THE COASTAL GRASSLANDS OF THE EASTERN CAPE, WEST OF THE KEI RIVER

THESIS

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ABSTRACT

The grasslands of South Africa are the foundation of commercial and subsistence agriculture, yet they are being degraded at an alarming rate. The coastal grasslands of the Eastern Cape are no exception and they suffer added pressure of coastal resort development because of their proximity to an attractive coastline. In order to determine the degree of conservation necessary for any area, it is essential to know what species occur there in order to determine if protection from habitat destruction is required.

Four aims were defined for this study. The initial aim was a phytogeographical classification of the grasslands in the coastal region west of the Kei River. This was done by vegetation sampling followed by computer based analysis with TWINSPAN. This analysis defined ten grassland associations, five being located in the area west of the Keiskamma River and five occurring east of it. The associations in the eastern half are termed mesic while those in the western half are xeric.

The second aim was to determine the presence of any underlying ecological gradients affecting the distribution of the associations. Indirect gradient analysis was carried out where samples are analysed irrespective of environmental factors. Direct gradient analysis was then carried out using scores per sample of various environmental factors. Environmental factors which might produce such gradients are both naturally-ocurring and man-induced. Natural factors which were recorded in the field include depth of soil at sample site, soil family, aspect and distance from the shore. An important factor is the land / sea interface. Natural factors analysed in the laboratory include soil pH, conductivity, percent organic matter, calcium, magnesium, phosphate and potassium. Man-induced factors are land use history e.g. Ploughing and grazing. Both direct and indirect gradient analysis were carried out with the computer based programme CANOCO.

The third aim of the study was to determine the presence of any successional trends between the ten defined associations. This was done using several characteristics of the associations. Alpha and beta diversity were the first factors compared between associations. The percentage contribution of the Cyperaceae, Fabaceae, Asteraceae and Poaceae to each association was assessed and compared. The presence of various life forms of the species occurring in each association was determined together with the cover abundance of different classes of grass species. These results were then combined and analysed in the light of the results from CANOCO analysis. They show that the mesic *Themeda triandra - Anthospermum herbaceum* association which occurs closest to the shore and with the least disturbance is a depauperate form of the mesic climax *Themeda triandra* association. The mesic *Hyparrhenia hirta - Diheteropogon amplectens* association may be a secondary grassland on account of phosphate and potassium poor soils and land-use. The mesic *Hyparrhenia hirta - Themeda triandra* association is a slightly degraded form of the climax association due to grazing. The severely disturbed *Stenotaphrum secundatum - Centella coriacea* association, which is located close to the shore, is a secondary grassland.

Analysis of the xeric associations indicates a clearly defined ordination of associations on the basis of land-use. The *Cynodon dactylon - Helictotrichon hirtulum* and *Sporobolis africanus - Setaria sphacelata* associations which occur where ploughed lands have been left to lie fallow are secondary in nature. The *Themeda triandra - Ehrharta calycina* association is thought to be the closest representative of a climax xeric association but the presence of *E. calycina* indicates that some disturbance has occurred. The vegetation is subject to moderate grazing. The *Cynodon dactylon - Ehrharta calycina* and *Diheteropogon filifolius - Ehrharta calycina* associations are subject to varying intensities of trampling and grazing and are degraded forms of the *Themeda triandra - Ehrharta calycina* association. Because of the overriding influence of the land-use gradient, separation along gradients of the remaining eight factors was limited.

The effect of fire and temporal change in the mesic *Themeda triandra* and *Hyparrhenia hirta - Themeda triandra* associations was assessed via long-term studies at Potter's Pass outside East London. The results show a quick response to burning with a return to 100% cover within six months by both associations. During spring the two associations could not be separated by either TWINSPAN or DECORANA, indicating a temporal shift from the *Hyparrhenia hirta - Themeda triandra* association to the *Themeda triandra* association.

The fourth and final aim was to identify plants requiring protection from habitat destruction and to make recommendations for further conservation areas and management of the coastal grasslands. Through the collection and identification of as many plants as possible a species checklist was prepared and the status of each was determined through reference to the Red Data Book of threatened and endangered species. *Kniphofia rooperi* is vulnerable in the Cape and *Euphorbia bupleuroides* is considered rare in kwazulu-Natal. Ten species are endemic to the Cape and / or South Africa. The richness of the vegetation lies in the presence of species representative of the four major floras which converge in the eastern Cape, i.e. The Cape, Nama-Karroo, Tongoland-Pondoland floras and the Kalahari Highveld Regional Transitional Zone.

Suggestions are made for the conservation of the grassland associations at various sites within the study area based on the present area conserved. Less than 2% of the coastline in the study area is conserved and it is felt that the area under conservation should be increased. Management suggestions based on the available literature are given for both farmed and conserved areas.

There is a great potential for further studies on grassland dynamics within the areas surveyed. In terms of management, the grasslands require careful examination to determine the most effective season in which to burn, if at all. As with most agricultural systems in South Africa, grazing strategies will benefit from further research. Any additional research on the dynamics of these grasslands can only be of benefit to the sustained utilisation of this vital resource.

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1. INTRODUCTION TO THE STUDY OF THE EASTERN CAPE COASTAL GRASSLANDS, WEST OF THE KEI RIVER

The vegetation studied for the purpose of this thesis consists of those natural grasslands that occur from the western bank of the Kei River to the Alexandria Forest as well as the pockets of grassland which occur within the Alexandria Forest. The seashore makes up one boundary, while either the presence of a belt of *Acacia karroo* or a distance of 5km from the shore defines the inland boundary. The grasslands are interrupted by Riverine Forest and Subtropical Thicket that occurs along the banks of the many streams and rivers which dissect the grasslands *en route* to the shore. Expanses of Coastal Forest or Subtropical Thicket separate the grasslands from the seashore in some places.

At the time of commencement of this study, the eastern border of the Eastern Cape was defined by the Kei River and this was chosen as the boundary for my study. Studies had already been carried out in the Transkei by researchers such as McKenzie (1984), Feely (1987) and Shackleton (1989) but the area proposed in my study had not been extensively surveyed. As the area falls into the tension zone which occurs as a result of the convergence of four major phytochoria (Tongoland-Pondoland, Karroo-Namib, Afromontane and Cape floras (Lubke and van Wijk, 1998)) and the transitional zone between the winter and summer rainfall regions (Lubke, 1998), it was felt that it warranted a study of its own.

Since 1936, the area outlined above has been generally described by several authors including Pole-Evans (1936); Dyer (1937) and Adamson (1938). However, by far the most influential author was Acocks, whose descriptions of the vegetation of South Africa were based on both the species composition and the farming potential of the area under consideration (Acocks, 1953; 1966; 1988). In his first publication the vegetation is described as being "dominated by *Acacia karroo*" with both sour and mixed grass species occurring. In 1988 this description was modified to read that the grass species were dominant with *Acacia karroo* invading. Consequently, although he described it as Eastern Province Thornveld, southern form (Acocks, 1953; 1966;

1988), the vegetation was later described as grassland, with the most recent report describing it as Coastal Grassland (Lubke *et al.*, 1996). Thus defined, the vegetation therefore became a part of the Grassland Biome that is currently the subject of much research and interest among certain grassland ecologists and pasture scientists within South Africa.

As defined by Rutherford and Westfall (1986), a biome is an area of vegetation which is "natural, reasonably homogenous" and generally fairly large. Life forms tend to be uniform since this is what distinguishes biomes from one another (Smith, 1974), and consequently, only grassland was examined in this study. Areas which were dominated by *Acacia karroo* or characterised by bushclump thickets were not sampled. The maximum cover by tall woody species did not exceed 10%.

With regard to past land-use practices, many researchers are of the opinion that the coastal grasslands along the eastern seaboard of South Africa are "false" and that originally the area was covered by forest. Man's activities resulted in the destruction of this forest vegetation and at present man-induced burning prevents them from undergoing the successional change which would result in the establishment of savannah and ultimately forest in their place. This interpretation implies that the grasslands are secondary in nature (Acocks, 1953; Mentis and Huntley, 1982; Rutherford and Westfall, 1986; O'Connor and Bredenkamp, 1997; Tainton, 1999). Other researchers disagree (McKenzie, 1984; Feely, 1987; O'Connor and Bredenkamp, 1997), supported by the fact that carbon-dating of samples taken from within the former Transkei indicate the area only began to be affected by human activities in the recent past. In effect, the grasslands have existed as such for far more than the past 2 000 years and were not man-induced (Feely, 1987; Hoffmann, 1997). It appears that the lack of wood itself discouraged human settlement (Feely, 1987). The grasslands in this study are therefore regarded as being primary in origin.

Several of the grassland areas were ploughed and subsequently re-seeded with non-native species. These grasslands were excluded from the study since it was felt that they would never represent the natural vegetation of the area. In the western half of the study area, extensive grasslands were ploughed for plantations of pineapple and other crops. When the soil was no longer able to support the crop, or the market for that particular crop declined, the vegetation was left fallow to revert to grassland. These grasslands are referred to as "Secondary". Grasslands that were known to have not been ploughed within the last 100 years or more are referred to as "Primary".

The grasslands of South Africa support a range of activities which include grazing for meat and dairy products and crop production, two aspects which are of major importance within the study area (Mentis and Huntley, 1982). Mentis and Huntley (1982) state that grasslands are South Africa's most productive biome and within the Eastern Cape, "domestic pastoralism is the most important land use practice" (de Bruyn, 1996). As Smuts (1955) so eloquently put it, "We literally live on grasses". Yet the grasslands of South Africa are being degraded at an alarming rate (Mentis and Huntley, 1982).

In addition to agricultural pressures, the coastal grasslands have the added attraction of their proximity to an attractive coastline and are therefore under threat from development in response to the tourist industry. The presence of a harbour at East London gives access to shipping which has resulted in increased pressure for industrialisation on the gently sloping land nearby (Moonieya, 1985; Anon, 1996; Birch, pers. comm.).

Since Acocks' time, man's attitude towards the environment has changed somewhat from a perception of the land as a resource to be utilised to its maximum agricultural potential to one which views it as a resource which must be taken care of. The concept of sustainable utilisation has become one of the strongest guiding forces in shaping our approach towards natural systems and our effect upon them. In 1982, in response to the negative impact which urbanisation and increased population pressure are having on the condition and area of grassland ecosystems, a study called the Grassland Biome Project was begun. Its aim is the understanding of grassland structure and function in order to predict the results of disturbance on grasslands (Mentis and Huntley, 1982).

Four main aims were identified for this study. The initial aim was the floristic definition of the grassland component of the Eastern Cape coastal region west of the Kei River. While "grassland" is a broad vegetation definition, detailed reconnaissance enables the definition of smaller vegetation units (Edwards, 1972). One of the most important features in ecosystem studies is the existence of patterns within the system (Weiner, 1995). The pattern of distribution of groups of species within the area under examination was the first analysis carried out in this study and was done using the computer-based programme TWINSPAN, or Two–Way Indicator Species Analysis programme (Hill, 1979a). TWINSPAN analysis is carried out on species presence and abundance data and the results and analysis thereof are presented in Chapter 3 of this thesis. In this way the associations within the grassland community as a whole were defined. The results were also used to prepare a species checklist for the area, which is given in Appendix 1.

Once the vegetation units present in the study area were defined, the second aim was to develop an understanding of the dynamics of the coastal grasslands. This required the identification of the most important factors affecting the distribution of these units, or associations. Weaver and Clements' (1938, in Tainton, 1996) approach to vegetation studies is that "Every plant is a product of the conditions under which it grows and is, therefore, a measure of environment". Based on this hypothesis, soil, location and land-use factors were used for each sample to measure their effect on the distribution of associations. The patterns of correlation, or ordination, between species distributions and environmental factors were determined using the computer package CANOCO, or Canonical Correspondence analysis (Hill, 1979b). The results and analysis of ordination of associations with and without the direct effect of selected environmental factors are presented in Chapter 4.

The third aim of the study was to identify the presence of any patterns of succession within the grasslands. Succession is defined by Odum (1969) as "the orderly process of community changes" which occur as a result of "modification of the physical environment by the community". Succession can be determined by elucidating the distribution and abundance of various key species, life forms and alpha and beta diversity. These aspects are often indicators of certain environmental parameters such as rainfall or disturbance and can reflect the dynamics of the ecosystem being studied. Analysis of these factors was carried out within and between associations. In addition, temporal changes may occur in vegetation and studies were carried out in a particular grassland to define these changes. The results and discussion of these studies are presented in Chapter 5.

The fourth and final aim of this study was to determine how necessary conservation might be within the study area and to try and formulate some management guidelines for the grassland vegetation. Apart from preserving the coastline from an aesthetic point of view, it was necessary to determine the presence of species worthy of conservation. The patterns of species distribution were used to identify areas of key importance for ecosystem functions and the degree of species conservation which currently exists in the study area. Information on the conservation requirements of each association was found by comparing the species checklists in Appendix 2 with the species listed in the Red Data Book (Hilton-Taylor, 1996). Results of this analysis are presented in Chapter 6.

After the patterns of species response to a number of different environmental factors and the presence of any successional relationships within the grasslands had been determined, some management guidelines were formulated. It must be stressed that they are based mainly on the compilation of research undertaken by various other authors and applied to suit the needs of the study area. These suggestions are also presented in Chapter 6.

Through compilation of the various patterns that have emerged, the results were interpreted to describe the dynamics within the coastal grassland ecosystem. A summary of all the results is presented in Chapter 7. Where there is a high degree of similarity between factors such as serpentine soils or rainfall and land-use, the results of one study may be used to predict the dynamics of another ecosystem. Prediction of the effects of various impacts such as ploughing or grazing between similar areas may also be made. Such compilations have value for effective management and development policies as discussed in Chapter 6. Such policies should have as their aim the management and utilisation of the grassland resource in a manner which both protects it from deterioration and maintains or even improves the productivity of that resource (Snyman, 1999). As stated by Mentis and Huntley (1982), the success of the Grassland Biome Project depends on the "effective integration of research" carried out at universities and government research stations. The same can be said of these results, that their value will lie only in their being effectively integrated within the framework of reference of the land-users and land-planners. It is hoped that these results will be put to good use by Cape Nature Conservation and by those powers responsible for development of the coastline of the Eastern Cape.

2. THE PHYSICAL ENVIRONMENT OF THE EASTERN CAPE COASTAL REGION

2.1 INTRODUCTION

In this chapter, a brief overview of the physical aspects of the Eastern Cape Coastal Region studied are presented. As stressed by Stone (1988), the physical environment of an ecosystem is the most important aspect with which to deal at the start of investigations into the vegetation and dynamics of that ecosystem. The vegetation which occurs in any area is partly defined by the soils and geomorphology on which it is located. Rainfall quantities and patterns are major factors influencing vegetation distribution, and thus all these factors need to be borne in mind when developing an understanding of the area under investigation.

A summary of previous studies of the vegetation by authors such as Pole-Evans (1936), Acocks (1953), and Lubke and de Moor (1998) is presented, since this will enable one to place the grassland vegetation within a broader frame of reference. The geology of the region has been compiled from studies done by Rust (1988), Nicol (1988) and Maud (1996). The rock formations of an area ultimately determine the soils which evolve and therefore are closely linked with the vegetation that can be supported. The soils which occur in the region are broadly defined on the basis of Hartmann's (1988) work and are discussed in detail in Chapter 4. Geomorphology explains landscape patterns which affect vegetation distribution, for example the presence of rivers and their associated vegetation. Work done by Nicol (1988) explains some of the geomorphological processes which have affected the Eastern Cape Coastal region.

Climatology is the final aspect of the physical environmental which is examined in this chapter. The role of rainfall distribution, temperature and winds as discussed by Kopke (1988) is vital for understanding vegetation distribution patterns.

2.2 COASTAL VEGETATION

The coastal vegetation from Alexandria to the Kei River was first described by Pole Evans (1936) as being Evergreen and Deciduous Bush and Sub - tropical Forest with no mention of grassland. Tall grass is recorded inland of this forest band, between 15 and 20 miles (24 - 32 km) from the coast. Comins in 1962 indicates grassland, *Acacia* woodland and scrub vegetation between the Keiskamma River and Kwenxura. Comins (1962) refers to Sweetveld and Sourveld but does not specify where they occur other than in wetter or drier areas.

Acocks (1975) records the vegetation of the study area in 1950 as being Bushveld while in 1988 it is shown as Coastal Forest and Thornveld. Lubke et al. (1986, 1988) indicate *Acacia* Savannah in the Alexandria area with Dune Thicket and Coastal Mixed and Sour Grassveld. Lubke et al. (1996) define the area simply as Coastal Grasslands but later expands this to record that sweetveld, sourveld and mixed grassveld occurs (Lubke and van Wijk, 1998). The coastal grasslands are cut off from those inland by a belt of *Acacia* savannah (Lubke et al. 1986)

2.3 GEOLOGY

The geology of the study area includes seven different groups which are derived from the Karroo and Cape Supergroup sequences, as well as the Alexandria and Nanaga formations (Maud, 1996).

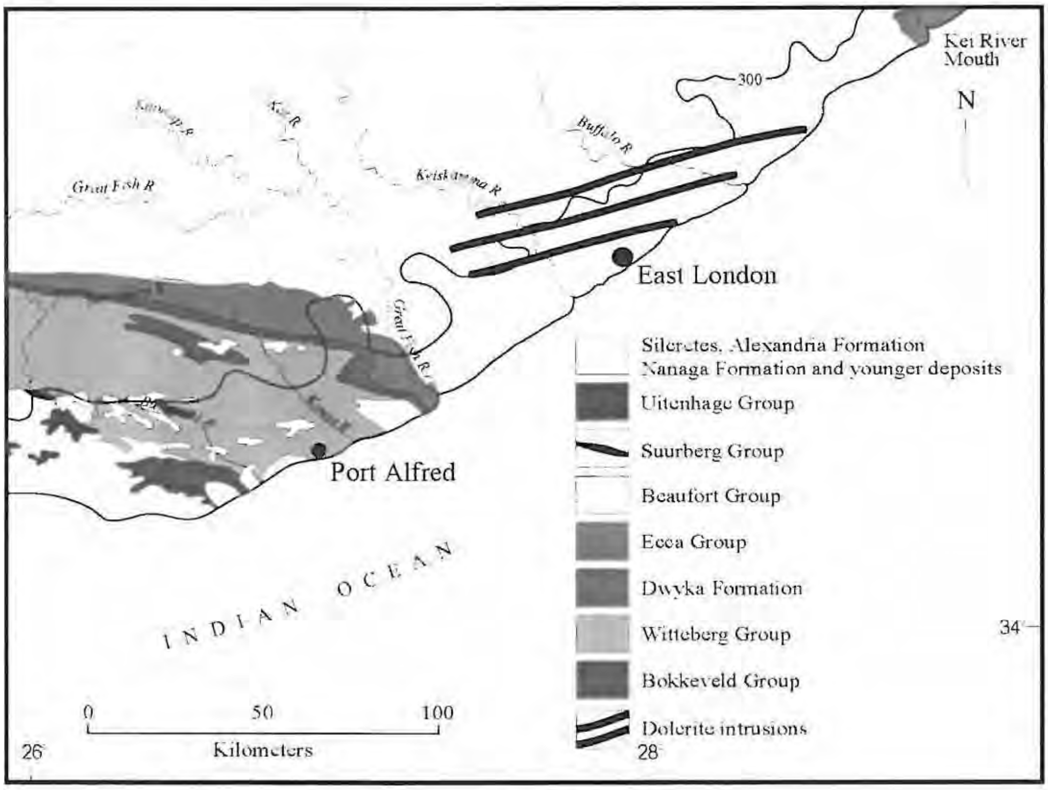


Figure 2.1 Geology of the Eastern Cape (adapted from Rust, 1988; Nicol, 1988; Maud, 1996).

As shown in Figure 2.1 above, at the western end of the study area the underlying geology of the Alexandria District is made up of silcretes and Cenozoic deposits of the Alexandria formation. These deposits are the youngest in geological age and were formed through the processes of wind and river borne sedimentation. Five to ten kilometres inland, this changes to the shale, siltstone and sandstone of the Bokkeveld Group, part of the Cape Supergroup. The Bokkeveld deposits intrude along the coast at several points west of Port Alfred. From east of Port Alfred to the Fish River, Witteberg quartzites of the Cape Supergroup dominate the geology. Both the Bokkeveld and Witteberg Group material is easily weathered, resulting in the formation of low rolling hills found in the area (Rust, 1988; 1998; Maud, 1996).

Between the Great Fish and Bira Rivers the Ecca Group is the underlying geology with a small intrusion of the Dwyka series at Great Fish River (Maud, 1996; Rust, 1998). The Ecca Group extends in a narrow band from east to west across the Southern Cape over 50km inland and meets the coast at this point. The Dwyka series follows the southern boundary of the Ecca Group material. Ecca material consists mainly of shale, mudstone and sandstone, while Dwyka is tillite. Dwyka material was deposited by glaciers and is characterised by the presence of embedded material from all other rock types. Both the Dwyka and Ecca are part of the Karroo Supergroup (Rust, 1988; 1998; Maud, 1996).

From here to Kei River Mouth at the eastern end of the study area the underlying geology is made up of the Beaufort series of the Karroo Supergroup. It is characterised by mudstone alternating with sandstone, with mudstone becoming more predominant as one moves eastward away from the Ecca group. The mudstones are easily eroded and have produced the rolling hills seen in this region together with dark clay soils where there are intrusions of Karroo dolerite. Three major dolerite intrusions occur within the study area, located at Kidd's Beach, Glen Garriff and Morgan's Bay. The eastern and western boundaries of the second dolerite intrusion and the western boundary of the third are all on fault lines originating in the Karroo (Figure 2.2.ii). The dolerite outcrops are dark grey, becoming brown and showing an "onion-skin" pattern with weathering (Rust, 1988; 1998; Maud, 1996).

2.4 GEOMORPHOLOGY

As shown in Figure 2.1, Nicol (1988) indicates a 300m contour lying up to 40km inland from the coast. The Eastern Cape Coastal Grasslands occur between the shore and this 300m contour. The contour defines an area referred to as the Coastal Sub - Region which is thought to have been formed by uplifting of the southern African interior between the Pliocene and Pleistocene eras over 2 million years ago. The inland upliftment of up to 350m is thought to have caused the outer edges of the continent to rise by 250 - 300m and tilt seawards, forming a fairly uniform plain. The Alexandria Plain, which was thus formed, begins east of Port Elizabeth and can be seen to stretch parallel to the coast all along the study area. Around Morgan's Bay the effects of the upliftment are more dramatically shown where cliffs drop straight into the sea from a height of over 100m and this pattern continues into the former Transkei. Within the Plain are to be seen gently rolling hills and deeply incised valleys where upliftment caused rivers to cut downwards because of the increased energy levels in the water. Examples of such rivers are the Bushman's, Kariega, Kowie, Keiskamma, Buffalo and Great Kei. There are also younger rivers that developed after the upliftment of the region, but they are much smaller. They include the Gqutywa, Tyolomnqa and Cefane Rivers (Nicol, 1988).

2.5 SOILS

Generally five soil types occur in the study area. In the western part from Alexandria Forest to Bushman's River sandy soils predominate. Between Bushman's River and just East of Port Alfred red sandy clay loams occur and from here to the Fish River soils are weakly developed with sandy red clays occurring in patches. From the Fish River to Kidd's Beach, weakly developed solonetzic soils occur with red clays and from here to the Great Kei soils are mainly weakly developed with black clays and clay loam soils (Hartmann, 1988).

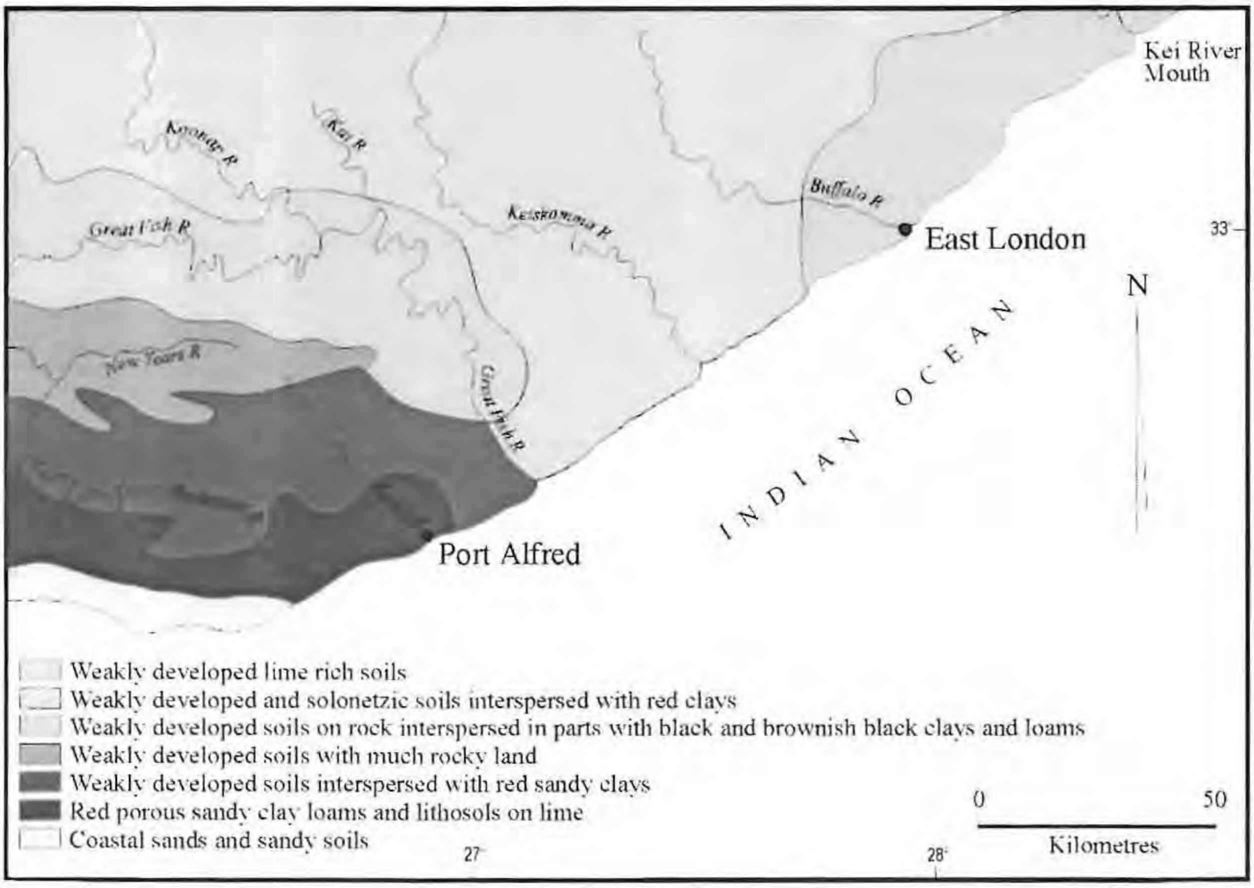


Figure 2.2. Soils of the Eastern Cape (from Hartmann, 1988)

Sandy soils occur over the Uitenhage Group, with red sandy clay loams over the Cape and Karroo Supergroup series (Figure 2.2). The Dwyka and Ecca formations contribute to a greater presence of clayey soils as well as solonetzic soils found around the Fish River and the Beaufort Series underlies the remainder of the study area. The black clay and clay loam soils are often associated with the dolerite intrusions and heavy clays are also found in these areas. Within the Morgan's Bay area, iron deposits are found in the surface layers of the soil.

Important features of the Alexandria district are karst limestone formations. Where limestone deposits overlie permeable rock (generally in the western half of the region) water is able to penetrate quickly through the soils to form deep pools of subterranean water. Where karst overlies impermeable rocks such as those of the Cape Supergroup, water penetration is slower and the subsoil water collects in broad shallow pools (Nicol, 1988; Rust, 1988; 1998). The water - retaining ability of the soils in this region has had tremendous significance for plant and animal populations as well as human impact on the area as these subterranean soils supply many of the local farms as well as the town of Alexandria itself (Nicol, 1988).

2.6 CLIMATOLOGY

The climate in the study area is typical of a coastal environment in that the temperature range is never greater than 14°C, because of the moderating influence of the sea (Kopke, 1988). The highest mean maximum temperature recorded is 26° C at Kei Mouth with the lowest mean minimum 8°C at Port Alfred. February is generally the hottest month and July the coldest. Rainfall is bimodal except in the extreme east, with peaks around March and October. The driest period is during the winter months of June to August. Annual rainfall increases from the west to the east along the study area and generally averages 500mm. Winds are predominantly south-westerly in winter and south-easterly in summer.

2.6.1 RAINFALL

Within the study area, two rainfall patterns occur. From the Kei River to midway between the Kowie and Bushman's rivers, the area experiences maximum rainfall during spring (Figure 2.3.i). This is illustrated by the Walter – Leith diagrams for Kei Mouth, East London and Great Fish Point. The remainder of the study area experiences maximum rainfall during winter as shown in the Walter-Leith diagram for Port Elizabeth (Figure 2.3.ii). The decrease in rainfall below the temperature curve indicates a dry season.

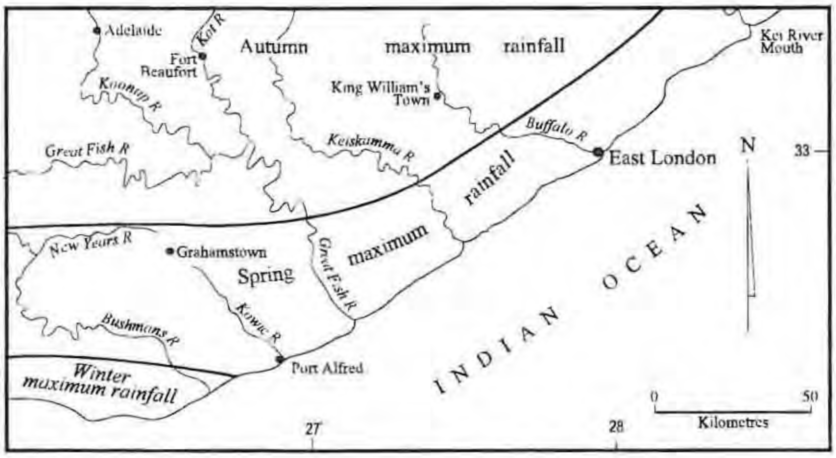


Figure 2.3.i Seasonal distribution patterns of rain in the Eastern Cape (Kopke, 1988)

The second rainfall pattern is that of unimodal and bimodal distribution. Rainfall in the extreme east of the study area at Kei Mouth is unimodal while bimodal rainfall becomes steadily more pronounced in a westerly direction. Annual rainfall increases steadily eastwards and as shown in Figure 2.3.iii, the eastern extreme of the study are falls within the 1 000mm annual rainfall contour. There is no time of the year at which rain does not occur except during drought conditions.

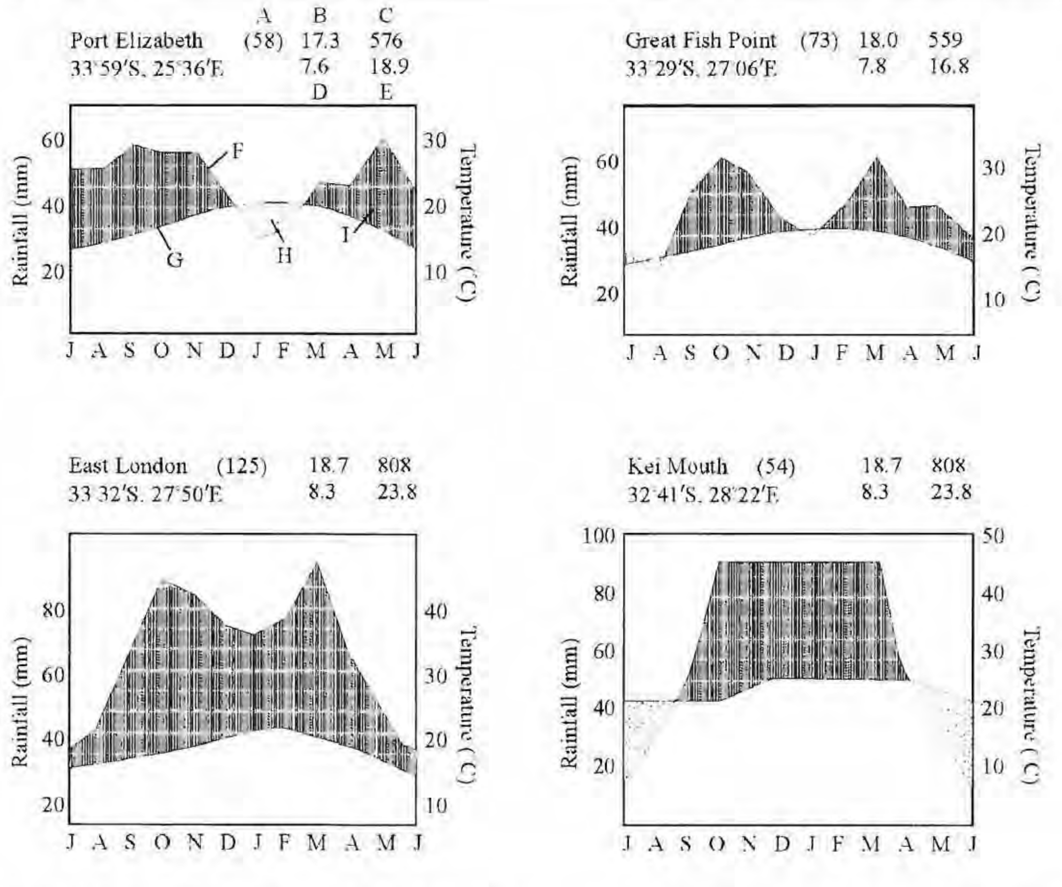


Figure 2.3.ii Walter-Leith climate diagrams for selected sites within the Eastern Cape (The South African Weather Bureau; Schulze, 1998). *Legend* A: height above sea level (m); B: mean annual temperature (°C); C: mean annual precipitation (mm); D: mean diurnal range in temperature (°C); E: mean annual maximum temperature (°C); F: rainfall curve; G: temperature curve; H: dry season; I: wet season (Meadows, 1985)

2.6.2 TEMPERATURE

Temperatures are generally highest in February and lowest in June or July. However, the range is small, never exceeding fourteen degrees. The average maximum temperature decreases from Kei Mouth to East London by five degrees.

2.6.3 WIND

The Eastern Cape coastline is notorious for its windy conditions (Kopke, 1988). Figure 2.3.iii indicates that south-westerly and north-easterly winds predominate in the eastern portion of the study area although wind from all directions is experienced. At the western end of the study area, Port Elizabeth experiences predominantly south-westerly winds with westerly and easterly winds being the second most common. The south-westerly winds are responsible for the winter rainfall which occurs in the western part of the study area, while the northerly winds bring tropical air in summer, causing thunderstorms (Kopke, 1988). The effect of wind-pruning on these coastlines is pronounced in many areas.

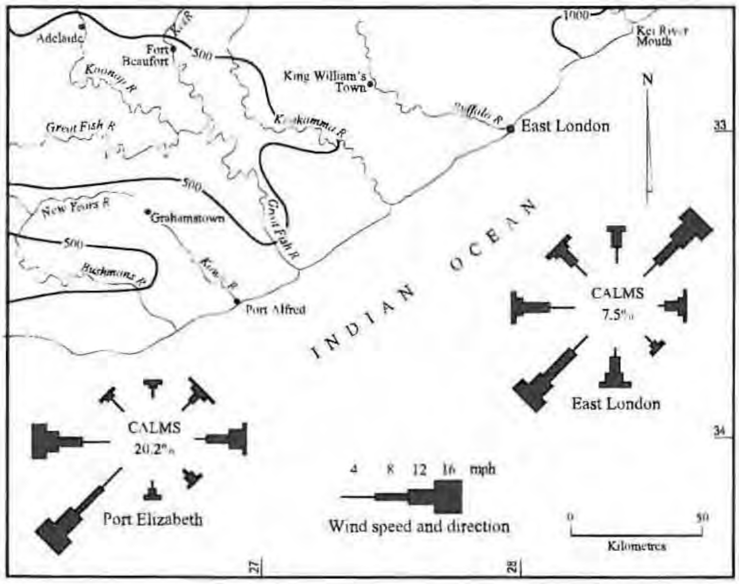


Figure 2.3.iii Wind patterns and average annual rainfall contours of the coastal region of the Eastern Cape (from Kopke, 1988)

The study area thus falls into two different rainfall regimes, but the influence of the sea moderates the effect of temperature. Wind plays a role in the moisture regime as well as affecting temperature because of the cooling influence of the south-easterly winds (Kopke, 1988). The variation in moisture regime undoubtedly contributes to the presence of the different vegetation types which converge in the Eastern Cape to result in the zone of transition centred at Grahamstown (Lubke, 1998).

3. DESCRIPTION AND ANALYSIS OF THE EASTERN CAPE COASTAL GRASSLANDS AND THEIR POSITION WITHIN THE SOUTHERN AFRICAN FLORA

3.1 INTRODUCTION

The area referred to in this study as the East Cape Coastal Grasslands has been described by several authors since 1936 when Pole-Evans reported on the vegetation of South Africa (see Table 3.1). Initially, grassland was not recognised in the study area at all, and Dyer (1937) and Adamson (1938) were the first to report grassland between riverine forest vegetation. Acocks (1953) and Martin and Noel (1960) record the presence of *Acacia karroo* as the most dominant vegetative feature with the grasses seeming to be of secondary importance. In 1962 Comins first reported grassland as a being a major vegetation unit, followed by Acocks revision in 1988. The work of Lubke *et al.* (1988a; 1988b; 1996; 1998) has established it firmly as part of the grassland biome. The descriptions refer mainly to dominant grass species with little detailed information on the herbaceous component.

Table 3.1 Synonymy and Descriptions of Eastern Cape Coastal Grasslands

Author and Synonymy	Description
Pole-Evans, 1936: Evergreen and deciduous bush and sub-tropical forest, with tall grass at 15 miles from the coast	Open woodland vegetation, thorn thickets and streambank bush. In the grassland, *Hyparrhenia hirta* is dominant with *Cymbopogon* species characterising more moist regions. Where rainfall is over 1000mm, *Andropogon, Tristachya, Trichopterix, Harpechloa* and *Miscanthidium* assume dominance.
Dyer, 1937: Coastal scrub and grassveld	Grassveld occurs on country between the river valleys from the landward edge of coastal scrub. Coastal scrub is short and dense. Grassveld mainly "sour". Where rainfall is 400mm to 650mm, *Themeda triandra* and *Digitaria eriantha* dominate. *Heteropogon, Cymbopogon* and *Hyparrhenia* restricted to forest margin. Total number of species approximately 125.

Adamson, 1938: *Acacia* grassland in temperate savannah. Adjacent to coast, warm temperate forest and succulent scrub in southern half, warm temperate forest in the northern half.	Closed field layer dominated *by Themeda triandra. Andropogon* and *Hyparrhenia* are common in the northerly areas, *Eragrostis* in the south. Annuals not at all abundant. *Acacia karroo* is woody component of savannah.
Acocks, 1953: Eastern province thorn veld, southern form.	Vegetation dominated by *Acacia karroo* with sour to mixed grasses present, including *Themeda triandra, Tristachya hispida, Digitaria* spp., *Cymbopogon* spp., *Hyparrhenia hirta* and *Pentaschistis angustifolia*. Many forbs are present and the family Cyperaceae is well represented. Fynbos elements present .
Martin and Noel, 1960: *Acacia* grassland and open scattered bush	Dominant species is *Acacia karroo*, together with *Themeda triandra, Eragrostis* spp., *Tristachya* spp. and other grasses. Several members of the families Fabaceae and Cyperaceae. Accorded the status of an association, namely the *Acacia karroo – Themeda triandra* association. Fynbos elements present.
Comins, 1962: Grassland and *Acacia* woodland	Where moisture is high enough, sourveld dominated by *Elionurus argenteus, Aristida junciformis, Themeda triandra, Alloteropsis semialata* and *Microchloa caffra*. In warmer, drier regions, sweetveld characterised by *Themeda triandra* and *Hyparrhenia hirta*, susceptible to invasion by *Acacia karroo*.
Acocks, 1988: Eastern Province Thornveld, southern form	Sourish mixed grass including *Themeda triandra, Hyparrhenia hirta, Tristachya leucothrix, Diheteropogon spp, Ehrharta calycina* and various forbs.
Lubke and van Wijk, 1988, 1998: Sour, sweet or mixed grassveld	Dominant grasses are *Themeda triandra* and *Stenotaphrum secundatum*. Common species include *Tristachya leucothrix, Aristida junciformis, Cymbopogon validus*, and *Eragrostis* species. Legumes and composites are numerous. Grasslands occur on ancient dunes and bush clumps and dune thicket are scattered throughout.
Lubke *et al*, 1996:	Coastal grassland dominated by *Themeda triandra, Tristachya leucothrix, Diheteropogon amplectens, Cymbopogon excavatus,*

Coastal Grassland. Coastal grassland incised by valley thicket along riverbanks in southern and northern portions with a band of Eastern Thorn Bushveld in the middle region. Coastal forest scattered throughout study area.	*Imperata cylindrica, Sporobolus nitens, Eragrostis plana, Hyparrhenia spp.. Heteropogon contortus* and *Stenotaphrum secundatum*. Many herbaceous plants as well as patches of Fynbos occur here.

The present study was carried out far more intensively than any of those done previously. Its purpose was to define the grasslands specifically in floristic terms, and to identify separate associations of species within the broad definition of East Cape Coastal Grasslands. The results are mapped at the scale of 1: 50 000 in Figures 3.1 to 3.9, illustrating the spatial relationships of the grasslands where they were sampled. It can be seen that in places they occur as a mosaic where different associations are located adjacent to one another. The mosaic pattern is derived from a range of factors from soils to land use, which are discussed in the subsequent chapter.

Since Acocks first published his work on the vegetation of South Africa in 1953, it has formed the basis upon which further vegetation studies were carried out. In recent years, there has been an increase in the number of studies done on a more specific level because our needs have changed. We no longer want only a comprehensive agricultural view of the vegetation of South Africa as produced by Acocks; we need to manage successfully all our vegetation to its best capacity. This includes recreational and aesthetic purposes. To this end, Bredenkamp *et al.*, (1989) and several other workers have carried out numerous studies around the country having first divided it up into several different biomes which were then subdivided into vegetation types. The vegetation types are defined as "a coherent array of communities which shared common species (or abundances of species), possessed a similar vegetation structure, and shared the same set of ecological processes" (Low and Rebelo, 1996). They would thus have similar uses, management programmes and conservation requirements. This study falls under the Grassland Biome and is the Coastal Grassland vegetation type. This chapter is a phytosociological analysis of SUs taken in grasslands from within the Alexandria Forest to the west bank of the Kei River.

Having determined the associations within the East Cape Coastal Grasslands, it is necessary to relate them in terms of species composition to the biomes of South Africa as a whole. This is done to elucidate the biogeographical relationships of the East Cape Coastal Grasslands to South African phytosociological associations and put them into a Southern African context. Finally, the grasslands are compared to pan-African phytosociological associations.

3.2 METHODS

3.2.1 FIELD STUDY

The study area was defined by using aerial photographs and maps of the coastline from the Sundays River mouth to the Kei River mouth. Grasslands were located and areas which had been planted to pasture were identified and excluded from the study since including them would render associations incomparable.

In order to determine the phytosociology and floristics of the study area, random sampling units (SUs) were used. Nested quadrat surveys were done in the first three areas sampled in order to determine the optimum size for sampling. A quadrat measuring 3m by 3m was found to be adequate for sampling. The species located within each SU were recorded as well as their abundance as a percentage of the total cover. Species were identified at the Selmar Schonland Herbarium in Grahamstown, where voucher specimens are housed.

Once in a grassland area, SUs were taken at random from sites closest to the sea, working inland. A Global Positioning System was used to record the exact position of the sites wherever possible; those which were not recorded with the GPS were marked on a map off which co-ordinates were later read. In addition, aspect was recorded and soils samples taken from both the A and B horizons, recording the depth at which the B horizon began. Soils were later analysed and the results are presented in Chapter 4. The grasslands were sampled more extensively in the eastern half of the study area than in the western half. Dyer (1937) records that all the previously climax *Themeda triandra* veld in the Bathurst district was ploughed up and planted to pineapples. This happened extensively throughout the region as far east as East London, from where the topography changes and becomes more steep and therefore ploughing is less viable. Some of the pineapple lands have been left fallow; these were sampled, but those which were planted to pasture were not. The species composition in a pasture-sown grassland will never resemble that which occurs in a system which has revegetated from ploughing without any addition of species, exotic or indigenous, and it was felt that for the sake of comparison such grasslands had to be excluded.

3.2.2 DATA SET

The field data was recorded as percentage cover. In order to put this information into the computer programmes TWINSPAN and DECORANA the values were converted to symbols using the programme CCP, or Cornell Conversion Programme. Within the TWINSPAN programme, species abundance values are grouped into nine categories, the "pseudospecies cut levels". Within the grasslands, many of the forbs occur at percentage cover values of below 10%, therefore four of the nine categories refer to abundance values ranging from below 1% cover to 8% cover. It was felt that this was necessary to enable the divisions to be sensitive to the forb component and not merely reflect the most abundant species.

3.2.3 CLASSIFICATION

The SUs were analysed using the computer - based programme TWINSPAN, or Two - Way Indicator Species Analysis (Hill, 1979a) and a classification table was prepared from the results (Figure 3.3.1). The packages TURBOVEG and MEGATAB that have been developed by Hennekens (1997) were used to analyse the data collected in this study. The improvement in time taken to analyse data is considerable. The older TWINSPAN took over 45 minutes to analyse 125 SUs whereas TURBOVEG analysed 325 SUs in less than five minutes. The pseudospecies cut levels are indicated by the numbers 1 - 9 and correspond to the following cover values:

1: 0 - 1,99%	6: 18 - 37%
2: 2 - 2,99%	7: 38 - 67%
3: 3 - 3,99%	8: 68 - 87%
4: 4 - 7,99%	9: 88 - 100%
5: 8 - 17%	

TWINSPAN is now the most widely used computer programme for phytosociological studies (Kent and Coker, 1992) and can be carried out on vegetation ranging from forest to coastal dune biomes (Avis, 1992). Hill (1979a) defines TWINSPAN as "A FORTRAN program for arranging multivariate data in an ordered two - way table by classification of the individuals and attributes".

Using reciprocal averaging, TWINSPAN generates a two - way matrix that groups SUs with similar suites of species at similar levels of abundance. Groups are separated by the presence of different indicator species and differing levels of abundance where the same species occurs in a number of SUs. Thus SUs are classified and interpreted to indicate phytosociological affinities. Species are also classified in the matrix. Their classification is determined by the SUs in which a species occurs and therefore depends on the prior grouping of SUs. By altering the level of division of SUs at which communities are described, species may be included or excluded (Hill, 1979a). This is the prerogative of the researcher. The two - way table is essentially the same as that which would have been prepared by hand using the Zurich - Montpellier School of vegetation analysis (Kent and Coker, 1992).

Prior to the development of TWINSPAN there were several computer-based programmes for data analysis, but all had limitations (Kent and Coker, 1996). TWINSPAN, although widely used, has come under criticism from a number of authors. Among the criticisms put forward by van Groenewoud (1992) is the technique's lack of indication of spatial vegetation patterns or the continuity of vegetation. He concluded that where two or more gradients exist, the SUs will be misclassified, and that beyond the first level of division, TWINSPAN is not reliable. Tausch *et al.* (1995) also find TWINSPAN unreliable, with results showing that by changing the order of the data input, results below the first level of division change. However, they found that by removing rare and infrequent species from the data, no changes took place in the first three levels of division (Tausch *et al.*, 1995).

Despite the concerns outlined above, TWINSPAN is still widely used in South Africa and forms the basis of several papers concerned with grassland studies (Shackleton *et al.*, 1991; Kay *et al.*, 1993; Smit *et al.*, 1993a, b; du Preez and Venter, 1992; Fuls *et al.*., 1993 a, c, d; Kooij *et al.*, 1990;a, b; Bredenkamp *et al.*, 1989; 1994; Eckhardt *et al.*, 1993; Coetzee *et al.*, 1994; Bezuidenhout *et al.*, 1991). In view of TWINSPAN's extensive use in the aforementioned studies, it was felt that the programme was suitable for the study undertaken, bearing in mind its reliability up to the third level of division.

3.2.4 COMMUNITY DESCRIPTIONS AND LOCATIONS

Community descriptions were prepared from the results of the TWINSPAN analysis. Dominant, characteristic and indicator species for each association and subassociation were determined and presented in Tables 3.3.2.2.i – x. Dominant species constitute the largest proportion of the vegetation and contribute a high proportion of the biomass (Bayer, 1955; Grime, 1998), or cover abundance. They occur in more that 75% of the SUs with an average cover abundance of 68% or greater. Characteristic species occur in 66% or more SUs in the community with average cover of above 2%. Indicator species occur at below 2% cover abundance in more than 50% of SUs, and are defined in two ways. Firstly, they may be found in only one association, or subassociation within one association, e.g. *Anthospermum herbaceum* in the *T. triandra – A. herbaceum* association; *Richardia brasiliensis* in the *R. brasiliensis – C. excavatus* subassociation of the *H. hirta – T. triandra* association. Secondly, they may occur in more than one association, but are recorded as indicator species if they occur at low abundance in conjunction with a particular suite of dominant species e.g. *Stenotaphrum secundatum* is an indicator species in the *T. triandra – A. herbaceum* association, where *T. triandra* is the dominant species, and in the *C. dactylon – H. hirtulum* association, where *C. dactylon* is the dominant species. Although *T. triandra* is a dominant species for several associations and subassociations, if several indicator species including *S. secundatum* are present at low abundances, then one can infer that the vegetation is probably of the *T. triandra – A.herbaceum* association. Indicator species may be seen to correspond with Grimes' (1998) subordinate species.

Based on the literature available, a brief description of environmental conditions under which the most important species occur was recorded in order to determine to a limited extent why the species were present in each association. Reference material from South African sources was obtained from Meyer *et al.*, (1997). A simple map showing the distribution of associations along the entire study area is shown in Figure 3.3.2. Detailed maps of the location of subassociations were prepared using the exact position of the relevés and 1:50 000 ordinance survey maps as shown in colour Figures 3.1 to 3.10. Having located the relevés on the 1:50 000 maps, areas under particular associations were determined using a combination of visual appearance, locality, land use and farm boundaries in order to record the extent of each association. Often, visual appearance was the clearest factor in determining association distribution.

3.2.5 COMMUNITY SIMILARITY STUDIES

In order to determine how similar the study area is to other grasslands in terms of species composition, a number of comparative studies were done. Referring to the literature (Chippindall, 1955; Gibbs-Russell *et al.*, 1991; van Oudtshoorn, 1992), a record was made of the biomes in which each grass species is known to occur. This is presented in Table 3.3.3.i. The entire species checklist was then compared with the species given as being the most prominent in the grasslands of Southern Africa defined by various authors in Vegetation of South Africa, Swaziland and Lesotho (Low and Rebelo, 1996). Grasslands which had similar species composition and importance to those of associations within this study are listed together with the associations to which they show the closest relationship. The results are given in Table 3.3.3.ii.

The third study was the comparison of the species checklist for this study against checklists from a number of grassland studies throughout the country. A list of species which were common with those listed for the former Transkei, Eastern Cape, Western Free State, KwaZulu-Natal and the western former Transvaal is presented in Appendix 3 and a summary table (Table 3.3.3.ii) is shown in the results and discussion section. It must be stressed that the species checklists with which my list was compared contained only the most common species for an area and seldom the entire species checklist, thus this study does not represent a complete comparison. However, it is felt that the comparisons, incomplete though they are, help to determine community similarities.

Finally, species in common with the pan-African study by White (1983) were determined by the same method of comparison. The entire list of similar species is given in Appendix 3 but a summary of the results is shown in Table 3.3.3.iv. White's (1983) study of the vegetation of Africa is extremely broad but it was felt that the comparison highlighted important aspects of the distribution of species common to this study.

3.3 RESULTS AND DISCUSSION

3.3.1 CLASSIFICATION

The study area has been divided into 10 associations (Table 3.3.1, Figure 3.3.1). The TWINSPAN divisions were continued as far as level 5 for the more complex mesic communities and as far as level 3 for the remaining grasslands; further division of the latter would not have contributed to understanding them. The TWINSPAN - generated phytosociological tables are shown in Appendix 2 while a table of the most important species for each association and subassociation is presented with their descriptions. Table 3.3.2 is a summary table of the Dominant, Characteristic and Indicator characteristic species for each association and subassociation. The TWINSPAN analysis of data indicates that the first level of division is between xeric grasslands and mesic grasslands (Figure 3.3.1).

Table 3.3.1 Classification of the Eastern Cape Coastal Grasslands

Mesic Grassland Associations

1 *Themeda triandra - Anthospermum herbaceum* association

2 *Themeda triandra* association

2.1 *Elionurus muticus - Diheteropogon amplectens* subassociation

2.2 *Heteropogon contortus - Pentaschistis pallida* subassociation

2.3 *Gazania krebsiana* subassociation

2.3 *Imperata cylindrica - Cymbopogon validus* subassociation

3 *Hyparrhenia hirta - Diheteropogon amplectens* association

3.1 *Ehrharta calycina* subassociation

3.2 *Themeda triandra* subassociation

4 *Hyparrhenia hirta - Themeda triandra* association

4.1 *Richardia brasiliensis - Cymbopogon excavatus* subassociation

4.2 *Stenotaphrum secundatum - Eragrostis plana* subassociation

5 *Stenotaphrum secundatum - Centella coriacea* association

Xeric Grassland Associations

6 *Diheteropogon filifolius- Ehrharta calycina* association

7 *Cynodon dactylon - Ehrharta calycina* association

7.1 *Heteropogon contortus* subassociation

7.2 *Chaetacanthus setiger* subassociation

8 *Themeda triandra - Ehrharta calycina* association

8.1 *Tristachya leucothrix* subassociation

8.2 *Helichrysum asperum* subassociation

9 *Sporobolus africanus - Setaria sphacelata* association

10 *Cynodon dactylon - Helictotrichon hirtulum* association

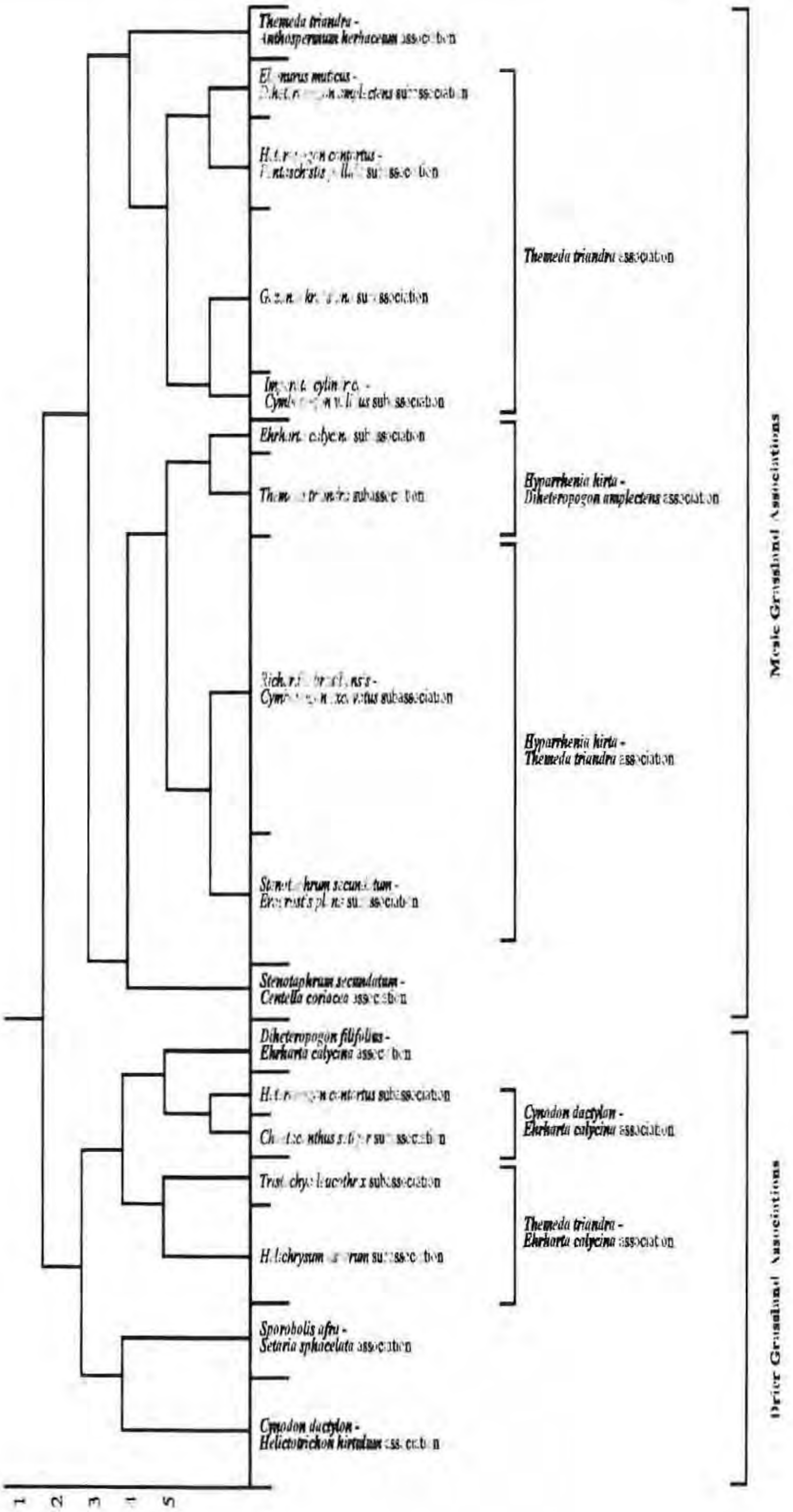


Figure 3.3.1 TWINSPAN classification of the Eastern Cape Coastal Grasslands (bold text indicates associations)

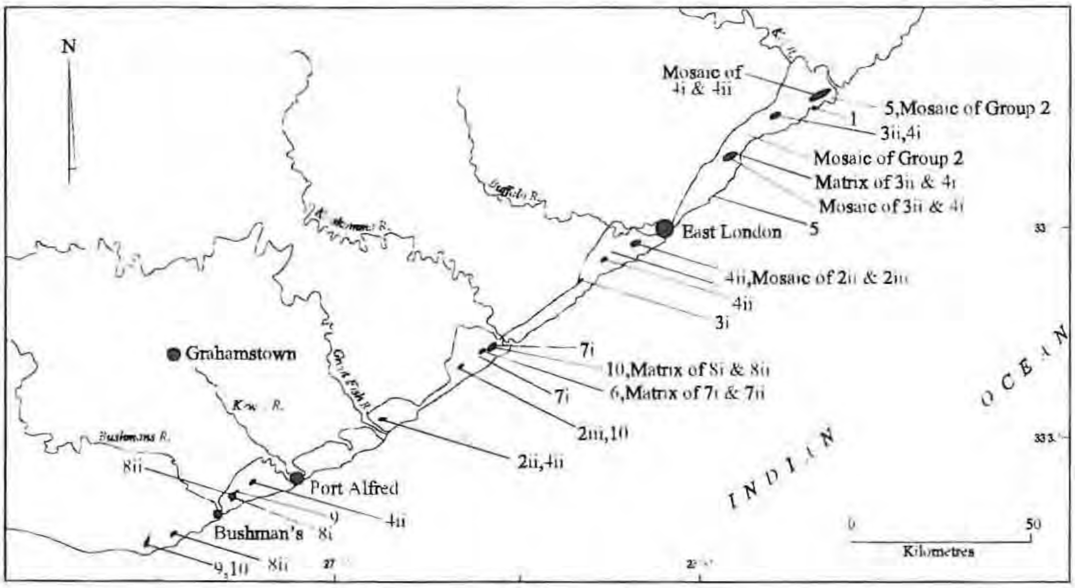


Figure 3.3.2 Map showing distribution of associations and subassociations of the Eastern Cape Coastal Grasslands

Key

Mesic Grassland Associations

1 ***Themeda triandra - Anthospermum herbaceum*** association

2 ***Themeda triandra*** association

2.i *Elionurus muticus - Diheteropogon amplectens* subassociation

2.ii *Heteropogon contortus - Pentaschistis pallida* subassociation

2.iii *Gazania krebsiana* subassociation

2.iv *Imperata cylindrica - Cymbopogon validus* subassociation

3 ***Hyparrhenia hirta - Diheteropogon amplectens*** association

3.i *Ehrharta calycina* subassociation

3.ii *Themeda triandra* subassociation

4 ***Hyparrhenia hirta - Themeda triandra*** association

4.i *Richardia brasiliensis - Cymbopogon excavatus* subassociation

4.ii *Stenotaphrum secundatum - Eragrostis plana* subassociation

5 ***Stenotaphrum secundatum - Centella coriacea*** association

Xeric Grassland Associations

6 ***Diheteropogon filifolius- Ehrharta calycina*** association

7 ***Cynodon dactylon - Ehrharta calycina*** association

7.i *Heteropogon contortus* subassociation

7.ii *Chaetacanthus setiger* subassociation

8 ***Themeda triandra - Ehrharta calycina*** association

8.i *Tristachya leucothrix* subassociation

8.ii *Helichrysum asperum* subassociation

9 ***Sporobolus africanus - Setaria sphacelata*** association

10 ***Cynodon dactylon - Helictotrichon hirtulum*** association

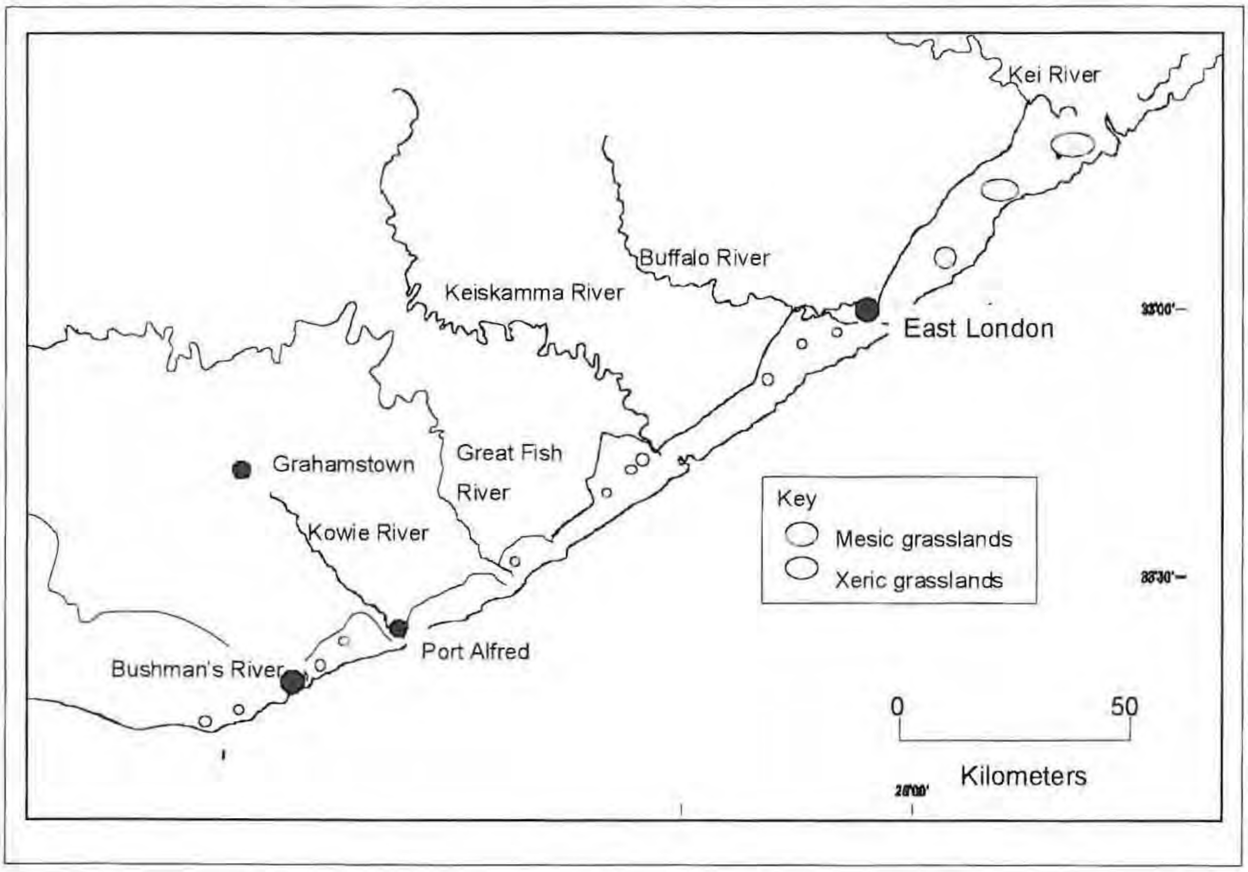


Figure 3.3.3 Map showing distribution of mesic and xeric grasslands along the study area

There is a clear spatial division between mesic and xeric grasslands at the Keiskamma River. West of the Keiskamma River mainly xeric grasslands occur, while to the east are the mesic grasslands (see Figures 3.3.2, 3.3.3). Some anomalies do occur. One mesic association was found west of Keiskamma in ploughed habitats while one dry association occurred east of Keiskamma in an unploughed area. The associations form a mosaic pattern of vegetation with the greatest diversity of associations occurring in the east where rainfall is highest.

3.3.2 COMMUNITY DESCRIPTIONS AND LOCATIONS

The results of TWINSPAN analysis provided clear species groupings based on presence and abundance data. The data were first used to determine the dominant, characteristic and indicator species for each association. This information was then incorporated into the descriptions of each community. TWINSPAN analysis indicated the presence of 55 species which were defined as dominant, characteristic, or indicator species. These species and the associations in which they are important are presented below in Table 3.3.2.i.

