

## Phytosociology of the B land type in the Newcastle – Memel – Chelmsford Dam area

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This study forms part of the Grassland Biome Project. The results of a numerical classification (TWINSPAN) of 74 relevés compiled in the Bb and Bd land types of the Newcastle – Memel – Chelmsford Dam area, were refined by Braun-Blanquet procedures. The analyses revealed five major plant communities which may be divided into seventeen plant communities. A hierarchical classification, description and ecological interpretation of the plant communities are presented.

Hierdie ondersoek maak deel uit van die Grasveldbloomprojek. Die resultate van 'n numeriese klassifikasie (TWINSPAN) van 74 relevés wat in die Bb- en Bd-landtipes van die Newcastle – Memel – Chelmsforddam-gebied saamgestel is, is met behulp van Braun-Blanquet-prosedures verfyn. Vyf plantegroeitipes wat in sewentien plantgemeenskappe onderverdeel kan word, is onderskei. 'n Hiërargiese klassifikasie, beskrywing en ekologiese interpretasie van die plantgemeenskappe word aangebied.

**Keywords:** B land type, Braun-Blanquet procedures, classification, plant communities.

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### Introduction

The phytosociological classification of the vegetation of the B land type, which includes the Bb and Bd land types in the Newcastle – Memel – Chelmsford Dam area, forms part of the South African National Grassland Biome Project (Mentis & Huntley 1982; Scheepers 1986). The aim of this project is 'to integrate knowledge, comprehension and expertise which will enable scientists to forecast the results of the available options of grassland management programmes' (Mentis & Huntley 1982).

Inventory type vegetation classification and mapping projects form the basis for detailed studies on vegetation dynamics and are also necessary for the formulation of regional veld management and conservation policies.

No previous phytosociological studies have been done in this area. Large-scale classification of the vegetation types of this area include those of Acocks (1953, 1988) and Edwards (1967). The vegetation of the Bb land type in the study area is representative of Acocks's (1988) Natal Sour Sandveld (Veld Type 66) and the Bd land type of Southern Tall Grassveld (Veld Type 65). The Bb land type is represented by the *Tristachya* – *Digitaria* Grassland and *Themeda* – *Hyparrhenia* Grassland described by Edwards (1967). The relatively high rainfall and associated leached soils have resulted in veld dominated by unpalatable grass species; these grasslands are commonly known as 'sourveld'. It is also believed to be a fire climax grassland, implying that the area is climatically suitable for the advance of plant succession beyond the grassland stage into either forest or woodland. The grassland stage is largely retained through the regular occurrence of fire (Tainton 1981). According to Scheepers (1986) the studies of Acocks (1953, 1988) and Edwards (1967) were conducted on a large scale and a considerable time ago. A more comprehensive and detailed phytosociological investigation of this area was therefore undertaken. The classification, description and

mapping of relative small-scale homogeneous vegetation units are a prerequisite for vegetation management and conservation.

### The study area

The study area is situated in the north-western Natal and the north-eastern Orange Free State, South Africa, between 27°33' and 28°00'S and 29°33' and 30°00'E. This area includes the Bb land type in the east of the study area (Figure 1) at an altitude of 1200 – 1400 m, and the Bd land type almost in the centre of the study area (Figure 1), at an altitude of 1500 – 1600 m.

Van der Eyk *et al.* (1969) refer to the study area as the Northern (Tugela) Basin, which consists of the Ngagane – Buffalo Plain of nearly flat to undulating country, and the Newcastle – Utrecht foothills which lead towards the Great Escarpment of the Drakensberg. Van der Eyk *et al.* (1969) as well as Edwards (1967) and Schulze (1982), refer to the mountain range in the study area as the 'Low Drakensberg'.

Within the area the Bb land type offers the only land suitable for cultivation, although by estimate not more than 50% of the area is ploughed or arable (Land Type Survey Staff 1990). The town of Newcastle is situated in the Bb56 land type with large industries at its borders. Several coal mines occur in this land type. The Chelmsford Dam Nature Reserve of the Natal Parks Board is the only conservation area in this particular grassland.

The location of the Bd26 land type in the north-west of the study area is quite remote from the Bb land types (Figure 1). According to Phillips (1973), the climate of this area corresponds to Bioclimatic Group 8, which is considerably drier than the rest of the study area. Most of the soils are not suitable for ploughing, and although the vegetation does not provide good grazing, mainly stock-farming is conducted here. A detailed description of the physical environment of the area is given by Smit (1992).

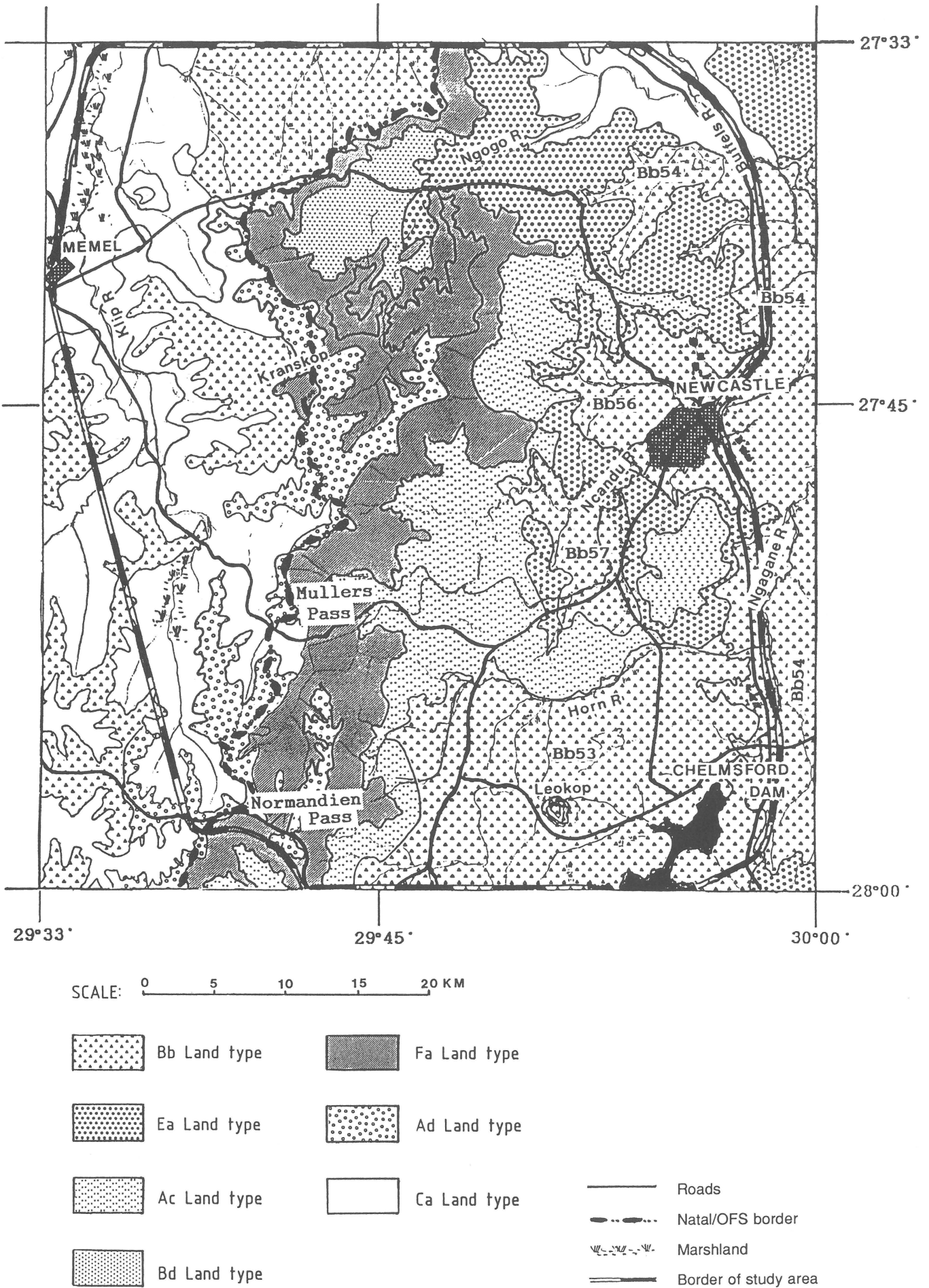


Figure 1 Positions of the Bb, Ea, Ac, Bd, Fa, Ad and Ca land types in the Newcastle - Memel - Chelmsford Dam area (adapted from 1:250 000 Land Type Series, 2728 Frankfurt).

