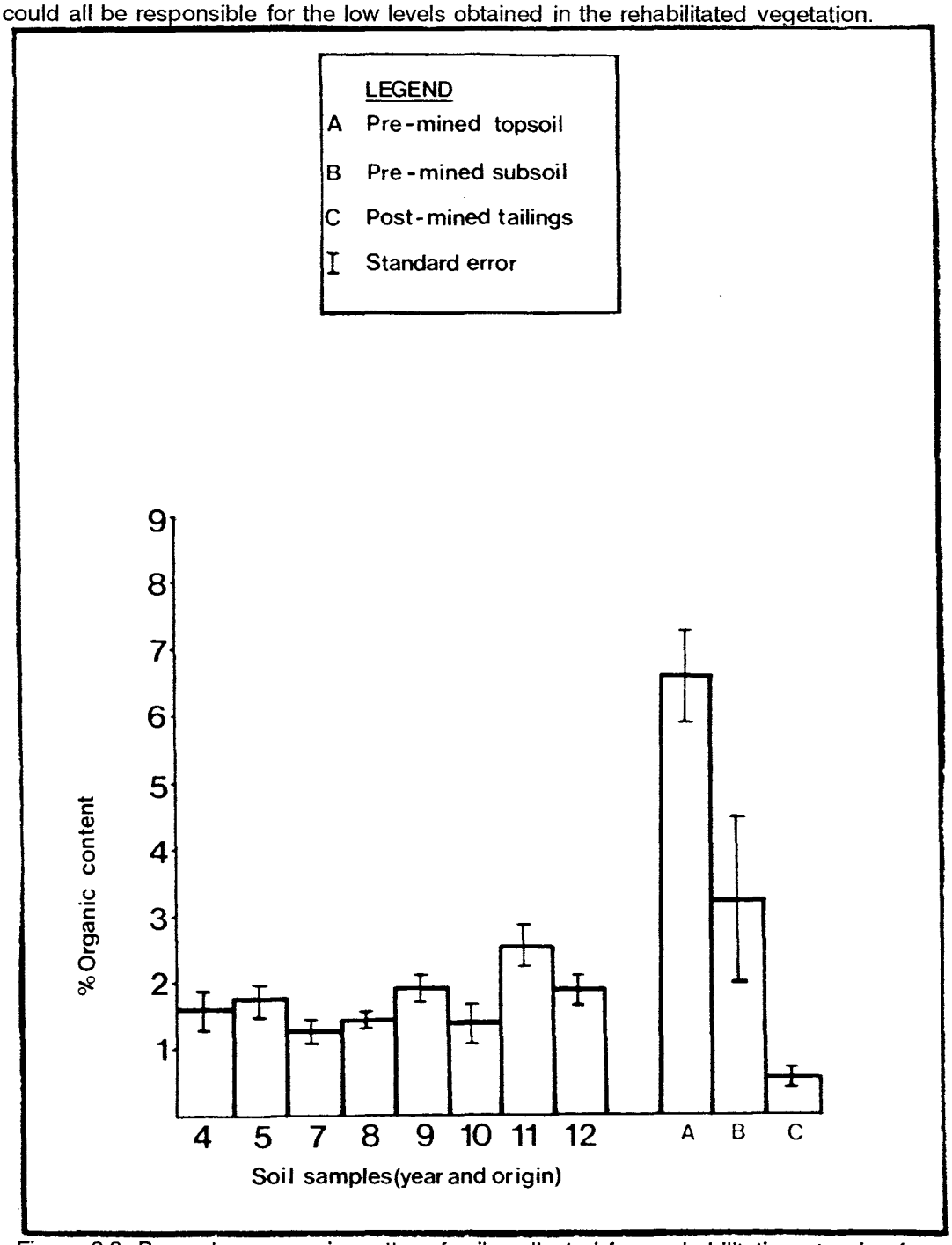

Figure 2.8; Percentage organic matter of soils collected from rehabilitation stands of different ages, tailings and pre-mined topsoil and subsoil.

The increase in organic content in the 11 year old stand may be because of a break down of fallen *Acacia karroo* branches and leaf litter which have built up over the years (Plate 2). The release of bound calcium from the soil during the mining process has produced higher pH values in the tailings (Fig 2.9).

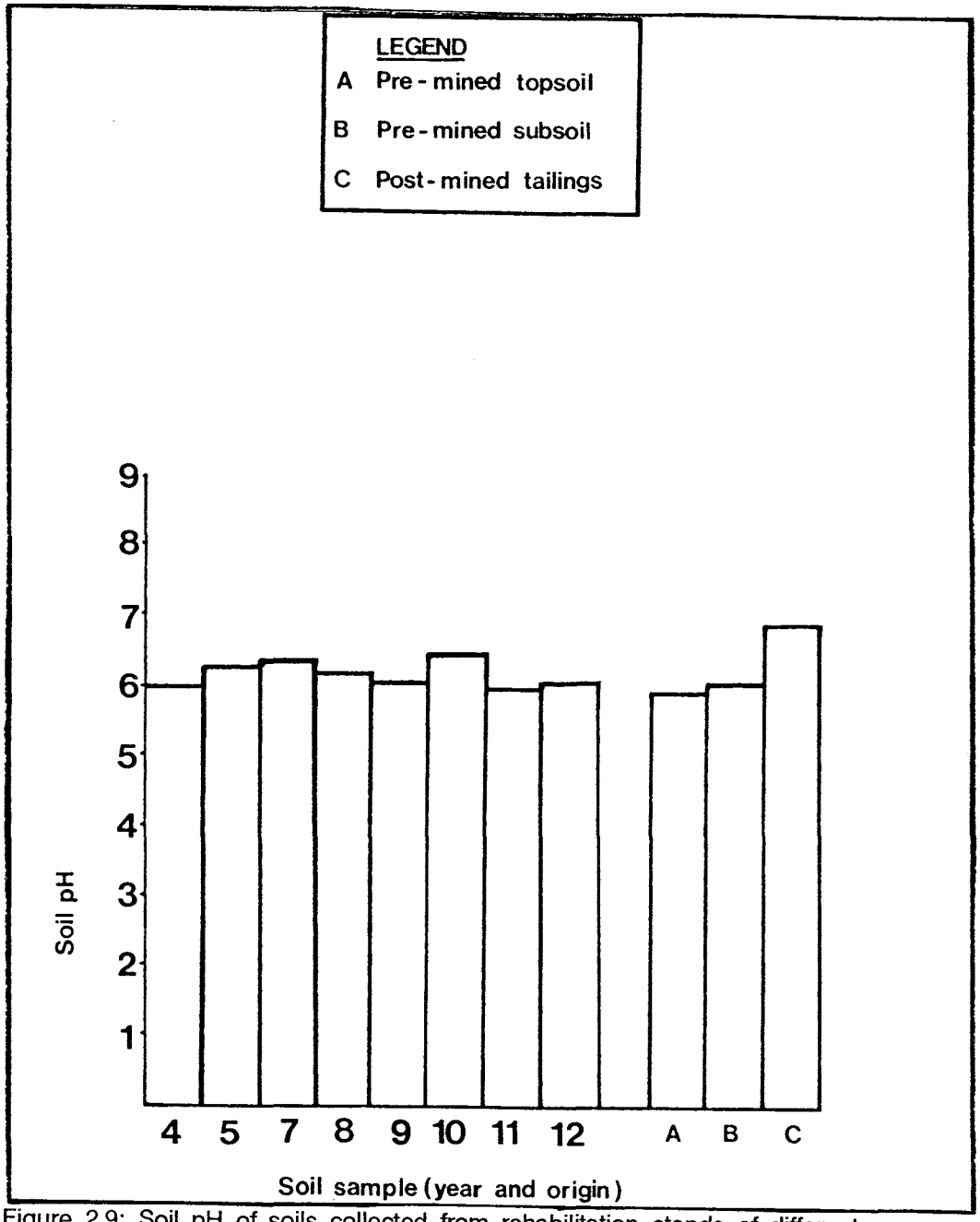

Figure 2.9; Soil pH of soils collected from rehabilitation stands of different ages, tailings and pre-mined topsoil and subsoil.

Lists of the species recorded in the rehabilitated grassland and wetland communities are presented in Appendices 3 and 4 respectively. Further results and experimentation carried out on the grassland area are covered in Chapter 5. The wetland is dominated by *Phragmites australis* and *Typha capensis*, seeds of which were spread on the water surface. This has

formed a thick growth of these two species together with some sedges, which provides both shelter and nesting sites for the large number of birds which have been attracted. It is hoped that the seeds and plant matter carried to the wetland by these birds will continue to introduce new species.

2.4 Discussion

Studies on short-term changes in the vegetation and observations of primary succession through definite seral stages are able to provide us with a wealth of information on vegetation dynamics. From the changes measured in vegetation and soil characteristics during their recovery from a disturbance it is possible to produce a simulation model of the post disturbance succession. The recovery of the vegetation can be measured in terms of its "resilience", that is the pace, manner and degree of recovery that occurs (Westman and O'Leary 1986). The restorer's aim in rehabilitating old mine sites to indigenous vegetation is to re-establish as soon as possible, with the help of natural processes such as succession, a viable and stable vegetation able to sustain itself with minimal management requirements. As changes occur in the species composition of progressively older stands so the structure of the vegetation changes (Plates 1, 2 and 3), and this affects the growing conditions and edaphic factors which enable different and more specialised species to establish (Avis, *et al* in prep). In order to promote rapid re-vegetation and to even accelerate succession, it is necessary to first understand the growth requirements of the desired species and then to be able to provide these requirements (Aber, 1990). By studying succession as it occurs naturally and using manipulative experiments to see how the vegetation reacts it is possible to acquire a better understanding of the growth requirements needed. Therefore the fact that *Acacia karroo* is the most important species in the natural succession pathway in the Richards Bay region supports the establishment of rehabilitation stands dominated by this species in early years. Studies undertaken overseas (Ford and Langkamp, 1987; Aber, 1990) have expressed the often limiting requirement, of the colonization by nitrogen-fixing species before late successionary species establish thus supporting the need for their presence in the early succession stages.

As the soil of the reconstructed tailings is totally disturbed, it needs to be recreated before mature plant communities can return, which raises questions as to which soil properties are the most important in supporting plant growth (Brooks 1986, Aber 1990). From the analysis of the base elements, calcium, phosphate and sodium in the rehabilitation sites at Richards Bay Minerals these parameters increase with the age of the rehabilitation stands, so they are not limiting plant growth. Unfortunately it was not possible to determine nitrogen levels but it is expected that if this is a limiting factor it has resulted in the dominance by *Acacia karroo* and could become problematic if it persists, as it will restrict the future growth of late-successional species that are now beginning to establish. According to Weisser (unpub) it is also a possibility that a " climber choke " may develop as the climbers growing on the support of *Acacia* trees out-compete the late successional species finally smothering them. However no evidence has been collected that suggests the rehabilitation communities are resisting the invasion of new species as is the case in the "climber choke" situation.

When we consider the age of mature forests along the Zululand coast, which are hundreds of years old (von Maltitz *et al*, 1991; Avis *et al*, in prep.), the rehabilitation stands of twelve years old are too immature to make predictions on the success being achieved. However from the changes in species composition and the increase in species richness and diversity within the ageing rehabilitation it can be accepted that primary succession is definitely taking place. From this aspect it can be inferred that primary succession to date at Richards Bay has been successful. By using Ewel's (1990) criteria, further evidence for success can be provided:

Sustainability: "is the reconstructed community capable of perpetuating itself or can it only be sustained if managed by people?"

After mining, the growth of the vegetation in the humid climate of Richards Bay is extremely rapid and ten years after the onset of rehabilitation a stratified woodland dominated by *Acacia karroo* is formed. The differentiation between old and young stands by TWINSPAN and DECORANA indicates that a change in species composition and community complexity as

expected (Aber, 1990; Ashby, 1990) is happening. The numerical analysis of community change has been used in many other studies (Williams *et al*, 1969; Sacheti and Scott, 1986) which lend support to the facilitation model of succession proposed by Connell and Slatyer (1977) or Clementsian succession (Avis *et al*, in prep).

The evidence of increased diversity within the older stands indicates that the community is changing and is likely to attain natural sustainability. Alien infestation especially of the older stands is almost non-existent. This may be ascribed to both the constant clearing of invaders and the out-competition by indigenous species which have utilized the more favourable growing conditions. If it is indeed so that *Acacia karroo* has an expected life span of about 25 years (Camp 1990) the other forest species will increase their cover in the near future to produce a more structurally complex dune forest community.

Invasibility: "Does the reconstruction yield a community that resists invasion by new species."

Once topsoiling, seeding and wind protection by artificial means cease at Richards Bay Minerals, little further manipulative management of the rehabilitated stands occurs. Rogers and Mokrzecki (1984) noted in Australia that the main tree species struggle to colonize the areas naturally during the early years of rehabilitation, however development of shrub and ground layer vegetation is extensive. This is believed to be because canopy species struggle to survive the disturbance caused by the mining and the transport of topsoil (Carey and Brooks, 1985). At Richards Bay most, but not all of the canopy species have been recorded in the rehabilitated stands. To ensure that these rare species return to the rehabilitated stands, seeds and seedlings need to be added on a continuous basis. Manual thinning of the *Acacia karroo* creating gaps in the thick canopy may enable other invasive woody species to colonize at an earlier stage. In indigenous coastal forests a uniform cover of trees of the same age never exists and gap - phase replacement is a valuable process in maintaining "stable" forest communities (Dingley, 1985; Geldenhuys and Maliepaard, unpub.). Key species in the successional process are shown in the analysis of data (Figures 2.3 and 2.4)

and also in the species checklists (Appendix 1). Invasion by species brought in by birds and other animals (mainly Vervet Monkeys) is taking place in the older stands bordering on undisturbed indigenous forest. These species are tightly clumped with no apparent adults of the species in the immediate vicinity, so it would appear they have been brought in by natural seed dispersers. The analysis of the seed bank, (refer to Chapter 3), although only a pilot study, showed that *Acacia karroo* and *Passerina rigida* seeds are possibly being produced by adult plants. Further management of the *Acacia* woodland should be geared towards increasing the speed of the invasion process and succession towards a state similar to that occuring in mature indigenous forests.

Productivity: "A restored community should be as productive as the original."

The coastal dunes support a variety of vegetation types and especially forests of high density and diversity, even though the young soils are of low nutrient status. With favourable year round climate of high annual rainfall and daily temperatures, productivity is high although leaching of the soil is rapid and the water retention capacity is low. Thus it is not surprising that the mined tailings with a spread of topsoil are able to support a dense vegetation cover a short time after rehabilitation. The dune system is comparable with Tropical Rainforest in that although there is a nutrient shortage, decomposition of organic matter is rapid providing adequate nutrients to sustain a high productivity. *Acacia karroo*, the first woody colonizer, is a nitrogen fixer and thus able to grow in nutrient poor soils. The build - up of nutrients in the soil (Fig 2.8) and the invasion by greater numbers of indigenous species (Fig 2.6) in the successively older rehabilitated stands indicates that the rehabilitated dune forests are indeed increasing in productivity.

Nutrient retention: "A reconstructed community that loses greater amounts of nutrient than the original is a defective imitation."

Both the rehabilitated *Acacia karroo* woodland and the natural dune system are characterised by slow soil development. This may be due to the lack of burrowing animals and the low densities of earthworms and other burrowing invertebrates in sandy soils. In a study of the

soils in the natural, primary succession at Mtunzini (Avis *et al*, in prep) showed marginal changes in the soil bases, then a rapid build-up of organic matter in the climax forest. As productivity and nutrient accumulation are both increasing it is unlikely that a retrogression stage will occur after the *Acacia karroo* woodland.

Biotic Interactions: "Reassembly of formerly associated plant populations often but not always lead to reconstitution of the entire community."

Even though reassembly of the plant populations implies the reconstruction of the natural ecosystems it does not indicate that all the essential species have returned. Some of these species could be necessary links in the food chain or key species in the ecosystem (Brooks, 1989). As mentioned before, this study is not a complete analysis of the ecosystem functioning but further studies are now being undertaken on the other aspects of the ecosystem. Ashby (1990) states that the success or failure of a restored forest may vary from area to area and even from tree to tree. If we interpret these findings properly it can provide us with information on the total community needs, and also on species requirements and interactions. It is only time that will be able to tell us with certainty that no essential components are missing from rehabilitated areas, but so far no evidence of missing parts has been collected.

Therefore using Ewel's (1990) criteria, further qualification on the success achieved to date in the rehabilitation at Richards Bay is provided. Continued monitoring and management of the rehabilitated dune forest is however still required. The clearing of alien weeds such as guava,(*Psiduim guajava)*, triffid weed,(*Chromolaena odorata)* and *Lantana camara* is an ongoing process and until now very good control of alien invaders has been achieved. If these species invade in large numbers they are able to upset the natural ecosystem functioning (le Roux, 1991) but it is unlikely this will take place in the rehabilitated stands with the good management and rapid colonization by indigenous species.

The effects of animals on the rehabilitation of vegetation should not be underestimated and

especially on the structuring of the plant community. According to Harper (1990) it is the belief of many plant ecologists that plant communities are what animal populations make them. In order to manage the rehabilitated vegetation properly it is important to encourage the return of birds and other animals. As these are the main seed dispersal agents of forest species they will help recreate the natural diversity in the rehabilitation stands (Allan, 1987). Thus by using nature's own means of ensuring self-perpetuation of the vegetation we can return a stable and viable forest community.

It must be noted that this assessment of the success and the future management required for the rehabilitated stands at Richards Bay is based only on the research done on the vegetation, and therefore any conclusions reached do not pertain to the entire ecosystem functioning. As Aber (1990) stated, "in order to understand how different forms of disturbance alter communities and ecosystems and to prescribe the best treatments for restoration, ecologists require information from many scientific disciplines."

The rehabilitated wetland area, although being very small with great fluctuations in the water level, supports a dense growth of species dominated by *Phragmites australis* and *Typha capensis*. The thick growth of vegetation and the plentiful supply of food in the form of algae, aquatic plants, tadpoles and fish (*Tilapia spp.*) has attracted numerous birds to the wetland. These birds and other animals are the main dispersal mechanisms for colonising species (Brooks, 1989). Experience gained from Australia has shown that once a stable wetland has been created with shallow areas for plant establishment and breeding of fish the wetland can be left to develop on its own. Any future management needs could include the creating of islands in the wetlands for breeding sites and the collection and dispersal on the water of seeds from those species that have not established naturally (Brooks, 1987b; 1988). To ensure the continued existence of the wetland areas it is necessary to recreate them on a scale that can endure shrinking of water surfaces during dry periods and with sufficient depth in some places to prevent the encroachment by the colonising species. The wetland created at Richards Bay Minerals is very shallow and is being smothered by *Phragmites* and *Typha* plants. It can be expected that as this dries out further it will revert to grassland which should be monitored to obtain insight into the processes involved behind this successionary change.