Table 3.3.2.1 Summary table of Dominant, Characteristic and Indicator species of the associations of the Eastern Cape Coastal Grasslands

Species	1	2i	2ii	2iii	2iv	3i	3ii	4i	4ii	5	6	7i	7ii	8i	8ii	9	10
Themeda triandra	D	D					C	C			C			D	D		
Anthospermum herbaceum	I																
Stenotaphrum secundatum	I									D							I
Hypoestes aristata	I									I							
Senecio pterophorus	I																
Tephrosia capensis	I			I							I						
Eriosema squarrosum		C	C	C							I	C					
Tristachya leucothrix		C	C											D			
Elionurus muticus		D				C	C					I					
Diheteropogon amplectens		D				C	C										
Helichrysum nudifolium		C															
Senecio bupleuroides		C															
Acacia karroo		I															
Cyperus obtusiflorus		I															
Gnidia anthylloides		I															
Heteropogon contortus			C								C	C		C	C		
Pentaschistis pallida			I											I			
Gazania krebsiana				I								I	I				
Chaetacanthus setiger				I							I		C				
Imperata cylindrica					C	C											
Cymbopogon validus					I			I									
Ficinia stolonifera					I												
Hyparrhenia hirta						D	D	D	C								
Chamaecrista capensis						C	C				I	C	C	C			
Ehrharta calycina						I					C	C	D	C	C	C	I
Senecio inaequidens						I				C		I	I				I
Helictotrichon hirtulum						I											C
Eragrostis curvula						I											C
Digitaria eriantha							I	C		I							
Centella coriacea							I	C	C	C							I
Paspalum notatum								C	C	C							
Richardia brasiliensis								C									
Cymbopogon excavatus								I									
Aristida junciformis								I									

Helichrysum peduncularis								I									
Eragrostis plana									I			C					
Species	1	2i	2ii	2iii	2iv	3i	3ii	4i	4ii	5	6	7i	7ii	8i	8ii	9	10
Pycreus oakfortensis										I							
Cynodon dactylon										I		C	D		C	C	D
Diheteropogon filifolius											C						
Helichrysum asperum											I				I		
Aizoon rigidum											I						
Indigofera heterophylla											I						
Acalypha peduncularis											I						
Eragrostis capensis												C		I			
Sporobolus africanus														C	C	I	
Setaria sphacelata														C		C	
Monsonia emarginata														I	I		
Commelina africana														I			
Koeleria capensis															I		
Rhynchosia adenodes															I		
Indigofera zeyheri															I		
Trachyandra revoluta															I		
Falckia repens																I	
Geranium incanum																I	
Senecio ilicifolius																I	

Key
D = Dominant, occurs in >75% of sample relevés in the association with >65% cover
C = Characteristic, occurs in >65% of sample relevés in the association with >2% cover
I = Indicator, commonly occurs in only one association or subassociation, cover usually <2%

Mesic Grassland Associations
1 *Themeda triandra - Anthospermum herbaceum* association
2 *Themeda triandra* association
- 2.i *Elionurus muticus - Diheteropogon amplectens* subassociation
- 2.ii *Heteropogon contortus - Pentaschistis pallida* subassociation
- 2.iii *Gazania krebsiana* subassociation
- 2.iv *Imperata cylindrica - Cymbopogon validus* subassociation

3 *Hyparrhenia hirta - Diheteropogon amplectens* association
- 3.i *Ehrharta calycina* subassociation
- 3.ii *Themeda triandra* subassociation

4 *Hyparrhenia hirta* - *Themeda triandra* association
 4.i *Richardia brasiliensis* - *Cymbopogon excavatus* subassociation
 4.ii *Stenotaphrum secundatum* - *Eragrostis plana* subassociation
5 *Stenotaphrum secundatum* - *Centella coriacea* association

Xeric Grassland Associations
6 *Diheteropogon filifolius*- *Ehrharta calycina* association
7 *Cynodon dactylon* - *Ehrharta calycina* association
 7.i *Heteropogon contortus* subassociation
 7.ii *Chaetacanthus setiger* subassociation
8 *Themeda triandra* - *Ehrharta calycina* association
 8.i *Tristachya leucothrix* subassociation
 8.ii *Helichrysum asperum* subassociation
9 *Sporobolus africanus* - *Setaria sphacelata* association
10 *Cynodon dactylon* - *Helictotrichon hirtulum* association

3.3.2.1 Description of dominant, characteristic and indicator species

The species identified as being dominant, characteristic or indicator species are described below in the order in which they occur in the associations, as listed above.

3.3.2.1.i. Dominant species

The three species that are dominant in more than one association are *Themeda triandra, Hyparrhenia hirta* and *Cynodon dactylon* as shown in Table 3.3.2. The grass *Themeda triandra* is a climax species which is especially common in undisturbed grassland (Bayer, 1955; Gibbs-Russel *et al.*, 1991; van Oudtshoorn, 1992) and which Bayer (1955) indicates should be the "natural climax grass over most of our grassland areas". It is found in the grassland, savannah, Nama-Karroo and fynbos biomes (Gibbs-Russel *et al.*, 1991; van Oudtshoorn, 1992). It is a pyrophytic grass, thriving where there is a degree of regular burning. It forms a dense sward within which many other species may be found, none of which will become more than locally dominant except, under certain conditions, *Hyparrhenia hirta* (Bayer, 1955).

The grass *Hyparrhenia hirta* is a subclimax species occurring on well drained, stony soils in warmer areas and is an important component of open grasslands. It is found in the fynbos, grassland, Nama-Karroo and savannah biomes. It is a constituent of undisturbed sweetveld or mixed grassveld, but is also found in overgrazed sweetveld, old lands and at roadsides. (Meredith and Rose, 1955; Zacharias, 1990; Gibbs-Russel *et al.*, 1991; van Oudtshoorn, 1992). While Scott (1955) records that it is a species which is "typical of relatively undisturbed veld", Meredith and Rose (1955) state that where extensive *Themeda triandra* grasslands have been replaced by excessive burning and grazing with *Eragrostis - Sporobolus* secondary grasslands. *H. hirta* can become a locally dominant species.

The grass *Cynodon dactylon* is a pioneer species, occurring mainly where disturbance has taken place. It is common on roadsides, overgrazed and trampled land and can become the dominant component of previously ploughed areas which are left fallow. Part of the reason for its occurrence in abandoned fields is that it has a preference for soils with a high nitrogen content (van Oudtshoorn, 1992). It grows in most soils and particularly the deep sandy soils found along the coast. While it occurs worldwide its distribution in South Africa is limited to the fynbos, savannah, grassland, Nama–Karroo and desert biomes (Bayer, 1955; Chippindall, 1955; Scott, 1955; Henderson and Anderson, 1966; Gibbs-Russel *et al.*, 1991; van Oudtshoorn, 1992).

The five remaining species that are dominant in the grasslands are *Stenotaphrum secundatum, Tristachya leucothrix, Elionurus muticus, Diheteropogon amplectens* and *Ehrharta calycina* (see Table 3.3.2). *S. secundatum* is a common coastal pioneer grass found near both fresh and saline water. It is characteristic of sandy soils and sand dunes around the tropical regions and in warm, temperate areas (Bayer, 1955; Chippindall, 1955; Zacharias, 1990; Gibbs-Russel *et al.*, 1991; van Oudtshoorn, 1992) and is salt tolerant. It is able to form very dense swards which allow few other species to co-exist (Bayer, 1955). *T. leucothrix* is found in high rainfall areas i.e. the sourveld. It prefers an environment, which is under-utilised in terms of grazing and seldom burnt (Bayer, 1955; van Oudtshoorn, 1992). It is distributed throughout tropical Africa and locally occurs in the fynbos, savannah and grassland biomes. It prefers stony, sandy slopes or marshy grasslands (Chippindall, 1955; Gibbs-Russel *et al.*, 1991; van Oudtshoorn, 1992). It often occurs together with *T. triandra* and is never found in trampled areas or fallow lands (Bayer, 1955).

Elionurus muticus is pyrophytic but unlike *T. triandra* it is an indicator of poor veld management, usually overgrazing and excessive burning (Scott, 1955; Comins, 1962; Gibbs-Russel *et al.*,1991; van Oudtshoorn, 1992). It occurs in higher rainfall regions in open grassland within the grassland and savannah biomes and while it will grow in many types of soil it prefers poor, stony conditions and thrives after fire (Scott, 1955; van Oudtshoorn, 1992). It is highly unpalatable (Comins, 1962; Zacharias, 1990; van Oudtshoorn, 1992). *D. amplectens* occurs in open grassland in higher rainfall regions on a range of soils but like *E. muticus* it prefers those which are poor and stony, often on hillsides (Chippindall, 1955; Gibbs-Russel *et al.*, 1991; van Oudtshoorn, 1992). It is found in the savannah and grassland biomes of Tropical Africa (Gibbs-Russel *et al.*, 1991; van Oudtshoorn, 1992). While it occurs in a wide range of environments, *E. calycina* prefers disturbed areas and is common on sandy soils (Zacharias, 1990; Gibbs-Russel *et al.*, 1991; van Oudtshoorn, 1992). It occurs in succulent Karroo, fynbos and savannah (Gibbs-Russel *et al.*, 1991; van Oudtshoorn, 1992).

3.3.2.1.ii Characteristic species

Most characteristic species are limited to a single association, however a few occurred in more than one. Species in the latter category include *Eriosema squarrosum, Heteropogon contortus, Imperata cylindrica, Chamaecrista capensis, Centella coriacea, Paspalum notatum* and *Setaria sphacelata*. Twelve species are characteristic of one subassociation only, these being *Helichrysum nudifolium, Senecio bupleuroides, Chaetacanthus setiger, Senecio inaequidens, Helictotrichon hirtulum, Eragrostis curvula, Digitaria eriantha, Richardia brasiliensis, Eragrostis plana, Diheteropogon filifolius, Eragrostis capensis* and *Sporobolus africanus* (see Table 3.3.2).

The leguminous forb *E. squarrosum* occurs on grassland and sandy flats along the Eastern Cape coast and inland to a small extent (Harvey and Sonder, 1861; Stirton, 1986). *H. contortus* is a widespread grass found in grassland, savannah, Nama - Karroo and fynbos vegetation in tropical and warm areas. It is common on well – drained stony soils and also in disturbed areas such as road verges (Gibbs-Russel *et al.*, 1991; van Oudtshoorn, 1992). It often occurs in association with *T. triandra* and where overgrazed areas are rested, it is able to recover and become the dominant species (Zacharias, 1990). *I. cylindrica* is fire resistant (van Oudtshoorn, 1992) and thrives on damp, poorly drained soils with a high water table. It occurs in the fynbos, savannah and grassland biomes (Bayer, 1955; Scott, 1955; Gibbs-Russel *et al.*, 1991; van Oudtshoorn, 1992). It is also common in disturbed areas (Bayer, 1955; Scott, 1955).

The forb *C. capensis* occurs throughout the central and eastern former Transvaal and the Eastern Cape (Ross, 1977). *C. coriacea* is a coastal forb which also occurs in moist environments inland, and is found worldwide (Adamson, 1951; Batten and Bokelmann, 1966; Bond and Goldblatt, 1984). It is able to colonise areas from which *T. triandra* have been removed through environmental pressures (Zacharias, 1990). *P. notatum* is a South American species, which has become naturalised in South Africa. It occurs mainly in moist disturbed areas that have sandy or clayey soils in the fynbos and grassland biomes (Chippindall, 1955; Scott, 1955; Gibbs-Russel *et al.*, 1991; van Oudtshoorn, 1992). *S. sphacelata* prefers habitats ranging from moist riverbanks to stony slopes, preferring well drained soils in the fynbos, savannah and grassland biomes (Gibbs-Russel *et al.*, 1991; van Oudtshoorn, 1992).

The forb *H. nudifolium* occurs southward from Zimbabwe and from the eastern half of South Africa to the Cape Peninsula on "moist rocky grass slopes and stabilised boulder beds" (Hilliard, 1983; Bond and Goldblatt, 1984). It is common to grassland ranging from sea level to approximately 1 600m (Hilliard, 1977). *S. bupleuroides* occurs in coastal grasslands and hillsides along the coast from the Eastern Cape to Natal (Batten and Bokelmann, 1966; Hilliard, 1977; Bond and Goldblatt, 1984). *C. setiger* is common to grassland and the forest margin of the Southern Cape Coast (Bond and Goldblatt, 1984). *S. inaequidens* occurs on rocky outcrops on grassy mountain slopes and along watercourses throughout Southern Africa. It is common in disturbed areas such as at roadsides and areas subject to trampling (Hilliard, 1977; Bond and Goldblatt, 1984).

Helictotrichon hirtulum is characteristic of shady, damp slopes near the coast and disturbed areas (Chippindall, 1955; Gibbs-Russel *et al.*, 1991) and occurs in fynbos, savannah and grassland (Gibbs-Russel *et al.*, 1991. *E. curvula* is a common component of disturbed areas such as fallow lands, where it will often assume dominance in the early stages of recolonisation. It is also characteristic of overgrazed and trampled veld, particularly in high rainfall areas. It occurs in savannah, grassland, fynbos, Nama-Karroo and succulent Karroo biomes (Bayer, 1955; Gibbs-Russel *et al.*, 1991; van Oudtshoorn, 1992).

Digitaria eriantha occurs in a variety of habitats, from sandy soils in dry environments to the damp soils of river banks. Zacharias (1990) records that it can reassert itself after veld degradation has taken place, referring to it as a "caretaker grass" which restores the environment where climax species *T. triandra* and *Setaria neglecta* have been grazed out. Scott (1955) regards it as an indicator of undisturbed sweetveld and consequently where it occurs naturally it is an indicator of good veld condition. It is found in the fynbos, savannah, grassland and Nama-Karroo biomes (Gibbs-Russel *et al.*, 1991; van Oudtshoorn, 1992).

Richardia brasiliensis is a South American species that has become naturalised in South Africa. In South America it occurs in savannah and prairie vegetation and along sandy waterways and coastlines. It is particularly common in disturbed areas such as road verges and railways on sandy soils. It prefers warm temperate environments and the Southern African climate has proved conducive to its success here. Although it is widespread in this country it is not a problematic weed, and, as in its native environment, it occurs frequently on roadsides and disturbed areas such as uncultivated lands. It is found in the Eastern Cape, Natal and the former Transvaal (Henderson and Anderson, 1966; Lewis and Oliver, 1974).

Eragrostis plana is characteristic of disturbed areas in sourveld and moist environments such as vleis and stream banks. Where the dominance of *T. triandra* has been removed due to overgrazing, incorrect burning or excess trampling, *E. plana* can assume dominance with *Sporobolus pyramidalis* and *E. curvula*, and it can assume dominance in the recolonisation of old fields. It is common in the savannah and grassland biomes (Bayer, 1955; Chippindall, 1955; Scott, 1955; Gibbs-Russel *et al.*, 1991; van Oudtshoorn, 1992). *D. amplectens* is common in coastal grasslands from the Eastern Cape to Natal in sandy to loamy soils of the grassland and savannah biomes (Bond and Goldblatt, 1984; Gibbs-Russel *et al.*, 1991; van Oudtshoorn, 1992). *E. capensis* is common to moist disturbed environments and is encouraged by burning. It is common to flats and slopes of the Southern and Eastern Cape and occurs as far north as southern Tropical Africa and Madagascar. In South Africa it occurs in the grassland, savannah and fynbos biomes (Scott, 1955; Bond and Goldblatt, 1984; Gibbs-Russel *et al.*, 1991). *S. africanus* is characteristic of disturbed areas such as roadsides and overgrazed grassland but is also common along streams and rivers and is found on grassland, savannah and fynbos vegetation (Chippindall, 1955; Comins, 1962; Gibbs-Russel *et al.*, 1991; van Oudtshoorn, 1992).

3.3.2.1.iii Indicator species

A number of indicator species are dominant in or characteristic of other associations, and these have already been described. Other species occur as indicators only but are present in more than one association, including *Hypoestes aristata, Tephrosia capensis, Pentaschistis pallida, Gazania krebsiana, Cymbopogon validus, Helichrysum asperum* and *Monsonia emarginata*. There are 20 species which are limited to one association only (see Table 3.3.2).

Hypoestes aristata is a forest margin species, occurring at the edges of coastal forest and moist scrub from the Southern Cape to Natal and as far north as Tropical East Africa (Batten and Bokelmann, 1966; Moriarty, 1982; Bond and Goldblatt, 1984). *Tephrosia capensis* is mainly a coastal species occurring in grasslands from the Cape to Natal with some record of it occurring in the former Transvaal and Free State (Forbes, 1948; Moriarty, 1982; Bond and Goldblatt, 1984). *P. pallida* occurs widely where there is disturbance in the fynbos and succulent Karroo biomes (Gibbs-Russel *et al.*, 1991).

Gazania krebsiana is a fire resistant forb occurring in coastal grassland and disturbed vegetation (Batten and Bokelmann, 1966). It is also found in dry grassland and road verges from the Eastern Cape to the former Transvaal (Moriarty, 1982; Bond and Goldblatt, 1984; Batten, 1988; Shearing, 1994). *C. validus* occurs in high rainfall regions and in moist areas of the savannah and grassland biomes (Chippindall, 1955; Gibbs-Russel *et al.*, 1991, van Oudtshoorn, 1992). It prefers rocky hillsides and is found in scrub vegetation as well as in forest margins (Chippindall, 1955; Gibbs-Russel *et al.*, 1991). Shackleton (1989) records a *Cymbopogon validus - Digitaria natalensis* grassland community in the Mkambati game reserve in the former Transkei, and notes that it occurred on the heavier clays which were well drained and always associated with Hutton soils.

Helichrysum asperum occurs in sandy soils along the coast from the Western Cape to the former Transkei. It occurs in grassland and fynbos and is also present to some extent in the Karroo and former Transvaal (Hilliard, 1977; 1983; Bond and Goldblatt, 1984). *M. emarginata* occurs in dunes and coastal grassland from the Southern Cape to the former Transkei (Moriarty, 1982; Bond and Goldblatt, 1984).

Of the indicator species which are present in only one association, 17 are non-grasses. *Anthospermum herbaceum* is characteristic of fire - prone grasslands and occurs on rocky slopes and in scrub near the sea within the salt spray zone. It may also occur along the forest margin. Its distribution ranges from the Southern Cape to Natal then north through the former Transvaal to Zimbabwe, and to Ethiopia via the Tropics (Bond and Goldblatt, 1984; Puff, 1986). There are a number of different forms of this species, two of which are the (Burnt) Grassland Form and the Salt Spray Zone Form. Although they were not distinguished in the field, both forms may occur since the grasslands are subject to both environmental impacts (Puff, 1986).

The tree legume *Acacia karroo* occurs in a very wide range of habitats, including grassland, coastal dunes and coastal scrub throughout southern Africa (Ross, 1975; Bond and Goldblatt, 1984). It can spread rapidly into overgrazed grassland, particularly sweetveld, and its presence may indicate that such encroachment is beginning to take place (Comins, 1962; Ross, 1975). *Gnidia anthylloides* occurs in coastal grasslands and hillsides along the coast from the Eastern Cape to Natal (Batten and Bokelmann, 1966; Hilliard, 1977; Bond and Goldblatt, 1984). *Ficinia stolonifera* occurs from the Western to the Eastern Cape, Natal and Lesotho (Bond and Goldblatt, 1984)

Cymbopogon excavatus is characteristic of high rainfall areas or damp sites such as vleis, with a preference for stony slopes. It is limited to the grassland and savannah biomes (Gibbs-Russel *et al.*, 1991; van Oudtshoorn, 1992). *Aristida junciformis* prefers moist soils on slopes but is common in disturbed ground. It is limited to the grassland biome (Bayer, 1955; Gibbs-Russel *et al.*, 1991; van Oudtshoorn, 1992). *Helichrysum pedunculare* is a common grassland species which occurs from southern Lesotho through to the former Transkei and the Eastern Cape

(Hilliard, 1983). *Aizoon rigidum* is common in sandy or rocky environments on the Southern and Eastern Cape coasts (Harvey and Sonder, 1861; Adamson, 1958; Bond and Goldblatt, 1984; Lubke and van Wijk, 1998).

Indigofera heterophylla is common in coastal grassland of the Western and Eastern Cape regions, favouring limestone - rich soils (Batten and Bokelmann, 1966; Bond and Goldblatt, 1984; Urton and Page, 1993), while *Acalypha peduncularis* occurs frequently in open grassland along the coast (Batten and Bokelmann, 1966). *Commelina africana* is a mesophytic herb commonly occurring on the coastal belt from the Cape Peninsula to Natal and inland to Tropical Africa. It is found in moist places within the undergrowth of forest environments and on damp river banks (Batten and Bokelmann, 1966; Henderson and Anderson, 1966; Moriarty, 1982; Bond and Goldblatt, 1984; Obermeyer, 1985).

Koeleria capensis occurs in steep, rocky areas in fynbos or grassland environments (Gibbs-Russel *et al.*, 1991). *Indigofera zeyheri* is a common coastal species occurring from the Southern Cape to Natal. It is widespread in coastal grasslands especially where it is exposed to high humidity from coastal fog (Batten and Bokelmann, 1966; Bond and Goldblatt, 1984). *Trachyandra revoluta* occurs in sandy coastal grasslands of the Southern and Eastern Cape, (Thistelton - Dyer, 1896; Batten and Bokelmann, 1966; Bond and Goldblatt, 1984) particularly on "seasonally damp, heathy flats" (Adamson, in Obermeyer, 1962).

The forb *Falckia repens* is a coastal species occurring in grasslands and vleis from the Western Cape to Natal. Because of ability to be salt tolerant it can occur among rocks immediately adjacent to the sea (Meeuse, 1957; Batten and Bokelmann, 1966; Moriarty, 1982; Bond and Goldblatt, 1984). *Geranium incanum* occurs in damp coastal grasslands throughout the Cape coastal belt (Batten and Bokelmann, 1966; Moriarty, 1982; Bond and Goldblatt, 1984). *Senecio ilicifolius* occurs on flats and slopes of the Southern and Eastern Cape coastal regions (Henderson and Anderson, 1966; Bond and Goldblatt, 1984). No information was found for the habitat preferences of *Senecio pterophorus*, *Cyperus obtusiflorus*, *Pycreus oakfortensis* or *Rhynchosia adenodes*.

3.3.2.2 VEGETATION DESCRIPTIONS

On the basis of TWINSPAN classification, (Figure 3.3.1) it was possible to 10 associations, which are further subdivided into 12 subassociations. The first level of division separates grasslands of a more mesic character from grasslands which are drier. The physical point at which separation is apparent is located at the Keiskamma River (Figures 3.3.2,.3.3.3). A few subassociations of the mesic grasslands occur west of this river, but only one of the xeric grassland associations was recorded to the east.

As shown in Appendix 2 there are a number of ubiquitous species which occur throughout the study area, including *Themeda triandra, Sporobolus africanus, Centella coriacea, Helictotrichon hirtulum, Eriosema squarrosum, Senecio inaequidens, Falckia repens, Senecio macrocephalus, Eriosema squarrosum* and three species of *Helichrysum*. Four species which occur predominantly in the xeric associations are *Setaria sphacelata, Ehrharta calycina, Chamaecrista capensis* and *Cynodon dactylon,* while *Hyparrhenia hirta, Elionurus muticus* and *Paspalum notatum* occur almost exclusively in the mesic associations. The total number of species recorded in the study area is 336.

3.3.2.2.1 *Themeda triandra - Anthospermum herbaceum* association

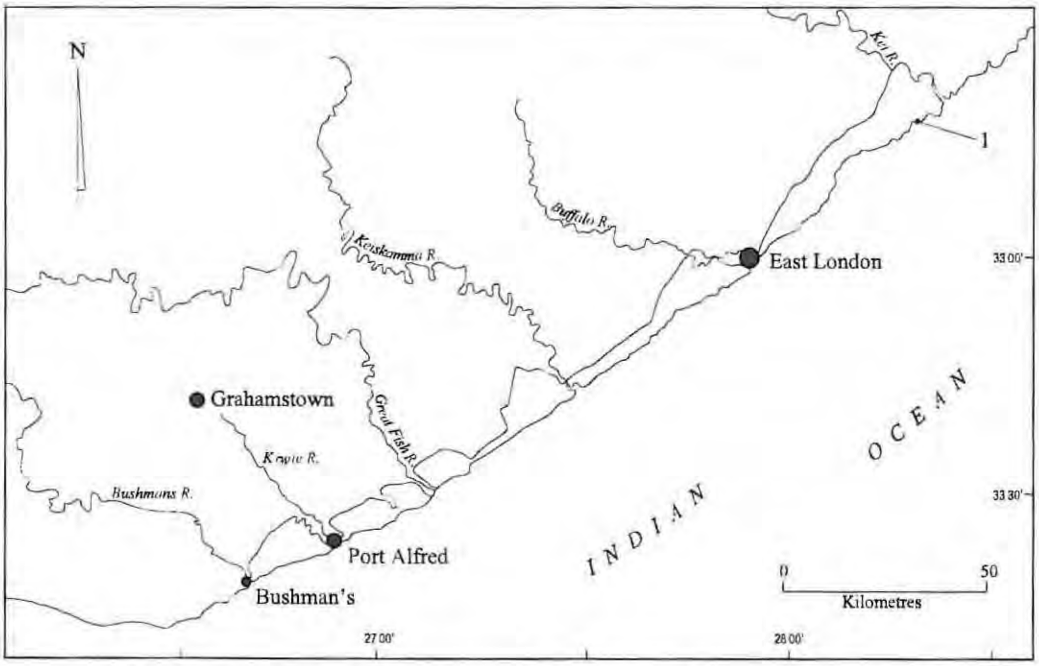


Figure 3.3.2.2.1 Distribution map of *Themeda triandra – Anthospermum herbaceum* grassland association of the Eastern Cape Coastal Grasslands

Table 3.3.2.2.1 Phytosociological table of the *Themeda triandra – Anthospermum herbaceum* grassland association of the Eastern Cape Coastal Grasslands (10 SUs)

Unique relevé nr.	1111111122 2233366833 8903556457
Themeda triandra	9.9997.9.6
Anthospermum herbaceum	424453.547
Stenotaphrum secundatum	29225795..
Hypoestes aristata	25222..5..
Senecio pterophorus	.....67.86
Tephrosia capensis	1.1.2...11
Senecio macrocephalus	1212......
Digitaria eriantha	...2....75
Eriosema squarrosum	....2..5.1
Setaria megaphylla	2..22.....
Passerina rigida	2.21......
Helichrysum cymosum	2..12.....
Hypoxis argentea	21..1.....
Thunbergia capensis	121
Falckia repens	1.1..2....
Gazania krebsiana	1.11......
Senecio inaequidens	.1.1...1..
Vigna vexillata	.1.11.....

This association is limited to a small number of localities on high rocky outcrops from Black Rock to Morgan's Bay. Although it consists of a small sample number, it is very clearly defined by TWINSPAN and can be located on the map as shown in Figures 3.1 and 3.3.2.2.i. Apart from the Black Rock locality, the association only occurs in protected Cape Nature Conservation areas. As the characteristic topography is limited to Nature Conservation areas, man's activities on this association are probably limited to trampling and possibly burning.

Themeda triandra is the dominant species in this association, of which *Anthospermum herbaceum* and *Stenotaphrum secundatum* are characteristic. *Hypoestes aristata* and *Tephrosia capensis* are indicator species (Table 3.3.2.2.i). Within this association several of the common species show tolerance to both fire and salt spray (*T. triandra, A. herbaceum, S. secundatum*) and given its location above the Morgan's Bay cliffs they are evidently well adapted to their environment. There has long been conjecture that the grasslands were burnt prior to the arrival of European settlers and if this is the case the presence of fire - resistant species is not unexpected. Although the area is located within a protected East Cape Nature Reserve, this does not prevent it from occasional accidental burning. The abundance of *T. triandra* and general cover suggest that this association is in good condition. It is considered to be a climax grassland characterised by salt tolerant and pyrophytic species in a mesic environment.

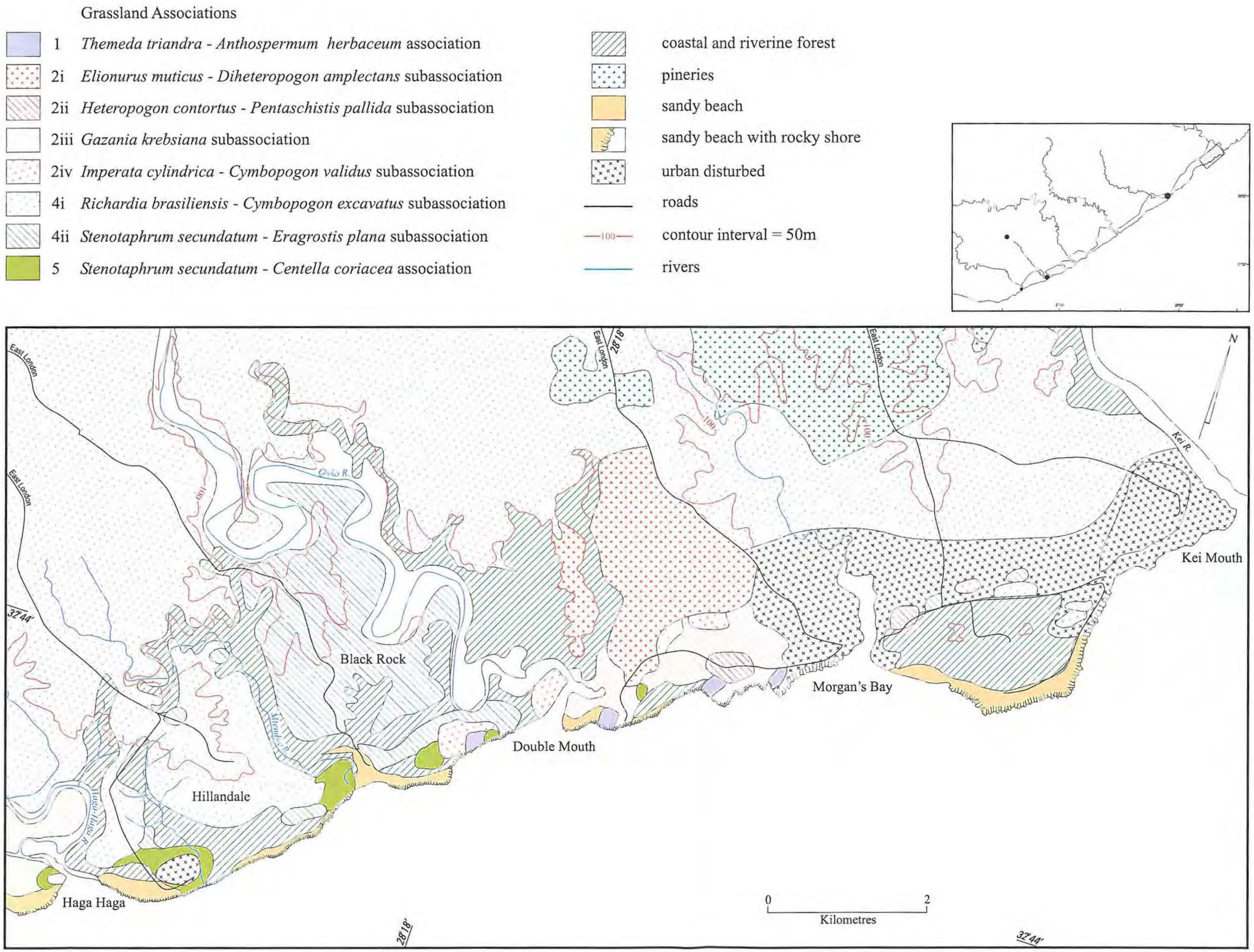


Figure 3.1: Distribution of Grassland Associations from Kei River Mouth to Haga Haga

3.3.2.2.2 *Themeda triandra* association

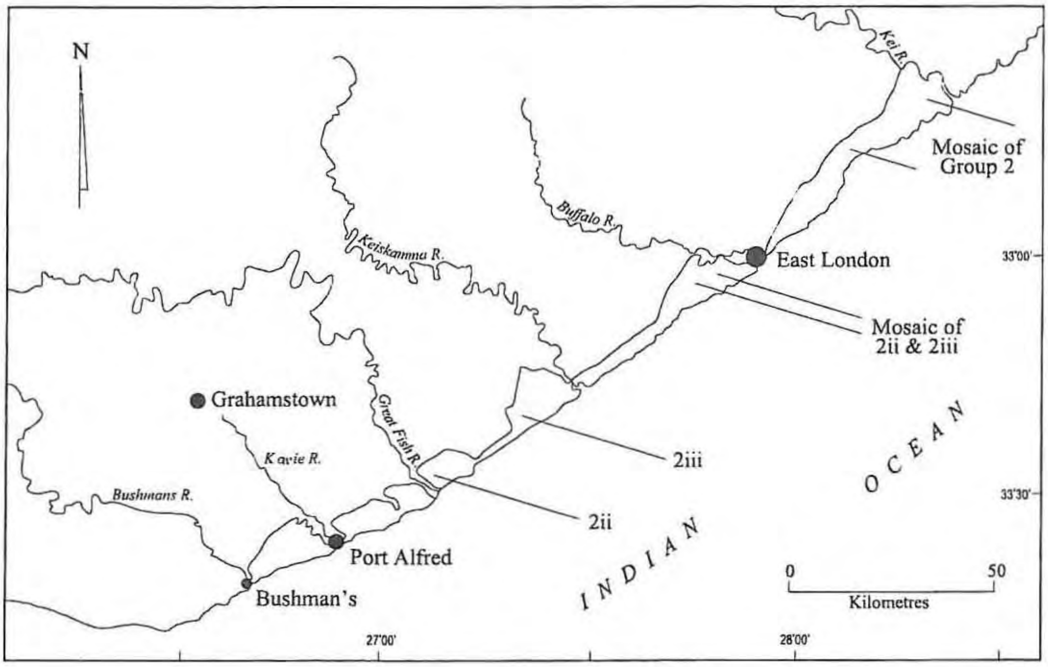


Figure 3.3.2.2.2 Distribution map of *Themeda triandra* grassland association of the Eastern Cape Coastal Grasslands

Figure 3.3.2.2.2.i Coastal grassland at the Dierama Wild Flower Reserve, Potter's Pass, showing *Themeda triandra* grassland behind coastal thicket with *Themeda triandra – Hyparrhenia hirta* grassland in the foreground. Note the rocky/sandy interface (see Chapter 4)

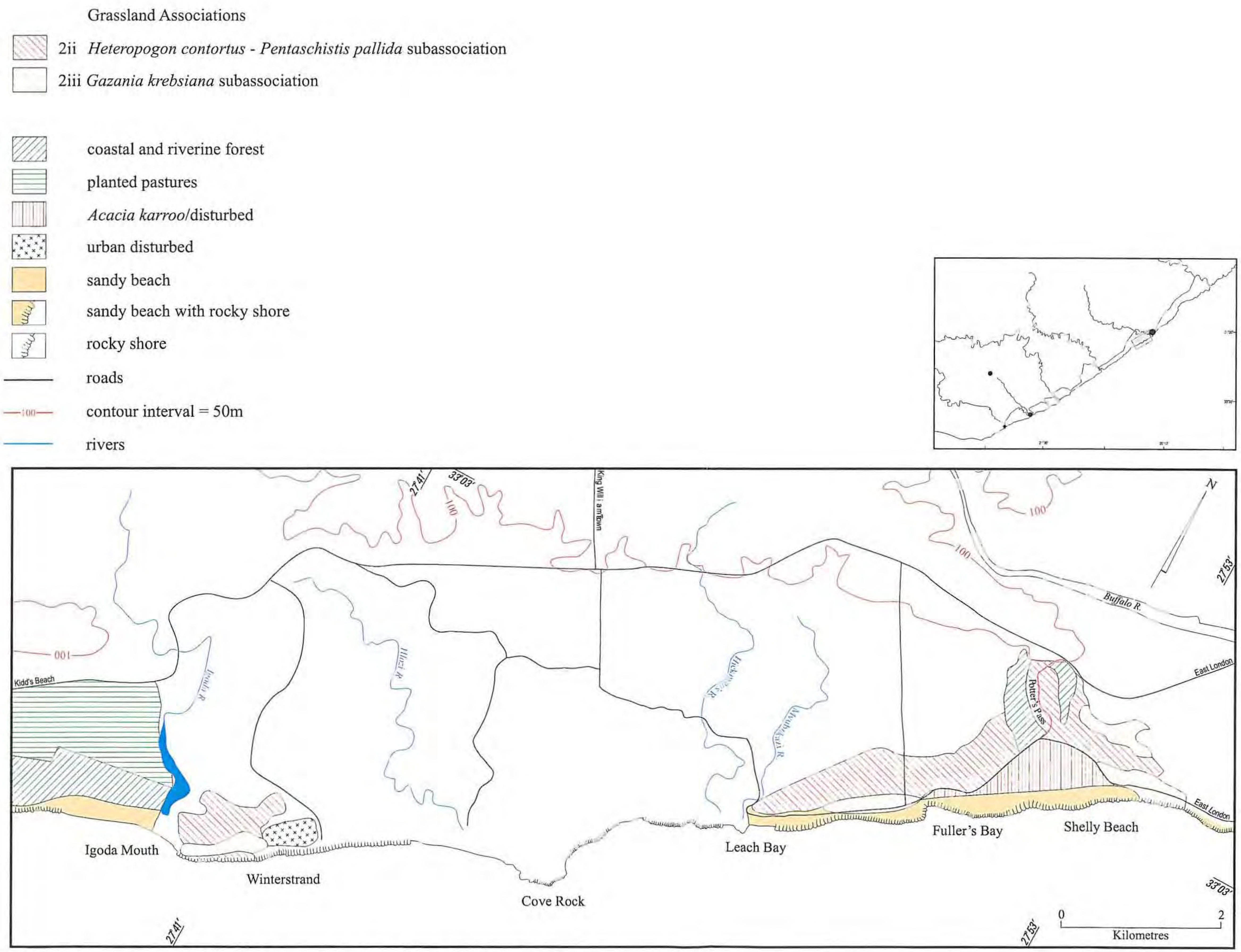


Figure 3.4: Distribution of Grassland Associations from Shelly Beach to Igoda Mouth

Table 3.3.3.2 Phytosociological table of the *Themeda triandra* mesic association of the Eastern Cape Coastal Grasslands

[illegible]

Species	Relevés
	[illegible]
Species of the *Themeda triandra* association	
Themeda triandra	[illegible]
Centella asiatica	[illegible]
Eriosema squarrosum	[illegible]
Helichrysum cymosum	[illegible]
[illegible]	[illegible]
Characteristic species of the *Elionurus muticus* - *Diheteropogon amplectans* subassociation	
Elionurus muticus	[illegible]
Diheteropogon amplectans	[illegible]
Acacia karroo	[illegible]
Cyperus obtusiflorus	[illegible]
Helichrysum nudifolium	[illegible]
Gnidia anthylloides	[illegible]
Senecio bupleuroides	[illegible]
Characteristic species of the *Heteropogon contortus* - *Pentaschistis pallida* subassociation	
Heteropogon contortus	[illegible]
Bulbostylis contexta	[illegible]
Pentaschistis pallida	[illegible]
Characteristic species of the *Gazania krebsiana* subassociation	
Gazania krebsiana	[illegible]
Anthospermum herbaceum	[illegible]
Digitaria eriantha	[illegible]
Tephrosia capensis	[illegible]
Chaetacanthus setiger	[illegible]
Species common to all subassociations except the *Imperata cylindrica* - *Cymbopogon validus* subassociation	
Tristachya leucothrix	[illegible]
[illegible]	[illegible]
Helichrysum appendiculatum	[illegible]
Abildgaardia ovata	[illegible]
Chamaecrista capensis	[illegible]
Eragrostis curvula	[illegible]
Characteristic species of the *Imperata cylindrica* - *Cymbopogon validus* subassociation	
Imperata cylindrica	[illegible]
Cymbopogon validus	[illegible]
[illegible]	[illegible]
[illegible] stolonifera	[illegible]

The *Themeda triandra* association occurs east of the Kiwane River but could only be described as extensive in East Cape Nature Conservation reserves at Igoda, Potter's Pass, and Double Mouth (Figures 3.1, 3.4). Around Kei Mouth and Morgan's Bay a mosaic of the four subassociations was distinguished (see Figure 3.1). These were the *Elionurus muticus - Diheteropogon amplectens*, *Heteropogon contortus - Pentaschistis pallida*, *Gazania krebsiana* and *Imperata cylindrica - Cymbopogon validus* subassociations.

The association is characterised by very high cover of *Themeda triandra*; apart from within this association, *T. triandra* only occurs at such levels of abundance in Association 4. Commonly occurring species include *Centella coriacea*, *Eriosema squarrosum*, *Helichrysum cymosum* and *Acalypha peduncularis*. Species richness is high with a total of 207 species found in this association.

The dominant species in this association is *Themeda triandra* which frequently accounts for between 80 and 100% of the cover. The characteristic species *Eriosema squarrosum*, *Tristachya leucothrix* and *Paspalum notatum* are common to relatively undisturbed grassland environments. The group of common species including *Helichrysum cymosum Chamaecrista capensis* and *Eragrostis curvula* indicate high moisture content, sandy soils and some degree of disturbance. Although these species seldom occupy more than 4% cover each, they are scattered throughout the first three subassociations and are characteristic of them (Table 3.3.3.2). The management regime and nature of the soils in the last subassociation may be one of the factors which account for the absence of the characteristic species in that subassociation.

3.3.2.2.2.i *Elionurus muticus - Diheteropogon amplectens* subassociation

This subassociation occurs almost exclusively inland of the East Cape Nature Conservation boundary above the Morgan's Bay cliffs (Figure 3.1). The ground has not been ploughed within memory of the occupants nor is it shown to have been disturbed on aerial photographs or maps. It was used for the grazing of dairy cattle at the time of survey. The subassociation occurs as part of the mosaic of the *Themeda triandra* grassland association in the vicinity of Morgan's Bay. It was not found at any sites west of Double Mouth Nature Reserve.

The subassociation is dominated by *Themeda triandra*, *Elionurus muticus* and *Diheteropogon amplectens* (*E. muticus* is also characteristic of the *Imperata cylindrica - Cymbopogon validus* subassociation). It is distinguished from the remaining subassociations by the presence of *Acacia karoo*, *Cyperus obtusiflorus* var. *flavissimus*, *Gnidia anthylloides*, *Helichrysum nudifolium* and *Senecio bupleuroides*. The grass *Tristachya leucothrix* is present at an average abundance of less than 10%. The total number of species present is 73.

Taking the species composition of this subassociation into account it can be seen that pyrophytic grasses (*T. triandra*, *E. muticus*) constitute the bulk of the vegetation cover in this subassociation. *E. muticus*, *D. amplectens* and *T. leucothrix* indicate high rainfall and stony soils. Disturbance due to poor veld management, particularly through burning, is indicated by the ubiquitous presence of *E. muticus* at cover abundance values ranging from 20 - 80 %, supported by the occurrence of *P. notatum*, *A. karroo*, *E. plana* and *E. curvula*. The low occurrence of *T. leucothrix* also indicates that there is disturbance in this subassociation as it is unable to withstand trampling and burning. The presence of *A. karroo* suggests that some degree of overgrazing is taking place in this subassociation because of the ability of this species to spread rapidly into grassland which is being overgrazed. It is unlikely that any of the vegetation has been ploughed since the species composition is not characteristic of such disturbance.

3.3.2.2.2.ii *Heteropogon contortus - Pentaschistis pallida* subassociation

This subassociation occurs along the coast east of the Bushman's River in East Cape Nature Conservation areas and in farmlands where extensive commercial cattle grazing occurs with no record of ploughing. It is present in the *Themeda triandra* association mosaic around Kei Mouth and Morgan's Bay, and in other areas west of East London (see Figures 3.1, 3.4, 3.6, 3.7, 3.8). The total number of species in this association is 105.

In this subassociation the cover abundance of *T. triandra* ranges from 1% to 100% thus it is not uniformly dominant. The next most commonly - occurring species is *H. contortus* which occurs at an average cover abundance of less than 10%. *P. pallida* occurs mainly in the former Ciskei. Its average cover abundance in this area only is 20% with a range of 7 - 85% i.e. it is not consistent in its abundance.The species composition indicates that there are fairly high moisture levels, representing a mesic environment. As it is located almost adjacent to the coast, sea mist will contribute to the moisture affecting the area. The soils are sandy and well drained. It appears that there is some disturbance taking place, particularly in the former Ciskei. The fact that no *A. karroo* was recorded for this subassociation at all indicates that the overgrazing occurring in the *Elionurus muticus* -

Diheteropogon amplectens subassociation may not be taking place here. *T. leucothrix* is present at its greatest abundance in this subassociation, suggesting that this subassociation is the least affected by trampling and grazing.

3.3.2.2.2.iii *Gazania krebsiana* subassociation

As well as occurring in the mosaic of subassociations around Kei Mouth and Morgan's Bay, this subassociation was found in close proximity to the *Elionurus muticus - Diheteropogon amplectens* subassociation (Figures 3.1, 3.2, 3.4, 3.5). It is, however, almost completely lacking the species that are diagnostic for that subassociation. *Themeda triandra* is present here at the highest level of abundance of all the subassociations, frequently occurring with percentage cover scores of between 80 and 100%. The association is characterised by species occurring at a high frequency but very low abundance. The characteristic species are *Gazania krebsiana, Anthospermum herbaceum, Digitaria eriantha, Tephrosia capensis* and *Chaetacanthus setiger.* The subassociation has the highest species diversity (138 species) of all the subassociations within the *Themeda triandra* association. The areas where the subassociation occurs are within East Cape Nature Conservation reserves which are subject to more frequent fires than the surrounding farmland but less trampling and grazing by livestock (pers. obs.).

The presence of *T. triandra, G. krebsiana* and *A. herbaceum* indicate that this subassociation is probably subjected to regular burning. The very high cover of *T. triandra* suggests that it is occurring in optimal conditions in this environment. Although *G. krebsiana* and *P. notatum* occur in disturbed areas, their low abundance values and the presence of *D. eriantha*, which is indicative of undisturbed sweetveld, suggests that there has been little physical disturbance of the environment. Although it was not possible to distinguish what forms of *A. herbaceum* were sampled, the forb also indicates proximity to the coast where it occurs within the salt spray zone at Igoda and Potter's Pass Nature Reserves. The high species richness is in contrast with a number of studies where dominance of *T. triandra* seems to result in a lower diversity but this high level may well indicate that the vegetation is in good condition.

3.3.2.2.2.iv *Cymbopogon validus - Imperata cylindrica* subassociation

Within the study area, this association was found only at Black Rock and above the Morgan's Bay cliffs (Figure 3.1; Plate 3.3.2.2.ii). It occurs on commercially owned land which is grazed with cattle and burnt on a fairly regular basis (Mr. Vernon Cockin, pers. comm.).

Figure 3.3.2.2.2.ii *Cymbopogon validus – Imperata cylindrica* subassociation, Black Rock

No single species dominates the vegetation in this subassociation. *Imperata cylindrica* is the most abundant indicator species together with *Elionurus muticus, Cymbopogon validus, Agrostis species* and *Ficinia stolonifera. Themeda triandra* , *Helichrysum cymosum* and *Acalypha peduncularis* are also important species in this subassociation. The subassociation has the lowest species richness recorded in the *Themeda triandra* association with 44 species in total.

The characteristic species of this subassociation (*Cymbopogon validus, Imperata cylindrica*) are pyrophytic, thrive on high moisture levels and are common to disturbed environments. Shackleton (1989) records a *Cymbopogon validus - Digitaria natalensis* grassland community in the Mkambati game reserve in the former Transkei, and notes that it occurred on the heavier clays which were well drained. The landowners on whose property this subassociation was common burn it on an annual or biennial basis. This is

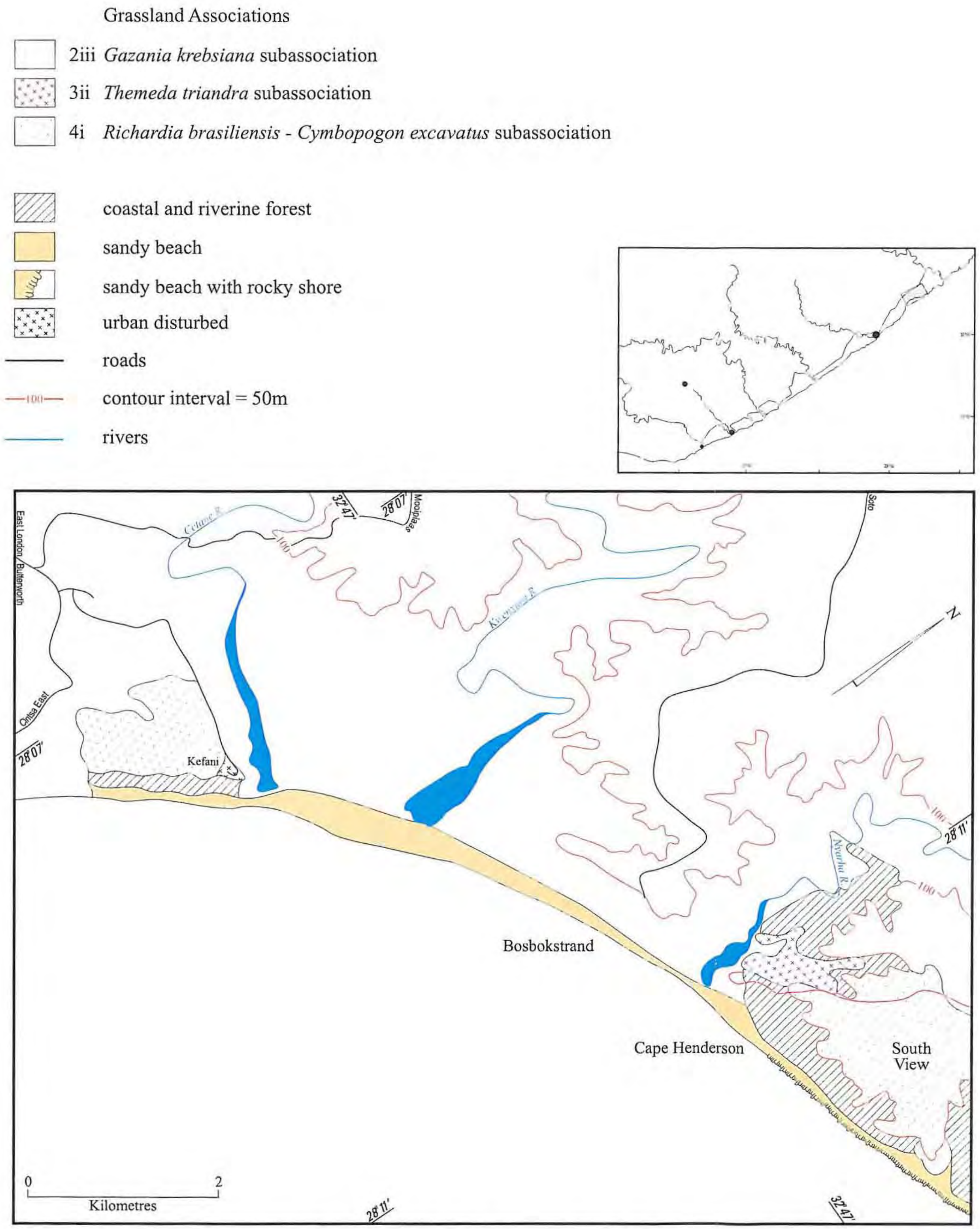


Figure 3.2: Distribution of Grassland Associations at Cape Henderson and Kefani

done because only the young growing shoots of *C. validus* are palatable and burning is the only way to produce some grazing from the grassland. It is also done in the belief that it helps to control the spreading of *C. validus* (Buck Wright, Vernon Cockin, pers. comms.). However, this practice encourages unpalatable grasses such as *E. muticus* without actually killing the unpalatable *I. cylindrica* or *C. validus*. If the distribution of *C. validus* is limited by soil factors then burning will not affect its distribution, only its palatability. The total number of species in this subassociation is almost half that of previously described subassociations. The fact that *C. validus* is a tall grass reaching heights of 2400mm (Gibbs-Russel *et al.*, 1991) may cause shading out of lower - growing forbs. In addition it is also possible that the high occurrence of burning has decreased the natural species richness, particularly the number of spring-flowering (vernal) forbs and grasses in the subassociation.

The species composition of the *Themeda triandra* association indicates that it is mainly a high rainfall (sourveld), fire-maintained grassland which can be divided into subassociations on the basis of soil types, proximity to the coast and the degree of disturbance caused by grazing animals. It does not appear to have been ploughed at any time although trampling has had an impact on the vegetation. There is a relatively high fynbos element in the *Heteropogon contortus - Pentaschistis pallida* subassociation.

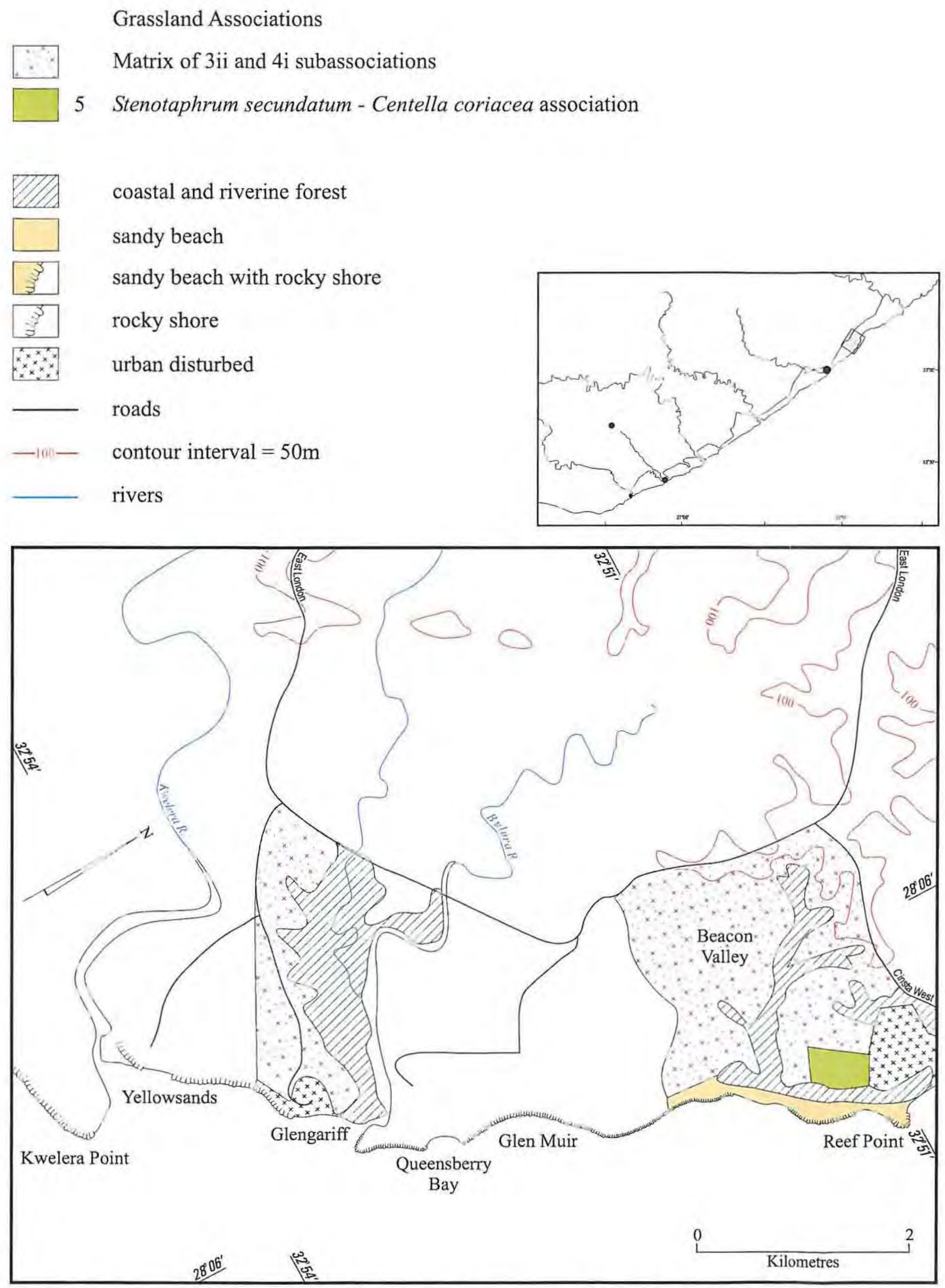


Figure 3.3: Distribution of Grassland Associations between Reef Point and Kwelera Point

3.3.2.2.3 *Hyparrhenia hirta - Diheteropogon amplectens* association

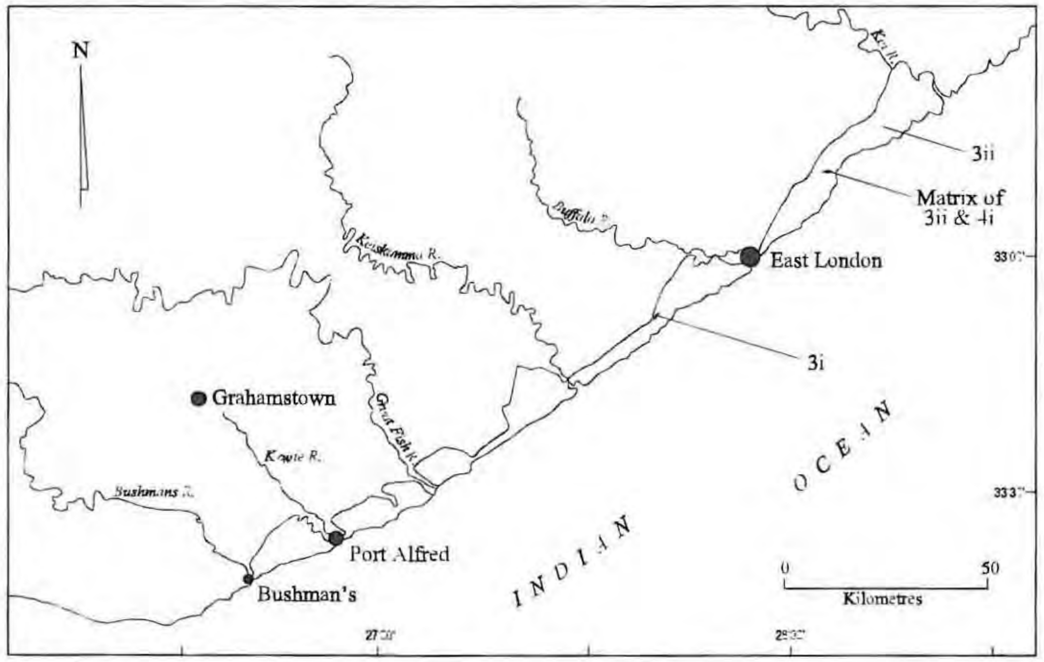


Figure 3.3.2.2.3 Distribution map of the *Hyparrhenia hirta - Diheteropogon amplectens* association of the Eastern Cape Coastal Grasslands

Table 3.3.2.2.3 Phytosociological table of the *Hyparrhenia hirta - Diheteropogon amplectens* association of the Eastern Cape Coastal Grasslands (24 SUs)

Unique relevé nr.	[illegible]
Species characteristic of the *Hyparrhenia hirta - Diheteropogon amplectens* association	
Hyparrhenia hirta	[illegible]
Diheteropogon amplectens	[illegible]
Elionurus muticus	[illegible]
Chamaecrista capensis	[illegible]
Species characteristic of the *Ehrharta calycina* subassociation	
Ehrharta calycina	[illegible]
Chaetacanthus setiger	[illegible]
Senecio inaequidens	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
Species characteristic of the *Themeda triandra* subassociation	
Themeda triandra	[illegible]
Digitaria eriantha	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
Tristachya leucothrix	[illegible]
Bulbostylis contexta	[illegible]
[illegible]	[illegible]

This association occurs between Cape Henderson and the Kiwane River (Figures 3.2, 3.3, 3.5). It was found in areas that have not been ploughed within living memory and are grazed mainly by cattle on an *ad hoc* basis. While some workers may have combined this association with the *Hyparrhenia hirta - Themeda triandra* association, it was felt that the differences in dominant and characteristic species warranted their separation at this point. The total number of species recorded for this association was 106. Two subassociations were recognised within this group, these being the *Ehrharta calycina* subassociation and *Themeda triandra* subassociations.

The dominant grasses are *Hyparrhenia hirta, Diheteropogon amplectens* and *Elionurus muticus*. The forb *Chamaecrista capensis* is a characteristic species of this association. *H. hirta* occurs at an average abundance of over 50% in the *Ehrharta calycina* subassociation and is present in all SUs. In the *Themeda triandra* subassociation, it is not present in all SUs and its average abundance is 20% (see Table 3.3.3.3).

3.3.2.2.3.i *Ehrharta calycina* subassociation

This subassociation was only found between the Tyolomnqa and Kiwane Rivers in the former Ciskei (Figure 3.5). It is unploughed but is grazed continuously by cattle. The dominant grass in this subassociation is *Hyparrhenia hirta*. The most important indicator species for this subassociation is *Ehrharta calycina* while other diagnostic species include *Chaetacanthus setiger, Senecio inaequidens, Thunbergia dregeana* and *Acacia karroo*. *Themeda triandra* is absent from all but two of the relevés in this subassociation. Total number of species is 44.

As shown in Table 3.3.3.3, the almost negligible presence of *Themeda triandra* and the occurrence of *Acacia karroo, D. amplectens* and *E. muticus* with a high cover abundance of *H. hirta* suggests that this grassland has been mismanaged, either through overgrazing, incorrect burning or a combination of the two. The subassociation would have been subject to communal grazing but the extent of burning and grazing in this area is not known.

3.3.2.2.3.ii *Themeda triandra* subassociation

This subassociation occurs east of East London at Cape Henderson and in association with the *Richardia brasiliensis - Cymbopogon excavatus* subassociation of the *Hyparrhenia hirta - Themeda triandra* association at Glengariff and Beacon Valley (Figures 3.3, 3.3). The indicator species include *Themeda triandra, Digitaria eriantha, Centella coriacea,* *Helictotrichon hirtulum*, *Tristachya leucothrix*, *Bulbostylis contexta* and *Thunbergia* species. The total number of species in this subassociation is 91.

In this subassociation there is no clear dominance of any species. *H. hirta* has over 50% cover abundance in less than 50% of the SUs while *D. amplectens*, *E. muticus* and *T. triandra* seldom exceed 40% cover abundance. *D. eriantha* occurs in over 60% of SUs at an average of 10-20 % cover abundance. *H. hirtulum* is present at just below 20% cover abundance in half of the SUs in this subassociation. Indicator species all occur throughout the association at low levels of cover abundance. The species richness in this subassociation is more than double that of the *Ehrharta calycina* subassociation. The climax grasses *T. triandra*, *D. eriantha* and *T. leucothrix* are present only in this subassociation.

The results indicate that the *Hyparrhenia hirta - Diheteropogon amplectens* association appears to be mixed sweet and sour veld, since it is characterised by grasses of both high and relatively low moisture regimes. It occurs on sandy soils and appears to be divided into two subassociations on the basis of man's utilisation of the veld. The *Ehrharta calycina* subassociation may represent a degraded form of the *Themeda triandra* subassociation. The presence of *E. muticus* points to overgrazing in both subassociations. *E. calycina* and *A. karroo* indicate that the *Ehrharta calycina* subassociation may have been more heavily utilised than the *Themeda triandra* subassociation., It is also suggested because of the presence of *T. triandra*, *D. eriantha* and *T. leucothrix* that the second subassociation has been less disturbed.

3.3.2.2.4 ***Hyparrhenia hirta* - *Themeda triandra* association**

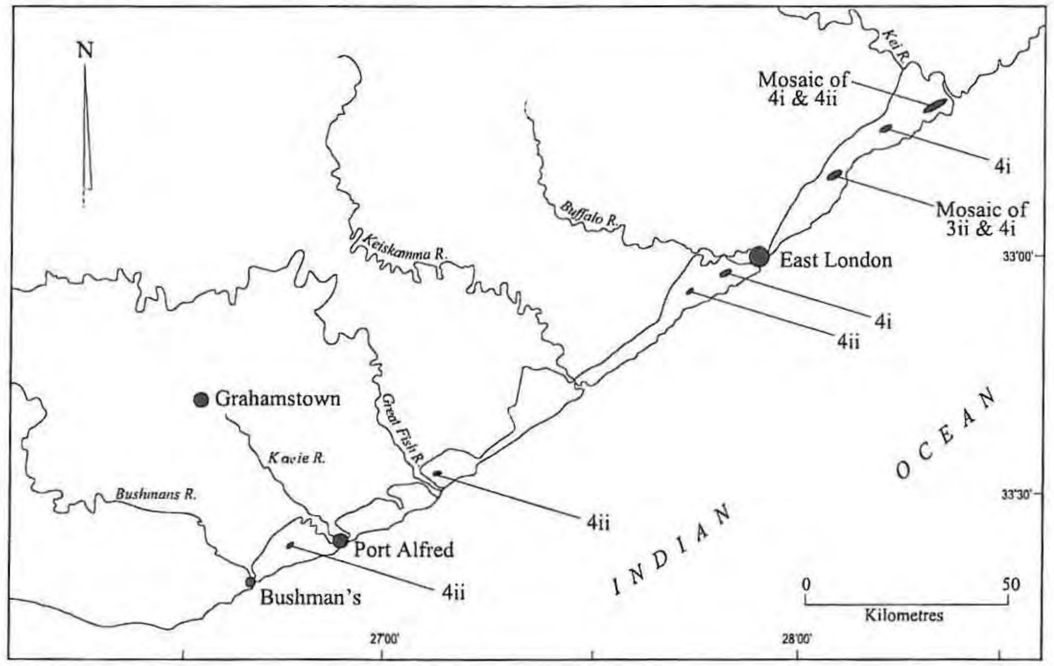


Figure 3.3.2.2.4 Distribution map of the *Hyparrhenia hirta - Themeda triandra* association of the Eastern Cape Coastal Grasslands

Figure 3.3.2.2.2.iii *Hyparrhenia hirta - Themeda triandra* association at Black Rock.

Table 3.3.3.4 Phytosociological table of the *Hyparrhenia hirta* - *Themeda triandra* mesic association of the Eastern Cape Coastal Grasslands

Unique relev, nr.		
	1112222222222222222222222222222222222222222222222222222222222223	1111111111112222222222333333
	3555000000001111112233333444444445566666777778888888889999999991	341888899999001225578111222
	8689034567890123563901489023456789350125956789012345789012367891	4106789023567127244946279245
Species of the *Hyparrhenia hirta* - *Themeda triandra* association		
Hyparrhenia hirta	.29498887.577.77567979.8898567.7.1..578572785..78582..5.1.6.976.	58855567.85..58.877775....86
Centella coriacea	.25425.6754.5665551....15544.27.72257154752665421216212155551...	6416646667676666466775......
Themeda triandra	...8555455111.5.5216.16.55....851.17555.6.25665557285885...64.65	...785645.6......5.515..5.65
Digitaria eriantha	......5565644975697.219..1.28167.81865.55.5.777716655779.8815555	.....1.551555..61..52.998618
Paspalum notatum	..521251..5.1...1151.1.....1..2.14...41125.15..5.511.41511.1112.	..2.5..51.47.559154.111.....
Eragrostis curvula	9....2.66654545141.5...5515856.5..6.5.1.597657.1241462511157175.	..4..........6.4.65558......
Sporobolus africanus	.....5552.11511.1.......55.11.21...1111111511...1..4..1....5.1..	2..556615.57......1514.565.4
Helictotrich hirtulum	.....56.5.771.555.....15..2....171.51..1..1..51.2..............9	8..1..55..........551.......
Elionurus muticus	...........6..15.......45....56....6...4.2..1.............6..5.	..........8.8...4..5....1...
Bulbostylis contexta	......2...1.1.115.621.1.54......................1.1.1...........	.......1........1......2412.
Species characteristic of the *Richardia brasiliensis* - *Cymbopogon excavatus* subassociation		
Richardia brasiliensis	..1112411.1.1.11..115..2111111..11...11..155.1111111112.5.11514.	..2...22...1.1.......1......
Cymbopogon excavatus	.....2.15...1.524...4..........1875......1.1.1.122.2441.1.......	....
Cymbopogon validus	.941....685...............................8...648...1.......	....
Aristida junciformis	....756...52.9762....	....
Helichrysum pedunculat	.......1..1.2..11.......1.......1....1..........11.1.1.....1....	....
Species characteristic of the *Stenotaphrum secundatum* - *Eragrostis plana* subassociation		
Stenotaphrum secundatu	....1.....................5........1..1..1.11.....14..11...5....	...7555.6....85.167.44...1.5
Eragrostis plana	..11..	.5..676677465...............
Setaria species	...1..............1.........1.1....1..1...............5.......5	.255551...1.....1.....5...1.
Argyrolobium rupestre	....1..................2.........................1..........2...	.....5422.....4.222..2......
Cynodon dactylon	....1.....1......1.171.......5....8.....1...........1............	.5.........4.115.......1.865
Ehrharta calycina	.........1..2	675...................521...