Soils

The soils in the Bb land types vary from deep and clayey to shallow and sandy. The soil classification nomenclature conforms to that of MacVicar *et al.* (1977). The soils are dystrophic and/or mesotrophic, and yellow-brown apedal soils predominate (MacVicar *et al.*, 1977), while the occurrence of red soils is not widespread (Land Type Survey Staff 1990). According to the Land Type Survey Staff (1990), the B land types in the study area are often unsuitable for ploughing, although extensive ploughed fields do occur (*e.g.* on the Avalon and Clovelly soil forms). The shallow soils are often a result of the widespread occurrence of 'oukclip' (ferricrete, hard plinthic horizon) (*e.g.* Wasbank and Westleigh soil forms). Soil analyses of the main soil types in the different plant communities are given in Table 1.

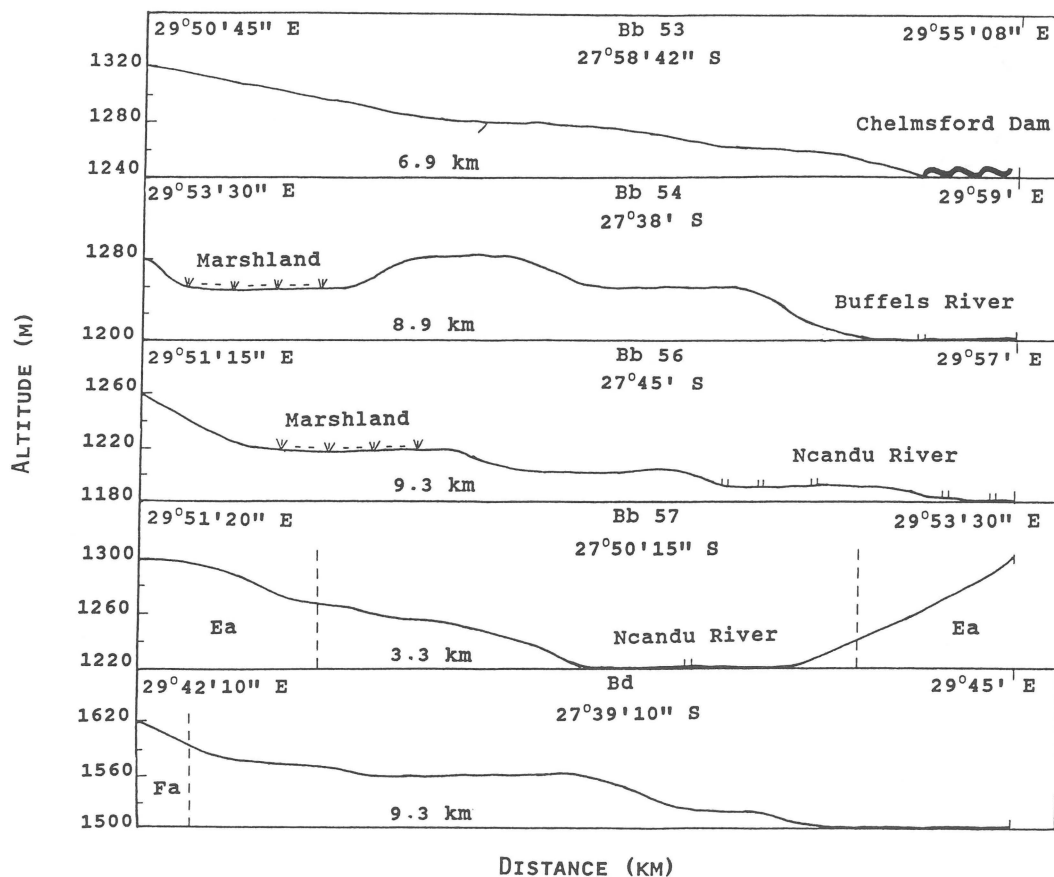
Topography

The topography of the B land types in the study area can be described as gently undulating to undulating (Figure 2). An exception is Leokop, a few kilometres west of Chelmsford Dam, which is a relic of the Fa land type. From the foot of this obvious landmark in the landscape run dolerite hills, mostly westward towards the escarpment of the Low Drakensberg. The Ngagane River, where it leaves the Chelmsford Dam, runs through a narrow gorge bordered by dolerite cliffs.

According to the Land Type Survey Staff (1990), the terrain types in the B land types are classified as A2 and A3. 'A' means that more than 80% of the area has slopes less than 8% and '2' and '3' indicate local relief, which in this case means that the difference between the highest and lowest points in the landscape varies from 30 to 150 m

**Table 1** An analysis of soil properties of plant communities in the B land type of the Newcastle – Memel – Chelmsford Dam area (Land Type Survey Staff 1990)

Community	Soil form	Soil series	Soil depth (mm)	% Sand	% Silt	% Clay	Water retentivity (%)		Exchangeable cations (me/kg soil)					pH (water)	Resistance (Ω)
							-33 kPa	-1500 kPa	Na	K	Ca	Mg	Total		
1.1	Katspruit	Killarney	0-1500	37	22	30	28.4	17.9	1	3	115	70	189	7.9	465
1.2, 2.1, 3.2	Avalon	Normandien	0-1200	26	15	53	26.7	18	1	2	6	2	11	4.9	3050
1.3, 2.2, 2.3	Wasbank	Warrick	0- 600	79	4	19	10.9	5.4	1	0	1	0	2	5.1	7500
3.2	Hutton	Farmingham	0- 500	57	8	33	17.1	10.8	1	3	4	4	12	5.3	3633
3.3	Cartref	Arrochar	0- 500	52	20	24	19.8	10	2	2	14	12	30	5.3	2650
5.1	Avalon	Ruston	0-1000	64	8	28	16.7	8.7	1	1	6	2	10	4.8	4950
3.1, 5.2	Shortlands	Shortlands	0-1100	19	24	60	38.5	25.5	1	1	38	74	114	6.2	1400



**Figure 2** Contour profiles of the B land types in the Newcastle – Memel – Chelmsford Dam area (South Africa 1:50 000 sheets 2729 DD Newcastle and 2729 DD Ingogo).

(Land Type Survey Staff 1984). Only a few small pans occur in this land type and marshlands are restricted to streambanks.

### Geology

A detailed description of the Middle Ecca Beds which occur in the Bb land type (Visser & Bishopp 1976), is given by Smit (1992). These sediments consist of shale of the Volksrust Formation and sandstone of the Vryheid Formation, with alluvium and small intrusions of dolerite. Van der Eyk *et al.* (1969) refer to the Middle Ecca Beds as the Coal Measures, because of the occurrence of coal seams here.

The geology of the Bd land type consists of Upper Ecca Formations (Visser & Bishopp 1976). The shale in this area is of the Volksrust Formation, with small areas of dolerite (Land Type Survey Staff 1990).

### Climate

The Bb land type is situated in the Newcastle – Utrecht plain and the Ngagane plain at 1200 – 1400 m altitude (Van der Eyk *et al.* 1969), and the climate of this area is discussed in detail by Smit (1992), where it is referred to as 'Plainlands'. The mean annual precipitation is given as 850 mm and corresponds to Phillips's (1973) Bioclimatic Group 6. The Bd land type lies at an altitude of 1500 – 1600 m and has a lower mean annual precipitation of 650 mm and corresponds with Phillips's (1973) Bioclimatic Group 8 (Schulze 1982; Weather Bureau 1990).