CHAPTER 3

ASSESSMENT OF POTENTIAL SEED BANK

3.1 Introduction

A major factor influencing the ongoing success of the rehabilitation at Richards Bay is the composition of the soil seed bank. Even though interspecies competition, environmental and soil conditions play a role in determining what species are able to return, the presence of viable seed is the most important criteria (Templeton and Levin, 1979; Thompson and Grime, 1979; Johnson and Bradshaw, 1979; Gross, 1980; Gross and Werner, 1982 and Levassor etal, 1990). The initial seed bank existing at the outset of rehabilitation is likely to contain seeds originating from three sources, namely, local seed collected from the indigenous vegetation and added to the topsoil, mulch formed due to clearing of vegetation prior to mining, and the topsoil spread over tailings (Carey and Jeffries, unpub; Camp, 1990). Additional seed is continuously added by birds and animals and from mature individuals of plant species. As the rehabilitated vegetation progresses throught the different successionary stages, it is hoped that most of the indigenous species will re-establish themselves. If a certain species does not return, a knowledge of what seeds are available should help to show whether this or some other factor is preventing its re-occurrence (Fenner, 1985).

This study of the seed banks of the increasingly older rehabilitated vegetation was an attempt to discover the identity and number of seeds that can be found in the topsoil of each stand. Since it was only a "pilot" study it would be wrong to make decisive conclusions based on the data obtained and therefore only preliminary predictions have been proposed (Fenner, 1985). This emphasises the need for indepth and comprehensive studies on the seed banks of the rehabilitated vegetation especially pertaining to the effect on future species diversity (Gross, 1987; Carey and Jeffries, unpub.).

The two main methods for elucidating the numbers and identification of seeds present in the

soil seed bank are seedling emergence (germination) and physical separation (sieving and floatation) (Roberts, 1981). Manders (1990) showed that both techniques have their advantages and disadvantages. Physical separation produced higher seed numbers, but many small seeds overlooked by this method were recorded by means of seedling emergence. The low numbers of seeds revealed by seedling emergence is believed to be due to the requirement of specific germination conditions or stimuli needed by some species (Gross, 1990). This was overcome by exposing the soil to similar environmental parameters as experienced in the rehabilitation stands so that the viability of seeds under these conditions could be determined. The seedling emergence technique is simpler (emergent seedlings are easier to identify than seeds) and quicker than physical separation, and although a combination of both methods would give the best results this was not feasible in the time available.

3.2 Materials and Methods

A trial test of seedling emergence from soil placed in both seed trays and kept under greenhouse conditions, and of sieved soil in sterile petri dishes placed in a constant environment, showed the former approach produced a higher germination number. The latter procedure was discarded because it proved to be both inefficient and inadequate and only seedling emergence in seed trays has been used in this study. Soil collected from pre-mined topsoil was used in this test but no results have been included as it only ran for three months, however the species identified were mostly similar to those noted in the final seed bank trial.

Soil samples were taken during August 1990 from each of the differently aged rehabilitation stands at Richards Bay. Soil was removed from two randomly selected sites of 30cm x 30cm and to a depth of 10cm in each stand. This soil was spread over small pieces of newspaper in two black plastic seedling trays (26 cm x 30cm) and placed in a greenhouse at Rhodes University, Grahamstown. Therefore two replicate trays with soils collected from different sites within the same aged rehabilitation stands were used during this study. The trays were watered each day and petri dishes of sterile sand were placed around the trays. Should seed from the greenhouse or elsewhere have been blown onto the soil and germinated this would have been indicated by seeds germinating in the petri dishes. Seedling emergence was recorded every two weeks from September 1990 until November 1991 which is long enough for most species to germinate (Levassor etal, 1990). Seedlings were left to grow to an identifiable size then matched against herbarium material and previous collections from this area.

3.3 Results

During the period of the study twenty species germinated; of these 18 could be identified to species level with certainty while the others remained too small to make a positive identification. Table 3.1 lists all the species recorded with the number of emergent seedlings of each species found in the differrently aged rehabilitation stands. The total number of individual plants found was 301 with an average emergence of 241 seeds/m^2 of soil and 37,6

per stand. The most seeds were found in either the youngest stands (4 and 5 year old) with 48 and 42 seeds and the oldest stands (10, 11 and 12 year old) with 40, 54 and 37 seeds respectively. Herbaceous plants constitute by far the majority of species (9) followed by grasses and sedges (4), trees and shrubs (3) and creepers (2). *Cyperus obtusiflorus* with (95) seeds, *Conyza bonariensis* (64), *Eleusine indica* (31) and *Helichrysum cephaloideum* (25) contribute the most seeds to the total seed count. The number of species germinating increased from 7 to 12 with progressive age of rehabilitation stands and is shown in Table 3.2. One can compare the seedlings which emerged during the experiment with the mean percentage cover of species recorded in the various seral stages as determined from five (10m x 10m) quadrats in each age of the rehabilitation stands, as given in Table 3.3. No seedlings germinated in the sterile soil in the petri dishes so it appears that no seeds could have been blown into the trays during the study.

Table 3.1; Numbers of emergent seedlings in the two trial trays from the seed bank in the topsoil of rehabilitated stands ranging from 4 to 12 years after initiation of rehabilitation at Richards Bay.

	AGE OF REHABILITATION STANDS IN YEARS							
SPECIES AND LIFE-FORM	4	5	7	8	9	10	11	12
TREES AND SHRUBS:								
Acacia karroo	0	0	0	0	0	0	6	3
Passerina rigida	0	0	0	0	0	0	0	1
Sesbania bispinosa var. *bispinosa*	0	0	0	1	0	0	1	1
Sub-total:	0	0	0	1	0	0	7	5
HERBS:								
Drimiopsis maculata	0	1	0	0	0	0	0	0
Laportea peduncularis	0	0	0	0	0	0	3	0
Sonchus oleraceus	2	0	0	1	0	1	3	2
Conyza bonariensis	7	4	6	4	1	17	19	6
Conyza sumatrensis	1	0	1	1	0	2	4	3
Oxalis latifolia	0	0	0	0	0	1	1	1
Helichrysum cephaloideum	2	4	4	0	0	5	5	5
Richardia brasiliensis	0	1	5	0	2	0	6	2
Tephrosia grandiflora	0	0	0	4	3	0	3	1
Sub-total:	12	10	16	10	6	26	44	20
GRASSES & SEDGES:								
Cyperus obtusiflorus var. *obtusiflorus*	32	20	7	6	9	9	3	9
Eleusine indica	3	7	2	14	0	2	0	3
Panicum maximum	0	0	0	4	0	0	0	0
Panicum hymeniochilum	0	5	0	0	1	2	0	0
Sub-total:	35	32	9	24	10	13	3	12
CREEPERS:								
Carpobrotus dimidiatus	0	0	0	1	0	0	0	0
Ipomoea ficifolia	0	0	0	0	1	0	0	0
Sub-total:	0	0	0	1	1	0	0	0
SPECIES INDET.:	1	0	2	0	0	1	0	0
Total:	48	42	27	36	17	40	54	37

Table 3.2; Breakdown of species represented in the soil seed bank of the differently aged rehabilitation stands.

	YEARS SINCE REHABILITATION BEGAN							
	4	5	7	8	9	10	11	12
NUMBER OF SPECIES FOR WHICH SEEDS WERE COLLECTED	7	7	7	9	6	9	11	12
SPECIES RECORDED DURING SAMPLING WITH SEEDS IN THE SEED BANK	5	4	7	9	8	3	7	5

Table 3.3; Total cover in the increasingly older rehabilitated stands of some of the species with seeds in the soil seed bank.

	YEARS SINCE REHABILITATION BEGAN							
SPECIES	4	5	7	8	9	10	11	12
Passerina rigida			2,8				3	
Acacia karroo	80	97	90	95	86	87	85	85
Laportea peduncularis			13				52	4,5
Conyza bonariensis			0,5	0,5				
Conyza sumatrensis	1		1	1,5	3,3	1,3		
Cyperus obtusiflorus			0,5	0,8	0,5			0,8
Oxalis latifolia	1			0,8			1	

3.4 Discussion

As only two soil samples were collected from each rehabilitated stand this was not a comprehensive seed bank study but rather an attempt to discover which species and the proportions of their seeds are still present in the topsoil of varing stand age. Levassor *et al* (1990) took 16 soil cores per site and Gross (1990) showed that 15 - 20 sampling sites were needed to accurately determine the number of species present in the seed bank by direct germination. However the data collected gives an indication of the most common species present from the early to old rehabilitation stands.

If succession is taking place it would be expected that the seeds of early successionary species and those of species that invade disturbed areas will occur in greater numbers in the younger rehabilitation stands. The most common seeds found in the early rehabilitation stands, those of *Cyperus obtusiflorus*, *Eleusine indica*, *Conyza bonariensis* and *Helichrysum cephaloideum* are all early successionary invader species. Herbaceous ground cover species such as *Laportea peduncularis* and *Panicum hymeniochilum* only appear in the older stands which is in accordance with trends of stratification of vegetation layers in complex communities. Seeds of both *Acacia karroo* and *Passerina rigida* are present in only the older (11 and 12 year old) stands and because those that were there have presumeably germinated, it would appear that they originate from adult individuals of these species within the communities. The lack of seed from other indigenous woody species can be ascribed to the low sampling intensity as these seeds do not occur in as high numbers as early successional species (Fenner, 1985, Levassor etal, 1990).

Seeds of forest tree species also remain in close proximity to their parent plants forming clumped distributions of these species (Hubbell, 1979). Carey and Brooks (1985) noted that seeds of the upper canopy species often fail to survive the mining disturbance and therefore may require direct seeding or the transplantation of seedlings. They require the presence of seed dispersing agents such as birds and monkeys to replenish their wide distribution in the seed bank of rehabilitated communities. This clustering of seeds which can have an effect

on the spacing of future species members will produce a reduced diversity of the vegetation (Fenner, 1985). This is already noticeable in the older rehabilitation stands where individuals of a species such as *Mimusops caffra*, *Peddia africana* and *Ficus natalensis* are growing close together which is possibly due to their dispersal by monkeys.

If seedlings or saplings are artificially planted into the rehabilitation sites this needs to be done randomly but with a relatively large spacing between conspecific individuals so as to maintain a high diversity. A fluctuation in seed numbers from high in young stands (4 and 5 years) to low in the intermediate stands (7, 8 and 9 years) and then high again in the older stands (10, 11 and 12 years) is evident from Table 3.1. This can be explained by the occurrence of numerous seeds of early successional and opportunistic weedy species in the young stands. They are not able to germinate due to the dense ground cover (40% in 4 and 5 year old stands) formed by dying *Eragrostis curvula* swards. Once the grass cover disintegrated in the intermediate aged stands these species germinated as indicated by their presence during the vegetation sampling of the rehabilitated areas. The release of seeds by species such as *Conyza bonariensis, C. sumatrensis, Cyperus obtusiflorus, Helichrysum cephaloideum* and *Sonchus oleraceus* together with the acquisition of seeds from adult plants of woody species caused the increase of seeds in the older stands. A rise in the number of species for which seeds were found with increased stand age is also apparent (Table 3.2). This is because of the addition of seeds of species from late successional stages, for example *Lapportea peduncularis* and *Panicum hymeniochilum*.

Fenner (1985) gives the number of seeds expected in forest soils in the range of 1000 to 10000 seeds per m^2. In this study only 241 seeds/m^2 were found. This small number may be once again due to the low sampling intensity or otherwise germination of available seeds without any replenishment from adult plants. Seed predation and loss of seeds during transport between pre-mined areas and the tailings could also be a factor (Fenner, 1985). However to compare densities of germinatible seeds between seed bank studies is not advisable as germination conditions and different species are involved (Siegley *et al*, 1988).

This low seed count emphasises the need to add indigenous seed to not only the topsoil before spreading on the tailings but also into the already established rehabilitation stands. The seeds can be collected in front of the mine path prior to mining and afterwards from the surrounding natural vegetation. This is especially important for those species common in the natural vegetation which are struggling to regenerate in the rehabilitated areas (Carey and Jefferies, unpub.). Fenner (1985) proposes that rare species can be prevented from re-establishing because of the requirement of definite regeneration conditions found in only isolated patches. Poor seed dispersal and a lack of gaps within the rehabilitated vegetation may prevent species from being able to colonise these limited areas. This gives support to proposals that seedlings and immature specimens of rare species should be translocated from the mine path before vegetation clearing to established rehabilitation stands. In this way a souce of seed can be generated within a few years in the actual rehabilitated areas themselves to fill all available niches within the community.

This study has not shown a substantial gain in seeds of forest species but it has reflected a seed bank composition that would be expected during the initial seral stages of succession. Possible replenishment of seeds by adult plants was also noted, even though only dominant *Acacia karroo* and *Passerina rigida* were recorded. A very encouraging aspect of the seed bank in the rehabilitation area is the absence of seeds of alien invader species such as *Chromolaena odorata* and *Lantana camara* which Henderson (1989) listed as dangerous colonisers of disturbed indigenous vegetation. However what this study highlighted the most is the need for extensive and thorough studies on the seed banks in the rehabilitated stands which were not possible during this study due to time constraints and the broad field of this research. This will enable us to discover the possible reasons behind the absence of particular species from the rehabilitation stands so that this situation can be prevented in the future.

CHAPTER 4

NATURAL SECONDARY SUCCESSION OF DUNE VEGETATION

4.1 Introduction

In recent years an increased amount of reseach has focused on the dynamics of natural succession in coastal forests. The Forest Biome group meeting of 1990 at Richards Bay was orginized in an attempt to present all the information gathered during the past years on forest dynamics and to correlate the needs for further research. Most of the studies completed are descriptions or quantitative assessments of the vegetation change following a disturbance. Work done in the past few years includes that described in Pammenter *et al* (1985), Weisser (1978), Weisser and Marques (1979), Weisser (1987), Weisser (unpub.), Camp and Weisser (1991), von Maltitz *et al* (1991) and von Maltitz *et al* (unpub.).

The man - induced disturbances include fire, clearing for agriculture, clearing for building construction, disused forestry areas and the clearing of vegetation for mining. The recolonisation by vegetation of mined areas differs from that occuring after other disturbances in that not only is the vegetation cleared but the soil profile is also totally disrupted. Therefore the vegetation cannot be left to return by its own means but needs to be actively re-introduced and managed by man, this being the process of rehabilitation. According to Aber (1990) and also Bradshaw (1990) this process should be referred to as primary succession, whereas the re-vegetation of sites disturbed by clearing of indigenous bush for agriculture, forestry or by fire is secondary succession. In order to have a successful rehabilitation it should match as closely as possible the succession occuring in the sites formed by other disturbances once the initial stabilization phase is completed. Of the studies mentioned above most were not carried out in the immediate vicinity of Richards Bay which makes it unfeasible to relate these findings directly to the rehabilitation techniques. Differences have been revealed in the changes taking place within the vegetation from separate areas and a number of successionary pathways have been described. For this reason previously

disturbed areas close to Richards Bay were identified and dated from aerial photographs and information supplied by R.B.M. ecologists and Dr. P.J. Weisser, of the National Botanical Institute. It was possible to determine an approximate date when the disturbance took place and therefore the age of the returned vegetation. A further site cleared of pine forests 23 years ago was identified at St. Lucia and included in this study to give a comparison of natural vegetation succession in another area. All the sites surrounding Richards Bay were dominated by *Acacia karroo* and appear to be following a successionary pathway characterized by the presence of this species in the initial forest canopy. The oldest site identified was about 50 years old and although a definite structuring of the community has developed large *Acacia* trees still form the largest cover in the canopy.

Ashby (1990) mentions that it is common for investigators to try to characterise succession by studying variations in communities across space, assuming that this will provide an insight into a process that actually occurs in time. He feels however, that these studies may have limited value as earlier differences in climate, species availability etc. are unknown. As no continued long - term monitoring data is available a study of stands in different areas but of known age was the only way to establish trends in the natural succession on which to base expectations of future changes in the rehabilitated vegetation. The inability to accurately assess what long - term fluctuations need to occur in the developing forest community is felt to be the biggest obstacle facing successful rehabilitation (Ashby 1990). Bradshaw (1990) emphasises the need to understand and take advantage of what takes place in natural succession, as our aims in rehabilitation ecology are generally modelled on the achievements of nature.

4.2 Materials and Methods

Cleared sites which have since revegetated naturally in the vicinity of Richards Bay were identified by Dr. P.J. Weisser and from aerial photographs taken during 1937, 1965 and 1985. Stands of approximately 50, 25 and 8 years since disturbance were created by clearing for forestry, the laying of roads and uncompleted building development. A further area just south of the mine path, cleared in 1976 for forestry was pointed out by Paul Camp, the chief ecologist at RBM. These four sites of indigenous vegetation are dominated by *Acacia karroo* and provide a sequence of increasingly older naturally revegetated stands in which to study forest dynamics. To make a comparison with the natural succession taking place further afield an area of previously disturbed land at St. Lucia has been included in this study. It is now 23 years since the plantation was felled and it has already revegetated extensively, although apparently, by a different successionary pathway.

Each of the revegetated stands was sampled using 10m x 10m quadrats which according to Avis et al (in prep) are too small for sampling in forests. However as the natural forests were to be compared to the rehabilitated forests (Chapter 5) a constant quadrat size was required. It was attempted to sample five 100m^2 plots in each community so as to make the total cover sampled the same as previously done in the rehabilitated vegetation. Unfortunately the stand of 25 year old naturally revegetated forest was not large enough for this and only three 100m^2 plots could be recorded, thus its exclusion from the diversity data. For each quadrat the cover and density of all the species present were recorded as well as the strata cover and their respective heights. From these data, species checklists, the mean and total species richness and diversity indices as described in Chapter 2 have been determined for each stand.

4.3 Results

All the species recorded from each stand of naturally vegetated forest are listed in appendices (5, 6, 7 and 8) with dominant species indicated in bold. Species identified from the 23 year old pine cleared site at St. Lucia are not presented as this was only used to quantitatively compare successionary pathways and species composition from other areas (Chapter 5). The species richness and diversity values of the progressively older natural stands from Richards Bay and St. Lucia are presented below in Table 4.1.

Table 4.1; Species richness and diversity values of naturally revegetated stands in the Richards Bay vicinity and the cleared site at St. Lucia.

YEARS SINCE REVEG.	TOTAL SPECIES RICHNESS	SIMPSON'S DIVERSITY (Ds)	INVERSE OF L(ds)	SIMPSON'S DOMINANCE	SHANNON DIVERSITY (base E)
8	52	0,922	12,767	0,078	1,107
14	64	0,948	19,363	0,052	1,368
50	55	0,931	14,478	0,069	1,148
23	105	0,970	33,479	0,029	1,400

4.3.1 Eight year old stand

The youngest area estimated at eight years old since disturbance is found next to the road to Two Mile beach (Plate 4). It has a mean species richness of 24 and a total species richness of 52. Its diversity (ds) is 12,767 and Shannon's diversity index (H') is 1,107. Simpson's dominance value was measured at 0,078. The canopy is a dense cover of *Acacia karroo* and the shrub layer is composed mainly of *Maytenus procumbens*, *Rhus pyroides* and *Trema orientalis* as well as alien invaders such as *Citrus sp.* and *Chromolaena odorata*. *Eleusine indica* and *Conyza sumatrensis* dominate the ground layer but the cover of this strata

Plate 4 Naturally revegetated stand of *Acacia karroo* estimated at approximately eight years old from aerial photographs and the local knowledge of Dr Pablo Weisser.