This association occurs throughout the study area in grassland owned by commercial farmers who subject the vegetation to varying degrees of cattle grazing. In addition, it occurs in close proximity to farm roads where there may be an added impact because of the driving of livestock. This is in contrast to all the previous associations which occur in open areas that are unlikely to have been subjected to this type of trampling (Figures 3.1, 3.2, 3.3, 3.5, 3.7). There is no record of ploughing having taken place.

The characteristic grass species include *Hyparrhenia hirta*, *Digitaria eriantha* and *Themeda triandra*. *Centella coriacea* is the most important forb, occurring more frequently than any of these grasses and in some areas having a greater abundance. Other important species include *Paspalum notatum*, *Eragrostis curvula*, *Sporobolus africanus*, *Helictotrichon hirtulum*, *Elionurus muticus* and *Bulbostylis contexta* (Table 3.3.3.4). Two subassociations were discerned, the *Richardia brasiliensis - Cymbopogon excavatus* and the *Stenotaphrum secundatum - Eragrostis plana* subassociation. The total number of species in this association is 183.

3.3.2.2.4.i *Richardia brasiliensis - Cymbopogon excavatus* subassociation

This subassociation occurs west of Double Mouth on the farms Hilandale and South View. A small area was located on the west bank of the Kefani River mouth and also in a mosaic with the *Themeda triandra* subassociation of the *Hyparrhenia hirta - Diheteropogon amplectens* association at Glen Garriff and Beacon Valley (Figures 3.1, 3.2, 3.3). The vegetation is under commercial grazing and along farm roads where it was probably subjected to cattle trampling and vehicular damage.

This subassociation is dominated by *H. hirta* and *T. triandra*. The key diagnostic species, *Richardia brasiliensis*, occurs at low levels of cover abundance but is almost ubiquitous. Other characteristic species include *Cymbopogon excavatus*, *C. validus*, *Aristida junciformis* and *Helichrysum pedunculare*. Their occurrence within the SUs is erratic as are their levels of abundance, but they are limited almost exclusively to this subassociation. Abundance values never exceed an average of 5% cover for the characteristic species. These grass species are common to the higher rainfall regions of the sourveld or mixed veld. They are also characteristic of well-drained stony slopes, and the forb component is typical of open grassland. The general appearance is that of a slightly disturbed sour to mixed grassland. The total number of species is 150.

3.3.2.2.4.ii *Stenotaphrum secundatum - Eragrostis plana* subassociation

This subassociation is found on commercially owned land grazed by cattle, sheep and goats. As with the previous subassociation it is probably subjected to some degree of trampling livestock as well as disturbance caused by vehicles. It is well-represented on the farm Black Rock and adjacent to the *Richardia brasiliensis* subcommunity on Hilandale. It is also located on the farm Kasouga at the settlement of the same name (Figures 3.1, 3.5, 3.7).

Stenotaphrum secundatum occurs in half of the SUs with an average cover abundance of less than 10% while *E. plana* is present at abundance values of 20 - 70% in the Black Rock - Hilandale region. *S. sphacelata* occurs at between 2 and 60% cover in this subassociation. *H. hirta* has a slightly greater cover abundance than *T. triandra* in this subassociation. The remaining indicator species, *A. rupestre*, *C. dactylon* and *E. calycina* , occur throughout the area with average cover abundance values of less than 5 %. The total number of species is 110.

The species composition of this subassociation indicates that it is a disturbed mixed grassland. It is known that no ploughing has occurred within the last 90 years on these grasslands, but they have been run under commercial grazing with regular burning (Vernon Cockin, Buck Wright, pers. comm.). The climax species *T. triandra* is one of the most important grasses present in terms of overall abundance, but the subclimax *H. hirta* is just as abundant. The characteristic species of this subassociation are all pioneer grasses which appear after disturbance, with the exception of *S. sphacelata*. These factors indicate that fairly severe disturbance has occurred in the past to produce this grassland association. The only exception may be made for presence of the dune pioneer *S. secundatum*, which may be attributable to proximity to the shore and the resultant salt spray effect.

The species composition of this association suggest that it is a mixed grassland but that changes such as those recorded by Meredith and Rose (1955) may be taking place, i.e. that this association represents the conversion of a *Themeda triandra* dominated primary grassland to a secondary grassland dominated by *Hyparrhenia hirta*. The characteristic species are all common to disturbed environments. The vegetation is not known to have been ploughed but the species composition indicates that severe disturbance has occurred. The two subassociations may be separated on the basis of proximity to the coast and intensity of land use. The species composition of the

Stenotaphrum secundatum – Eragrostis plana subassociation suggest that it is or was subject to higher level of disturbance than the *Richardia brasiliensis – Cymbopogon excavatus* subassociation.

3.3.2.2.5 *Stenotaphrum secundatum - Centella coriacea* association

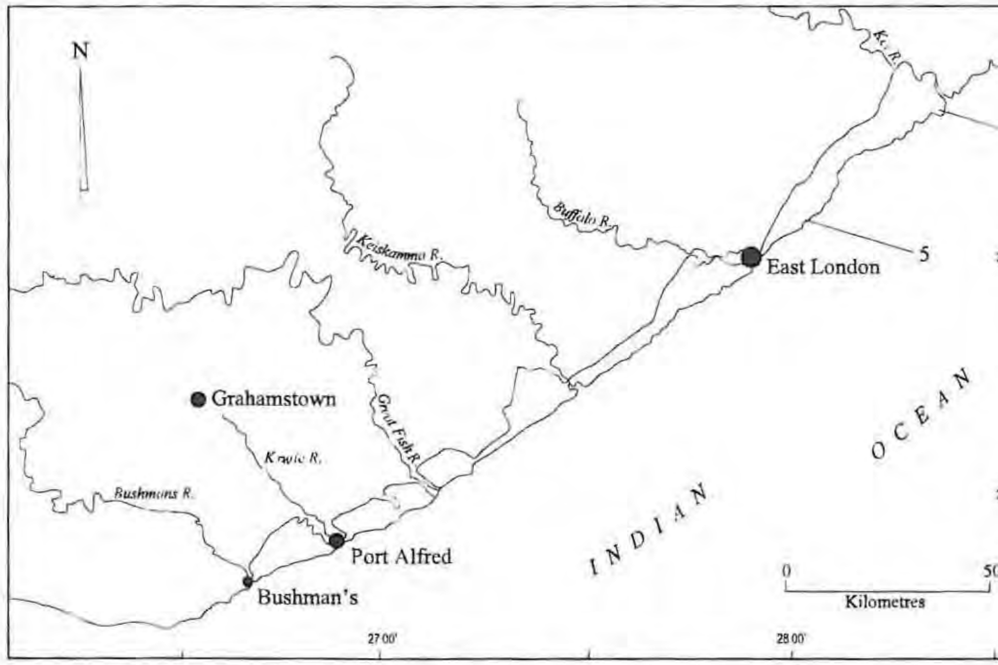


Figure 3.3.2.2.5 Distribution map of the *Stenotaphrum secundatum – Centella coriacea* association of the Eastern Cape Coastal Grasslands

Table 3.3.2.2.5 Phytosociological table of the *Stenotaphrum secundatum - Centella coriacea* association of the Eastern Cape Coastal Grasslands (12 SUs)

Unique releve nr.	111111222222 788999222559 323189678674
Stenotaphrum secundatum	985997.55576
Centella coriacea	2564615..565
Themeda triandra	.59..79....9
Hypoestes aristata	.555..576...
Senecio inaequidens	.521..5.2.14
Paspalum notatum	...451.27.11
Cynodon dactylon	.2..45445...
Pycreus oakfortensis	.54.1..22...
Digitaria eriantha	...5.15..7.5
Panicum aequinerve	...2.1.26...
Kyllinga species	.......76...
Aristida diffusa	.........77.

This association occurs in areas of extremely high soil disturbance and at informal parking areas along the shore between Haga - Haga and Double Mouth (Figures 3.1, 3.3). It is dominated by *Stenotaphrum secundatum*, which occurs throughout the association at an average of 50 - 60% cover. The indicator species include *Centella coriacea*, *Cynodon dactylon*, *Hypoestes aristata* and *Paspalum notatum*, all of which are indicators of one or more other communities in the study and most of which are indicative of disturbance. Total number of species is 60.

It can be seen from both the locations and the species composition that this association reflects the disturbance they experience through their proximity to suburban roads and other sites of disturbance. It has the second lowest percentage of species in the entire study, having more species only than the *Themeda triandra - Anthospermum herbaceum* association (see Table 3.3.3.5). The high cover abundance of the pioneer species *S. secundatum* and *C. dactylon* are indicative of a secondary grassland. The presence of the climax species *T. triandra* indicates that this might be the grass expected to dominate the area in the absence of disturbance. The invasive *P. notatum* is indicative of disturbance as well as higher moisture levels due to runoff from the road and watering from the surrounding homes. The presence of the forest margin species *H. aristata* and *P. aequinerve* indicate the link between the grassland and the coastal and riverine forests which border most of the localities to varying extents. This is the most disturbed association in the mesic grassland associations.

3.3.2.2.6 *Diheteropogon filifolius* - *Ehrharta calycina* association

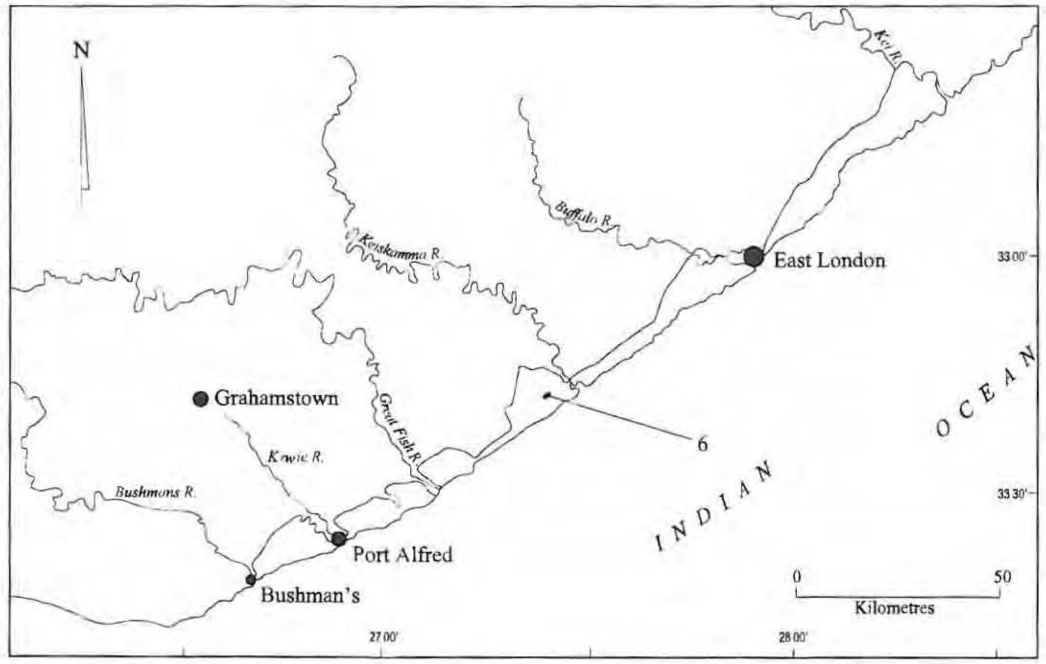


Figure 3.3.2.2.6 Distribution map of the *Diheteropogon filifolius* - *Ehrharta calycina* association of the Eastern Cape Coastal Grasslands

Table 3.3.2.2.6 Phytosociological table of the *Diheteropogon filifolius*- *Ehrharta calycina* association of the Eastern Cape Coastal Grasslands (12 SUs)

Unique relevé nr.	238888899999 304678901234
Diheteropogon filifolius	..5575855555
Ehrharta calycina	5.7.65516656
Heteropogon contortus	985658.75...
Themeda triandra	5.5...556678
Chaetacanthus setiger	2..111.1.141
Helichrysum asperum	.1..1.5.2122
Aizoon rigidum	.5..7.52.254
Chamaecrista capensis	..1...212541
Tephrosia capensis	.5.2.541..1.
Eriosema squarrosum	..41.2..1..1
Indigofera heterophylla	45455
Acalypha peduncularis	.....4226..2

This association is located on the east bank of the Kiwane River and to a lesser extent on the farm Lessendrum in the former Ciskei (Figure 3.5). The Kiwane area is subject to communal grazing from a nearby settlement. Only cattle were observed and it is not known how often the area is burnt or what numbers of livestock are kept on it. The total number of species recorded is 72.

There is no single dominant species in this association, but the two species which occur most commonly and with almost uniform abundance are *Diheteropogon filifolius* at 15 - 20 % cover abundance and *Ehrharta calycina* at about 40% cover abundance. This association contains the lowest number of species in any of the xeric grassland communities with only 21% of the total species in the study being recorded here. The grass species in this association do not define it in any appreciable manner except to indicate that it has been disturbed. While the grass *Diheteropogon filifolius* occurs in open grassland on hillsides in coastal areas, *Ehrharta calycina* and *Heteropogon contortus* are indicative of disturbance. The species *Themeda triandra* and *H. contortus* appear to be almost mutually exclusive This is in agreement with Zacharias (1990) who indicates that although *H. contortus* and *T. triandra* often occur together, *H. contortus* is able to withstand heavy utilisation better than *T. triandra* and can assume dominance following such utilisation. The forb component consists of coastal species including *Aizoon rigidum*, *Tephrosia capensis*, *Indigofera heterophylla* and *Acalypha peduncularis* which are scattered throughout the grassland and tend to be more common and abundant where *T. triandra* is present. They are far less frequent in those SUs where *H. contortus* is common (see Table 3.3.3.6). The species composition in this association indicates that it may represent the transition from a primary *Themeda triandra* - type climax grassland to a *Heteropogon contortus* dominated secondary grassland following disturbance.

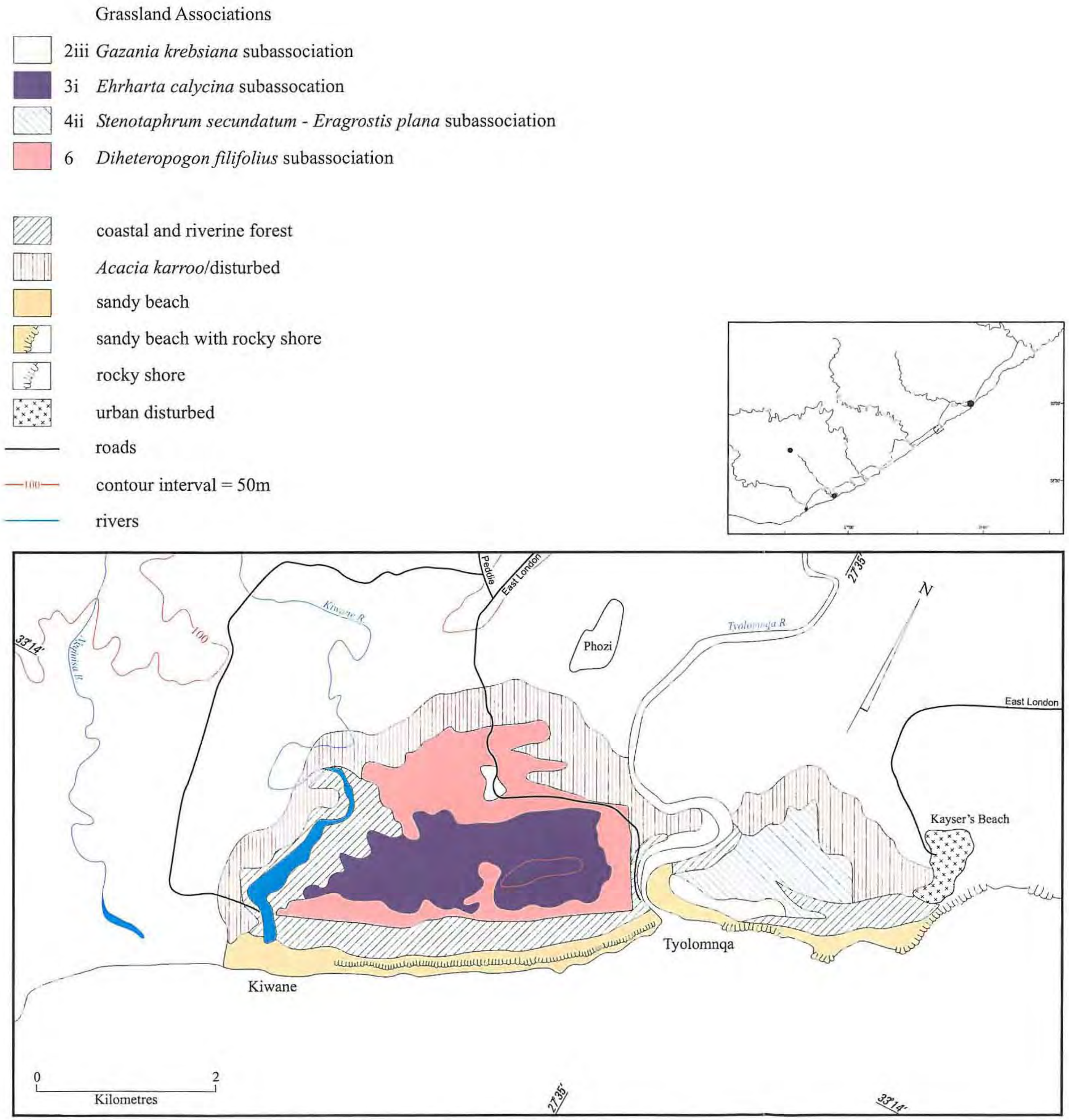


Figure 3.5: Distribution of Grassland Associations at Tyolomnqa and Kiwane Rivers

3.3.2.2.7 *Cynodon dactylon - Ehrharta calycina* association

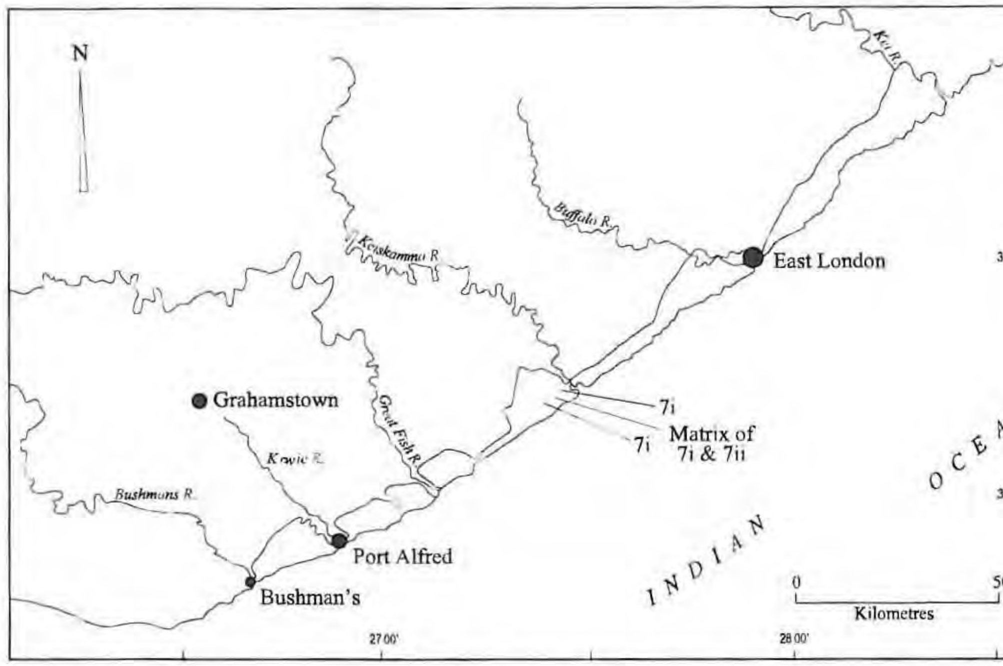


Figure 3.3.2.2.7 Distribution map of the *Cynodon dactylon – Ehrharta calycina* association of the Eastern Cape Coastal Grasslands

Table 3.3.2.2.7 Phytosociological table of the *Cynodon dactylon - Ehrharta calycina* association of the Eastern Cape Coastal Grasslands (16 SUs)

Unique rele'é nr.		
	56777788	34445699
	29126701	74790057
Species characteristic of the no on act on hrharta ca cina Association		
Cynodon dactylon	7555..2.	78777688
Ehrharta calycina	.55.6555	7776666.
Setaria sphacelata	5.56..26	6....551
Chamaecrista capensis	11114241	..2211..
Eriosema squarrosum	21.1461.	..122...
Helichrysum asperum	1.5.5...	4.1.2.51
Gazania krebsiana	21.1...1	25.1.21.
Species characteristic of the eteropo on contortus subassociation		
Heteropogon contortus	74555567	....6...
Eragrostis capensis	..651457	....
Eragrostis plana	.55525..	.1...6..
Elionurus muticus	.756....	1
Bulbostylis contexta	5517....	...2....
Species characteristic of the haetacanthus seti er subassociation		
Chaetacanthus setiger	11......	1.11114.
Aizoon rigidum	....	5...424.
Dolichos species	....	..211.11
Crotalaria obscura	11......	...221..

This association occurs in small areas from the Kiwane River west towards the Fish River in the former Ciskei (Figure 3.6). Dominant species in this association are *Cynodon dactylon* and

Ehrharta calycina, both of which are characteristic of disturbed, sandy soils. The climax species *Themeda triandra* is poorly represented. Table 3.3.3.7). There is no clear indication as to what the original grassland composition of this vegetation might have been and the surrounding associations may be more representative of the original grassland. The forb species are mainly coastal in distribution. The total number of species is 91. Two subassociations were discerned within this association, these being the *Heteropogon contortus* subassociation and the *Chaetacanthus setiger* subassociation.

3.3.2.2.7.i *Heteropogon contortus* subassociation

This subassociation occurred on communally grazed land as well as on land that was owned by a parastatal cattle-breeding organisation (Figure 3.6). The land-use history was not available, but from ordinance survey maps and the condition of the areas it did not appear that any ploughing had taken place in the last 20 years. The total number of species is 54.

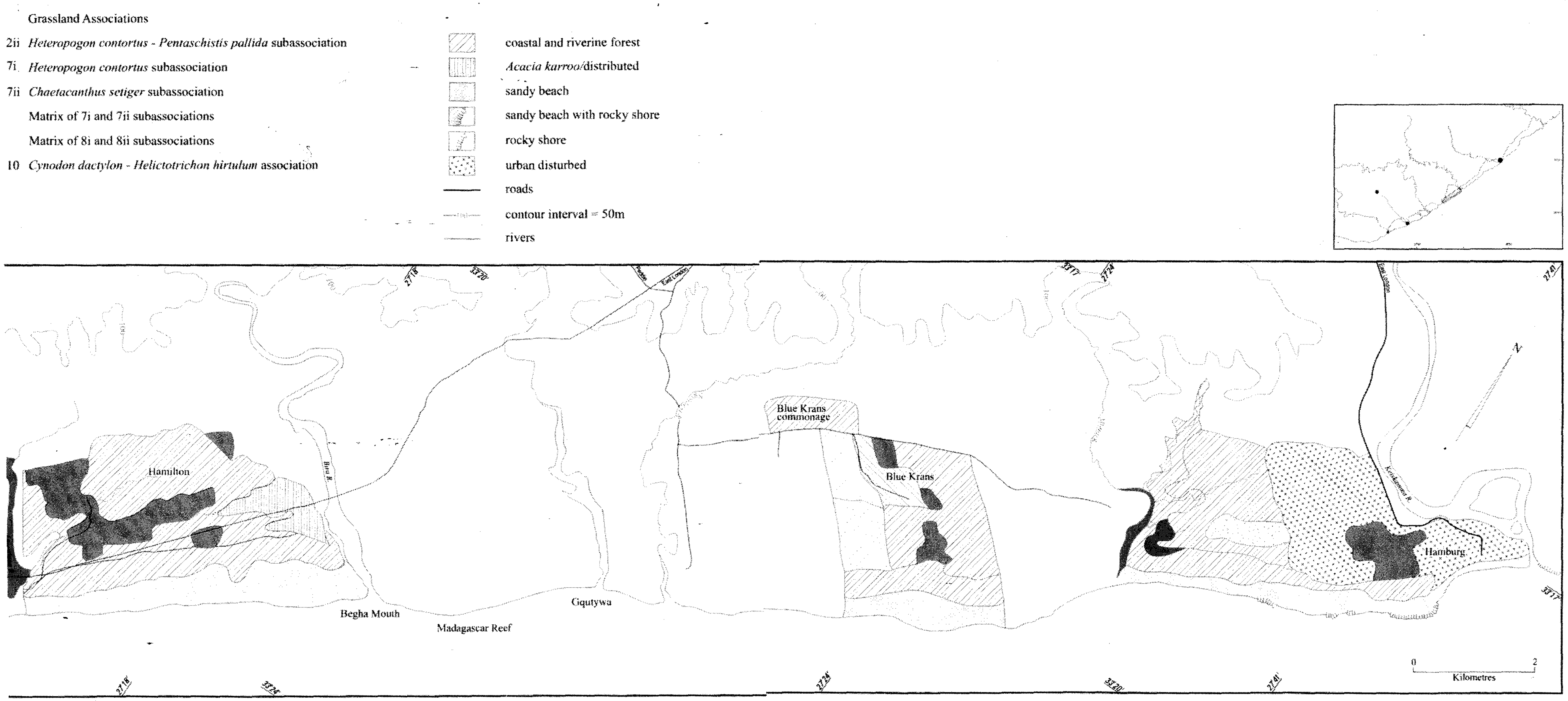
The most abundant species in this subassociation is *Heteropogon contortus* with *Eragrostis capensis* as the next most common species. The remaining grass species characteristic of the subassociation, *Eragrostis plana* and *Elionurus muticus*, are indicative of areas which have been subject to poor veld management. *T. triandra* was present at less than 3% cover abundance in one third of the SUs representative of this subassociation while *H. hirta* did not occur at all. These species indicate that the vegetation has been subject to overutilisation, possibly due to a combination of overgrazing, trampling and some excess of burning. It is not possible to state what the composition of the grassland was in former times, but the low abundance of climax species and the high cover of pioneer species and species common to secondary grasslands suggests that it has become degraded. It is possible that this was formerly a mixed grassland subassociation.

3.3.2.2.7.ii *Chaetacanthus setiger* subassociation

Like the previous subassociation, this subassociation is also located on parastatal farmland and communally owned land in the former Ciskei (Figure 3.6). The dominant species are *Cynodon dactylon* and *Ehrharta calycina* and it is differentiated from the first subassociation by the presence of the forbs *Chaetacanthus setiger*, *Aizoon rigidum*, *Dolichos sp.* and *Crotalaria obscura*. The total number of species in this subassociation is 67.

In this subassociation, the high cover abundance values of the pioneer grasses *Cynodon dactylon* and *Ehrharta calycina* suggest heavy disturbance in the area. These grasses are present in greater abundance than in the *Heteropogon contortus* subassociation, indicating that the *Chaetacanthus setiger* subassociation is the more heavily disturbed of the two. In addition, the occurrence of the climax species *T. triandra* is even lower here than in the first subassociation. The absence of *Eragrostis capensis* and *Elionurus muticus* indicate that this subassociation may have been subject to a lower incidence of burning than the *Heteropogon contortus* subassociation, and it is possibly more xeric than the latter. Comins (1962) indicates that degradation of *Themeda triandra* grasslands results in the presence of species such as *E. plana* and *C. dactylon* assuming dominance, and that ultimately severe degradation results in a grassland dominated by *C. dactylon*. This is what appears to be taking place in this subassociation. The forb component consists of species whose distribution is limited to the Southern Cape and Natal coastal regions.

The *Cynodon dactylon - Ehrharta calycina* association is a disturbed grassland which is divided into two subassociations on the basis of the degree of disturbance. The lack of abundance of species associated with climax grasslands renders it impossible to state firmly what the original grassland composition was; it is the presence of pioneer species and those which are common to disturbed areas that indicate the present nature of this association.



3.6: Distribution of Grassland Associations from the Keiskamma River to the Mgwalana River

3.3.2.2.8 *Themeda triandra - Ehrharta calycina* association

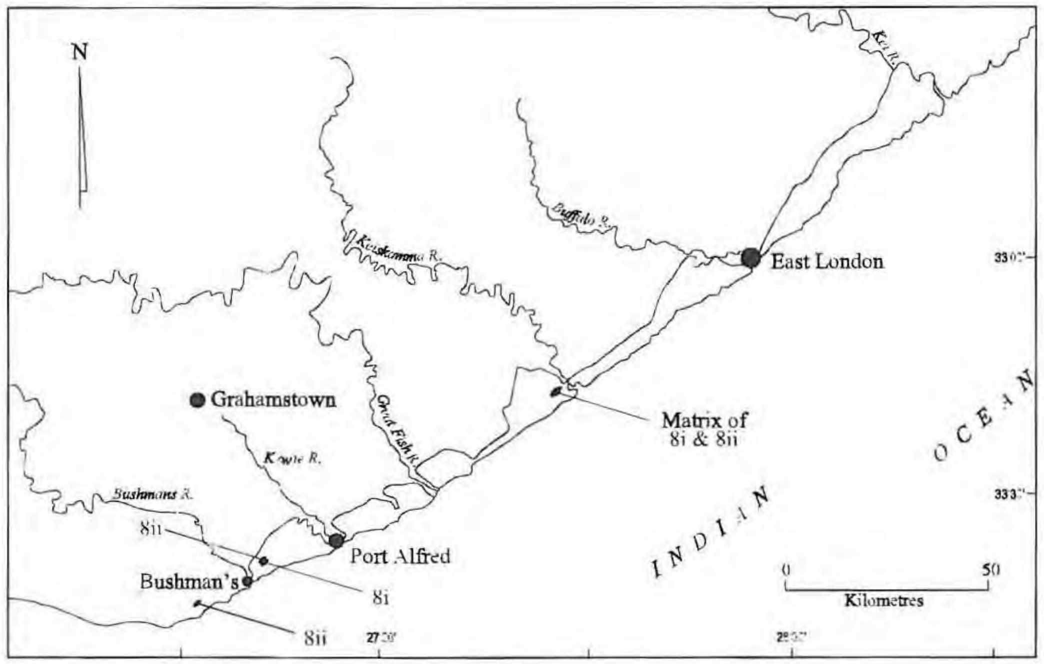


Figure 3.3.2.2.8 Distribution map of the *Themeda triandra - Ehrharta calycina* association of the Eastern Cape Coastal Grasslands

Table 3.3.2.2.8 Phytosociological table of the *Themeda triandra - Ehrharta calycina* association of the Eastern Cape Coastal Grasslands (32 SUs)

Unique releve nr.	|
	1333333
	11111346[illegible] | 1112[illegible]112
	30[illegible]3135|1[illegible]451
Species of the *Themeda triandra - Ehrharta calycina* Association	
Themeda triandra	[illegible]
Ehrharta calycina	.11.5146..5|4441.[illegible]1151.7[illegible].
Heteropogon contortus	....1.551.5|1[illegible]..155.5551....
Setaria sphacelata	.1[illegible]115.5.5|.....5.. 15..[illegible]
Cynodon dactylon	5..515...5.|[illegible].4.161....[illegible].1....
Sporobolus africanus	1...11...[illegible].|1.144..1141....[illegible]1.1
Thunbergia capensis	.4.1.1..11.|........181.1........
Senecio inaequidens	....11..111|.11.....1.1.11....11.
Oxalis species	..111......|1..11111..1.....1...11
[illegible] emarginata	.11.....11.|1....1.1....1......1..
Species characteristic of the *Tristachya leucothrix* subassociation	
Tristachya leucothrix	[illegible]155|.....................
Chamaecrista capensis	141.11...11|.11...........1......
Eragrostis capensis	45.45[illegible]....5|.....................
Pentaschistis pallida	.5.1.1.[illegible]|.....................
Commelina africana	111111.....|1...1..1..............
Species characteristic of the *Helichrysum asperum* subassociation	
Helichrysum asperum	.1...1......|.11..11.1.1.1[illegible]......
[illegible] capensis	5..........|11111[illegible]...1...[illegible].....
Rhynchosia adenodes	1..........|1111.151...........
Indigofera [illegible]	.1..........|114.1...141.........
Dolichos species	1..........|1111..11............
[illegible]	....1......|.....11.111..........

This association occurs at Hamburg, on the farm Glendower outside Port Alfred, and within the Alexandria Forest (Figures 3.6, 3.8, 3.9). In the latter two localities it is known that within the last 150 years ploughing has not occurred (Mr. A. Ford; Mr. van Rooyen, pers. comm.) and it is probable that the vegetation was never disturbed in this way. According to the Survey maps used for this study, no ploughing has been recorded in any of these areas. The two subassociations which were identified by TWINSPAN could not be separated at Hamburg and occurred together in a matrix.

The dominant species is *Themeda triandra* while characteristic species include *Ehrharta calycina*, *Heteropogon contortus*, *Setaria sphacelata*, *Cynodon dactylon Sporobolus africanus*, *Thunbergia capensis*, *Senecio inaequidens* and *Monsonia emarginata*. The total species richness is 120. This association contained the highest number of representatives of the Poaceae and Asteraceae, as well as the greatest number of species for the xeric grassland associations.

Two subassociations were determined, the *Tristachya leucothrix* subassociation and the *Helichrysum asperum* subassociation.

3.3.2.2.8.i *Tristachya leucothrix* subassociation

This subassociation was clearly defined as occurring on the south facing hillsides at Hamburg and Glendower (Figure 3.8). *Tristachya leucothrix* is the dominant species and occurs at a higher level of abundance than *Themeda triandra*. Other characteristic species include *Chamaecrista capensis*, *Eragrostis capensis*, *Pentaschistis pallida* and *Commelina africana*. The total number of species in this subassociation is 84.

The co-dominance of *Tristachya leucothrix* and *Themeda triandra* indicate that the vegetation is not being intensively utilised. The species indicating disturbance, *Ehrharta calycina*, *Eragrostis capensis* and *Pentaschistis pallida*, do not occur frequently enough or at high enough levels of abundance to indicate major disturbance. As the areas on which the subassociation occurs are seaward facing slopes, they are likely to receive moisture in the form of coastal fog. This enables mesophytes such as *Commelina africana* to occur here as well as encouraging *Tristachya leucothrix* and *Eragrostis capensis*, which prefer moist environments. This subassociation is thought to be the least degraded grassland found in the xeric grassland associations.

3.3.2.2.8.ii *Helichrysum asperum* subassociation

This subassociation was located on the seaward facing slopes at Hamburg, on the north facing side of dunes at Glendower, and in unploughed areas within the Alexandria forest (Figures 3.8, 3.9). It is dominated by *Themeda triandra* with *Heteropogon contortus* being co - dominant at Glendower. A number of species occurring at low abundance levels are characteristic of this subassociation, including *Helichrysum asperum, Koeleria capensis, Rhynchosia adenodes, Indigofera zeyheri, Dolichos sp.* and *Trachyandra revoluta*. The total number of species in this subassociation is 89.

In this subassociation the higher abundance levels of *Themeda triandra, Heteropogon contortus* and *Ehrharta calycina* at the expense of *Tristachya leucothrix* may indicate that it is subject to heavier environmental pressure than the *Tristachya leucothrix* subassociation. Since *T. triandra* thrives under judicious burning and *T. leucothrix* is easily removed by physical disturbance, the species composition indicates that the degree of either grazing, burning, trampling or a combination of any of these factors may be higher in the *Helichrysum asperum* subassociation.

Very few of the indicator species occur at abundance levels in excess of 5% in this subassociation, and they are scattered among the SUs. They are generally common coastal grassland species occurring in sandy soils with slightly elevated moisture levels. Their low abundance within the Alexandria Forest area is not accounted for. Possible reasons may be the physical barrier of the forest itself or a decrease in available moisture in the form of sea mists and fog. *Indigofera zeyheri* and *Trachyandra revoluta* were limited to Glendower.

The species composition of these two subassociations indicates that the second is either a slightly disturbed form of the first or it is subject to more xeric conditions. It is possible that the *Tristachya leucothrix* subassociation represents the best climax vegetation that can occur in the xeric component of the Eastern Cape Coastal Grasslands. The disappearance of *T. leucothrix* from all SUs in the *Helichrysum asperum* subassociation may be due to edaphic conditions or aspect, but it is also possible that the environmental pressures to which the vegetation is subjected have removed this species, which is sensitive to disturbance. This association contained the highest number of representatives of the Poaceae and Asteraceae, as well as the greatest number of species for the xeric grassland associations. It is regarded as being the least disturbed and nearest in species richness and abundance to a climax primary grassland in the xeric Eastern Cape Coastal Grasslands.

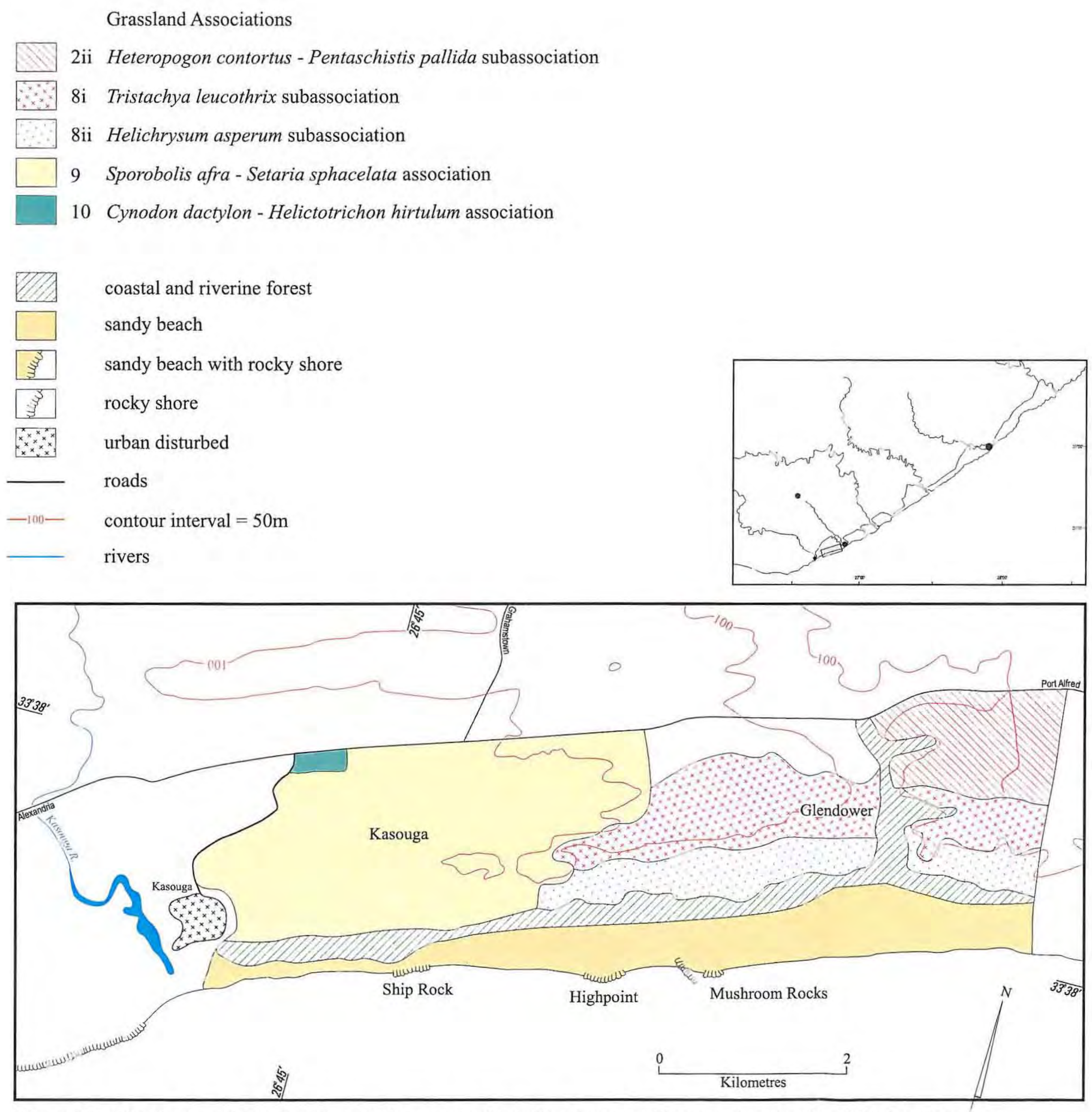


Figure 3.8: Distribution of Grassland Associations on the farms Glendower and Kasouga between Port Alfred and Kasouga

3.3.2.2.9 *Sporobolus africanus* - *Setaria sphacelata* association

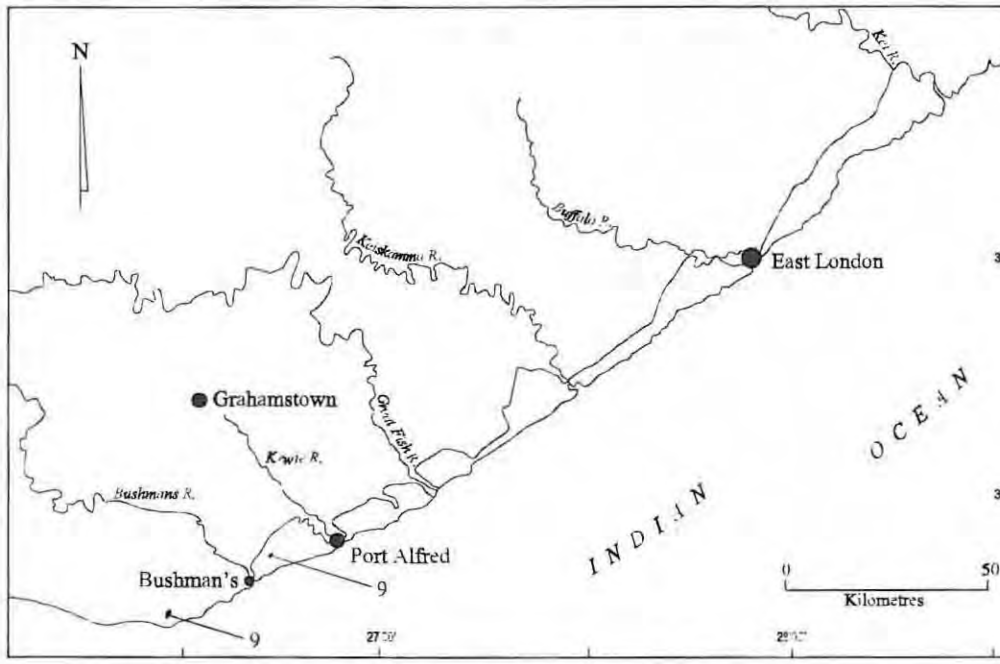


Figure 3.3.2.2.9 Distribution map of the *Sporobolus africanus* - *Setaria sphacelata* association of the Eastern Cape Coastal Grasslands

Table 3.3.2.2.9 Phytosociological table of the *Sporobolus africanus* - *Setaria sphacelata* association of the Eastern Cape Coastal Grasslands (15 SUs)

Unique releve no.

	111123[illegible]
	5023[illegible]1[illegible]
	[illegible]22461345[illegible]
Sporobolus africanus	4.7[illegible]6553.55[illegible]
Setaria sphacelata	[illegible]7....8455[illegible]
Cynodon dactylon	.[illegible]44[illegible]..[illegible]....[illegible]
Ehrharta calycina	.51...[illegible]555..11
Falckia repens	..5[illegible].111.1..1.
Stenotaphrum secundatum	.5114........4..
Themeda triandra	[illegible].45.........1
Geranium incanum	......[illegible].[illegible]....
Senecio illicifolius	......[illegible].5[illegible]1...
Helichrysum [illegible]	.......1.4..1..

This association occurs on the farm Kasouga, adjacent to the river of the same name, and within the Alexandria Forest (Figures 3.8, 3.9). The original grassland had been ploughed for crops between 10 and 40 years ago and was then allowed to revert to grassland. No species had a consistent abundance of over 20%. The characteristic species are *Sporobolus africanus*, *Setaria sphacelata*, *Cynodon dactylon*, *Ehrharta calycina*, and *Falckia repens*. *Stenotaphrum secundatum*, *Themeda* *triandra*, *Geranium incanum*, *Senecio ilicifolius* and *Helichrysum rosum* are also present. The total number of species recorded is 85.

From the previous land use records, it is known that this association represents a secondary grassland since the areas on which it occurs were ploughed over 60 years ago (Mr. Fick, pers. comm.). The species composition indicates that the majority of the species found here are characteristic of disturbed, secondary grasslands and that little restoration of a climax grassland community has taken place (see Table 3.3.3.9). The most common species, *Sporobolus africanus*, is a pioneer of disturbed environments and usually appears where *Themeda triandra* has been eradicated. *Cynodon dactylon* is also a pioneer species while *Ehrharta calycina* is common in disturbed environments. The appearance of *Themeda. triandra* and *Setaria sphacelata* suggests that they may have been important grasses prior to disturbance. *T. triandra* was possibly the dominant species. *T. triandra* may have begun to re-establish itself or in those SUs where its abundance is high, it may be that that area escaped ploughing. The forb *Falckia repens* is a mesophytic coastal species whose presence together with *Stenotaphrum secundatum* indicates that the areas are subject to saline conditions. Judging from the localities and appearance, it is possible that this association was originally similar to the *Themeda triandra - Ehrharta calycina* association.

The association recorded the smallest number of members of the Poaceae and Fabaceae for the xeric grassland associations, indicating that theses two families have been the most affected by the disturbance. However, it has the second highest number of Asteraceae.

3.3.2.2.10 *Cynodon dactylon - Helictotrichon hirtulum* association

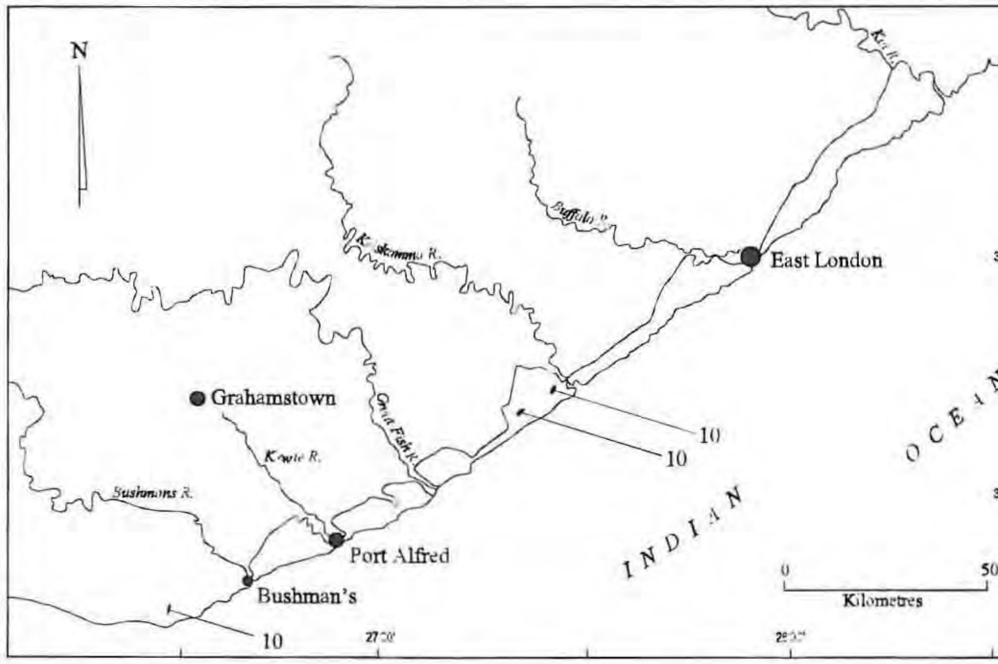


Figure 3.3.2.2.10 Distribution map of the *Cynodon dactylon - Helictotrichon hirtulum* association of the Eastern Cape Coastal Grasslands

Table 3.3.2.2.10 Phytosociological table of the *Cynodon dactylon - Helictotrichon hirtulum* association of the Eastern Cape Coastal Grasslands (23 SUs)

Unique rele nr.	[illegible]
Cynodon dactylon	5....7..7.4.......5..
Helictotrichon hirtulum	71.5.5..1.....5...5
Stenotaphrum secundatum	........5.5..5..1...
Ehrharta calycina	11........5..55.......1
Sporobolus africanus	.1.......15.1...15...5.
Centella coriacea	[illegible]
Senecio inaequidens	41.......1...51....51....
Setaria sphacelata	.1...........5.1.1...5
Helichrysum asperum	11..........15..51.11...
Chamaecrista capensis	51.......1...1...5.....
Rhynchosia [illegible]	..........5.7....15.....

This association occurs at Hamburg, on the farm Lessendrum in the former Ciskei, and in the Alexandria Forest (Figures 3.6, 3.7, 3.8, 3.9). It is found in areas that were ploughed more than 20 years previously and in adjacent regions subject to vehicular and animal disturbance. There are no uniformly dominant species within this association. Characteristic species include *Stenotaphrum secundatum*, *Ehrharta calycina* and *Sporobolus africanus*. *Centella coriacea*, *Senecio inaequidens*, *Setaria sphacelata, Helichrysum asperum, Chamaecrista capensis* and *Rhynchosia adenodes* also occurred in this association. The total number of species present was 90.

This association occurs on lands that were abandoned between ten and twenty years prior to sampling. It also occurs adjacent to roads on which both cars and livestock are driven as well as at Hamburg where there is no regulation of cattle numbers and movement. It is composed of the pioneer grass species *Cynodon dactylon, Helictotrichon hirtulum, Stenotaphrum secundatum, Ehrharta calycina* and *Sporobolus africanus* and the common coastal forbs *Centella coriacea, Helichrysum asperum* and *Chamaecrista capensis* (see Table 3.3.3.10). The lowest number of Asteraceae of any of the xeric grassland associations and the second lowest number of Poaceae are recorded in this association. The lack of any climax grass species makes it difficult to estimate what the original grassland was, but judging from surrounding vegetation and localities one may infer that it was similar to the *Themeda triandra - Ehrharta calycina* association. In over 10 years since the areas were ploughed, no climax grass species have re-asserted themselves. This suggests that the environmental pressures on the association may be too great for it to develop into a more stable association with the appearance of climax species. This association probably represents a stage in the development of a secondary grassland between when it was first allowed to revert after disturbance and the *Sporobolus africanus - Setaria sphacelata* association that shows the appearance (or re-appearance) of the climax species *Themeda triandra*.

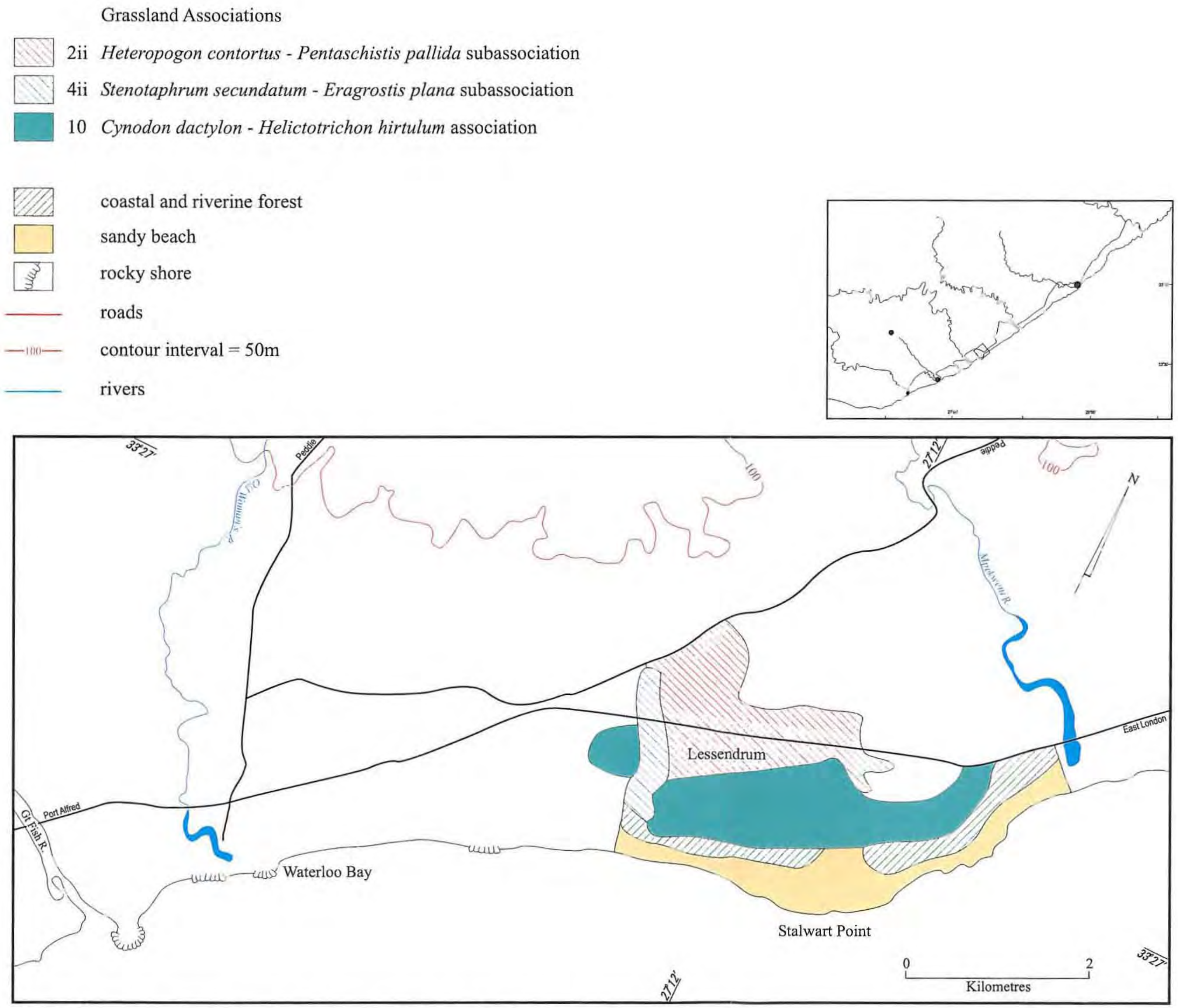


Figure 3.7: Distribution of Grassland Associations on the farm Lessendrum at Stalwart Point

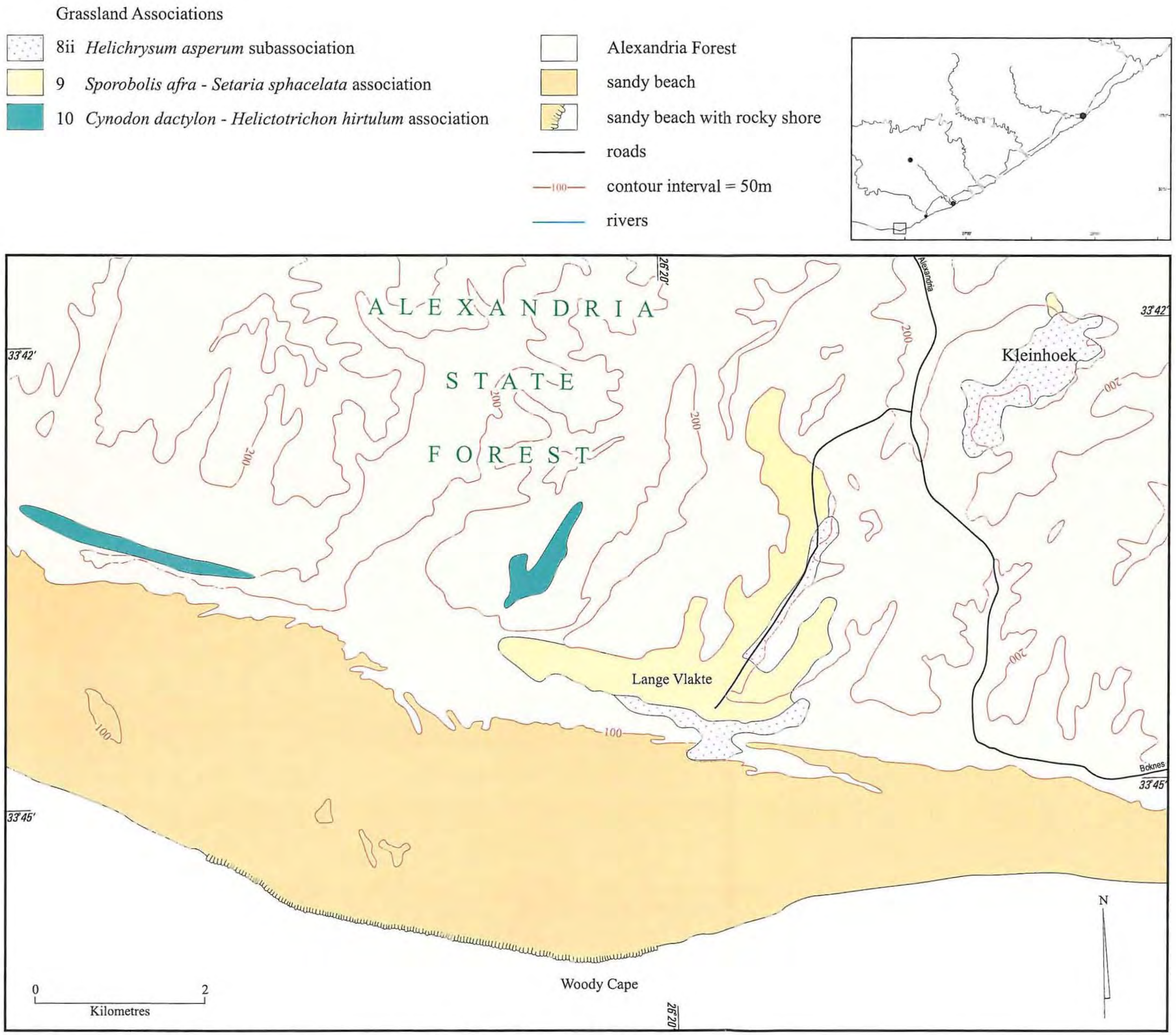


Figure 3.9: Distribution of Grassland Associations within the Alexandria Forest near Woody Cape

Mesic Grassland Associations

1	*Themeda triandra - Anthospermum herbaceum* association
2	*Themeda triandra* association
2i	*Elionurus muticus - Diheteropogon amplectens* subassociation
2ii	*Heteropogon contortus - Pentaschistis pallida* subassociation
2iii	*Gazania krebsiana* subassociation
2iv	*Imperata cylindrica - Cymbopogon validus* subassociation
3	*Hyparrhenia hirta - Diheteropogon amplectens* association
3i	*Ehrharta calycina* subassocation
3ii	*Themeda triandra* subassociation
4	*Hyparrhenia hirta - Themeda triandra* association
4i	*Richardia brasiliensis - Cymbopogon excavatus* subassociation
	Matrix of 3ii and 4i subassociations
4ii	*Stenotaphrum secundatum - Eragrostis plana* subassociation
5	*Stenotaphrum secundatum - Centella coriacea* association

Xeric Grassland Associations

6	*Diheteropogon filifolius - Ehrharta calycina* association
7	*Cynodon dactylon - Ehrharta calycina* association
7i	*Heteropogon contortus* subassociation
7ii	*Chaetacanthus setiger* subassociation
	Matrix of 7i and 7ii subassociations
8	*Themeda triandra - Ehrharta calycina* association
8i	*Tristachya leucothrix* subassociation
8ii	*Helichrysum asperum* subassociation
	Matrix of 8i and 8ii subassociations
9	*Sporobolis afra - Setaria sphacelata* association
10	*Cynodon dactylon - Helictotrichon hirtulum* association
	coastal and riverine forest
	pineries
	planted pastures
	Acacia karroo/disturbed
	Alexandria Forest
	sandy beach
	sandy beach with rocky shore
	rocky shore
	urban disturbed
	roads
	contour interval = 50m
	rivers

3.3.3 COMMUNITY SIMILARITY STUDIES

The degree of similarity between the Eastern Cape Coastal Grasslands and other grasslands in Southern Africa was assessed through the examination of available literature. It is acknowledged that as my study could not include every single species in the area and that often only the most common species are published in vegetation studies, the results are incomplete. Further studies need to be carried out in the Eastern Cape Coastal Grasslands and probably all the relevant grasslands with which it was compared to get a complete representation of the overlap of species distributions.

3.3.3.1 Distribution of grasses within South African Biomes

The distribution of the grass species which occurred in the study site within the biomes of South Africa was determined from the work of Chippindall (1955), Gibbs-Russel *et al.* (1991) and van Oudtshoorn (1992). The results are presented below in Table 3.3.3.i

Table 3.3.3.i Distribution of Grasses found in Eastern Cape Coastal Grasslands within the South African Biomes according to Chippindall (1955) Gibbs-Russel *et. al.*, (1990) and van Oudtshoorn (1992)

Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Alloteropsis semialata	X	X					
Aristida diffusa	X	X	X				
Aristida junciformis	X	X		X			
Brachiaria serrata	X	X		X			
Bromus pectinatus	X	X	X	X			
*Chloris gayana**	X	X		X			
Cymbopogon excavatus	X	X					
Cymbopogon validus	X	X					
Cynodon dactylon	X	X	X	X	X		
Digitaria eriantha	X	X	X	X			
Digitaria monodactyla	X	X					
Digitaria velutina	X	X					
Diheteropogon amplectens	X	X					
Diheteropogon filifolius	X	X					
Ehrharta calycina	X		X	X		X	
Elionurus muticus	X	X					
Eragrostis capensis	X	X		X			

Eragrostis curvula	X	X	X	X			
Eragrostis plana	X	X					
Eragrostis racemosa	X	X		X			
Eustachys paspaloides	X	X		X			
Festuca costata		X					
Festuca longipes		X					
Harpochloa falx	X	X		X			
Helictotrichon turgidulum	X	X		X			
Helictotrichon hirtulum	X	X	X	X			
Hyparrhenia hirta	X	X	X	X			
Imperata cylindrica	X	X		X			
Ischaemum fasciculatum	X	X					
Koeleria capensis		X		X			
Lagurus ovatus							
Melinis nerviglumis	X	X		X			
Melinis repens	X		X				
Miscanthus capensis	X	X		X			
Monocymbium ceresiiforme	X	X					
Panicum aequinerve		X					X
Panicum coloratum	X	X	X				
Panicum deustum	X						X
Panicum maximum	X		X	X			X
Paspalum dilatatum	X	X	X	X			
Paspalum notatum		X		X			
Pentaschistis pallida			X	X			
Setaria megaphylla	X	X			X		
Setaria nigrirostris	X	X					
Setaria pallide-fusca	X	X	X				
Sporobolus africanus	X	X		X			
Sporobolus fimbriatus	X	X	X	X			
Sporobolus virginicus	X		X	X	X	X	
Stenotaphrum secundatum						X	
Themeda triandra	X	X	X	X			
Tristachya leucothrix	X	X		X			
Total	43	43	17	28	3	2	3

Key
1 = Savannah; 2 = Grassland; 3 = Nama-Karroo; 4 = Fynbos; 5 = Desert; 6 = Coastal; 7 = Forest

As shown in Table 3.3.3.i, the majority of the grasses in the study area are common to the savannah and / or grassland biomes. Over 50% of the grasses are also located in the fynbos biome while a third occur in the Nama – Karroo. Three grass species occur in desert and fynbos biomes. Two are characteristic of coastal environments (*Stenotaphrum secundatum* and *Ehrharta calycina*).

3.3.3.2 Affinities between Eastern Cape Coastal Grassland species and southern African Grasslands

Affinities were determined between the Eastern Cape Coastal Grasslands and other southern African grasslands. This was based on the number of common, dominant or characteristic species shared between the associations found in this study and the communities described by various authors in Vegetation of South Africa, Swaziland and Lesotho (Low and Rebelo, 1996). The results are presented in Table 3.3.3.ii below.

Table 3.3.3.ii Table of Affinities between Eastern Cape Coastal Grasslands and the Vegetation of Southern Africa (after Lowe and Rebelo, 1996)

Grassland Community	Location	Affiliated Eastern Cape Coastal Grassland Associations	Author
Moist Clay Highveld Grassland (degraded forms) (35)	Southern Mpumalanga, 1 500 – 1 700m	2 *T. triandra* 8 *T. triandra – E. calycina*	Bredenkamp and van Rooyen, 1996a
Dry Sandy Highveld Grassland (37)	Western Free State to south-east of North-West Province	2 *T. triandra*	Bredenkamp and van Rooyen, 1996b
Moist Sandy Highveld Grassland (38)	Mpumalanga, 1 600 – 1 800m	2 *T. triandra* 4 *H. hirta – T. triandra* 6 *D. filifolius – E. calycina* 8 *T. triandra – E. calycina*	Bredenkamp and van Rooyen, 1996c
Moist Cool Highveld Grassland (undegraded form) (39)	Highveld: central and eastern Free State: southern and eastern Gauteng	2 *T. triandra* 8 *T. triandra – E. calycina*	Bredenkamp and van Rooyen, 1996d
Moist Cool Highveld Grassland (degraded form) (39)	Highveld: central and eastern Free State: southern and eastern Gauteng	4 *T. triandra – E. calycina* 7 *H. hirta – T. triandra*	Bredenkamp and van Rooyen, 1996e
Moist Cold Highveld Grassland (40)	North and north-eastern Eastern Cape: western Free State, 1 350 – 2000m	2 *T. triandra* 3 *H. hirta – D. amplectens* 4 *H. hirta – T. triandra* 8 *T. triandra – E. calycina*	Bredenkamp, van Rooyen and Lubke, 1996
Wet Cold Highveld Grassland (41)	Lower slopes of Drakensberg, +1 750m	3 *H. hirta – T. triandra* 4 *H. hirta – T. triandra*	Bredenkamp, van Rooyen and Granger, 1996a
Moist Upland Grassland (42)	Lower Drakensberg, Eastern Cape and Kwazulu-Natal: Amatola Winterberg Range	2 *T. triandra* 3 *H. hirta – T. triandra* 4 *H. hirta – T. triandra*	Bredenkamp, Granger, Lubke and van Rooyen, 1996a

		8 *T. triandra – E. calycina*	
South – Eastern Mountain Grassland (44)	Karroo uplands; north – western slopes of Great Escarpment	3 *H. hirta – T. triandra* 4 *H. hirta – T. triandra* (in part) 6 *H. hirta – T. triandra* 7 *H. hirta – T. triandra* 8 *T. triandra – E. calycina* 9 *S. africanus – S.sphacelata* 10 *C. dactylon – H.hirtulum*	Lubke, Bredenkamp and van Rooyen, 1996
Afro Mountain Grassland (45)	Drakensberg plateaux and slopes, 1 700 – 2 500m	1 *T. triandra – A.herbaceum* 2 *T. triandra* 3 *H. hirta – T. triandra* 4 *H. hirta – T. triandra* 8 *T. triandra – E. calycina*	Granger and Bredenkamp, 1996a
Short Mistbelt Grassland (47)	Kwazulu – Natal interior, 900 – 1 400m	2 *T. triandra* 3 *H. hirta – T. triandra* 4 *H. hirta – T. triandra* 8 *T. triandra – E. calycina*	Granger and Bredenkamp, 1996b
Eastern Mixed Nama Karroo (52)	Central Karroo	2 *T. triandra* 3 *H. hirta – T. triandra* 4 *H. hirta – T. triandra* 5 *S. secundatum – C.coriacea* 6 *H. hirta – T. triandra* 7 *H. hirta – T. triandra* 8 *T. triandra – E. calycina*	Hoffmann, 1996
West Coast Renosterveld (62)	Western Cape	1 *T. triandra – A.herbaceum* 3 *H. hirta – T. triandra* 4 *H. hirta – T. triandra* 6 *H. hirta – T. triandra* 7 *H. hirta – T. triandra* 8 *T. triandra – E. calycina* 9 *S. africanus – S.sphacelata*	Rebelo, 1996a
Grassy Fynbos (65)	Eastern half of Eastern Cape	2 *T. triandra* 3 *H. hirta – T. triandra* 4 *H. hirta – T. triandra* 6 *H. hirta – T. triandra* 7 *H. hirta – T. triandra* 8 *T. triandra – E. calycina*	Rebelo, 1996b

Table 3.3.3.ii indicates that there are strong affinities between the Highveld grasslands of the former Transvaal and Free State and the mesic and undisturbed xeric Eastern Cape Coastal Grassland associations, excluding the *T. triandra – A. herbaceum* association. The KwaZulu –

Natal and Eastern Cape grasslands show strong affinities for the same associations. The Karroo Upland grasslands show strong affinities for the xeric associations of the Eastern Cape Coastal Grasslands. The Nama-Karroo grasslands have affinities with all the Eastern Cape Coastal Grasslands except the *T. triandra* - *A. herbaceum* association and the ploughed xeric grasslands (*S. africanus* - *S. sphacelata* and *C. dactylon* - *H. hirtulum*). The Mixed Nama Karroo has a few grass genera in common with the Eastern Cape Coastal Grassland associations, and the presence of *Themeda triandra* and *Acacia karroo* are the strongest elements of affinity. These results support those of Table 3.3.3.i where the grasses of the study area are common to grassland, savannah and Nama-Karroo vegetation.