The mean annual temperature for this region is 16°C, while the highest mean daily maximum temperature of 28°C has been recorded in January and the lowest mean daily minimum temperature of 2°C in July. Frost commonly occurs from April to September.

### Methods

Over the entire study area, relevés were compiled in 282 stratified random sample plots. Stratification was firstly based on land type. The number of sample plots allocated to the various land types recognized in the area, was determined *pro rata* and on area basis. In this way, 74 sample plots were placed in the Bb and Bd land types. Stratification within the land type was defined on terrain units. Plot sizes were 10 × 10 m for grassland vegetation (Bredenkamp & Theron 1978) and 10 × 20 m for woodland (Bredenkamp 1982).

The terrain form sketches of the Land Type Survey Staff for these land types were not available, but profiles were drawn from 1:50 000 topocadastral maps (Figure 2). In these, five terrain units were recognized on which stratification was based, namely 1 (crest), 2 (scarp), 3 (midslope), 4 (footslope) and 5 (valley bottom or floodplain). Due to the predominant gently undulating topography, the B land type is of the single-phase terrain type (Land Type Survey Staff 1984).

Total floristic composition in each sample plot was recorded, using the Braun-Blanquet cover-abundance scale (Mueller-Dombois & Ellenberg 1974), along with habitat information such as geology, topography, topographic position, soil form and series (whenever possible), percen-

tage rockiness of the soil surface, rock size and vegetation structure. Vegetation structure was classified according to Edwards's system (Edwards 1983), and where appropriate used in the names of the plant communities. Taxa names conform to those of Gibbs Russell *et al.* (1985, 1987, 1990).

Classification of the floristic data was done by using Two-way Indicator Species Analysis (TWINSpan) (Hill 1979). The results of this analysis were a first approximation of the vegetation types of the area, which were then further refined by using Braun-Blanquet procedures (Westhoff & Van der Maarel 1987; Behr & Bredenkamp 1988; Bezuidenhout 1988; Bredenkamp *et al.* 1991). The results are presented in a phytosociological table (Table 2).

## Results and Discussion

### Classification

The classification of the vegetation of the B land type revealed two main grassland communities, namely the *Themeda triandra* – *Monocymbium cerasiiforme* Grassland and the *Themeda triandra* – *Hyparrhenia hirta* Grassland. The first community can be regarded as representative of the climax grass community of this area, while the latter represents communities on shallow and rocky soils as well as secondary communities on abandoned cultivated fields. *Themeda triandra* seems to be the most widespread and often dominant species. Grass species such as *Eragrostis racemosa*, *Eragrostis curvula* and *Elionurus muticus* (species group U, Table 2) also occur widespread and are constantly present in this vegetation. Limited hygrophilous communities as well as woodland communities on rocky dolerite hills were identified. Very disturbed communities were identified at localities where cattle tend to flock together and trample the vegetation, for example at farm gates, and also at areas adjacent to ploughed fields.

The communities are hierarchically classified as follows:

1. *Monopsis decipiens* – *Helichrysum aureonitens* pan and marsh communities of poorly drained soils
  - 1.1 *Monopsis decipiens* – *Polygonum salicifolium* Low Closed Grassland of pans and marshes
  - 1.2 *Monopsis decipiens* – *Pycneus macranthus* Low Closed Herbland on marshes
  - 1.3 *Monopsis decipiens* – *Eragrostis gummiflua* Low Closed Grassland of depressions and shallow soils
2. *Themeda triandra* – *Monocymbium cerasiiforme* Grassland of non-rocky soils
  - 2.1 *Themeda triandra* – *Raphionacme hirsuta* Tall Closed Grassland of deep, loamy soils
  - 2.2 *Themeda triandra* – *Oxalis obliquifolia* Low Closed Grassland of shallow, sandy soils
  - 2.3 *Themeda triandra* – *Diheteropogon filifolius* Low Closed Grassland on shallow soils
3. *Hyparrhenia hirta* – *Themeda triandra* Grassland on rocky dolerite hills, disturbed sites and shallow soils
  - 3.1 *Hyparrhenia hirta* – *Acalypha caperonioides* Tall Closed Grassland on rocky dolerite hills, shallow soils and abandoned ploughed fields
  - 3.2 *Hyparrhenia hirta* – *Setaria sphacelata* Tall Closed Grassland on dolerite hills and disturbed sites
  - 3.3 *Themeda triandra* – *Helichrysum coriaceum* Low Closed Grassland of the Bd land type

4. *Rhus rehmanniana* – *Diospyros lycioides* subsp. *lycioides*  
Woodland on rocky dolerite hills
  - 4.1 *Rhus rehmanniana* – *Lantana rugosa* Low Closed  
Woodland on rocky dolerite hills and east-facing  
midslopes
  - 4.2 *Acacia caffra* – *Ziziphus mucronata* Low Forest on  
midslopes of dolerite hills
5. *Bidens pilosa* Disturbed Grassland
  - 5.1 *Eragrostis plana* – *Eleusine indica* Disturbed Grass-  
land
  - 5.2 *Cynodon dactylon* – *Cyperus esculentus* Disturbed  
Grassland.

### Description of communities

#### 1. The *Monopsis decipiens* – *Helichrysum aureonitens* pan and marsh communities

This community is found in moist habitats such as pans, marshlands, streambanks, depressions and poorly drained soils. The Katspruit soil form occurs most commonly at these moist habitats (Table 1).

The soil supports a hygrophilous vegetation dominated by the forbs *Monopsis decipiens*, *Helichrysum aureonitens* and *Commelina africana* (species group E, Table 2). These species are also the diagnostic species of this community. The most commonly occurring grasses are *Themeda triandra*, *Eragrostis plana* and *Eragrostis curvula* (species group U, Table 2), followed by *Monocymbium cereziiforme* (species group I, Table 2) and *Aristida congesta* subsp. *congesta* (species group C, Table 2).

The three subdivisions of this community are based on moisture regime of the soil, and each supports a distinct group of diagnostic species. Specific sedge species seem to be restricted to specific zones, although *Fimbristylis complanata* and other species of species group C (Table 2), occur in both communities 1.1 and 1.2, indicating a close floristic and ecological relationship between the two communities. Community 1.3 seems to be a somewhat drier community with a relationship to the *Themeda triandra* – *Monocymbium cereziiforme* Grassland (Community 2), due to the abundance of *Themeda triandra*, *Monocymbium cereziiforme* and *Eragrostis racemosa* on relatively drier situations.

#### 1.1 The *Monopsis decipiens* – *Polygonum salicifolium* Low Closed Grassland

Two relevés were compiled in this very restricted community, both in the Bb land type in pans with standing water.

In both cases the soil type was identified as the Katspruit soil form, Killarney series (Table 1) (Land Type Survey Staff 1990). The neutral to slightly alkaline pH is due to a high concentration of exchangeable calcium. The water retentivity of these soils is fairly high while the electrical resistance is very low, due to the leaching of salts from the soil (Table 1).

The diagnostic species of this community are given in Table 2 as species group A, which includes hygrophilous forbs such as *Polygonum salicifolium*, *Mentha aquatica*, *Vernonia hirsuta*, *Senecio lygodes*, *Ornithogalum ornithogaloides*, *Aponogeton junceus* subsp. *junceus* and the free-floating *Urticularia stellaris*, and hygrophilous grasses such

as *Arundinella nepalensis*, *Eragrostis planiculmis* and *Paspalum urvillei*.

The sedge *Fimbristylis complanata*, the forb *Mentha aquatica* and the grass *Arundinella nepalensis* were recorded as dominant in some cases, while the grasses *Aristida congesta* subsp. *congesta* and *Eragrostis curvula* are often dominant at localities which show signs of previous over-utilization. Abundant in standing water are the free-floating forb, *Urticularia stellaris*, the monocotyledonous forbs *Aponogeton junceus* subsp. *junceus* and *Ornithogalum ornithogaloides* as well as the dicotyledonous forbs *Monopsis decipiens* and *Helichrysum aureonitens*.