Plate 5 The prominent *Acacia karroo* canopy with other species forming an extensive sub-canopy below on the twenty five year old site on Naval Island.

is minimal.

4.3.2 *Fourteen year old stand*

This stand of *Acacia karroo* woodland is found just south of the mining operation. It was cleared for forestry in 1976 (therefore 14 years old) but never planted and has returned to indigenous woodland. A mean species richness of 34 was calculated from the five quadrats sampled and 64 species in total were recorded. Diversity indices including a (ds) value of 19,363, Shannon's index (H') of 1,368 and a Simpson's dominance value of 0,052 were recorded. Therefore it has both a higher species richness and diversity than the eight year old site but the dominance of certain species is lower. *Acacia karroo* still forms a dense canopy cover with smaller individuals of *Celtis africana* and *Dalbergia abovata* beginning to penetrate the upper layers of *the canopy. Canthium inerme*, *Scutia myrtina*, *Clausena anisata* and *Maytenus heterophylla* occur in the shrub layer while the ground cover is composed largely of *Acyranthes aspera* and *Commicapus pentandrus*. Grazing by the local inhabitants' goats and cattle appears to have had an effect on the revegetation of this stand which is possibly the reason for the presence of numerous thorny species in the shrub layer. These are resistant to grazing and their growth has not been retarded as is the case for more vunerable species.

4.3.3 Twenty five year old stand

Located on Naval Island in the Richards Bay harbour this stand has regrown since 1965 when it was shown to be clear of vegetation (Plate 5). Uncertainty exists as to whether this is a process of natural succession following disturbance or if it is the original colonisation of the island. However this is not important as we know the vegetation is about 25 years old. The mean species richness of this revegetated site is 32 and a total of 45 species were recorded from the 3 samples undertaken. Large *Acacia karroo* trees grow above a lower shrub strata dominated by *Clerodendrum glabrum* and *Celtis africana*. The ground layer of herbs and grasses is dominated by *Asystasia gangetica*, *Commelina benghalensis* and *Panicum*

hymeniochilum.

4.3.4 Fifty year old stand

This site is found north of the Nhlabane estuary where an area of old *Casuarina* plantation was felled then left to return to natural vegetation. The 1937 photographs showed this area to be colonised by grassland which has since reverted to *Acacia karroo* woodland and now secondary dune forest of approximately 50 years old. The mean species richness of 25 is very low but an overall total of 52 species were identified. This could be caused by a constant sampling size as only one or two large canopy trees fit into a $100m^2$ sample and tend to produce a large number of seedlings that cluster around the parent plant. This may also be the reason behind the lower diversity (ds) of 14,478 for the fifty year old site compared to 19,363 for the fourteen year old site. Shannon's diversity is also lower at 1,148 but Simpson's dominance is higher at 0,069 indicating that certain species are present in large number. This is especially so for the shrub and ground layer in which *Peddia africana* and *Isoglossa woodii* form dense stands.

4.3.5 Twenty three year old stand

As this stand was located at St. Lucia and follows a different successionary pathway to the vegetation in the Richards Bay area, it has only been used to expose the differences in the succession process. Twenty three years ago a pine plantation was cleared in this area and it has since returned to natural vegetation. Some of the pine stumps still are visible amongst the indigenous species. This area has a very high mean species richness of 68 and a total of 105 species recorded in $500m^2$. The diversity (ds) of 33,479 is also very high while Shannon's diversity is 1,4 and Simpson's dominance very low at 0,029. Therefore from this it appears that species distribution is uniform in this area, the most common species being *Apodytes dimidiata*, *Macaranga capensis*, *Kraussia floribunda*, *Diospyros natalensis* and *Helichrysum kraussia*. These species have formed a scrubland or thicket community which differs quite markedly in structure and composition from *Acacia karroo* woodland.

4.4 Discussion

The succession pathway followed by natural vegetation in the Richards Bay area is clearly dominated by *Acacia karroo* trees for at least 50 years following a disturbance. After this period most of the *Acacia* trees begin to die out with only some large, solitary individuals remaining (Weisser, pers. com. 1990). Other large forest, canopy species are also present including *Chaetachme aristata*, *Vepris undulata*, *Trichilia emetica*, *Pavetta revoluta*, *Apodytes dimidiata* and *Mimusops caffra*. The shrub layer and undergrowth was mainly composed of one dominant species in the older stands, the most common being *Peddia africana* and *Isoglossa woodii*. Moll (1972) states that when *Isoglossa* is present few herbaceous or intermediate species occur as *Isoglossa* grows very fast and large, out-competing most other ground cover species. Weisser and Marques (1979) together with other authors support this observation of *Isoglossa woodii* acting as a suppressant of other species under an *Acacia karroo* canopy. The *Isoglossa* undergoes a cycle of approximately seven years of growth after which it seeds then dies off as new seedlings begin to regrow. Thus when it is close to full maturity it forms an extremely dense cover of up to 3 metres in height. This may account for the low species richness and diversity values presented in Table 4.1 for the 50 year old stands of indigenous vegetation as the number of tree and canopy species has increased.

That species diversity is generally expected to increase over time in a successional community is an accepted fact (Whittaker 1975 and Golley 1977). However in some circumstances a single late-successional species may take advantage of favourable conditions and exclusively colonise a particular site, thus lowering the diversity. This has been observed after fire where *Trema orientalis* contributed to over 70 percent of the regenerated forest (Pammenter *et al*, 1985). Other species do re-appear, as in this case only three years after the fire the number of species recorded in the burnt area was similar to that in the unburnt forest. The distribution and numbers of individual species remained low however which has caused the continued dominance by *Trema orientalis*. Weisser (unpub) has also noted the dominance by *Trema orientalis* of revegetation after fire and on a landslide inside an arcuate scar. Therefore this species must be characteristic of a successional pathway following fire

or mass soil movement. The high species richness and diversity in the younger (8 and 14 year old) natural revegetated stands can be ascribed to the presence of both early colonists and species of later seral stages. Some of the early colonists persist, due to their ability to compete with and even inhibit the growth of other species or possibly because of their longevity (Connell and Slatyer, 1977). Another factor that could affect the diversity in naturally colonised stands is the proximity of mature coastal forests. The site sampled at Naval Island was relatively isolated from other forests with only one patch of highly diverse coastal forest found on the island. As this is separated by a wide expanse of disturbed grassland and roads it is not easy for species recruitment to occur, which could be one possible answer to queries on the low species richness at this site. Another factor is that the site is very small and therefore as only three samples covering an area of 300m^2 were recorded, this limits the chances of rare or isolated species being accounted for.

What causes the alternative successional pathways found in the re-vegetation of coastal forests in Zululand is not quite clear but definite differences in structure and species composition can be identified. von Maltitz, etal (unpub.) has postulated a few hypotheses on why the three successional pathways namely *Acacia karroo* woodland and *Syzigium* or *Apodytes* initiated bushclumps take place. The formation of *Acacia* woodland appears almost certainly to be linked to intensive disturbance of the indigenous vegetation, be this by slash and burn agriculture, mining or simply the clearing of the original forest. This could be attributed to a number of factors including the ability of *Acacia* seed (which is produced in large numbers) to remain viable for an extensive period. von Maltitz *et al* (1990) postulate that as other *Acacia* species are stimulated to germinate by disturbance and increased light levels this may well be the case for *Acacia karroo*.

The bushclump pathway identified by von Maltitz *et al* (unpub.) established in a very different manner, either *Syzigium cordatum* or another species attracting birds with their fleshy fruit. Seeds dropped by the birds germinated and soon a cluster of forest trees colonises the surrounding area of secondary grassland or cleared land. Another possible successionary

route indicated by *Apodytes dimidiata* dominance was discussed by von Maltitz *et al* (1990) during which bushclumps are once again formed. The twenty three year old site that has reverted back to indigenous vegetation may have followed either of these pathways as both species are present in the community sampled. It has a much higher diversity than any of the *Acacia* stands and uniformity in the species distribution does not occur at all. From the studies undertaken to date on natural revegetation it is evident that an association between the form of disturbance and the successionary pathway is possible. If this is indeed the case then further management of the rehabilitated stands to produce a mosaic of successionary pathways could be used to increase the diversity of the returned community.

CHAPTER 5

COMPARISON OF NATURAL AND REHABILITATION INDUCED SUCCESSION

> *"So when we experiment in planting forests we find ourselves at last doing as Nature does. Would it not be well to consult with Nature in the outset? for she is the most extensive and experienced planter of all .....?"*
>
> H.D. Thoreau (in Jordan *et al*, 1990)

5.1 Introduction

If rehabilitation is to be judged a success or not, it is necessary to have some standard against which to measure the returned vegetation. The common approach for determining the success of rehabilitation, simply by its resemblance to the original (Ewel,1990), is not only subjective but is also not decisive, as some vital components of the community may still be missing. Using quantitative techniques (Chapter 2) it was possible to quantify the success of the initial stages of rehabilitation, because they are progressing through expected seral stages of increased complexity. However as the vegetation matures these successionary changes slow down and become more subtle and harder to recognize (Ashby, 1990; Gross, 1990). By considering what happens in the naturally induced succession of dune forest (Chapter 4) we are able to formulate an idea of how the rehabilitation should proceed and at what stage changes in species composition and community complexity should appear. Harper (1990) encourages the use of accurate discriptions of vegetational successions in the past to enlighten us on the process and make predictions on the nature of future succession. In this way a set of guidelines for the development of rehabilitated vegetation can be created. Ongoing manipulative experiments can be used to determine ways to enhance the pace of the process or to repair areas of failed rehabilitation. At this point it might be worthwhile to recall that rehabilitation does not involve the competely successful return of the entire ecosystem but is the continued progression towards this state.

If the restorer copies nature in his attempts to return vegetation then it is highly likely that the rehabilitation will be successful (Gilpin, 1990). Therefore a comparison was made in this study between the rehabilitation stands of 4 to 12 years old and the naturally revegetated sites. This gives us a good idea of just how similar the succession taking place in the natural and rehabilitated vegetation is. Some of the species recorded in the naturally revegetated forest but not in the rehabilitated stands have been identified. These species are not rare in the local indigenous forest so it appears that either their dispersal into the rehabilitated stands is restricted by a lack of agents or the conditions are not favourable for their colonisation.

Due to the total disruption of the soil structure during mining, objections may be raised to the comparison of the rehabilitated communities with the vegetation returning after less intense disturbances such as the clearing of forest for plantations or agriculture. However if it can be shown that the recovery of the vegetation is similar especially in the initial stages then the rehabilitation techniques used to stabilize the dunes after mining can be accepted as successful in replacing the correct growing conditions required. As the rehabilitated vegetation matures it could be proven that some structure such as the disturbed soil profile or the lack of "macrochannels" for soil aeration, root growth and water movement (Ashby, 1990) are retarding the successionary process. Identifying these problems will only be possible if we have an understanding of the natural successionary process. As Cairns (1990) states, "aspects of the structure, function and dynamics of both natural and artificial systems are most frequently revealed most dramatically and unmistakably when the systems are under severe stess and during their rehabilitation and reconstruction". Therefore in this chapter a comparison has been made using quantitative and analytical data on the present differences and expected development of rehabilitated vegetation in contrast to the naturally colonising vegetation.

5.2 Materials and Methods

The data collected for Chapters 2 and 4 were used in this part of the study thus the methods employed in obtaining these results are the same as described before. The comparision of the data in this chapter was the main reason for using a standard 10m x 10m quadrat throughout all the sampling, although this has been proved to be inadequate for forest sampling in certain cases (van Daalen *et al*, 1986). The data has been analysed by TWINSPAN and DECORANA multivariate analysis techniques to give an indication of the similarities between the rehabilitated stands and the naturally revegetated stands in terms of species composition and community complexity. Westman and O'Leary (1986) have used DECORANA in their assessment of vegetation recovery after fire. They used species cover to ordinate samples from different habitats and vegetation ages. Further comparisons have been made in the form of species richness, diversity and Sorenson's co-efficient of community similarity (CC).

5.3 Results

Definite similarities do exist between the older rehabilitation stands and the younger naturally revegetated stands as can be seen in the arrangement of quadrats by TWINSPAN analysis (Fig 5.1). The younger rehabilitated stands and the older revegetated stands including the site sampled at St. Lucia are placed at opposite extremes of the TWINSPAN dendrogram.

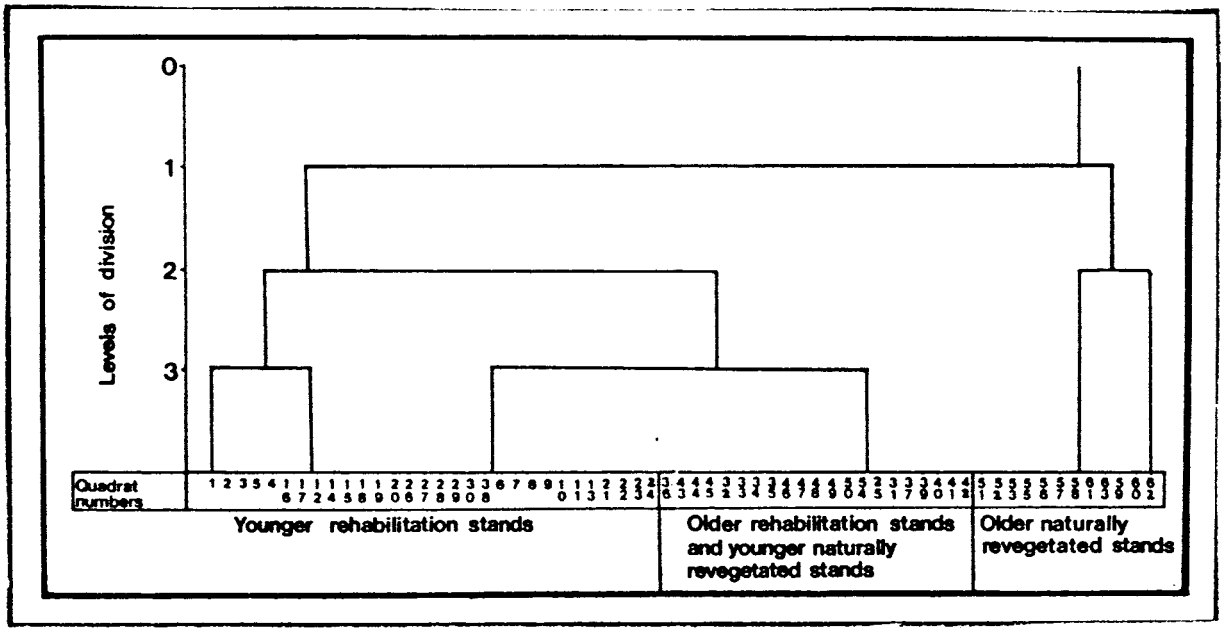

Figure 5.1; Dendrogram produced by TWINSPAN indicating the separation of stands into groups of different age and either rehabilitated or naturally revegetated stands.

At the first level of division the older naturally revegetated stands split from the other, while the post-mining rehabilitation stands are still grouped with the younger naturally revegetated stands. Then at the second division a split occurs between the younger rehabilitated stands and the older rehabilitated stands, which are still grouped with the young naturally re-

vegetated stands. Thus a close affinity exists between the young natural areas and the rehabilitated sites, with rehabilitated stands of 11 and 12 years old intermixed amongst the 8 and 14 year old natural stands.

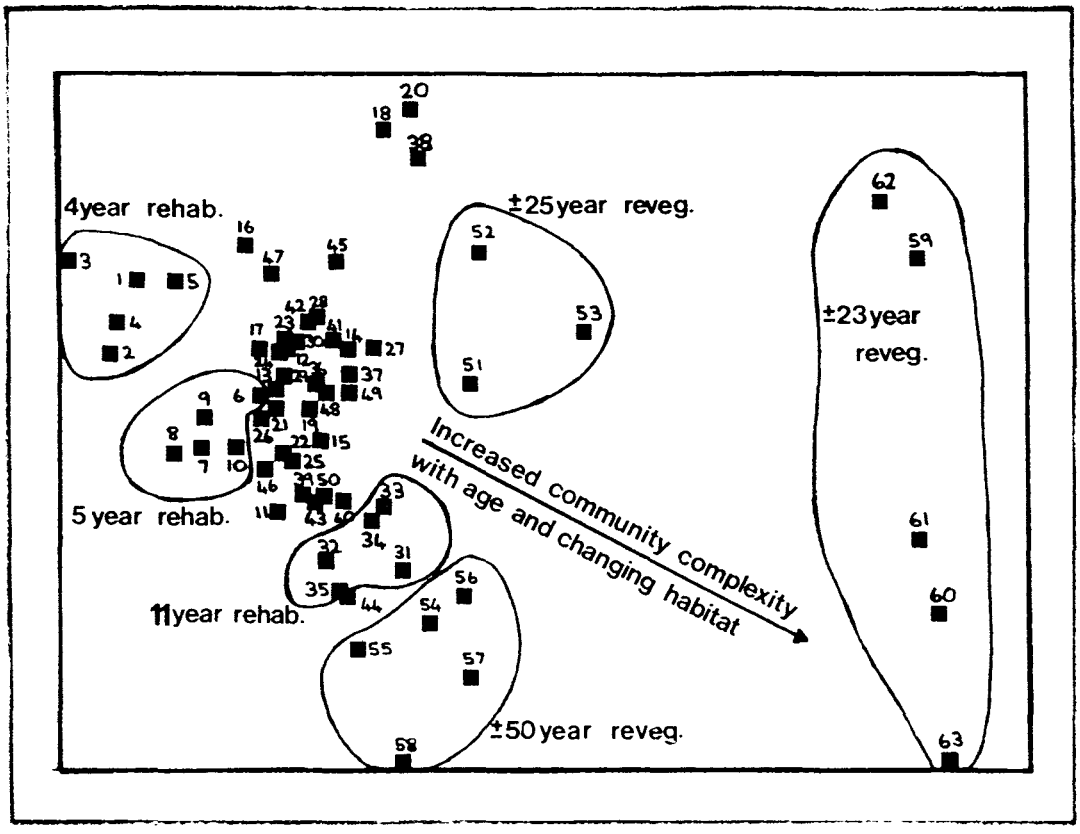

Figure 5.2; DECORANA plot showing the relationship between the rehabilitation stands of various ages and the naturally revegetated stands of increasing age in the Richards Bay area.

The DECORANA plot of axis one and two (Fig 5.2) depicts the grouping obtained by TWINSPAN along gradients of increased complexity and changing habitat. Groups formed on the left show community complexity while the older revegetated sites, found on the right, have more species and habitat diversity (ie alpha and beta diversity) as shown in Tables 5.1 and 5.2.

Table 5.1; Diversity and dominance values of rehabilitated stands and naturally revegetated sites in the Richards Bay area.