The affinities between the West Coast Renosterveld and mesic Eastern Cape Coastal Grassland associations lie in the grass understorey layer. However, the xeric Eastern Cape Coastal Grasslands show affinities to both the forb and grass components and overall have a greater affinity than do the mesic grasslands. Together with the Nama-Karroo grasslands, the West Coast Renosterveld enjoys the greatest affinity to associations of the Eastern Cape Coastal Grasslands. The Grassy Fynbos has affinities with the mesic and unploughed xeric grasslands but this is limited to the grass component only and not the forbs.

3.3.3.3 Comparison of families common to the Eastern Cape Coastal Grasslands and other grasslands of South Africa

Species which were common to grasslands in other studies carried out in South Africa were determined and are presented below in Table 3.3.3.iii. For a full list of species and references see Appendix 3

Table 3.3.3.iii Number of species of the Poaceae, Asteraceae, Fabaceae and other families common to major South African grasslands and the Eastern Cape Coastal Grasslands

	Study area total	**Eastern Cape ***	**Former Transkei**	**Western Free State**	**KwaZulu-Natal**	**Western former Transvaal**
Poaceae	60 (18%)	46	26	34	27	28
Asteraceae	41 (13%)	33	3	11	8	4
Fabaceae	40 (12%)	25	1	4	3	4
Other families	184 (56%)	112	10	35	22	18
Total number of common species	325 (100%)	216 (66%)	40 (12%)	84 (25%)	60 (18%)	54 (16%)

(see Appendix 3 for full list)

* (excluding the present study)

The overlap between species of the Asteraceae and Fabaceae families was much lower than for the Poaceae in all grasslands except for those of the Eastern Cape. Within the Eastern Cape Coastal Grasslands, the Poaceae, Fabaceae and Asteraceae constitute 75% of the families present. The high occurrence of species of the Fabaceae and Asteraceae is not common to other grasslands, and is a feature of the Eastern Cape Coastal Grasslands which separates it from other South African grassland types. Goldblatt (1978) shows that the largest family of the Cape Flora Kingdom is the Asteraceae, with Fabaceae the fifth largest, giving an indication of affinity between the Fynbos vegetation and Eastern Cape Coastal Grasslands.

Examination of studies of the Eastern Cape show that it has the highest number of species in common with the Eastern Cape Coastal Grasslands, followed by the Western Free State. Kwazulu - Natal , the former Transvaal and Transkei have less than half the number of Poaceae in common. KwaZulu - Natal has less than 25% of the same species of Asteraceae and less than 12% of the same Fabaceae, while the former Transvaal shares less than 12% of either of these families.

The small number of species in common with the grasslands of KwaZulu-Natal may be because most of the Natal grassland articles examined are located on or near the Drakensberg Mountains. The former Transkei has extremely low numbers of Asteraceae and Fabaceae in common. The small number of species common to the Transkei may be strongly influenced by the small number of studies with which this study could be compared: the only literature available was that of

McKenzie (1984), Feely (1987) and Shackleton (1989), which list only dominant and common species. Since dominant and common species are usually grasses, many of the forbs would have been omitted. The small number of common species is therefore probably due to the lack of available data on species diversity in the grasslands of the former Transkei.

The abundance of grasslands in the Highveld which have affinities with the mesic and undisturbed xeric grasslands is partly due to the widespread occurrence of the common grass species, e.g. *Themeda triandra*, *Setaria sphacelata*, *Elionurus muticus*, *Eragrostis plana* and *Cynodon dactylon*. Within the forb component, several genera are common e.g. *Berkheya*, *Crabbea* and *Anthospermum*. The Free State and Kwazulu – Natal grasslands tend to be "sourveld" and the abundant grasses are common to higher rainfall areas e.g. *Hyparrhenia hirta*, *Cymbopogon* spp., *Harpochloa falx* and *Elionurus muticus*; thus their affinities are mainly with the mesic grasslands. There are more affinities between the Eastern Cape Coastal Grassland associations and the Karroo vegetation than with any other vegetation classified by Low and Rebelo (1996) except the West Coast Renosterveld. Many grasses are common e.g. *T. triandra*, *Ehrharta calycina* and *Helictotrichon hirtulum*, as are several forb genera. The Karroo grasslands include grasses found only in the xeric Eastern Cape Coastal Grassland associations as well as those occurring throughout the study area, but not those limited to the mesic grasslands. These results reflect the spatial proximity of mesic and xeric associations to other grasslands within South Africa. In addition they highlight the influence of climate, with xeric associations occurring in areas where rainfall and temperature regimes are similar to those of the Western Cape.

The study area falls within the region of convergence of five major phytochoria which has resulted in the formation of a tension zone (Gibbs – Russel and Robinson, 1991; Lubke and de Moor, 1998). The fairly high percentage overlap shown between the grass species of four of these phytochoria illustrate the fact that the study area is indeed a part of this convergence zone. It is to be expected that there is a high overlap between the occurrence of grass species found in the Eastern Cape Coastal Grasslands and in the savannah and grassland biomes of South Africa (Table 3.3.3.ii). No grasses were limited to the study area, and those that are endemic to South Africa were endemic to at least two of the biomes (Gibbs – Russel *et al.*, 1991). However, the high occurrence of species common to the fynbos is surprising and highlights the importance of this flora within the study area. The results may indicate the extreme eastward limits of distribution of those members of the fynbos vegetation.

3.3.3.4 Affinities between the Eastern Cape Coastal Grasslands and the Phytochoria of Africa

The affinities between the species of the Eastern Cape Coastal Grasslands and White's (1983) phytochoria were examined in order to determine the affinities between the Eastern Cape Coastal Grasslands and the African flora. Only those phytochoria which had more than 5 genera and / or species in common with those of the study area are shown below.

Table 3.3.3.iv Species affinities between the Eastern Cape Coastal Grasslands and African Phytochoria as defined by White (1983)

Phytochorological region	Genera common to study area	Species common to study area
Kalahari Highveld Regional Transitional Zone	20	19
Karroo–Namib Region	26	2
Tongoland – Pondoland Regional Mosaic	6	6
East Malagasy Regional Centre of Endemism	8	5
Somali – Masai Regional Centre of Endemism	12	4

(see Appendix 3 for full table)

Table 3.3.3.iv above shows that the greatest overall affinity exists between the Kalahari Highveld Regional Transitional Zone, which shares 20 genera and nineteen species with those recorded in the Eastern Cape Coastal Grasslands. The Karroo - Namib Region follows, with 26 genera in common but only two species. The Tongoland – Pondoland Regional Mosaic, in which White classified the study area, has the lowest affinity of the five phytochoria presented, sharing only six genera and six species, probably because White (1983) considers forest to be the climax vegetation for this region. Consequently there may have been serious undersampling of the grassland component of this region. This highlights the difficulties faced when trying to compare vegetation sampled at different scales. Both the Somali – Masai Regional Centre of Endemism and the East Malagasy Regional Centre of Endemism have a greater degree of affinity with the Eastern Cape Coastal Grasslands than does the Tongoland – Pondoland Regional Mosaic.

3.4 CONCLUSIONS

The Eastern Cape Coastal Grasslands have been divided into two major groupings using TWINSPAN, namely the mesic grasslands in the eastern half of the study area and the xeric grasslands in the western half. The grasslands appear to differentiate at the Keiskamma River. Within the mesic grasslands, the *Themeda triandra - Anthospermum herbaceum* association is clearly different from the other associations as shown in Table 3.3.2.1 while the *Stenotaphrum secundatum - Centella coriacea* association is the most disturbed mesic association. The *Themeda triandra - Ehrharta calycina* association is the most undisturbed of the xeric grasslands and the *Cynodon dactylon - Helictotrichon hirtulum* association represents the most severely disturbed association.

The xeric grasslands in the western half of the study area can be divided into two main categories: ploughed and unploughed. The *Diheteropogon filifolius- Ehrharta calycina*, *Cynodon dactylon - Ehrharta calycina* and *Themeda triandra - Ehrharta calycina* associations are not known to have been ploughed while the *Sporobolus africanus - Setaria sphacelata* and *Cynodon dactylon - Helictotrichon hirtulum* associations have been. In the less disturbed communities, *T. triandra* is the most important climax grass, with *Cynodon dactylon* being the most important in the disturbed associations. The least disturbed grassland association is the *Themeda triandra - Ehrharta calycina* association which has the species richness in the xeric associations. This association is thought to be the closest approximation to the vegetation of the xeric grasslands under optimal management conditions. Of the previously ploughed vegetation, the *Sporobolus africanus - Setaria sphacelata* association is the less degraded, having had a longer recovery period than the *Cynodon dactylon - Helictotrichon hirtulum* association. The latter association is the most disturbed association the xeric grassland vegetation.

As Gibbs – Russel and Robinson (1991) state, the climate and ecology of the Eastern Cape is representative of many different parts of Southern Africa, and this is reflected in the affinity tables of section 3.3.3. The closer affinity between the Eastern Cape Coastal Grasslands and the Kalahari Highveld regional Transitional Zone highlights the fact that the coastal grasslands represent the eastern, western and southern extremes of distribution of species from the Karroo, Fynbos and Tongoland – Pondoland vegetation types. The Eastern Cape Coastal Grasslands are thus part of the phytochorological tension zone described by Lubke and de Moor (1998).

With regard to the African flora, despite the fact that White (1983) describes the study area as being part of the Tongoland – Pondoland Regional Mosaic, of all five phytochoria with which the

Eastern Cape Coastal Grasslands were compared this has the lowest species affinity (for a full list of comparisons, see Appendix 4). In keeping with the literature, the highest affinity appears to be between the Eastern Cape Coastal Grasslands and the Kalahari Highveld Regional Transitional Zone. This is expected since the Transitional Zone occurs over the areas of the Free State and western former Transvaal (White, 1983, p 192); thus the overlap is in keeping with the results obtained in Table 3.3.3.iv. The high number of genera in common with the Karroo – Namib region concurs with the results shown in Table 3.3.3.i, where 33% of grass species found in the study area also occur in the Nama – Karroo and 54% occur in the Fynbos. Most unexpected of all was the very low degree of commonality between the species of the Tongoland – Pondoland Regional Mosaic, in which White (1983) categorises the Eastern Cape Coastal Grasslands. Even the East Malagasy and Somali - Masai Regional Centres of Endemism have more species and genera in common with the Eastern Cape Coastal Grasslands than does the Tongoland – Pondoland Regional Mosaic. One of the main reasons for this may be the fact that White records mainly the dominant species within a vegetation type, and the Tongoland – Pondoland Regional Mosaic was considered more as a woodland type than a grassland vegetation. This is also the case with Acocks' (1953) work, where he records the vegetation as being of a Thornveld type (Eastern Province Thornveld). As both Goldblatt (1978) and Werger (1978) point out, the geographical distinctions between White's (1983) phytochoria in Southern Africa are difficult to determine and this is especially true in the Eastern Cape where four major regions converge.

4.THE EFFECTS OF SOILS AND MANAGEMENT ON THE DISTRIBUTION OF GRASSLAND ASSOCIATIONS WITHIN THE EASTERN CAPE COASTAL REGION

4.1 INTRODUCTION

The structure and dynamics of any ecosystem are governed by the complex interactions of soils, climate, animal and human impact; grasslands are no exception. In some cases a single factor can determine the functioning of an ecosystem, but all factors will play some role. In grasslands, the most significant factors are usually rainfall, organic matter, and disturbance (Bredenkamp *et al.*, 1983; O'Connor, 1985; Barnes *et al.*, 1991; Heitschmidt *et al.*, 1995; Perez Corona *et al.*, 1995; Rodriguez *et al.*, 1995).

According to Bruce *et al* (1995) the factors which determine the productivity of an ecosystem can be divided into two main categories. These are the "Inherent" category, which includes climate and soil, and the "Cultural" category, which includes the crops and animals which utilise the environment. For the purposes of this study, I have included grazing, trampling and disturbance caused by urban development as "Cultural" factors.

In South Africa mean annual precipitation generally increases in a southwest-to-northeast direction across the country (excluding the winter rainfall area of the Western Cape). Within the study area it has been shown that the western half is drier than the eastern half (see Chapter 2) (Schultz and McGee, 1978; Kopke, 1988). Studies within other grassland and savannah areas in Southern Africa have shown the importance of rainfall in the composition of annual and perennial grasses as well as herbaceous species (O'Connor, 1985; Barnes *et al.*, 1991; Steenkamp and Bosch, 1995). In the United States, Jenny (1980) has shown that the amount of biomass produced by grasslands increases with increasing moisture.

Soil factors are of great importance in determining plant communities. O'Connor (1985) indicates that soil type in combination with climatic conditions determine the floristics of savannah systems. The most important soil factors include texture, organic content and the macroelements nitrogen, phosphorus, potassium, calcium, magnesium and sodium (Jenny, 1980). The organic content of soils plays four major roles: firstly, it contains the macroelements described above. Secondly, it acts as a sponge, holding nutrients in solution as well as water for plant uptake. Thirdly, it encourages root development and soil aggregation, and lastly it increases the infiltration rate of water (Kelly and Walker, 1976; du Preez and Snyman, 1993). In addition organic matter provides a niche for soil micro-organisms which are instrumental in releasing elements for plant uptake. As the soil organic matter influences vegetation, so vegetation influences organic matter and the amount of organic matter present can indicate how well developed the vegetation is (Tisdall, 1991; Bruce *et al* 1995).

The macroelements listed above are important as each one, if present at too low a concentration, can be a growth limiting factor. Nitrogen is used for protein synthesis. Phosphorus is involved in energy transfer via phosphorylation and potassium is responsible for the translocation of organic molecules and the mechanism controlling stomatal opening. Calcium stabilises macromolecular chains and magnesium is the most important component of chlorophyll as well as being a cofactor for many enzyme reactions. Magnesium is also an important enzyme cofactor. Where the levels of calcium and sodium are excessively high in the soil, they can become detrimental, damaging root structure and inhibiting growth. This is usually the case in drier regions; where there is high rainfall, leaching can take place, causing nutrient deficiencies. In addition, pH plays an important role as it affects the availability of certain micro and macronutrients for uptake by the plant. Soils with a pH of 5 to 6 are described as fertile, while those of pH8 are usually calcareous and effectively have a lower nutrient status (Jenny, 1980).

Another inherent factor affecting ecosytems is aspect. The degree of insolation affects grasslands in that certain grasses favour the cooler southern slopes while others prefer warmer northern aspect environments. In addition, the dominant winds are from the south-east and south-west, and as well as bringing moisture they also carry salt. Thus communities occurring on southern aspect slopes are more likely to require some degree of salt tolerance. Distance from the coast and the land-sea interface will also affect the degree to which salt spray affects vegetation, as communities behind coastal forest will be more protected than those which occur just above a rocky shore. The further the distance from the shoreline, the less will be the impact of salt spray.

Man's impact in terms of land-use and the alteration of animal utilisation of vegetation play a significant role in determining the presence, distribution and abundance of plant species. The primary effect of pastoralism is the replacement of a diverse group of browsing and grazing species by two or three different species, namely cattle, sheep and goats (Chirara *et al.*, 1998; Hoffman, 1997.). Cattle and sheep are grazers rather than browsers, while goats graze and browse. Grazing is regarded as a major factor in determining grassland species composition both in South Africa and worldwide (Fleischer, 1994; Hurt *et al.*, 1993; Noy-Meir *et al.*, 1989). Cattle and sheep are "selective grazers" i.e. they graze preferred species first and most heavily, only grazing less palatable species as the abundance of preferred species decreases. In general the view held on grazing is that it has a negative impact on preferred, or palatable, species while enhancing the growth of unpalatable species. This results in the loss of biodiversity and often a decrease in population densities which in turn produces a degraded environment (Acocks, 1966; 1988; Fuls, 1992; Fleischner, 1994; Hardy, 1995; Kirkman, 1995; Kirkman and Moore, 1995; O'Reagain and Grau, 1995). Grazing is believed to be partly responsible for the encroachment of woody species such as *Acacia karroo* in many areas which were formerly grassland (Chirara *et al.*, 1988; Hoffman, 1997.). Livestock also alter vegetation indirectly by trampling and changing the nutrients available to the soil through the excretion of dung and urine (Gibson, 1988, Fleischner, 1994; Gross *et al* 1995). In addition, compaction caused by trampling and the removal of vegetation cover through grazing causes an increase in runoff and a decrease in infiltration of rainwater (Fuls, 1992; Bari, 1993; Mworia *et al.*, 1997).

The importance of rainfall in assessing the effect of pastoralism appears to be critical. Season of grazing, stocking rates and grazing system are all important but the overriding factor controlling the direction of change in grazed grasslands appears to be the rainfall regime (Danckwerts and Barnard, 1981; O'Connor, 1985; 1991; 1993; 1994; Frost *et al.*, 1986; Westoby, Walker and Noy-Meir 1989 ; Barnes, 1990; Mworai *et al.*, 1997). The life history of the dominant grasses and their different responses to environmental stress as well as the initial species composition of a grassland are also important in determining the response of the association to grazing (van Rensburg, 1942; Nel, 1974; Vorster, 1975; Drewes and Tainton, 1981; Gibbs-Russel, 1983; Nel *et al.*, 1983, 1993; O'Connor, 1985, 1994; Everson *et al.*, 1988; Hardy and Hurt, 1989; Janse van Rensburg and Bosch, 1990; Hurt *et al.*, 1993).

The most severe disturbance that man can inflict on the environment is to plough the vegetation up or clear it with machinery such as a bulldozer which effectively disrupts the plant – soil interface. In the western half of the study area, a large percentage of the original grasslands were ploughed up to plant pineapples, but as the market dwindled and the soils became leached, the fields were abandoned. Some were planted to pasture, others merely allowed to revert to grassland. In the eastern half of the study area ploughing did not occur, probably due to the steeper topography. However, this area is far more intensively settled with holiday homes increasing in number every year. This has led to increased soil compaction by vehicles as well as pedestrians and interference with surrounding land by developers. These two impacts are regarded as having the most severe impact on the environment.

The aim of this chapter is to link the environmental factors described above with the vegetation associations which were determined in Chapter 3. Using computer programmes the effect of each factor in both the mesic and xeric grasslands is assessed to determine which factor or group of factors has the greatest impact in determining the structure and dynamics of the grasslands. This will enable one to infer the possible effects of certain impacts on an association and ultimately to provide management guidelines for the grasslands, particularly those which fall under the protection of Cape Nature Conservation.

4.2 METHODS AND MATERIALS

4.2.1 Sampling

The method by which the vegetation was sampled has been described in Chapter 3.Corresponding soil samples were taken from each sample unit and site factors such as aspect and land-use history were recorded. Soil samples from each vegetation sample unit were analysed for pH, conductivity organic matter content and soil family. Having classified the sample units as described in Chapter 3, half of the soil samples from each vegetation association and subassociation were analysed for cation content. The soil from every second sample unit of each association and subassociation was used for this analysis.

4.2.2 Soil family and analysis

In order to analyse the edaphic factors soil samples were taken of the A and B horizons from the centre of each quadrat in the study. The depth of the A horizon was determined and where possible, that of the B horizon as well. The colour of each horizon was recorded using Munsell charts. Based on the colour and texture of the A and B horizons, the soil family for each sample was determined using the standard South African reference (McVicar *et al.*, 1991).

Soils from the top of the A horizon were put into plastic bags and sealed before being taken back to the laboratory where they were sieved and air-dried prior to analysis. Soils were prepared for pH and conductivity analysis by suspending 10g of soil in 100ml of distilled water and shaking for an hour. The water was filtered and the filtrate analysed. The pH was recorded using a Sentron 1001 pH meter and conductivity was recorded with a Zeiss dds 200 conductivity meter.

To determine the organic matter content, approximately 10g of air-dried, sieved soil was weighed out into a crucible and placed in a Gallenkamp muffle furnace at 400° C for at least 12 hours. The sample was then re-weighed and the percentage of organic matter burnt was calculated.

Cation content was determined by sending samples to Dohne Research Station and analysing for phosphorus, potassium, calcium and magnesium. For each grassland association, the mean values of soil pH, conductivity, % organic content and cations were determined, as well as the most common soil family.

4.2.3 Utilisation of grassland associations in terms of recreation / agriculture

During the course of sampling the area, landowners and managers were asked about known land-use history as well as current farming practices. In this way grazing and some of the burning practices in the commercially farmed and nature reserve areas were determined. Unfortunately, no grazing or management history was available for the communally-farmed areas. Satellite images and maps were examined for signs of ploughing. Where ploughing had taken place, the time at which it had started and when this practice was discontinued were in some cases known by the current landowner. This information was then used to analyse the human impact on the floristics of the study area.

The human impact on each sample site was given a score depending upon what the land was being used for at the time of sampling and past land-use practices. Nature Conservation areas which are affected only by human traffic, have never been ploughed and are not grazed in anyway were described as "pristine" and given the lowest score (1). Grasslands on the periphery of urban areas which have been disturbed by developers and are subject to severe trampling and / or grazing were given the highest score (11).

Table 4.2.i Land-use impact scores

Land-use impact	Score
Nature conservation area, human trampling	1
Nature conservation area, cattle grazing	2
Commercial farming, cattle grazing	3
Commercial farming, cattle and goat grazing	4
Parastatal farming, cattle grazing	5
Communal rangeland, cattle grazing	6
Commercial farming, ploughed +40 years ago, cattle grazing	7
Parastatal farming, ploughed +30 years ago, cattle grazing	8
Nature conservation area, ploughed 20 years ago, cattle grazing	9
Communal rangeland, ploughed 20 years ago, cattle grazing	10
Urban disturbed areas	11

4.2.4 Effect of salt spray and land/sea interface

The effect of salt spray could not be determined using conventional methods since it was not possible to set up salt spray traps along the coastline simultaneously. However, the proximity of each community to the shoreline was determined from maps and recorded to within the nearest 10m. From the fieldwork, an additional factor which appeared to play a role in vegetation distribution was land/sea interface. Five different interfaces were determined and scored ranging from most sheltered (1) to that which offers the least protection (5):

Table 4.2.ii Land/sea interface scores

Interface	Score
Grassland behind coastal forest facing a sandy shore	1
Grassland above a rocky/sandy shore with patches of coastal forest	2
Grassland above a rocky/sandy shore	3
Grassland above a rocky shore with patches of coastal forest	4
Grassland above rocky shore	5

4.2.5 Aspect

The aspect of each sample site was recorded. In addition to the effect of insolation, aspect can play a role in determining the degree to which communities are exposed to wind, salt spray and moisture in the form of fog. Since the prevailing winds are south-easterly and south-westerly, these aspects were given the highest rating, while the north-east and north-west aspect was given the lowest rating as they are considered to be milder than the directly north-facing slopes.

Table 4.2.iii Aspect scores

Aspect	Score
North-east, north-west aspect	1
North aspect	2
East, west aspect	3
South aspect	4
South-east, south-west	5

Because of the large data set, analysis was not carried out for the entire study. Instead the mesic associations were analysed together and the xeric associations were analysed together. There are mesic samples and xeric samples.

4.2.6 Data analysis

Since the analyses of cation content had been carried out only for a subset of the entire sample set, the average value per association was determined for phosphate, potassium, calcium and magnesium. Average values of pH, conductivity and organic content for each association as well as the predominant soil family were also calculated. The results are given in Table 4.3.1. These results were not used in canonical ordination, but were utilised in discussion of each community.

Direct and indirect ordination was carried out on the remaining data. The mesic and xeric associations were analysed separately because of the large sample numbers and complexity of the data. A total of 194 mesic samples were used and 134 xeric samples. Indirect ordination was based on the species scores for each sample. For direct ordination, nine environmental variables were used per sample, these being pH, conductivity, percentage organic content, depth of soil A horizon, soil family, land-use, distance from the shore, land/sea interface and aspect.

4.2.7 Ordination of grasslands in relation to soil characteristics

The data matrix of samples and species was subjected to ordination programmes in order to assess the presence (if any) of underlying ecological gradients. Initial analysis was carried out using DECORANA, or DEtrended CORrespondence ANAlysis which is an indirect gradient technique used without any quantified environmental variables (Hill, 1979b). Since DECORANA allows indirect gradient analysis, one does not have to determine the most important ecological variables before carrying out a vegetation study. This enables the researcher to carry out studies without a set of preconceived ideas that may result in unnecessary studies or the omission of vital factors. Ordination is most valuable for those community studies where there is no prior information and is ideal for exploratory analyses. In addition, the use of DECORANA places the results of this vegetation study in a framework comparable with many of the vegetation studies that have been carried out recently in South Africa by authors such as Bredenkamp *et al.* (1989).

The second analysis was carried out using a direct gradient technique, DCCA, or Detrended Canonical Correspondence Analysis. This is used when there are known environmental variables for each sample. In the DCCA output, the ordination axes are "constrained to be linear combinations of supplied environmental variables"; hence the term canonical is used. The regression coefficient for each environmental variable is determined from the analysis and is used to indicate the degree of variation accounted for by that particular factor (Hill, 1979b). It is accepted that there are environmental gradients other than those used in this study and that there may be other important gradients which are therefore not being recognised (Økland, 1996).

Both DECORANA and DCCA have evolved from reciprocal averaging and are improvements on the latter type of ordination because the detrending aspect avoids the arch effect arising from a strong relationship between the first and second axes of ordination. While the first axis is determined by reciprocal averaging, the arching effect is avoided because there is no systematic relationship at all between this axis and any higher axes (Hill, 1979b).

The second problem in reciprocal averaging is that scaling of the axes is not uniform and commonly the ends of an axis are contracted (Hill, 1979b). This is also referred to as the "edge effect" (ter Braak and Prentice, 1988). In detrended programmes rescaling takes place so that the scale is more uniform over the entire length of the axis. This is done by expanding the areas on the axis with a low standard deviation (because of low sample scores) and contracting those with a high standard deviation in an effort to attain an average standard deviation throughout the samples (Hill, 1979b; ter Braak and Prentice, 1988).

A number of authors, including Minchin (1987) and van Groenewoud (1992), have questioned the robustness of DECORANA particularly when the sample pattern is random and the species response curves are complex. Minchin (1987) objects that the gradient which should be highlighted by ordination is determined after running the programme as opposed to being clearly defined beforehand. This indicates that distortions by DECORANA itself must be considered, while van Groenewoud (1992) states that DECORANA illustrates only the strongest vegetation gradient if the effects of subsequent gradients are very small. When a second gradient was introduced, recovery of the first gradient was weaker than when the first gradient alone was used.

In response to Minchin's (1987) work, ter Braak and Prentice (1988) have said that the data should be "reasonably representative of sections of the major underlying environmental gradients". They state categorically that for the ordination process to work, one must simplify the species response curves and assume all follow unimodal, Gaussian-type response curves and that there is a single set of common environmental variables (ter Braak and Prentice, 1988). Through mere observation it is not always possible to elucidate the presence of environmental gradients in restricted areas but major gradients can usually be determined from *a priori* knowledge such as land-use patterns and rainfall. In the present study these factors were known when sampling was carried out; thus the sampling was aimed at being as representative as possible. In addition, data was analysed in subsets rather than as a complete whole since the environmental gradients would have been too conflicting.

Two further improvements proposed by ter Braak and Prentice (1988) are the use of detrending by polynomials instead of segments to remove the arch effect by a less rigorous degree, and dropping the non-linear rescaling where the edge effect does not appear to be too serious. In this study the detrending analyses were carried out using second order polynomials. This results in the axes being uncorrellated with both the previous axes and the polynomials of those axes. The result is to remove the arch effect without distorting or removing other environmental gradients.

Non-linear rescaling may also distort variation because of underlying gradients, and ter Braak and Prentice (1988) "advise against the routine use of non-linear rescaling". Originally it was devised to reduce the edge effect but if this is not perceived as a major problem then the option can be omitted. Non-linear rescaling was accordingly not carried out in the analyses of the data set in the present study.

Tausch *et al.* (1995) also indicate problems with DCA in that there is variation in results if the order of data input is altered. These authors indicate that axes one and two show the least amount of variation and accordingly only these two axes were used for results. Oksanen and Minchin (1997) recommend that CANOCO should be updated and produced with more strict requirements for the convergence of data points, such as a tolerance level of 0.000005. Some samples were removed from analysis on account of their outlying positions on the ordination axes and this may contribute to displacing the rest of the sample points. Despite these considerations it was felt that using DCA placed the results in a comparable light with respect to other vegetation studies carried out in South Africa (e.g. Bredenkamp *et al.*, 1983; Cilliers and Bredenkamp, 1999a; 1999b).

4.3 RESULTS AND DISCUSSION

4.3.1 Analysis of soils

Soil analyses include the pH, conductivity, and percentage organic content for each sample in the study area. The average values per factor per association are given in Table 4.3.1 below. A subset of each association was analysed for phosphate, potassium, calcium and magnesium content and the average values per association are also given in Table 4.3.1. Finally, the predominant family in each association is listed, having been deduced from all the samples within an association.

Mr Jimmy Mullins, formerly of the Soils Department within the Department of Agriculture, aided the assessment of the soil analysis by providing a "rule of thumb" formula for assessing the available potassium within a soil sample. The formula is as follows:

$$\text{Cation ratio} = \frac{K + Ca + Mg}{K}$$

Where cation ratio is <5, K is freely available

>5, K is less available

>10, K is deficient

The results of applying the formula are also presented in Table 4.3.1 below

Table 4.3.1 Soil Factors

Association Factor	**1**	**2**	**3**	**4**	**5**	**6**	7	**8**	**9**	**10**
pH	6.4	6.5	5.8	6.1	6.4	6.9	7	7	6.8	7.2
Conductiv. µm/cm	3050	594	426	1548	4291	2355	859	1275	1517	1225
% Organic	20	10	3	9	15	4	3	5	9	4
Ca mg/l	1816	1492	635	1144	2693	1558	399	1753	1119	2109
Mg mg/l	527	345	1299	370	327	664	495	819	458	642
P mg/l	10	10	6	12	15	8	3	11	18	12
K mg/l	345	177	123	177	345	106	108	134	276	188
Avail. K	7	11	17	10	10	22	9	20	6	16
Predominant Family	Mispah	Katspruit/ Fernwood	Fernwood	Katspruit/ Fernwood	ND	Fernwood	Fernwood	Clovelly	ND	Hutton

Key

Mesic

1 = *T. triandra – A. herbaceum* association
2 = *T. triandra* association
3 = *H. hirta – D. amplectens* association
4 = *H. hirta – T. triandra* association
5 = *S. secundatum* association

- **ND = no dominant family**

Xeric

6 = *D. filifolius – E. calycina* association
7 = *C. dactylon – E. calycina* association
8 = *T. triandra – E. calycina* association
9 = *S. africanus – S. sphacelata* association
10 = *C. dactylon – H. hirtulum* association

As shown in Table 4.3.1, the pH ranges from more acidic in the mesic grasslands to almost neutral or more alkaline soil recorded in the xeric grasslands. The mesic associations would therefore be more fertile than the xeric associations (Jenny, 1980). Conductivity shows an enormous range with the highest level recorded in the disturbed mesic *S. secundatum* association. This association occurred in environments which had been severely disturbed and which were often in close proximity to the coast. The *T. triandra – A. herbaceum* association which occurs just above the cliff face at Morgan's Bay and Double Mouth had the next highest recorded conductivity. The lowest values were recorded in the *H. hirta – D. amplectens* association.

The percentage organic content in the grasslands range considerably from 20% in the *T. triandra - A. herbaceum* association to 3% in the *Hyparrhenia hirta – Diheteropogon amplectens* association. The organic content never exceeded 10% in the xeric grassland associations. The high percentage organic content in the *Themeda triandra - Anthospermum herbaceum* association can be attributed to several factors. First, the vegetation is not subject to grazing and despite having low species richness it has a high vegetation in the form of grasses (see Chapters 3 and 5). The fact that the vegetation is not being removed increases the amount of dry matter available for incorporation into the soil and hence the high levels recorded in this association. Despite the *Themeda triandra* association occurring within Nature Conservation areas, it had usually been subjected to burning within the two years prior to sampling, thus the association had less organic matter in the soil.

The low level of organic matter in the *Hyparrhenia hirta - Diheteropogon amplectens* association reflects the land-use status of the vegetation, i.e. that it is grazed. The association has the lowest cover abundance because of the grass species of the mesic associations (see Chapter 5) and there is a correspondingly low level of litter. The association may be subject to more intensive land-use than the remaining mesic associations. The low levels of organic matter in the xeric associations is possibly due to the lower rainfall experienced by those areas in which they occur (see Chapter 2). In addition, the *Diheteropogon filifolius - Ehrharta calycina, Cynodon dactylon – Ehrharta calycina* and *Themeda triandra – Ehrharta calycina* associations are all subject to grazing. It is interesting to note that the *Themeda triandra – Ehrharta calycina* association, which is subject to lighter stocking than the other two associations, has only 2% more organic matter than the most severely grazed *Cynodon dactylon - Ehrharta calycina* association.

Although the *Sporobolus africanus* – *Setaria sphacelata* association is a secondary grassland with the lowest cover abundance of grass species in the xeric vegetation, it has the highest soil organic matter of the xeric associations (see Chapter 5). This may well be because very little grazing of this grassland occurs (Mr Fick, pers. comm.), so that the organic matter has been built up over time.

Cation analysis of the soils indicated that the levels of calcium and magnesium in the soils are high according to the standards given for the South African Agricultural Services. These elements are certainly not limiting. Excess calcium decreases the uptake of potassium (Jacob and von Uexküll, 1960), hence its use in the formula defining available potassium. This effect is seen in the resultant available potassium levels in the various associations. While potassium levels were average to high, the available potassium was limiting in the *Themeda triandra*, *Hyparrhenia hirta* – *Diheteropogon amplectens*, *Hyparrhenia hirta* – *Themeda triandra*, *Stenotaphrum secundatum* and *T. triandra* – *E. calycina* associations (Mr Jimmy Mullins, pers. comm.).

Phosphate levels are low for the *Hyparrhenia hirta* – *Diheteropogon amplectens*, *Diheteropogon filifolius* – *Ehrharta calycina* and *Cynodon dactylon* – *Ehrharta calycina* associations. Although most soils tend to be naturally deficient in phosphorus, low levels may be exacerbated by the grazing pressure affecting these associations. Since phosphorus is concerned with cell division it is usually concentrated in actively growing shoot tips, which are also the most palatable to domesticated livestock. Acidity further reduces the availability of phosphorus (Woodhouse, 1969). Analysis of the soil factors suggests that the majority of the soils in the study area are phosphorus-deficient and soils of the *Hyparrhenia hirta* – *Diheteropogon amplectens* association in particular are both potassium and phosphate deficient.

Within the study, eleven different soil families were identified but ultimately only five proved to be present in the majority of samples within associations. The Fernwood family was most common, particularly in the mesic grasslands, while there was no clearly dominant family in the highly disturbed *Stenotaphrum secundatum* and *Sporobolus africanus* – *Setaria sphacelata* associations.

4.3.2 Ordination of mesic and xeric grassland associations

Indirect gradient analysis to show ordination of the samples based on the species scores was the first ordination carried out. This was followed by direct gradient analysis where ordination of the samples using nine of the factors described in Methods (above) was carried out. As previously stated, the mesic and xeric associations were analysed separately because of the large and complex data set.

4.3.2.1 Indirect Gradient Analysis (Detrended correspondence analysis)

4.3.2.1.a Mesic grasslands

As shown in figure 4.3.2.1.a below, the mesic grasslands were not easily separated by DECORANA, and many sampling units had identical scores. The T. *triandra – A. herbaceum, T. triandra, H. hirta - D. amplectens and H. hirta - T. triandra* associations form a complex with one subset of the *T. triandra* association and one of the *H. hirta – T. triandra* association. The highly disturbed *S. secundatum* association is the only one which separated from the remaining associations, and it can be inferred that the separation was on a disturbance gradient.

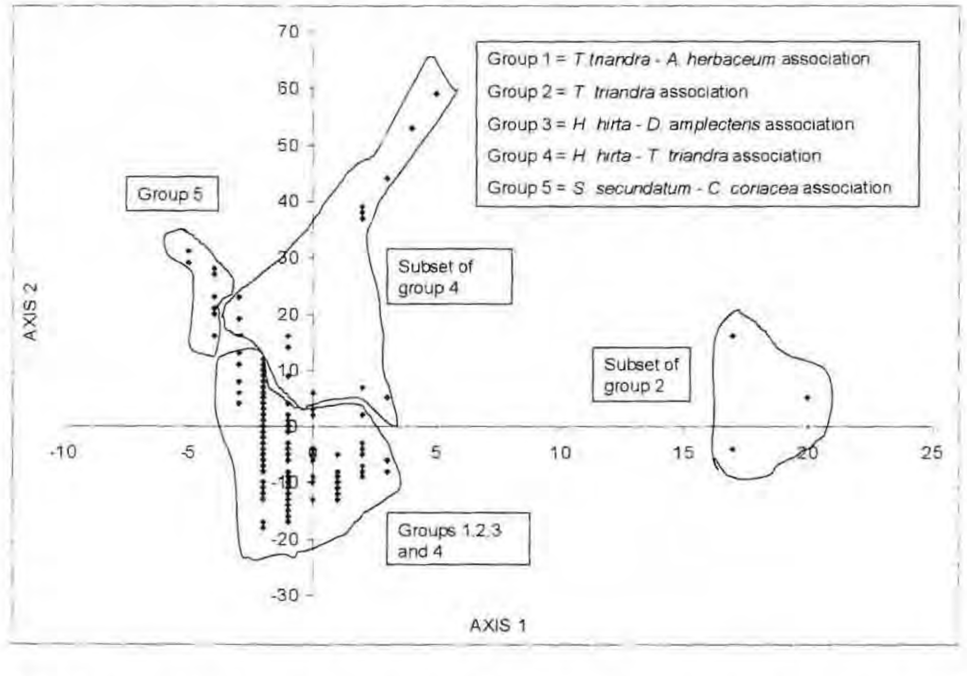


Figure 4.3.2.i.a Results of indirect ordination of mesic grassland associations using DECORANA

It is difficult to deduce the separation responsible for the subset of the *T. triandra* association, but as the subset is positioned at the opposite edge of the graph from the *S. secundatum* grouping, this implies that the vegetation in these samples reflects the least disturbed environment. No distinguishing feature could be determined for the subset of the *H. hirta* - *T. triandra* association. A number of samples had identical results, and the difficulty in separating the first four associations reflects the close similarities between them.

4.3.2.i.b Xeric grasslands

The xeric grasslands were clearly separated along a disturbance gradient by DECORANA (Figure 4.3.2.i (b). The least disturbed association is the *T. triandra* – *E. calycina* association, and the samples in this association were closely grouped together. The *D. amplectens* and *C. dactylon* – *E. calycina* associations were never physically disturbed by ploughing but were subject to grazing. The grazing impact was lower in the *D. amplectens* - *E. calycina* association and this is shown by the close grouping of samples as well as the position on the graph. The grazing impact was less controlled in the *C. dactylon* – *E. calycina* association and likely to have been higher and this is illustrated by the wider spread of the samples and the fact that some were located in close proximity to the more disturbed *S. africanus* – *S. sphacelata* and *C. dactylon* - *H. hirtulum* associations.

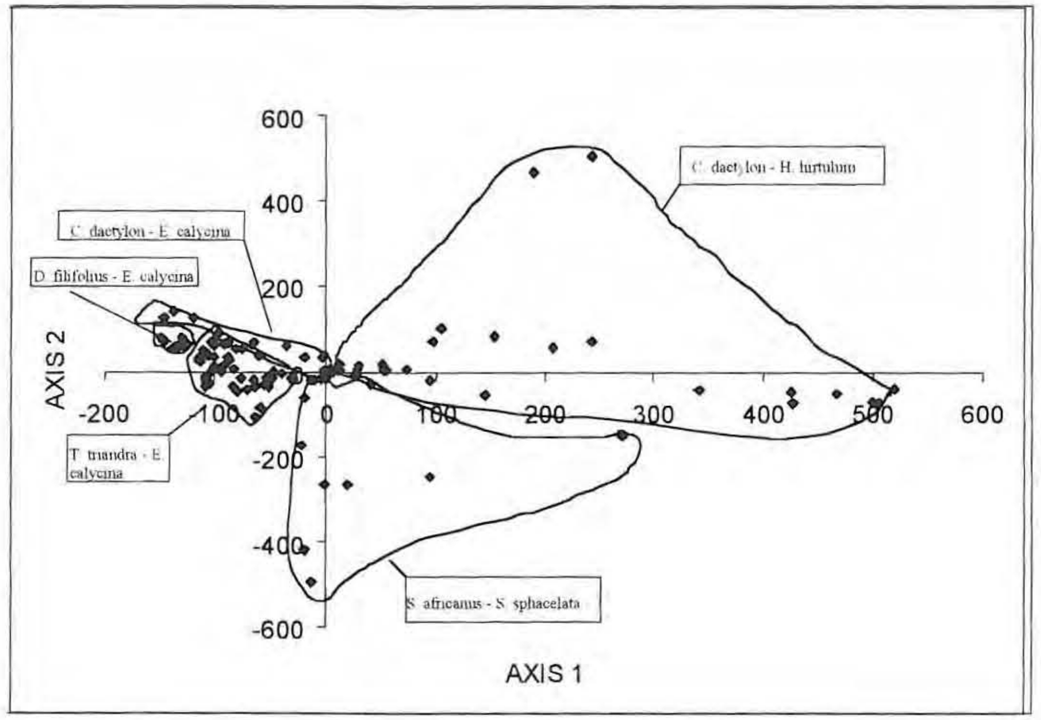


Figure 4.3.2.i.b Results of indirect ordination of xeric grasslands using DECORANA

The *S. africanus* – *S. sphacelata* and *C. dactylon* *H. hirtulum* associations were both ploughed ten or more years prior to the study. The vegetation in the *S. africanus* – *S. sphacelata* association was ploughed at least 40 years ago and in Figure 4.3.2.i(b) the samples are more closely spaced than in the *C. dactylon* - *H. hirtulum* association, which was more recently ploughed. In addition, the *S. africanus* - *S. sphacelata* association is located closer to the *T. triandra* - *E. calycina* association in the figure, indicating less disturbance on the ordination gradient.

4.3.2.ii Direct Gradient Analysis (Detrended canonical correspondence analysis)

Both mesic and xeric associations were analysed by direct gradient techniques using nine environmental factors: pH, conductivity, organic content, soil depth, soil family, land use, land/sea interface, aspect and distance from the shore. The results are presented below.

4.3.2.ii.a Mesic grasslands

As shown in Figures 4.3.2.ii(a) and (b), the regression analysis results were taken for axes 1 and 2 of the ordination by DCCA, using the environmental parameters given in Methods (section 4.2). It can be seen that the strongest environmental gradient in the mesic grasslands is that of the land/sea interface. The next strongest ordination gradient is that of percentage organic matter, closely followed by land-use. The influence of pH was fairly strong, with aspect having a lower effect. Relative to these parameters, conductivity, soil family, soil depth and distance from the shore do not play a strong role in the ordination of the associations.

The *T. triandra* and *H. hirta* - *T. triandra* associations occur together along all gradients, thus indicating that they can tolerate wide variety of environmental conditions. This is illustrated by the fact that they are the most widely distributed associations within the study area. The *T. triandra* association has a slightly wider tolerance, being able to withstand the more extreme land/sea interface conditions than the *H. hirta* – *T. triandra* association. In addition, it occurs in a wider range of soil conditions with regard to percentage organic content of the soil.

The *Themeda triandra* - *Anthospermum herbaceum* association is limited to the most extreme land/sea interface and soils organic conditions, i.e. it is associated with the more severe natural environmental factors and high levels of organic content in the soil. At the other extreme, the *H. hirta* - *D. amplectens* association shows the least response to these factors and the greatest response to land-use. The disturbed *S. secundatum* - *C. coriacea* association is the only one which appears to be affected by aspect and distance from the shore. This reflects its location, which is often around coastal resorts facing the shore. Conductivity, soil family and soil depth do not appear to be important environmental factors in the mesic associations.

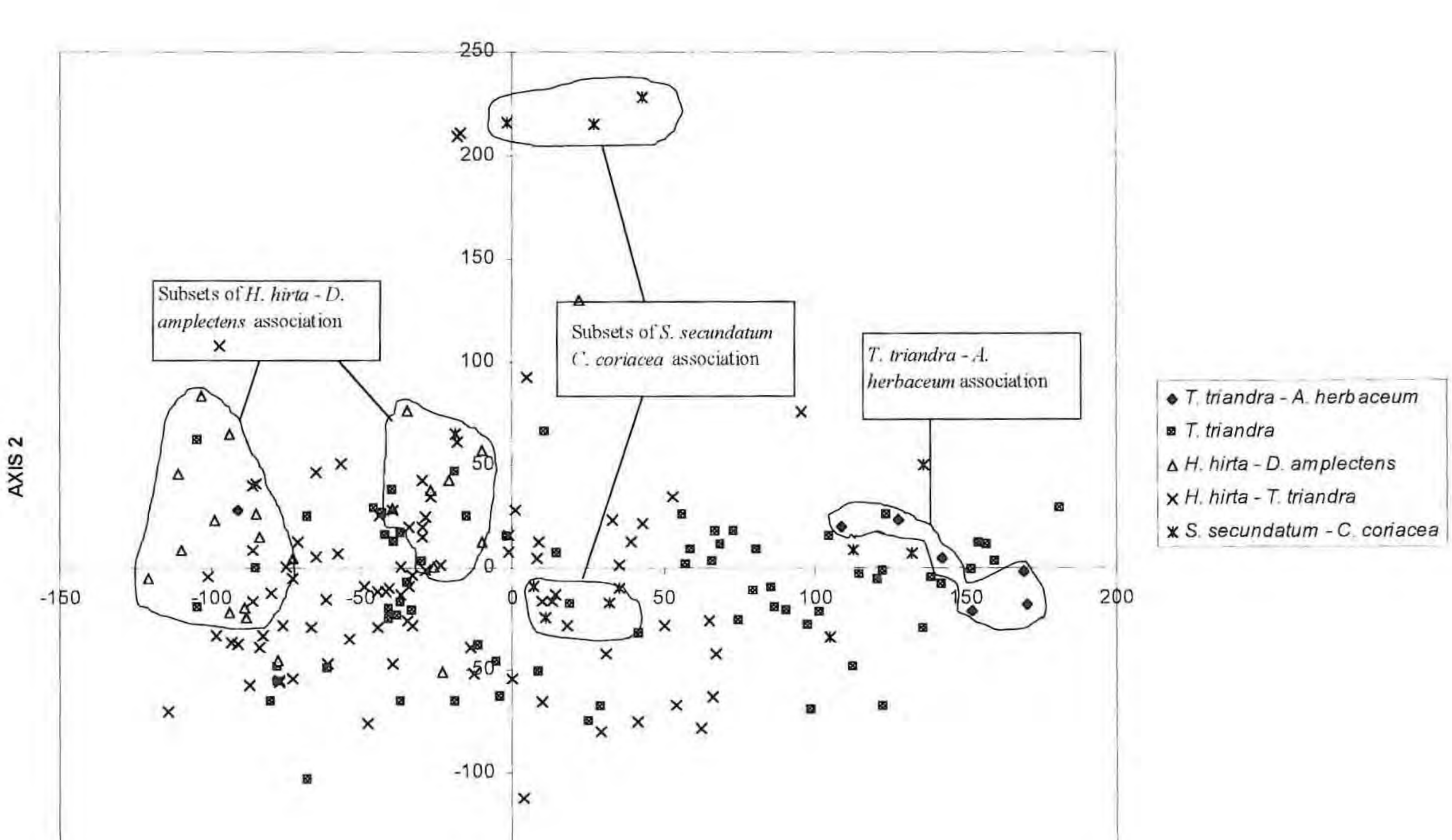


Figure 4.3.2.ii (a) DCCA of mesic associations with environmental variable as constrained linear values, axes 1 and 2

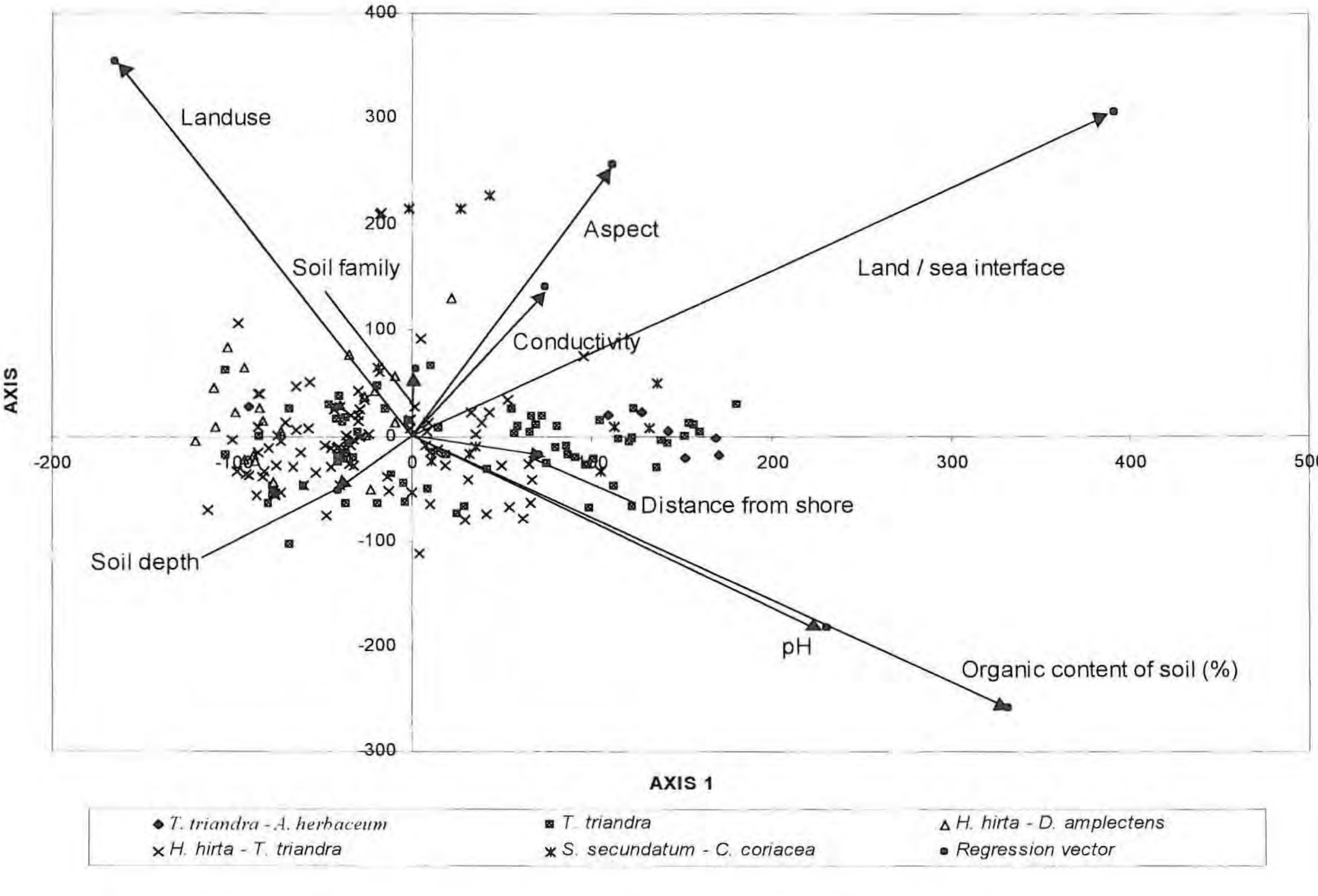


Figure 4.3.2.ii(b) DCCA of mesic associations showing regression vectors of environmental variables, axes 1 and 2

4.3.2.ii.b Xeric grasslands

In the xeric grasslands, the most important ordination axis is the land/sea interface, just as it is for the mesic grasslands (Figures 4.3.2 (c) and (d)). Soil family was the next strongest factor, followed by land-use. Distance from the shore is the next most important environmental gradient for ordination of these samples, followed by conductivity. However, with the exception of land-use and soil organic content, the environmental factors affected only the *C. dactylon H.hirtulum* association. Aspect, soil depth, soil family and pH have the least importance in ordination of the xeric grassland associations.

The results shown in Figures 4.3.2.ii (c) and (d) support those of indirect gradient analysis presented in Figure 4.3.2.i (b). The indirect analysis shows that separation of associations occurs on the basis of samples taken from ploughed and unploughed vegetation. The vegetation growing in areas where the soil had been disturbed less than twenty years prior to sampling (*C.dactylon – H. hirtulum* association) responded to land/sea interface, conductivity, soil depth, pH, distance from the shore, aspect and soil family. In addition, it is the only association which responds to ordination along a land-use gradient. The association occurs over a wide range of all the environmental variables described. This is the only community in the study which may be regarded as being a pioneer community (see Chapter 5) and its ability to occupy areas covering a wide range of environmental conditions bears this out. By contrast, only the *D. filifolius – E.calycina* association showed some ordination along a gradient of soil organic content, and no other associations showed any response to ordination along the environmental variables examined.

Soil disturbance plays a major role in the ordination of samples taken from the xeric associations, as seem in Figure 4.3.2.i (b) above. This is emphasised by the results obtained in direct ordination. It is possible that removal of *C. dactylon – H. hirtulum* association samples from the ordination data set may enable one to determine the effect of the defined environmental factors on the remaining associations.

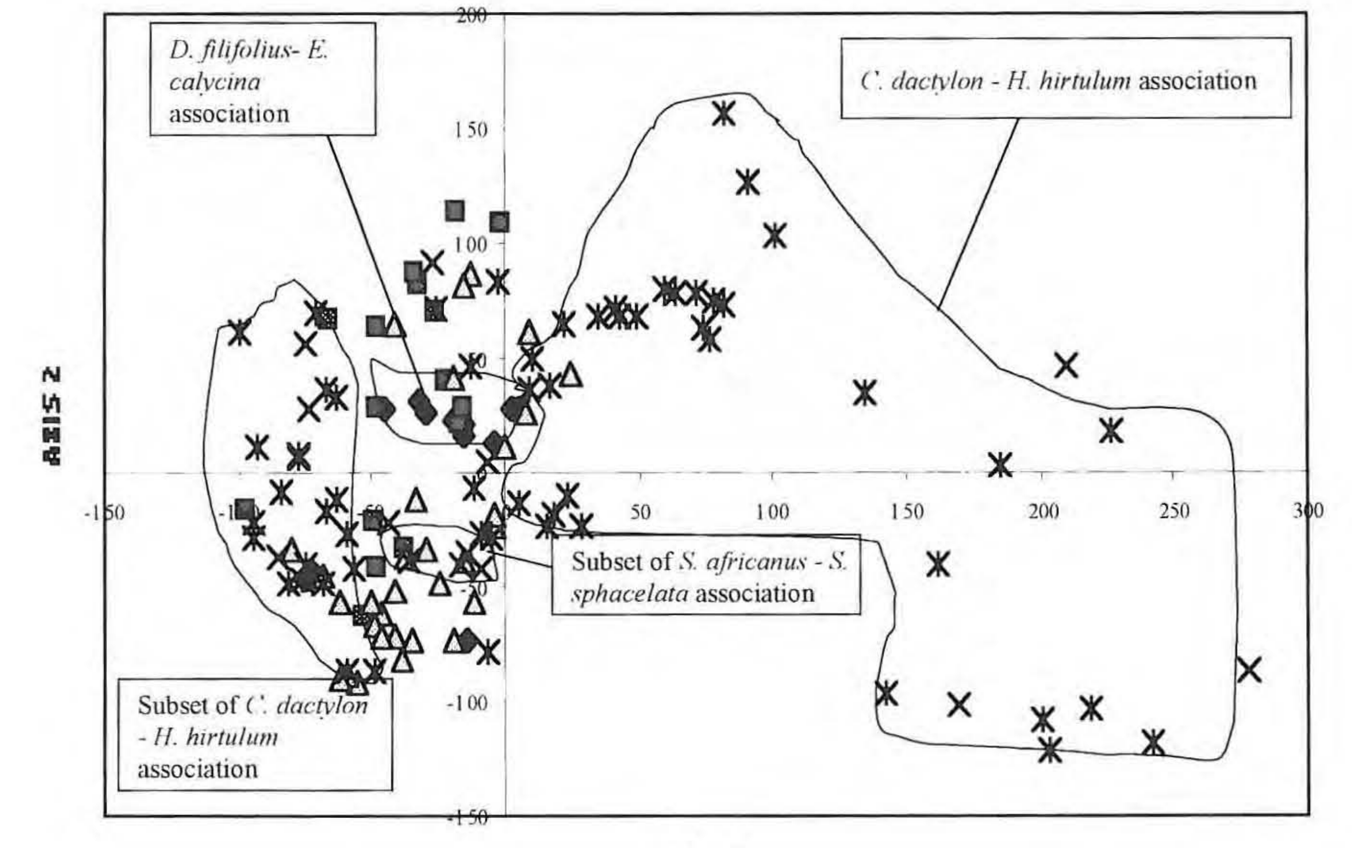


Figure 4.3.2.ii (c) DCCA of xeric associations with environmental variables as constrained linear values, axes land 2

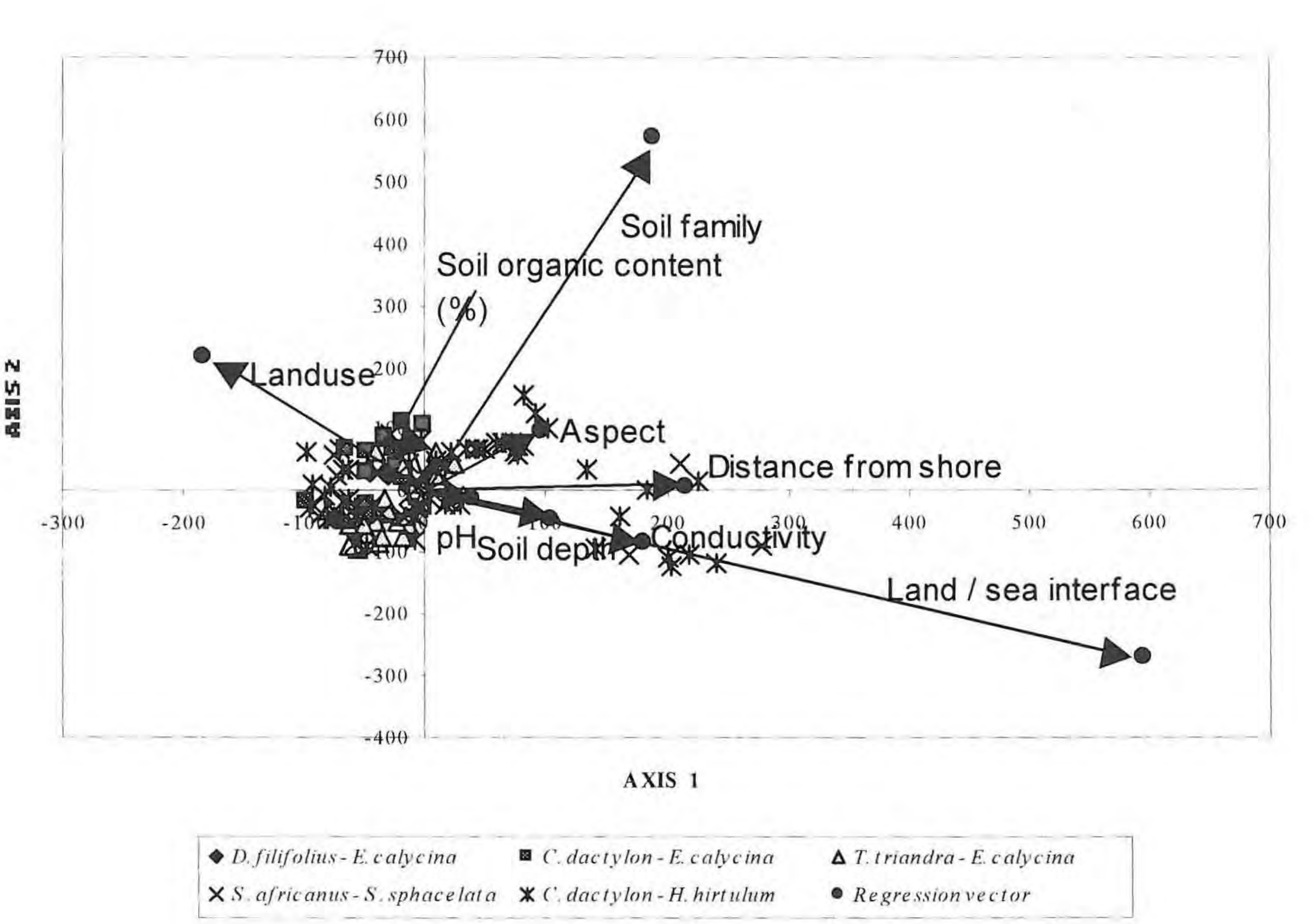


Figure 4.3.2.ii (d) DCCA of xeric associations showing regression vectors of environmental variables, axes 1 and 2

4.4 CONCLUSIONS

These results indicate that soils of the East Cape Coastal Grasslands tend to be neutral or slightly acidic, with fairly high conductivity. Soils in the more mesic associations have higher organic content, possibly because the influence of a higher moisture regime results in increased plant growth and better decomposition of plant material. In addition, these associations tend to be located either in nature reserves or commercial farmland which traditionally has a lower stocking rate than communal rangeland; hence there would be more plant litter to be incorporated into the organic content of the soil.

Levels of calcium and magnesium vary widely across the study area. Calcium plays a role in reducing the available potassium in several of the associations. The high levels may be the residual effect of fertilisation but this was not established in the study. Potassium varies across the study area and is regarded as being limiting to plant growth in the *Themeda triandra*, *Hyparrhenia hirta* – *Diheteropogon amplectens*, *Diheteropogon filifolius* – *Ehrharta calycina*, *Themeda triandra* – *Ehrharta calycina* and *Cynodon dactylon* – *Helictotrichon associations*. Adaptation to low potassium levels may be a feature of the species occurring in the study area. Phosphate is highest in the disturbed environments and greatest in the grasslands which were ploughed most recently. Soils of the *Hyparrhenia hirta* – *Diheteropogon amplectens* association appear to be both phosphate and potassium deficient, possibly reducing the ability of the vegetation to withstand grazing pressure and subsequently resulting in a secondary grassland (see Chapter 5). The soil families vary along the coast but the commonest is the Fernwood type with Mispah and Katspruit soils common in the mesic grasslands and Clovelly and Hutton types present in the xeric associations.

From Figure 4.3.2.i.(a) it can be seen that indirect ordination of the associations in the mesic grasslands is not clear-cut at all. The first four associations cannot be distinguished from one another except for a subset of the *Themeda triandra* and *Hyparrhenia hirta* – *T. triandra* associations. Only the *Stenotaphrum secundatum* – *Centella coriacea* association is distinguishable from the rest of the data points, and this association is extremely disturbed in contrast to the remaining associations. The lack of a clear environmental gradient with DECORANA highlights the similarities between the first four associations in the mesic grasslands. The spatial proximity between the association is illustrated in Figures 3.1 to 3.9 (Chapter 3). Direct analysis indicates that the strongest environmental gradient affecting the mesic associations is the land/sea interface. The percentage organic content and land-use also produce strong environmental gradients.

By contrast, indirect analysis of the xeric grasslands in Figure 4.3.2.i.(b) indicates clear separation along a disturbance gradient from lightly stocked grasslands to those which had been left fallow within the last 10 years but still grazed. With direct analysis however, ordination is illustrated only for the most recently ploughed vegetation. The most important ordination axis for the disturbed *Cynodon dactylon - Helictotrichon hirtulum* association is along the land / sea interface gradient, just as for the mesic grasslands, indicating that this is the most important observed factor in ordination of the entire East Cape Coastal Grassland areas studied. The second most important factor was organic content, which is one of the most important factors in soil development as mentioned previously. Land-use was the third most important ordination gradient. The lack of ordination of the remaining associations is thought to be attributable to the overrriding influence of the samples taken from the most recently soil-disturbed environments. Ordination of the data without the presence of these samples may prove useful.

It appears that the most important environmental factor assessed for direct ordination of the grasslands of the East Cape Coast is the land / sea interface, which is an "Inherent" factor according to Bruce (1995). The percentage organic content of the soil is indirectly related to man's activities and the land-use is obviously determined by man. The availability of phosphate and particularly potassium are regarded as being crucial soil elements affecting the vegetation as well. These five factors are thus regarded as being the most significant factors affecting the associations which were determined by TWINSPAN analysis in Chapter 3.

5. SUCCESSION: SPECIES DIVERSITY, LIFE FORMS AND TEMPORAL CHANGE IN THE EASTERN CAPE COASTAL GRASSLANDS

5.1 INTRODUCTION

The concept of succession may be defined as "a dimensional change in community structure and function", with this change being additional and progressive and resulting in a community which has a different structure and function from the original (Putman and Wratten, 1984). Succession was first described in detail by Clements who defined it as the progression of vegetation from a pioneer community which occurs on bare soil through various stages of complexity until it reaches a climax community which is stable and unchanging. In his view, each stage results in changes to the environment, which cause a decrease in its suitability for the current species and encourage the growth of species of the next, more advanced community. Succession always tends to produce a more stable community and the end point, or climax community, is determined by competition and the presence of species which prevent invasion by other species (Shimwell, 1971; Connel and Slatyer, 1977; Noble and Slatyer, 1980; Usher, 1981; Hobson, 1986). Different stages in the progress of succession are called seres, and according to Clements' view, different seres should converge to form the same climax community (Shimwell, 1971; Putman and Wratten, 1984). Pioneer stages have lower species diversity and a high number of ephemeral species as opposed to climax associations, which have a high diversity and a large component of perennial species. The climax community is also in equilibrium with its environment, utilising the available resources to their maximum. A community may be held back from developing to the full climax by man's activities or by environmental factors such as edaphic conditions (Shimwell, 1971).