#### 1.2 The *Monopsis decipiens* – *Pycnus macranthus* Low Closed Herbland

This community occurs in the Bb 53 land type, in the Chelmsford Dam Nature Reserve and also close to the foothills of the Low Drakensberg. Elevations vary from 1240 m at Chelmsford Dam to 1360 m at the foothills of the Low Drakensberg.

Some relevés were compiled in slight depressions with poor drainage in the Chelmsford Dam Nature Reserve and the soils here were identified as the Katspruit form, Killarney series, the properties being similar to those of community 1.1 (Table 1). In other relevés the Avalon form, Normandien series, was identified. The clay content of the B-horizon of both the Katspruit and Avalon soils is fairly high (30 – 53%). The Avalon form, Normandien series, is dystrophic in the B21 horizon (MacVicar *et al.* 1977) and mildly acidic. The exchangeable cations are rather low, but water retentivity is high and electrical resistance considerably high (Table 1).

The diagnostic species of this community are given in species group B (Table 2) and include the sedges *Pycnus macranthus*, *Kyllinga erecta* and *Fuirena pubescens*, the hygrophilous forbs *Hypoxis filiformes*, *Lobelia flaccida* subsp. *mossiana* and the prostrate *Centella asiatica*, the hygrophilous grasses *Helictotrichon turgidulum*, *Pennisetum sphacelatum* and *Miscanthus junceus*.

The dominant species are the forbs *Monopsis decipiens*, *Helichrysum aureonitens* and the sedge *Pycnus macranthus*. Abundant in several cases are the sedges *Kyllinga erecta*, *Fuirena pubescens* and *Fimbristylis complanata*.

#### 1.3 The *Monopsis decipiens* – *Eragrostis gummiiflua* Low Closed Grassland

This community occurs in the Chelmsford Dam Nature Reserve and also to the west of Newcastle, in the Bb land type. According to the soil profile done by the Land Type Survey Staff (1990) in this vicinity, the soil type occurring here is the Wasbank soil form, Warrick series, which is shallow (600 mm) and sandy (79% sand) (Table 1). The widespread occurrence of 'oukclip' or ferricrete may be responsible for the shallowness of the soil. In some places the ferricrete is exposed with no topsoil present. This seems to be a very unproductive soil as it has very low water retentivity, is extremely poor in exchangeable cations, is moderately acidic and has a very high electrical resistance (Table 1).

The dominant species in this community are the grass species *Themeda triandra*, *Eragrostis racemosa* and

**Table 2** A phytosociological table of the plant communities of the B land type of the Newcastle – Memel – Chelmsford Dam area

RELEVÉS	20	000012	01122	000100110	000000001	11	000001000000001	12212212	22222	011	12	22222	12	
	27	367322	52755	677878232	222233363	77	888631545886535	20531455	77888	588	85	14455	96	
	60	174305	45389	812439442	310924965	12	7855543982649108	79060891	89021	056	77	77923	54	
COMMUNITIES	1			2			3			4			5	
	1.1	1.2	1.3	2.1	2.2	2.3	3.1	3.2	3.3	4.1	4.2	5.1	5.2	
<b>Species group A</b>														
<i>Polygonum salicifolium</i>	+1													
<i>Eragrostis planiculmis</i>	++													
<i>Mentha aquatica</i>	2													
<i>Arundinella nepalensis</i>	4	++												
<i>Vernonia hirsuta</i>	+													
<i>Senecio lygodes</i>	+													
<i>Faspalum urvillei</i>	+													
<i>Kniphofia multiflora</i>	+													
<i>Urticularia stellaris</i>	1													
<i>Ornithogalum ornithogaloides</i>	1													
<i>Aponogeton junceus</i>	1													
<b>Species group B</b>														
<i>Pycreus macranthus</i>		+3133												
<i>Hypericum aethiopicum</i>		++ ++												
<i>Hypoxis filiformes</i>		+1 2						+						
<i>Lobelia flaccida</i>		+ 1	+											
<i>Kyllinga erecta</i>		222												
<i>Fuirena pubescens</i>		22												
<i>Helictotrichon turgidulum</i>		++												
<i>Centella asiatica</i>		+1	+					+	+					
<i>Pennisetum sphacelatum</i>		++												
<i>Miscanthus junceus</i>		+1												
<b>Species group C</b>														
<i>Fimbristylis complanata</i>	3	2 3												
<i>Aristida congesta</i>	4	+ ++	+		+		+	+						
<i>Erioseperum abyssinicum</i>	+	+ +							+					
<b>Species group D</b>														
<i>Eragrostis gummiiflua</i>		+	+++		++	+			1 +				+	
<i>Aristida junciformis</i>			++1											
<b>Species group E</b>														
<i>Monopsis decipiens</i>	1	121212	++ +											
<i>Helichrysum aureocitens</i>	1	32122	1+3+	+	+	+		+						
<i>Commelina africana</i>		1+ 12+	++ +		+	+		+	+		++			
<b>Species group F</b>														
<i>Raphionacme hirsuta</i>				++++ ++	+	+	+	+	+					
<i>Helichrysum subluteum</i>		+	+	++ ++					++	+				
<i>Dicoma anomala</i>				++ ++	+		+							
<i>Polygala uncinata</i>				+++		+								
<i>Polygala amatymbica</i>			+	+	+		+							
<b>Species group G</b>														
<i>Oxalis obliquifolia</i>		+		+	+++ ++				+	+	+			
<i>Senecio affinis</i>					++ +									
<i>Eulophia foliosa</i>					+ +									
<i>Scilla nervosa</i>				+	++ +									
<i>Sopubia cana</i>				+	++									
<i>Helichrysum oreophyllum</i>				+	++			+						
<b>Species group H</b>														
<i>Diheteropogon filifolius</i>					+									
<i>Gnidia caffra</i>														
<i>Microchloa caffra</i>														
<i>Parinari capensis</i>														
<i>Stoebe vulgaris</i>														
<b>Species group I</b>														
<i>Monocymbium cereisiiforme</i>	1+	2	+223	323232 33	133111123	31		+	1 1 +	11				
<i>Tristachya leucothrix</i>	+2		3+	+2121+3+1	1 11+111	1+		11	+	1		+2	1+	
<i>Trachypogon spicatus</i>	33	1		33 2 +	33232 33+	1		+	4++1 3	2		++		
<i>Diheteropogon amplexans</i>	+		+	++ ++ 1+	1+1 +++	1+		+	+	++		2	+	
<i>Panicum natalense</i>	++			+1 ++	+++++ +	++								
<i>Helichrysum pilosellum</i>	++		+	++ ++	+									
<i>Loudetia simplex</i>			+	11+ 1 2	211+ 1	1+		1				1	+	
<i>Helichrysum miconiifolium</i>				+++++	++ ++	++				+		+	+	
<i>Hypoxis rooperi</i>				1+1++ +	+++ +			+	+	+		+	+	
<i>Urelytrum agropyroides</i>	+		+	1++ ++ 1	1+++ +			+	1					
<i>Cyanotis speciosa</i>				++++ +	++ ++									
<i>Alloteropsis semialata</i>				11+ 1+1+	+++21									
<i>Gnidia kraussiana</i>				+ + + + +	+++++									
<i>Hemizygia pretoriae</i>				++ ++	++++									
<i>Graderia scabra</i>				++ ++	++ + + + +									
<i>Elephantorrhiza elephantina</i>				+++1 +	+++ ++									
<i>Senecio venosus</i>				+++ +	++ ++									
<i>Sebaea sedoides</i>				+ + +	+ + + +									
<i>Eriosema kraussiana</i>				1 + +	+ 1 ++	+						++		
<i>Clerodendrum triphyllum</i>				+++ ++	++ +									
<i>Helichrysum acutatum</i>				++ +	++ +									
<i>Clutia monticola</i>				++	++ +									
<i>Sebaea grandis</i>	+			+	+									
<i>Andropogon schirensis</i>				3 3		3+						+		
<b>Species group J</b>														
<i>Acalypha caperonioides</i>								+++++	+++++		++	+	+	
<i>Hermannia depressa</i>								+	+++++	+	++	+	+	
<i>Striga bilabiata</i>						++		+	++ +	+			++	
<i>Eucomis autumnalis</i>								+++++	++ +	+				
<i>Gerbera piloselloides</i>				++	+			+	++	++				
<i>Berkheya setifera</i>				+	+			+	++	++				
<i>Thesium costatum</i>								+	++	++				
<i>Moraea natalense</i>								+	++	++				
<i>Lactuca capensis</i>								+	++	++				
<i>Thunbergia atriplicifolia</i>				+				+	++	++				
<i>Conyza obscura</i>								+	++	++				
<i>Berkheya onopordifolia</i>								+	++	++				
<i>Raphionacme species</i>								+	++	++				