YEARS SINCE REHAB.	TOTAL SPECIES RICHNESS	SIMPSON'S DIVERSITY(Ds)	INVERSE OF L(ds)	SIMPSONS DOMINANCE	SHANNON DIVERSITY (Base E)
4	28	0,859	7,098	0,149	0,298
5	25	0,868	7,607	0,131	0,371
7	44	0,891	9,167	0,109	0,677
8	43	0,911	11,262	0,089	0,892
9	41/43	0,901	10131	0,099	0,755
10	41/32	0,912	11394	0,087	0,803
11	47/47	0,902	10,263	0,097	0,778
12	52/46	0,930	14,248	0,070	0,928
YEARS SINCE REVEG.					
8	52	0,922	12,767	0,078	1,107
14	64	0,948	19,363	0,052	1,368
50	55	0,931	14,478	0,069	1,148
23	105	0,970	33,479	0,029	1,400

Species richness of the older rehabilitation stand is very similar to that of the young revegetated stands. The youngest area that revegetated to *Acacia karroo* woodland, that of eight years old had a mean species richness of 24, which is higher than the equivalent aged rehabilitation stand with a value of 15. However it is the same as the value obtained from five $100m^2$ samples in the oldest rehabilitation stand (12 years). Total species richness also compares favourably with 52 species found in both the youngest natural and oldest rehabilitated stands. The fourteen year old naturally revegetated stand had a mean species richness of 34 species and a total species richness of 64. Therefore it is not much higher than the oldest rehabilitated stands. The oldest areas of naturally recolonised vegetation those of approximately 25 and 50 years old showed a decrease in mean species richness (32 and 25) as well as total species recorded (45 and 55) in five $100m^2$ quadrats. It is probable that this was due to the small quadrat size as larger quadrats should have been used in these two communities but this would have prevented direct comparison with the other stands. Also dominance by one or two species as highlighted in Chapter 4 could have had an effect.

Diversity indices (ds) and Simpson's dominance values of the older rehabilitated and young revegetated stands are similar, particularly those of the eight year old natural and twelve year old rehabilitated stands (Table 5.1). The fourteen year old revegetated stand has a higher diversity of 19,363 but a lower dominance of 0,052. Sorenson's co-efficient of community similarity shows interesting relations between the older rehabilitated stands and revegetated stands. The number of shared species between two communities depicted on the

Table 5.2; Community similarity (CC) values (above shaded) and shared species (below shaded) between the different ages of rehabilitated stands and naturally revegetated stands. Total species richness (shaded) in the diagonal.

YEARS SINCE REVEGETATION | REHABILITATION BEGAN	YEARS SINCE REHABILITATION | REVEGETATION BEGAN											
	4	5	7	8	9	10	11	12	8	14	50	23
4	28	0,26	0,38	0,37	0,34	0,30	0,27	0,16	0,35	0,26	0,19	0,15
5	7	25	0,41	0,35	0,47	0,35	0,31	0,34	0,31	0,31	0,30	0,15
7	14	14	44	0,53	0,60	0,45	0,26	0,42	0,48	0,40	0,32	0,28
8	13	12	23	43	0,49	0,48	0,40	0,40	0,44	0,48	0,37	0,26
9	12	16	26	21	43	0,48	0,60	0,56	0,59	0,44	0,47	0,28
10	9	10	17	18	18	32	0,51	0,49	0,45	0,47	0,37	0,29
11	10	11	12	18	27	20	47	0,47	0,55	0,43	0,53	0,30
12	6	12	19	18	25	19	22	46	0,51	0,40	0,48	0,27
8	14	12	23	21	28	19	27	25	52	0,53	0,49	0,33
14	12	14	22	26	24	23	24	22	31	65	0,47	0,31
50	8	12	16	18	23	16	27	24	26	28	55	0,33
23	10	10	21	19	21	20	23	20	26	26	26	105

lower half of Table 5.2, indicates that a number of similar species are found in the 9, 11 and 12 year old rehabilitated stands and the 8, 14 and 50 year old revegetated stands. This is supported by high CC values above the line for the same stands which show a great degree of similarity between the older rehabilitation stands and revegetated areas.

Some of the species found in the eight year old stand and fourteen year old stand do not occur in the rehabilitated stands. These are listed below;

Commicarpus pentandrus

Draceana hookerana

Maytenus heterophylla

Ochna semulata

Dovyalis rhamnoides

Senecio quinquelobus

Indigofera sp.

It is not known why these species do not occur and no information exists on whether their

seeds are found in the seed bank of the rehabilitated stands. Therefore it is possible that this factor or unfavourable conditions may be limiting the return of these species, however as the species similarity between the rehabilitated stands and revegetated sites is so great it appears that the previous reason is more likely. Therefore attempts should be made to introduce these species artificially into the rehabilitated stands.

5.4 Discussion

That natural forces are the major determinates in establishing successful rehabilitation cannot be questioned. Therefore it is imperative that we understand these forces and how they have influenced natural revegetation and are likely to influence the rehabilitated communities. Borman et al (1990) state that one of the greatest difficulties faced by restorationist, especially those rehabilitating long-lived ecosystems such as forests, is to obtain definite knowledge about the development process. Only when this knowledge is available can the manager alter or enhance succession to achieve the desired end product. Concern has been raised for example on the extensive damage to soil crumb structure, which is built up over a long period by natural soil processes. This is an important factor which can restrict the rooting potential of some plants (Bradshaw, 1990). Other factors influencing the colonisation of mined areas include the altered soil nutrients and the low light penetration caused by the thick *Acacia karroo* canopy. No data was collected on the soil properties of the revegetated *Acacia karroo* woodland but it cannot be expected that this differs much from the topsoil of the mature forests. This topsoil compared favourably with the rehabilitated soil in regards to it's constituent parts. Light penetration appears to be the same for both the younger revegetated sites and older rehabilitated sites. However in the older 25 and 50 year old natural communities the *Acacia karroo* canopy is not as dense, thus enabling other tree and shrub species to reach maturity. Most of the ground cover species are those adapted to low light intensities, such as *Acyranthes aspera*, *Asystasia gangetica*, *Isoglossa woodii*, *Laportea peduncularis* and *Microsorium scolopendrium*. Climbers which appear to be just as dense as in the rehabilitation stands grow on the old *Acacia* trees weighing them down and breaking off the old dead branches. These climbers have not smothered the growth of the other species and seem to senesce once the ground cover plants grow over them. Therefore there is a possibilty that a "climber choke" situation could develop but from what has happened in the old revegetated stands this is not likely. *Viscum verucosum*, an aggressive strangling parasite (Gibson, 1975) in the rehabilitated *Acacia* woodland, was not found in the older revegetated sites. This is the only climber species likely to smother lower vegetation but like *Cynanchum natalitium* and *Secamone filiformis* it has not become a problem as yet.

Isoglossa woodii, the ground cover species that forms a dense growth of up to 3m high in a cyclic growth pattern (Moll, 1972) is now becoming evident in the ground layer of the rehabilitated forests. It has been shown that this species can out-compete other herbs and shrubs, exclusively dominating the understorey canopy in the latter stages of its "growth cycle". This is believed to slow down the development of other species but it would not be wise to interfere with this process as it is a natural event that occurs in the revegetated sites. Even though it is the aim of the restorer to return the mined area back to its original state as soon as possible, a compromise should be reached under circumstances which could affect the long term success of the rehabilitation and nature should be allowed to run its course. If we adopt this attitude then the presence of *Isoglossa woodii* in the older rehabilitated vegetation can be viewed as a sign of success. The similarity between the younger revegetated and older rehabilitated stands support this conclusion of initial success. By considering developments in the older stands we can achieve an insight into the future of the rehabilitated stands and manage them according to these observations. As Bradshaw (1990) put it, "what is required for successful restoration is indicated by the vegetation colonising natural areas".

CHAPTER 6

EXPERIMENTAL STUDIES ON GRASSLAND REHABILITATION

6.1 Introduction

Rehabilitation at Richards Bay has concentrated largely on the return of either dune forest or commercial plantations, although small areas of grassland and wetland communities have been returned with varying success. The rehabilitation of these two communities was carried out as a trial investigation into the procedure needed for their establishment and thus the technique still has to be refined. The presence of other vegetation types is of great value in achieving an overall successful rehabilitation of a large area. Not only does it introduce new species to the area but it also produces a variety of habitats for returning flora and fauna. Grassland communities are also fairly common on the dunes along the Zululand coast, especially on the landward side of the initial dune ridge (Conlong and van Wyk 1991). The grassland area at Richards Bay minerals is now two years old, it has a low diversity and is still dominated by the planted and seeded "cover crop" grass *Eragrostis curvula*. The swards formed by this grass are very dense and prevent all but the most robust and quick growing species such as *Panicum maximum, Cymbopogon validus, Dactyloctenium germinatum* and *Acacia karroo* from becoming established in high densities. The wetland formed in 1986 by the turning of the dredge path has been described in Chapter 2 and therefore no further detail will be given in this chapter.

The grassland area, being both small and immature, provides the ideal location for implementing experimental manipulation studies. Grassland species are fast growing especially in the sub-tropical climate and because they are early successional species they recover quickly after most forms of treatment. Due to these factors experimental studies were undertaken on the grassland to improve their rehabilitation and long-term management. Kline and Howell (1990) who have worked on the restoration of America's prairies feel that this community lends itself to experiments carried out on a small scale, over a reasonable length

of time even where conventional agricultural techniques are employed. At Richards Bay the aim of the experimental manipulation of the grassland was to improve the diversity of the current grassland and reduce the dominance of *Eragrostis curvula*. The grassland was created by preventing the successional formation of an *Acacia karroo* woodland, simply by chopping out this species. This is a round about method and a small scale experiment was carried out in an attempt to establish grassland from the outset. The topsoil returned to the existing *Eragrostis* dominated grassland originated from areas previously covered by dune forest and could not be expected to contain many seeds of grassland species. This is probably the main reason for the low species diversity and low recruitment of grassland species into this area. Seeds of those species that do reach the grasslands struggle to germinate as *Eragrostis curvula* grows in such a thick cover that no light reaches the surrounding soil.

The treatments applied in this experiment were chosen after considering logistical factors such as expense, ease of implementation and the impact on the stability of the mined site. They would also have to be carried out over a large area of difficult terrain, thus preventing the usage of complex and time-consuming treatments. The use of manipulative experiments in studying the dynamics of the vegetation and steps required for successful rehabilitation has been suggested by some prominent scientists. Cairns (1990) proposed that the colonisation process itself is instructive, especially where manipulations are carried out to determine what is enhancing or retarding recolonisation. Ashby (1990) and Gross (1990) both support the use of experimental manipulations to establish which mechanisms account for changes in communities, especially the diversity and abundance of particular species.

In order to increase the diversity of the grassland both grass and forb species need to be introduced and encouraged to colonise. In most natural grasslands, grasses are generally more abundant than forbs, but more forb species occur compared to grass species (Kline and Howell, 1987). Recent studies done on grasslands in the Zululand coastal dune cordon include, Venter (1972) in the Richards Bay area, Conlong (1986) on the Eastern Shores of

Lake St. Lucia and van Wyk (unpublished) on grasslands south of Sodwana Bay. The study done by Venter (1972) is the most relevant to this study. He found that *Eragrostis capensis* was the climax species in the community. Other species associated with *E. capensis* are *Paspalum commersonii*, *Cyperus obtusiflorus* and *C. natalensis*. *Aristida junciformis* was the most widespread grass which represents a seral change in the primary succession of dunes. This domination may possibly have resulted from selective grazing of more palatable species. The species composition of rehabilitated grasslands needs to be determined by what species occur in the vicinity of the mine site, preferably in areas where interference by grazing and cultivation are limited. Unfortunately in this study no areas unaffected by grazing from the local inhabitants' livestock or alien invasion were located. Therefore topsoil and grass sods from non-pristine grasslands had to be used in the experimental treatments. However the main aim of these experiments was to establish means of reducing the *Eragrostis curvula* dominance and increase species diversity but not to return a completely "pristine" grassland.

6.2 Materials and Methods

The favourable climate in the Richards Bay region leading to a rapid growth and colonisation rate of grassland species has made it possible to experimentally manipulate the grassland. In this way the best means of establishing and maintaining a diverse community can be determined. The procedure used was a split plot design arranged on four replicated transect lines laid out on rehabilitated grassland (Fig 6.1) and two transects on bare tailings. The split plot design consists of 10m x 10m plots on each side of the four transects (Plate 6) , in which five randomly situated 1m x 1m sample quadrats have

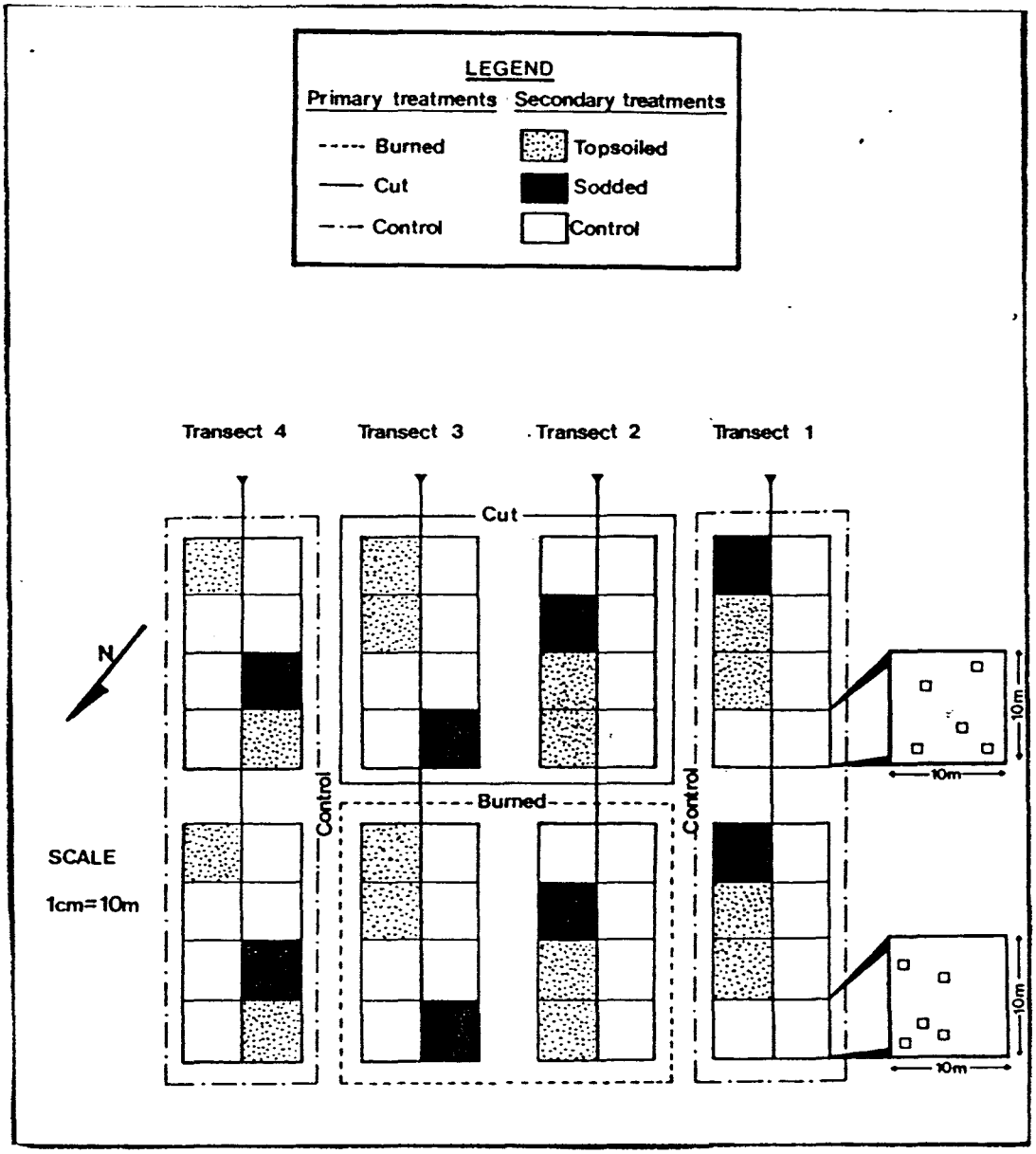

Figure 6.1; A diagram showing the layout of the split plot design, arranged along four transects running at right angles up the dune slope, with the treatment and control plots applied.

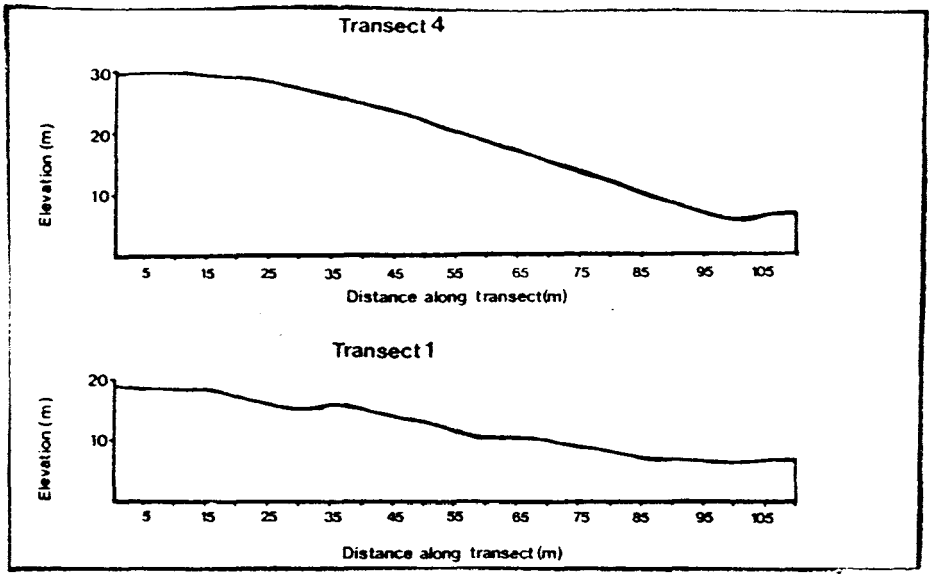

Figure 6.2; The profiles of transects 1 and 4 showing the variation in slope along the recreated dune ridge.

been permanently marked. The transects were aligned down the slope (Fig 6.2) in case any natural variability occurred between sites and also replicated due to the arrangement of transects along the slope.

The established *Eragrostis* dominated grassland was subjected to two primary treatments, viz. cutting and burning. Burning has been proposed on a number of occasions as the factor most important in controlling the origin and development of grasslands (Sauer, 1950; Stewart, 1951,1955, 1956, 1963 and Jordan etal, 1990). Kline and Howell (1987) indicate that fire is an essential tool in the restoration and management of prairies. The second primary treatment, cutting, was an attempt to simulate grazing, as it was not feasible to use local livestock as they could introduce unwanted alien species. Grazing has also been documented to have an effect on species composition, increasing the number of unpalatable species (Kozlowski, 1974) which would not be the case when uniform cutting is undertaken. Secondary treatments applied to both the bare tailings and established grassland are:

1. Topsoiling with soil collected in the area.
2. Introducing sods from grasslands in the area.

A further treatment of seeding with indigenous grassland species was not carried out as seed was not available at the start of the experiment. A control plot has been sited next to each of the secondary treatment plots along the transect lines. The outside transect lines act as controls for the inner plots which were subjected to the primary treatments. Rosenzweig

(1990) has indicated that when doing experimental work on rehabilitated vegetation it is of great importance to have sufficient controls. Quadrats were monitored for just over a year (December 1990 to January 1992) to establish which treatments reduced the dominance of *Eragrostis curvula* and produced the greatest species diversity . The July 1990 sample representing the situation before any treatments were applied. Importance values of *Eragrostis curvula* and species richness were used to determine what changes occur in the grassland community due to the treatments. The results obtained have been analysed using analysis of variance (ANOVA) to show whether they are significant or not (Tables 6.1, 6.2, 6.3 and Figures 6.7 and 6.8). Comparisons have been made between the *Eragrostis curvula* grassland and that created on bare tailings in terms of species richness and composition. All the species recorded during the grassland experiments are listed in Appendix 3.