Primary succession takes place in an environment that has been newly created, such as that following volcanic activity or on accreting sand dunes. Secondary succession takes place in an environment where vegetation did occur but has been removed by activities such as ploughing or severe overgrazing. Primary succession generally follows the described pattern for Clementsian succession, but secondary succession shows deviations from this orderly and predictable pattern.

Gleason was the next major researcher to have an impact upon successional theories. In contrast to Clements, he postulates that species associations are dependent upon the requirements and characteristics of the individual species themselves. He felt that an orderly pattern of succession could not yet be defined and that it would differ for every situation (Usher, 1981).

Most researchers support the Clementsian view, but with many refinements and alterations. Whittaker (1953, in Shimwell, 1971) suggested that environment played a role in community structure. He postulated that the climax community is determined by the environmental conditions where it occurs and that it represents a "shifting pattern of populations which correspond to a similar pattern of environmental gradients". The environmental gradient is essential for interpreting the climax community and there is no "absolute climax" community for any given area.

Egler (1954, in Connel and Slatyer, 1977), proposed that where succession takes place after disturbance, it is the species that precede the disturbance that will determine the final climax species composition. Odum (1969) presented a model showing that whatever route succession followed, it would result in an accumulation of biomass. Margalef (1968, in Facelli and D'Angela, 1990) proposed that random events such as climatic variation would have a greater impact on communities at early successional stages. Thus, unpredictable vegetation changes should occur predominantly in pioneer stages rather than in later stages. His theory that the properties of the species present would reduce the amount of change is based on the underlying Gleasonian idea that individual species' interactions define community structure and override fluctuations in environmental conditions. The rate of change of species declines as succession progresses and later species control community structure.

Connel and Slatyer (1977) describe succession following disturbance, or secondary succession. They postulate that secondary succession may follow three different pathways, namely facilitation, tolerance or inhibition. The facilitation pathway is essential Clementsian succession whereby the first suite of species facilitates the growth of the next suite. In the tolerance pathway, the success of later species is independent of preceding species. In the inhibition pathway, later species are prevented from reaching maturity when earlier species are present.

Noble and Slatyer (1980) put forward five factors which have a major role in (secondary) succession.

1. Immediately after disturbance, species composition will depend on propagules within the site which have either remained after the disturbance or arrived from an external source, or upon the vegetative resprouting of survivors.

2. A pulse of recruitment or regrowth occurs immediately after disturbance where there is little competition.

3. Recruitment decreases after the initial pulse because of the difficulty of displacing established plants.

4. The subsequent recruitment of new species may be facilitated by species present at the site but it is often restricted and may even be inhibited by present or prior species.

5. Where no further disturbance takes place the vegetation will be dominated by long-lived species and those which are able to regenerate in the presence of adults of their own species.

The most recent models concerning succession and relating directly to grasslands are the non-equilibrium and the state - and - transition theories. (Frost *et al.*, 1986; Westoby *et al.*, 1989). The equilibrium model which developed from climax theory states that vegetation will exist in a "single persistent state" or climax if it is not subject to grazing, fire or other disturbance. If such a disturbance takes place, the system will return to its initial climax state after a period of sufficient time. It is obvious from numerous studies that within grassland and savannah ecosystems, such a return to a steady climax state does not take place where the disturbance crosses a certain threshold. This leads to the hypothesis of non-equilibrium that states that a return to the pre-disturbed state does not automatically follow after disturbance has ceased. Instead, the vegetation will either remain in its post-disturbance state or continue to change in the same direction as that caused by the disturbance. In order to return to its original state, some disturbance, other than the original disturbance and acting in the opposite direction, must take place (Frost *et al.*, 1986; Westoby *et al.*, 1989; Mentis and Bailey, 1990).

From the hypothesis that grassland and savannah ecosystems do not automatically revert to the original equilibrium upon removal or modification of disturbance, the state-and-transition model was developed (Westoby *et al.*, 1989). In this model a particular ecosystem consists of vegetation in discrete "states" between which it can fluctuate by virtue of "transitions". Westoby *et al.* (1989) also recognise that "transient states" may occur, these being conditions in which the vegetation is shifting from one state to another. Transitions may be brought about by natural activities such as drought or by human activities such as man-induced fires and grazing. The time taken for a transition between two states to occur may vary but it will progress until a new, steady state has been reached (Westoby *et al.*, 1989). The open-ended approach taken in this model results in a far wider variety of possible outcomes than those predicted by older successional models. It enables one to reflect the results of different types and intensities of disturbance on a given environment. As it must be based on actual studies, it will enable one to make closer approximations of what happens in different environments under different disturbance events.

In order to interpret data using the state-and-transition and non-equilibrium theories, one must have an understanding of a number of different ecosystem qualities. These include stress, disturbance, stability, recuperative stability and resilience (McKenzie, 1982; Frost *et al.*, 1986). Stress is defined as an environmental factor which "restricts the productivity and efficiency of an individual and, by extension, the ecosystem" (Frost *et al.*, 1986). Such a disturbance may be drought or overgrazing. The disturbance often results in the death of individuals, releasing resources for the establishment of other individuals. Stability refers to the ability of an ecosystem to withstand change that is due to disturbance (McKenzie, 1982; Frost *et al.*, 1986). The more stable a system, the less the effect of disturbance on species composition and abundance. Recuperative stability is defined as "the ability of a system to return to an equilibrium state after a temporary disturbance" (Hollings, 1973, in McKenzie, 1982). Upon disturbance, the more stable the system, the more quickly it will return to its original form. Resilience is defined as "the system's ability to absorb changes and still persist coupled with the speed at which it returns to its original condition" (Hollings, 1973, in McKenzie, 1982). Systems that are resilient are usually unstable since the species composition and abundance vary greatly under disturbance (Walker, 1980).

A further complicating factor in understanding grassland dynamics with respect to vegetation states is the degree to which grasslands show temporal variation (Frost *et al.*, 1986). Temporal variation is linked to a wide variety of factors ranging from carbon assimilation, continuous versus periodic shoot growth to flowering time (Sarmiento and Monasterio, 1975). Herbaceous species show the widest variation in phenotypic responses, but this is also prevalent among the most common species making up the grass component of the Eastern Cape Coastal Grasslands (Bayer, 1955; Frost *et al.*, 1986).

Succession can be studied in two particular ways. In the first method, the same area of vegetation is examined for changes over a period of time. Since succession can take decades and even hundreds of years, this method does not show immediate trends. The second method is to examine areas which are thought to have originally supported the same vegetation but which have been subject to different environmental impacts at known periods of time. This is known as side-by-side sampling. The major problem with this is obvious: the vegetation may not have been sampled prior to disturbance and homogeneity is inferred. While this method is not perfect, it is however the best option for many secondary successional studies (Mueller-Dombois and Ellenberg, 1974).

5.1.1 Species Diversity

In order to gain an understanding of the successional status of associations within a community, one can begin by examining the diversities that occur. Diversity is defined by the combination of alpha, beta and gamma diversity (Cowling *et al.*, 1997). Alpha diversity is the number of species occurring within a defined homogenous area. It may sometimes be combined with the abundance of each species as well (Whittaker, 1965, 1972, 1975, Cowling *et al.*, 1992; 1996; 1997; Vitrousek and Hooper, 1992). Alpha diversity is also often termed species richness and can indicate the potential ability of a system to withstand stress. According to the postulations that increased species richness results in increased ecosystem stability, alpha diversity will also give an indication of stability and resilience. Kent and Coker (1992) however, state that there is no clearly defined relationship between alpha diversity and stability. Beta diversity refers to species turnover and is the difference in species between two defined areas along a habitat gradient (Whittaker, 1965, 1972a, 1975; Cowling *et al.*, 1992; 1997; Vitrousek and Hooper, 1992). Gamma diversity is the change of species between environments that are similar but are placed on a geographical gradient (Cowling *et al.*, 1997). In this study only alpha and beta diversity have been examined.

5.1.2 Structure and Function

In recent years, plant functional types, or PFTs, have become a focus for determining vegetation interactions and response to the most important environmental factors (Noble and Gitay, 1996; Hadar *et al.*, 1999; McIntyre *et al.*, 1999). Functional types have been defined as groups of species which have "certain plant functional attributes in common" (Skarpe, 1996). In addition, PFTs are groups of plants which show "similar responses to environmental conditions and having similar effects on dominant ecosystem processes" (Diaz *et al.*, 1999). Since these species respond to environmental change, an analysis of PFTs should enable one to deduce past or present impacts on an environment as well as the current dynamics of the vegetation being studied. As expounded by McIntyre *et al.* (1999) and Noble and Gitay (1999), PFTs are being used to provide a simplified description of plant diversity while illustrating the most important processes and attributes within a defined unit of vegetation. They are obviously useful in outlining any successional trends occurring within the vegetation.

In order to determine the structure and functional groups within the grasslands and relate them to succession, plant functional groups were analysed for each association. Skarpe (1996) indicates that the use of PFTs assumes that the vegetation in question is in equilibrium with its environment. If one follows any type of succession, in theory PFTs would only apply to the most stable communities. They would not be relevant to those that had been recently disturbed by events such as ploughing, or those that are being grazed. However, several authors have used PFTs to elucidate community responses to recent and on-going disturbance (McIntyre *et al.*, 1995; Diaz *et al.*, 1999; Hadar *et al.*, 1999). It was therefore felt that PFTs could be examined in the present study, which includes vegetation being grazed at different levels of intensity as well as vegetation from different areas that were ploughed at different times.

The functional groups used in research vary between authors depending on research requirements. They may relate to environmental disturbance or climatic change. The subjective choice of attribute used to define the functional groups is linked to what the researcher is examining (Noble and Gitay, 1996; McIntyre *et al.*, 1999). Noble and Gitay (1996) suggest five categories into which species may be classified:

1. Phylogenetic i.e. based on taxonomy
2. Structure i.e. life forms
3. Resource use i.e. "guilds" of species which utilise the same resources
4. Perturbation response group i.e. species which respond to a defined perturbation or disturbance
5. Functional groups i.e. those which play a role in ecosystem function

Chapter 3 has already defined the species of the Eastern Cape Coastal Grasslands in terms of phylogeny. For the purpose of this chapter, phylogenetic, structure and life form categories of the associations were examined. The intention behind the choice of these categories was that they should aid in the determination of whether or not species associations showed changes in response to moisture gradients and different land usage. Studies by Diaz *et al.* (1999) indicate that disturbance history and intensity as well as climate are among the most important factors in determining vegetation dynamics. As Pillar (1999) indicates, in choosing plant traits one should select those characters that best illustrate the perceived relationships between vegetation and the most important environmental factors. As I have done throughout the study, distinction is again made between the mesic and xeric associations to illustrate the effect of different moisture regimes. Land use is perceived as one of the strongest environmental characteristics (see Chapter 4) and in choosing plant traits which reflect these two factors it was hoped that PFTs related to these important environmental factors would emerge.

5.1.3 Temporal Changes

Seasonal fluctuations in cover abundance of dominant species is a known phenomenon of grasses (Bayer, 1955) and may influence vegetation studies to a certain extent. Some researchers view fire as an agent that causes secondary succession to take place. Fire is an extremely old management practice associated with the grasslands east of East London and particularly the vegetation of the former Transkei (McKenzie, 1984; Feely, 1987). Fire is also one of the key factors influencing succession in grasslands since it is thought to suppress the growth of taller woody species e.g. tallgrass prairie in the USA (Hulbert, 1986; Anderson, 1990). Several authors maintain that the grasslands of the former Transkei are prevented from becoming forest because of fire and grazing (Bayer, 1955; White, 1983; Tainton, 1999) but this theory is the subject of much controversy (McKenzie, 1982; Feely, 1987). As Connel and Slatyer (1977) indicate, in environments where fire is infrequent, such an event may destroy several species leaving no propagules in the area. However, in environments where fire is a regular occurrence, most of the species will be fire-tolerant and able to regenerate rapidly after such an event. This will result in the maintenance of species diversity and few species will be lost. However, all systems have a threshold of resistance to fire frequencies and where the frequency is too high the system will begin to decline in richness and cover i.e. if the recuperative stability requirement is exceeded. In this study, fire is not regarded as causing secondary succession in the coastal grasslands where the climax species such as *Themeda triandra* are able to resprout after burning and where it has been a part of the environmental conditions under which the vegetation has developed (Feely, 1987).

All the above aspects of the vegetation – diversity, structural groups and temporal change – are discussed in this chapter in an effort to explain the successional status of the coastal grasslands of the Eastern Cape.

5.2 METHODS

5.2.1 Diversity

Alpha diversity is thought to be controlled by environmental factors as well as species' abilities to compete for vital resources such as light and nutrients, and their abilities to withstand environments of different extremes. As some of the theories on succession described above indicate that species richness fluctuates between pioneer and climax states, alpha diversity is determined for each association in an effort to place it within a successional context. In addition, alpha diversity can indicate the conservation value of a particular area or vegetation type. Beta diversity is elucidated in order to determine the similarities between defined areas and hence to gain an insight into how closely linked associations are.

A diversity table was prepared for the associations within the Eastern Cape Coastal Grasslands from the species tables in Appendix 2. Alpha diversity is the total number of species occurring in the association. Beta diversity is the number of species that differ between two associations. Sørensen's coefficient of similarity (Kent and Coker, 1992) was calculated between all associations and is combined with the alpha and beta diversity scores in Table 5.3.1.

The formula for Sorensen's similarity coefficient is:

$$Ss = 2a / (2a + b + c)$$

Where

a = number of species occurring in both associations

b = number of species occurring in first association

c = number of species occurring in second association

5.2.2 Structure and Function

Phylogenetically, the most abundant families were defined for each association. The percentage of alpha diversity derived from the three largest families i.e. Fabaceae, Asteraceae, Poaceae as well as Cyperaceae and others was recorded.

In examining structure, the species were separated into forb, woody and grass components. Each of these components was further broken down into various categories relating to the life forms. Life forms were based loosely on Raunkiaer (1934, in McIntyre *et al.*, 1995) classification. They were determined through field observation as well as reference to herbarium material and literature (Gibbs-Russel *et al.*, 1991; van Oudtshoorn, 1992). In each association, the alpha diversity accounted for by each life form was calculated as a percentage of the total species richness of that association.

In the case of the woody and grass components, the average cover abundance contributed by each life form per association was calculated. In order to do this, the data from TWINSPAN analysis were used. Although in the field cover abundance was estimated at 5% intervals, for TWINSPAN analysis the cover abundance values per species per relevé were grouped into classes (see Chapter 3 for pseudospecies cutoff levels). These values are shown for each association in Appendix 2 and are the values that were used to estimate the cover abundance of each life form in each association. The average cover abundance for each particular class of grass species per relevé was determined and is shown in the figures below.

In many of the mesic associations grass species cover abundance exceeds 100%. This is the case since several species occur at different heights and there may be a number of layers of vegetation within a sample (see also Figures 5.3.3.1.c and 5.3.3.2.f below). In addition, experimental error may have occurred through the use of the class score for each species rather than the actual score. However, if this is the case then the error will be the same throughout and as the results are used in comparison rather than as absolute figures, it is felt that such data analysis is acceptable.

Cover abundance was not calculated for the forb component since for most life forms it would often have been less than 10%. It was therefore felt that this would not be particularly meaningful. With regard to the woody component, very few tree species were recorded, with most cover being accounted for by *Acacia karroo* and *Tarchonanthus camphoratus*. It must be stressed that tree species were below 1.5m in height at the time of sampling.

The grasses were categorised in terms of their height (below or above 1m), growth forms (tufted, stoloniferous) and whether they were annual or perennial. It must be noted that some grass species can be tufted, rhizomatous and stoloniferous (e.g. *Eustachys paspaloides*) or mat-forming, rhizomatous and stoloniferous (e.g. *Cynodon dactylon*) no species has both tufted and mat-form growth habits (Gibbs-Russel *et al.*, 1991; van Oudtshoorn, 1992). Under conditions of heavy trampling pressure, aerial portions of stoloniferous species came into contact with the earth and are able to root. This results in a shorter, more mat-like sward. Rhizomatous species avoid local extinction under high grazing and trampling pressures through the persistence of vegetative reproductive organs in the soil. After ploughing, rhizomatous and stoloniferous grasses tend to be more persistent in deep sandy soils than tufted species (Bayer. 1955).

5.2.3 Temporal variation in mesic associations and the effect of fire

In order to study seasonal variations in the mesic grasslands, a long-term study was conducted at the Dierama Wild Flower Reserve on Potter's Pass, a grassland area on the West Bank of East London (see Fig 3.4). Originally, seven permanent plots were located within the *Themeda triandra* association and ten in the *Themeda triandra* - *Hyparrhenia hirta* mesic grassland association. Unfortunately some of the markers were destroyed or removed during the course of the study and ultimately only three remained in the *T. triandra* association, and nine in the *T. triandra* - *H. hirta* association. The percentage cover abundance of each species was recorded for each plot every eight weeks. The raw data was analysed using DECORANA (see Chapters 3 and 4; Judd, 1995). The results for July, October and December are shown below.

The effect of fire was observed on the *Themeda triandra* and *Themeda triandra* - *Hyparrhenia hirta* associations. Cover abundance and number of species were recorded as an average of all the plots per association per treatment. A portion of the *T. triandra* grasslands was burnt in June just after sampling had begun. No records of previous fires were available for either association. All the sample plots in the *T. triandra* association were burned by an accidental fire in late April. In the *T. triandra* - *H. hirta* grassland, the unburned sample plots were burned in April and the originally burned sample plots were burned in May by accidental fires. This study only indicates the immediate response of the vegetation to fire events and does not reflect the long-term effects of fire.

5.3 RESULTS

5.3.1 Diversity studies

The alpha and beta diversity scores for each association are presented below in Tables 5.3.1.a and b. Also shown are the Sørensen coefficients of similarity

Table 5.3.1.i Table of alpha and beta diversity and Sørensen coefficients for the mesic associations of the Eastern Cape Coastal Grasslands

Mesic Associations	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1 *Themeda triandra - Anthospermum herbaceum*	**49**	.45	.37	.24	.45	.19	.27	.25	.30	.26
2 *Themeda triandra*	7	**206**	.35	.24	.25	.27	.29	.33	.30	.25
3*Hyparrhenia hirta - Diheteropogon amplectens*	22	122	**106**	.36	.29	.33	.37	.34	.30	.29
4 *Hyparrhenia hirta - Themeda triandra*	12	89	22	**183**	.22	.27	.32	.32	.30	.29
5*Stenotaphrum secundatum - Centella coriacea*	23	160	72	137	**60**	.21	.26	.27	.32	.35

Table 5.3.1.ii Table of alpha and beta diversity and Sorensen coefficients for the xeric associations of the Eastern Cape Coastal Grasslands

Xeric associations	1	2	3	4	5	6	7	8	9	10
6 *Diheteropogon filifolius-Ehrharta calycina*	34	153	61	137	42	**72**	.35	.31	.25	.26
7 *Cynodon dactylon - Ehrharta calycina*	23	144	48	120	34	28	**90**	.35	.32	.33
8 *Themeda triandra - Ehrharta calycina*	20	127	46	109	26	30	32	**119**	.35	.34
9 *Sporobolus africanus - Setaria sphacelata*	20	142	66	125	26	46	48	64	**85**	.32
10 *Cynodon dactylon Helictotrichon hirtulum*	25	155	66	128	32	44	46	64	43	**90**

Key

Alpha diversity = numbers in bold

Beta diversity = numbers in shaded section

Coefficient of similarity = numbers unshaded section

5.3.2 Results of structural and functional analysis

A compilation of the species diversity accounted for by four families and the percentage of life forms and / or their cover abundance are presented for each association below.

5.3.2.i *Themeda triandra – Anthospermum herbaceum* association

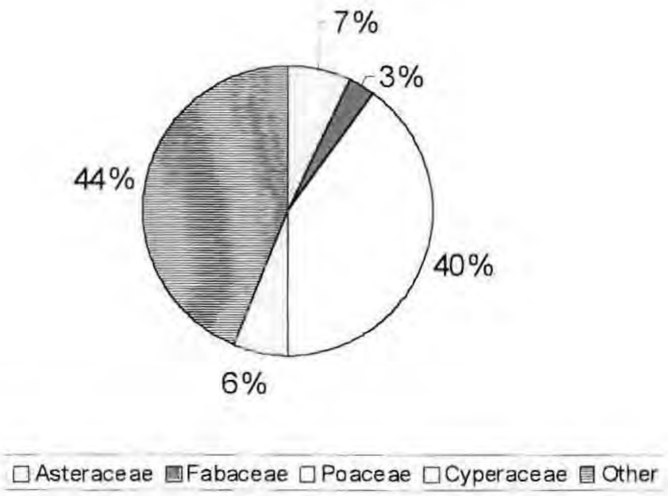


Figure 5.3.2.i Percentage of species richness accounted for by the Fabaceae, Asteraceae, Poaceae, Cyperaceae and other families, *Themeda triandra - Anthospermum herbaceum* association

Table 5.3.2.i a Percentage life forms of forb component, *Themeda triandra - Anthospermum herbaceum* association

Percentage life forms of forb component	
Annuals	3
Perennials	97
Forbs taller than 1m	3
Forbs shorter than 1m	84
Prostrate forbs	14
Mat-forming forbs	11
Creepers	0
Succulents	3
Geophytes	11

From the pie chart, Figure 5.3.2.i, it can be seen that the Poaceae make the greatest contribution to species richness at the family level. The Asteraceae, Cyperaceae and Fabaceae each contribute less than 10% while the Poaceae constitute almost as many species as the remaining families do. Compared to the other mesic grassland associations, the grasses make the greatest contribution to the family level of species richness in this association. Of the forb component, the majority are perennial species below 1m in height with approximately 25% of the species being either mat-forming or prostrate (Table 5.3.2.i.b). This indicates a fairly short forb component.

Table 5.3.2.i.b Percentage life forms of woody component, *Themeda triandra - Anthospermum herbaceum* association

Percentage life forms of woody component	
Trees	0
Shrubs	50
Dwarf shrubs	50

Table 5.3.2.i.c Percentage cover abundance of woody component, *Themeda triandra - Anthospermum herbaceum* association

Percentage cover abundance accounted for by woody component	
Trees	0%
Shrubs	<1%
Dwarf shrubs	<1%

There are no tree species among the woody component of which half of the species are dwarf shrubs and half are shrubs (Tables 5.3.2.i.b and c). The woody component comprises less than 1% of the average cover per plot.

Table 5.3.2.i.d Percentage life forms of grass component. *Themeda triandra - Anthospermum herbaceum* association

Percentage life forms of grass component	
Perennial	90
Annual	10
Grasses shorter than 1m	50
Grasses taller than 1m	50
Tufted	60
Mat-forming	10
Stoloniferous	10
Rhizomatous	30

Table 5.3.2.i.e Percentage cover abundance accounted for by grass species. *Themeda triandra - Anthospermum herbaceum* association

Percentage cover abundance accounted for by grass species	
Perennial	150
Annual	0
<1m tall	114
>1m tall	36
Tufted	119
Mat forming	31
Stoloniferous	3
Rhizomatous	8

Tables 5.3.2.i.d and e refer to the grass component. They indicate that 90% of the species are perennial and constitute an average of 150% of the cover abundance per plot. The 10% of annual species contribute practically nothing in cover abundance. While there are as many species shorter than 1m in height as there are above 1m tall, in terms of cover abundance the shorter grasses account for 114% cover as opposed to 36% cover in the tall species. There are six times as many tufted species as there are either mat-forming or stoloniferous and tufted species account for over 100% of the cover abundance. Rhizomatous species constitute 30% of the life form but only 8% of the cover. In some cases a grass may be both tufted and rhizomatous, or rhizomatous and mat-forming, leading to overlaps between the life forms.

5.3.2.ii *Themeda triandra* association

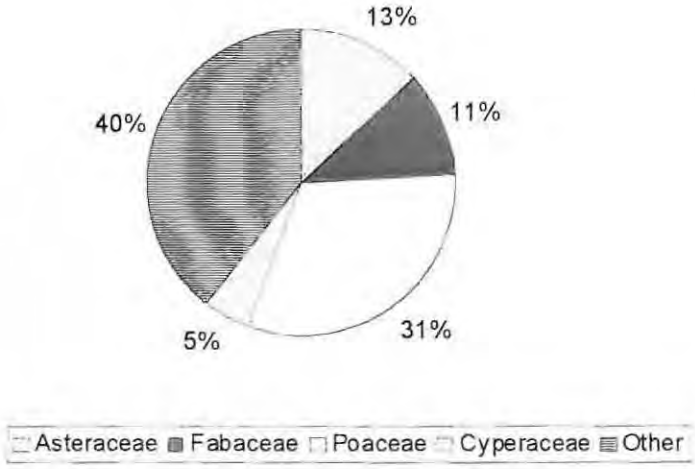


Figure 5.3.2.ii Percentage of species richness accounted for by the Fabaceae, Asteraceae, Poaceae, Cyperaceae and other families, *Themeda triandra* association

Table 5.3.2.ii a Percentage life forms of forb component, *Themeda triandra* association

Percentage life forms of forb component	
Annuals	3
Perennials	97
Forbs taller than 1m	3
Forbs shorter than 1m	86
Prostrate forbs	7
Mat-forming forbs	6
Creepers	1
Succulents	5
Geophytes	16

In this association the Poaceae constitute approximately one third of the species richness, with both Asteraceae and Fabaceae representing over 10% of the remaining species. The Cyperaceae only account for 5% of the alpha diversity, their lowest value in the mesic grasslands.

Table 5.3.2.ii.a indicates that the majority of the forb species are perennials below 1m in height. Prostrate and mat-forming species account for less than 15% of the diversity, while the greatest number of geophyte species in the mesic grasslands occurs in this association.

Table 5.3.2.ii.b Percentage life forms of woody component, *Themeda triandra* association

Percentage life forms of woody component	
Trees	32
Shrubs	36
Dwarf shrubs	32

Table 5.3.2.ii.c Percentage cover abundance accounted for by woody component, *Themeda triandra* association

Percentage cover abundance accounted for by woody component	
Trees	<0,1%
Dwarf shrubs	<0,1%
Shrubs	<0,1%

Tables 5.3.2.ii.b and c indicate that the woody component species are evenly divided between tree, dwarf shrub and shrub species. None of the woody components account for more than 0.1% cover, the lowest abundance recorded for woody species in the entire study.

Table 5.3.2.ii.d Percentage life forms of grass component, *Themeda triandra* association

Percentage life forms of grass component	
Perennial	94
Annual	6
Grasses shorter than 1m	39
Grasses taller than 1m	61
Tufted	76
Mat-forming	12
Stoloniferous	12
Rhizomatous	27

Table 5.3.2.ii.e Percentage cover abundance accounted for by grass species, *Themeda triandra* association

Percentage cover abundance accounted for by grass species	
Perennial	135
Annual	2.5
<1m tall	70
>1m tall	65
Tufted	125
Mat forming	1
Stoloniferous	1
Rhizomatous	42

The grass component consists mainly of perennial species, which account for 135% of the cover abundance of grasses (Tables 5.3.2.ii.d and e). Although only 39% of the grass species are shorter than 1m in height, they constitute 70% of the cover. The remaining 61% of tall species contribute 60% cover, so there is a fairly even mixture of tall and short grasses. Tufted species are the most numerous life form, and account for 125% of the cover. However, rhizomatous species make up 27% of the alpha diversity and account for 42% cover abundance of the grasses, the highest value for rhizomatous species in the mesic associations.

5.3. 2.iii *Hyparrhenia hirta – Diheteropogon amplectens* association

From Figure 5.3.2.iii below it can be seen that this association has the highest number of members of the Asteraceae and Cyperaceae in the mesic grasslands. The Poaceae are still the most numerous family but only 21% of the species in the association belong to this family. This is the lowest representation of the Poaceae in the mesic grasslands and its abundance has been replaced by an increase in the numbers of species belonging to the Asteraceae, Fabaceae and Cyperaceae.

The forb component is almost completely perennial and below 1m in height (Table 5.3.2.iiia). The association has the lowest percentage of geophytes and the highest percentage of creeping species in the mesic grasslands.

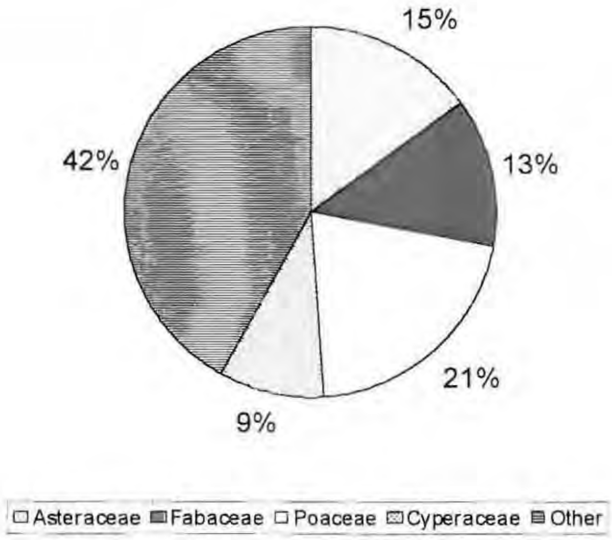


Figure 5.3.2.iii Percentage of species richness accounted for by the Fabaceae, Asteraceae, Poaceae, Cyperaceae and other families. *Hyparrhenia hirta - Diheteropogon amplectens* association

Table 5.3.2.iii a Percentage life forms of forb component, *Hyparrhenia hirta - Diheteropogon amplectens* association

Percentage life of forb component	
Annuals	4
Perennials	96
Forbs taller than 1m	1
Forbs shorter than 1m	87
Prostrate forbs	9
Mat-forming forbs	5
Creepers	3
Succulents	3
Geophytes	4

Table 5.3.2.iii.b Percentage life forms of woody component, *Hyparrhenia hirta - Diheteropogon amplectens* association

Percentage life forms of woody component	
Trees	13
Shrubs	25
Dwarf shrubs	63

Table 5.3.2.iii.c Percentage cover abundance of woody component, *Hyparrhenia hirta - Diheteropogon amplectens* association

Percentage cover abundance of woody component	
Trees	3%
Shrubs	<1%
Dwarf shrubs	<1%

The woody component of the association makes up almost 4% of the average cover abundance per sample (Tables 5.3.2.iii.b and c). Although tree species only account for 13% of the woody life forms, they occupy 3% of the cover abundance. Dwarf shrubs are more common that shrubs, but neither provides as much as 1% cover.

Table 5.3.2.iii.d Percentage life forms of grass component, *Hyparrhenia hirta - Diheteropogon amplectens* association

Percentage life forms of grass component	
Perennial	100
Annual	0
Grasses shorter than 1m	43
Grasses taller than 1m	57
Tufted	86
Mat-forming	5
Stoloniferous	10
Rhizomatous	29

Table 5.3.2.iii.e Percentage cover abundance of grass component, *Hyparrhenia hirta - Diheteropogon amplectens* association

Percentage cover abundance accounted for by grass species	
Perennial	96
Annual	0
<1m tall	38
>1m tall	58
Tufted	90
Mat forming	0.1
Stoloniferous	0.2
Rhizomatous	10

Tables 5.3.2.iii.d and e indicate that there are no annual grass species at all in this association, and cover abundance is 96%. This is the lowest cover abundance of grass species in the mesic grasslands. This association has the highest diversity and abundance of grasses taller than 1m, although the cover accounted for by grasses shorter than 1m is almost 40%. The lowest number of mat-forming grasses and fairly low numbers of stoloniferous species occur in this association. Cover abundance due to mat-forming, stoloniferous and rhizomatous species is higher in all other mesic grassland associations.

5.3.2.iv *Hyparrhenia hirta –Themeda triandra* association

As shown in Figure 5.3.2.iv this association has the same number of members of the Asteraceae as it does the Cyperaceae. There are slightly more Fabaceae and almost twice as many Poaceae as Asteraceae, while other families constitute almost 40% of the species richness. This association has the highest number of Cyperaceae in the mesic grasslands.

There is a small percentage of annual species within the forb component, but it consists mainly of perennial species (Table 5.3.2.iv.a). The majority of the forbs are below 1m in height. There are few prostrate, mat-forming or creeper forbs in this association.

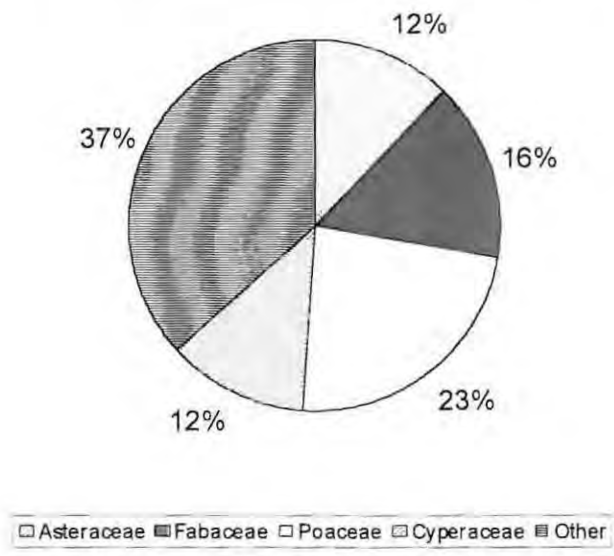


Figure 5.3.2.iv. Percentage of species richness accounted for by the Fabaceae, Asteraceae, Poaceae, Cyperaceae and other families, *Hyparrhenia hirta - Themeda triandra* association

Table 5.3.2.iv.a Percentage life forms of forb component, *Hyparrhenia hirta - Themeda triandra* association.

Percentage life forms of forb component	
Annuals	4
Perennials	96
Forbs taller than 1m	2
Forbs shorter than 1m	87
Prostrate forbs	8
Mat-forming forbs	2
Creepers	2
Succulents	2
Geophytes	7

Table 5.3.2.iv.b Percentage life forms of woody component, *Hyparrhenia hirta - Themeda triandra* association

Percentage life forms of woody component	
Trees	25
Shrubs	50
Dwarf shrubs	25

Table 5.3.2.iv.c Percentage cover abundance of woody component, *Hyparrhenia hirta - Themeda triandra* association

Percentage cover abundance of woody component	
Trees	<1%
Shrubs	<1%
Dwarf shrubs	<1%

As shown in Tables 5.3.2.iv.b and c, the woody component consists mainly of shrubs, but none of the life forms accounts for 1% cover abundance.

Tables 5.3.2.iv.d and e indicate that although there are a few annual grass species, the cover that they contribute is negligible. The cover contributed by grasses below 1m in height is in accordance with the species richness, with both values at approximately 30%. Tufted grasses make up the majority of species and account for 96% of the grass cover. Although over 30% of grass species are mat-forming, stoloniferous or rhizomatous, they account for less than 20% of the cover. The grass component is thus mainly a tufted sward of perennial grasses above 1m in height.

Table 5.3.2.iv.d Percentage life forms of grass component. *Hyparrhenia hirta - Themeda triandra* association

Percentage life forms of grass component	
Perennial	97
Annual	3
Grasses shorter than 1m	36
Grasses taller than 1m	64
Tufted	85
Mat-forming	9
Stoloniferous	12
Rhizomatous	15

Table 5.3.2.iv.e Percentage cover abundance of grass component, *Hyparrhenia hirta - Themeda triandra* association

Percentage cover abundance accounted for by grass species	
Perennial	102
Annual	<1%
<1m tall	32
>1m tall	70
Tufted	96
Mat forming	7
Stoloniferous	3
Rhizomatous	8

5.3.2.v *Stenotaphrum secundatum – Centella coriacea* association

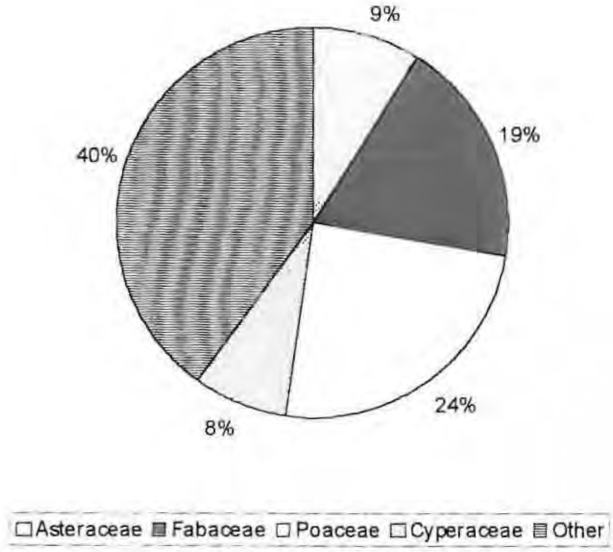


Figure 5.3.2.v Percentage of species richness accounted for by the Fabaceae, Asteraceae, Poaceae, Cyperaceae and other families. *Stenotaphrum secundatum - Centella coriacea* association

Table 5.3.2.v a Percentage life forms of forb component, *Stenotaphrum secundatum - Centella coriacea* association

Percentage life forms of forb component	
Annuals	5
Perennials	95
Forbs taller than 1m	5
Forbs shorter than 1m	80
Prostrate forbs	15
Mat-forming forbs	5
Creepers	0
Succulents	3
Geophytes	10

In this association, the Poaceae are the largest family as shown in Figure 5.3.2.v. Compared with the other mesic associations, the Fabaceae are present at the highest species richness in this association. Table 5.3.2.v.a indicates that the forb component is mainly perennial with the majority of species being below 1m in height. There are no creepers in this association but prostrate and mat-forming species account for 20% of the species richness. The number of geophytes (10% of species richness) is high relative to that of the *Hyparrhenia hirta* – *Diheteropogon amplectens* and *Hyparrhenia hirta* – *Themeda triandra* associations.

Table 5.3.2.v.b Percentage life forms of woody component, *Stenotaphrum secundatum* - *Centella coriacea* association

Percentage life forms of woody component	
Trees	20
Shrubs	60
Dwarf shrubs	20

Table 5.3.2.v.c Percentage cover abundance of woody component, *Stenotaphrum secundatum* - *Centella coriacea* association

Percentage cover abundance of woody component	
Trees	<1%
Shrubs	6%
Dwarf shrubs	<1%

As shown in Tables 5.3.2.v.b and c, shrubs make up the largest component of the woody life forms. In addition to being the most numerous species, they also constitute an average of 6% cover per sample, the highest cover abundance recorded for the shrub component of mesic grasslands. Although both tree and dwarf shrub species were present, they accounted for less than 1% cover abundance each.

Table 5.3.2.v.d Percentage life forms of grass component, *Stenotaphrum secundatum* - *Centella coriacea* association

Percentage life forms of grass component	
Perennial	83
Annual	17
Grasses shorter than 1m	50
Grasses taller than 1m	50
Tufted	67
Mat-forming	25
Stoloniferous	25
Rhizomatous	17

Table 5.3.2.v.e Percentage cover abundance of grass component, *Stenotaphrum secundatum* - *Centella coriacea* association

Percentage cover abundance accounted for by grass species	
Perennial	106
Annual	5
<1m tall	90
>1m tall	17
Tufted	47
Mat forming	53
Stoloniferous	53
Rhizomatous	11

Tables 5.3.2.v.d and e above show that within the grass component, there is a large number of annual species although they do not constitute more than 5% of the cover abundance. Despite the fact that half of the species are above 1m in height, the tall grasses only account for 17% of the cover per sample. This association has the highest number of mat-forming, stoloniferous and mat-

forming grasses of the mesic associations, and they account for over 50% of the cover. Although there are more tufted species, they account for less than 40% of the cover. These tables indicate that the grass sward is short with half of the cover being provided by the mat-forming and stoloniferous species.

5.3.vi *Diheteropogon filifolius – Ehrharta calycina* association

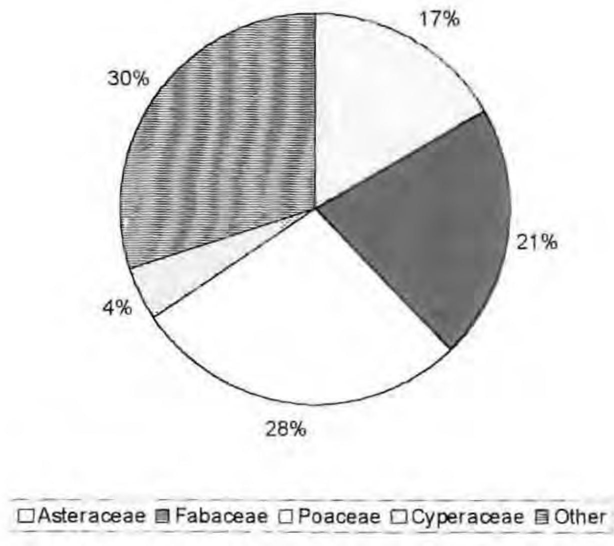


Figure 5.3.2.vi Percentage of species richness accounted for by the Fabaceae, Asteraceae, Poaceae, Cyperaceae and other families, *Diheteropogon filifolius - Ehrharta calycina* association

Table 5.3.2.vi a Percentage life forms of forb component, *Diheteropogon filifolius - Ehrharta calycina* association

Percentage life forms of forb component	
Annuals	4
Perennials	96
Forbs taller than 1m	2
Forbs shorter than 1m	82
Prostrate forbs	14
Mat-forming forbs	4
Creepers	2
Succulents	2
Geophytes	12

As shown in Figure 5.3.2.vi above, this association is characterised by the highest number of Fabaceae and Poaceae in the xeric grassland associations. It also has the lowest number of species in families other than the Fabaceae, Asteraceae, Poaceae and Cyperaceae and the fewest Cyperaceae. Almost 20% of the species belong to the Asteraceae, which is far greater than that recorded in the mesic grasslands.

The forb component of the association is mainly perennial and the majority of species are below 1m in height (Table 5.3.2.vi.a). Prostrate, mat-forming and creeping forbs make up 20% of the cover. The association has the highest number of geophytes recorded in the xeric grasslands.

Table 5.3.2.vi.b Percentage life forms of woody component. *Diheteropogon filifolius - Ehrharta calycina* association

Percentage life forms of woody component	
Trees	33
Shrubs	33
Dwarf shrubs	33

Table 5.3.2.vi.c Percentage cover abundance of woody component, *Diheteropogon filifolius - Ehrharta calycina* association

Percentage cover abundance of woody component	
Trees	<1%
Shrubs	1%
Dwarf shrubs	<1%

As shown in Tables 5.3.2.vi.b and c. trees, shrubs and dwarf shrubs each account for a third of the woody species present per sample. However, while the shrubs provide 1% cover, the remaining woody species do not constitute as much as 1%.

Table 5.3.2.vi.d Percentage life forms of grass component, *Diheteropogon filifolius - Ehrharta calycina* association

Percentage life forms of grass component	
Perennial	100
Annual	0
Grasses shorter than 1m	50
Grasses taller than 1m	50
Tufted	100
Mat-forming	0
Stoloniferous	0
Rhizomatous	19

Table 5.3.2.vi.e Percentage cover abundance of grass component, *Diheteropogon filifolius - Ehrharta calycina* association

Percentage cover abundance accounted for by grass species	
Perennial	110
Annual	0
<1m tall	95
>1m tall	15
Tufted	110
Mat forming	0
Stoloniferous	0
Rhizomatous	20

Tables 5.3.2.vi.d and e indicate that there are no annual grass species present in the association. Although there are as many grass species present that are less than 1m in height as there are tall species, the short grasses provide 95% of the cover. All the grass species are tufted and approximately 20% of those species are also rhizomatous. No mat-forming or stoloniferous species were present. Total grass cover is 110%, of which 20% was provided by species that are rhizomatous as well as tufted.

5.3.2.vii *Cynodon dactylon – Ehrharta calycina* association

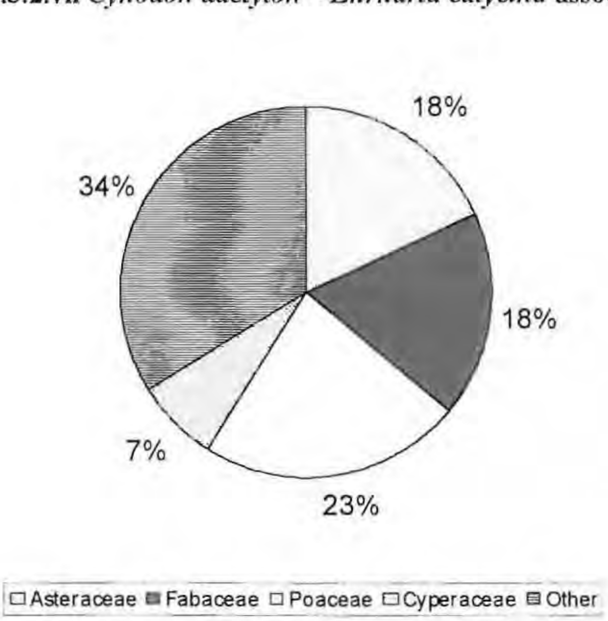


Figure 5.3.2.vii Percentage of species richness accounted for by the Fabaceae, Asteraceae, Poaceae, Cyperaceae and other families, *Cynodon dactylon - Ehrharta calycina* association

Table 5.3.2.vii a Percentage life forms of forb component, *Cynodon dactylon - Ehrharta calycina* association

Percentage life forms of forb component	
Annuals	5
Perennials	95
Forbs taller than 1m	5
Forbs shorter than 1m	81
Prostrate forbs	13
Mat-forming forbs	5
Creepers	2
Succulents	3
Geophytes	11

As shown in Figure 5.3.2.vii above, the Asteraceae and Fabaceae each constitute almost 20% of the species richness in this association. The Poaceae make up slightly more with 23%. There are almost twice as many species belonging to the Cyperaceae in this association as in the *Diheteropogon filifolius – Ehrharta calycina* association. Species in families other than the four described constitute almost 35% of species richness.

Table 5.3.2.vii.a indicates that the majority of the forb component consists of perennial species with only 5% being above 1m in height. Prostrate, mat-forming and creeping species account for 20% of the forb cover as in the *Diheteropogon filifolius – Ehrharta calycina* association. There is a relatively high percentage of geophytes.

Table 5.3.2.vii.b Percentage life forms of woody component, *Cynodon dactylon - Ehrharta calycina* association

Percentage life of woody component	
Trees	66
Shrubs	0
Dwarf shrubs	33

Table 5.3.2.vii.c Percentage cover abundance of woody component, *Cynodon dactylon - Ehrharta calycina* association

Percentage cover abundance of woody component	
Trees	<1%
Shrubs	0
Dwarf shrubs	<1%

Tables 5.3.2.vii.b and c indicate that there are no shrubs in the woody component of the association. While tree species account for two thirds of the woody species, neither these nor the dwarf shrub species account for more than 1% of the vegetation cover.

Table 5.3.2.vii.d Percentage life forms of grass component, *Cynodon dactylon - Ehrharta calycina* association

Percentage life forms of grass component	
Perennial	100
Annual	0
Grasses shorter than 1m	37
Grasses taller than 1m	63
Tufted	84
Mat-forming	11
Stoloniferous	16
Rhizomatous	32

Table 5.3.2.vii.e Percentage cover abundance of grass component, *Cynodon dactylon - Ehrharta calycina* association

Percentage cover abundance accounted for by grass species	
Perennial	135
Annual	0
<1m tall	98
>1m tall	37
Tufted	87
Mat forming	34
Stoloniferous	35
Rhizomatous	58

Within this association, no annual grass species were recorded. Although grasses shorter than 1m accounted for less than 40% of the species richness, they contributed approximately 100% cover. The 60% of tall species accounted for less than 40% cover. This grassland has the highest percentage cover of grass species. The majority of grass species were tufted and accounted for almost 90% of the cover. However, mat-forming, rhizomatous and stoloniferous species accounted for approximately 130% cover between them. Mat-forming species accounted for over 30% of cover while rhizomatous species accounted for almost 60% of the cover.

5.3.2.viii *Themeda triandra – Ehrharta calycina* association

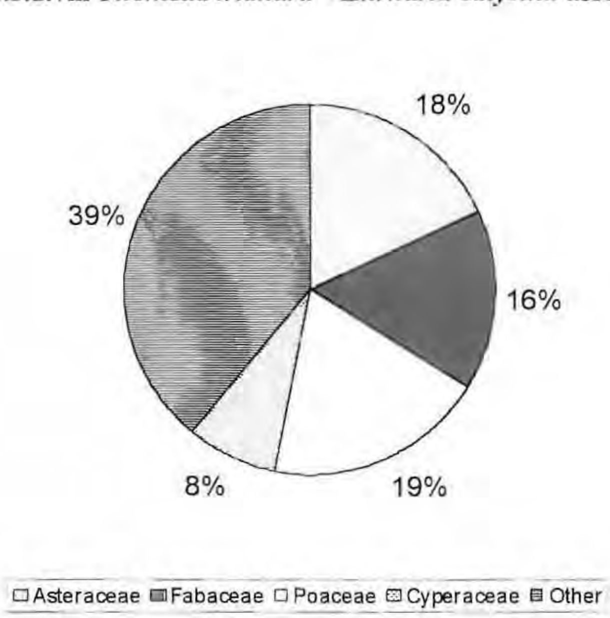


Figure 5.3.2.viii Percentage of species richness accounted for by the Fabaceae, Asteraceae, Poaceae, Cyperaceae and other families, *Themeda triandra-Ehrharta calycina* association

Table 5.3.2.viii a Percentage life forms of forb component, *Themeda triandra - Ehrharta calycina* association

Percentage life forms of forb component	
Annuals	3
Perennials	97
Forbs taller than 1m	1
Forbs shorter than 1m	84
Prostrate forbs	13
Mat-forming forbs	4
Creepers	2
Succulents	2
Geophytes	10

As shown in Figure 5.3.2.viii above, the species richness in this association is between 15 and 20% for the Asteraceae, Fabaceae and Poaceae. The Cyperaceae constitute 8%, the second highest richness for that family in the xeric grasslands. Species richness due to other families is approximately 40%.

The forb component includes few annual species (Table 5.3.2.viii.a) and all but 1% are below 1m in height. Prostrate, mat-forming and creeper species comprise almost 20% of species richness, and geophytes account for 10% of species.

Table 5.3.2.viii.b Percentage life forms of woody component, *Themeda triandra - Ehrharta calycina* association

Percentage life forms of woody component	
Trees	33
Shrubs	33
Dwarf shrubs	33

Table 5.3.2.viii.c Percentage cover abundance of woody component, *Themeda triandra - Ehrharta calycina* association

Percentage cover abundance of woody component	
Trees	<1%
Shrubs	<1%
Dwarf shrubs	<1%

As shown in Tables 5.3.2.viii.b and c. The woody species are evenly spread between tree. shrub and dwarf shrub components. However. none of them account for as much as 1% cover abundance.

Table 5.3.2.viii.d Percentage life forms of grass component. *Themeda triandra - Ehrharta calycina* association

Life forms as % of alpha diversity: grass component	
Perennial	100
Annual	0
Grasses shorter than 1m	45
Grasses taller than 1m	55
Tufted	85
Mat-forming	10
Stoloniferous	15
Rhizomatous	30

Table 5.3.2.viii.e Percentage cover abundance of grass component. *Themeda triandra - Ehrharta calycina* association

Percentage cover abundance accounted for by grass species	
Perennial	103
Annual	0
<1m tall	93
>1m tall	10
Tufted	93
Mat forming	10
Stoloniferous	10
Rhizomatous	35

In this association there are no annual grass species. Although the number of species shorter than 1m is roughly the same as those which grow to 1m or taller. the short species account for 93% of cover abundance as opposed to 10% by the taller species. The majority of species are tufted with 10% mat-forming. 15% stoloniferous and 30% rhizomatous. These figures are reflected in the percentage cover abundance for each of these life forms. Stoloniferous and rhizomatous species account for 45% of the vegetation cover.

5.3.2.ix *Sporobolus africanus – Setaria sphacelata* association

As shown in Figure 5.3.2.ix below. the percentage species richness accounted for by each of the Asteraceae. Fabaceae. Poaceae and Cyperaceae families is between 10 and 15%. with other species making up 46% of species richness. This association has the highest number of Cyperaceae and the lowest Fabaceae and Poaceae species in the xeric grasslands. The number of species in the Asteraceae is the second lowest in the xeric grasslands. being fewer only in the *Cynodon dactylon – Helictotrichon hirtulum* association. This association was ploughed over 40 years ago (see Chapter 4).

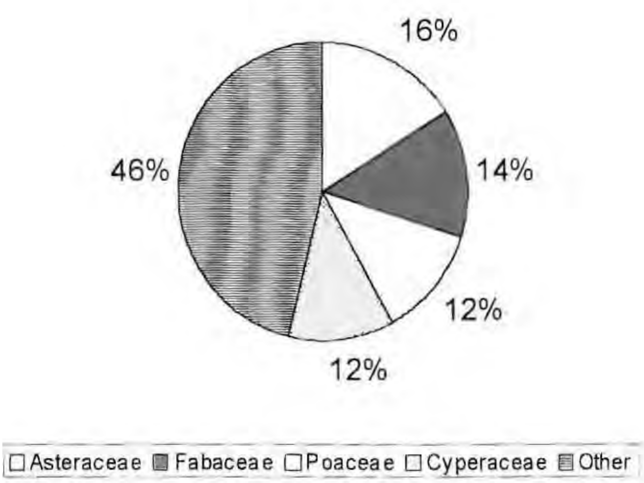


Figure 5.3.2.ix Percentage of species richness accounted for by the Fabaceae, Asteraceae, Poaceae, Cyperaceae and other families, *Sporobolis africanus - Setaria sphacelata* association

Table 5.3.2.ix a Percentage life forms of forb component, *Sporobolis africanus - Setaria sphacelata* association

Percentage life forms of forb component	
Annuals	3
Perennials	97
Forbs taller than 1m	0
Forbs shorter than 1m	86
Prostrate forbs	8
Mat-forming forbs	7
Creepers	3
Succulents	4
Geophytes	4

Table 5.3.2.ix.a indicates that most of the forb component consists of perennial species and none of the species are above 1m in height. Prostrate, mat-forming and creeping species make up almost 20% of the forb component. Geophyte numbers are low, with the lowest percentage for the xeric grasslands occurring in this association.

Table 5.3.2.ix.b Percentage life forms of woody component, *Sporobolis africanus - Setaria sphacelata* association

Life forms as % of alpha diversity: woody component	
Trees	0
Shrubs	50
Dwarf shrubs	50

Table 5.3.2.ix.c Percentage cover abundance of woody component, *Sporobolis africanus - Setaria sphacelata* association

Percentage cover abundance accounted for by woody component	
Trees	0
Shrubs	<1%
Dwarf shrubs	<1%

Tables 5.3.2.ix.b and c indicate that there are no tree species among the woody component and that the shrub and dwarf shrub species each comprise less than 1% of the percentage cover.

Table 5.3.2.ix.d Percentage life forms of grass component, *Sporobolis africanus* - *Setaria sphacelata* association

Life forms as % of alpha diversity: grass component	
Perennial	100
Annual	0
Grasses shorter than 1m	50
Grasses taller than 1m	50
Tufted	80
Mat-forming	20
Stoloniferous	20
Rhizomatous	30

Table 5.3.2.ix.e Percentage cover abundance of grass component, *Sporobolis africanus* - *Setaria sphacelata* association

Percentage cover abundance accounted for by grass species	
Perennial	81
Annual	0
1m tall	51
1m tall	30
Tufted	57
Mat forming	24
Stoloniferous	24
Rhizomatous	29

As shown in Tables 5.3.2.ix.d and e, there are no annual grass species in this association. Percentage cover abundance of grasses is 81%, the lowest value for the xeric grasslands. Although half of the species are above 1m in height and half are below, only 30% cover is due to the taller species. Tufted grasses are the most numerous and make up almost 60% of the vegetation cover while mat-forming species account for 20% of the grass species and over 20% of the cover. Stoloniferous and rhizomatous species make up 50% of the species richness and over 50% of the cover abundance.

5.3.2.x *Cynodon dactylon – Helictotrichon hirtulum* association

Figure 5.3.2.x indicates that half of the species in this association belong to families other than the Asteraceae, Fabaceae, Poaceae or Cyperaceae. This is the highest representation of other families in the xeric grasslands. The association contains the lowest percentage of Asteraceae and the second lowest Cyperaceae in the xeric grassland associations. The Fabaceae and Poaceae each represent almost 20% of the species present. The association occurs in areas that were ploughed within 20 years of the study (see Chapter 4).

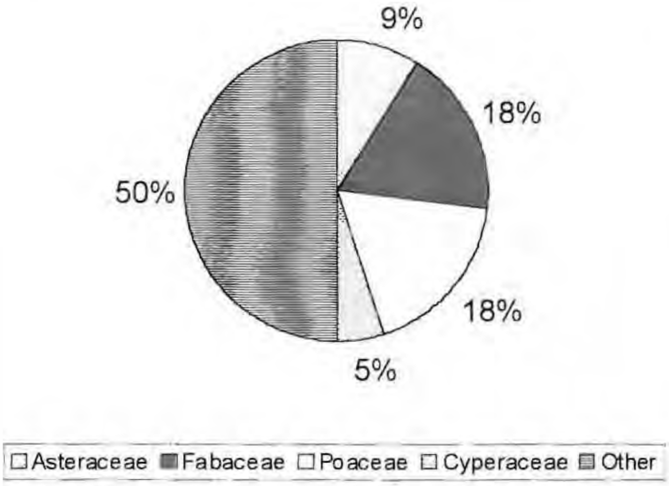


Figure 5.3.2.x Percentage of species richness accounted for by the Fabaceae, Asteraceae, Poaceae, Cyperaceae and other families, *Cynodon dactylon - Helictotrichon hirtulum* association

Table 5.3.2.x a Percentage life forms of forb component, *Cynodon dactylon - Helictotrichon hirtulum* association

Percentage life forms of forb component	
Annuals	1
Perennials	99
Forbs taller than 1m	3
Forbs shorter than 1m	80
Prostrate forbs	14
Mat-forming forbs	3
Creepers	3
Succulents	4
Geophytes	10

As shown in Tables 5.3.2.x.b and c, the life forms of the woody component are evenly shared between tree, shrub and dwarf shrub species. However, none of the life forms constitutes as much as 1% of the cover abundance in the vegetation.

Table 5.3.2.x.b Percentage life forms of woody component, *Cynodon dactylon - Helictotrichon hirtulum* association

Life forms as % of alpha diversity: woody component	
Trees	33
Shrubs	33
Dwarf shrubs	33

Table 5.3.2.x.c Percentage cover abundance of woody component, *Cynodon dactylon - Helictotrichon hirtulum* association

Percentage cover abundance accounted for by woody component	
Trees	<1%
Shrubs	<1%
Dwarf shrubs	<1%

Tables 5.3.2.x.d and e indicate that almost half of the grass species present in this association are annual while slightly more than half are perennial species. The annual species only account for 10% of the cover abundance of grass species, while the perennial make up almost 110% cover. Over 90% of the grass species are above 1m in height but only account for 25% of the percentage cover. While 87% of species are tufted and 13% are mat-forming, the former account for 45% of the cover while the latter account for 63% cover. Grasses that are stoloniferous and rhizomatous account for 40% of the alpha diversity and over 110% of the cover.

Table 5.3.2.x.d Percentage life forms of grass component, *Cynodon dactylon - Helictotrichon hirtulum* association

Life forms as % of alpha diversity: grass component	
Perennial	53
Annual	47
Grasses shorter than 1m	7
Grasses taller than 1m	93
Tufted	87
Mat-forming	13
Stoloniferous	20
Rhizomatous	20

Table 5.3.2.x.e Percentage cover abundance of grass component, *Cynodon dactylon - Helictotrichon hirtulum* association

Percentage cover abundance accounted for by grass species	
Perennial	108
Annual	10
<1m tall	93
>1m tall	25
Tufted	45
Mat forming	63
Stoloniferous	64
Rhizomatous	48

5.3.3 Results of studies on temporal changes and the effect of fire in mesic associations

5.3.3.1 Temporal variation in mesic associations

The results of DECORANA analysis of the *Themeda triandra* and *Themeda triandra – Hyparrhenia hirta* associations are shown below in Figures 5.4.2.1.a, b and c. The data for July, October and December are given, indicating the positions of the associations at mid-winter, spring and mid-summer respectively. (Other associations present in that study area are omitted for the sake of simplicity).

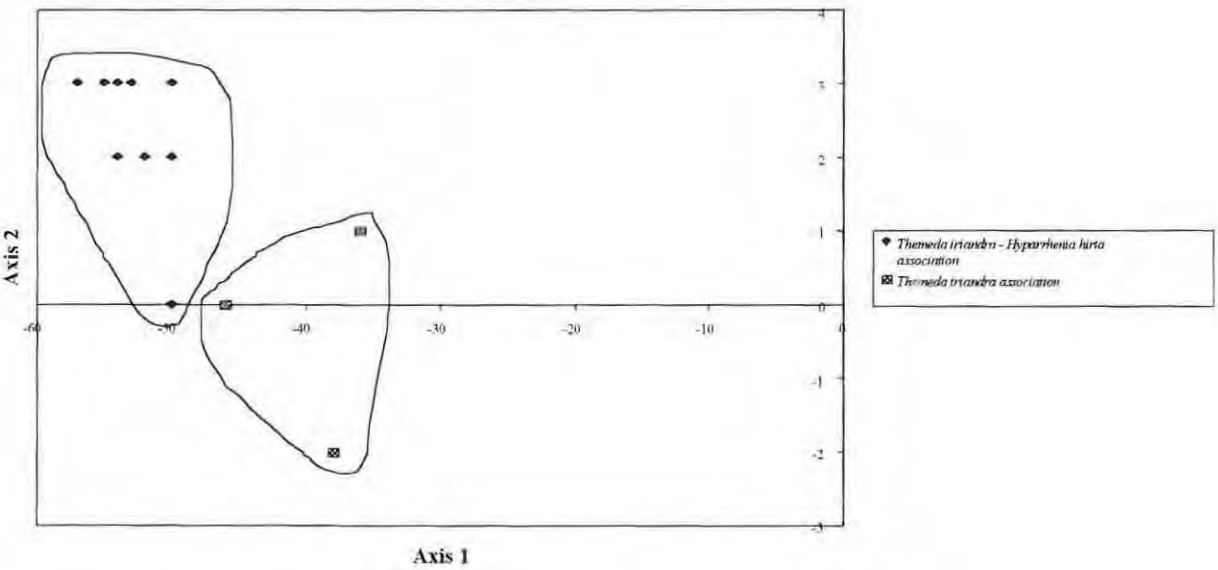


Figure 5.3.3.1.a DECORANA analysis of mesic associations, Potter's Pass, July

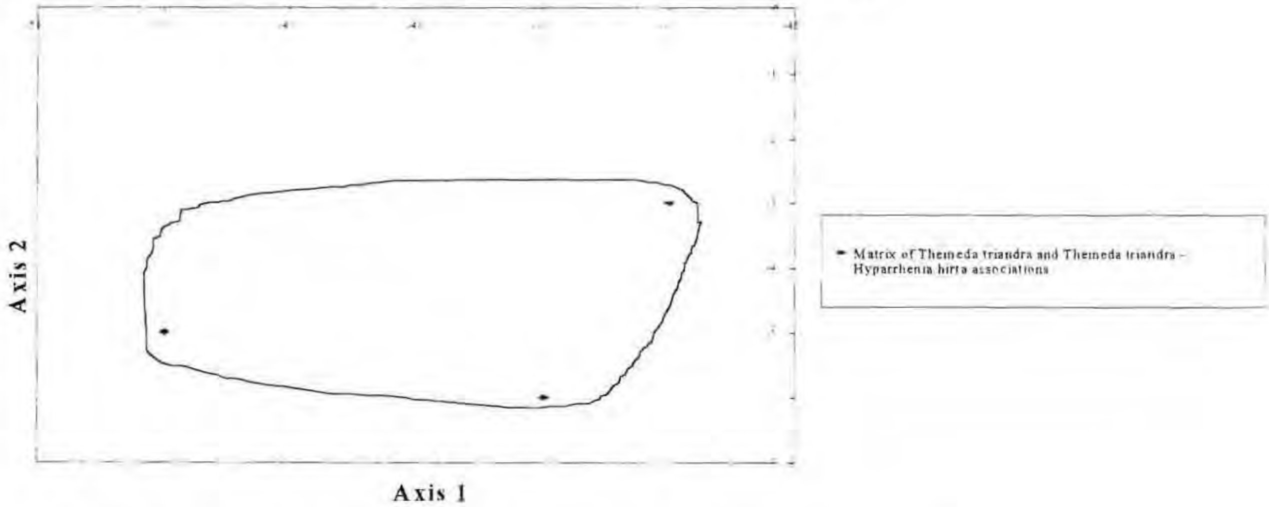


Figure 5.3.3.1.b DECORANA analysis of mesic associations, Potter's Pass, October

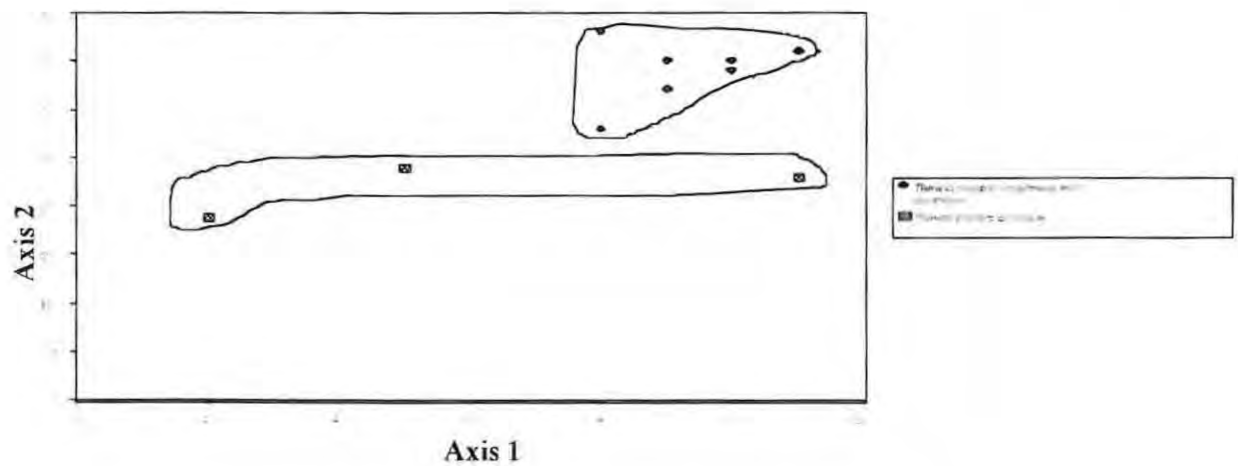


Figure 5.3.3.1.c DECORANA analysis of mesic associations. Potter's Pass. December

As shown in the results above, the two associations showed clear separation during mid-summer and mid-winter. However, the twelve samples taken in October were inseparable, with ten samples having the same values and the remaining two being very close.

5.3.3.2 Effect of Fire on Mesic Associations

5.3.3.2.a *Themeda triandra* association

Within the *Themeda triandra* association, two sets of plots were sampled over a twelve month period starting in June. One set of plots had been burnt when the study commenced while the last time at which the other set had been burnt was not known. All the plots were subject to unplanned burning in April the following year (Judd, 1995).