Table 2 Continued

RELEVES	20 27 60	000012 367322 174305	01122 52755 45389	000100110 677878232 812439442	000000001 222233363 310924965	11 77 12	0000010000000001 8886315445886535 7855543982649108	12212212 20531455 79060891	22222 77888 89021	011 588 056	12 85 77	22222 14455 77923	12 96 54
COMMUNITIES	1			2		3			4		5		
	1. 1	1.2	1.3	2.1	2.2	2. 3	3.1	3.2	3.3	4.1	4. 2	5.1	5. 2
<b>Species group K</b>													
<i>Setaria sphacelata</i>				+		+	+	2 ++ ++	++	++			+
<i>Aristida congesta</i>								+1+ + +					
<i>Grewia hispida</i>								+ +			+		
<i>Melinis repens</i>								1 +	+				
<b>Species group L</b>													
<i>Helichrysum coriaceum</i>			+		+		+	++ +++		2+1+1			
<b>Species group M</b>													
<i>Hyparrhenia hirta</i>		1 + +		+ 2	+++++2	+	5443241443444243	3334 23	+++41	+2	+		+
<i>Cymbopogon excavatus</i>				2 +		1	1++++1+++1+++ 1	+ ++1+	++ +	1	+		+
<i>Turbina oblongata</i>				+++	+		+++ + + ++	+ + +	+	++	++		++
<i>Chaetacanthus burchellii</i>				+ +	+		++ ++++++ + +	+ + +					
<i>Crabbea acaulis</i>				+ + +			+ ++++++ ++ +	+ ++					
<i>Haplocarpa scaiosa</i>				+ +			++ ++ + +++++	++	+ +	+			
<i>Phyllanthus glaucophyllus</i>							+++++ + + + +	+ +			+		
<i>Rhynchosia totta</i>							++ + + + +	++ +	++				
<i>Cucumis zeyheri</i>							++ + + + + +	+ + +					
<i>Helichrysum rugulosum</i>				+ +			+++ ++++++	+ + +	2+ 2+				+
<i>Corchorus confusus</i>							+++++		+	++			
<i>Eriosema cordatum</i>							+++++			++			
<i>Walafrida densiflora</i>				+			+ ++ + +	++ +	+ +				+
<i>Acalypha punctata</i>							++	+		1+			
<i>Tolpis capensis</i>						+	+		+ +				
<i>Rhus discolor</i>							++		+				
<i>Monsonia angustifolia</i>							+	+	++	+			
<b>Species group N</b>													
<i>Ledebouria ovatifolia</i>			+	+++++++	+ ++++++	+	+ + + + + +	+ + + +			+		
<i>Brachiaria serrata</i>				+++++ ++	+++++++	++	+++ + + +	++ + +					
<i>Hypoxis rigidula</i>				+1+1+ 1	+++++++1	+	+ + + + + + + +	+ 21	+ +	+			
<i>Pygmaeoethamnus chamaedendrum</i>				+++++++ +	+ + + + + 1		+++++ + + 1+ +	+ + +	+1 +	+			
<i>Anthospermum pumilum</i>				+ + +	+ + + +		+++++++ + + +	+ + +	++	+			
<i>Becium obovatum</i>	+		+	+++++++	+ + + + + +		+ + + + + +	+ + +					
<i>Scabiosa columbaria</i>				+ + + +	+ + + +		++ ++++++ + +	+ + + +					
<i>Pentania angustifolia</i>				+++++ +3	++ +++++		+++++	+	++				
<i>Zornia milneana</i>					++ + + + +	+	++ + + + + +	+		++			
<i>Indigofera sanguinea</i>			+	+ + + +	1 + + + + +	++	++	+					
<i>Acalypha schinzii</i>				+++ +	++		++	++ +		++			
<i>Hypoxis multiceps</i>				+ + +	++++		++	++ +					
<i>Vernonia natalense</i>			++	+ + +	+		+ + + + + + +	+	+				
<i>Vernonia oligocephala</i>	+		+	+ + + +	++ +		++ + + + +	+	+	+			
<i>Digitaria tricholaenoides</i>	+			+ + 1 +	1 3	3	+	2+ 2+					
<i>Ipomoea crassipes</i>				+ +	+			+ +					
<i>Vernonia galpinii</i>				+			++	+		+			
<b>Species group O</b>													
<i>Lantana rugosa</i>				+			+ +		+	+++	+		
<i>Hypoxis rigidula subsp. pilosissima</i>										++			
<i>Pimpinella caffra</i>										++			
<i>Pentania prunelloides</i>								1		++			
<i>Hemizygia macrophylla</i>										++			
<i>Cissus cussonioides</i>										++			
<i>Cymbopogon validus</i>								+		++			
<i>Rhus dentata</i>										++			+
<i>Maytenus heterophylla</i>										+			
<i>Myrsiphyllum ramosissimum</i>										+			
<i>Helinus integrifolius</i>										+			
<i>Allophyllus melanocarpus</i>										+			
<i>Cheilanthes quadripinnata</i>										+			
<i>Hypoxis interjecta</i>										+			
<i>Gazania krebsiana</i>										+			
<i>Aloe maculata</i>										+			
<i>Jasminum breviflorum</i>										+			
<i>Cyphostemma natalitium</i>										+			
<i>Celtis africana</i>										+			
<i>Alectra orobanchoides</i>										+			
<i>Scolopia mundii</i>										+			
<b>Species group P</b>													
<i>Acacia caffra</i>							+						
<i>Ziziphus mucronata</i>										1	3+		
<i>Rhoicissus tridentata</i>										+	11		
<i>Leonotis leonurus</i>											++		
<i>Dais cotiniifolia</i>											++		
<i>Sphenostylis marginata</i>											+		
<i>Rubus rigidus</i>											+		
<i>Prosphytochloa prehensilis</i>											+		
<i>Gnidia caffra</i>											+		
<i>Acacia karroo</i>											1		
<i>Zinnia peruviana</i>											+		
<i>Sparmannia ricinocarpa</i>											+		
<i>Solanum retroflexum</i>											+		
<i>Rhus pyroides</i>											+		
<i>Opuntia ficus-indica</i>											+		
<i>Olea europaea</i>											+		
<i>Euclea crispa</i>											+		
<b>Species group Q</b>													
<i>Diospyros lycioides</i>					R		++R 1	+ 2		2R	2+		+
<i>Rhus rehmanniana</i>							+ +			2 1	1+		
<i>Euclea natalensis</i>										+	++		
<i>Melinis nerviglumis</i>										+	+		
<i>Cheilanthes viridis</i>										+	+		
<i>Cheilanthes hirta</i>										+	+		
<i>Barleria obtusa</i>										+	+		
<i>Protasparagus setaceus</i>										+	+		
<i>Rhus lucida</i>							+			+	+		
<i>Cussonia paniculata</i>										1	+		