6.3 Results

The short period available for this study (two years) has meant that findings have had to be based on results recorded over the duration of just more than a year. The results of the experimentation undertaken are given in Figures 6.3 and 6.4 which show the changes in species richness over time following a certain treatment. Similarly importance values of *Eragrostis curvula* have been depicted in Figures 6.5 and 6.6 for the same time period.

Burning:

The burnt area has shown an increase in species richness for both the burnt, treated plots and burnt, control plots, Figure (6.3). The area burnt and then treated with topsoil and sods have shown the most significant increase. The control area that was not burnt has shown only minor increases in species richness, the greatest increase occurring in the sodded quadrat. The importance value of *Eragrostis curvula* decreases in the burnt area, particularly those with topsoil and sods added. The unburnt area also has a decrease in *Eragrostis* dominance, once again mainly in the plots with topsoil and sods applied.

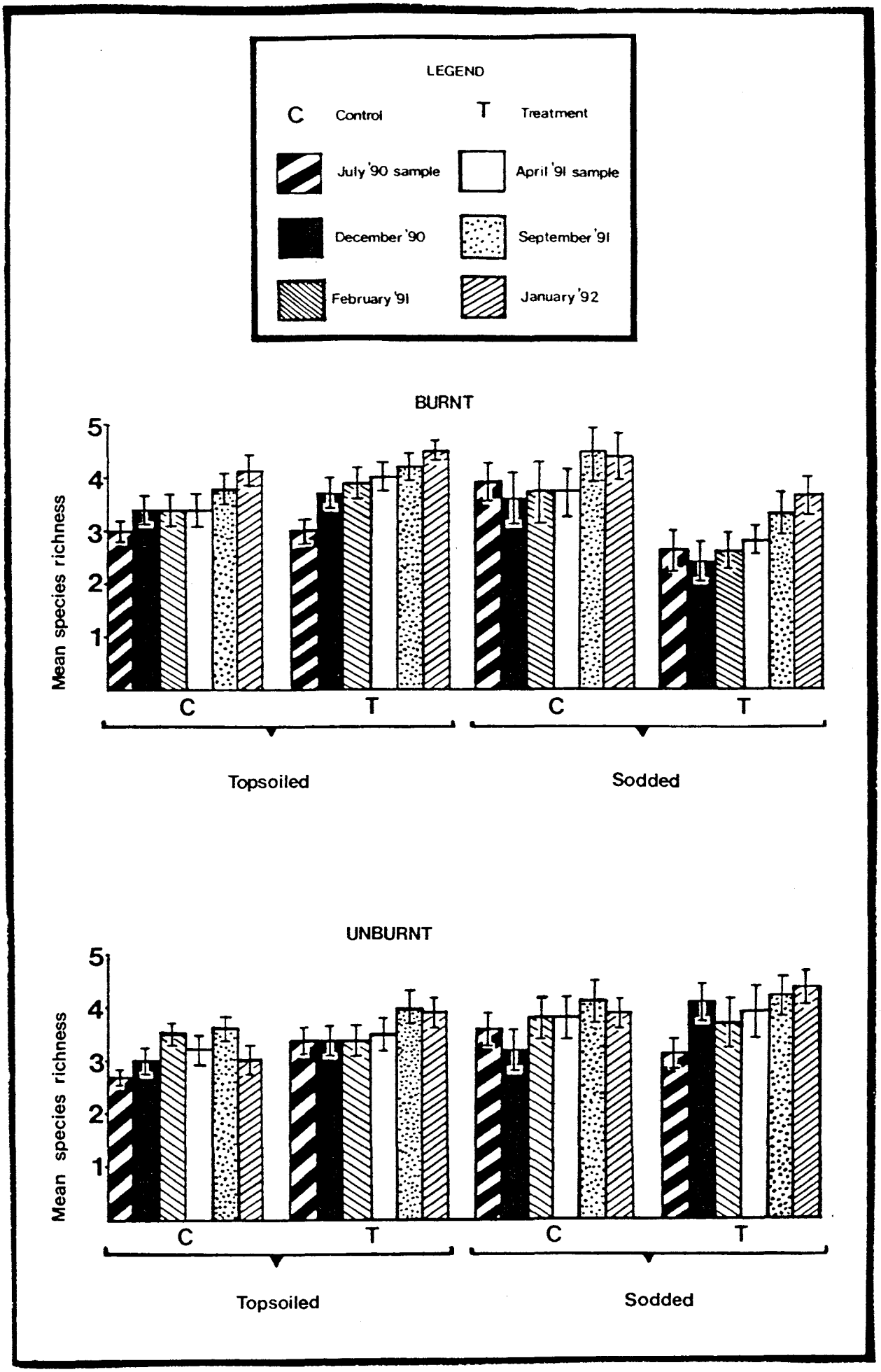

Figure 6.3; Mean species richness recorded from the burnt, unburnt, topsoiled and sodded quadrats and their controls (I=Standard error).

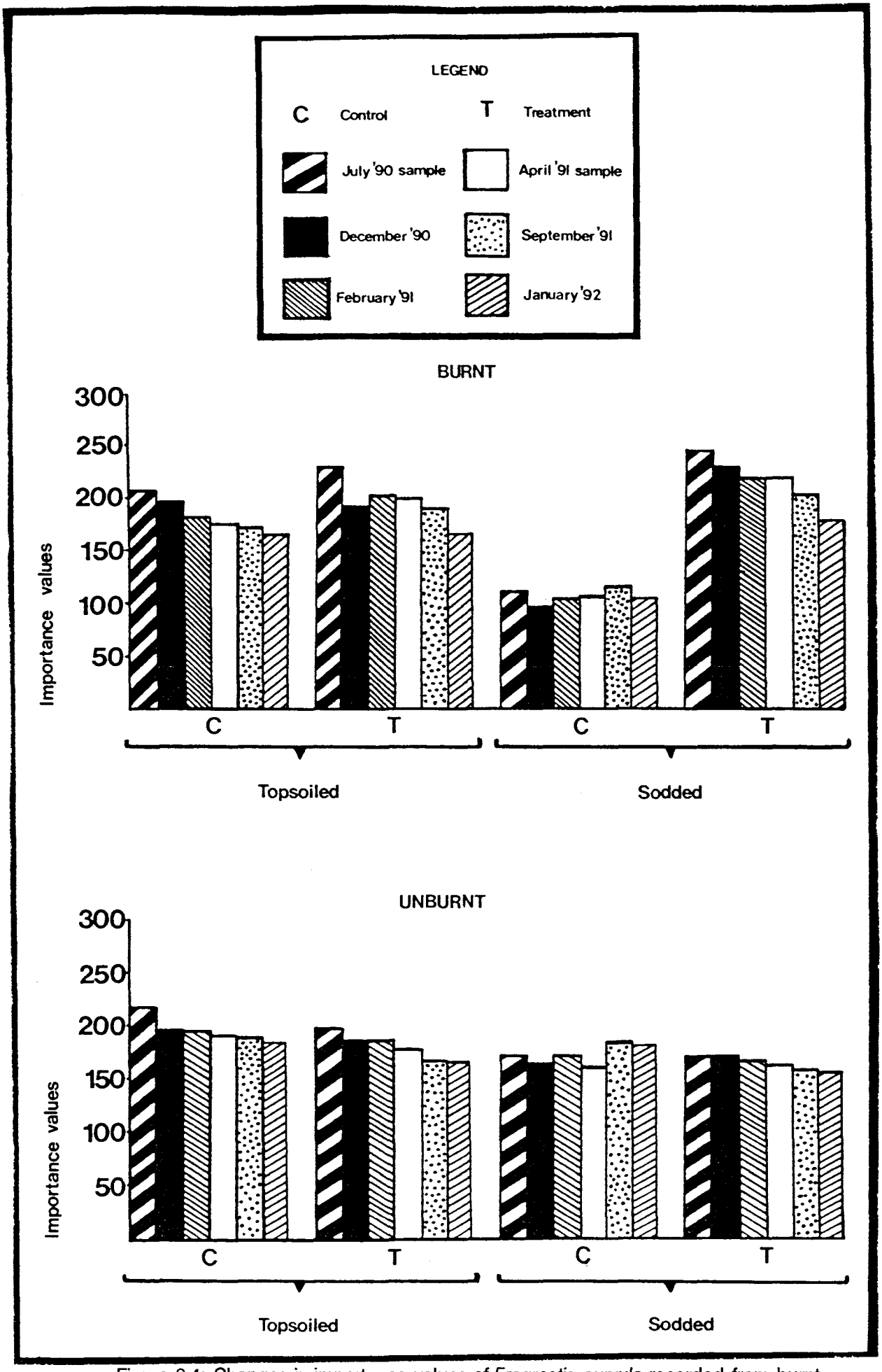

Figure 6.4; Changes in importance values of *Eragrostis curvula* recorded from burnt, unburnt, topsoiled and sodded quadrats and their controls.

Cutting:

This has produced results which show a relatively constant level of species richness in all the cut plots, the only increase taking place in the cut and topsoiled plot,(Figure 6.4). The control plots all have indicated an increase in species richness with time. The importance value of *Eragrostis curvula* decreases as well in the cut and topsoiled quadrat as does the value in the uncut/topsoiled plot. Minor decreases do also take place in the other quadrats but these are not as significant.

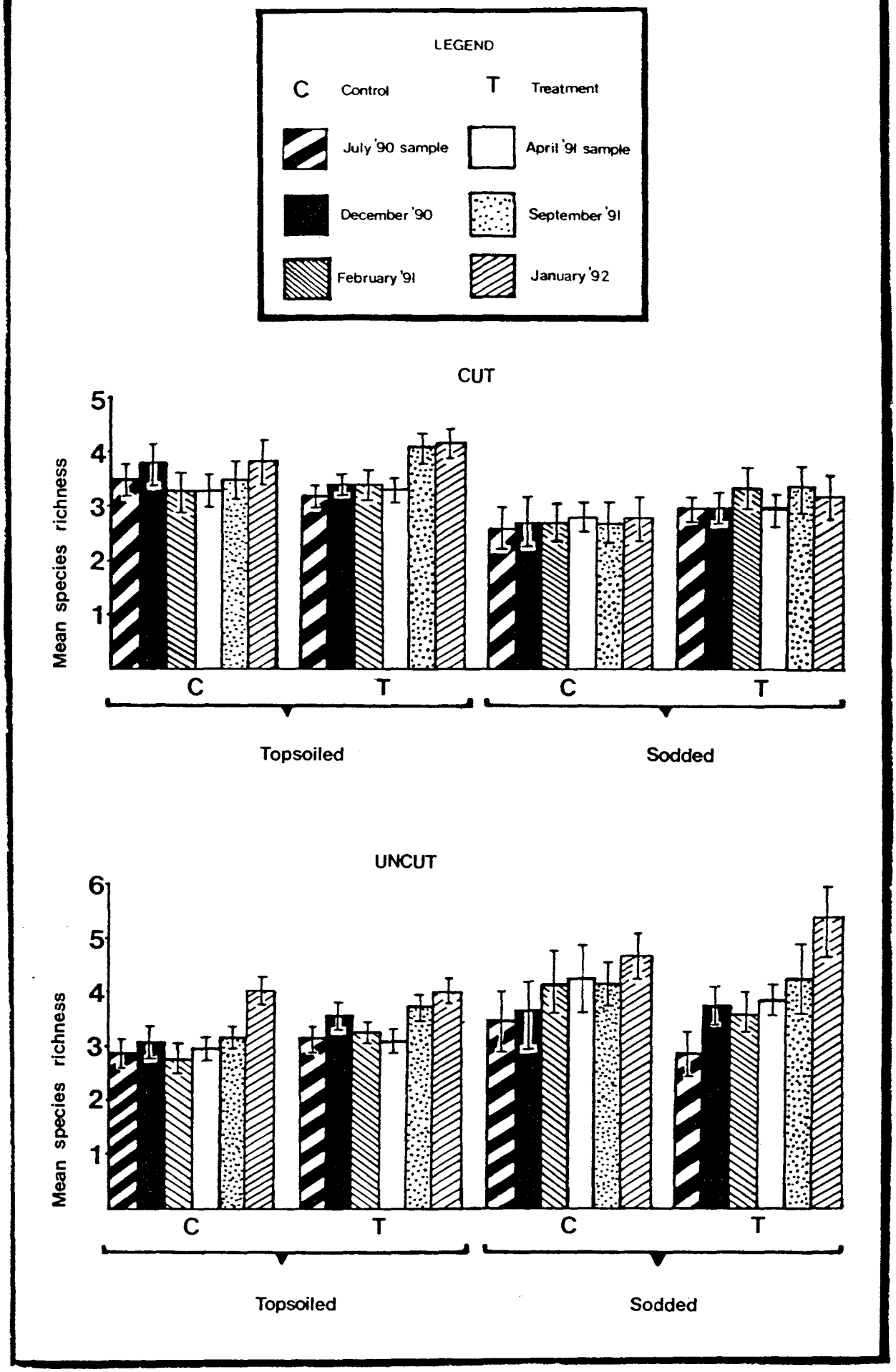

Figure 6.5; Mean species richness recoded from cut, uncut, topsoiled and sodded quadrats and their controls (I=Standard Error).

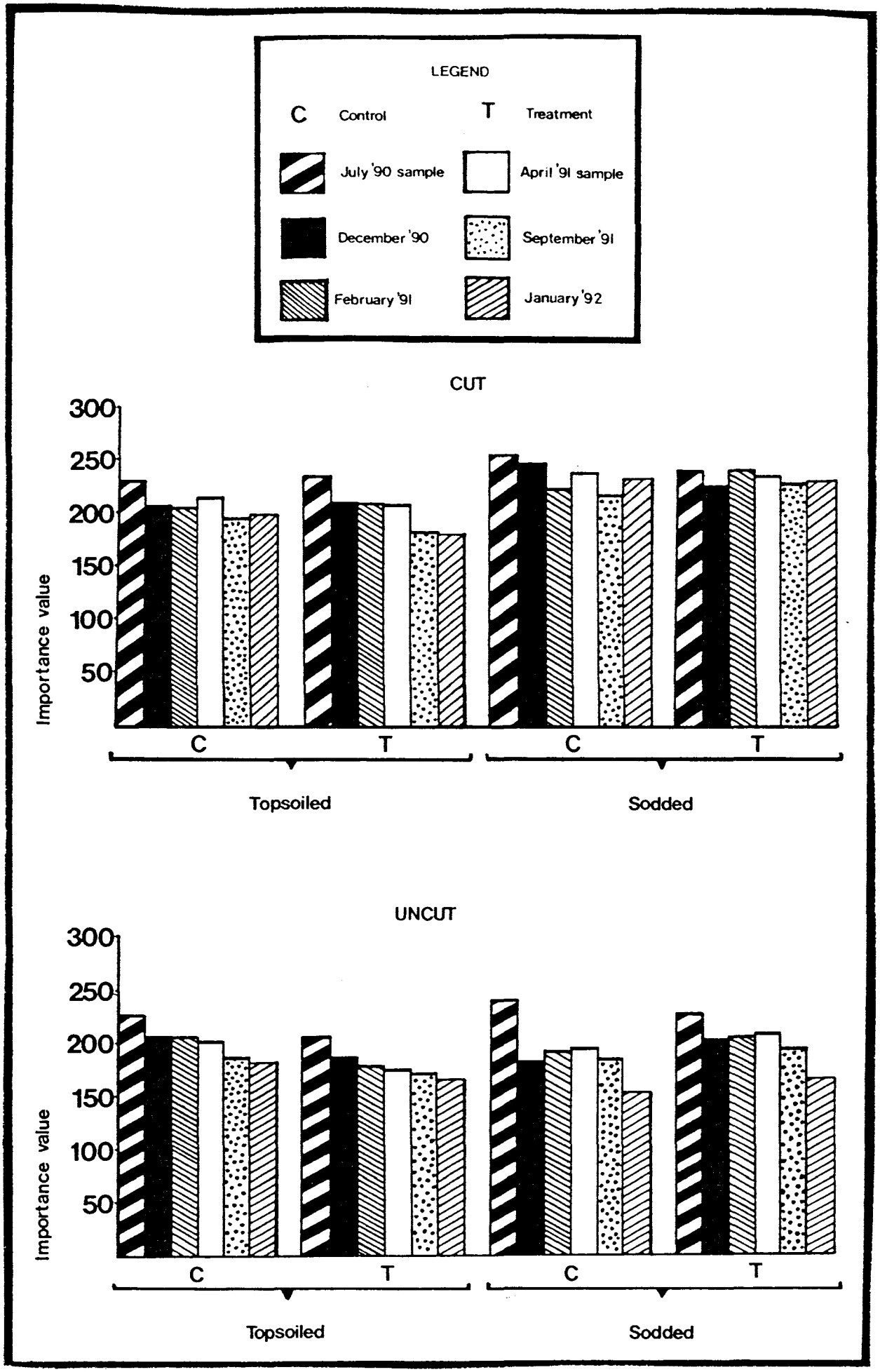

Figure 6.6; Changes in importance values of *Eragrostis curvula* recorded from cut, uncut, topsoiled and sodded quadrats and their controls.

From the results it can be noted that a combination of burning and further topsoiling of the established *Eragrostis* grassland appears to be the best treatment to increase species richness. These treatments have also produced the largest decrease in the importance value of *Eragrostis curvula* in all the quadrats. The grassland created on bare tailing by just spreading topsoil collected from a previously natural grassland community produced a cover of over 80% in less than two months. The grass species that have been found to dominate include *Dactyloctenium germinatum, Panicium maximum* and *Brachiaria humidicola*. A number of herbs have colonised this grassland, most of which are similar to those found in the *Eragrostis* dominated grassland. The total species richness recorded in ten 1m x 1m random plots for the tailings grassland was 20 and the average for ten 1m x 1m plots in the *Eragrostis* dominated grassland was 15. Therefore applying grassland topsoil directly to the tailings results in a higher species richness than establishing an *Eragrostis curvula* dominated grassland.

The ANOVA statistical analysis of the results shows no significance for the entire data set of the two main effects (Table 6.3). Plots of the 95% LSD intervals for factor means show significance between the pre-treatment sample and latter sample means (Fig 6.7). The final sample taken in January 1992 also is significantly different to the earlier samples. At 95% LSD intervals there is a significant difference between the treatments and the controls (Fig 6.8). The results of multiple range analysis are listed for the different dates of samples (Table 6.1) and for the range of treatments (Table 6.2). This shows that not all the treatments are significantly different to their controls and only the first and last sample times show relative differences to the other dates of sampling.

Table 6.1; Multiple range analysis for percentage cover of *Eragrostis curvula* by the date of sampling to show singnificance of results.