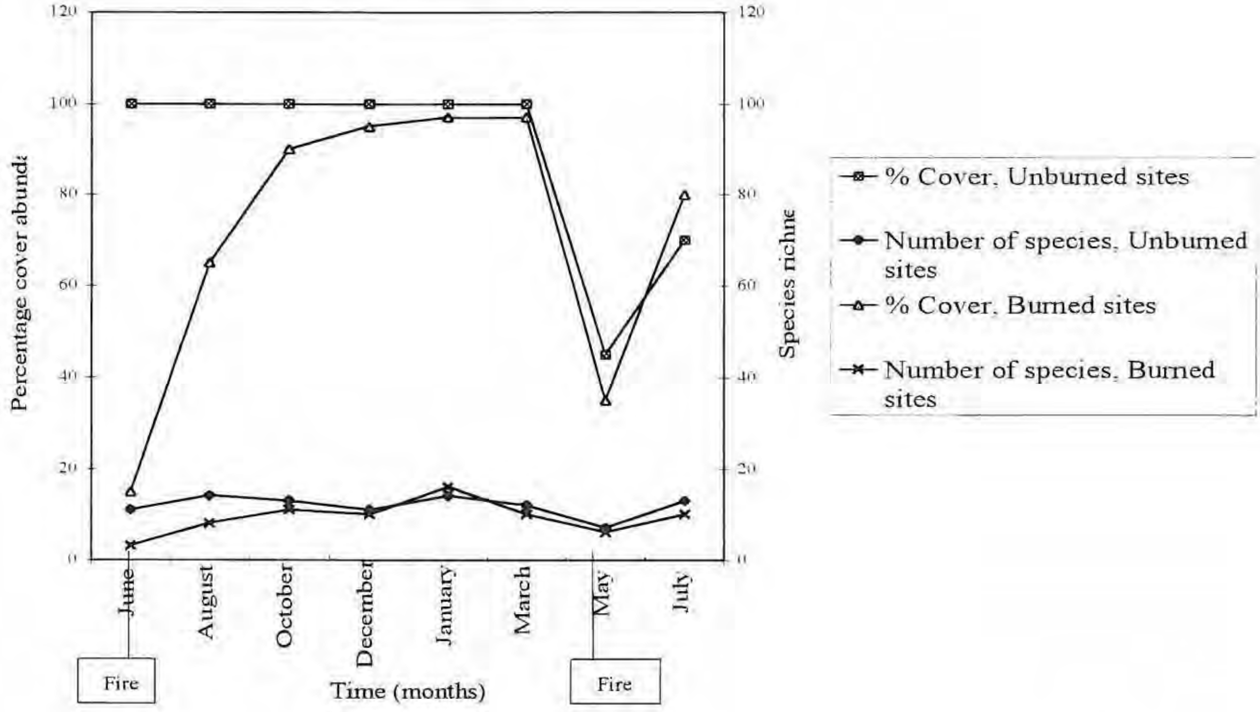


Figure 5.3.3.2.a Average percentage cover and number of species before and after burning, *Themeda triandra* grassland

The results shown in Figure 5.3.3.2.a indicate that the percentage cover of the sites not burned in June remained at 100% until the onset of fire. The sites burned in June showed a rapid increase in cover and by October this had reached 85% having started at 5%. However a maximum of 95% cover was only attained seven months later in January. Because of the occurrence of another fire in mid-April, all the samples were burnt. By July, the vegetation that had been burnt the previous year showed a greater percentage cover than that which had not been burnt. The study could not be continued because of the removal of the markers for the sample sites by human interference.

Figure 5.3.3.2.b *Themeda triandra* grassland within six weeks of burning

Figure 5.3.3.2.c *Themeda triandra* grassland nine months after burning

The species richness in the samples that were not burned in June remained lower than that of the unburned samples until January, when it increased to three species more than those in the unburned samples. However it decreased over the following two months suggesting that several of these species were annuals. After all samples were subject to fire in April, the species richness of both the previously burned and unburned sites was the same, suggesting that there is a consistent group of species which is not destroyed by fire. The species present included *Themeda triandra*, *Hyparrhenia hirta*, *Clutia heterophylla*, *Gerbera piloselloides* and *Dierama pendulum*. Other species present were in seedling form and not immediately identifiable.

Within eight weeks of the April fire, percentage cover and species richness in the samples which had been burned the previous July were slightly higher than in the samples which had not been burned. No comment is made on this as it is felt the lack of subsequent data prevents further inferences from being made.

5.3.3.2.b *Themeda triandra – Hyparrhenia hirta* association

The samples used in the analysis of *Themeda triandra - Hyparrhenia hirta* grasslands were unburned at the start of the study. The results shown in Figure 5.3.3.2.d indicate that the sites which were subsequently burned in July had a slightly greater percentage cover abundance at the beginning of the study than those which were not burned, while the species richness of the former was slightly less than that of the latter.

The burned vegetation reached 95% cover abundance within seven months and equalled that of the unburned samples in January when it attained 100% cover. A subsequent fire in April prevented further determination of this vegetation's response to fire. The unburned vegetation reached its maximum cover in January, after which it began a slow decline and by May it was 90%. A fire occurred in late May, thus long-term variation could not be examined.

Initial species richness in the originally unburned sites was higher than in those that were burned in June. Diversity showed a steady decline until March when numbers began to increase. The increase may be due to the decrease in cover abundance of perennial species, which enabled annual species to establish themselves before being ousted by the increasing cover of perennial species. In the burned vegetation, species diversity showed an initial decrease after fire followed by an increase to a richness greater than that showed in the unburned vegetation. Diversity declined from October to May as the cover abundance increased. After burning in April species richness was the same, because of the persistence of such fire-resistant species as *Themeda triandra, Hyparrhenia hirta, Gazania krebsiana, Clutia heterophylla* and *Gerbera piloselloides*.

Figure 5.3.3.2.d Average percentage cover and number of species before and after burning, *Themeda triandra - Hyparrhenia hirta* grassland

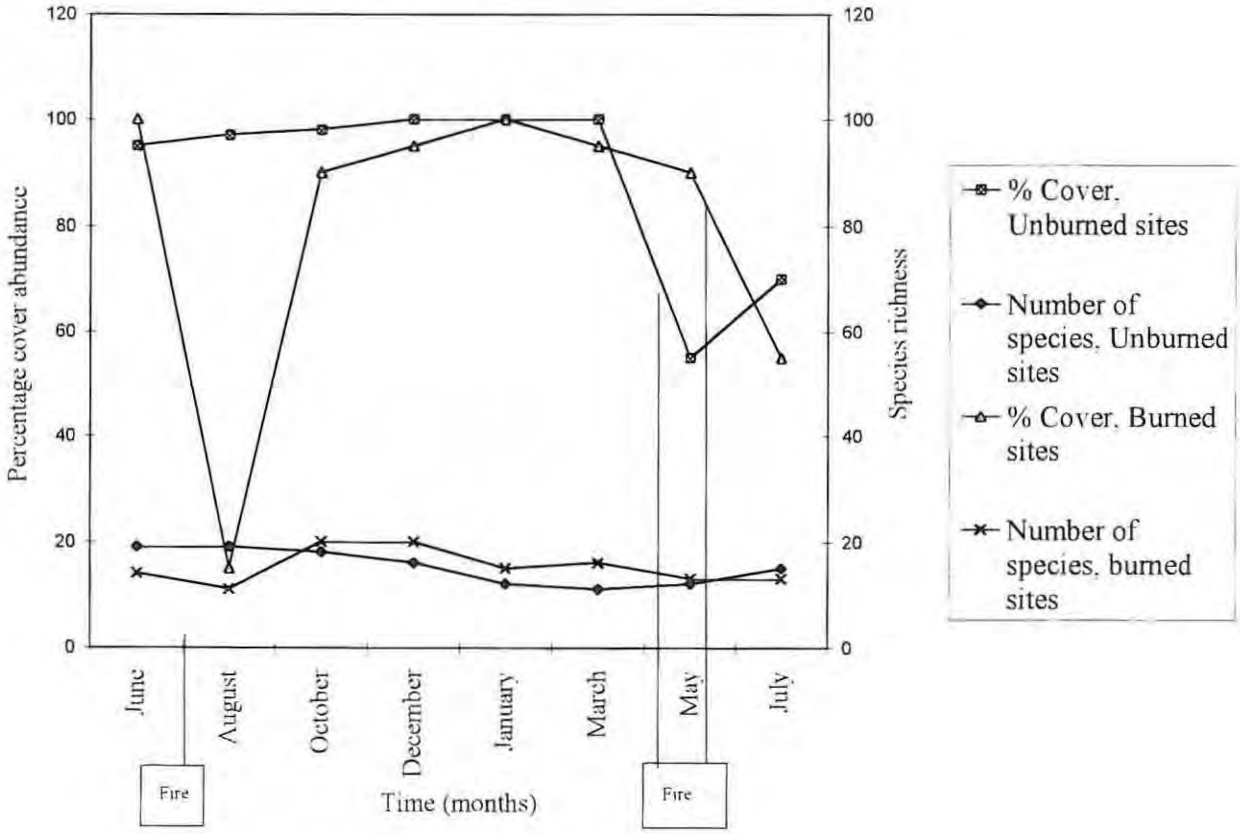


Figure 5.3.3.2.e *Themeda triandra – Hyparrhenia hirta* grassland shortly after burning

Figure 5.3.3.2.f *Themeda triandra – Hyparrhenia hirta* grassland five months after burning

The results show that following fire there is an initial increase in annual species which is not sustained as the perennial species regain their abundance. Establishment of annuals is therefore opportunistic and follows the pattern outlined for succession whereby ephemeral species are the first to colonise after disturbance. The presence of propagules such as seeds in the soil and the persistence of vegetative portions of perennial species determine initial species composition.

5.4 DISCUSSION

5.4.1Diversity and Life Forms

From Table 5.3.1.a and b above it is apparent that the highest alpha diversity in the Eastern Cape Coastal Grasslands occurs in the mesic *Themeda triandra* association with 206 species. The mesic grasslands are subjected to varying amounts of grazing, trampling and burning. The *Stenotaphrum secundatum - Centella coriacea* association occurs in areas that have been subjected to severe trampling and physical disturbance. In the xeric grasslands, the greatest diversity occurs in the *Themeda triandra - Ehrharta calycina* association which has 119 species. The *Diheteropogon filifolius- Ehrharta calycina* and *Cynodon dactylon - Ehrharta calycina* associations are subject to intensive grazing pressure, while the *Sporobolus africanus - Setaria sphacelata* and *Cynodon dactylon - Helictotrichon hirtulum* associations occur on areas that were ploughed. It is felt that the *Themeda triandra* association represents the climax vegetation of the mesic grasslands, while the *Themeda triandra - Ehrharta calycina* association represents the climax vegetation within the xeric grasslands. The results shown in table 5.2.2.ii indicate that there is high beta diversity between the mesic and xeric associations. It is slightly less between mesic associations than between the xeric associations.

In accordance with McIntyre *et al.* (1995), lightly grazed and ungrazed associations had greater alpha diversity than grazed associations. This partially supports the Intermediate Disturbance Hypothesis (van der Maarel; 1993). It is in contrast with studies on savannah vegetation in India where protected vegetation showed a lower diversity than grazed vegetation (Pandey and Singh, 1991). Areas which were more severely grazed or stressed by environmental conditions had a lower species diversity in agreement with results by Westhoff (1971, in van der Maarel, 1996; Belsky, 1986, in Pandey and Singh, 1991; Pandey and Singh, 1991). This also supports the work of Watt

(1947) that in vegetation under high environmental stress, a species-poor association will develop. In contrast, where there is a low degree of environmental stress, species-rich associations will develop. Contrary to studies by McKenzie (1987) in the former Transkei, the rate of species change along a disturbance gradient due to ploughing is greater than along a grazing gradient.

Within the mesic associations, the *Themeda triandra - Anthospermum herbaceum* association has the lowest alpha diversity. This may be attributable to the fact that it is the least extensive association and that it appears to be limited to the steep cliffs in the vicinity of Morgan's Bay. In addition its proximity to presumed high levels of salt spray and exposed location contribute to environmental stress. The high abundance of the mesic forb *Anthospermum herbaceum* indicates high moisture levels, which may be influenced by sea fog. Beta diversity is lowest between this association and the *Themeda triandra* and *Hyparrhenia hirta -Themeda triandra* associations which are located adjacent to it. This result supports the findings of Cowling *et al.* (1997) who state that beta diversity is lowest between a habitat which is small in extent and a larger contiguous habitat than between two larger habitats. The similarity coefficients are highest between the *Themeda triandra - Anthospermum herbaceum* and *Themeda triandra* and *Stenotaphrum secundatum Centella coriacea* associations, this indicates that the *Themeda triandra - Anthospermum herbaceum* association is most similar to the least and most disturbed associations, reflecting its physical location adjacent to these association.

Overall, this association is characterised as short, perennial-dominated grassland. It has low species richness and may be considered to be a depauperate form of the *Themeda triandra* association. It has the lowest alpha diversity, highest number of mat-forming and prostrate forb species, highest number of mat-forming, rhizomatous and stoloniferous grass species, and the second highest number of annual species within the mesic grasslands. It has the highest percentage cover of grass species and no tree species are present at all. The short nature of the vegetation and low diversity is in accordance with its locality on shallow soils on extremely exposed cliffs above the ocean with little protection against prevailing salt-laden winds. The high number of annuals and rhizomatous and stoloniferous species indicates that it is a low successional sere.

The *Themeda triandra* association is the most extensive grassland type in the Eastern Cape Coastal Grasslands. As it covers a wide area it occurs in a wide variety of habitats it is to be expected that it has a high alpha diversity relative to the other associations. The lowest beta diversity occurs between this association and the *Themeda triandra - Anthospermum herbaceum* association. However, the *Themeda triandra* association has a far higher alpha diversity with approximately four times the species richness of the *Themeda triandra - Anthospermum herbaceum* association. The coefficient of similarity indices show that apart from the *Themeda triandra - Anthospermum herbaceum* and *Hyparrhenia hirta - Diheteropogon amplectens* associations, it is most similar to the climax xeric *Themeda triandra - Ehrharta calycina* association.

Overall, this association has the highest alpha diversity of the mesic grasslands and the highest number of geophyte species. It has a high percentage of perennial forbs and grasses and extremely low abundance of woody species. It is mixed grassland in terms of height, with about half the cover due to species which never exceed 1m in height. It is felt that this grassland association represents the climax mesic grassland in the study area.

The *Hyparrhenia hirta - Diheteropogon amplectens* association has the third largest alpha diversity within the mesic grasslands. It is most similar to the *Hyparrhenia hirta - Themeda triandra* and *Themeda triandra* associations. It has coefficients of similarity of between .30 and .40 with all but the most disturbed xeric and mesic associations. These relatively high values coupled with its low species abundance indicates that the species present are common throughout the study area. The association occurs on soils which are phosphate and potassium limiting; therefore only these species which can tolerate such conditions are present. Such species are likely to have wide ecological amplitudes i.e. ability to over a wide range of environmental conditions. The soil factors may explain the low alpha diversity of this association.

This association has no annual grass species and few annual forbs. The alpha diversity is almost half that of the *Themeda triandra* association, which is considered to be the climax association in the mesic grasslands. The cover abundance is low relative to that of all the other mesic associations, and there are the least number of geophytes and forbs above 1m in height. The grass component consists mostly of tufted species and approximately 60% is above 1m in height. The sward thus does not have a uniform height appearance (see Figure 5.4.1). This grassland was located in areas where cattle were grazed and the effect of land use may have been to cause a decrease in diversity and abundance in the association (see Chapter 4).

The *Hyparrhenia hirta - Themeda triandra* association has the second highest alpha diversity of the Eastern Cape Coastal Grasslands. Although the lowest beta diversity occurs between it and the *Themeda triandra* association, the coefficient of similarity is relatively low. The association has low coefficients of similarity with most of the mesic associations but values of above .30 are common for the xeric associations. This indicates that species similarity is closer to that of the xeric associations, possibly because of the effect of grazing (see Chapter 4).

This association is characterised by a high alpha diversity, tufted grass species and a sward that is generally above 1m in height. It is the tallest sward in the mesic grasslands. There is little cover by woody species and few annual, mat-forming and prostrate forbs occur. The overall average cover per sample is lower than that of the *Themeda triandra* association, possibly because this grassland is subject to grazing by cattle (see Chapter 4).

The *Stenotaphrum secundatum - Centella coriacea* association has the second lowest alpha diversity of all the associations within the study area. It shows little similarity to any mesic association except the *Themeda triandra - Anthospermum herbaceum* association. The coefficient of similarity is .45, one of the highest values in the study, suggesting again the presence of species able to withstand severe environmental pressure. The lowest beta diversity occurs between the association and the *Themeda triandra - Ehrharta calycina* and *Sporobolus africanus - Setaria sphacelata* associations of the xeric grasslands while coefficients of similarity are slightly higher with these associations. The close similarity between the association and the *Sporobolus africanus - Setaria sphacelata* association indicates its similarity to severely soil disturbed environments.

The *Stenotaphrum secundatum – Centella coriacea* association is characterised by a short grass sward with the lowest cover abundance of species above 1m in height. It has the highest cover due to mat-forming and rhizomatous species. It has the highest number of annual species and the lowest alpha diversity within the mesic grasslands. This grassland occurs in areas subject to intense disturbance because of vehicular pressures and pedestrian trampling (see Chapter 4) which may well account for the low nature of the vegetation and the high number of annuals. This association is regarded as being at a low seral stage in terms of succession.

The *Diheteropogon filifolius - Ehrharta calycina* association has the lowest alpha diversity of the xeric grasslands. Similarity to the mesic associations is very low as shown by the beta diversity and coefficients of similarity. These factors indicate that it is most similar to the soil disturbed *Sporobolus africanus - Setaria sphacelata* and *Cynodon dactylon – Helictotrichon hirtulum* associations. The association occurs in heavily grazed communal land (see Chapters 3 and 4). It appears that the effect of heavy grazing on species richness is more severe than the effect of a major soil disturbance such as ploughing. There is roughly 40% beta diversity between this association and the *Cynodon dactylon - Ehrharta calycina* and *Themeda triandra - Ehrharta calycina* associations but with the remaining two xeric grasslands, beta diversity is above 60%.

The association is characterised by a short grass sward dominated by perennial grasses and a high number of annual forb species. Members of the Fabaceae and Asteraceae dominate the forb component. Prostrate and mat-forming forbs comprise almost 20% of this component. The grasses are all tufted although some are also rhizomatous. The association has the highest number of grass species within the xeric associations.

The *Cynodon dactylon - Ehrharta calycina* association has the second highest alpha diversity of the xeric associations. It is most similar to the xeric associations which were not subjected to ploughing. In addition, beta diversity is relatively low and the coefficient of similarity high with *Hyparrhenia hirta – Diheteropogon amplectens* association. This suggests species similarities based on ability to withstand grazing and trampling.

The association is characterised by perennial grasses with the highest cover abundance for grass species in the xeric grasslands. Cover abundance due to mat-forming species is highest in this association of the xeric grasslands. Prostrate and mat-forming forbs form one fifth of the forb species richness. There are no shrubs and the woody component accounts for less than 1% of the total vegetation cover. Alpha diversity is the second highest value recorded in the xeric grasslands. The grass sward consists mainly of short species with approximately one third of cover being due to mat-forming grasses. The association occurs on heavily grazed and trampled communally-owned areas (see Chapter 3) and the results support findings by Acocks (1966) and McKenzie (1984). These authors have found that heavy continuous grazing results in a uniform sward with high cover abundance of grasses, as demonstrated in this association. The presence of mat-forming species is indicative of high trampling pressure.

The *Themeda triandra - Ehrharta calycina* association has the highest alpha diversity of the xeric grasslands and is almost 60% of the highest alpha diversity in mesic associations. It is regarded as representing the climax vegetation of the xeric associations. Beta diversity and coefficient of similarity values indicate that the highest similarity is between the association and the *Cynodon dactylon - Ehrharta calycina* and *Sporobolus africanus - Setaria sphacelata* associations. There is also fairly high similarity between the association and the climax mesic association.

The association is characterised by a short grass sward with a low abundance of woody species and up to 20% of the forb component consisting of prostrate or mat-forming species. Only 10% of the cover is due to mat-forming grasses. There are few annual forbs and no annual grass species present. This association has the highest alpha diversity in the xeric grasslands but only the third highest cover abundance of grasses. It is considered to be the association which most closely represent the climax vegetation of the xeric grassland associations. Since this association did not occur extensively in unutilised or lightly utilised vegetation, it is felt that a climax association was not defined in the study. The presence of *Ehrharta calycina*, which occurs after disturbance, indicates that the vegetation may not be pristine.

The *Sporobolus africanus - Setaria sphacelata* association has the second lowest alpha diversity of the xeric grasslands. It occurs on highly disturbed soils that were ploughed within the last 40 years but that have since been allowed to revegetate. The vegetation is now utilised for cattle grazing (see Chapters 3 and 4). The highest coefficient of similarity indices are with the *Cynodon dactylon - Ehrharta calycina* and *Themeda triandra - Ehrharta calycina* associations, but it also has a relatively high similarity to the mesic associations. This supports the idea that there is a group of species common to all the associations in the study area.

The association is characterised by a short sward with no annual grasses and few annual forb species. There are no tree species present and the number of geophytes is the lowest recorded for the xeric grasslands. The association has the highest number of Cyperaceae and the lowest number of Poaceae species as well as having the lowest cover abundance of grasses in the xeric grasslands. Members of the Fabaceae are poorly represented in this association, which has the second lowest alpha diversity of the xeric grasslands. It is a true secondary grassland.

The *Cynodon dactylon* – *Helictotrichon hirtulum* association occurs on soils that were ploughed within the last 20 years and have since been left fallow. They provide grazing for a small number of cattle (see Chapters 3 and 4). The beta diversity and coefficient of similarity values indicate dissimilarities between the association and most of the mesic associations. It shows greatest similarity to the xeric associations and soil-disturbed *Stenotaphrum secundatum* – *Centella coriacea* association. It is regarded as being the nearest representative of a pioneer community in the grasslands. The similarity indices suggest that there is a suite of species within the mesic and xeric grasslands, which are able to survive severe environmental stress and that these species will persist despite these stresses. They are the species that give the system its resilience.

The association is characterised by a short grass sward dominated by mat-forming perennial species. There are many annual grass species, unlike all the other xeric grassland associations, which lack annual grasses. There may have been more annual species immediately after ploughing was discontinued but this is not known. Perennials below 1m in height dominate the forb component with low cover abundance accounted for by woody species. The geophyte component is as high as that of the *Themeda triandra* – *Ehrharta calycina* association. This was unexpected seeing that the soil had been ploughed. The cover abundance is fairly low but species richness is the second highest in the xeric grasslands.

Studies of the alpha diversity of the grassland associations indicate that the mesic associations are generally richer than the xeric associations. The exception to this is the *Themeda triandra - Anthospermum herbaceum* association, which may be regarded as a depauperate form of the *Themeda triandra* association. Grazing and ploughing reduce diversity in all associations.

The results of the diversity study indicate that there is high beta diversity between the mesic and xeric grassland associations. Within the mesic grasslands the lowest beta diversity scores are between the *Themeda triandra - Ehrharta calycina, Diheteropogon filifolius- Ehrharta calycina* and *Cynodon dactylon - Ehrharta calycina* associations, indicating that the highest level of similarity and lowest species turnover rate occurs between these associations. The beta diversity between the *Themeda triandra - Anthospermum herbaceum* association and the *Stenotaphrum secundatum Centella coriacea* association indicates similarity between the physically disturbed and the environmentally stressed associations. The *Stenotaphrum secundatum - Centella coriacea* association shows the lowest beta diversities between itself and the xeric grasslands. This may be a function of disturbance, since this is the most disturbed of the mesic associations. The high beta diversity between the *Themeda triandra* association and the *Hyparrhenia hirta - Diheteropogon amplectens* association may be partly due to the potassium and phosphate deficient soils on which the latter association occurs (see Chapter 4).

The coefficient of similarity indices support the results of beta diversity analysis. They show that there is a greater degree of similarity between xeric associations than between mesic associations. this was unexpected given the fact that the xeric associations have been subjected to greater disturbances than the mesic associations. Coefficients of similarity are much the same between grazed and ploughed vegetation in the xeric associations. However, beta diversity is lower between the grazed and climax associations than between the ploughed and climax associations. Between the most heavily grazed *Diheteropogon filifolius- Ehrharta calycina* association and the *Cynodon dactylon - Helictotrichon hirtulum* association that was ploughed 20 years prior to sampling, beta diversity is high. These results imply that the effects of disturbance due to grazing and ploughing are dissimilar. Recovery from these two types of disturbance is not likely to lead towards convergence of the vegetation. Species turnover in the xeric grasslands along a ploughing gradient is higher than along a grazing gradient, indicating that the former disturbance is more significant even though the species richness is higher.

Of the families examined within each association, the Poaceae are the most important in the study area. The effect of ploughing in the xeric grasslands appears to be a severe decrease in the number of grass species. There were no annual species recorded in the mesic associations while in the xeric associations annual grass species were only found in the *Sporobolus africanus – Setaria sphacelata* association. This may be due to the fact that the *Sporobolus africanus – Setaria sphacelata* association was not being grazed as heavily as the other xeric associations. All the associations throughout the study area were grazed, so it may be that the lack of annual grasses in the xeric associations is due to a combination of less moisture and grazing. In addition, ploughing in the xeric grasslands appears to give rise to an increase in the number of Cyperaceae species, at the expense of the Poaceae. This effect is more pronounced in the areas which were ploughed 40 years ago than in those which were ploughed 20 years ago. This may indicate that moisture conditions have improved more in the areas which were ploughed over 40 years ago than in areas which were ploughed more recently, enabling the Cyperaceae to colonise more of these areas than in other associations.

In the xeric grasslands the Asteraceae and Fabaceae contribute as much to species richness as the Poaceae although the Asteraceae appear to decline after ploughing. Legume interactions as described by Schwinning and Parsons (1996) indicate that under poor soil nitrogen conditions, the growth of legumes that are able to fix nitrogen is favoured. When soil nitrogen conditions are good, the growth of grasses is favoured because of more efficient nitrogen uptake (after Thornley *et al.*, 1995). Ultimately a balance is established, allowing for co-existence of both grass and legume. While soils nitrogen conditions were not examined in the study because of experimental constraints, the results suggest that in the xeric associations, nitrogen levels may be low, favouring the legumes over the grasses. Within the xeric grasslands themselves, grasslands subject to the heaviest grazing and trampling pressure i.e. the *Diheteropogon filifolius – Ehrharta calycina* association have a wider variety of legume species than the grasslands which were formerly ploughed. This is consistent with results shown by Hader *et al.* (1999) who found that legumes increased more than any other family in shrublands that were cleared and grazed. It was expected that the legume numbers would be lower in the ploughed lands because of the application of fertilisers but they are still far more common than in the mesic grasslands and seem to play a greater role in the xeric grasslands. This may be due to soil nitrogen levels but rainfall requirements, temperature and seasonality may also be involved. Further study of this aspect of grassland structure is warranted.

Other families contribute 35 – 45% of species richness in the mesic grasslands, but the range is wider in the xeric grasslands where they contribute 30 – 50% of diversity. It is possible that the lower rainfall experienced by the xeric grasslands results in conditions which are less suitable for grass species and thus a wider variety of other species is able to exist. The mesic grasslands have a higher average cover abundance of grass species per plot than do the xeric grasslands, which is consistent with findings by Jenny (1980), O'Connor (1985) and others that grass productivity increases with increasing rainfall (see Chapter 4).

In terms of perennial versus annual species, annual species did not contribute more than 5% cover in any association except the *Cynodon dactylon – Helictotrichon hirtulum* association. This indicates that within 20 years of a major disturbance of the soil, up to 90% of the vegetation cover is accounted for by perennial species and that grazing in either mesic or xeric grasslands does not encourage the occurrence of annual species. In successional theory, initial colonisers after a major soil disturbance event are annual species, followed by perennials (Noble and Slatyer, 1977). Hader *et al.* (1999) and McIntyre *et al.* (1995) indicated that grazing increased the number of annual species. The results from this study may imply that while grazing has opened physical space for annual species to enter the associations, it may be causing their mortality before they have time to reach maturity and set seed. The relatively high number of annuals in the *Cynodon dactylon – Helictotrichon hirtulum* association, which is extremely lightly grazed, supports this suggestion. It is surmised that studies in the first ten years following a disturbance such as ploughing would indicate a greater importance of annual species than in these areas, which were sampled twenty years and more after the event.

Grazing decreased the cover of grasses above 1m in height and resulted in a greater percentage cover derived from shorter grass species. The same result was found by Belsky (1992) working in the Serengeti grasslands. The anomaly to this finding occurred in the *Themeda triandra - Ehrharta calycina* association where grass cover derived from species shorter than 1m in height was 90%. The explanation may lie in the high percentage cover of *Themeda triandra* (see Chapter 3) which does not exceed 1m in height throughout the study area. This association was the least grazed of the unploughed grasslands.

Severe disturbance gave rise to a greater abundance of mat-forming species. This agrees with results by Noy-Meir *et al.* (1989) in Mediterranean grasslands. In mesic associations, mat-forming grasses contributed more than 10% of cover abundance only in areas subject to disturbance and severe wind and salt spray effects. In the xeric grasslands they made up more than 25% cover in all associations except those subject to intense grazing and trampling. Mat-forming species are generally regarded as being characteristic of lower seres in the successional process and indicating a closer relationship to pioneer states than tufted grasses. This is supported by the results of this study, where mat-forming species contributed the highest cover abundance in the most recently disturbed areas. Species which were rhizomatous and/or stoloniferous were far more numerous in the xeric grasslands as compared to those found in the mesic grasslands, and contributed far more to cover abundance, probably because of grazing. Mesic grasslands had more grass species which attain heights of over 1m and greater cover abundance by those grasses than the xeric grasslands did. This agrees with broad-scale studies done by Lane *et al.* (2000) in temperate grasslands of the United States.

5.4.2 Temporal variation

The inability to separate the same sites by TWINSPAN and DECORANA was not due to a change in species composition, since the species making up the associations are perennials. It is due to changes in cover abundance of the species within each grassland, and bears out the work of Bayer (1955). He found that the change in appearance of a grassland dominated by both *Themeda triandra* and *Hyparrhenia hirta* showed such a strong response to season that one could record it as two different types depending on the time of sampling. During spring when *T. triandra* is flowering it dominates the grassland and its cover abundance exceeds that of the *H. hirta*. *H. hirta* is a late-summer flowering species (Gibbs-Russel *et al.*, 1991) and shows co-dominance only at the end of summer.. Thus the two associations appear to be a single *Themeda triandra* grassland during spring but separate from midsummer and remain so until the following spring. This indicates the difference which phenology and time of sampling can make to the perceived structure of an association. It also indicates that the *Themeda triandra* – *Hyparrhenia hirta* association may enter a transitional stage for this period of time. It is possible that if the right events were to occur, it might revert to being permanent *Themeda triandra* grassland.

With regard to temporal changes in the mesic associations studied, the results highlight the fact that the grasslands cannot be seen as static associations that show variation only when disturbed or stressed. Seasonality and positive environmental factors such as elevations in rainfall and the cessation of grazing can cause associations to fluctuate between various states and may ultimately cause them to undergo a significant transition to a higher state or sere. Temporal variation therefore plays an important role in grassland dynamics and it must be more fully studied in order to gain a better understanding of the functioning of grassland ecosystems.

The mesic associations in this study show high resilience in response to disturbance due to fire. Recuperative stability is high but this is only a preliminary study and studies examining the long-term effect of fire as well as the effects of frequency and season of burning need to be carried out. The high resilience exhibited indicates that the associations are unstable.

As well as showing resilience towards disturbance by fire, the associations studied also show resilience towards favourable changes such as the transition from a *Themeda triandra* - *Hyparrhenia hirta* association to a *Themeda triandra* association. McKenzie (1982) also noted such resistance to positive change with respect to the *Aristida* grasslands of the former Transkei. This result follows the theory of the non-equilibrium model which states that in order to return vegetation to its original state not only must the disturbance cease but another disturbance acting in the opposite direction is required (Frost *et al.*, 1986; Westoby *et al.*, 1989; Mentis and Bailey, 1990). Assuming that the *Themeda triandra* association is the climax vegetation for the mesic areas, the cessation of burning and grazing (which was carried out over 20 years ago) will not be enough to return the vegetation to this climax state. Some other effect will be necessary.

5.5 CONCLUSIONS

The greatest alpha diversity was recorded in a mesic grassland association, with the highest alpha diversity in a xeric association being almost half the number of species. Disturbance through grazing, trampling and soil disturbance in both the mesic and xeric grasslands resulted in a decrease in alpha diversity. The effect of salt spray may be the cause of the lowest alpha diversity, recorded in the *Themeda triandra - Anthospermum herbaceum* association. This theory needs further testing.

The *Themeda triandra* association is the least disturbed and most extensive of the mesic associations, occurring over a wide area and having the highest diversity. The associations in which Hyparrhenia *hirta* is co-dominant are grazed, which leads to drop in alpha diversity and thus also an increase in beta diversity with other associations. The species similarities between the *Hyparrhenia hirta - Diheteropogon amplectens* and *Hyparrhenia hirta – Themeda triandra* associations highlight the effects of grazing, namely a decline in species richness and abundance. Excessive disturbance, illustrated by the *Stenotaphrum secundatum Centella coriacea* association, causes more damage than severe environmentally-related effects of wind and salt (*Themeda triandra - Anthospermum herbaceum* association). Species turnover is less between climax grasslands and those that are affected only by grazing than between climax grasslands and those which are subject to severe soil disturbance.

The *Themeda triandra – Ehrharta calycina* association is the least disturbed of the xeric associations and has the highest alpha diversity. Alpha diversity decreases with increasing grazing pressure but has an anomalous relationship with soil disturbance due to ploughing. This may be due to favouring of annual species after severe disturbance (*Cynodon dactylon - Helictotrichon hirtulum* association) but which then become less numerous as perennial species begin to dominate the vegetation (*Sporobolus africanus Setaria sphacelata* association). As experienced in the mesic associations, excessive soil disturbance resulted in a higher species turnover than did grazing. The low beta diversities between the disturbed xeric grasslands and the depauperate and disturbed mesic grasslands may indicate that throughout the study area, when disturbance takes place similar suites of species will recolonise the affected areas.

The grassland associations become progressively shorter from the mesic to xeric and from less disturbed to more disturbed areas. Prostrate and mat-forming forbs become more numerous in the xeric and disturbed environments while geophytes vary tremendously throughout the study area. Surprisingly, there is a fairly high number of geophytes in the *Cynodon dactylon* – *Helictotrichon hirtulum* association despite the fact that it was ploughed as recently as 20 years ago. There are more geophytes in this association than in the *Sporobolus africanus* – *Setaria sphacelata* association, and this may be because there could be more propagules in the surrounding vegetation and also because the association has been less heavily grazed. Succulence does not play a major role in the forb component of the grasslands. No pattern could be determined for the presence of woody species.

The mesic associations studied to determine temporal changes show that there is a seasonal transition from *Themeda triandra* – *Hyparrhenia hirta* vegetation to *Themeda triandra* dominated vegetation. However this change is not sustained and represents a temporary transient state. The period at which it remains at this stage may extend if environmental parameters such as moisture and fire frequency are altered but this requires much further research. The associations show high recuperative stability and resilience in response to fire. They are not regarded as being particularly unstable when subject to fires at this frequency but in the light of response to soil disturbance and grazing they are regarded as being unstable. The Eastern Cape Coastal Grasslands are therefore regarded as being fire-climax, as described by McKenzie (1982) and Tainton (1999).

6.CONSERVATION AND MANAGEMENT OF EASTERN CAPE COASTAL GRASSLANDS

6.1 INTRODUCTION

The Eastern Cape Coastal grasslands occur along an attractive shoreline that is relatively undeveloped when compared with the Natal, Western and Southern Cape coastlines. However, it is coming under increasing pressure for development, both residential and commercial (Anon, 1985; Moonieya, 1985). There has been some commitment to conserving the coastal area, but to date, along a 200km length of coastline no more than 3km are conserved, and none of the conservation areas extends more than 3km inland. The grasslands are conserved in the Double Mouth Nature Reserve, Cape Henderson Nature Reserve, within the State Forest Reserve at Igoda Mouth, and in the Alexandria Forest (see Figure 6.1 below) The Alexandria Forest Reserve contains pockets of grassland but the largest area of grassland within the Forest itself remains the property of commercial farmers (see Figure 3.9). Apart from these small pockets in the Forest, no xeric grassland associations occur in Eastern Cape Nature Reserves.

The reasons for which species are conserved include the fact that they might be "rare, endemic, large, attractive or of economic importance" (Bond, 1992). If these are the criteria for determining what to conserve and where, then they must be applied to all the species found within the study area in order to determine its conservation potential. This will indicate whether or not there is anything worth preserving in the Eastern Cape Coastal Grasslands. If there is, the most important areas for conservation of botanical species-richness must be determined.

Having identified areas worthy of conservation and those areas that already are, one must address the issue of management. Historically, grasslands have been the habitat for a wide range of browsers and grazers, but today most areas which are under conservation are either grazed by a few remaining indigenous animals or are grazed in concentrated amounts by one or two species of domestic livestock. In addition, conservation areas suffer from trampling pressure in very specific places, such as camping and parking areas. All these factors need to be taken into account for the successful maintenance of the area being conserved.

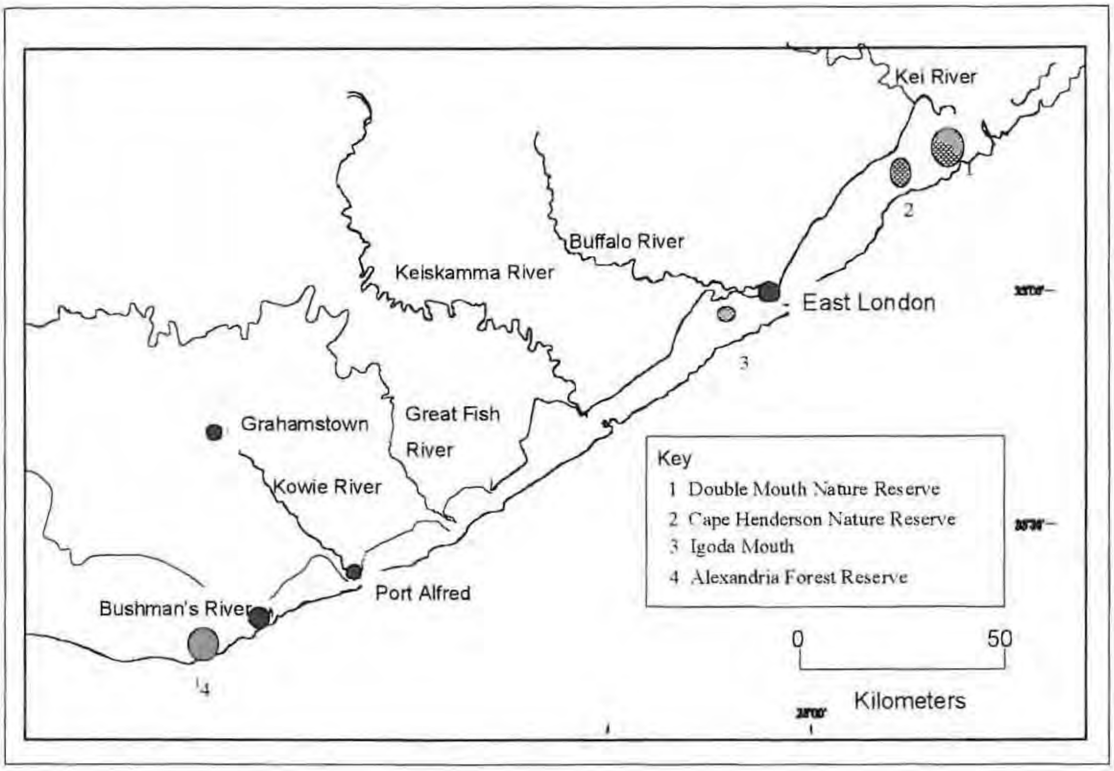


Figure 6.1 Map of study area showing conservation areas

6.2CONSERVATION

6.2.1 Area under conservation

The majority of Cape Nature Conservation areas are located in the eastern half of the study area. Cape Nature Conservation areas in the western half are limited to the grassland located within the Alexandria National Forest. This grassland is a *Cynodon dactylon – Helictotrichon hirtulum* association. As one moves eastward the next Cape Nature Conservation area is located at Igoda Mouth, which is mainly *Themeda triandra* association grassland. Cape Henderson and Double Mouth are the most easterly located Cape Nature Conservation areas. Cape Henderson Nature Reserve is mainly thicket vegetation and contains very little grassland. Double Mouth includes vegetation from the *Themeda triandra - Anthospermum herbaceum, Themeda triandra, Hyparrhenia hirta - Themeda triandra* and *Stenotaphrum secundatum - Centella coriacea* associations. The total area of grassland included in these reserves is less than 5km².

6.2.2 Planned Cape Nature Conservation areas

Cape Nature Conservation has proposed purchasing the area adjacent to the Alexandria Forest known as the farm Lange Vlakte (see Figure 3.9). Finances are a limiting factor at this stage and despite communication with the World Wildlife Fund for Nature this purchase has not yet been made (Eastern Cape Nature Conservation officer, pers. comm.). This area includes a small area of *Themeda triandra - Ehrharta calycina* grassland, which is regarded as being the climax association of the xeric grasslands and is as yet not conserved.

The Dierama Wild Flower Reserve at Potter's Pass on East London's West Bank has still not been proclaimed as a Nature Reserve 30 years after it was first proposed (Jacot-Guillarmod and Brink, 1982; Judd, 1995). There is an ongoing debate as to if and when this will take place. The area includes vegetation representing the *Themeda triandra*, *Hyparrhenia hirta - Themeda triandra*, *Themeda triandra - Anthospermum herbaceum* and *Stenotaphrum secundatum - Centella coriacea* associations. Apart from grassland associations, several types of woody vegetation and a doleritic vegetation type not observed elsewhere in the study area occur within the region defined by this supposed Nature Reserve. It is extremely species-rich (Judd, 1995) but its proximity to the industrial area west of East London and relatively flat topography make it an ideal candidate for development. At the time of writing up this thesis the process of proclaiming it as a Nature Reserve has proceeded no further than it had six years ago (Kevin Cole, pers. comm.)

6.2.3 Conservation status of Eastern Cape Coastal Grassland associations

Of the ten different grassland associations that were determined in this study, five were located within Nature Conservation areas. Five were not in conserved areas at all, and one was located in an area proposed for Nature Conservation (Table 6.1).

Table 6.1 Area conserved for each grassland association

Mesic Associations	Area conserved	Map reference
Themeda triandra - Anthospermum herbaceum association	<1km²	Figure 3.1
Themeda triandra association	<1km²	Figures 3.1, 3.4
Hyparrhenia hirta - Diheteropogon amplectens association	0	Figures 3.2, 3.3, 3.5
Hyparrhenia hirta - Themeda triandra association	<1km²	Figures 3.1, 3.2, 3.3, 3.5, 3.7
Stenotaphrum secundatum - Centella coriacea association	<1km²	Figures 3.1, 3.3
Xeric associations		
Diheteropogon filifolius- Ehrharta calycina association	0	Figure 3.5
Cynodon dactylon - Ehrharta calycina association	0	Figure 3.6
Themeda triandra - Ehrharta calycina association	0	Figures 3.8, 3.9
Sporobolus africanus - Setaria sphacelata association	0	Figures 3.8, 3.9
Cynodon dactylon - Helictotrichon hirtulum association	<1km²	Figures 3.8, 3.9

The *Hyparrhenia hirta - Diheteropogon amplectens* association of the mesic grasslands is not conserved (Table 6.1). Only the most disturbed of the xeric grasslands are in a conservation area. The highest priority for conservation would therefore be the xeric associations. However, the area of mesic grasslands under conservation is not regarded as being particularly large and as they are all located within one nature reserve, any major disturbance to this reserve would affect the only conserved grassland representative of these associations.

6.2.4 Rare, endangered and endemic species

The species present in the study area were compared with those listed in the Red Data Book (Hilton – Taylor, 1996) to determine if any were threatened. Endemism was also recorded (Gibbs - Russel, 1990; Hilton – Taylor, 1996).

Table 6.2 Distribution, endemism and conservation status of certain species within the Eastern Cape Coastal Grasslands (after Gibbs - Russel, 1990; Hilton – Taylor, 1996)

Species	South Africa	Cape	KwaZulu-Natal	Free State	Former Transvaal	Status in ECCG
Ehrharta calycina	Endemic					Conserved (Alexandria Forest)
Euphorbia bupleurifolia		No longer threatened Endemic	Rare Endemic			Not conserved
Festuca costata	Endemic					Conserved (Alexandria Forest)
Festuca longipes	Endemic					Not conserved
Helichrysum rutilans	Endemic	No longer threatened		No longer threatened		Not conserved
Kniphofia rooperi		Vulnerable Endemic	Endemic			Conserved (Double Mouth)
Monopsis unidentata		No longer threatened Endemic				Not conserved
Nemesia fruticans	Endemic	No longer threatened				Conserved (Morgan's Bay)
Pentaschistis pallida		No longer threatened Endemic				Not conserved
Sutera campanulata		Endemic				Conserved (Alexandria Forest)

As shown in Table 6.2 above, no endangered species were recorded in this study although several taxa have only recently been listed as not threatened (Hilton-Taylor, 1996). While *Euphorbia bupleurifolia* is no longer threatened in the Cape, it is regarded as being rare in KwaZulu – Natal. Four species are endemic to the Cape only and a further two are endemic to the Cape and KwaZulu – Natal. Four species are endemic to South Africa. It must be stressed that vegetation surveys were all carried out during the spring and summer months and that there may be autumn and winter species that were not collected. In addition, fire – stimulated species such as *Cyrtanthus* have been overlooked, while management practices such as grazing may have resulted in the absence of flowering material and the consequent omission of inconspicuous species. The species checklist is therefore not regarded as listing every species that occurs in the grasslands and it is hoped that further species will be added to the list by other researchers. Compared with the Karroo and Fynbos biomes, grasslands generally have low species diversity and the Eastern Cape Coastal Grasslands are no exception with a total of 364 species recorded during the study (see Appendix 5).

6.2.5 Rationale for conservation of Eastern Cape Coastal Grasslands

It is not their species-richness that makes the Eastern Cape Coastal Grasslands worthy of conservation but rather the diverse number of phytochoria which are represented in them. The eastern half of the Eastern Cape is the site of convergence of five major phytochoria, with the centre of this convergence being located around Grahamstown (Gibbs-Russel and Robinson, 1981; Lubke and de Moor, 1998). These phytochoria are the Indian Ocean Coastal Belt, and the Zambezian, Afromontane, Karroo–Namib and Capensis domains. The overlap between grass species in the Eastern Cape Coastal Grasslands and several of these phytochoria is shown in Table 3.3.3.iii, Chapter 3. Some of the species recorded in the study area represent the eastern and western extremes of distribution of those species, e.g. *Centella linifolia* (western extreme) and many of the *Helichrysum* species (eastern extreme).

In the light of Bond's (1992) criteria for conservation, which are the most commonly used factors determining the necessity to conserve areas, the Eastern Cape Coastal Grasslands fall short of those aspects which would make them eminent candidates for conservation. Gibbs – Russel and Robinson (1981) suggest that the low number of endemic species in the region may be due to the fact that within one of the five phytochoria occurring at this convergence area, there may be species which are ideally suited to each different environmental niche. This effectively reduces or even prevents speciation from occurring. This theory may account for the low number of endemic species found within the study area. It is therefore recommended that areas of the Eastern Cape Coastal Grasslands be conserved because of their richness of phytochoria which are represented in them and the location of species at the extremes of their geographical distributions.

6.2.6 Areas recommended for conservation

It is strongly recommended that the Dierama Wild Flower Reserve proposed for the Potter's Pass area on the West Bank of East London be formally gazetted and accepted as a Nature Reserve by Cape Nature Conservation and that efforts be made to run it as a Nature Reserve. If this is not financially possible then arrangements with business and industry should be considered. The farm Lange Vlakte is a suitable area for the conservation of xeric grasslands and the fact that it adjoins the Alexandria Forest would be a great advantage. Conservation of some of the grasslands within the former Ciskei is also recommended. This is partly because it would enable further research to be carried out into the effects of grazing on the species composition and dynamics of the xeric grasslands. It may be possible to restore the grazed associations to a more favourable condition. A greater area of the climax *Themeda triandra - Ehrharta calycina* association would be beneficial since this is the most species rich association in the xeric grasslands.

6.3 MANAGEMENT

It appears from the literature that grassland systems respond most strongly to rainfall and that any management applied to the system will be of secondary consequence (see Chapter 4; Barnes, 1990; Jenny, 1980; Danckwerts and Barnard, 1981; Richardson *et al.*, 1984; O'Connor, 1991a, 1985, 1993, 1994; Noy – Meir *et al.*, 1989; Barnes, 1990; Rodriguez, 1995; Bond, 1997; Tainton and Hardy, 1999). While the land manager cannot control the rainfall, he can alter the way in which the grassland is managed in response to moisture conditions. Increased rainfall results in an increase in the herbage yield that will require a different management approach to drier conditions such as drought, or in drier regions such as the western half of the study area.

6.3.1 Fire

Fire has been used as a management tool in African grasslands for centuries with the aim of improving the palatability of grasses for grazing (Scott, 1970; McKenzie, 1984; Hall, 1984; Tainton and Mentis, 1984; Feely, 1987; Barnes, 1992; Zacharias, 1995; Bond, 1997; Kepe and Scoones, 1999). Many grasses are at their most palatable in the early stages of growth, and some such as *Elionurus muticus* become completely unpalatable a few months after burning. In addition, lack of fire and/or grazing can result in some species e.g. *Themeda triandra* becoming moribund with in a decrease in plant vigour. This is followed by reduction in veld condition as poorer grasses become more abundant (Scott, 1970; Robinson *et al.*, 1979; Downing and Marshall, 1983; Edwards, 1984; Everson and Tainton, 1984; O'Connor, 1985; Barnes, 1990; Bond, 1997). The effect of fire is moisture-dependent with the greatest effect in high-rainfall regions because of a higher fuel load (Bond, 1997). In the Eastern Cape, fire is of particular importance in combating the spread of the woody species *Acacia karroo* into grasslands (Scott, 1970; du Toit, 1972; Trollope, 1974; 1980).

Although grasses are reputed to be among the least susceptible plant types to fire, exposure of their reproductive organs such as tillers and buds to burning will result in severe damage (Bond, 1997). There has been much research as to when the most favourable time is for burning (O'Connor, 1985; Everson *et al.*, 1985; Trollope, 1987; Bond, 1997). Season of burn has been shown to have a direct effect on species abundance and composition in grasslands (Robinson *et al.*, 1979; Scotcher and Clarke, 1981; Tainton and Mentis, 1984); thus it is of critical importance in grassland. Most research into burning strategies has focused on the optimal season of burning to ensure good regrowth of palatable species for sheep and cattle grazing. Trollope (1987) found that burning of False Thornveld vegetation in the Eastern Cape during mid-winter had the least impact on grass recovery. However, burning during spring and early summer had the most severe effects, damaging the grass plants and prolonging their recovery time. Steinke and Nel (1967) found that a late winter burn had severely deleterious effects on the condition of the grass sward in the Dohne Sourveld. This was also found to be the case in the Natal grasslands (Scotcher and Clarke, 1981; Tainton, 1981). By burning while the grasses are actively growing, one destroys the new tillers that are being formed thus it is obviously preferable to burn grassland while it is dormant. Burning of False Thornveld in winter resulted in greater numbers of forbs than plots burned after rains had begun. Frequent burning favours grasses while longer intervals between fires result in greater numbers of forb species (Robinson *et al.*, 1979).

Tainton, Groves and Nash (1977) found that in the Natal Tall Grassveld, burning must be followed by an adequate recovery period before grazing if burning is carried out in spring. Grazing alone resulted in higher quantities of grass yield than did burning followed by grazing. Spring burning is carried out to provide a high protein content for ewes with newborn lambs. Overall yield is lower than for grassland which was only grazed. Spring burnt vegetation is thus highly susceptible to damage if followed by grazing.

If one does not require grassland for grazing, fire only becomes necessary when the veld is in danger of becoming moribund. Where there is no excess of plant material it is inadvisable to carry out burning for burning's sake. Mowing (or grazing) produces a greater yield the following season and so may be preferable to burning (Scott, 1970). For example, Shackleton (1991) found that in certain grassland associations in the former Transkei, two summers were necessary to restore grassland vigour to the same level as it was prior to burning while condition was restored within 12 months of grazing. However, removal of fire appears to result in bush encroachment in sweetveld (Scott, 1970). Researchers such as Acocks (1975), Tainton (1981; 1999) and White (1983) are of the opinion that fire prevents the coastal grasslands of the former Transkei from becoming thornveld and ultimately forest. Feely (1987), on the basis of archaeological evidence, however disagrees with this and indicates that the area has been grassland for several thousand years. Nevertheless, some parts of the coastal grasslands are certainly being invaded by *Acacia karroo*, for example on the formerly State – subsidised farm of Lessendrum near Hamburg (Dave Cocroft, pers. comm.). It is emphasised that if grasslands are to be burnt in order to reduce bush encroachment, this must be done ***while the grass sward is dormant*** (Trollope and Tainton, 1986).

Themeda triandra is one of the most important grasses in the Eastern Cape Coastal Grasslands, occurring in eight of the ten grassland associations defined in the study. It is the most common, widespread, and at times most abundant species, and as it is a climax grass, attention has been paid to its environmental requirements. *T. triandra* does not respond well to shading, which prevents tiller formation with subsequent decrease in vigour and ultimately plant mortality (Downing and Marshall, 1983; Everson, Everson and Tainton, 1988; Bond, 1997). Studies show that summer burning all but destroys *T. triandra*, while winter burning does not appear to cause damage (Everson, Everson and Tainton 1985) Edwards (1984), found that fire favoured *T. triandra* while mowing favoured *Tristachya leucothrix* in tall grasslands of Natal. Autumn burning causes change in species composition from *T. triandra* dominated veld to *T. leucothrix* dominated veld. In the drier western grasslands of the Free State it was recommended that burning in drier regions be carried out infrequently although a period of greater than three years between fires led to the grass becoming moribund. In the Dohne Sourveld of the Amatola Mountains, burning every two to three years was found to be optimal (Downing *et al.*, 1978, in Downing and Marshall, 1983).

T. triandra can tolerate, and in fact, requires regular defoliation to maintain vigour, which declines with a decrease in utilisation (le Roux and Morris, 1977; Downing and Marshall, 1983; Everson and Tainton, 1984). The vigour of *Heteropogon contortus* has also been shown to decrease with a decrease in utilisation in the Tall grasslands of Natal (Everson and Tainton, 1984; Bond, 1997), and these two species are replaced by *Tristachya leucothrix*, *Alloteropsis semialata*, and *Harpochloa falx* (Everson, Everson & Tainton, 1988).

With respect to the genus *Cyrtanthus*, flowering is stimulated by fire, while germination of *Themeda triandra* seeds is enhanced by smoke from several grassland species as well as itself (Baxter *et al.*, 1995; Bond, 1997). Spring-flowering grassland geophytes tend to die out if fire is completely excluded from the system

Fire must be used carefully as a management tool since the season at which burning takes place is critical. It is also important to determine what one is trying to achieve by burning, whether one is trying to change species composition and abundance, maintain the vigour of existing grasses or stimulate flowering of geophytes. Bond (1997) recommends that for nature reserves, lightning-caused fires should be allowed to burn, and that where fire is required to maintain grassland vigour, burning should be carried out at a range of different seasons, intensities, and frequencies.

Mentis and Bailey (1990) also recommend this variation of pattern of occurrence of fires. This idea is endorsed by the author and all managers of nature conservation areas are encouraged to develop this type of burning regime where fire is considered necessary. Downing *et al.* (1978: in Downing and Marshall, 1983) found that burning every second or third year in Dohne Sourveld resulted in the best cover and highest diversity of grasses. It is suggested that areas under Cape Nature Conservation management should be assessed every 2 – 3 years in the mesic eastern half, and every 3 – 4 years in the drier western half, for burning requirements. The tendency for veld to become moribund should be the criterion on which burning is based, rather than a set pattern of frequency and season, as advocated by Mentis and Bailey (1990) and Bond (1997).

6.3.2. Grazing

The grasslands of southern Africa are primarily used for the grazing of cattle and sheep; thus much research has focused on the response of the vegetation to defoliation. The frequency and intensity of defoliation, as well as the species consuming the plant are of significance in determining the impact of grazing on grassland (Noy – Meir *et al.*, 1989; O'Reagain and Grau, 1995). In grasses, the apical meristem from which new leaves are produced is located at the base of the tiller while in young leaves, meristematic tissue is located at the base of the blade. In older leaves the blade may no longer be growing but the sheath continues, while in the oldest leaves, neither blade nor sheath are growing. If the meristematic tissue of either the leaf blade or sheath is removed, growth in those organs will cease. Where the blade or sheath of mature leaves is removed, the overall result will be merely the loss of photosynthetic tissue. Removal of photosynthetic tissue decreases the amount of carbohydrate available for either storage or growth. This has one of two effects: either there is a decline in the growth rate of the plant which may delay flowering until a less favourable time, or the vigour of the plant is reduced (Wolfson, 1999). In addition, grazing may remove all flowering tissues and so prevent the formation of seed. In the grasslands of southern Africa individual species respond differently to grazing or other defoliation treatments, thus studies of the effects of grazing are of paramount importance in maintaining South Africa's grasslands.

Grazing has a negative impact on plants as it results in injury (Rodriguez *et al.*, 1995) and causes a decrease in photosynthetic area (Kirkman and Moore, 1995; Peddie, 1995; Rodriguez *et al.*, 1995; Wolfson, 1999). Studies in South Africa indicate that sheep have a more severe impact on grass species than do cattle since they graze closer to the ground and are more selective i.e. they consume a narrower range of species (Hardy, 1995; Kirkman and Moore, 1995; O'Reagain and

Grau, 1995; Peddie, 1995). Long term overutilisation of grasses results in a decrease in plant cover because of a decline in plant vigour and the appearance of a mosaic pattern in grassland vegetation. Species that are highly palatable are repeatedly grazed and are eventually unable to withstand the high grazing pressure. These species die out and consequently less palatable species invade the open patches. The result is a grassland consisting of patches of undisturbed vegetation interspersed with patches of species which are usually less palatable and able to withstand the high levels of grazing pressure (Noy – Meir *et al.*, 1989; Fuls, 1992; Kirkman and Moore, 1995; Rodriguez *et al.*, 1995).

In South Africa, the situation arises where certain species are only palatable when they are short, e.g. *Cymbopogon* spp., *Elionurus muticus*. Where they are continuously grazed at high enough densities, these species are maintained at a short, palatable condition. When the grassland is subject to selective grazing because of small flocks and / or rotational grazing, these species become unpalatable. This results in increased pressure on palatable species and encourages patch development and overgrazing of palatable species. Acocks (1966) found that in the former "Native areas" of the Ciskei and Transkei, where grazing pressure is too high to allow this form of selective grazing to occur, there are areas of extremely short grasslands which consist of dense growth of climax species such as *Themeda triandra*. This pattern was recorded in the sourveld of the Transkei and in the former Ciskei (Acocks, 1975; McKenzie, 1982; de Bruins, 1998). The extrapolation of this into commercial farming is to stock small portions of veld at very high stocking rates for a short period of time, and allow the maximum possible period for regrowth after grazing, up to one year or longer.

The frequency of utilisation of grasses in the thornveld of the Eastern Cape appears to be less important than the height of defoliation. The lower the height at which defoliation took place, the greater the reduction in herbage yields the following season. When grazed by sheep or sheep and cattle during the growing season, *Themeda triandra* and *Tristachya leucothrix* began to show signs of mortality by the second year of grazing. Veld in good condition seems to be more susceptible to grazing than veld in poorer condition. This can be explained by the structure of the plants (Danckwerts and Barnard, 1981). "Better" species are those such as *T. triandra* and *T. leucothrix*, which have a high nutritional value for grazers. They grow in a tuft form where the growing meristematic tissue is raised above the ground. "Poorer" grasses are those which have a lower nutritional value and include *Digitaria eriantha* and *Eragrostis obtusa*. These grasses are semi – stoloniferous, i.e. their meristematic tissue is closer to the ground and more difficult to graze. They therefore have a physical advantage over the more palatable species.

Other issues affecting the vigour of grasslands include the time at which the grasses are grazed, and the length of time that herbivores have access to the plants. Overgrazing can be caused by continuous grazing whereby plants are unable to set seed and seedling recruitment is not allowed to take place. This can occur even at low or moderate grazing intensities if they occur continuously. It is also caused by annual grazing during the flowering and growing periods of the dominant grass species (Fuls, 1992; Peddie, 1995; Todd and Hoffman, 1998). Vorster (1975) found that grazing during the late winter and early spring in sourveld grasslands was far less detrimental than grazing during summer and autumn. However, Drewes and Tainton (1981) found that grazing *T. triandra* in spring had the most severe impact in plant vigour. Grazing during the growing season following a drought is especially detrimental to grassland vegetation. It is thus felt that grazing during winter will probably result in the least damage to grasses.

Several grazing systems have been devised over the years to address the management of grasslands. Rotational grazing systems which subject the vegetation to a short, intense defoliation must allow a long enough period of regrowth for recovery before grazing occurs again (Kirkman and Moore, 1995; O'Reagain and Grau, 1995). O'Reagain and Grau (1995) recommend that stock be removed when 60 – 70% of palatable plants have been grazed.

Vorster (1975) recommends that veld condition should determine grazing rather than grazing according to fixed seasons. In the case of nature reserves the author agrees with this. Where veld condition is poor such as at Alexandria, grazing should be discouraged and only applied when the grass species are not growing, flowering or setting seed. Where vegetation is dense and may be at risk of becoming moribund, such as at Alexandria, grazing should be encouraged. Where Nature Conservation is able to adjust grazing on its own Nature Reserves, this should be the system of choice.

It is suggested that grazing of nature reserve areas should be allowed at various times of the year (excluding midsummer to autumn) depending on the condition of the vegetation, for 2 – 3 years in a row. This should be followed by a complete year's rest. Grazing should be carried out at a high stocking rate for a short period of time (the Department of Agriculture is able to provide recommended stocking rates for each area) with livestock being completely removed to enable regrowth to take place. It is recommended that the Department of Nature Conservation use Nature Reserves for grazing as their own study sites. Farmers should be is given certain periods of time during which to utilise the land, rather than hiring it for a certain number of years at a fixed rate. In this way, the Department will be able to control the management and be able to interpret results with great accuracy. In addition, the Reserve Manager will be able to detect unfavourable changes quickly and remedy them as soon as possible. Monitoring of veld condition should be carried out.

Ultimately overutilisation reduces plant cover and results in a change in the abundance of species, particularly the dominant species (Fuls, 1992; Todd and Hoffman, 1998). Since the grasslands are the backbone of the extensive system of agriculture practised in South Africa it is of the utmost importance that they are utilised sustainably, so as to improve and restore degraded vegetation wherever possible.

6.3.3 Effects of trampling

In cases of trampling (and severe overgrazing), plant cover is reduced to a minimum and ultimately bare areas of soils will result. Raindrop impact on bare soil causes the breakdown of soil aggregates and fine particles fill the pores between larger aggregates. This results in the formation of a mud layer which then dries out to form a compacted, impenetrable surface crust. The crust reduces the degree of infiltration of rainwater, resulting in increased runoff leading to erosion. The ecosystem degradation which results is therefore caused by a decrease in effective rainfall as well as the loss of topsoil (Weltz and Wood, 1986; Pandey and Singh, 1991; Fuls, 1992; Zacharias, 1995; Mworia *et al.*, 1996;)

Liddle (1975) summarised the impact of trampling on vegetation structure and the changes in vegetation which result from trampling. Plants that have low meristematic growth points are less susceptible to trampling and tall grasses are the first to show a negative effect of trampling. This is supported by Evans (1993) who showed that *Themeda triandra* is more susceptible to trampling than *Stenotaphrum secundatum*. The forb component of the Eastern Cape Coastal Grasslands also responded in the same manner with the taller, upright species *Helichrysum cymosum* being affected more rapidly than low-growing forbs such as *Indigofera* spp. and *Falckia repens* (Johnson, 1989; Traub, 1989; Evans, 1993). Liddle (1975) also indicates that vegetation is more susceptible to damage due to trampling when the soil is wet.

It is accepted that Nature Reserves are provided for man's use, and that access in the form of roads and pathways are necessary. Within the farming context, paths are obviously also required. It is recommended that roads and pathways be clearly defined and limited to as few as possible in order to gain access to desired points. If a pathway begins to be developed on a Nature Reserve, two steps should be taken. First, the reason and necessity for the development of the pathway should be assessed. Secondly, if it is found that such a pathway is necessary, for example to reach a viewing point, then the surrounding vegetation should be examined. People generally take the shortest route, and this may result in the formation of pathways through sensitive or vulnerable plant populations. In addition, the pathway may be located on a steep slope, leading to erosion of the pathway and surrounding damage. Should a pathway be necessary it must be laid out so as to avoid sensitive areas and follow as gentle a contour as possible. If the pathway is merely a "shortcut" or a "test-drive" route, such as at Potter's Pass (Judd, 1995), then all efforts should be made to prevent its development. Nature Reserves are for the protection of vegetation as well as for human enjoyment and must be utilised sustainably.

6.3.4 Monitoring Vegetation

No detailed, quantifiable grazing or burning studies were carried out in the study area thus it was not possible to develop a technique for the assessment of veld condition in the Eastern Cape Coastal Grasslands. However, the impact of fire and grazing and the effects of rainfall on the vegetation can be monitored for the development of assessment techniques. This can be done in two ways, or a combination of both. One method is to demarcate permanent plots of 10m X 10m within the grassland being monitored and the abundance of all species within these plots recorded. The second method is to demarcate a permanent transect of 100m in length and to sample 5 points at each metre along this transect. From either method a species presence and abundance score can be determined. The significance of the permanent sites is that they can be repeatedly sampled. By knowing the land use i.e. grazing and burning regimes to which the vegetation has been subjected, and with rainfall data, one can begin to build up a picture of the effect of different management regimes on the vegetation.

For Nature Conservation areas such as those at Double Mouth, all species and their abundance should be recorded from year to year. The abundance of species should be recorded seasonally by sampling permanent plots or transects two to four times per year. Results should be assessed annually in conjunction with grazing and rainfall figures for each season. Particular note should be taken of species that appear during years when there is no grazing and of major increases and decreases in abundance levels. This will enable a Reserve Manager to identify species that are sensitive to grazing and determine whether they require special protection.