Table 2 Continued

RELEVES	20	000012	01122	000100110	000000001	11	00000100000000001	12212212	22222	011	12	22222	12				
	27	367322	52755	677878232	222233363	77	8886315445886535	20531455	77888	588	85	14455	96				
	60	174305	45389	812439442	310924965	12	7855543982649108	79060891	89021	056	77	77923	54				
COMMUNITIES	1			2			3			4		5					
	1.1	1.2	1.3	2.1	2.2	2.3	3.1	3.2	3.3	4.1	4.2	5.1	5.2				
Species group R																	
<i>Eleusine indica</i>																	
<i>Tagetes minuta</i>									+			+					
<i>Verbena bonariensis</i>													321				
<i>Digitaria ciliaris</i>													++ ++				
<i>Chloris virgata</i>													++++				
<i>Commelina benghalensis</i>													32				
<i>Polygonum pulchrum</i>													3				
<i>Cyperus difformis</i>													+				
<i>Acacia dealbata</i>													+				
													4				
Species group S																	
<i>Cynodon dactylon</i>									+	+							
<i>Cyperus esculentus</i>													+				
<i>Ipomoea purpurea</i>													15				
<i>Hyparrhenia quarrei</i>							+	+					++				
													4				
Species group T																	
<i>Bidens pilosa</i>												+	1+ ++				
<i>Cleome monophylla</i>													++				
<i>Amaranthus hybridus</i>													+				
<i>Xanthium strumarium</i>													+				
Species group U																	
<i>Themeda triandra</i>		+3	2	34323	+13231433	322111333		133323233333	2 2	4	23	33	3+112	433	1		
<i>Eragrostis racemosa</i>		1		22+2	21+2+1121	1+222212+	23	++2+++2+++121		2	++	2	+				
<i>Eragrostis curvula</i>	4	1+	+	++ +	+ ++ +	++ ++ ++	+	+++++++ +1+1		+	+	+	++31			1	+
<i>Elyonurus muticus</i>		++		++	1+++++++	+12+++++	++	++2		+	+	+	++ +				
<i>Eragrostis plana</i>		1+2+	+	+ +3+		+ +	+			+	+	+	+++				+2+3
<i>Eragrostis capensis</i>		+		+	+	++	++	+++		+	+	+	1 +++				
<i>Sporobolus pyramidalis</i>		+ 1		+		+	++	+		+	+	+	++				+3+3
<i>Senecio erubescens</i>		+	++	++		++	+	+		+	+	+					
<i>Andropogon appendiculatus</i>		+	+	1		2	1	+	+	+	2	+	+	+			

*Monocymbium ceresiiforme*. The dominance of these species suggests that this community is transitional between communities 1 and 2.

2. The *Themeda triandra* - *Monocymbium ceresiiforme* Grassland

This community is representative of the vegetation in the Bb land types on non-rocky soils. The diagnostic species are given in species group I (Table 2), and include the grass species *Monocymbium ceresiiforme*, *Tristachya leucothrix*, *Trachypogon spicatus*, *Diheteropogon amplexans*, *Panicum natalense*, *Loudetia simplex*, *Urelytrum agropyroides*, *Allotheropsis semialata* and *Andropogon schirensis*. The most important diagnostic forbs are *Helichrysum miconiifolium*, *Hypoxis rooperi*, *Cyanotis speciosa*, *Hemizygia pretoriae*, *Graderia scabra*, *Elephantorrhiza elephantina*, *Senecio venosus*, *Sebaea sedoides*, *Gnidia kraussiana*, *Eriosema kraussiana* and *Clerodendrum triphyllum*.

The dominant grass species are *Themeda triandra*, *Eragrostis racemosa*, *Monocymbium ceresiiforme* and *Tristachya leucothrix*. These species are regarded as representative of fire climax communities (Tainton 1981).

Within this community a clear distinction between a community on deep, loamy soils (2.1) and two communities on shallow, sandy soils (2.2 and 2.3) is made.

2.1 The *Themeda triandra* - *Raphionacme hirsuta* Tall Closed Grassland

This community occurs on the Bb land type, in or near Chelmsford Dam Nature Reserve and near the foothills of the Low Drakensberg.

Most sample plots were situated on crests and midslopes. The soil properties in this community will be closest to

those given for the Avalon soil form, Normandien series (Table 1).

The diagnostic species are given in species group F (Table 2), of which the forbs *Raphionacme hirsuta*, *Helichrysum subluteum*, *Dicoma anomala*, *Polygala uncinata* and *Polygala amatymbica* are the species with the highest constancy.

The vegetation is dominated by the grass species *Themeda triandra*, *Monocymbium ceresiiforme*, *Tristachya leucothrix* and *Eragrostis racemosa*.

2.2 The *Themeda triandra* - *Oxalis obliquifolia* Low Closed Grassland

This community occurs on the Bb land type near Newcastle, or on the Bb land type, in or near the Chelmsford Nature Reserve. The shallowness of the soils in this community is due to the widespread occurrence of ferricrete ('oukclip'), and therefore the soil properties are similar to those of the Wasbank soil form, Warrick series (Table 1). The difference between this community and community 1.3 is that the latter occurs on much wetter, bottomland situations, in pans and marshes.

The diagnostic species of this community are given in species group G (Table 2), namely the forbs *Oxalis obliquifolia*, *Senecio affinis*, *Helichrysum oreophyllum* and the geophytes *Eulophia foliosa* and *Scilla nervosa*.

The most prominent species in the community are the grass species *Themeda triandra*, *Monocymbium ceresiiforme*, *Tristachya leucothrix* and *Trachypogon spicatus*.

2.3 The *Themeda triandra* - *Diheteropogon filifolius* Low Closed Grassland

This community occurs close to the town of Newcastle on shallow, sandy soils which correspond with the Wasbank



form, Warrick series (Table 1).

The diagnostic species are given in species group H (Table 2), and include the grasses *Microchloa caffra* and *Diheteropogon filifolius*. The occurrence of the latter species in this low-lying area is quite uncommon, as this grass species is normally found at higher elevations. Tainton (1981) stated that this species may become more dominant as a result of selective grazing. Diagnostic forbs are *Gnidia caffra*, *Stoebe vulgaris* and *Parinari capensis*.

The most prominent grasses are *Monocymbium ceresii-forme* and *Eragrostis racemosa*. The absence of *Themeda triandra* is also a conspicuous feature of this community.

### 3. The *Hyparrhenia hirta* – *Themeda triandra* Grassland

This grassland, the second of the two main grassland types found in the Bb land types, mostly occurs on rocky dolerite hills or as secondary climax communities (Tainton 1981), on disturbed areas such as abandoned ploughed fields or on sites of abandoned mine villages.

The dolerite-derived soils in community 3.1 are mainly of the Shortlands form and in community 3.2 of the Hutton form. Community 3.2 seems to be transitional between communities 2 and 3.

The diagnostic species include the grass *Hyparrhenia hirta*, the forbs *Chaetacanthus burchellii*, *Crabbea acaulis*, *Haplocarpha scaposa*, *Phyllanthus glaucophyllus*, *Rhynchosia totta*, *Cucumis zeyheri*, *Helichrysum rugulosum*, *Corchorus confusus*, *Eriosema cordata* and *Walafrida densiflora* (species group M, Table 2).

The community is dominated by the taller grass, *Hyparrhenia hirta*, and by *Themeda triandra*.

Three distinct communities were identified.

#### 3.1 The *Hyparrhenia hirta* – *Acalypha caperonioides* Tall Closed Grassland

This community occurs in three distinct habitats, namely on shallow soils, on abandoned ploughed fields and on rocky dolerite outcrops or hills. The rocky outcrops and dolerite hills include crests, midslopes and footslopes and the aspects are due south or north and do not seem to have an influence on the open grassland vegetation. The soil form identified here was mostly the Shortlands form, Shortlands series (Table 1).

The abandoned ploughed fields were mostly on deep, loamy soils of the Avalon and Hutton soil forms in the Chelmsford Nature Reserve. This area was declared a nature reserve 24 years ago, concluding that a secondary climax with the all-dominant *Hyparrhenia hirta* has been reached here.