DATE NUMBER	DATE OF SAMPLE	RELEVANT SIGNIFICANT DIFFERENCE
1	July 1990	1 to 2, 1 to 3, 1 to 4, 1 to 5, 1 to 6
2	December 1990	2 to 6
3	February 1991	3 to 6
4	April 1991	4 to 6
5	September 1991	None
6	January 1992	None

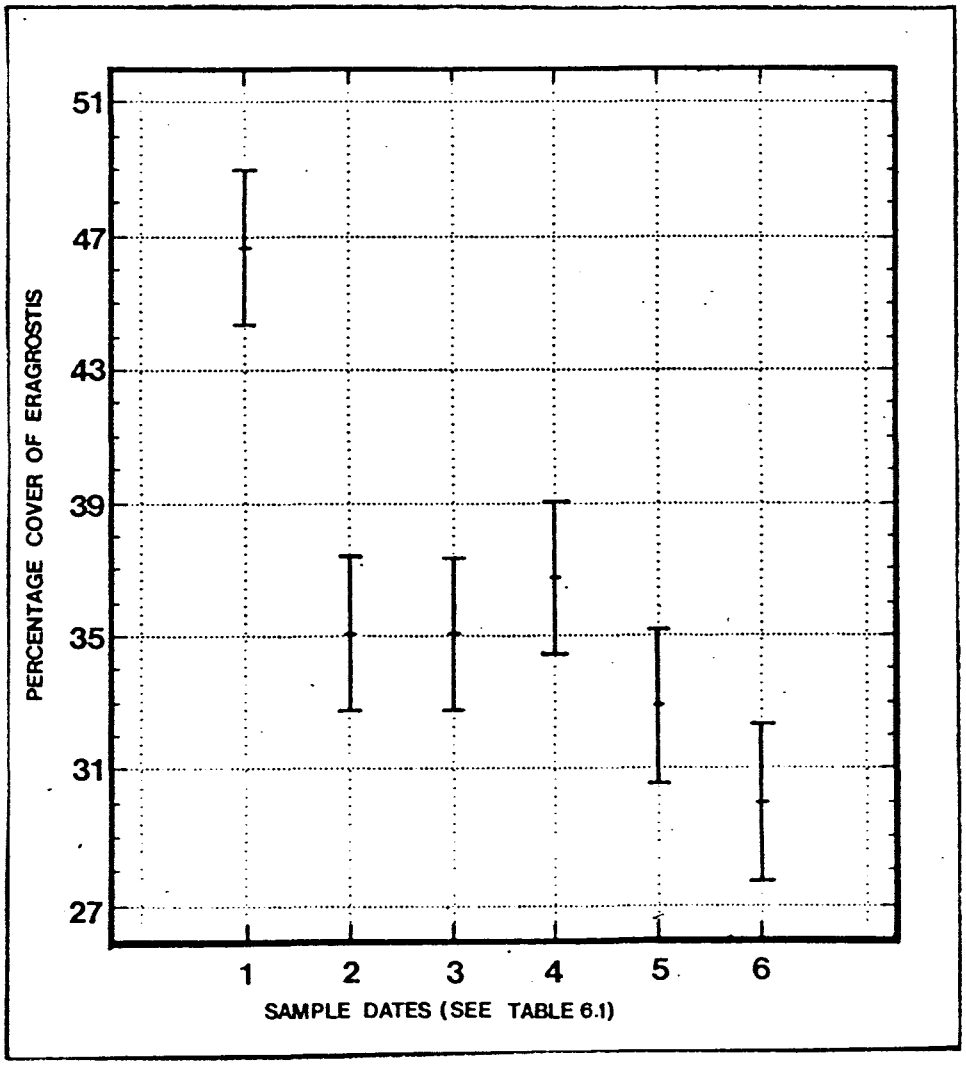

Fig 6.7; Using 95% LSD, the plot of intervals for factor means of percentage cover for *Eragrostis curvula* at the different dates of sampling.

Table 6.2; Multiple range analysis for percentage cover of *Eragrostis curvula* by the treatment applied to show significance of results.

TREATMENT NUMBER	TREATMENT	RELEVANT SIGNIFICANT DIFFERENCE
1	Cut control / Topsoiled control	1 to 7
2	Cut control / Topsoiled	2 to 5, 2 to 7
3	Cut control / Sodded control	3 to 5, 3 to 7, 3 to 8
4	Cut control / Sodded	4 to 5, 4 to 6
5	Cut / Topsoiled control	5 to 6, 5 to 7, 5 to 8
6	Cut / Topsoiled	6 to 4, 6 to 5, 6 to 7, 6 to 8
7	Cut / Sodded control	7 to 1, 7 to 2, 7 to 3, 7 to 5, 7 to 6
8	Cut / Sodded	8 to 3, 8 to 5, 8 to 6
9	Burned control / Topsoiled control	9 to 10, 9 to 11, 9 to 13, 9 to 14, 9 to 15
10	Burned control / Topsoiled	10 to 15
11	Burned control / Sodded control	11 to 15
12	Burned control / Sodded	12 to 13, 12 to 14, 12 to 15
13	Burned / Topsoil control	13 to 15, 13 to 16
14	Burned / Topsoil	14 to 15, 14 to 16
15	Burned / Sodded control	15 to 9, 15 to 10, 15 to 11, 15 to 12, 15 to 13, 15 to 14, 15 to 16
16	Burned / Sodded	16 to 13, 16 to 14, 16 to 15

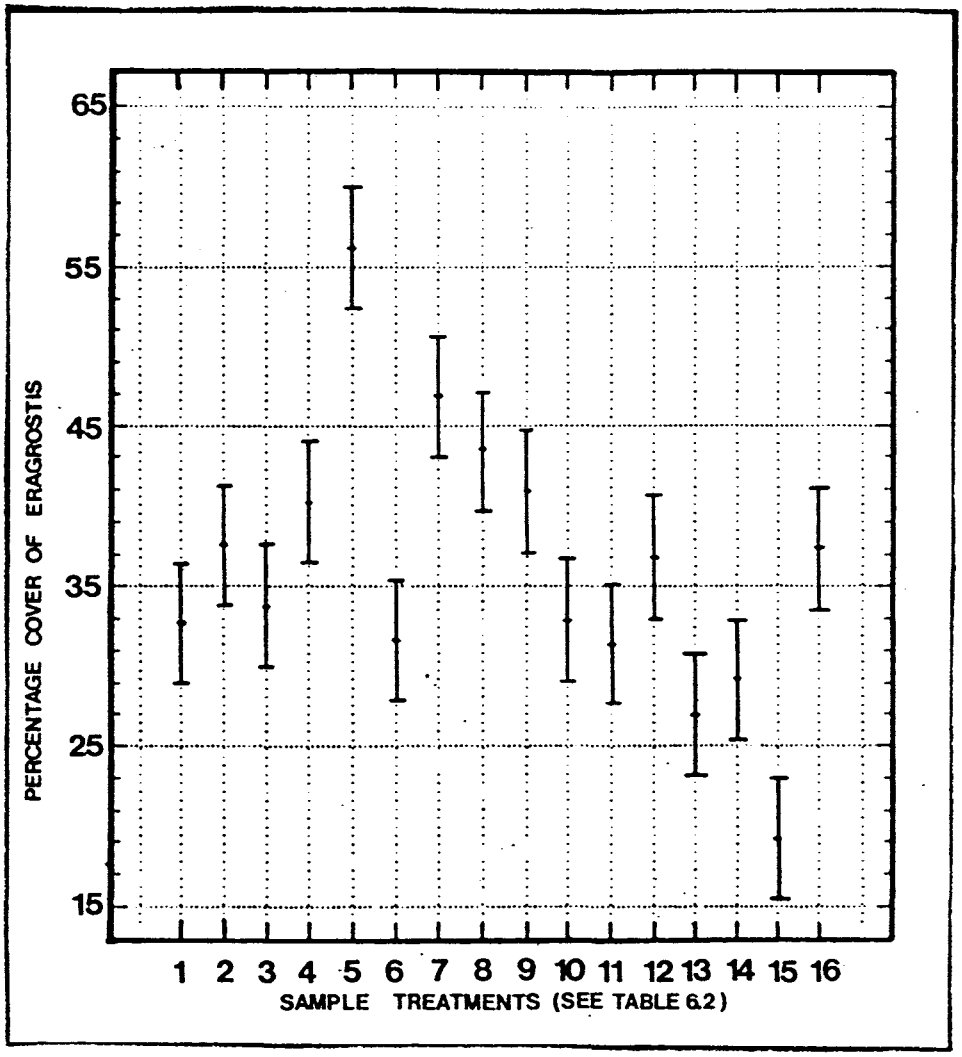

Fig 6.8; Using 95% LSD, the plot of intervals for factor means of percentage cover for *Eragrostis curvula* for the different treatments.

Table 6.3; Analysis of variance results for two main effects

SOURCE OF VARIATION	SUM OF SQUARES	d.f.	MEAN SQUARE	F-RATIO
MAIN EFFECTS				
A: time	25847.847	5	5169.5694	11.779
B: treatment	66120.057	15	4408.0038	10.043
RESIDUAL	412123.24	939	438.89589	
TOTAL (CORRECTED)	504091.14	959		

All F-ratios are based on the residual mean square error.

SIGNIFICANCE LEVEL 0.000

Plate 6 Rehabilitated grassland, wetland and *Casuarina* plantations showing the layout of the split plot design (poles with chevron tape) in the foreground. This was before any of the manipulations had been implemented.

Plate 7 The rehabilitated grassland following the application of treatments. Note the unstable conditions caused by the grazing of cattle (indicated with arrows).

Plate 8 Translocated sod from natural grassland showing that in less than a year the species established and are expected to seed and propagate into the surrounding vegetation in future seasons (sod outlined by broken line).

6.4 Discussion

The return of grassland for the restoration of mined and farmed land has taken place quite extensively in some areas of South Africa particularly on the mine dumps in the Witwatersrand region. Most of this work concentrated on the return of homogenous, pasture communities and not much emphasis was placed on the creation of highly diverse natural grasslands. Therefore little knowledge exists on the return of diverse grassland communities following large scale disturbances on the Natal coastline. Conlong and van Wyk (1991) have attributed the presence of grasslands in this region to the clearing and burning for cultivation and grazing purposes. The grassland forms a seral stage of succession that has been maintained in this state only by constant disturbances, otherwise it reverts back to shrubland and eventually thicket.

Fire and grazing play the major role in the maintenance of grasslands in pristine conserved areas and therefore their use in the management of rehabilitated grasslands needs to be encouraged (Tainton 1988). To use grazing for the management of rehabilitated areas is however very dangerous as it can affect the stability of unconsolidated dunes. Evidence of disturbance and the possibility of erosion on the steep slopes (Plate 7) in the *Eragrostis curvula* grassland exists after extensive grazing in this area by the local inhabitants' cattle. The cattle bring in the seeds of alien species, which have been observed germinating out of the cow dung. Thus cutting which can simulate grazing in certain aspects is better to use especially as the cut material is not removed and adds to the organic content of the soil. Ford and Langkamp (1987) propose the cutting and baling of grass and their seeds which is spread onto the soil in order to facilitate the return of grassland. The use of sods collected from local undisturbed grassland and replaced into the rehabilitated community is expected to have an effect on the species diversity in the long term. This was not clearly shown in the experiments undertaken as the monitoring period was not sufficient for regeneration to occur. However it was encouraging to note that all the species translocated in the sods survived and are now growing profusely and beginning to spread into the surrounding vegetation (Plate 8). Unfortunately the grasslands in the vicinity of Richards Bay are heavily grazed with a low

species diversity and high alien infestation. Therefore not many new species can be expected to invade unless more diverse donor grasslands are found.

For some of the treatments the two year period was not enough to show the entire effect they can be expected to have on the species composition of the rehabilitated grassland community. Sodding requires more than one season in which to restore the growth of its own component species and then to regenerate and spread into the surrounding vegetation. Burning, although observed to have an initial effect on the dominance of *Eragrostis curvula* needs to be repeated at regular intervals to be really significant (Kozlowski, 1974). Cutting has an immediate effect on the *Eragrostis curvula* dominance but needs to be continuously undertaken to have a lasting effect on the cover of this species. Adding topsoil can be expected to promote the growth of all the species and introduce the seeds of new species once it has been applied. Even though some of the treatments did not produce sufficient changes in the species diversity in the time available they did give an indication of what to expect in the future after their implementation. The words of Ewel (1990) are most appropriate in expressing the worth of such experimentation - "Ecosystem restoration is an activity at which everyone wins: when successful, we are rewarded by having returned a fragment of the earth's surface to its former state; when we fail, we learn an immense amount about how ecosystems work, provided we are able to determine why the failure occurred."

Seeding of the grasslands by a diverse seed mixture of indigenous, local species would be most practical and cost - effective means of improving the rehabilitation success. However this would require extensive collection of seeds from pristine grasslands without removing too many seeds and negatively effecting these areas (Ford and Langkamp, 1987). By adding further topsoil at the same time it would encourage the germination of these species and possibly others in the soil's seed bank. Using fire has the effect of reducing the cover of all species enabling further species to germinate in the spaces in between the dominant species. Kozlowski (1974) highlights the effect fire has in reducing the woody species but also results in an increase in the number of herb species. Repeated burning of native grassland

does not reduce species diversity and on many occassions has promoted the growth of additional grasses, legumes and forbs.

The experimental manipulation of natural grasslands has been used before in South Africa (Tainton, 1988), in which grazing and browsing regimes were studied and procedures for the creation of diverse, natural secondary grassland investigated. *Eragrostis curvula* was used in a number of rehabilitation programmes especially of disturbed roadsides and although it remains dominant for a number of years it is eventually replaced. The older swards of *Eragrostis curvula* with their long leaves have a sweeping effect on the soil around the grass clumps which may prevent the establishment of young seedlings. This is possibly the reason why a combination of burning and topsoil treatments proved successful during the experimentation in increasing the species richness and reducing *Eragrostis curvula* dominance. Although the initial establishment phase appears more rapid for establishing grassland compared to *Acacia karroo* woodland, continued monitoring and management, including burning regimes and alien species control, will be necessary to introduce a diverse grassland community.

CHAPTER 7

GENERAL DISCUSSION AND RECOMMENDATIONS

Now that twelve years of rehabilitation have been successful (Chapter 2) in returning stable and relatively diverse vegetation communities to the mined area at Richards Bay we need to ask, what of the future? Will *Acacia karroo* continue to dominate, suppress the growth of other species and eventually leave a stunted forest community when it begins to senesce? Or will a "climber choke" situation develop which smothers all shrub and tree growth? Hopefully none of these cicumstances will develop and the *Acacia karroo* will gradually thin out as has happened in naturally revegetated areas, so allowing other indigenous forest species to mature and propogate. After having established that the early years of natural revegetation are similar in most aspects to the rehabilitated stands (Chapter 5), surely this is what can be expected to happen. The best method of determining what should be aimed at during rehabilitation, according to Ford and Langkamp (1987) is to monitor, over a period of time, what changes occur in the type and structure of the rehabilitated plant community and then by comparing these trends with changes in undisturbed ecosystems it will indicate the final composition of the climax community.

Whatever the final objective of the rehabilitation process may be it is critical for continued management and monitoring of the vegetation to take place. Only in this way can the perpetual development of the rehabilitated communities be observed and quantitatively recorded. Where necessary, manipulations can be used to speed up the successionary change or improve failed areas of restoration. Frequent research needs to be carried out on the changes to physical conditions that take place in the evolving forest community. As these conditions are modified they enable new species to colonise, and therefore can be limiting to forest development if they don't occur (Ashby, 1990). The clearing and monitoring of alien invasion in the rehabilitation areas needs to be a continous process to prevent alien establishment and the competition they exert on indigenous species. Alien species can be

introduced by a number of dispersal mechanisms, the most comon being the birds and monkeys which eat the juicy fruits. However birds, small mammals and monkeys play the most important part in the natural dispersal and recruitment of indigenous seeds into the rehabilitated areas and need to be encouraged. The effect that animals have on the rehabilitated vegetation is quite extensive and everything should be done to make these habitats more attractive to them (Allan, 1987; Ashby, 1990). The rehabilitated areas bordering on the natural forest, namely the eleven and twelve year old stands have the highest species richness. This can be attributed to the frequent occurrence of monkeys and frugiverous birds that move into this area from the adjacent indigenous vegetation. The possibility of leaving small refugia of natural vegetation in the form of long strips within the mine path needs to be considered (MacMahon, 1990). These attract the animal seed dispersers and while en route to the natural islands they expel seeds of indigenous species into the rehabilitated vegetation.

In the future attempts should be made at transplanting rare species and those that have not reappeared in the rehabilitation stands. This can be done by either direct translocation of small, juvenile trees from the mine path or by collecting seeds before mining, germinating the seedlings and then planting them into the rehabilitated sites. If this is done, priority should be given to fruiting species and those that are struggling to colonise the rehabilitation stands. Some species are only found in specific niches of the indigenous forests, and the physical conditions required by these species need to be determined and re-created to enable their return (Cairns, 1990). Species which are of economic importance for the "muti" trade should also be targeted for re-introduction into the rehabilitated stands. Some of these species are becoming over utilized and endangered in the natural indigenous forest and their presence in the rehabilitated vegetation could only help increase the importance of these communities.

7.1 Recommendations for management of forest rehabilitation:

1) Data needs to be collected annually in each rehabilitation stand; these data should include changes in the species composition, abundance and cover as well as changes in the strata cover and soil properties.

2) Experimental manipulations need to be carried out in the forest community;- these will be long term experiments and permanent sites will have to be established and monitored over a number of years. Examples of manipulations include thinning of the *Acacia* canopy, adding fertilizers to the topsoil and adding feeding posts for frugiverous birds and mammals.

3) Seeds and seedlings need to be added to the rehabilitated stands on a continous basis especially those of rare plants unable to recolonise the reconstructed vegetation.

4) Before mining moves into an area of indigenous bush an inventory of the species present and their numbers needs to be recorded: this can be done at regular intervals along the survey lines cut through the bush.

5) The distribution of cut branches of indigenous bush below the immature forest canopy before a dense ground cover and shrub layer becomes established - this will introduce further seeds and help increase the amount of forest litter; it will also create micro-environments for invertebrates, reptiles and small animals.

6) If possible one particular vegetation type should never be completely removed so as to assist in the rehabilitation with a mosiac of vegetation types. This would improve the species diversity in adjacent areas and allow migration of species into the rehabilitation sites. It would also improve the visual appeal of the rehabilitation area.

7) When using topsoil for the rehabilitation of a specific community this topsoil should come from the same or a similar community because of the presence of seeds and propagules in the topsoil.

8) Only seeds collected from local communities before mining should be added to the topsoil. This is important, as ecotypes of a particular species which do not occur naturally in this habitat should not be used.

9) The seed mixture should be balanced and not contain an excess of one species which would then dominate.

7.2 Recommendations on the management of the soil seed bank:

1) Studies are necessary on seed characteristics because of the importance of direct seeding in rehabilitation.

2) Compiling seed requirement lists before collection ie. quantities of seed needed for each species dependent on their expected seed viability, success of re-establishment in existing rehabilitation and the area to be revegetated.