With regard to response to grazing, grasses in South Africa have been classified by a number of researchers as being decreasers, increasers or invaders by virtue of their response to grazing. (Bosch and Janse van Rensburg, 1987; Hardy and Hurt, 1989; Janse van Rensburg and Bosch, 1990; Hurt *et al.*, 1993). Decreasers are those that decrease with under or over utilisation, increasers increase with increased utilisation and invaders appear when severe overutilisation has occurred. Increaser 1 species occur with moderate utilisation, while Increaser 2 species become abundant under heavier utilisation (see Table 6.3.3)

Table 6.3.3 Summary of species response to utilisation pressure

(Taken from van Rensburg, 1941; Barnes *et al.*, 1984; Bosch and Janse van Rensburg, 1987; Hardy and Hurt, 1989; Barnes, 1990; Janse van Rensburg and Bosch, 1990; Bosch and Gauch, 1991; Hurt *et al.*, 1993; Nel *et al.*, 1993)

Decreaser	**Increaser 1**	**Increaser 2**	**Invader**
Themeda triandra	*Eragrostis curvula*	*Cynodon dactylon*	*Hyparrhenia hirta*
*Tristachya leucothrix**	*Eragrostis plana*	*Aristida spp*	*Sporobolus africanus*
Harpochloa falx	*Sporobolus africanus*		
Digitaria eriantha	*Hyparrhenia hirta*		
Heteropogon contortus^	*Diheteropogon filifolius*		
Diheteropogon amplectens	*Eragrostis capensis*		
Brachiaria serrata	*Harpochloa falx*		
Alloteropsis semialata	*Heteropogon contortus*		
Eragrostis spp.	*Aristida diffusa*		
Setaria sphacelata	*Cymbopogon excavatus*		
	Brachiaria serrata		
	Digitaria eriantha		
	Themeda triandra		
	Elionurus muticus		

* - unpalatable therefore indicates underutilisation of veld (Bosch and Gauch, 1991)

^ - increases in abundance with utilisation, then decreases (Hurt and Hardy, 1989; Barnes, 1990)

It can be seen from Table 6.3.3 that several species fall into more than one category. This depends on the grassland type as well as on the utilisation pressure to which the species has been subjected. Although it is not particularly palatable, *Tristachya leucothrix* prefers undisturbed environment under-utilised in terms of grazing and seldom burnt (Bayer, 1995; van Oudtshoorn, 1992). It is therefore regarded as being an indicator of well-managed or lightly grazed grasslands.

Heteropogon contortus initially increases with increased grazing but can quickly begin to decrease (Hardy and Hurt, 1989; Barnes, 1990). It is a widespread grass often occurring in association with *T. triandra* and where overgrazed areas are rested, it is able to recover and become the dominant species (Zacharias, 1990) which is also found in disturbed areas such as road verges (Gibbs-Russel *et al.*, 1991; van Oudtshoorn, 1992). These anomalies highlight the need for specific studies of individual species within the study area under known land-use histories. Another problem associated with using these species as indicators of veld condition is that the studies were carried out in different grasslands and so one cannot be sure that they reflect conditions within the Eastern Cape Coastal Grasslands. As Wolfson (1999) indicates, each species varies in its response to defoliation and this will vary between different environments. Thus studies need to be carried out in the Eastern Cape Coastal Grasslands to determine the sensitivity of the species to grazing pressure and also to determine if there are other grasses which are of economic importance that can give indications of veld condition.

Grazing studies have shown that the effect of severe grazing is often only apparent in the second year after grazing and criticisms of this type of veld condition assessment include that it is not sensitive enough and only shows changes once severe utilisation has started taking place. To try to counteract this lack of sensitivity, it is felt that assessment of the forb component at species or at least genus level should be carried out. Since grasses form the bulk of the herbage available to grazers, forbs and shrubs may be affected by higher utilisation pressure because they are less abundant. In addition, certain forbs are highly unpalatable and where they show an increase, could indicate the presence of overutilisation of more favourable species. They may thus give a slightly earlier indication of the level of pressure that a grassland is experiencing.

Forbs which may be of use as indicators of veld condition include *Centella coriacea*, which is able to colonise areas from which *T. triandra* have been removed through environmental pressures (Zacharias, 1990). *Senecio inaequidens* is a common forb in disturbed areas such as at roadsides and areas subject to trampling (Hilliard, 1977; Bond and Goldblatt, 1984). *Gazania krebsiana* is a fire resistant forb occurring in disturbed vegetation and roadside verges (Batten and Bokelmann, 1966; Moriarty, 1982; Bond and Goldblatt, 1984; Batten, 1988; Shearing, 1994). *Anthospermum herbaceum* is also found in fire - prone grasslands and occurs near the sea within the salt spray zone (Bond and Goldblatt, 1984; Puff, 1986). There are a number of different forms of this species, two of which are the (Burnt) Grassland Form and the Salt Spray Zone Form. Although they were not distinguished in the field, both forms may occur since the grasslands are subject to both environmental impacts (Puff, 1986). Distinguishing which forms occur where and whether there is any change in response to burning or protection form fire may result in this species becoming a useful indicator for fire management needs. The legume *Acacia karroo* is able to spread rapidly into overgrazed grassland, particularly sweetveld, and changes in its abundance levels may indicate that such encroachment is beginning to take place (Comins, 1962; Ross, 1977).

Taking the above information into account, it is clear that the most valuable means of devising management plans is for consistent monitoring of grasslands by the land-user himself. It is strongly emphasised that using grasses in Table 6.3.3 as indicator species for veld condition in the Eastern Cape Coastal Grasslands will only be a rough guide until further studies within these grasslands have been carried out. More specific studies need to be done on specific response to defoliation and burning within the Eastern Cape Coastal Grasslands in order to use grass species as indicators of veld condition. The use of forbs as slightly more sensitive indicators of disturbance in the grassland should be investigated.

6.4 CONCLUSIONS

A small number of endemic / rare species was found in the study, but they are not the main reason for conserving the vegetation. The greatest reason for conserving the grasslands is not because they contain unique species but because of their species composition. One is able to see elements of Karroo-Namib flora in close proximity to those from the Indian Ocean Coastal Belt, illustrating the convergence of the different domains (see Chapter 3). Many of the grasses present occur all over South Africa and alone do not warrant special consideration, while the forbs often occur in either Natal or the Western Cape. It is more the combination of species that makes these grasslands unique and noteworthy. In addition, the fact that there is a clear distinction between the xeric and mesic grasslands indicates that they too form part of the phytochorological tension zone centred around Grahamstown. The importance of conserving some of the xeric grasslands is highlighted by the fact that only a tiny portion of primary grassland is conserved within the Alexandria Forest Reserve.

Management of the coastal grasslands must take into account the different rainfall regimes along the coast, the intensity of trampling and the fact that virtually all the natural herbivores have been removed from the vegetation. The grasslands should not be maintained in isolation, but should be utilised for pasture by surrounding farmers, provided that this is done with regard to the fact that one is trying to conserve the grassland and not preserve the life of the livestock. The areas currently set aside for Nature Reserves are too small to sustain the re-introduction of indigenous wildlife, but the grasslands would benefit from utilisation. By allowing local farmers the use of the grasslands, they will see Nature Reserves as a resource from which they can derive a benefit rather than being areas that are denied to them and are therefore ignored or resented. Another benefit is that grazing will prevent the grasslands from becoming moribund and should reduce the need for frequent burning. The use of cattle rather than sheep as grazers is strongly recommended.

Burning is a practice that should be included in grassland management but it is one that can very easily be mismanaged. Both the threat of burning at incorrect times and of runaway fires can be reduced if grazing is utilised as a management tool as well. The utilisation of fire to consume dead material and so prevent the grasslands from becoming moribund must be undertaken with caution and good judgement. In the case of Nature Reserves, it is suggested that naturally - occurring fires be allowed to burn and that active burning should be undertaken only when absolutely necessary.

7. SUMMARY OF THE CHARACTERISTICS OF THE EASTERN CAPE COASTAL GRASSLANDS WEST OF THE KEI RIVER

7.1 INTRODUCTION

The first aim of this thesis was to define the vegetation units occurring within the grasslands of the Eastern Cape west of the Kei River on the basis of the floristics i.e. species presence and abundance. The second aim was to elucidate the dynamics of these associations. This was done by examining the influence of various factors on the previously described associations. The third aim was to determine whether or not successional relationships existed between associations. In order to assess this, the associations were examined in terms of diversity, structure and function and land-use. Finally, conservation requirements and management options for the grasslands were to be identified. A summary of the results attained to meet all these aims is presented below.

7.2 SUMMARY OF RESULTS

As the work presented in Chapter 3 shows, in this study the grasslands of the Eastern Cape west of the Kei River are separated into two groups, the mesic and the xeric. The mesic associations occur between the Kei and Keiskamma Rivers with a few patches located west of the Keiskamma River. The xeric associations are limited to the area west of the Keiskamma River and patches located within the Alexandria Forest (see Figure 3.3.3). Environmentally and successionally the associations have been described in Chapters 4 and 5 and suggestions for management and conservation given in Chapter 6.

For each association, dominant, characteristic and indicator species were determined, and comparisons were made between them. It is apparent that certain families are particularly well represented in the grasslands and their contribution to species richness was determined.

Table 7.1 Summary of important species and families for mesic grassland associations

Mesic Association	Dominant, characteristic and indicator species	Family richness
Themeda triandra – Anthospermum herbaceum	*Themeda triandra* dominant. *Anthospermum herbaceum and Stenotaphrum secundatum* are characteristic. Indicator species are *Hypoestes aristata* and *Tephrosia capensis*	Asteraceae 7% Fabaceae 3% Poaceae 40% Cyperaceae 6% Others 44%
Themeda triandra	*Themeda triandra* dominant. *Eriosema squarrosum, Tristachya leucothrix* and *Paspalum notatum* are characteristic. Indicator species for subassociations include *Acacia karroo, Cyperus obtusiflorus, Gnidia anthylloides, Pentaschistis pallida, Gazania krebsiana, Chaetacanthus setiger, Cymbopogon validus* and *Ficinia stolonifera.*	Asteraceae 13% Fabaceae 11% Poaceae 31% Cyperaceae 5% Others 40%
Hyparrhenia hirta – Diheteropogon amplectens	Dominant species is *Hyparrhenia hirta.* Characteristic species *Elionurus muticus, Diheteropogon amplectens, Imperata cylindrica, Chamaecrista capensis.* Indicator species for subassociations include *Ehrharta calycina, Senecio inaequidens, Helictotrichon hirtulum, Eragrostis curvula, Digitaria eriantha* and *Centella coriacea.*	Asteraceae 15% Fabaceae 13% Poaceae 21% Cyperaceae 9% Others 42%
Hyparrhenia hirta – Themeda triandra	Dominant species *Hyparrhenia hirta.* Characteristic species *Themeda triandra, Digitaria eriantha, Centella coriacea. Paspalum notatum* and *Richardia brasiliensis.* Indicator species *Cymbopogon validus, C. excavatus, Aristida junciformis, Helichrysum pedunculari*s and *Eragrostis plana.*	Asteraceae 12% Fabaceae 16% Poaceae 23% Cyperaceae 12% Others 37%
Stenotaphrum secundatum - Centella coriacea	Dominant species *Stenotaphrum secundatum.* Characteristic species *Senecio inaequidens, Centella coriacea, Paspalum notatum.* Indicator species *Hypoestes aristata, Digitaria eriantha, Pycreus oakfortensis* and *Cynodon dactylon*	Asteraceae 9% Fabaceae 19% Poaceae 24% Cyperaceae 8% Others 40%

Table 7.2 Summary of important species and families for xeric grassland associations

Xeric Association	Dominant, characteristic and indicator species	Family richness
Diheteropogon filifolius - Ehrharta calycina	No dominant species. Characteristic species include *Themeda triandra, Heteropogon contortus, Ehrharta calycina* and *Diheteropogon filifolius*. Indicator species *Tephrosia capensis, Eriosema squarrosum, Chaetacanthus setiger, Chamaecrista capensis, Helichrysum asperum, Aizoon rigidum, Indigofera heterophylla* and *Acalypha peduncularis*.	Asteraceae 17% Fabaceae 21% Poaceae 28% Cyperaceae 4% Others 30%
Cynodon dactylon - Ehrharta calycina	*Cynodon dactylon* and *Ehrharta calycina* dominant. Characteristic species include *Eriosema squarrosum, Heteropogon contortus, Chamaecrista capensis, Eragrostis plana* and *E. capensis*. Indicator species *Elionurus muticus, Gazania krebsiana* and *Senecio inaequidens*.	Asteraceae 18% Fabaceae 18% Poaceae 23% Cyperaceae 7% Others 34%
Themeda triandra - Ehrharta calycina	Dominant species *Themeda triandra* and *Tristachya leucothrix*. Characteristic species *Heteropogon contortus, Chamaecrista capensis, Ehrharta calycina, Cynodon dactylon* and *Sporobolus africanus*. Indicator species *Pentaschistis pallida, Helichrysum asperum, Eragrostis capensis, Monsonia emarginata, Commelina africana, Koeleria capensis, Rhynchosia adenodes, Indigofera zeyheri* and *Trachyandra revoluta*.	Asteraceae 18% Fabaceae 16% Poaceae 19% Cyperaceae 8% Others 39%
Sporobolus africanus - Setaria sphacelata	No dominant species. Characteristic species *Ehrharta calycina, Cynodon dactylon, Setaria sphacelata*. Indicator species *Sporobolus africanus, Falckia repens, Geranium incanum* and *Senecio ilicifolius*.	Asteraceae 16% Fabaceae 14% Poaceae 12% Cyperaceae 12% Others 46%
Cynodon dactylon - Helictotrichon hirtulum	*Cynodon dactylon* dominant. Characteristic species include *Helictotrichon hirtulum, Eragrostis curvula*. Indicator species *Stenotaphrum secundatum, Ehrharta calycina, Senecio inaequidens* and *Centella coriacea*.	Asteraceae 9% Fabaceae 18% Poaceae 18% Cyperaceae 5% Others 50%

The most important species characteristics in each association were examined and are presented in Tables 7.3 and 7.4 below. In addition, relevant soil, land-use and successional characteristics are summarised.

Table 7.3 Summary of important characteristics of mesic grassland associations

Mesic Association	**Species Characteristics**	**Soil and land-use Characteristics**	**Successional Characteristics**	**Factors causing vegetation change**
Themeda triandra – Anthospermum herbaceum	Fire-tolerant species common e.g. *Themeda triandra, Anthospermum herbaceum, Stenotaphrum secundatum* Most species-poor association of the entire grassland study area. Lowest beta diversity with *Themeda triandra* association.	Slightly acid soils. Highest soil organic content. Mispah family. Strongly influenced by land / sea interface.	Climax primary grassland. Depauperate form of *Themeda triandra* mesic association with which it shows highest affinity.	Wind, salt spray i.e. land / sea interface.
Themeda triandra	Fire-tolerant climax grass species dominant, i.e. *Themeda triandra.* Most species rich association in the study area.	Slightly acid soils. Katspruit / Fernwood family. Occurs over a wide range of environmental variables.	Represents climax primary grassland under optimal conditions.	Subject to some grazing and recreational pressure
Hyparrhenia hirta – Diheteropogon amplectens	Dominated by subclimax species i.e. *Hyparrhenia hirta.* Several species indicative of mismanagement present i.e. *Elionurus muticus, Imperata cylindrica.* Low alpha diversity, high beta diversity with *Themeda triandra* association.	Most acidic soils in study. Fernwood family. Low organic content of soils, phosphorus and potassium limiting soil factors. Distribution strongly influenced by land-use.	Represents degraded climax grassland; may also be affected by poor availability of phosphorus and potassium	Land-use i.e. grazing of cattle and goats. Available potassium.
Hyparrhenia hirta - Themeda triandra	Dominated by subclimax species i.e. *Hyparrhenia hirta.* Presence of species indicating disturbance including *Centella coriacea, Paspalum notatum, Richardia brasiliensis, Aristida junciformis.*	Fairly acid soils. Katspruit and Fernwood families. Average organic content of soil. Distribution not markedly affected	Represents climax grassland that has been subject to grazing.	Grazing of cattle and possibly goats.

	Relatively high alpha diversity, low beta diversity with *Themeda triandra* association.	by any environmental factor analysed.		
Stenotaphrum secundatum Centella coriacea	Dominated by *Stenotaphrum secundatum*, indicator of severe disturbance. Presence of other species indicative of disturbance including *Centella coriacea, Paspalum notatum, Cynodon dactylon*. Low alpha diversity, high beta diversity with *Themeda triandra* association.	Slightly acidic soil. No dominant family. High percentage organic content. Strongly influenced by land / sea interface and organic content of soil.	Represents grasslands affected by proximity to coast and subject to severe trampling and disturbance.	Salt spray, trampling and soil disturbance.

Table 7.4 Summary of important characteristics of xeric grassland associations

Xeric Association	Species Characteristics	Soil and land-use Characteristics	Successional Characteristics	Factors affecting vegetation change
Diheteropogon filifolius Ehrharta calycina	No dominant species present. Characteristic species climax species *Themeda triandra, Ehrharta calycina*. Lowest alpha diversity in xeric associations, relatively low beta diversity with other xeric associations.	Weakly acidic soil. Low organic content. Fernwood family. Slightly affected by land-use. Potassium may be a limiting factor.	Represents degraded xeric grassland on account of grazing and trampling.	Grazing, trampling
Cynodon dactylon Ehrharta calycina	Dominant species only in one subassociation. Dominant species *Ehrharta calycina* and *Cynodon dactylon*. Relatively high alpha diversity for xeric associations, low for entire study.	Neutral soil. Lowest organic content in xeric associations. Fernwood family. Most affected by land-use.	Represents degraded xeric grassland on account of grazing and trampling.	Grazing, trampling

Themeda triandra - Ehrharta calycina	Dominant species *Themeda triandra* with *Tristachya leucothrix* co-dominant. *Ehrharta calycina* characteristic. Characteristic and indicator species show mix of climax and subclimax species. Highest alpha diversity species. Highest alpha diversity of xeric grasslands, almost half that of mesic association. Beta diversity with other xeric associations below 55%.	Neutral soil. Low organic content. Clovelly family. Unaffected by most environmental variables with the exception of land-use. Potassium may be a limiting factor.	Represents the nearest vegetation structure to climax xeric grassland, but is still a slightly disturbed form.	Grazing
Sporobolus africanus Setaria sphacelata	No dominant species. Characteristic species *Cynodon dactylon*, *Ehrharta calycina* and *Setaria sphacelata*. Low alpha diversity. Highest beta diversity in xeric associations occurs between this and *Diheteropogon filifolius – Ehrharta calycina* association	Slightly acidic soil. No dominant family. Highest organic content of xeric associations. Occurs over a wide range of environmental variables with the strongest response being to land-use.	Represents secondary grassland formed after severe soil disturbance.	Ploughing, grazing
Cynodon dactylon – Helictotrichon hirtulum	*Cynodon dactylon* dominant. Characteristic species Helictotrichon hirtulum, Eragrostis curvula. Indicator species *Ehrharta calycina*, *Senecio inaequidens*, *Centella coriacea*. Low alpha diversity.	Alkaline soil. Hutton family. Very low organic content. Occurs over a wide range of environmental parameters but shows strongest response to land / sea interface, land-use and soil family. Potassium may be a limiting factor.	Represents secondary grassland formed after severe soil disturbance.	Soil disturbance, land / sea interface, land-use.

The structural and functional characteristics of each association were compiled. Schematic representation of these characteristics and some of the environmental factors affecting grassland dynamics are presented in Figures 7.1 and 7.2.

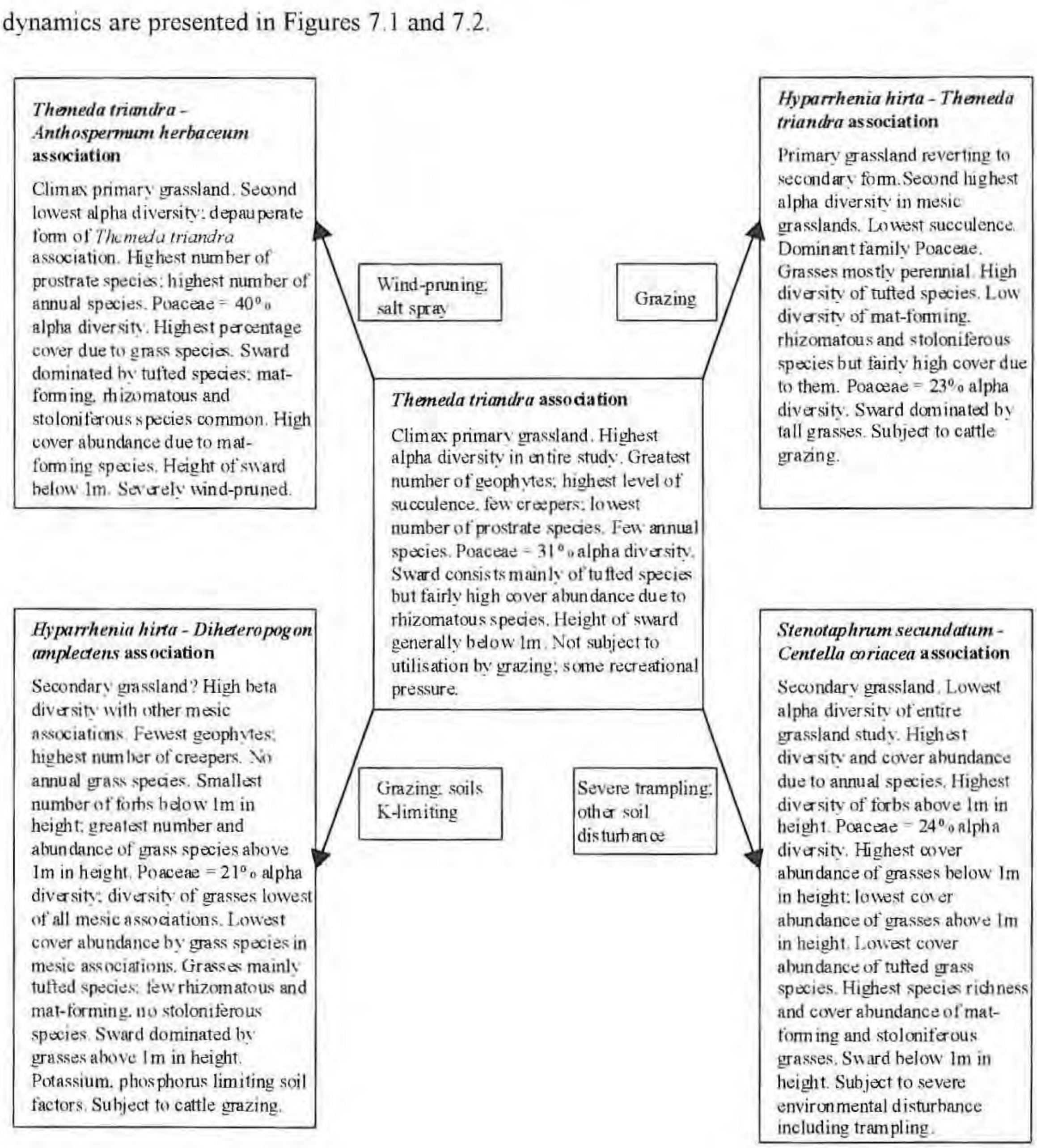


Figure 7.1 Relationships between environmental factors, diversity, structure and function of mesic grassland associations

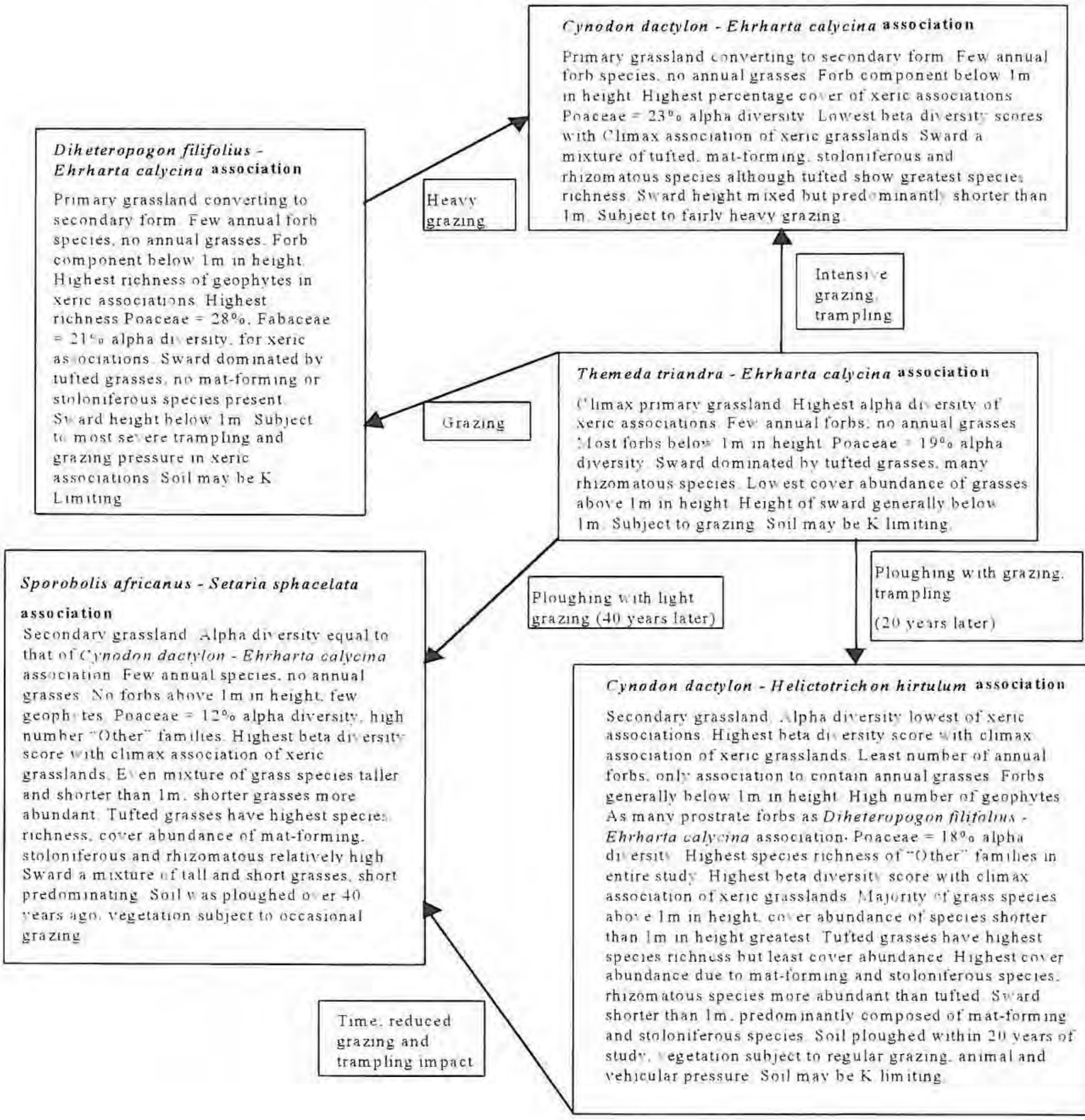


Figure 7.2 Relationships between associations environmental factors, diversity, structure and function of xeric grassland associations

In order to asses the conservation status of each association and what its conservation value is, a table listing the area conserved and endemic species was prepared for each association.

Table 7.5 Area conserved and presence of endemic, vulnerable and rare species in Eastern Cape Coastal Grassland associations

Association	**Area under conservation**	**Number of endemic species**
Themeda triandra – Anthospermum herbaceum	<1km²	2 endemic; 1 vulnerable
Themeda triandra	<1km²	6 endemic; 1 vulnerable; 1rare
Hyparrhenia hirta – Diheteropogon amplectens	0	6 endemic; 1 rare
Hyparrhenia hirta – Themeda triandra	<1km²	4 endemic
Stenotaphrum secundatum – Centella coriacea	<1km²	2 endemic
Diheteropogon filifolius – Ehrharta calycina	0	2 endemic
Cynodon dactylon – Ehrharta calycina	0	4 endemic
Themeda triandra - Ehrharta calycina	0	5 endemic
Sporobolus africanus – Setaria sphacelata	0	4 endemic
Cynodon dactylon – Helictotrichon hirtulum	<1km²	4 endemic

7.3 DISCUSSION

It can be seen from the results summarised in Tables 7.1 and 7.2 that the key species (Bond, 1992) for undisturbed associations throughout the grassland is *Themeda triandra*, a fire-climax grass. Where disturbance due to grazing takes place in mesic associations, *Hyparrhenia hirta*, which is a subclimax species common to disturbed areas, (Gibbs-Russel *et al.*, 1991; van Oudtshoorn, 1992) becomes more important. In the xeric associations, *Ehrharta calycina* is also a key species although its abundance is generally less than that of *T. triandra*. Disturbance due to grazing in the xeric associations reduces the abundance of *T. triandra* while *E. calycina* and *Cynodon dactylon* become more abundant. *C. dactylon* is able to withstand high nitrogen levels that can result from high animal impact as well as from fertilising soil. It increases under conditions of increasing disturbance and is thus a good indicator of overutilisation of vegetation (van Oudtshoorn, 1992). It is therefore apparent that the xeric associations are being subjected to levels of grazing pressure which are having a more serious effect than the grazing experienced by the mesic associations, and this is confirmed by the pattern of distribution.

The xeric associations subject to the highest grazing pressure are all located within the former Ciskei where animals area grazed under a communal system. As found by Kepe and Scoones (1999), a sward dominated by *C. dactylon* is maintained by heavy grazing. McKenzie (1982) and de Bruyn (1998) have verified Acocks' (1966; 1975) findings that the more heavily grazed grasslands support a higher growth of *T. triandra* and other climax species. This is reflected in the results for xeric associations where the most heavily grazed association produced the highest cover abundance while the association that was slightly less heavily grazed contained many climax species. It is felt that the mesic associations do not compare in this instance because none of them are subject to grazing pressures of such intensity, and the higher rainfall experienced prevents comparison between xeric and mesic associations.

Despite the effects of grazing on grass sward composition, disturbance due to grazing does have a negative impact on vegetation as it causes injury and loss of photosynthetic area (Kirkman and Moore, 1995; Rodriguez *et al.*, 1995; Wolfson, 1999). While many species within the grasslands are adapted to disturbances such as grazing and fire, many species are not and thus species richness declines. This is indicated by the decrease in species richness between climax and disturbed vegetation. Decreasing moisture availability in terms of quantity and seasonality of rain is thought to be largely responsible for the decline in species richness and cover abundance from west to east. This moisture pattern may be responsible for the higher prevalence of members of the Asteraceae and Fabaceae in the xeric associations.

The structure of the grasslands is influenced by the moisture regime as well as the patterns of disturbance (O'Connor, 1985; Barnes *et al.*, 1991; Steenkamp and Bosch, 1995). Jenny (1980) states that the amount of biomass produced increases with increasing rainfall. The biomass increase is partly due to increased cover and increased height, and the grass sward becomes increasingly taller as one moves eastwards through the study area. In addition, mat-forming species are most common in vegetation which is either severely trampled or which occurs on soil that has been previously disturbed by impacts such as ploughing. This is because tufted species are more susceptible to trampling while the rhizomatous and stoloniferous species that make up mat-forming grasses can withstand this pressure. Rhizomatous and stoloniferous species are usually more persistent in the deep sandy soils on which ploughing has taken place (Bayer, 1955), as experienced in this study.

Soil factors have been reported to play a key role in the determination of plant associations (O'Connor, 1985), and soil family, organic content and pH are some of the most important variables in explaining ordination of the samples. Land-sea interface, organic content and pH are the most important variables affecting ordination of the mesic associations. Indirectly the xeric associations are most strongly influenced by land-use while land/sea interface, distance from the shore and soil family are the most important factors for direct ordination. The dynamics of land/sea interface need further consideration and aspects such as soil depth and soil texture of the forest areas adjacent to grasslands need to be compared with these grasslands. An analysis of the effect of salt-spray would also be desirable. At a smaller scale the role of potassium in grassland dynamics needs to be further explored as this may be a limiting factor in the *Hyparrhenia hirta* - *Diheteropogon amplectens*, *Diheteropogon filifolius* - *Ehrharta calycina*, *Themeda triandra* - *Ehrharta calycina* and *Cynodon dactylon* - *Helictotrichon hirtulum* associations (Mr Jimmy Mullins, pers. comm.).

The mesic grasslands are more extensively conserved than the xeric and support more endemic species. The former also supports a vulnerable and rare species and has a higher diversity than the latter. However it is felt that the area conserved for mesic associations is too small and that more vegetation should be set aside. Despite the lower diversity and disturbed nature of the xeric associations it is felt that they should also be conserved with an emphasis on examining the response of the vegetation to different management techniques aimed at improving their condition. The grasslands occur on the coastal extremes of the tension zone created by the convergence of four major phytochoria (Lubke, 1998). As they contain species representing the eastern and western extremes of distribution of these phytochoria, it is felt that they warrant conservation on account of the diversity of floras which they represent.

7.4 CONCLUSIONS

The results presented above indicate that the coastal grasslands of the eastern Cape west of the Kei River can be divided into ten clearly distinguished associations. The ten associations were divided spatially at the Keiskamma River with five associations occurring to the east and five to the west of this river. The underlying factor which separated the associations is considered to be moisture regime i.e. the amount of annual precipitation as well as its seasonality. While annual rainfall increases from west to east, the midsummer "drought" becomes almost imperceptible at the Great Fish River, after which it is no longer recorded.

The five associations that occur east of the Keiskamma River have higher species diversity and cover abundance than the five associations west of this river. While certain species such as *Themeda triandra, Centella coriacea* and others occurred throughout the study area, others were limited to either xeric or wetter regions. Under conditions of disturbance, *Hyparrhenia hirta* became abundant while *Cynodon dactylon* was more common under xeric conditions. The coastal pioneer species *Stenotaphrum secundatum* became dominant under conditions of extreme disturbance in both mesic and xeric associations.

The impact of man-induced and intrinsic environmental factors varied between the ten associations. Within the mesic associations, land/sea interface, organic content, pH and land-use are the most significant factors affecting the spatial distribution of the associations. The climax mesic association was able to occur over a wide range of environmental variables. In the xeric associations, land-use was an overriding factor that caused a separation between ploughed and unploughed vegetation. Within the xeric associations, land/sea interface and soil family had the strongest influence. The relationship between the vegetation and land/sea interface needs further study including assessment of the effects of salt spray and fog on the vegetation. In addition, comparisons between grassland and the surrounding woody vegetation should be undertaken. It was observed in the field that coastal forest is adjacent to the sea only where there is a sandy or rocky/sandy shore with grassland behind it. Grassland occurs where there is a rocky or rocky/sandy shore. This relationship needs further examination.

In terms of succession, in the mesic associations a relationship between disturbed and undisturbed vegetation was elucidated. The studies indicated that most of the grassland was primary in nature but environmental constraints such as extreme windiness did cause one association to remain in a depauperate state. Disturbance due to grazing caused the climax vegetation to regress to a subclimax form. Severe soil disturbance resulted in the formation of a secondary association. In terms of temporal change, the mesic associations indicated the existence of a transitional state between climax and subclimax grassland during spring. This indicates possibilities for improvement of vegetation and indicates that further work on vegetation dynamics may produce some interesting results for management.

In the xeric associations, no "pristine" climax grassland was recorded. The association that was subject to the least grazing pressure appears to be the closest representation of climax xeric grassland. Soil disturbance resulted in the formation of secondary grassland. Heavy and severe grazing also drive the vegetation towards the formation of a secondary grassland. The results indicated that succession (or regression) in the grazed grassland was proceeding in a different direction to that of vegetation which had been soil-disturbed and that the resulting grasslands would not be similar. It was difficult to compare the two situations as the soil disturbed associations are being allowed to advance while the grazed associations are under a continued negative pressure.

The conservation potential of the coastal grasslands was assessed in terms of species richness and the presence of rare and endemic species. The results indicate that the grasslands do not support many rare or endemic species, although one vulnerable species, *Kniphofia rooperi*, is recorded. Not all of the associations have been conserved and the xeric associations are particularly poorly represented. While it is understandable that one would rather conserve undisturbed than disturbed vegetation, the importance of conserving disturbed vegetation and monitoring it for further change is emphasised. The representation of four major phytochoria (Cape, Kalahari-Highveld Regional Transitional Zone, Karroo-Namib and Tongoland-Pondoland Regional Mosaic) is regarded as a recommendation for conserving a greater area of the coastal grasslands.

Management options for the grasslands remain those of grazing strategy and fire regime with moisture taken into account. It is emphasised again that the latest literature stresses the importance of burning when the sward is not growing in the case of the farmers. For Nature Conservation areas, it is recommended that natural fires be allowed to run their course and that if a burning regime is absolutely necessary, that such fires be carried out at varying times of the year as opposed to on a regular seasonal basis. The impact of trampling in certain areas is to be minimised where possible. Monitoring of vegetation wherever possible is strongly encouraged.

The results presented in this thesis were intended to improve the knowledge of the grasslands west of the Kei River since little information was available concerning their diversity and extent. An understanding of the environmental factors influencing the grassland dynamics is given and future studies can build upon this beginning. It is clear that studies of the long-term effects of ploughing and grazing will be beneficial to both the land-user and the grassland scientist for landscape predictions and management options. Finally, it is hoped that the results of these studies will enable all land-users to make better decisions concerning our impact on the grasslands upon which we rely.

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APPENDIX ONE
SPECIES CHECKLIST FOR THE EASTERN CAPE COASTAL GRASSLANDS WEST OF THE KEI RIVER

Genus Number	Family / Species and Author
	ADIANTACEAE
0000340	*Cheilanthes viridis* (Forssk.)Swartz
	CYPERACEAE
0459000	*Cyperus* sp.
0459000	*Cyperus brevis* Boeck.
0459000	*Cyperus obtusiflorus* Vahl. var *flavissimus* Boeck.
0459000	*Cyperus obtusiflorus* Vahl. var *obtusiflorus*
0459000	*Cyperus obtusiflorus* Vahl.
0459010	*Pycreus oakfortensis* C. B. Cl.
0459030	*Mariscus* sp.
0459030	*Mariscus albomarginatus* C.B. Cl.
0459030	*Mariscus congestus* (Vahl.) C.B.Cl.
0459030	*Mariscus sumatrensis* (Retz.) J. Raynal
0459030	*Mariscus tabularis* (Schrad.) C.B. Cl.
0462000	*Kyllinga* sp.
0462000	*Kyllinga alba* Nees
0462000	*Kyllinga elatior* Kunth
0462000	*Kyllinga erecta* Schumach.
0465000	*Ficinia arenicola* Arnold & Gordon - Grey
0465000	*Ficinia indica* (Lam.) Pfeiffer
0465000	*Ficinia stolonifera* Boeck.
0467000	*Fuirena* sp.
0468010	*Schoenoplectus* sp.
0471000	*Fimbristylis* sp.
0471000	*Fimbristylis complanata* (Retz.) Link
0471010	*Bulbostylis* sp.
0471010	*Bulbostylis contexta* (Nees) Bodard
0471020	*Abildgaardia ovata* (Burm.f.) Kral
492000	*Rhynchospora brownii* Roem. & Schult.
0515000	*Scleria* sp.
0521000	*Schoenoxiphium sparteum* (Wahlenb.) C.B. Cl.
	COMMELINACEAE
0896000	*Commelina* sp.
0896000	*Commelina africana* L.
0896000	*Commelina livingstonii* C.B.Cl.
	JUNCUS
0936000	*Juncus* sp.
	ASPHODELACEAE (PART A)
0985000	*Bulbine* sp.
0985010	*Trachyandra* sp.
0985010	*Trachyandra revoluta* (L.) Kunth
	ASPHODELACEAE (PART B)
1024000	*Kniphofia rooperi* (Moore) Lem.
1026000	*Aloe* sp.
	HYACINTHACEAE
1079000	*Albuca caudata* Jacq.
1086000	*Scilla* sp.
1088000	*Eucomis comosa* (Houtt.) Wehrh.
1090000	*Drimiopsis* sp.
	ASPARAGACEAE
1113000	*Asparagus densiflorus* (Kunth) Oberm.

	HAEMADORACEAE
1162000	*Wachendorfia thyrsiflora* Burm.
	AMARYLLIDACEAE
1167000	*Haemanthus albiflos* Jacq.
1168000	*Boophane* sp.
1230000	*Hypoxis* sp.
1230000	*Hypoxis argentea* Harv. Ex bak.
1230000	*Hypoxis longifolia* Bak.
1230000	*Hypoxis stellipilis* Ker - Gawl
1230000	*Hypoxis villosa* L.f.
	IRIDACEAE
1265000	*Moraea* sp.
1284000	*Bobartia* sp.
1295000	*Aristea* sp.
1295000	*Aristea abyssinica* Pax.
1295000	*Aristea schizolaena* Harv. Ex Bak.
1303000	*Dierama igneum* Klatt
1306000	*Tritonia lineata* (Salisb.) Ker - Gawl
1311000	*Gladiolus* sp.
1311000	*Gladiolus ochroleucus* Bak.
1311000	*Gladiolus permeabilis* Delaroche
1315000	*Watsonia x longifolia* J.W.Mathews & L. Bol.
1315000	*Watsonia galpinii* L.Bol.
	ORCHIDACEAE
1430000	*Satyrium* sp.
1430000	*Satyrium parviflorum* Swartz
	SANTALACEAE
2117000	*Thesidium minus* A.W.Hill
2118000	*Thesium junceum* Bernh.
	POLYGONACEAE
2195000	*Rumex acetosella* L. ssp *angiocarpus* (Murb.) Murb.
	AIZOACEAE
2389000	*Pharnaceum thunbergii* Adamson
2399000	*Galenia secunda* (L.f.) Sond.
2401000	*Aizoon rigidum* L.f.
	MESEMBRYANTHEMUM
2405021	*Carpobrotus deliciosus* (L.Bol.) L.Bol.
2405066	*Lampranthus* sp.
2405073	*Mesembryanthemum* sp.
	CARYOPHYLLACEAE (PART A)
2430000	*Cerastium* sp.
2430000	*Cerastium capense* Sond.
	CARYOPHYLLACEAE (PART B)
2490000	*Silene* sp.
2490000	*Silene bellidioides* Sond.
2490000	*Silene gallica* L.
2490000	*Silene primuliflora* Eckl. & Zeyh.
	RANUNCULACEAE
2541010	*Knowltonia capensis* L. Huth.
2542000	*Clematis* sp.
2542000	*Clematis brachiata* Thunb.
2546000	*Ranunculus multifidus* Forssk.
	BRASSICACEAE
2875000	*Heliophila subulata* Burch. Ex DC
	CRASSULACEAE
3168000	*Crassula nemorosa* (E. & Z.) Endl. Ex. Walp.

3175000	*Adromischus maculatus* (Salm - Dyck) Lem.
	FABACEAE
3446000	*Acacia karroo* Hayne
3536010	*Chamaecrista capensis* (Thunb.) E. Mey.
3669000	*Crotalaria obscura* DC
3673000	*Argyrolobium incanum* Eckl.& Zeyh.
3673000	*Argyrolobium rupestre* (E & Z) Walp.
3688000	*Medicago laciniata* (L) Mill
3689000	*Melilotus indica* (L.) All.
3690000	*Trifolium* sp.
3690000	*Trifolium burchellianum* Ser.
3702000	*Indigofera* sp.
3702000	*Indigofera heterophylla* Thunb.
3702000	*Indigofera hilaris* E & Z
3702000	*Indigofera stricta* L.f.
3702000	*Indigofera verrucosa* E & Z
3702000	*Indigofera zeyheri* Spreng ex E & Z
3703040	*Otholobium decumbens* (Ait.) C.H.Stirton
3718000	*Tephrosia* sp.
3718000	*Tephrosia angulata* E. Mey.
3718000	*Tephrosia capensis* (Jacq.) Pers.
3718000	*Tephrosia macropoda* (E.Mey.) Harv.
3718000	*Tephrosia purpurea* (L) Pers.
3756000	*Lessertia stenoloba* E. Mey.
3804000	*Zornia capensis* Pers.
3807000	*Desmodium incanum* DC
3810000	*Alysicarpus* sp.
3810000	*Alysicarpus rugosus* (Willd.) DC
3852000	*Vicia sativa* L.
3856000	*Indigastrum fastigiatum* (E.Mey.) Schrire
3897000	*Rhynchosia adenodes* E & Z
3897000	*Rhynchosia capensis* (Burm.) Schinz
3897000	*Rhynchosia caribaea* (Jacq.) DC
3898000	*Eriosema squarrosum* (Thunb.) Walp.
3905000	*Vigna* sp.
3905000	*Vigna luteola* (Jacq.) Benth.
3905000	*Vigna unguiculata* (L.) Walp.
3905000	*Vigna vexillata* (L.)A.Rich. var *angustifolia* (Schumach.& Thonn.)Bak.
3905000	*Vigna vexillata* (L.) A.Rich. var. *vexillata*
3905000	*Vigna vexillata* (L.) A.Rich.
3910000	*Dolichos* sp.
3910000	*Dolichos falciformis* E.Mey.
	GERANIACEAE
3924000	*Geranium incanum* Burm.f.
3925000	*Monsonia* sp.
3925000	*Monsonia emarginata* (L.f) L'Herit
3928000	*Pelargonium* sp.
3928000	*Pelargonium alchemilloides* (L.) L'Herit
3928000	*Pelargonium pulverulentum* Colv. Ex Sweet
	OXALIDACEAE
3936000	*Oxalis* sp.
3936000	*Oxalis bifurca* Lodd.
3936000	*Oxalis corniculata* L.
	LINACEAE
3945000	*Linum* sp.
3945000	*Linum thunbergii* Eckl. & Zeyh.

	POLYGALACEAE
4273000	*Polygala illepida* E.Mey.ex Harv.
	EUPHORBIACEAE
4407000	*Acalypha peduncularis* E. Mey. Ex Meisn.
4448000	*Clutia heterophylla* Thunb.
4498000	*Euphorbia bupleurifolia* Jacq.
4498000	*Euphorbia gorgonis* Berger
	ANACARDIACEAE
4594000	*Rhus dentata* Thunb.
4594000	*Rhus incisa* L.f.
	CELASTRACEAE
4641000	*Cassine tetragona* (L.f.) Loes.
	TILIACEAE
4966000	*Grewia occidentalis* L.
	MALVACEAE
4983000	*Abutilon sonneratianum* (Cav.) Sweet
4998000	*Sida dregei* Burtt Davy
4998000	*Sida rhombifolia* L.
5013000	*Hibiscus aethiopicus* L.
5013000	*Hibiscus trionum* L.
	STERCULIACEAE
5056000	*Hermannia incana* Cav.
	THYMELIACEAE
5435000	*Gnidia anthylloides* (L.f.) Gilg.
5435000	*Gnidia nodiflora* Meisn.
5435000	*Gnidia styphelioides* Meisn.
5461000	*Passerina rigida* Wikstr.
	MYRTACEAE
5578000	*Eugenia albanensis* Sond.
5598000	*Eucalyptus* sp.
	ONAGRACEAE
5804000	*Oenothera rosea* L'Herit. Ex Ait.
	APIACEAE
5894000	*Centella coriacea* Nannfd.
5894000	*Centella linifolia* (L.f.) Drude
5894000	*Centella villosa* L.
5922000	*Alepidea longifolia* E. Mey.
6116000	*Peucedanum capense* (Thunb.) Sond.
	PRIMULACEAE
6338000	*Anagallis arvensis* L.
	EBENACEAE
6404000	*Euclea crispa* (Thunb.) Guerke
6406000	*Diospyros dichrophylla* (Gand.) De Winter
6406000	*Diospyros villosa* (L.) De Winter
	GENTIANACEAE
6481000	*Sebaea sedoides* Gilg.
6503000	*Chironia baccifera* L.
	APOCYNACEAE
6559000	*Carissa* sp.
6747000	*Raphionacme hirsuta* (E.Mey.) R.A.Dyer ex Phill.
	ASCLEPIADACEAE
6777000	*Xysmalobium involucratum* (E.Mey.) Decne
6777000	*Xysmalobium orbiculare* (E.Mey.) D.Dietr.
6791000	*Asclepias* sp.
6791000	*Asclepias albens* (E.Mey.) Schltr.
6791000	*Asclepias densiflora* N.E.Br.
6791000	*Asclepias gibba* (E.Mey.) Schltr.

6791000	*Asclepias hastata* (E.Mey.) Schltr.
6791000	*Asclepias nana* Verdoorn
6914000	*Dregea* sp.
	CONVOLVULACEAE
6972000	*Falckia repens* L.f.
6993000	*Convolvulus natalensis* Bernh.apud Krauss
6993000	*Convolvulus sagittatus* Thunb.
7003000	*Ipomoea* sp.
7003000	*Ipomoea ficifolia* Lindl.
	BORAGINACEAE
7064000	*Cynoglossum hispidum* Thunb.
	VERBENACEAE
7138000	*Verbena bonariensis* L.
7145000	*Lippia javanica* (Burm.f.) Spreng.
	LAMIACEAE
7212000	*Teucrium africanum* Thunb.
7281000	*Stachys aethiopica* L.
7290000	*Salvia scabra* L.f.
	SOLANACEAE
7407000	*Solanum* sp.
	SCROPHULARIACEAE (PART A)
7476000	*Nemesia fruticans* (Thunb.) Benth.
7519000	*Sutera* sp.
7519000	*Sutera campanulata* (Benth.) Kuntze
7519000	*Sutera laxiflora* (Benth.) Kuntze
7519000	*Jamesbrittenia maritima* (Hiern.) Hilliard
7521000	*Phyllopodium cuneifolium* (L.f.) Benth.
7523000	*Zaluzianskya capensis* (L.) Walp.
7523000	*Zaluzianskya maritima* (L.f.) Walp.
	SELAGINACEAE
7566000	*Hebenstretia integrifolia* L.
7568000	*Selago corymbosa* L.
	SCROPHULARIACEAE (PART B)
7614000	*Graderia scabra* (L.f.) Benth.
7623000	*Cycnium tubulosum* (L.f.) Engl.
7625000	*Striga elegans* Benth.
7627000	*Harveya speciosa* Bernh. Ex Krauss
	ACANTHACEAE
7914000	*Thunbergia* sp.
7914000	*Thunbergia atriplicifolia* E.Mey. Ex Nees
7914000	*Thunbergia capensis* Retz.
7914000	*Thunbergia dregeana* Nees
7941000	*Chaetacanthus setiger* (Pers.) Lindl.
7972000	*Crabbea angustifolia* Nees
7973000	*Barleria obtusa* Nees
7980000	*Blepharis capensis* (L.f.) Pers.
8032000	*Hypoestes aristata* (Vahl.) Soland ex Roem. & Schult.
	PLANTAGINACEAE
8116000	*Plantago* sp.
	RUBIACEAE
8283110	*Coddia rudis* (E.Mey. Ex Harv.) Verdc.
8348000	*Pentanisia prunelloides* (Klotzsch ex Eckl. & Zeyh.) Walp.
8435000	*Galopina aspera* (Eckl. & Zeyh.) Walp.
8438000	*Anthospermum aethiopicum* L.
8438000	*Anthospermum galioides* Reichb.f.

8438000	*Anthospermum herbaceum* L.f.
8438000	*Anthospermum paniculatum* Cruse
8464000	*Richardia brasiliensis* Gomes
	DIPSACACEAE
8546000	*Scabiosa* sp.
8546000	*Scabiosa albanensis* R.A. Dyer
8546000	*Scabiosa columbaria* L.
	CUCURBITACEAE
8568000	*Kedrostis nana* (Lam.) Cogn.
	CAMPANULACEAE
8668000	*Wahlenbergia grandiflora* V. Brehm.
8668000	*Wahlenbergia kowiensis* R.A. Dyer
8668000	*Wahlenbergia stellarioides* Cham. & Schlechtd.
	LOBELIACEAE
8681000	*Cyphia assimilis* Sond.
8694000	*Lobelia* sp.
8694000	*Lobelia flaccida* (Presl.) A.DC ssp *flaccida*
8694000	*Lobelia flaccida* (Presl.) A.DC
8694000	*Lobelia tomentosa* L.f.
8695000	*Monopsis scabra* (Thunb.) Urb.
8695000	*Monopsis unidentata* (Dryand.) E.Wimm.
	GOODENIACEAE
8751000	*Vernonia sp.*
8751000	*Vernonia capensis* (Houtt.) Druce
8751000	*Vernonia dregeana* Sch. Bip.
	ASTERACEAE
8919000	*Felicia filifolia* (Vent.) Burtt Davy
8919000	*Felicia mossamedensis* (Hiern.) Mendonca
8925000	*Nidorella auriculata* DC
8926000	*Conyza obscura* DC
8937000	*Tarchonanthus camphoratus* L.
8992050	*Pseudognaphalium luteo-album* (L.) Hilliard & Burtt
9006000	*Helichrysum* sp.
9006000	*Helichrysum appendiculatum* (L.f.) Less.
9006000	*Helichrysum asperum* (Thunb.) Hilliard & Burtt
9006000	*Helichrysum cymosum* (L.) D.Don.
9006000	*Helichrysum herbaceum* (Andr.) Sweet
9006000	*Helichrysum litorale* H.Bol.
9006000	*Helichrysum nudifolium* (L.) Less.
9006000	*Helichrysum odoratissimum* (L.) Sweet
9006000	*Helichrysum pedunculatum* Hilliard & Burtt
9006000	*Helich rosum* (Berg.) Less. var *arcuatum* Hilliard
9006000	*Helichrysum rosum* (Berg.) Less.
9006000	*Helichrysum rutilans* (L.) D.Don.
9006000	*Helichrysum simillimum* DC
9006000	*Helichrysum umbraculigerum* Less.
9351000	*Cotula sericea* Thunb.
9358000	*Artemisia afra* Jacq. Ex Willd.
9406000	*Cineraria britteniae* Hutch. & R.A.Dyer
9406000	*Cineraria geraniifolia* DC
9411000	*Senecio bupleuroides* DC
9411000	*Senecio chrysocoma* Meerb.
9411000	*Senecio ilicifolius* L.
9411000	*Senecio inaequidens* DC
9411000	*Senecio macrocephalus* DC
9411000	*Senecio oxyriifolius* DC

9411000	*Senecio pterophorus* DC
9427020	*Chrysanthemoides monilifera* (L.) T.Norl.
9432020	*Arctotheca calendula* (L.) Levyns
9434000	*Gazania krebsiana* Less.
9434000	*Gazania linearis* (Thunb.) Druce
9438000	*Berkheya* sp.
9438000	*Berkheya decurrens* (Thunb.) Willd.
9501000	*Dicoma spinosa* (L.) Druce
9528000	*Gerbera piloselloides* (L.) Cass.
9572000	*Hypochaeris radicata* L.
9596000	*Lactuca inermis*
	POACEAE
9900100	*Ischaemum fasciculatum* Brongn.
9900280	*Elionurus muticus* (Spreng.) Kunth
9900370	*Imperata cylindrica* (L.) Raeuschel
9900380	*Miscanthus capensis* (Nees) Anderss.
9900720	*Cymbopogon excavatus* (Hochst.) Stapf ex Burtt Davy
9900720	*Cymbopogon validus* (Stapf) Stapf ex Burtt Davy
9900730	*Hyparrhenia hirta* (L.) Stapf
9900750	*Monocymbium ceresiiforme* (Nees) Stapf
9900800	*Heteropogon contortus* (L.) Roem. & Schult.
9900810	*Diheteropogon amplectens* (Nees) Clayton
9900810	*Diheteropogon filifolius* (Nees) Clayton
9900830	*Themeda triandra* Forssk.
9900890	*Digitaria diagonalis* (Nees) Stapf
9900890	*Digitaria eriantha* Steud.
9900890	*Digitaria monodactyla* (Nees) Stapf
9900890	*Digitaria velutina* (Forssk.) Beauv.
9900940	*Alloteropsis semialata* (R.Br.) Hitchc.
9901040	*Brachiaria* sp.
9901040	*Brachiaria serrata* (Thunb.) Stapf
9901070	*Paspalum dilatatum* Poir.
9901070	*Paspalum notatum* Fluegge
9901080	*Stenotaphrum secundatum* (Walt.) Kuntze
9901160	*Panicum aequinerve* Nees
9901160	*Panicum coloratum* L.
9901160	*Panicum deustum* Thunb.
9901160	*Panicum maximum* Jacq.
9901280	*Setaria* sp.
9901280	*Setaria megaphylla* (Steud.) Dur. & Schinz.
9901280	*Setaria nigrirostris* (Nees) Dur. & Schinz.
9901280	*Setaria pallide-fusca* (Schumach.) Stapf. & C.E.Hubb.
9901340	*Setaria sphacelata* (Schumach.) Moss
9901340	*Melinis nerviglumis* (Franch.) Zizka
9901340	*Melinis repens* (Willd.) Zizka
9901390	*Pennisetum* sp.
9901600	*Ehrharta calycina* J.E.Sm.
9901740	*Tristachya leucothrix* Nees
9901970	*Helictotrichum hirtulum* (Steud.) Schweick.
9901970	*Helictotrichon turgidulum* (Stapf.) Schweick.
9902050	*Pentaschistis pallida* (Thunb.) Linder
9902430	*Agrostis* sp.
9902610	*Lagurus ovatus* L.
9902620	*Aristida* sp.
9902620	*Aristida diffusa* Trin.

9902620	*Aristida junciformis* Trin. & Rupr.
9902830	*Sporobolus africanus* (Poir.) Robyns & Tournay
9902830	*Sporobolus fimbriatus* (Trin.) Nees
9902830	*Sporobolus virginicus* (L.) Kunth
9902860	*Eragrostis capensis* (Thunb.) Trin.
9902860	*Eragrostis curvula* (Schrad.) Nees
9902860	*Eragrostis plana* Nees
9902860	*Eragrostis racemosa* (Thunb.) Steud.
9902960	*Cynodon dactylon* (L.) Pers.
9902980	*Harpochloa falx* (L.f.) Kuntze
9903010	*Chloris gayana* Kunth
9903020	*Eustachys paspaloides* (Vahl.) Lanza & Mattei
9903740	*Koeleria capensis* (Steud.) Nees
9903860	*Melica* sp.
9904170	*Festuca costata* Nees
9904170	*Festuca longipes* Stapf.
9904280	*Bromus pectinatus* Thunb.

APPENDIX TWO

Complete list of species of the *Themeda triandra* - *Anthospermum herbaceum* association

Unique relevé, nr.	
	1111111122
	2233366833
	8903556457
Anthospermum herbaceum	424458.547
Arctotheca calendula	.....5....
Berkheya decurrens	.......1..
Bulbine species	.......1..
Bulbostylis contexta	4
Carissa species	1.........
Centella coriacea	....1..5..
Cheilanthes viridis	........1.
Cynodon dactylon	.....2....
Digitaria eriantha	...2....75
Dolichos falciformis	.....2....
Elionurus muticus	15
Eriosema squarrosum	....2..5.1
Falckia repens	1.1..2....
Gazania krebsiana	1.11......
Gerbera piloselloides	...11.....
Gladiolus ochroleucus	1..1......
Helichrysum appendiculatum	..12......
Helichrysum cymosum	2..12.....
Helichrysum nudifolium	1
Helichrysum rutilans	.....5...6
Helictotrichon hirtulum	15
Hypoestes aristata	25222..5..
Hypoxis species	.....5....
Hypoxis argentea	21..1.....
Indigofera stricta	........2.
Mariscus congestus	4
Monopsis scabra	.......1..
Nemesia fruticans	.......1..
Panicum deustum	1
Passerina rigida	2.21......
Pelargonium species	1.........
Pycreus oakfortensis	.......1..
Senecio inaequidens	.1.1...1..
Senecio macrocephalus	1212......
Senecio pterophorus	.....67.86
Setaria megaphylla	2..22.....
Setaria pallide-fusca	.......5..
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Stenotaphrum secundatum	29225795..
Tephrosia capensis	1.1.2...11
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Thunbergia species	121
Thunbergia dregeana	.....11...
Tristachya leucothrix	7
Trifolium species	.......1..

Vigna unguiculata	.......11.
Vigna vexillata	.1.11.....
Wahlenbergia grandiflora	.......1..
Watsonia x longifolia	........4.

Complete list of species of the *Themeda triandra* association

Unique relevé, nr	1111111111111 | 11111111111 | 11111111111111111111111111111 | 111111
	4444441555567|44555557778001111 41 1|901111 4 4568888677777 1 3 1 | 57 1
	345 7 1 3 5| 5 47 0353 24 01 1 1|5735743711 7 0571 37 0 4678 2 675 44 015
Abildgaardia ovata	...5...55.5|..55...55................|...4....1.......................5.......|.......
Acacia karroo	5.41111......|.......5...5...............|..|.......
Acalypha peduncularis	..1.....11.1..|......11...1221.......1...|..1.........4+1.......................|..1..1.
Adromischus maculatus	............|.........................|..|.......
Agrostis species	............|.........................|..|..+0+..
Aizoon rigidum	............|...........5.............|..|.......
Albuca setosa	............|...........1.............|..|.......
Alepidea longifolia	............|.........................|.................11.....................|.......
Alloteropsis semialata	............|.....8....5..............|..|.......
Aloe species	............1|........................|..|.......
Alysicarpus species	............1|........................|..............................21.........|.......
Alysicarpus rugosus	............|.........................|..............................1.........|.......
Anthospermum [illegible]	............|.........................|..|...7..
Anthospermum galioides	............|..........1..............|..|.......
Anthospermum herbaceum	............|.........................|.......1......1.......5..348.........4.|.....5.
Anthospermum paniculatum	............|...........5.............|..|.......
Arctotheca calendula	............|.........................|..|...11..
Argyrolobium rupestre	............|.........................|...............................1........|.......
Aristea species	............|...................11....|..|.......
Aristea abyssinica	............2|........................|..|.......
Aristea schizolaena	.......11.1..|........................|..|.......
Artemisia afra	............|.........................|..|....4..
Asclepias species	............|.........1........1......|..|.......
Asclepias albens	............|.........................|..|.......
Asclepias [illegible]	............|.....1...................|..|.......
Asclepias gibba	............|.........................|...........................1....1.........|.......
Asparagus densiflorus	............|........................1|..|.......
Barleria obtusa	............1|..................2.......|......4.....................1............|.......
Berkheya species	............|.........................|5.......................................|.......
Berkheya decurrens	............|..............121.......|...................11.....................|.....1.
Boophane species	............|.........................|..|.......
Bulbine species	............|.........................|...5....................................|.......
Bulbostylis species	............|........5................|..|.......
Bulbostylis contexta	............|..8525587.1.........5.1|..1.........4.1...............521.........|.......
[illegible]	............|.........................|...............................1..........|.......
[illegible] species	............|.........................|..........1.............................|.......
[illegible]	............|.........................|..|5.5....
Centella [illegible]	......1...5..177.....1....51...1.11.1.|55....11...11...1..11...1.25.....51..|.1...5.
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Centella villosa	.............|.......................11..|.............1..........................|.......	
Chamaecrista [illegible]	.........21..|..111..11112.......11.1|11.........111...............4....|.......	
Chaetacanthus setiger	............|...........1.........1|11............1.1.....1111..1...1.|.......	
Chironia baccifera	............|.......................|...................................|...1...	
Chrysanthemoides monilifera	.1..........|.......................|...................................|.......	
Clutia heterophylla	............|........111..1......11.1|.............11...1.......11....1....|.....1.	
Commelina species	1.........1..|..1......1.........1....|...................................|.......	
Commelina livingstonii	............|.......................|............................11....|...1...	
[illegible]	............|.......................|............................11....|.......	
[illegible]	............|..........1............|.......................1...........|.......	
Crassula nemorosa	............|...11....................|...................................|.......	
Crotalaria [illegible]	............|..1........1....1.......|...1........1......................|.......	
[illegible]	....1..11..1.|.......................|....................1..............|.......	
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Cymbopogon validus	............|.......................|...........................411.....|..5.5..	
Cynodon dactylon	.........1...|.......5....5.........5|1......................1............|.......	
Cyperus [illegible]	............|.......................|............................1.....|.....1..	
Cyperus obtusiflorus	...55.1......|.......................|..............1..........1....1.....|.......	
Cyphia assimilis	............|.....1..................|...................................|.......	
[illegible] species	............|.......................|........................1..........|.......	
Dierama [illegible]	1...........|...............21.......|..5................................|.......	
Digitaria eriantha	............|.......................5|...........................54415.|.......	
Digitaria monodactyla	............|.........4..............|...................................|.......	D
[illegible]	............|.......................|........................5...........|.......	
Diheteropogon amplectens	545.5555555.|.......................|..............1.1..........11.......|.......	
Diheteropogon filifolius	............|........7..............|...................................|.......	
Diospyros dichrophylla	............|.......................|...................................|5......	
Diospyros villosa	............|.......................|...................................|.......	
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Drimiopsis species	............|.......................|...........................1.......|.......	
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Elionurus muticus	5.5555555.555|5.......5..45...........|...................................|..5554.	
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Eriosema squarrosum	.1...111111..|....11..5.11..1.1.1111|1.1..1.1.1.1..1111.11...111..2...1.|.1....	
[illegible]	............|.......................|.....................4.............|.......	
[illegible]	............|.......................|...................................|.......	
[illegible]	............|.......................|................................4...|.......	
Euphorbia bupleurifolia	............|.........1..............|...................................|.......	E
Falckia repens	............1|.......................1.......111.........1..........1|.......	
[illegible]	............|.......................|...................................|..551..	
Fimbristylis species	..........1.|.......................|...................................|.......	
[illegible]	............|.......................|............................1.....|.......	
Gazania krebsiana	............5|...............1.......|.....4..11...1.1.1.1.1.1...1..1..1.|....1..	
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Gnidia anthylloides	..1..1....111...........1................|....................1..........1......|.......
Gnidia nodiflora	..............|.........1..........|..|.......
Gnidia [illegible]ides	..1.11.11.......1..1......................................1.........................|.......
Gr[illegible]	..............|............................|...|.......
Gr[illegible]	..............|............................|...|.......
Harpochloa falx	..............|............................|...|.......
Her[illegible] sp[illegible]	..............|............................|.....................1....11........|.......
Helichrysum [illegible]	1....1....1111...............1111.111|1.......1.1.1111.1.1.1.1.......|.......
Helichrysum [illegible]	..........................1...........|...|.......
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Helichrysum nudifolium	111.1.1...1..1......6.................|.................11.1...11...11.........|.......
Helichrysum [illegible]um	.........11.|......................1..|..............11.1..........................|.......
Helichrysum [illegible]	..............|............................|...|.......
Helichrysum rutilans	..1...1.......|............................|.....................12..5.6.....11.1.|.......
Helichrysum simillimum	..............|............................|.................1...........................|.......
Helichrysum umbraculigerum	..............|...................1.......|...|.......
Heliophila subulata	..............|............................|..............................1.1......|.......
Helictotrichon hirtulum	............7|.......6......1....1......|1.1...............1...1.......71....41....|.......
Hermannia [illegible]	..............|..........................1|...|.......
Heteropogon contortus	..............|2.66557454.7.61555.....25.....5................5.1..1........|......1
Hibiscus trionum	..............|...................1........|...|......1
Hyparrhenia hirta	1.............|......6.........5.6..1..|.......
Hypericum [illegible]	..............|............................|.......1..1.1..........................1.|......1
Hypoxis species	..............|............................|.......1.........6.................1.1..|.......
Hypoxis argentea	..............|.........................11|....2.....1........1....85..1.1........|.......
Hypoxis [illegible]	.1............|............................|...........................1..........|.......
Hypoxis villosa	..............|..........................5|.......4...................................|.......
Imperata cylindrica	..............|............................|.1.................................5......|55445
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Indigofera zeyheri	..............|......................1......|...2..............................11........
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K[illegible]	..............|...................4........|.....1.6..............421....55.........|.......
K[illegible]	..............|...................1........|......1..............................|....1...
Kyllinga alba	.1............|............................|...|.......
Kyllinga erecta	..............|............................|...|.......
Lactuca inermis	..............|............................|...|.......
Linum thunbergii	............1.|............................|...|.......
Lippia javanica	..............|............................|...|.......
Lobelia species	..............|........................11..|...|.......
Lobelia [illegible]	..............|...................1..4.......|......................1.....................|.......
M[illegible]	..............|............................|...................................1.|.......