The diagnostic species of this community are given in species group J (Table 2) and are all forbs, namely *Acalypha caperonioides*, *Hermannia depressa*, *Helichrysum coriaceum*, *Striga bilabiata*, *Eucomis autumnalis*, *Gerbera piloselloides*, *Berkheya setifera*, *Thesium costatum*, *Moraea natalense*, *Lactuca capensis*, *Thunbergia atriplicifolia*, *Conyza obscura*, *Berkheya onopordifolia* and a *Raphionacme* species.

The community is dominated by the grass species *Hyparrhenia hirta* and *Themeda triandra*. Game in the Chelmsford

Nature Reserve graze selectively and heavily on *Themeda triandra* which is the only palatable grass species of significance in this community.

#### 3.2 The *Hyparrhenia hirta* – *Setaria sphacelata* Tall Closed Grassland on dolerite soils and disturbed sites

Two distinct habitats are recognized in this community, namely the rocky doleritic derived soils and the abandoned ploughed fields and disturbed sites.

Most of the doleritic derived soils are of the Hutton form and according to the clay content, of the Farningham series (Table 1), which is dystrophic in the B horizon (MacVicar *et al.* 1977). Water retentivity is moderate, exchangeable cations quite low and the soil is strongly acidic.

All relevés were recorded on crests, midslopes and footslopes, the slopes facing east or north-east. The rockiness on the surface varies from 10 to 75%, and in size from rocks to gravel (Smit 1992). The disturbed communities occur on abandoned ploughed fields, in deserted mine villages and at the edges of wattle groves.

The soil profile was disturbed in the ploughed fields and can best be described as sand on soft plinthite, presumably of the Longlands form. Sample plots in the mine villages were on exposed ferricrete, while the others were on the Avalon soil form, Normandien series (Table 1).

The diagnostic species of this community are given in species group K (Table 2) and include the grasses *Setaria sphacelata*, *Aristida congesta* subsp. *barbicollis* and *Melinis repens* (the latter two species reveal the disturbed nature of this community), and one shrub species *Grewia hispida*.

The community is dominated by the two grasses *Hyparrhenia hirta* and *Themeda triandra*. The occurrence of a 'Low Closed Grassland' in some sample plots is due to the absence of the tall *Hyparrhenia hirta*. As is the case in community 3.1, *Themeda triandra* is selectively and heavily grazed.

#### 3.3 The *Themeda triandra* – *Helichrysum coriaceum* Low Closed Grassland

This community is characterized by the absence or sparse occurrence of the diagnostic species of community 3.2. The forb *Helichrysum coriaceum* is the only diagnostic species (species group L, Table 2). All relevés were compiled in the Bd land type, on crests, mid- and footslopes, which differs in several aspects from the Bb land types of the study area. It is situated at a much higher altitude (1500 – 1600 m, Figure 2), in Bioclimatic Group 8, which is much drier than Bioclimatic Group 6 (Phillips 1973), in which the Bb land types of the study area are situated (Smit 1992).

The soils belong mostly to the Cartreff form, Arrochar series (Table 1). These soils are sandy and moderately acidic and the total exchangeable cations are not high. Water retentivity is fairly low and resistance moderately high, indicating the presence of a fair amount of salts due to low leaching.

*Themeda triandra* is the most prominent grass and *Helichrysum coriaceum* and *Helichrysum rugulosum* are the dominant forbs. The floristic and ecological relationships between communities 2 and 3 are mediated by species group M.

#### 4. The *Rhus rehmanniana* – *Diospyros lycioides* subsp. *lycioides* Woodland

The diagnostic species are given in species group Q (Table 2), of which *Rhus rehmanniana* and *Euclea natalensis* are the most prominent and manifest themselves as shrubs or small trees. It is believed that the rocks protect young trees against fire and supply protection against the cold winter nights. *Cussonia paniculata* is normally present in these communities, and the lower stratum is characterized by species such as the forb *Barleria obtusa*, the ferns *Cheilanthes hirta* and *Cheilanthes viridis* var. *viridis* and the grass *Melinis nerviglumis*.

The habitat is very rocky dolerite hills and the lithosols are shallow. Where the soil could be sampled, the shallow Hutton and Shortland forms were mostly identified. It seems as though these communities on the rocky dolerite hills in the Bb land type are related to those of the Ea land type (Smit 1992).

#### 4.1 The *Rhus rehmanniana* – *Lantana rugosa* Low Closed Woodland

This community is associated with gentle to steep east-facing slopes of rocky dolerite hills. Most relevés were recorded on the rocky slopes of the Ngagane River valley.

The diagnostic species of this community are given in Table 2 as species group O and include the shrub *Lantana rugosa* and forbs *Hypoxis rigidula* var. *pilosissima*, *Pimpinella caffra*, *Pentanisia prunelloides*, *Hemizygia macrophylla*, *Cissus cussonioides*, and the grass *Cymbopogon validus*. The woody component consists of *Rhus dentata* and *Maytenus heterophylla*, normally found on rocky doleritic hills.

The most prominent grass is *Themeda triandra*, a prominent shrub is *Lantana rugosa* and the woody vegetation is dominated by *Diospyros lycioides* subsp. *lycioides* and *Rhus rehmanniana*.

#### 4.2 The *Acacia caffra* – *Ziziphus mucronata* Low Forest

This community occurs on the Bb land type on the edge of the ravine in which the Ngagane River flows, facing south-east, or on steep doleritic south-western slopes adjacent to the Bd land type. Both areas are extremely rocky and the woody component in both is dominated by *Acacia caffra*, which are of the largest trees in the area, with spreading crowns.

Diagnostic species appear in species group P (Table 2), of which the woody component includes *Acacia caffra*, *Ziziphus mucronata*, *Dais cotinifolia*, *Acacia karroo*, *Olea europaea* subsp. *africana* and *Euclea crispa*, with the liana *Rhoicissus tridentata*. The forbs listed are *Leonotis leonurus* and *Solanum retroflexum*, shrubby species are *Sparmannia ricinocarpa* and *Rubus rigidulus*, as well as the forest grass *Prosphytochloa prehensilis*.

Edwards (1967) also found *Acacia caffra* communities to occur on dolerite-derived soils on rocky south-facing slopes, but mentioned that they are also found on other soil types and slope aspects. He also stated that, along the Low Drakensberg, *Acacia caffra* Scrub grades into Mountain *Podocarpus* Forest.

#### 5. The *Bidens pilosa* Disturbed Grassland

Most of the sample plots in this community are at disturbed sites such as the edges of maize fields or other crops, at farm gates and in *Acacia dealbata* forests. The natural vegetation has mostly been destroyed and therefore this can be regarded as a secondary community.

The diagnostic species of this community are given in species group T (Table 2) and include the forbs *Bidens pilosa*, *Cleome monophylla*, *Amaranthus hybridus* and *Xanthium strumarium*. No species seem to be dominant in the community as a whole, but in community 5.1 a number of grass species are dominant, such as *Sporobolus pyramidalis*, *Eragrostis plana* and *Eleusine indica*. Community 5.2 is dominated by *Cynodon dactylon*.

#### 5.1 The *Eragrostis plana* – *Eleusine indica* Disturbed Grassland

This community occurs on disturbed areas, adjacent to crop fields or at farm gates and in *Acacia dealbata* forests.

The analytical data of the Avalon soil form, Ruston series, are given in Table 1.

The diagnostic species of this community appear under species group R (Table 2), of which the most important are the grasses *Eleusine indica* and *Digitaria ciliaris* and the forbs *Tagetes minuta* and *Verbena bonariensis*. Other diagnostic species of single occurrence are the grass species *Chloris virgata*, the forbs *Commelina benghalensis*, *Polygonum pulchrum*, the sedge *Cyperus diffusa* and the alien tree, *Acacia dealbata*.