3) Studies on the effect of time of sowing (seasonality) on the establishment rates and fatalities of selected forest species.

7.3 Recommendations for additional grassland management:

1) Seed collected in the previous years and during mining should be added once the grassland has established itself.

2) Grass sods (at least 2m x 2m in size) should be collected and then placed at random sites in the rehabilitated areas. These will act as small refugia and as a futher seed source. They will also contain species which regenerate vegetatively by means of bulbs and tubers and help to increase diversity.

3) Once a diverse grassland has been created, further management such as controlled burning and grazing will be necessary to maintain it in this state, to increase diversity and to prevent invasion of alien species.

4) The loss of viable seed during the mining process can not be prevented but may be reduced by transporting the topsoil to and spreading it on the tailings immediately after it has been collected. This will reduce the time of exposure during which seed predation and wind dispersal may occur. Collecting further seed and adding it to the grassland at a latter stage would compensate for this loss.

CONCLUSION

The discription given by Ford and Langkamp (1987) on the events responsible for natural revegetation, and how rehabilitation sets out to achieve a similar result, is most appropriate to this study. Here follows an account of their views on the return of vegetation and the rehabilitation process. Natural ecosystems have evolved over an extensive period and thus possess a great diversity of species which are connected by a series of complex relationships. When disturbed, ground is invaded by colonising species; these provide shade, nutrients and organic litter enabling other species to establish and the community to progress through a series of successive stages until a stable state is achieved. The rate of successionary change is dependent on the availability of seeds and the occurrence of favourable conditions for seedling establishment. Mining or any other form of extensive disturbance is likely to destroy the existing ecosystem. Rehabilitation therefore requires the artificial management of the succession process and helps to increase the rate at which the community returns to a climax stage (Ford and Langkamp, 1987). Richards Bay Minerals is following the general programme of rehabilitation as laid out above, and in doing so have obtained an initial success of vegetation return. That there is a need for rehabilitation ecology to develop into one of the most important and active forms of scientific research is definite and is the rationale behind this study. However it is questionable how soon man is going to realize just how much he can abuse and destroy the earth's natural vegetation without trying to return it to its original state. In conclusion I turn to the profound words of Turner (1990), "Our destiny as a species now appears to be bound up with the success of our attempts to reconstruct our living environment."

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APPENDIX I

CHECKLIST OF SPECIES RECORDED DURING SAMPLING OF THE REHABILITATION STANDS

* alien species

SPECIES NAME	FAMILY
Abutilon grantii A. Meeuse	MALVACEAE
Acacia karroo Hayne	FABACEAE
Acalypha petiolaris Hochst.	EUPHORBIACEAE
Achyranthes aspera L. var. *aspera*	AMARANTHACEAE
Adenia gummifera (Harv.) Harms var. *gummifera*	PASSIFLORACEAE
Allophyllus natalensis (Sond.) De Winter	SAPINDACEAE
Aneilema aequinoctiale (P.Beauv.) Loudon	COMMELINACEAE
Anthericum saundersiae Bak.	LILIACEAE
Apodytes dimidiata E.Mey. ex Arn. subsp. *dimidiata*	ICACINACEAE
Astripomoea malvaceae (Klotzsch) A. Meeuse	CONVOLVULACEAE
Asystasia gangetica (L.) T. Anders.	ACANTHACEAE
Brachylaena discolor DC. subsp. *discolor*	ASTERACEAE
Canthium inerme (L.f.) Kuntze	RUBIACEAE
Carissa bispinosa (L.) Desf. var. *bispinosa*	APOCYNACEAE
Carpobrotus dimidatus (Haw.) L.Bol.	MESEMBRYANTHEMACEAE
* *Catharanthus roseus* (L.) G.Don	APOCYNACEAE
Celtis africana Burm.f.	ULMACEAE
Centella asiatica (L.) Urb.	APIACEAE
* *Cestrum laevigatum* Schlechtd.	SOLANACEAE
Cheilanthus viridis (Forssk.) Schwartz var. *glauca* (Sim) Schelpe & N.C. Anthony	ADIANTACEAE
* *Chromolaena odorata* (L.) R.M. King & H.Robinson	ASTERACEAE
Cissampelos mucronata A. Rich	MENISPERMACEAE
Cissampelos torrulosa E. Mey. ex Harv.	MENISPERMACEAE
Clausena anisata (Willd.)Hook.f. ex Benth.	RUTACEAE
Clerodendrum glabrum E. Mey. var. *glabrum*	VERBENACEAE
Coccinia rehmannii Cogn. var. *littoralis* A.Meeuse	CUCURBITACEAE
Commelina africana L.	COMMELINACEAE
Commelina benghalensis L.	COMMELINACEAE
Commelina livingstonii C.B.Cl.	COMMELINACEAE
Commelina diffusa Burm.f.	COMMELINACEAE
* *Conyza bonariensis* (L.) Cronq.	ASTERACEAE
* *Conyza sumatrensis* (Retz.) E.H. Walker	ASTERACEAE
Crassula alba Forssk. var. *alba*	CRASSULACEAE
Crassula multicava Lem. & Verschoff	CRASSULACEAE
Crocosmia aurea Planch.	IRIDACEAE
Crotolaria capensis Jacq.	FABACEAE
Ctenomeria capensis (Thunb.) Harv. ex Sond.	EUPHORBIACEAE
Cynanchum natalitium Schltr.	ASCLEPIADACEAE
Cyperus albostriatus Schrad.	CYPERACEAE
Cyperus obtusifolius Vahl. var. *obtusifolius*	CYPERACEAE
Cyphostemma cirrhosum (Thunb.) Descoings subsp. *cirrhosum*	VITACEAE
Dactyloctenium geminatum Hack.	POACEAE
Dioscorea sylvatica (Kunth.) Eckl.	DIOSCOREACEAE
Dodonaea angustifolia L.f.	SAPINDACEAE
Dolichos sericeus E. Mey. subsp. *sericeus*	FABACEAE

Drimiopsis maculata Lindl.	LILIACEAE
Ekebergia capensis Sparrm.	MELIACEAE
Eleusine indica (L.) Gaertn.	POACEAE
Eragrostis curvula (Schrad.) Nees	POACEAE
Eugenia capensis (Eckl. & Zeyh.) Harv. ex Sond.	MYRTACEAE
Gardenia thunbergii L.f.	RUBIACEAE
Grewia occidentalis L.	TILIACEAE
Hibiscus surattensis L.	MALVACEAE
Ipomoea ficifolia Lindl.	CONVOLVULACEAE
Isoglossa woodii C.B.Cl.	ACANTHACEAE
Kedrostis nana (Lam.) Cogn. var. *nana*	CUCURBITACEAE
Kraussia floribunda Harv.	RUBIACEAE
Lablab purpureus (L.) Sweet subsp. *purpureus*	FABACEAE
* *Lactuca indica* L.	ASTERACEAE
* *Lantana camara* L.	VERBENACEAE
Laportia peduncularis (Wedd.) Chew subsp. *latidens* Friis	URTICACEAE
Macrotyloma axillare (E. Mey.) Verdc. var. *glabrum* (E. Mey.) Verdc.	FABACEAE
Maerua nervosa (Hochst.) Oliv.	CAPPARACEAE
Mariscus congestus (Vahl.) C.B.Cl.	CYPERACEAE
Mariscus albomarginatus C.B.Cl.	CYPERACEAE
Panicum natalense Hochst.	POACEAE
Paspalum vaginatum Swartz	POACEAE
Passerina rigida Wikstr.	THYMELIACEAE
Phoenix reclinata Jacq.	ARECACEAE
Phyllanthus burchellii Muell. Arg.	EUPHORBIACEAE
Protasparagus densiflorus (Kunth) Oberm.	LILIACEAE
Protasparagus falcatus (L.) Oberm.	LILIACEAE
Pupalia atropurpurea Moq.	AMARANTHACEAE
Pycreus macranthus C.B.Cl.	CYPERACEAE
Rhoicissus digitata (L.f.) Gilg. & Brandt	VITACEAE
Rhoicissus tridentata (L.f.) Wild & Drum.	VITACEAE
Rhus macowanii Schonl.	ANACARDIACEAE
Rhus natalensis Bernh.	ANACARDIACEAE
Rhus pyroides Burch.	ANACARDIACEAE
* *Richardia brasiliensis* Gomes	RUBIACEAE
Rubia cordifolia (L.) subsp. *conotricha* (Gand.) Verdc.	RUBIACEAE
Sansevieria hyacinthoides (L.) Druce	HYACINATHACEAE
Sarcostemma viminale (L.) R.Br.	ASCLEPIADACEAE
Scutia myrtina (Burm.f.) Kurz	RHAMNACEAE
Secamone alpini Schultes	ASCLEPIADACEAE
Secamone filiformis (L.f.) J.H. Ross	ASCLEPIADACEAE
Senecio deltoides Less.	ASTERACEAE
Senecio helminthoides (Sch.Bip.) Hilliard	ASTERACEAE
Senecio macroglossus D.C.	ASTERACEAE
Senecio sp.	ASTERACEAE
Sideroxylon inerme L.	SAPOTACEAE
Smilax kraussiana Meisn.	SMILACACEAE
Solanum aculeatissimum Jacq.	SOLANACEAE
* *Sonchus oleraceus* L.	ASTERACEAE
Synaptolepis kirkii Oliv.	MYRTACEAE
Syzygium cordatum Hochst.	RUBIACEAE
Tragia durbanensis Kuntze	EUPHORBIACEAE
Trema orientalis (L.) Blume	ULMACEAE

Tricalysia sonderiana Hiern.	RUBIACEAE
Trichilia emetica Vahl.	MELIACEAE
Triumfetta rhomboidea Jacq.	TILACEAE
Tulbaghia acutiloba Harv.	LILIACEAE
Vepris undulata (Thunb.) Verdoorn & C.M.Sm.	RUTACEAE
Vigna unguiculata (L.) Walp. subsp. *dekindtiana* (Harms) Verdc.	FABACEAE
Viscum verrucosum Harv.	VISCACEAE
Zanthoxylum capense (Thunb.)Harv.	RUTACEAE
sp. indet	CONVOLVULACEAE
sp. indet	CONVOLVULACEAE
1 species unidentified to family	

109 SPECIES RECORDED DURING SAMPLING OF THE REHABILITATION STANDS

APPENDIX : 2

SPECIES COLLECTED BY CAMP AND WEISSER (1991) NOT RECORDED DURING THIS STUDY AND LATER COLLECTIONS BY PAUL CAMP

* alien species

SPECIES NAME	FAMILY
1. Camp and Weisser (1991)	
Acacia kraussiana Meisn. ex Benth.	FABACEAE
* *Acanthospermum glabratum* (DC.) Wild.	ASTERACEAE
Albizia adianthifolia (Schumach.) W.F. Wight	FABACEAE
Alysicarpus vaginalis (L.) DC. var. *vaginalis*	FABACEAE
* *Amaranthus spinosus* L.	AMARANTHACEAE
* *Ambrosia artemisiifolia* L.	ASTERACEAE
* *Argemone subfusiformis* G.B. Ownbey	PAPAVERACEAE
Asclepias physocarpa (E.Mey.) Schltr.	ASCLEPIADACEAE
Brachiaria humidicola (Rendle) Schweick	POACEAE
Bulbostylis contexta (Nees.) Bodard	CYPERACEAE
Carissa macrocarpa (Eckl.) A.DC.	APOCYNACEAE
Cassia mimosoides L.	FABACEAE
Chloris gayana Kunth	POACEAE
Chrysanthemoides monilifera (L.) T.Norl.	ASTERACEAE
Commelina modesta Oberm.	COMMELINACEAE
Commelina undulata R.Br.	COMMELINACEAE
Crassula pellucida L.	CRASSULACEAE
Crotalaria globifera E. Mey.	FABACEAE
Crotalaria juncea L.	FABACEAE
Crotalaria lanceolata E.Mey.	FABACEAE
Crotalaria vasculosa Wall. ex Benth.	FABACEAE
Cuscuta gerrardii Bak.	CONVOLVULACEAE
Cyperus tenax Boeck.	CYPERACEAE
Deinbollia oblongifolia (E. Mey. ex Arn.) Radlk.	SAPINDACEAE
Desmodium canum (J.F. Gmel.) Schinz. & Thell.	FABACEAE
Dichrostachys cinerea (L.) Wight & Arn. subsp. *africana* Brenan & Brumm. var. *africana*	FABACEAE
Dracaena hookeriana K. Koch	LILIACEAE
Ehrharta calycina J.C.Sm.	POACEAE
Eragrostis capensis (Thunb.) Trin.	POACEAE
Eragrostis ciliaris (L.) R.Br.	POACEAE
Eriosema psoraleoides (Lam.) G.Don	FABACEAE
Erythrina lysistemon Hutch.	FABACEAE
Ficus burtt-davyi Hutch.	MORACEAE
Gladiolius dalenii Van Geel.	IRIDACEAE
Gnaphalium declinatum L.f.	ASTERACEAE
Helichrysum candolleanum Buek	ASTERACEAE
Helichrysum decorum DC.	ASTERACEAE
Helichrysum kraussii Sch. Bip.	ASTERACEAE
Helichrysum longifolium DC.	ASTERACEAE
Hewittia sublobata (L.f.) Kuntze	CONVOLVULACEAE
Hypoxis rooperi S.Moore	HYPOXIDACEAE
Indigofera inhambanensis Klotzsch	FABACEAE
Indigofera sanuinea N.E.Br.	FABACEAE
Indigofera trita L.f.	FABACEAE

Indigofera vicioides Jaub. & Spach.	FABACEAE
Leonotis leonurus (L.) R.Br.	LAMIACEAE
Limeum viscosum (Gay) Fenzl subsp. *viscosum* var. *viscosum*	AIZOACEAE
Lotononis florifera Duemmer	FABACEAE
Manulea crassifolia Benth.	SCROPHULARIACEAE
Manulea parviflora Benth.	SCROPHULARIACEAE
Mariscus dubius (Rottb.) Kuekenth. ex G.E.C.Fischer	CYPERACEAE
Ocimum urticifolium Roth. subsp. *urticifolium*	LAMIACEAE
* *Oenothera parodiana* Munz. subsp. *parodiana*	ONAGRACEAE
Oxygonum dregeanum Meisn. var. *dregeanum*	POLYGONACEAE
Pennisetum americanum (L.) R.Br.	POACEAE
Polygonum sp.	POLYGONACEAE
Priva meyeri Jaub. & Spach. var. *meyeri*	VERBENACEAE
Rhus dentata Thunb.	ANACARDIACEAE
Rhus nebulosa Schonl.	ANACARDIACEAE
Ricinus communis L.	EUPHORBIACEAE
Scadoxus membranaceus (Bak.)Friis & Nordal	AMARYLLIDACEAE
Sclerocarya birrea (A.Rich) Hochst. subsp. *caffra* (Sond.) Kokwaro	ANACARDIACEAE
Selago wooddii Rolfe	SELAGINACEAE
Senecio polyanthemoides Sch. Bip.	ASTERACEAE
* *Sesbania bispinosa* (Jacq.) W.F.Wight var. *bispinosa*	FABACEAE
* *Solanum nigrum* L.	SOLANACEAE
Strelitzia nicolai Regel & Koern	STRELITZIACEAE
Tapinanthus sp.	LORANTHACEAE
Tephrosia burchellii Burt-Davy	FABACEAE
Typha capensis (Rohrb.) N.E. Br.	TYPHACEAE
Vangueria infausta Burch.	RUBIACEAE
Vernonia aurantiaca (O.Hoffm.) N.E.Br.	ASTERACEAE
* *Xanthium strumarium* L.	ASTERACEAE

2. Paul Camp records

Aloe thraskii Bak.	LILIACEAE
Annona senegalensis Pers.	ANNONACEAE
Antidesma venosum E.Mey. ex Tul.	EUPHORBIACEAE
Aristea ecklonii Bak.	IRIDACEAE
Aristida junciformis Trin. & Rupr. subsp. *junciformis*	POACEAE
Bauhinia tomentosa L.	FABACEAE
Brachiaria chusqueoides (Hack.) Clayton	POACEAE
Bridelia micrantha (Hochst.) Baill.	EUPHORBIACEAE
Crinum macowanii Bak.	AMARYLLIDACEAE
Fagara capensis Thunb.	FABACEAE
Ficus sycomorus L.	MORACEAE
Ficus trichopoda Bak.	MORACEAE
Gloriosa superba L.	LILIACEAE
Harpephyllum caffrum Bernh.	ANACARDIACEAE
Kalanchoe sp.	CRASSULACEAE
Nymphaea caerulea Sav.	NYMPHAEACEAE
Senecio pleistocephalus S. Moore	ASTERACEAE
Senecio tamoides DC.	ASTERACEAE
Sesbania sesban (L.) Merr subsp.	

sesban var. *nubica* Chiov.	FABACEAE
Solanum duplo-sinuatum Klotzsch	SOLANACEAE
Stangeria eriopus (Kunze.) Baill.	STANGERIACEAE
Stenochlaena tenuifolia (Desv.) Moore	BLECHNACEAE
Stenotaphrum secundatum (Walt.) Kuntze	POACEAE
Ziziphus mucronata Willd.	RHAMNACEAE

97 SPECIES COLLECTED AND RECORDED BY CAMP AND WEISSER (1991) AND RECORDED BY CAMP IN ADDITION TO THOSE WITH VOUCHER COLLECTIONS.