Melinis nerviglumis	............|.............................|.......................................5...|.......
Mesembryanthemum spec.	............|.........................11...|.......
Monopsis scabra	............|.5.....11..................|1......1...................1.........1..|.......
Monsonia species	............|.............................|.....................................1.1.........|.......
Monsonia emarginata	............|.....1...............1.....|...1..|1......
Nemesia fruticans	............|..11...1.1.................|.......................111..1..11......1.|.......
Nidorella auriculata	...........1|.............................|...|.......
Oxalis species	............|.............................|.......................................1.......|.......
Oxalis bifurca	............|.............................|...|.......
Panicum aequinerve	............|.............................|............................1................|.......
Panicum deustum	............|.............................|.......................................1.....1...|..5..1.
Paspalum dilatatum	............|.............................|...|.......
Paspalum notatum	.1.........11|.......................11..|........1.....1......1.....1.....1.....1..|.......
[illegible]	............|.............................|.....1...1.....................................|.......
Pelargonium alchemilloides	............|.............................|..........................11.......1.......1.|.......
Pelargonium pulverulentum	............|.................1...........|...|....... 1
Pentaschistis pallida	.............|.....5.5...5....1.5.........|...|5......
Pennisetum species	............|.............................|...|.......
Phyllopodium cuneifolium	............|.............................|..1.......|..1.1.1
Polygala illepida	......1111..|.............................|...|.......
Raphionacme hirsuta	............|.............................|..1......|.......
Rhus dentata	............|.............................|...|1......
Rhus lucida	............|.............................|...|.......
Rhynchosia adenodes	............|........................11...|...|.......
Richardia brasiliensis	........1...|.............................|......................11........................|.......
Scabiosa species	...1........|..................1.......1.|.......................1.......................|.......
Scabiosa albanensis	............|.............................|........1....................................|.......
Scabiosa columbaria	............|.............................|..1......|.......
Schoenoplectus species	............1|.............1...............|...|.......
Schoenoxiphium sparteum	............|.............................|..................1.11....1..............1..|.......
Selago species	1...........|.............................|...|.......
Selago corymbosa	............|............1................|...|.......
Senecio [illegible]	1.11...11.1.|.............1...11.........|........................1........................|.......
Senecio inaequidens	............|.1........................1.|..1..1.|.......
Senecio macrocephalus	............|..............1...141.111.|1.1.1.1.1.1..11.1.1..1.1..........1..|.......
Senecio oxyriifolius	............|.............................|...|.......
Senecio pterophorus	............|.............................|........................1.1.......................|.......
Setaria sphacelata	..........1..1......55.1.1.......11...|11........1......1.1.....1.1.....1.......|.......
Setaria megaphylla	............|.............................|........1....................................|.......
Silene pilosellifolia	............|.............................|...1...1.|.......
Solanum species	............|.............................|............................1................|.......
Sporobolus africanus	.........11.|.............................11|..........1..1.......................1..|.......
Sporobolus virginicus	............|.............................|...|.......
Stachys aethiopica	............|..............1..............|.......1..........1.4.............................|.......
Stenotaphrum secundatum	............|..........................1.|.................1..........................1..1.1......
Sutera species	............|.............................|.......1.....................................|.......
Sutera campanulata	............|.............................|.....................................1.1...1|4......

Trachyandra amplectens	..............|..............................|...................11...................|.......
Tephrosia species	..............|...1...111.1..............|......11...........................1..|.......
Tephrosia ampulata	..............|........5.................|.......................................|.......
Tephrosia capensis	..............|.............1......11...|..1....1.111...1.1.411.........5.1.1.|.......
Tephrosia macropoda	..............|..........................|..........................11.....1....|.......
Tephrosia purpurea	..............|..........................|.......................................|.1.....
Themeda triandra	[illegible]
Thesidium pilosum	..............|..........................|...................................1..|.......
Thesium lineatum	11...1.....11|..........1..11..........|..1..............11.1..11.11..1....1.|.......
Thunbergia species	..............|..1..1...1...............|.1..........11...............111..111.|...1...1
Thunbergia atriplicifolia	..............|1.............11.111......|........1........11..................|.......
Thunbergia dregeana	..............|..........................|...................1....1111.........1..|.......
Tristachya leucothrix	[illegible]
Trifolium species	..............|................1.........|.......................................|.......
Vernonia species	.1............|..........................|.......................................|.......
Vernonia capensis	..............|...................1......|..1....................................|.......
Vernonia dregeana	....1.........|..........................|.......................................|.......
Vigna unguiculata	..............|............1....1111111.|1.....1.....1.1........................|.......
Vigna vexillata	..............|..........................|.........1.............................|.......
Wahlenbergia krebsiana	....1.........|..................1.......|.......................................|.......
Wahlenbergia undulata	..............|..........................|..........1.............................|.......
Watsonia x longifolia	..............|...........1..............|.....................1...5........1.....|.......
Watsonia meriana	..............|...........1..............|..1....................................|.......
Xysmalobium involucratum	.1............|..........................|.......................................|.......
Xysmalobium undulatum	.......1.1....|..........................|.......................................|.......
Zaluzianskya capensis	..............|..........................|.......................................|.......

Complete species checklist of the *Hyparrhenia hirta – Diheteropogon amplectens* association

Unique relevé nr.		
	11	1122222222222222
	4499900	50912455556667777
	0668902	59440101283480123
Abildgaardia ovata	....	...............2.
Acacia karroo	56..5..	..........6..5...
Acalypha peduncularis	.....2.	.2....2......1.1.
Aizoon rigidum	..4....	....
Alloteropsis semialata	...5...	....
Anthospermum paniculatum	...2..4	.4...............
Arctotheca calendula	....	......1..........
Argyrolobium incanum	....	..........2......
Berkheya species	.5.1...	....
Bobartia species	....	...6.............
Bulbostylis species	....52.	....
Bulbostylis contexta	....	...5..122......64
Centella coriacea	5......	556......5125...1
Chamaecrista capensis	..22211	114122111...112..
Chaetacanthus setiger	1.121.1	.......1........1
Clutia heterophylla	....	.....11........1.
Commelina species	11.1...	1......1.......1.
Commelina africana	....	......1.....1...1
Convolvulus natalensis	...2...	....
Conyza obscura	....	.........111.....
Crabbea angustifolia	....	....1............
Crassula nemorosa	....	1................
Crotalaria obscura	..1....	....
Cymbopogon excavatus	....	...2......5......
Cynodon dactylon	.1.....	.....1...........
Cyperus brevis	....	.....1...........
Desmodium incanum	....	............4....
Digitaria eriantha	....	..6285.525.15..64
Diheteropogon amplectens	..64521	..15.466565676555
Dolichos species	.....1.	....
Dregea species	....	..........1......
Ehrharta calycina	.555555	....
Elionurus muticus	..566.8	..876..788..1651.
Eragrostis capensis	....	....1.5...4......
Eragrostis curvula	....	.........5.4..1.1
Eragrostis racemosa	....	..5...1..........
Eriosema squarrosum	...12..	.1...1.1......1.1
Eugenia albanensis	5	......1..........
Euphorbia bupleurifolia	...1.1.	1
Eustachys paspaloides	..1....	....
Gazania krebsiana	..2.1.1	.....1...........
Gerbera piloselloides	....	.........1...1...
Gnidia anthylloides	....	.2.....25........
Gnidia styphelioides	....	..1..............
Helichrysum appendiculatum	....1.1	1.1.1.1.1........
Helichrysum asperum	..1....	.....2...........
Helichrysum cymosum	....	........1........
Helichrysum nudifolium	....	..1...1..........
Helichrysum pedunculatum	....	11
Helichrysum rutilans	....	............255..

Helictotrichon hirtulum	1......	...525765.46.....
Heteropogon contortus	....	....5.1...85.....
Hyparrhenia hirta	9578685	9954.8416.67.7979
Hypoxis argentea	....	.....1...........
Imperata cylindrica	....	.2....5..........
Indigofera species	...2...	...1.............
Indigofera stricta	....	..........4..1...
Indigofera zeyheri	....	.......1....1....
Ipomoea species	..1.1..	....
Kyllinga alba	....	..5..............
Lactuca inermis	....	.1................
Lippia javanica	.....1.	.2...............
Lobelia species	....	.........1.....11
Lobelia flaccida	....	........1........
Lobelia tomentosa	2	....
Mariscus albomarginata	....	.....1.11........
Mariscus congestus	...1...	....
Melica species	....	............7....
Monopsis scabra	....	1111
Monsonia emarginata	....	.2...............
Nemesia fruticans	....	............1....
Paspalum dilatatum	....	........1........
Paspalum notatum	....	.......1...1..211
Pelargonium species	....	6................
Pelargonium pulverulentum	...1..1	.......1.........
Pentaschistis pallida	....	5...........5...1
Phyllopodium cuneifolia	...1...	....1.11.........
Plantago species	....	.1...............
Polygala illepida	....	1111
Pycreus oakfortensis	....	......114.....1..
Rhynchosia adenodes	....	..........1......
Richardia brasiliensis	....	.......11....1...
Scabiosa species	....42.	.1...............
Schoenoxiphium sparteum	....	.............1...
Scleria species	....	.1...............
Selago corymbosa	..4....	....
Senecio bupleuroides	....	.............11..
Senecio inaequidens	1511...	...........11....
Senecio macrocephalus	1......	1..........11...1
Setaria species	....	11....5...5.....1
Sida dregei	..1....	....
Solanum species	.....1.	....
Sporobolus africanus	....	.........111.1...
Sutera campanulata	....	.1..11......1....
Sutera laxiflora	....	........1........
Tephrosia species	...1..1	.1....111....1...
Tephrosia capensis	....	.............1.11
Themeda triandra	75	..554.55545177521
Thunbergia species	....	.1.......11..1111
Thunbergia capensis	....	...........11....
Thunbergia dregeana	..1122.	.2....1.1........
Tristachya leucothrix	....	..75.1.....55...1
Vernonia dregeana	....	......11.........
Vigna unguiculata	..11...	.........111.....
Watsonia x longifolia	....	.1...............
Zaluzianskya maritima	....	............1....

Complete species checklist for the *Hyparrhenia hirta – Themeda triandra* association

Species	Relevés
Abildgaardia ovata	[illegible]
Acacia karroo	[illegible]
Acalypha peduncularis	[illegible]
Agrostis species	[illegible]
Alepidea longifolia	[illegible]
[illegible]	[illegible]
[illegible] species	[illegible]
Anagallis arvensis	[illegible]
Anthospermum [illegible]	[illegible]
Anthospermum herbaceum	[illegible]
[illegible]	[illegible]
Aristida species	[illegible]
Aristida diffusa	[illegible]
Aristida junciformis	[illegible]
Asclepias species	[illegible]
[illegible]	[illegible]
Asparagus [illegible]	[illegible]
Barleria obtusa	[illegible]
Berkheya species	[illegible]
Berkheya [illegible]	[illegible]
[illegible] species	[illegible]
Brachiaria serrata	[illegible]
Bulbine species	[illegible]
Bulbostylis species	[illegible]
Bulbostylis contexta	[illegible]
Centella [illegible]	[illegible]
Chamaecrista capensis	[illegible]
[illegible]	[illegible]
[illegible] species	[illegible]
[illegible] phylla	[illegible]
[illegible]	[illegible]
Commelina species	[illegible]
Commelina africana	[illegible]
Commelina livingstonii	[illegible]
[illegible]	[illegible]
Conyza [illegible]	[illegible]
Crotalaria [illegible]	[illegible]
[illegible]	[illegible]
Cymbopogon excavatus	[illegible]
Cymbopogon validus	[illegible]
Cynoglossum hispidum	[illegible]
Cynodon dactylon	[illegible]
Cyperus species	[illegible]
Cyperus [illegible]	[illegible]

Cyperus obtusi v. flavi	.1.1.4.1..515.15.....115..1.1.....1........11...11.............45.|....1............1.1..1......
Cyperus obtusi v. obtus	...................1.........1...............................|............................
Cyperus obtusiflorus	...............1...|............................
Dianthus [illegible]	..................................1..........................|...................4.1......
Dierama [illegible]	...1...|............................
Digitaria diagonalis	....1..............|............................
Digitaria eriantha	......[illegible]...|.....1.55[illegible]..[illegible]...
Dihetropogon amplectens	..1.......115..1..................1.......11.........5.11.11...11.............11...........1.........
Dihetropogon filifolius	....|............................
Diospyros villosa	....|..........................5....
Ehrharta calycina	..........1...|475.....................5.1...
Elionurus muticus	............6.15.......45....50....[illegible]...4....[illegible]..............5.|............5..5....1...
Eragrostis capensis	...................11.....1..............1...............1.1.....1.....|.......15....................
Eragrostis curvula	......[illegible]...
Eragrostis plana	..11..|.........[illegible]............
Eriosema [illegible]	.....111.................1.14.1.....................1.......1...11.............|..241.........1...1..........1
Felicia muricata	....|............................11
Festuca [illegible]	....|............................
Ficinia [illegible]	....|............................
Fimbristylis species	..11..|............................
Fimbristylis complanata	........1.1..........................1..............11.........|............................
Galopina [illegible]	........1...........................1...................1........|............................
Gazania krebsiana	....................111..................................1.............|.........1..................
Gazania linearis	....|...........................1
Gerbera piloselloides	......................1.............1.................................1.....|........1...................
Gladiolus [illegible]	.......1..|............................
Helichrysum species	....|.........................1...
Helichrysum appendiculatum	..1...1.........|.......1.......11..........
Helichrysum aureum	......................1.......................................|............................
Helichrysum cerastioides	.........................1....................................|.................1..1.....1...1
Helichrysum herbaceum	....1.................|............................
Helichrysum nudifolium	1.......11..1.11.1111.............|...............1............
Helichrysum [illegible]	....|............................
Helichrysum [illegible]	........1..1....11.........1.........1......1..............11.1.1.......1.....|............................
Helichrysum rutilans	...11..11..................35111...1..............1....111111.....1......|.......11.1....1.....11.....
Heliophila [illegible]	....|............................
Helictotrichon hirtulum	.....[illegible]...........1.........171.51...1...1..51...............|.........[illegible].......551.......
Hermannia [illegible]	....|............................1.1
Heteropogon contortus	......................1.......................................|............................
Hibiscus aethiopicus	....1................|............................
Hyparrhenia hirta	.[illegible]...
Hypochaeris radicata	....|.........1..1..................
Hypoxis acuminata	....|...........................11..
Hypoxis [illegible]	....|......................1......
Imperata cylindrica	..........................15..............1.....1.............|......................1......
Indigofera species	...........1....1.......................................1.....|.......11........1.........1
Indigofera heterophylla	....|..1......................11...
Indigofera hilaris	.......1...1............|............................
Indigofera [illegible]	....|............................
Indigofera [illegible]	....|............................
Indigastrum fastigiatum	....|............................
Ipomoea species	1...|............................

Juncus species	[illegible]
Koeleria capensis	[illegible]
Kyllinga alba	[illegible]
Kyllinga alata	[illegible]
Kyllinga erecta	[illegible]
Lactuca inermis	[illegible]
Linum thunbergii	[illegible]
Lippia javanica	[illegible]
Lobelia species	[illegible]
Lobelia flaccida	[illegible]
Lobelia thunbergii	[illegible]
Mariscus species	[illegible]
Mariscus albomarginatus	[illegible]
Mariscus congestus	[illegible]
Mariscus sumatrensis	[illegible]
Melinis nerviglumis	[illegible]
Melica species	[illegible]
Mesembryanthemum spp.	[illegible]
Miscanthus capensis	[illegible]
Monopsis scabra	[illegible]
[illegible]	[illegible]
Monocymbium ceresiiforme	[illegible]
Nemesia fruticans	[illegible]
Nidorella auriculata	[illegible]
Oenothera rosea	[illegible]
Oxalis species	[illegible]
Panicum ecklonii	[illegible]
Panicum natalense	[illegible]
Paspalum dilatatum	[illegible]
Paspalum notatum	[illegible]
Pennisetum sphacelatum	[illegible]
Pennisetum clandestinum	[illegible]
Pentanisia prunelloides	[illegible]
Pentaschistis pallida	[illegible]
Pentzia punctata	[illegible]
Phymaspermum thunbergii	[illegible]
Phyllopodium cuneifolium	[illegible]
Plantago species	[illegible]
Polygala hottentotta	[illegible]
Pseudognaphalium luteo-album	[illegible]
Pycreus cf. [illegible]	[illegible]
Rhynchosia capensis	[illegible]
Rhynchosia totta	[illegible]
Rhynchospora brownii	[illegible]
Richardia brasiliensis	[illegible]
Schoenoplectus species	[illegible]
Schizachyrium sanguineum	[illegible]
Scabiosa columbaria	[illegible]
Senecio coronatus	[illegible]
Senecio inaequidens	[illegible]
Senecio macrocephalus	[illegible]
Senecio pterophorus	[illegible]

Setaria species	...1...............1...........1.1....1..1...................5.......5l..55551...1.....1.....5...1.
Setaria pallide-fusca	................................5..
Sida rhombifolia	....1..........1...1..
Solanum species	................1............2.................1...........i...2..5........5............
Sporobolus africanus	.....5552.22511.2.......55.11.21...2111111511....i..4..1.....5.1..i..255=16.55.......1516.1.1.1
Sporobolus virginicus	..........................1...
Stachys aethiopica	....1....11..
Stenotaphrum secundatum	....1....................5........1..1..1.11.....11..11...5...........7555.5...5.1.7.1...1.5
Striga elegans	....4................
Sutera species	..................1..
Sutera laxiflora	...................1...
Tarchonanthus camphoratus	.....................5...
Tephrosia species	....11...1...1....................1.1.1.......1
Tephrosia capensis	1.1....................11.......1..........1..........11.1...........1...4...................1
Tephrosia macropoda	.......................1...
Tephrosia purpurea	.1...
Themeda triandra	...+55645511.5.521+.1+.55.....+51.17555.5..5++55557+5++5...+1.+5+...7+5+45.+......5.5.5..5.+5
Thesium junceum	..............1............................2..
Thunbergia species	.......................11..........1.1.1.....1.....1.1.....1...........................
Thunbergia atriplicifolia	....1............................
Thunbergia capensis	................................1.......................1...............................
Thunbergia dregeana	.............................21...
Trachyandra species	.................1...
Trachyandra saltii	....1.......1....1...................
Tristachya leucothrix	...5................55.5...55.....55...................1.....................5...
Trifolium species	....1................11......
Verbena bonariensis	....1..........
Vernonia oligocephala	....1.........
Vigna unguiculata	..............................1...1.11..........................11...21.........1.......
Vigna vexillata var. angustifolia	..................1...
Wahlenbergia undulata	...1..
Zornia capensis	..............1..11..........

Species comprising the *Stenotaphrum secundatum – Centella coriacea* Association

Unique relevé, nr.	111111222222 788999222559 323189678674
Acacia karroo	..4..2......
Alysicarpus species	....2....22.
Anthospermum herbaceum	...4........
Arctotheca calendula	......4.....
Argyrolobium incanum	.5.........2
Argyrolobium rupestre	....1..2....
Aristida species	1
Aristida diffusa	.........77.
Barleria obtusa	.....1...1..
Bulbine species	1
Centella coriacea	2564615..565
Chamaecrista capensis	...2........
Chaetacanthus setiger	......1.....
Clutia heterophylla	...1.......1
Commelina livingstonii	......112...
Cotula sericea	.........1..
Cynodon dactylon	.2..45445...
Digitaria eriantha	...5.15..7.5
Digitaria velutina	1...........
Diheteropogo amplecten	...1........
Eriosema squarrosum	1
Falckia repens	....5.......
Gazania krebsiana	......1....1
Gladiolus species	..1.........
Helichrysum cymosum	....2....1..
Helichrysum rutilans	....1.....44
Helictotrich hirtulum	....1...2.1.
Hibiscus trionum	1.....5.....
Hypoestes aristata	.555..576...
Hypoxis argentea	....11......
Hypoxis longifolia	........4...
Kyllinga species	.......76...
Lactuca inermis	.1..1....1..
Lagurus ovatus	..........6.
Mariscus albomarginat	1
Melica species	.......65...
Monopsis scabra	.....1..5...
Nemesia fruticans	.11....1...1
Oxalis corniculata	.1..........
Panicum aequinerve	...2.1.26...
Paspalum notatum	...451.27.11
Pycreus oakfortensis	.54.1..22...
Rhynchosia adenodes	......2.....
Richardia brasiliensis	....1......1
Scabiosa species	.........1..
Schoenoxiphi sparteum	.........1..
Senecio inaequidens	.521..5.2.14
Senecio macrocephalus	...2........
Setaria species	.....11.....
Setaria pallide-fusca	.21.........
Silene primuliflora	.11.........
Sporobolus africanus	....41....1.
Stenotaphrum secundatu	985997.55576

Tephrosia capensis	...1.......1
Themeda triandra	.59..79....9
Thunbergia atriplicifo	......21....
Thunbergia dregeana	2....1......
Vigna unguiculata	.21......14.
Vigna vexill v. angust	........5...
Wahlenbergia grandiflo	...1....2...

Species comprising the *Diheteropogon filifolius- Ehrharta calycina* Association

Unique relev, nr.	238888899999 904678901234
Acacia karroo	..2.........
Acalypha peduncularis	.....4226..2
Aizoon rigidum	.5..7.52.254
Alloteropsis semialata	...5...55..2
Anthospermum galioides	..2.........
Argyrolobium incanum	...1.....111
Asclepias albens	.......1....
Asclepias densiflora	...2........
Asclepias hastata	...2...1....
Berkheya species	........4..5
Brachiaria species	..........1.
Brachiaria serrata	...2........
Bulbostylis species	.......62..2
Bulbostylis contexta	..27.5......
Chamaecrista capensis	..1...212541
Chaetacanthus setiger	2..111.1.141
Clutia heterophylla	.112..1...1.
Commelina species	......4.....
Convolvulus natalensis	....1.......
Cotula sericea	142
Diheteropogo amplecten	75
Diheteropogo filifoliu	..5575855555
Dolichos species	....2.1.....
Ehrharta calycina	5.7.65516656
Elionurus muticus	..4.........
Eragrostis capensis	..55........
Eragrostis curvula	.6..........
Eragrostis plana	..4.........
Eriosema squarrosum	..41.2..1..1
Eugenia albanensis	...1.....5..
Eustachys paspaloides	511
Ficinia indica	...2........
Gazania krebsiana	....1.1.2.44
Gnidia anthylloides	.....1......
Grewia occidentalis	1...........
Helichrysum appendicul	...1........
Helichrysum asperum	.1..1.5.2122
Helichrysum cymosum	....4.1.....
Helichrysum nudifolium	...1........
Heliophila subulata	..1.........
Heteropogon contortus	985658.75...
Hypoestes aristata	.....2.1....
Hypochaeris radicata	.........1..
Hypoxis species	.1..........
Hypoxis longifolia	..1.........
Indigofera species	.412..1....1
Indigofera heterophyll	45455
Indigofera zeyheri	.....4......
Koeleria capensis	.5..........
Lampranthus species	...1...11...
Lobeli flacci s. flacc	..4.........
Monocymbium ceresiifor	...55.......
Moraea species	1...........
Panicum maximum	..1.........

Pelargonium pulverulen	..1.........
Pentaschistis pallida	..5.1..5..1.
Phyllopodium cuneifoli	......1.....
Pycreus oakfortensis	.....5......
Scabiosa species	.....2.1....
Senecio bupleuroides	..1.........
Senecio chrysocoma	..1.........
Senecio inaequidens	..1.2....211
Stachys aethiopica	.......1....
Tephrosia capensis	.5.2.541..1.
Themeda triandra	5.5...556678
Thunbergia species	..1.1.......
Thunbergia atriplicifo	1....111....
Thunbergia dregeana	........1...
Tristachya leucothrix	..7.........
Vigna species	....1......1
Wahlenbergia grandiflo	..1.........
Watsonia x longifolia	...2........

Complete species checklist for the *Cynodon dactylon* – *Ehrharta calycina* association

Unique relev, nr.			
	567777788	34445699	
	291246701	74790057	
Abildgaardia ovata	.22..2...	....	Abildgaardia ovata (Burm.f.) Kral
Acacia karroo	2	....	Acacia karroo Hayne
Acalypha peduncularis	....	......4.	Acalypha peduncularis E.Mey. ex Meisn.
Aizoon rigidum	....	5...424.	
Alloteropsis semialata	....	7	
Argyrolobium incanum	....2....	....	Argyrolobium incanum Eckl. & Zeyh.
Blepharis capensis	.1.......	....	
Bulbine species	....	.....1.4	
Bulbostylis species	......5..	....	
Bulbostylis contexta	55175....	...2....	Bulbostylis contexta (Nees) M.Bodard
Centella coriacea	..1......	..6.2...	Centella coriacea Nannf.
Chamaecrista capensis	111114241	..2211..	
Chaetacanthus setiger	11.......	1.11114.	Chaetacanthus setiger (Pers.) Lindl.
Cineraria britteniae	....	.....1..	Cineraria britteniae Hutch. & R.A.Dyer
Clutia heterophylla	....	...1....	Clutia heterophylla Thunb.
Commelina species	.1...1...	.2.1...1	
Cotula sericea	....	.1......	Cotula sericea L.f.
Crassula nemorosa	.1.1.....	....	Crassula nemorosa (Eckl. & Zeyh.) Endl. ex Walp.
Crotalaria obscura	11.......	...221..	Crotalaria obscura DC.
Cynodon dactylon	7555...2.	78777688	Cynodon dactylon (L.) Pers.
Diheteropogo amplecten	....	......2.	Diheteropogon amplectens (Nees) Clayton
Dolichos species	....	..211.11	
Dolichos falciformis	.11......	....	Dolichos falciformis E.Mey.
Ehrharta calycina	.55..6555	7776666.	
Elionurus muticus	.7565....	1	Elionurus muticus (Spreng.) Kunth
Eragrostis capensis	..6551457	....	Eragrostis capensis (Thunb.) Trin.
Eragrostis curvula	2	..5.5...	Eragrostis curvula (Schrad.) Nees
Eragrostis plana	.555.25..	.1...6..	Eragrostis plana Nees
Eriosema squarrosum	21.11461.	..122...	Eriosema squarrosum (Thunb.) Walp.
Eucalyptus species	....	.....2..	
Eustachys paspaloides	......5..	1	Eustachys paspaloides (Vahl) Lanza & Mattei
Falckia repens	....	..2.....	Falckia repens L.f.
Felicia mossamedensis	....	1.......	Felicia mossamedensis (Hiern) Mendon‡a
Ficinia indica	....	....1..1	
Gazania krebsiana	21.1....1	25.1.21.	

Gerbera piloselloides	....2....	....	Gerbera piloselloides (L.) Cass.
Gladiolus ochroleucus	...1.....	....	
Gladiolus permeabilis	....	..1......	
Harpochloa falx	....	...1.....	Harpochloa falx (L.f.) Kuntze
Helichrysum appendicul	11	.1.......	Helichrysum appendiculatum (L.f.) Less.
Helichrysum asperum	1.5..5...	4.1.2.51	
Helichrysum litorale	.1.......	....	Helichrysum litorale Bolus
Helichrysum nudifolium	....2....	....	Helichrysum nudifolium (L.) Less.
Helichrysum rutilans	....	..1......	Helichrysum rutilans (L.) D.Don
Helictotrich hirtulum	..51.....	....	Helictotrichon hirtulum (Steud.) Schweick.
Heteropogon contortus	745555587	....6....	Heteropogon contortus (L.) Roem. & Schult.
Hyparrhenia hirta	5....87..	.......1.	Hyparrhenia hirta (L.) Stapf
Hypochaeris radicata	.......1.	....	Hypochaeris radicata L.
Hypoxis stellipilis	....1....	1........	Hypoxis stellipilis Ker Gawl.
Indigofera species	.1111....	..4..4...	
Indigofera heterophyll	.111.....	....	Indigofera heterophylla Thunb.
Indigofera zeyheri	.....4...	....	Indigofera zeyheri Spreng. ex Eckl. & Zeyh.
Ipomoea species	....	....1....	
Koeleria capensis	.......2.	....	Koeleria capensis (Steud.) Nees
Lactuca inermis	....	.....1...	Lactuca inermis Forssk.
Lampranthus species	1......1.	....	
Lobelia species	11	.......1.	
Lobelia tomentosa	....	1	Lobelia tomentosa L.f.
Mariscus congestus	....	1	Mariscus congestus (Vahl) C.B.Clarke
Melilotus indica	....	.....1...	Melilotus indica (L.) All.
Monopsis scabra	.1.1.....	.1.......	Monopsis scabra (Thunb.) Urb.
Nemesia fruticans	..11.....	....	Nemesia fruticans (Thunb.) Benth.
Nidorella auriculata	....	.......4.	Nidorella auriculata DC.
Oxalis species	....1....	....	
Pelargonium species	....	..1..1...	
Pelargonium pulverulen	1........	1	Pelargonium pulverulentum Colvill ex Sweet
Pentaschistis pallida	.5.54....	....	Pentaschistis pallida (Thunb.) H.P.Linder
Phyllopodium cuneifoli	....	......1.1	Phyllopodium cuneifolium (L.f.) Benth.
Rhynchosia adenodes	....	.....2...	Rhynchosia adenodes Eckl. & Zeyh.
Satyrium species	.1.......	....	
Scabiosa species	.1.......	....	
Schoenoxiphi sparteum	....	..1......	Schoenoxiphium sparteum (Wahlenb.) C.B.Clarke
Scilla species	.1.......	....	
Senecio inaequidens	.1.....1.	......1.2	Senecio inaequidens DC.
Senecio pterophorus	....	.....1...	Senecio pterophorus DC.
Setaria species	5.561..26	6....551	
Setaria nigrirostris	....	...54....	Setaria nigrirostris (Nees) T.Durand & Schinz

Silene species	.1.......|.....1..	
Solanum species	.........|.......2	
Sporobolus africanus	.........|1.......	Sporobolus africanus (Poir.) Robyns & Tournay
Sporobolus fimbriatus	.........|...5....	Sporobolus fimbriatus (Trin.) Nees
Stenotaphrum secundatu	.51......|........	Stenotaphrum secundatum (H.Walter) Kuntze
Tephrosia species	..11.....|.......1	
Tephrosia capensis	.........|.....1..	
Themeda triandra	.5.24....|..6..7..	Themeda triandra Forssk.
Thunbergia species	....11...|.....1..	
Thunbergia dregeana	.........|......11	Thunbergia dregeana Nees
Vigna species	.........|......1.	
Vigna unguiculata	.........|...112.1	
Wahlenbergia grandiflora	.........|..2.....	Wahlenbergia grandiflora Brehmer

Complete species checklist for the *Themeda triandra – Ehrharta calycina* association

Unique relev, nr.			
		1333333	
	1111134668	1112660000112	
	90568923135	123456781473263029451	
Acacia karroo Hayne	....	.2...................	Acacia karroo
Aizoon rigidum	......2..2.	..2..2....2.25.......	
Anagallis arvensis arvensis L.	....	........2............	Anagallis
Arctotheca calendula calendula (L.) Levyns	....	2	Arctotheca
Asclepias species	.....1....1	..............1......	
Berkheya species	1.......11.	....	
Berkheya decurrens decurrens (Thunb.) Willd.	....	.................2...	Berkheya
Bulbine species	.2......4..	............2........	
Bulbostylis contexta contexta (Nees) M.Bodard	.......5...	....	Bulbostylis
Carpobrotus deliciosus deliciosus (L.Bolus) L.Bolus	....	......7..............	Carpobrotus
Centella coriacea coriacea Nannf.	2..........	....	Centella
Cerastium species	..2........	....	
Cerastium capense capense Sond.	....	................2..2.	Cerastium
Chamaecrista capensis	141222...12	.11..........12......	
Chaetacanthus setiger setiger (Pers.) Lindl.	....	..............4......	Chaetacanthus
Cineraria geraniifolia geraniifolia DC.	....	7...41.2.............	Cineraria
Clutia heterophylla heterophylla Thunb.	.1..1......	.1.......212.........	Clutia
Commelina species	1	...................1.	
Commelina africana	111111.....	1..21..1.............	
Convolvulus sagittatus	....	...................1.	
Cotula sericea L.f.	12...1.....	....1.....1.....1....	Cotula sericea
Crassula nemorosa nemorosa (Eckl. & Zeyh.) Endl. ex Walp.	...1...1...	....	Crassula
Crotalaria obscura obscura DC.	.....1.1...	...................1.	Crotalaria
Cymbopogon excavatus excavatus (Hochst.) Stapf ex Burtt Davy	...5.......	....	Cymbopogon
Cynodon dactylon (L.) Pers.	5..515...5.	82.42161....662.1....	Cynodon dactylon
Cyperus species	....	...............21.21.	
Cyperus brevis Boeck.	....	1	Cyperus brevis
Digitaria eriantha eriantha Steud.	....	...............1...1.	Digitaria
Dolichos species	1..........	1111..11.............	
Dolichos falciformis falciformis E.Mey.	........2..	..........1..........	Dolichos
Ehrharta calycina	.1125145..5	4441.761151.76.75556.	

Elionurus muticus	.1..2..5..5|.....................	Elionurus
muticus (Spreng.) Kunth		
Eragrostis capensis	45.445....5|.................26..	Eragrostis
capensis (Thunb.) Trin.		
Eragrostis curvula	..1.......5|.....1.............1.	Eragrostis
curvula (Schrad.) Nees		
Eragrostis plana	..........5|............1........	Eragrostis plana
Nees		
Eriosema squarrosum	1...1......|.....................	Eriosema
squarrosum (Thunb.) Walp.		
Eucalyptus species	.........2.|.....................	
Eustachys paspaloides	...1.......|.....................	Eustachys
paspaloides (Vahl) Lanza & Mattei		
Falckia repens	1..........|.1....1.111....1....1	Falckia repens
L.f.		
Festuca costata	...........|................1....	Festuca costata
Nees		
Ficinia arenicola	...........|........1............	
Ficinia indica	.1.........|.....................	
Fimbristylis species	........5..|............2........	
Fuirena species	1..........|.....................	
Galenia secunda	..........2|.....................	Galenia secunda
(L.f.) Sond.		
Gazania krebsiana	......5....|............2..1.....	
Gerbera piloselloides	.1.........|....1...........1....	Gerbera
piloselloides (L.) Cass.		
Gladiolus ochroleucus	.........1.|.....................	
Haemanthus albiflos	...1.......|1....................	Haemanthus
albiflos Jacq.		
Harpochloa falx	1.........5|.....................	Harpochloa falx
(L.f.) Kuntze		
Helichrysum appendicul	1..........|.....................	Helichrysum
appendiculatum (L.f.) Less.		
Helichrysum asperum	.1...1.....|.21..11.1.1.15.2.....	
Helichrysum cymosum	....1......|111..12.............6	
Helichrysum litorale	........1..|.....................	Helichrysum
litorale Bolus		
Helichrysum nudifolium	....1.2....|..........1..........	Helichrysum
nudifolium (L.) Less.		
Helich rosum v. arcuat	......5....|......1..............	Helichrysum
rosum (P.J.Bergius) Less. var. arcuatum Hilliard		
Helichrysum rosum	...........|................222..	
Helictotrich hirtulum	.....1...1.|...............11....	Helictotrichon
hirtulum (Steud.) Schweick.		
Hermannia incana	.12........|.12...5.............1	Hermannia incana
Cav.		
Heteropogon contortus	...212551.5|188878..1559.5551....	Heteropogon
contortus (L.) Roem. & Schult.		
Hyparrhenia hirta	........4..|.....................	Hyparrhenia
hirta (L.) Stapf		
Hypoxis longifolia	...........|111..................	Hypoxis
longifolia Baker		
Hypoxis stellipilis	......2....|.....................	Hypoxis
stellipilis Ker Gawl.		
Imperata cylindrica	...........|..........1...1......	Imperata
cylindrica (L.) Raeusch.		
Indigofera species	......55...|....................1	
Indigofera verrucosa	...........|...............5.....	Indigofera
verrucosa Eckl. & Zeyh.		
Indigofera zeyheri	.5.........|114.12..141..........	Indigofera
zeyheri Spreng. ex Eckl. & Zeyh.		

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Indigastrum fastigiatu      ...........|..........11.........   Indigastrum
fastigiatum (E.Mey.) Schrire
Jamesbritten maritima       .1.1.......|...........1.........   Jamesbrittenia
maritima (Hiern) Hilliard
Juncus species              ...........|....................1
Koeleria capensis           5..........|11111587...1...5.....   Koeleria
capensis (Steud.) Nees
Kyllinga erecta             ...........|....................1
Lactuca inermis             .........1.|1........1...........   Lactuca inermis
Forssk.
Lessertia stenoloba         ...........|...........1.....4...   Lessertia
stenoloba E.Mey.
Linum species               ..1........|.....................
Mariscus tabularis          1..........|.....................
Melilotus indica            ......2....|..................1..   Melilotus indica
(L.) All.
Monopsis scabra             .......2...|.....................   Monopsis scabra
(Thunb.) Urb.
Monsonia emarginata         .11.....11.|1....1.1....1.....1..   Monsonia
emarginata (L.f.) L'H,r.
Moraea species              ...........|......1..........1.1.
Nemesia fruticans           ...........|1..111...............   Nemesia
fruticans (Thunb.) Benth.
Otholobium decumbens        ...........|.................2...   Otholobium
decumbens (Aiton) C.H.Stirt.
Oxalis species              ..111......|1..11111..1....1...11
Pelargonium alchemillo      ..2........|1..1.................   Pelargonium
alchemilloides (L.) L'H,r.
Pentaschistis pallida       .5.1.1.7.56|.....................   Pentaschistis
pallida (Thunb.) H.P.Linder
Peucedanum capense          1..........|.....................
Phyllopodium cuneifoli      ..1........|............1........   Phyllopodium
cuneifolium (L.f.) Benth.
Rhynchosia adenodes         1..........|1111.151....22......2   Rhynchosia
adenodes Eckl. & Zeyh.
Richardia brasiliensis      .........2.|.....................   Richardia
brasiliensis Gomes
Salvia scabra               ...........|..........1....2..1..   Salvia scabra
L.f.
Scabiosa species            ........1..|.....................
Scabiosa columbaria         .....11....|...............21.11.   Scabiosa
columbaria L.
Schoenoxiphi sparteum       ...........|...11...........1..1.   Schoenoxiphium
sparteum (Wahlenb.) C.B.Clarke
Selago corymbosa            .........2.|..............1......   Selago corymbosa
L.
Senecio bupleuroides        ...........|..................1..   Senecio
bupleuroides DC.
Senecio chrysocoma          ..........1|.....................   Senecio
chrysocoma Meerb.
Senecio ilicifolius         ...........|..................11.   Senecio
ilicifolius L.
Senecio inaequidens         ....11..111|.11.....1.1.112...11.   Senecio
inaequidens DC.
Senecio macrocephalus       1......11..|...11.............1.1   Senecio
macrocephalus DC.
Setaria species             .275115.5.5|.....5..715..51.4.42.
Silene primuliflora         ...........|...........1.....1...   Silene
primuliflora Eckl. & Zeyh.
Sporobolus africanus        1...11...6.|1.144..1141....571.16   Sporobolus
africanus (Poir.) Robyns & Tournay
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Stachys aethiopica           ...........|.1...................   Stachys
aethiopica L.
Stenotaphrum secundatu       1......5...|14.4...1..........54.   Stenotaphrum
secundatum (H.Walter) Kuntze
Sutera campanulata           ....1......|.11...1......1.......   Sutera
campanulata (Benth.) Kuntze
Tephrosia species            ...........|..................1.2
Tephrosia angulata           ....11.....|.........1...........   Tephrosia
angulata E.Mey.
Tephrosia capensis           ...1.1.....|......4.5.1....11...1
Themeda triandra             55797755.87|776785688995779689898   Themeda triandra
Forssk.
Thunbergia species           .4.2.1..11.|........151.12.......
Thunbergia atriplicifo       ......2....|.....................   Thunbergia
atriplicifolia E.Mey. ex Nees
Thunbergia capensis          ...........|.........11..........   Thunbergia
capensis Retz.
Thunbergia dregeana          ...........|...........1..1......   Thunbergia
dregeana Nees
Trachyandra revoluta         ....1......|.....112111..........   Trachyandra
revoluta (L.) Kunth
Tristachya leucothrix        87758786155|.....................   Tristachya
leucothrix Nees
Tritonia lineata             ....1......|.....................
Trifolium species            5....5.....|...1.....1..2...1....
Vigna luteola                ...........|1....................   Vigna luteola
(Jacq.) Benth.
Vigna vexillata              1..........|1..1...1...1.........
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Species comprising the *Sporobolis africanus – Setaria sphacelata* association

Table part 1 (2000/01/19; 12:09:18)

	11112333333333
	502366000000122
	962246134567603
Abildgaardia ovata	5..............
Acalypha peduncularis	.2...........22
Anthospermum herbaceum	....8..........
Arctotheca calendula	....2..........
Asparagus densiflorus	1
Barleria obtusa	....1..........
Bulbine species	.............1.
Bulbostylis contexta	1
Cerastium capense	........2..2...
Chamaecrista capensis	1............11
Chaetacanthus setiger	1............11
Clematis brachiata	.......2.......
Clutia heterophylla	11
Commelina species	........1.....1
Commelina livingstonii	.....2.........
Conyza obscura	1..............
Cotula sericea	.....22...2....
Cynodon dactylon	.74464..19...74
Cyperus species	..........1.2..
Cyperus brevis	1
Digitaria eriantha	...2...7.....67
Dolichos falciformis	....5..........
Ehrharta calycina	.51...87555..11
Euphorbia gorgonis	1..............
Falckia repens	..511.111.1..1.
Felicia filifolia	......42.......
Galenia secundatum	..7............
Gazania krebsiana	...151.........
Geranium incanum	......75.47....
Helichrysum asperum	15....4........
Helichrysum cymosum	..2.....7......
Helichrysum rosum	......21.4..1..
Helichrysum rutilans	....1..........
Helictotrichon hirtulum	5..............
Hermannia incana	1
Hypoestes aristata	..12.2.........
Hypoxis species	....5..........
Hypoxis argentea	11
Indigofera species	............11.
Indigofera heterophylla	.............1.
Ipomoea ficifolia	..7.1..........
Juncus species	67
Koeleria capensis	......45.......
Kyllinga erecta	.............1.
Lactuca inermis	1...........1..
Mariscus albomarginata	.............1.
Mariscus congestus	1
Medicago laciniata	......2........
Melilotus indica	...........11..
Mesembryanthemum spec.	.............1.
Monsonia emarginata	1.4.......1....
Moraea species	..........1....
Nemesia fruticans	....2.1..1..1..

Oxalis species	..........1....
Oxalis corniculata	...1...........
Panicum coloratum	........1......
Passerina rigida	1
Pelargonium species	1..............
Pelargonium alchemilloides	........1......
Phyllopodium cuneifolia	1..............
Rhynchosia adenodes	1....9........1
Salvia scabra	.........2.....
Scabiosa columbaria	.......4.......
Schoenoxiphium sparteum	..........11...
Senecio ilicifolius	......51.521...
Senecio inaequidens	.1.11..........
Senecio macrocephalus	11.............
Senecio pterophorus	....2..........
Setaria sphacelata	67....545585251
Silene gallica	...2...........
Solanum species	........1......
Sporobolus africanus	4.796555.552265
Stachys aethiopica	....1..........
Stenotaphrum secundatum	.5114......94..
Sutera campanulata	.1.......1.....
Tephrosia species	.............1.
Tephrosia capensis	......12.......
Themeda triandra	82.45.......9.1
Thunbergia species	1..............
Thunbergia dregeana	.1.............
Tristachya leucothrix	1
Trifolium species	..........5....
Vicia sativa	........1..2...
Vigna unguiculata	.1...1.........
Wahlenbergia grandiflora	1..............

Species comprising the ***Cynodon dactylon* – *Helictotrichon hirtulum*** association

Unique relevé, nr.	
	1233
	22222222333334566681201
	01245678135698157821580
Abutilon sonneratianum	..5.....2..............
Acacia karroo	..................4....
Aizoon rigidum	........4......4.......
Alepidea longifolia	..1..2.2...............
Asparagus mariae	...............1.......
Bromus pectinatus	..1....1145............
Bulbine species	...................2...
Bulbostylis species	...................1...
Centella coriacea	.2..5....51.52......5..
Chamaecrista capensis	51.......1...12..5.....
Chaetacanthus setiger	.............1.........
Chloris gayana	..................6....
Clematis brachiata	..5.....1..............
Commelina species	.............1.........
Commelina africana	.11....................
Cotula sericea	.1.........2...........
Crotalaria obscura	...........1...........
Cynodon dactylon	5.8.77.87.7.4777.2895.2
Cyperus obtusiflorus	.........1.............
Dolichos falciformis	......2................
Ehrharta calycina	11.......577855...6...1
Eragrostis curvula	..............2...5....
Eragrostis plana	................2......
Eriosema squarrosum	1.........1...1........
Euphorbia gorgonis	...............2.......
Falckia repens	.1.....................
Festuca longipes	...2...................
Ficinia indica	78....1.......5........
Gazania krebsiana	............1...1......
Geranium incanum	42.....................
Gladiolus ochroleucus	..1....................
Gladiolus permeabilis	.............1.........
Harpochloa falx	.7.....................
Hebenstretia integrifolia	...1......11...........
Helichrysum asperum	11.........15..51.11...
Helichrysum cymosum	11.........1......2....
Helichrysum rosum	.....................1.
Helictotrichon hirtulum	71.57657.81.25...55..58
Helictotrichon turgidulum	........5..............
Heteropogon contortus	.......5...............
Hyparrhenia hirta	............5..........
Hypoxis species	........1..............
Indigofera species	.........1.............
Ipomoea species	..1..1....2.1..........
Jamesbritten maritima	91.....1...............
Koeleria capensis	...8...17..............
Lactuca inermis	.1..11...1.....1..1.1..
Lessertia stenoloba	....1..................
Lobelia flaccida	.4.....................
Melilotus indica	....1.41........1......
Monopsis scabra	..................2....
Monopsis unidentata	.........1.5...........
Monsonia emarginata	.............1.........

Moraea species	.......11............1.
Nemesia fruticans	...11.11.5.............
Oxalis species	.1....................1
Panicum maximum	..5....................
Pelargonium species	................1......
Pelargonium alchemilloides	....1.......1..........
Peucedanum capense	....1..1...............
Plantago species	............1..........
Pycreus oakfortensis	....................4..
Rhynchosia adenodes	.........6.7...255.....
Rhynchospora brownii	...1...................
Richardia brasiliensis	..................12...
Rumex acetosella	...................1...
Salvia scabra	........1..............
Satyrium parviflorum	.........1.............
Scabiosa columbaria	.....................1.
Schoenoxiphium sparteum	1...1................1.
Senecio bupleuroides	...1...................
Senecio inaequidens	415....1...51....512...
Senecio macrocephalus	11.................2...
Setaria species	.1..........5.1.1...558
Silene bellidioides	.......1...............
Solanum species	.......1...............
Sporobolus africanus	.1...6...15.1...15...5.
Stenotaphrum secundatum	.2....8..5.56.7899.199.
Tephrosia capensis	.1...............1.....
Teucrium africanum	..1....................
Thunbergia species	21.....................
Thunbergia atriplicifolia	.......1...............
Trachyandra revoluta	1......................
Trifolium species	.4.............1.....1.
Trifolium burchellianum	....2.5................
Vicia sativa	.....................1.
Vigna vexillata v. angust	....1..................
Vigna vexillata	...1...................
Vigna vexillata	.......1...............
Wahlenbergia grandiflora	.............1.1.......

• APPENDIX 3

LIST OF ECCG SPECIES IN COMMON WITH OTHER SOUTH AFRICAN GRASSLANDS

1 = Eastern Cape
2 = Natal
3 = Free state
4 = TVL
5 = Transkei

See end of table for references to source of data

	1	2	3	4	5
Family / Species					
	X				
ADIANTACEAE	X				
Cheilanthes viridis (Forssk.)Swartz	X	X	X		
CYPERACEAE					
Cyperus obtusiflorus Vahl.	X	X		X	
Cyperus obtusiflorus Vahl. var *flavissimus* Boeck.	X				X
Cyperus obtusiflorus Vahl. var *obtusiflorus*	X	X			
Mariscus congestus (Vahl.) C.B.Cl.	X	X	X		
Mariscus tabularis (Schrad.) C.B. Cl.	X				
Kyllinga alba Nees	X		X	X	
Kyllinga elatior Kunth	X				
Kyllinga erecta Schumach.	X		X	X	
Ficinia stolonifera Boeck.	X				
Fimbristylis complanata (Retz.) Link	X				
Bulbostylis contexta (Nees) Bodard	X			X	
Abildgaardia ovata (Burm.f.) Kral	X		X	X	
Schoenoxiphium sparteum (Wahlenb.) C.B. Cl.	X				
COMMELINACEAE					
Commelina africana L.	X	X	X	X	
Commelina livingstonei C.B.Cl..	X				
ASPHODELACEAE (PART A)					
Trachyandra revoluta (L.) Kunth	X				
ASPHODELACEAE (PART B)					
Kniphofia rooperi (Moore) Lem.	X				
HYACINTHACEAE					
Albuca caudata Jacq.	X				
Eucomis comosa (Houtt.) Wehrh.	X				
ASPARAGACEAE					
Asparagus densiflorus (Kunth) Oberm.	X				
AMARYLLIDACEAE					
Haemanthus albiflos Jacq.	X				
Hypoxis argentea Harv.ex Bak.	X		X	X	
Hypoxis longifolia Bak.	X				
Hypoxis stellipilis Ker - Gawl	X				
Hypoxis villosa L.f.	X				
IRIDACEAE					
Aristea abyssinica	X				

Aristea schizolaena Harv.ex Bak.	X				
Aristea species					
Dierama igneum Klatt	X				X
Tritonia lineata (Salisb.) Ker - Gawl	X				
Gladiolus ochroleucus Bak.	X				
Gladiolus permeabilis Delaroche	X				
Watsonia x longifolia J.W.Mathews & L. Bol.	X				

ORCHIDACEAE					
Satyrium parviflorum Swartz	X				
Satyrium species					
SANTALACEAE					
Thesium junceum Bernh.	X				X
POLYGONACEAE					
Rumex acetosella L. ssp *angiocarpus* (Murb.) Murb.	X	X			
AIZOACEAE					
Galenia secunda (L.f.) Sond.	X				
Aizoon rigidum L.f.	X				
MESEMBRYANTHEMUM					
Carpobrotus deliciosus (L.Bol.) L.Bol.	X				X
CARYOPHYLLACEAE (PART A)					
Cerastium capense Sond.	X				
CARYOPHYLLACEAE (PART B)					
Silene bellidioides Sond.	X				
Silene primuliflora Eckl. & Zeyh.	X				X
RANUNCULACEAE					
Knowltonia capensis L. Huth.	X				
Clematis brachiata Thunb.	X	X	X	X	
Ranunculus multifidus Forssk.	X	X	X		
BRASSICACEAE					
Heliophila subulata Burch ex DC	X				
CRASSULACEAE					
Crassula nemorosa (E. & Z.) Endl.ex. Walp.	X				
Adromischus maculatus (Salm - Dyck) Lem.	X				
FABACEAE					
Acacia karroo Hayne	X		X	X	
Crotalaria obscura DC	X				
Argyrolobium incanum E & Z	X				
Argyrolobium rupestre (E & Z) Walp.	X				
Chamaecrista capensis (Thunb.) E. Mey.	X				
Medicago laciniata (L.) Mill	X				
Melilotus indica (L.) All.	X				
Trifolium burchellianum Ser.	X				
Indigofera heterophylla Thunb.	X				
Indigofera hilaris E & Z	X	X		X	X
Indigofera stricta L.f.	X				
Indigofera verrucosa E & Z	X				
Indigofera zeyheri Spreng.ex E & Z	X		X		
Tephrosia capensis (Jacq.) Pers.	X		X	X	
Tephrosia macropoda (E.Mey.) Harv.	X	X			
Zornia capensis Pers.	X				

Alysicarpus rugosus (Willd.) DC	X	X			
Vicia sativa L.	X				
Rhynchosia adenodes E & Z	X			X	
Rhynchosia capensis (Burm.) Schinz	X				
Rhynchosia caribaea (Jacq.) DC	X				
Eriosema squarrosum (Thunb.) Walp.	X				
Vigna vexillata (L.) A.Rich.	X		X		
Vigna unguiculata (L.) Walp.	X				
Dolichos falciformis E.Mey	X				
GERANIACEAE					
Geranium incanum Burm.f.	X				
Monsonia emarginata (L.f.) L'Herit	X				
Pelargonium alchemilloides (L.) L'Herit	X		X		
Pelargonium pulverulentum Colv.ex Sweet	X				
OXALIDACEAE					
Oxalis corniculata L.	X				
Oxalis bifurca Lodd.	X				
LINACEAE					
Linum thunbergii Eckl. & Zeyh.	X		X		
EUPHORBIACEAE					
Acalypha peduncularis E. Mey.ex Meisn.	X				
Clutia heterophylla Thunb.	X				
Euphorbia bupleurifolia Jacq.	X				
ANACARDIACEAE					
Rhus dentata Thunb.	X		X		
Rhus incisa L.f.	X				
CELASTRACEAE					
Cassine tetragona (L.f.) Loes.	X				
TILIACEAE					
Grewia occidentalis L.	X		X		
MALVACEAE					
Abutilon sonneratianum (Cav.) Sweet	X	X			
Sida dregei Burtt Davy			X	X	
Sida rhombifolia L.	X				
Hibiscus aethiopicus L.	X		X		
Hibiscus trionum L.	X	X	X	X	
STERCULIACEAE					
Hermannia incana Cav.	X				
THYMELIACEAE					
Gnidia anthylloides (L.f.) Gilg.	X				
Gnidia nodiflora Meisn.	X				X
Passerina rigida Wikstr.	X				
MYRTACEAE					
Eugenia albanensis Sond.	X				
Eucalyptus species	X				
ONAGRACEAE					
Oenothera rosea L'Herit.ex Ait.	X		X		
APIACEAE					
Centella coriacea Nannfd.	X				
Alepidea longifolia E. Mey.	X	X			X
Peucedanum capense (Thunb.) Sond.	X		XX		

PRIMULACEAE					
Anagallis arvensis L.	X				
EBENACEAE					
Euclea crispa (Thunb.) Guerke	X		X		
Diospyros dichrophylla (Gand.) De Winter	X				
Diospyros villosa (L.) De Winter	X				
GENTIANACEAE					
Sebaea sedoides Gilg.	X	X	X		
Chironia baccifera L.	X				
APOCYNACEAE					
Raphionacme hirsuta (E.Mey.) R.A.Dyer ex Phill.		X	X	X	
ASCLEPIADACEAE					
Xysmalobium involucratum (E.Mey.) Decne	X				
Xysmalobium orbiculare (E.Mey.) D.Dietr.	X				
Asclepias gibba (E.Mey.) Schltr.	X		X		
CONVOLVULACEAE					
Falckia repens L.f.	X				
Convolvulus natalensis Bernh.apud Krauss	X				
Convolvulus sagittatus Thunb.	X		X		
Ipomoea ficifolia Lindl.	X				
BORAGINACEAE					
Cynoglossum hispidum Thunb.	X				
VERBENACEAE					
Verbena bonariensis L.	X		X	X	
Lippia javanica (Burm.f.) Spreng.	X		X		
LAMIACEAE					
Teucrium africanum Thunb.	X				
Stachys aethiopica L.	X				
Salvia scabra L.f.	X				
SCROPHULARIACEAE (PART A)					
Nemesia fruticans (Thunb.) Benth.	X				
Sutera campanulata (Benth.) Kuntze	X				
Zaluzianskya capensis (L.) Walp.	X				
Zaluzianskya maritima (L.f.) Walp	X				
SELAGINACEAE					
Hebenstretia integrifolia L.	X				
Selago corymbosa L.	X				
SCROPHULARIACEAE (PART B)					
Graderia scabra (L.f.) Benth.	X	X	X	X	
Striga elegans Benth.	X		X		
Harveya speciosa Bernh.ex Krauss	X				
ACANTHACEAE					
Thunbergia atriplicifolia E.Mey.ex Nees	X	X	X		
Thunbergia capensis Retz.	X				
Chaetacanthus setiger (Pers.) Lindl.	X		X	X	
Crabbea angustifolia Nees		X	X	X	
Barleria obtusa Nees	X	X	X		
Blepharis capensis (L.f.) Pers.	X				
Hypoestes aristata (Vahl.) Soland ex Roem. & Schult.	X				
RUBIACEAE	X	X			
Coddia rudis (E.Mey.ex Harv.) Verdc.					

Pentanisia prunelloides (Klotzsch ex Eckl. & Zeyh.) Walp.	X				
Galopina aspera (Eckl. & Zeyh.) Walp.	X				
Anthospermum aethiopicum L.	X				
Anthospermum galioides Reichb.f.	X				
Anthospermum herbaceum L.f.	X				X
Anthospermum paniculatum Cruse	X	X	X		
Richardia brasiliensis Gomes	X				X
DIPSACACEAE					
Scabiosa albanensis R.A. Dyer	X	X			
Scabiosa columbaria L.	X				X
CUCURBITACEAE					
Kedrostis nana (Lam.) Cogn.	X	X	X	X	
CAMPANULACEAE					
Wahlenbergia grandiflora V.Brehm.	X				
Wahlenbergia stellarioides Cham. & Schlechtd.	X				
LOBELIACEAE					
Lobelia flaccida (Presl.) A.DC	X				
Lobelia flaccida (Presl.) A.DC ssp *flaccida*	X		X	X	
Lobelia tomentosa L.f.	X				
Monopsis scabra (Thunb.) Urb.	X				
Monopsis unidentata (Dryand.) E.Wimm.	X				
GOODENIACEAE					
Vernonia capensis (Houtt.) Druce	X				
Vernonia dregeana Sch. Bip.	X	X	X	X	
ASTERACEAE					
Felicia filifolia (Vent.) Burtt Davy	X				
Nidorella auriculata DC	X		X		
Conyza obscura DC	X				
Tarchonanthus camphoratus L.	X	X	X		
Pseudognaphalium luteo-album (L.) Hilliard & Burtt	X		X		
Helich rosum (Berg.) Less. var *arcuatum* Hilliard	X		X	X	
Helichrysum appendiculatum (L.f.) Less.	X				X
Helichrysum asperum (Thunb.) Hilliard & Burtt	X	X			
Helichrysum cymosum (L.) D.Don.	X				
Helichrysum herbaceum (Andr.) Sweet	X				
Helichrysum nudifolium (L.) Less.	X				
Helichrysum odoratissimum (L.) Sweet	X		X	X	
Helichrysum pedunculatum Hilliard & Burtt	X		X		
Helichrysum rosum (Berg.) Less.	X				
Helichrysum rutilans (L.) D.Don.	X				
Helichrysum simillimum DC	X				
Helichrysum umbraculigerum Less.	X				
Cotula sericea Thunb.	X				
Artemisia afra Jacq.ex Willd.	X				
Senecio bupleuroides DC	X	X	X		X
Senecio chrysocoma Meerb.	X				
Senecio inaequidens DC	X				
Senecio macrocephalus DC	X		X		
Senecio oxyriifolius DC	X				X
Senecio pterophorus DC	X	X			

Chrysanthemoides monilifera (L.) T.Norl.	X				
Arctotheca calendula (L.) Levyns	X				
Gazania krebsiana Less.	X	X			
Gazania linearis (Thunb.) Druce	X	X	X	X	
Berkheya decurrens (Thunb.) Willd.	X				
Gerbera piloselloides (L.) Cass.	X				
Hypochaeris radicata L.	X	X	X		
Lactuca inermis	X	X	X	X	
POACEAE					
Ischaemum fasciculatum Brongn.	X				
Elionurus muticus (Spreng.) Kunth	X	X			X
Imperata cylindrica (L.) Raeuschel	X	X	X	X	
Miscanthus capensis (Nees) Anderss.	X		X		
Cymbopogon excavatus (Hochst.) Stapf ex Burtt Davy	X				
Cymbopogon validus (Stapf) Stapf ex Burtt Davy	X	X	X	X	X
Hyparrhenia hirta (L.) Stapf	X	X	X		X
Monocymbium ceresiiforme (Nees) Stapf	X	X	X	X	
Heteropogon contortus (L.) Roem. & Schult.		X	X	X	X
Diheteropogon amplectens (Nees) Clayton	X	X	X	X	X
Diheteropogon filifolius (Nees) Clayton	X	X	X	X	X
Themeda triandra Forssk.	X	X	X	X	X
Digitaria diagonalis (Nees) Stapf	X	X	X	X	
Digitaria eriantha Steud.	X				X
Digitaria monodactyla (Nees) Stapf	X		X	X	
Stenotaphrum secundatum (Walt.) Kunze	X				
Alloteropsis semialata (R.Br.) Hitchc.	X			X	X
Brachiaria serrata (Thunb.) Stapf	X	X	X	X	X
Paspalum dilatatum Poir.	X	X	X	X	X
Paspalum notatum Fluegge	X	X	X	X	
Panicum aequinerve Nees	X				X
Panicum coloratum L.	X				
Panicum deustum Thunb.	X		X		
Panicum maximum Jacq.	X				X
Setaria nigrirostris (Nees) Dur. & Schinz.	X	X	X	X	X
Setaria pallide-fusca (Schumach.) Stapf. & C.E.Hubb.			X	X	
Setaria sphacelata (Schumach.) Moss	X				X
Melinis nerviglumis (Franch.) Zizka			X		
Melinis repens (Willd.) Zizka	X	X	X	X	
Ehrharta calycina J.E.Sm.	X	X	X	X	
Tristachya leucothrix Nees	X				X
Helictotrichum hirtulum (Steud.) Schweick.	X		X		X
Helictotrichon turgidulum (Stapf) Schweick.	X	X	X	X	
Pentaschistis pallida (Thunb.) Linder	X				
Aristida diffusa Trin.	X				
Aristida junciformis Trin. & Rupr.	X		X	X	X
Sporobolus africanus (Poir.) Robyns & Tournay	X	X	X	X	X
Sporobolus fimbriatus (Trin.) Nees	X	X	X	X	
Sporobolus virginicus (L.) Kunth	X		X		
Eragrostis capensis (Thunb.) Trin.	X				X
Eragrostis curvula (Schrad.) Nees	X	X	X	X	X
Eragrostis plana Nees	X	X	X	X	X

Eragrostis racemosa (Thunb.) Steud.	X	X	X	X	X
Cynodon dactylon (L.) Pers.	X	X	X	X	X
Harpochloa falx (L.f.) Kuntze	X	X	X	X	X
Eustachys paspaloides (Vahl.) Lanza & Mattei	X	X	X	X	X
Koeleria capensis (Steud.) Nees	X		X	X	
Festuca costata Nees	X	X	X		
Festuca longipes Stapf.	X	X			
Bromus pectinatus Thunb.	X				
	X				
	1	2	3	4	5
	1	2	3	4	5
Fabaceae	25	3	4	4	1
Asteraceae	33	8	11	4	3
Poaceae	46	27	34	28	26
Other	112	22	35	18	10

1 = Everard, 1987; Hoare and Bredenkamp, 1999; Johnson, 1997; Lubke and Strong, 1989; Palmer, 1991; Phillipson, 1987; Phillipson and Russel, 1988; Shackleton *et al.*, 1991; Taylor and Morris, 1981; Judd, 1995

2 = Eckhardt, van Rooyen and Bredenkamp, 1996; Hill, 1996; Smit, Bredenkamp and van Rooyen, 1993(a); 1993(b); 1995(a); 1995(b)

3 = Bredenkamp, Joubert and Bezuidenhout, 1989; Breytenbach *et al.*, 1992; 1993(a); 1993(b); 1993(c); Coetzee, Bredenkamp and van Rooyen, 1993 (a); 1993(b); du Preez and Venter, 1992; Eckhardt, *et al.* 1993(a); Fuls, Bredenkamp and van Rooyen, 1992(a); 1992(b); 1993 (a); 1993(b); 1993(c); 1993(d); Fuls, Bredenkamp, van Rooyen and Theron, 1992; Kay, Bredenkamp and Theron, 1993; Kooij, Bredenkamp and Theron, 1990(a); 1990(b); 1990(c); Smit, Bredenkamp and van Rooyen, 1992; Malan, Venter and du Preez, 1995; 1999; Cilliers and Bredenkamp, 1999(a); 1999(b)

4 = Bezuidenhout and Bredenkamp, 1991; Bezuidenhout, Bredenkamp and Theron, 1993; 1994(a); 1994(b); 1994(c); 1994(d); Bloem, Theron and van Rooyen, 1993; Bredenkamp, Bezuidenhout, Joubert and Naude, 1994; Coetzee, Bredenkamp and van Rooyen, 1995; Coetzee, Bredenkamp, van Rooyen and Theron, 1994; Brown, Bredenkamp and van Rooyen, 1997

5 = McKenzie, 1984; Feely, 1987; Shackleton, 1989

APPENDIX 4

- **Species affinities between the East Cape Coastal Grasslands and African Phytochoria as defined by White (1983)**

	Karroo-Namib Region		Kalahari Highveld Regional Transitional Zone		Tongoland – Pondoland Regional Mosaic		East Malagasy Regional Centre of Endemism		Somali Masai Regional Centre of Endemism	
	G	Sp	G	Sp	G	Sp	G	Sp	G	Sp
Acacia karroo						X				
Aizoon	X									
Alloteropsis semialata				X		X		X		
Anthospermum			X							
Aristida congesta	X			X			X		X	
Aristida junciformis				X		X				
Asclepias			X							
Barleria	X		X							
Berkheya	X		X							
Brachiaria serrata				X						
Bulbine	X									
Chloris virgata				X					X	
Chrysocoma	X									
Conyza			X							
Cotula	X									
Crotalaria	X									
Cymbopogon excavatus	X		X				X			
Cymbopogon validus						X				
Cynodon dactylon				X						X
Cyperus obtusifolius	X			X						
Digitaria					X		X		X	
Diheteropogon amplectens					X					
Elionurus muticus				X			X			
Eragrostis capensis	X			X			X		X	
Eragrostis plana				X						
Eragrostis racemosa				X						
Eulalia villosa						X				
Euphorbia			X							
Eustachys paspaloides				X						X
Felicia filifolia	X			X						
Galenia	X									
Gnidia			X							
Harpochloa falx				X						
Helichrysum	X		X						X	
Heliophila	X									
Hermannia	X		X							
Heteropogon contortus				X		X		X		

Hyparrhenia hirta		X			X			X		X
Hypoxis			X							
Imperata cylindrica								X		
Indigofera	X		X						X	
Ipomoea			X						X	
Kyllinga									X	
Monocymbium ceresiiforme				X						
Monsonia	X									
Oxalis	X									
Osteospermum			X							
Oxalis			X							
Panicum							X		X	
Paspalum					X					
Pelargonium									X	
Pentaschistis							X			
Rhynchosia			X							
Scabiosa			X							
Scilla			X							
Selago	X									
Senecio	X									
Stachys			X							
Setaria sphacelata				X				X	X	
Sporobolis	X						X		X	
Stipagrostis	X									
Stipagrostis	X									
Sutera	X									
Tephrosia	X									
Themeda triandra		X		X	X					X
Tristachya leucothrix				X	X					
Vernonia			X							
Total	26	2	20	19	6	6	8	5	12	4