#### 5.2 The *Cynodon dactylon* – *Cyperus esculentus* Disturbed Grassland

This community occurs at the edges of maize fields in the Bb land type.

The soil was identified as the Shortlands form, Shortlands series (Table 1).

The diagnostic species are given in species group S (Table 2) and include the tall grass *Hyparrhenia quarrei* and the very short pioneer grass *Cynodon dactylon*, the sedge *Cyperus esculentus* and the exotic climber *Ipomoea purpurea*.

*Hyparrhenia quarrei* is the dominant grass in the outer zone which is structurally classified as 'Tall Closed Grassland' and the inner zone is dominated by *Cynodon dactylon*, and its vegetation structure therefore conforms to 'Short Closed Grassland' (Edwards 1983).

#### Concluding remarks

The results of a TWINSpan classification were successfully refined by means of Braun-Blanquet procedures (see also Behr & Bredenkamp 1988; Bredenkamp *et al.* 1991). The recognized plant communities are considered to be ecologically interpretable, as each is indicative of specific environmental conditions.

The results of this phytosociological study should be incorporated with those of the Ea, Ac, Fa, Ad and Ca land types within the study area, as well as with the results of compatible studies by other workers in the Grassland Biome. This will enable the compilation of a much needed hierarchical syntaxonomy of the vegetation of the north-

western part of Natal and the adjacent part of the Orange Free State.

At present there exists a need for research into management programmes which will suit the specific conditions of the three climatic regions (Mountain Regions, Plainlands and Bioclimatic Group 8, including the Orange Free State area) (Smit 1992) of the study area. As this study is the first of its kind in this area, it could be used as a basis for formulating conservation policies and management principles, based on the ecologically sound plant communities identified in this area.

## References

- ACOCKS, J.P.H. 1953. Veld types of South Africa, 1st. edn. *Mem. bot. Surv. S. Afr.* No. 28: 1 – 192. Government Printer, Pretoria.
- ACOCKS, J.P.H. 1988. Veld types of South Africa, 3rd. edn. *Mem. bot. Surv. S. Afr.* No. 57: 1 – 146. Government Printer, Pretoria.
- BEHR, C.M.J. & BREDEKAMP, G.J. 1988. A phytosociological classification of the Witwatersrand National Botanic Garden. *S. Afr. J. Bot.* 54: 525 – 533.
- BEZUIDENHOUT, H. 1988. 'n Plantsosiologiese studie van die Mooirivier opvanggebied, Transvaal. M.Sc. thesis, Potchefstroom University for C.H.E., Potchefstroom.
- BREDEKAMP, G.J., BEZUIDENHOUT, H., BOSCH, O.J.H. & JANSE VAN RENSBURG, F.D. 1991. A comparison of vegetation classifications from wheel point and total floristic data sets from a South African grassland. *Bot. Bull. Acad. Sinica* 32: 187 – 195.
- BREDEKAMP, G.J. & THERON, G.K. 1978. A synecological account of the Suikerbosrand Nature Reserve I. The phytosociology of the Witwatersrand geological system. *Bothalia* 12: 513 – 529.
- BREDEKAMP, G.J. 1982. 'n Plantekologiese studie van die Manyeleti Wildtuin. D.Sc. Thesis, University of Pretoria, Pretoria.
- EDWARDS, D. 1967. A plant ecological survey of the Tugela Basin. *Mem. bot. Surv. S. Afr.* No. 35: 1 – 285. Town and Regional Planning Commission, Natal.
- EDWARDS, D. 1983. A broad-scale classification of vegetation for practical purposes. *Bothalia* 14: 705 – 712.
- GIBBS RUSSELL, G.E., REID, C., VAN ROOYEN, J. & SMOOK, L. 1985. List of species of southern African plants, edn. 2, Part 1. *Mem. bot. Surv. S. Afr.* No. 51: 1 – 152. Government Printer, Pretoria.
- GIBBS RUSSELL, G.E., WATSON, L., KOEKEMOER, M., SMOOK, L., BARKER, N.P., ANDERSON, H.M. & DALLWITZ, M.J. 1990. Grasses of Southern Africa. *Mem. bot. Surv. S. Afr.* No. 58: 1 – 437. Botanical Research Institute, Pretoria.
- GIBBS RUSSELL, G.E., WELMAN, W.G., RETIEF, E., IMMELMAN, K.L., GERMISHUIZEN, G., PIENAAR, B.J., VAN WYK, M., NICHOLAS, A., DE WET, C. MOGFORD, J.C. & MULVENNA, J. 1987. List of species of Southern African plants, edn. 2, Part 2. *Mem. bot. Surv. S. Afr.* No. 56: 1 – 270. Government Printer, Pretoria.
- HILL, M.O. 1979. TWINSpan – a FORTRAN program for arranging multivariate data in an ordered two-way table by classification of individuals and attributes. Cornell, New York.
- LAND TYPE SURVEY STAFF. 1984. Land types of the maps 2522 Bray, 2622 Morokweng, 2524 Mafeking, 2624 Vryburg. *Mem. agric. nat. Resources S. Afr.* No. 1: 1 – 281.
- LAND TYPE SURVEY STAFF. 1990. Geological, climatological and soil analyses data for the 2728 Frankfort land type map. Computer print-out, Soil and Irrigation Research Institute, Pretoria.
- MACVICAR, C.N., LOXTON, R.F., LAMBRECHTS, J.J.N., LE ROUX, J., DE VILLIERS, J.M., VERSTER, E., MERRYWEATHER, F.R., VAN ROOYEN, T.H. & HARMSE, H.J. von M. 1977. Soil classification, a binomial system for South Africa. Department of Agricultural Technical Services, Pretoria.
- MENTIS, M.T. & HUNTLEY, B.J. 1982. A description of the Grassland Biome Project. Cooperative Scientific Programme, Council for Scientific and Industrial Research, Report No. 62. Graphic Arts Division of the CSIR, Pretoria.
- MUELLER-DOMBOIS, D. & ELLENBERG, H. 1974. Aims and methods of vegetation ecology. Wiley, New York.
- PHILLIPS, J. 1973. The agricultural and related development of the Tugela Basin and its influent surrounds. A study in Subtropical Africa. Natal Town and Regional Planning Report, Vol. 19. Town and Regional Planning Commission, Natal.
- SCHEEPERS, J.C. 1986. Grassland Biome Project: Proceedings of the workshop on classification and mapping. Ecosystems Programmes Occasional Report Series No. 16, CSIR, Pretoria.
- SCHULZE, R.E. 1982. Agrohydrology and -climatology of Natal. Agricultural Catchments Research Unit, Report No. 14. Department of Agricultural Engineering, University of Natal, Pietermaritzburg, South Africa.
- SMIT, C.M. 1992. Phytosociology of the Newcastle – Memel – Chelmsford Dam area. M.Sc. Thesis, University of Pretoria, Pretoria.
- TAINTON, N.M. 1981. Veld and pasture management in South Africa. Shuter & Shooter, Pietermaritzburg; in association with the University of Natal, Pietermaritzburg.
- VAN DER EYK, J.J., MACVICAR, C.N. & DE VILLIERS, J.M. 1969. Soils of the Tugela Basin: a study in subtropical Africa. Natal Town and Regional Planning Reports, Volume 15. Town and Regional Planning Commission, Natal.
- VISSER, H.N. & BISHOPP, D.W. 1976. The geology of the Newcastle and Dundee areas and a detailed description of the Klip River Coalfield of Northern Natal: Explanation of the sheets 2729D (Newcastle), 2730C (Utrecht) and 2829B (Elands-laagte), 2830A (Dundee). Geological Survey, Department of Mines, South Africa.
- WEATHER BUREAU. 1990. Climatological data for 1987 – 1990 for the Newcastle weather station. Computer printout, Weather Bureau, Pretoria.
- WESTHOFF, V. & VAN DER MAAREL, E. 1987. The Braun-Blanquet Approach. In: Classification of Plant Communities, ed. R.H. Whittaker. Junk, The Hague.