APPENDIX : 3

SPECIES CHECKLIST OF SPECIES RECORDED IN REHABILITATED GRASSLAND
* alien species

SPECIES NAME	FAMILY
Abrus precatorius L. subsp. *africanus* Verdc.	FABACEAE
Abutilon grantii A.Meeuse	MALVACEAE
Acacia karroo Hayne	FABACEAE
Aeschynomene micranthum DC.	FABACEAE
Anthericum saundersiae Bak.	LILIACEAE
* *Bidens pilosa* L.	ASTERACEAE
Canavalia maritima (Aubl.) Thouars	FABACEAE
Carpobrotus dimidiatus (Harv.) L.Bol.	MESEMBRYANTHEMACEAE
* *Catharanthus roseus* (L.) G.Don	APOCYNACEAE
Commelina livingstonii C.B.Cl.	COMMELINACEAE
* *Conyza bonariensis* (L.) Cronq.	ASTERACEAE
* *Conyza sumatrensis* (Retz.) E.H. Walker	ASTERACEAE
Cymbopogon validus(Stapf) Stapf ex Burt-Davy	POACEAE
Cynodon dactylon (L.) Pers.	POACEAE
Cyperus natalensis Hochst.	CYPERACEAE
Cyperus obtusiflorus Vahl.	CYPERACEAE
Dactyloctenium australe Steud.	POACEAE
Dactyloctenium geminatum Hack	POACEAE
Digitaria eriantha Steud.	POACEAE
Dodonaea angustifolia L.f.	SAPINDACEAE
Eragrostris curvula (Schrad.) Nees	POACEAE
Eulophia speciosa (R. Br. ex Lindl.) H.Bol.	ORCHIDACEAE
Hebenstretia dentata L.	SELAGINACEAE
Helichrysum asperum (Thub.) Hilliard & Burtt. var. *asperum*	ASTERACEAE
Helichrysum cymosum (L.) D.Don subsp. *cymosum*	ASTERACEAE
Hyparrhenia hirta (L.) Stapf	POACEAE
Imperata cylindrica (L.) Raeuschel	POACEAE
Indigofera spicata Forssk.	FABACEAE
* *Lactuca indica* L.	ASTERACEAE
Lobelia tomentosa L.f.	LOBELIACEAE
Macrotyloma axillare (E.Mey.) Verdc. var. *axillare*	FABACEAE
Mariscus albomarginatus C.B.Cl.	CYPERACEAE
Panicum maximum Jacq.	POACEAE
Paspalum sp.	POACEAE
Phragmites australis (Cav.) Steud.	POACEAE
Phyllanthus burchellii Muell. Arg.	EUPHORBIACEAE
Rhynchelytrum repens (Willd.) C.E. Hubb	POACEAE
* *Senecio madagascariensis* Poir.	ASTERACEAE
Solanum aculeatissimum Jacq.	SOLANACEAE
* *Sonchus oleraceus* L.	ASTERACEAE
Sorghum sp.	POACEAE
Sporobolus africanus (Poir.) Robyns & Tournay	POACEAE
Sutera floribunda (Benth.) Kuntze	SCROPHULARIACEAE
Tephrosia grandiflora (Ait.) Pers.	FABACEAE
Triumfetta rhomboidea Jacq.	TILIACEAE
Wahlenbergia undulata (L.f.) A.DC.	CAMPANULACEAE
Zornia capensis Pers.	FABACEAE

48 SPECIES RECORDED IN 1 X 1 M SAMPLE PLOTS IN THE REHABILITATED GRASSLAND.

APPENDIX 4

SPECIES CHECKLIST OF VASCULAR PLANTS RECORDED IN WETLAND

* alien species

SPECIES NAME	FAMILY
* *Amaranthus spinosus* L.	AMARATHACEAE
Asclepias physocarpa (E.Mey.) Schltr.	ASCLEPIADACEAE
Canavalia maritima (Aubl.) Thouars	FABACEAE
* *Conyza bonariensis* (L.) Cronq.	ASTERACEAE
Cyperus natalensis Hochst.	CYPERACEAE
Cyperus sp.	CYPERACEAE
Epilobium salignum Hausskn.	ONAGRACEAE
Eragrostis curvula (Schrad.) Nees	POACEAE
* *Lactuca indica* L.	ASTERACEAE
Phragmites australis (Cav.) Steud.	POACEAE
Pycreus polystachyos Beauv.	CYPERACEAE
* *Sonchus oleraceus* L.	ASTERACEAE
Typha capensis (Rohrb.) N.E.Br.	TYPHACEAE

13 SPECIES RECORDED IN 2 SAMPLE PLOTS OF 5 X 5M.

APPENDIX 5

SPECIES CHECKLIST OF AN APPROXIMATELY 8 YEAR OLD NATURALLY REVEGETATED STAND.

* alien species

SPECIES NAME	FAMILY
Acacia karroo Hayne	FABACEAE
Acacia kraussiana Meisn. ex. Benth.	FABACEAE
Achyranthes aspera L. var. *aspera*	AMARANTHACEAE
Adenia gummifera (Harv.) Harmes var. *gummifera*	PASSIFLORACEAE
Allophyllus natalensis (Sond.) De Winter	SAPINDACEAE
Apodytes dimidiata E.Mey. ex. Arn. subsp. *dimidiata*	ICACINACEAE
Asystasia gangetica (L.) T. Anders	ACANTHACEAE
Brachylaena discolor DC. subsp. *discolor*	ASTERACEAE
Celtis africana Burm. f.	ULMACEAE
Cheilanthes viridis (Forssk.) Schwartz (Sim) Schelpe & N.C. Anthony var. *glauca*	ADIANTACEAE
* *Chromolaena odorata* (L.) R.M. King & H.Robinson	ASTERACEAE
* *Commelina livingstonii* C.B.Cl.	COMMELINACEAE
* *Conyza sumatrensis* (Retz.) E.M. Walker	ASTERACEAE
Citrus sp.	RUTACEAE
Clausena aristata (Willd.) Hook. f. ex. Benth.	RUTACEAE
Clerodendrum glabrum E. Mey. var. *glabrum*	VERBENACEAE
Coccinia rehmannii Cogn. var. *littoralis* A. Meeuse	CUCURBITACEAE
Commelina africana L.	COMMELINACEAE
Cynanchum natalitium Schltr.	ASCLEPIADACEAE
Cyperus sexangularis Nees	CYPERACEAE
Dioscorea sylvatrica (Kunth.) Eckl.	DIOSCOREACEAE
Draceana hookerana K. Koch	LILIACEAE
Ekebergia capensis Sparrm.	MELIACEAE
Eleusine indica (L.) Gaertn.	POACEAE
Eugenia capensis (Eckl. & Zeyh.) Harv. ex. Sond.	MYRTACEAE
Grewia occidentalis L.	TILIACEAE
Ipomoea ficifolia Lindl.	CONVOLVULACEAE
Isoglossa woodii C.B.Cl.	ACANTHACEAE
Kraussia floribunda Harv.	RUBIACEAE
Lablab purpureus (L.) Sweet subsp. *purpureus*	FABACEAE
Mariscus albomarginatus C.B.Cl.	CYPERACEAE
Maytenus heterophylla (Eckl. & Zeyh.) N. Robson	CELASTRACEAE
Maytenus procumbens (L.f.) Loes.	CELASTRACEAE
Microsorium scolopendrium (Burm. f.) Copel.	POLYPODIACEAE
Mimusops caffra E. Mey. ex A. DC.	SAPOTACEAE
Oxalis latifolia H.B.K.	OXALIDACEAE
* *Sonchus oleraceus* L.	ASTERACEAE
Panicum maximum Jacq.	POACEAE
Phoenix reclinata Jacq.	ARECACEAE
Rhoicissus tridentata (L.f.) Gilg. & Brandt	VITACEAE
Rhus pyroides Burch.	ANACARDIACEAE
Scutia myrtina (Burm. F.) Kurz	RHAMNACEAE
Secamone filiformis (L.f.) J.H. Ross	ASCLEPIADACEAE
Senecio helminthoides (Sch. Bip.) Hilliard	ASTERACEAE
Strelitzia nicolai Regel & Koern.	STRELITZIACEAE
Tragia durbanensis Kuntze	EUPHORBIACEAE

Trema orientalis (L.) Blume	ULMACEAE
Tricalysia sonderiana Hiern.	RUBIACEAE
Vepris undulata (Thunb.) Verdoorn & C.M. Sm.	RUTACEAE
Vernonia aurantiaca (O. Hoffm.) N.E.Br.	ASTERACEAE
Vigna unguiculata (L.) Walp. subsp. *dekindtiana* (Harms) Verdc.	FABACEAE
Zanthoxylum capense (Thunb.) Harv.	RUTACEAE

52 SPECIES WERE RECORDED IN THE FIVE SAMPLE PLOTS FOR THE 8 YEAR OLD NATURALLY REVEGETATED STAND.

APPENDIX 6

SPECIES CHECKLIST OF AN APPROXIMATELY 14 YEAR OLD NATURALLY REVEGETATED STAND.

* alien species

SPECIES NAME	FAMILY
Abutilon grantii A. Meeuse	MALVACEAE
Acacia karroo Hayne	FABACEAE
Achyranthes aspera L. var. *aspera*	AMARANTHACEAE
Allophyllus natalensis (Sond.) De Winter	SAPINDACEAE
* *Apium* sp.	APIACEAE
Bachmannia woodii (Oliv.) Gilg.	CAPPARACEAE
Brachylaena discolor DC. subsp. *discolor*	ASTERACEAE
Canthium inerme (L.f.) Kuntze.	RUBIACEAE
* *Catharanthus roseus* (L.) G.Don	APOCYNACEAE
Celtis africana Burm. f.	ULMACEAE
Centella asiatica (L.) Urb.	APIACEAE
Cheilanthes viridis (Forssk.) Schwartz var. *glauca*	ADIANTACEAE
* *Chromolaena odorata* (L.) R.M. King & H. Robinson	ASTERACEAE
Cissampelos hirsuta Klotzsch.	MENISPERMACEAE
* *Citrus* sp.	RUTACEAE
Clausena anisata (Willd.) Hook. f. ex. Benth.	RUTACEAE
Coccinia rehmannii Cogn. var. *littoralis* A. Meeuse	CUCURBITACEAE
Commelina africana L.	COMMELINACEAE
Commelina benghalensis L.	COMMELINACEAE
Commelina livingstonii C.B.Cl.	COMMELINACEAE
Commicarpus pentandrus (Burch.) Heim.	NYCTAGINACEAE
* *Conyza bonariensis* (L.) Cronq.	ASTERACEAE
* *Conyza sumatrensis* (Retz.) E.M. Walker	ASTERACEAE
Cynanchum natalitium Schltr.	ASCLEPIADACEAE
Dalbergia obovata E. Mey.	FABACEAE
Desmodium hirtum Guill. & Perr.	FABACEAE
Dovyalis rhamnoides (DC.) Harv.	FLACOURTIACEAE
Drimiopsis maculata Lindl.	LILIACEAE
Eugenia capensis (Eckl. & Zeyh.) Harv. ex. Sond.	MYRTACEAE
Helichrysum sp.	ASTERACEAE
Hibiscus surattensis L.	MALVACEAE
Indigofera sp.	FABACEAE
Ipomoea purpurea (L.) Roth	CONVOLVULACEAE
Isoglossa woodii C.B.Cl.	ACANTHACEAE
Laportea peduncularis (Wedd.) Chew subsp. *latidens* Friis	URTICACEAE
Mariscus albomarginatus C.B. Cl.	CYPERACEAE
Maytenus procumbens (L.f.) Loes.	CELASTRACEAE
Mikania natalensis DC.	ASTERACEAE
Ochna serrulata (Hochst.) Walp.	OCHNACEAE
Oxalis latifolia H.B.K.	OXALIDACEAE
Panicum maximum Jacq. (Sim) Schelpe & N.C. Anthony	POACEAE
Panicum sp.	POACEAE
Pavetta lanceolata Eckl.	RUBIACEAE
Protasparagus saundersiae Bak.	LILIACEAE
Rhoicissus tridentata (L.f.) Gilg. & Brandt	VITACEAE
Rhus natalensis Bernh.	ANACARDIACEAE
Sansevieria hyacinthoides (L.) Druce	LILIACEAE
Scutia myrtina (Burm. f.) Kurz	RHAMNACEAE

Secamone filiformis (L.f.) J.H. Ross	ASCLEPIADACEAE
Senecio deltoides Loes.	ASTERACEAE
Senecio helminthoides (Sch. Bip.) Hilliard	ASTERACEAE
Senecio madagascariensis Poir.	ASTERACEAE
Solanum aculeatissimum Jacq.	SOLANACEAE
Strelitzia nicolai Regal & Koem	STRELITZIACEAE
Tragia durbanensis Kuntze.	EUPHORBIACEAE
Tricalysia sonderiana Hiern.	RUBIACEAE
Trichilia emetica Vahl.	MELIACEAE
Vepris undulata (Thunb.) Verdoorn & C.M. Sm.	RUTACEAE
Vernonia aurantiaca (O.Hoffm.) N.E.Br.	ASTERACEAE
Vigna unguiculata (L.) Walp subsp. *dekindtiana* (Harmes) Verdc.	FABACEAE
Viscum verrucosum Harv.	VISCACEAE
Zanthoxylum capense (Thunb.) Harv.	RUTACEAE
2 specimens unidentified to family	

64 SPECIES RECORDED IN 5 SAMPLE PLOTS OF 10 X 10 M.

APPENDIX 7

SPECIES CHECKLIST OF VASCULAR PLANTS RECORDED IN 25 YEAR OLD NATURAL REVEGETATED STAND

* alien species

SPECIES NAME	FAMILY
Acacia karroo Hayne	FABACEAE
Acacia kraussiana Meisn. ex Benth.	FABACEAE
Acyranthes aspera L. var. aspera	AMARANTHACEAE
Allophylus natalensis (Sond.) De Winter	SAPINDACEAE
Apodytes dimidiata E.Mey. ex Arn. subsp. *dimidiata*	ICACINACEAE
Asystasia gangetica (L.) T.Anders.	ACANTHACEAE
Brachylaena discolor Dc. subsp. *discolor*	ASTERACEAE
Celtis africana Burm. f.	ULMACEAE
Cheilanthus viridus (Forssk.) Swartz var. glauca (Sim) Schelpe & N.C. Anthony	ADIANTACEAE
Clausena anisata (Willd.) Hook.f. ex Benth.	RUTACEAE
Clerodendrum glabrum E. Mey. var. glabrum	VERBENACEAE
Commelina africana L.	COMMELINACEAE
Commelina benghalensis L.	COMMELINACEAE
Cynanchum natalitium Hochst.	ASCLEPIADACEAE
Cyperus obtusifolius Vahl. var. *obtusifolius*	CYPERACEAE
Cyperus sexangularis Nees	CYPERACEAE
Dioscorea sylvatica (Kunth.) Eckl.	DIOSCOREACEAE
Draceana hookerana K.Koch	LILIACEAE
Eugenia capensis (Eckl. & Zeyh.) Harv. ex Sond.	MYRTACEAE
Grewia occidentalis L.	TILIACEAE
Ipomoea ficifolia Lindl.	CONVOLVULACEAE
Ipomoea sp.	CONVOLVULACEAE
Isoglossa woodii C.B.Cl.	ACANTHACEAE
Kraussia floribunda Harv.	RUBIACEAE
Lablab purpureus (L.) Sweet	FABACEAE
Microsorium scolopendrium (Burm.f.) Copel.	POLYPODIACEAE
Maytenus heterophylla (Eckl. & Zeyh.) N.Robson	CELASTRACEAE
Oxalis latifolia H.B.K.	OXALIDACEAE
Panicum sp.	POACEAE
Pupalia atropurpurea Moq.	AMARANTHACEAE
Rhoicissus digitata (L.f.) Gilg. & Brandt	VITACEAE
Rhoicissus tomentosa (Lam.) Wild & Drum.	VITACEAE
Rhoicissus tridentata (L.f.) Wild & Drum.	VITACEAE
Rhus macowanii Schonl.	ANACARDIACEAE
Rhus pyroides Burch.	ANACARDIACEAE
Scutia myrtina (Burm. f.) Kurz	RHAMNACEAE
Secamone filiformis (L.f.) J.H. Ross	ASCLEPIADACEAE
Senecio helminthoides (Sch. Bip.) Hilliard	ASTERACEAE
Sideroxylon inerme L.	SAPOTACEAE
* *Sonchus oleraceus* L.	ASTERACEAE
Trema orientalis (L.) Blume	ULMACEAE
Tricalysia sonderiana Hiern.	RUBIACEAE
Trichilia emetica Vahl.	MELIACEAE
Vepris undulata (Thunb.) Verdoorn ex. C.M.Sm.	RUTACEAE
Zanthoxylum capense (Thunb.) Harv.	RUTACEAE

45 SPECIES RECORDED IN 3 SAMPLE PLOTS OF 10 X 10M.

APPENDIX 8

SPECIES CHECKLIST OF VASCULAR PLANTS RECORDED IN 50 YEAR OLD NATURAL REVEGETATED STAND

* alien species

SPECIES NAME	FAMILY
Abutilon grantii A. Meeuse	MALVACEAE
Acacia karroo Hayne	FABACEAE
Acacia kraussiana Meisn. ex Benth.	FABACEAE
Acalypha peticlaris Hochst.	FABACEAE
Achyranthes aspera (L.) var *aspera*	AMARANTHACEAE
Adenia gummifera (Harv.) Harms var. *gummifera*	PASSIFLORACEAE
Allophylus natalensis (Sond.) De Winter	SAPINDACEAE
Apodytes dimidiata E.Mey. ex Arn. subsp. *dimidiata*	ICACINACEAE
Asystasia gangetrica (L.) T. Anders.	ACANTHACEAE
Brachylaena discolor DC. subsp. *discolor*	ASTERACEAE
Canthium inerme (L.f.) Kuntze	RUBIACEAE
Celtis africana Burm.f.	ULMACEAE
Chaetachme aristata Planch.	ULMACEAE
Clausena anisata (Willd.) Hook.f ex Benth.	RUTACEAE
Commelina africana L.	COMMELINACEAE
Cynanchum natalitium Hochst.	ASCLEPIADACEAE
Cyperus sexangularis Nees	CYPERACEAE
Cyphostemma cirrhosum (Thunb.) Descoings subsp. *cirrhosum*	VITACEAE
Dioscorea sylvatica (Kunth.) Eckl.	DIOSCOREACEAE
Dracaena hookerana K.Koch	LILIACEAE
Drimiopsis maculata Lindl.	LILIACEAE
Eleusine indica (L.) Gaertn.	POACEAE
Grewia occidentalis L.	TILIACEAE
Ipomoea ficifolia Lindl.	CONVOLVULACEAE
Isoglossa woodii C.B.Cl.	ACANTHACEAE
Kedrostis nana (Lam.) Cogn. var. *nana*	CUCURBITACEAE
Kraussia floribunda Harv.	RUBIACEAE
Laportia peduncularis (Wedd.) Chew subsp. *latidens* Friis	URTICACEAE
Macrotyloma axillare (E.Mey.) Verdc. var. *glabrum* (E.Mey.) Verdc.	FABACEAE
Microsorium scolopendrium (Burm. f.) Copel.	POLYPODIACEAE
Mikania natalensis D.C.	ASTERACEAE
Mimusops caffra E.Mey. ex A.DC.	SAPOTACEAE
Ochna natalitia (Meisn.) Walp.	OCHNACEAE
Panicum sp.	POACEAE
Pavetta revoluta Hochst.	RUBIACEAE
Protasparagus densiflorus (Kunth) Oberm.	LILIACEAE
Protasparagus falcatus (L.) Oberm.	LILIACEAE
Rhoicissus tomentosa (Lam.) Wild & Drum.	VITACEAE
Rhoicissus tridentata (L.f.) Wild & Drum.	VITACEAE
Rhus natalensis Bernh.	ANACARDIACEAE
Sansevieria hyacinthoides (L.) Druce	LILIACEAE
Scutia myrtina (Burm.f.) Kurz	RHAMNACEAE
Secamone filiformis (L.f.) J.H. Ross	ASCLEPIADACEAE
Senecio helminthoides (Sch.Bip.) Hilliard	ASTERACEAE

Smilax kraussiana Meisn.	SMILACACEAE
Teclea gerrardii Verdoorn	RUTACEAE
Tragia durbanensis Kuntze	EUPORBIACEAE
Trema orientalis (L.) Bl.	ULMACEAE
Tricalysia sonderiana Hiern	RUBIACEAE
Trichilia emetica Vahl.	MELIACEAE
Vepris undulata (Thunb.) Verdoorn & C.M. Sm.	RUTACEAE
Zanthoxylum capense (Thunb.) Harv.	RUTACEAE

55 SPECIES RECORDED IN 5 SAMPLE PLOTS OF 10 X 10 M.

3 species unidentified to family