GRASSLANDS OF UMTAMVUNA NATURE RESERVE, KWAZULU-NATAL: A DESCRIPTION AND RECOMMENDATIONS FOR MONITORING

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GRASSLANDS OF UMTAMVUNA NATURE RESERVE, KWAZULU-NATAL :

A DESCRIPTION AND RECOMMENDATIONS FOR MONITORING

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DECLARATION

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I Noel Peter le Roux declare that the work contained in this thesis is entirely

my own work, unless specifically acknowledged, referenced or quoted in the

text.

NP le Roux   December 1995

CONTENTS

PREFACE

This project was an effort to contribute towards the classification of grasslands of the coastal belt of KwaZulu-Natal. The Umtamvuna Nature Reserve (UNR) was considered an appropriate study site because no classification or map of the vegetation communities of the UNR has yet been produced, despite its reputation as a centre of endemism and its high floral diversity. Also, no monitoring of change, especially in relation to the impact of fire, has been undertaken.

The classification and monitoring reported on in this study could have been approached as 'standard, recipe-based' descriptive project, which would have produced quick results. However, too little attention has been paid to the efficiency of techniques and this shortcoming was addressed as part of the study. The map that was produced as a result of the study could have been more detailed, but I was aware of the need for a practical product at a scale that was appropriate for use by reserve managers and conservation planners. However, the detail that is not reflected is not lost, because the data are stored in a data base which could be added to and the TWINSPAN analysis could be used to produce a finer resolution, if needed. The approach towards monitoring deviated from the popular point based methods advocated over the past ten years, but the exceptionally high species diversity of the UNR, as well as the need to monitor both at the species and community levels, required a more pragmatic approach.

ABSTRACT

The main aim of this study was to classify and map the threatened coastal grassland communities of the 3 257 ha Umtamvuna Nature Reserve (UNR) in KwaZulu-Natal (30°07'30" to 30°11'05"E; 30°55'00" to 31°04'30"S). Secondary aims were to relate past management and selected environmental variables to community composition and to develop guidelines for monitoring.

Alpha diversity was measured using a Whittaker plot and revealed 119 species. A pilot study to test the efficiency of botanical techniques showed that a point based technique (nearest plant method in a 20 X 20 m plot) was efficient (52 minutes for recording 200 points), but recorded only 23% of the species. By increasing the number of points to six hundred, 34% of the species were recorded in 178 minutes; the same time was required to randomly place 30 quadrats (50 X 50 cm), which revealed 80% of the species. Tests for replicate similarity showed a high retrieval of internal association (PS = 86%), using abundant species only and 100 points per plot. The point based technique was thus efficient in detecting abundant species and was acceptable for producing a classification, especially in this case where a comprehensive species list already existed.

Indirect gradient analysis (TWINSPAN) identified six grassland communities. An ordination using detrended correspondence analysis (DCA) contributed towards the community classification and grazing and fire frequency gradients were inferred from this ordination. *Protea roupelliae* communities were common but did not influence grass species composition. Canonical ordination

revealed that, of the eight environmental variables measured, 'distance from the sea' strongly affected species distribution ($r = 0.83$).

Cost effectiveness was considered in the development of a monitoring programme. Point based monitoring techniques favoured by sourveld researchers in KwaZulu-Natal were found to be inefficient, particularly for studies requiring the measurement of both species richness and community composition. Randomly located 100 X 100 cm quadrats, located in selected sites which represent previously identified communities, was more efficient.

This study contributed towards a refinement of information on the grassland communities of KwaZulu-Natal and supported the use of point data for the classification of grasslands not previously studied. It also demonstrated that point based techniques were not suitable for meeting all grassland monitoring requirements.

ACKNOWLEDGEMENTS

CHAPTER 1   INTRODUCTION

1.1   Rationale

Many descriptions of southern African vegetation communities have been
produced over the past 70 to 75 years. Some classifications, such as that of
Acocks (1953), covered most of southern Africa and were consequently
mapped at an appropriately small scale (1:1 500 000). In the province of
KwaZulu-Natal (Figure 1.1) many local vegetation descriptions have been
undertaken, *inter alia* by Bews (1920), Aitken & Gale (1921), Pentz (1949),
Woods & Moll (1967), Edwards (1967) and Phillips (1973). These descriptions
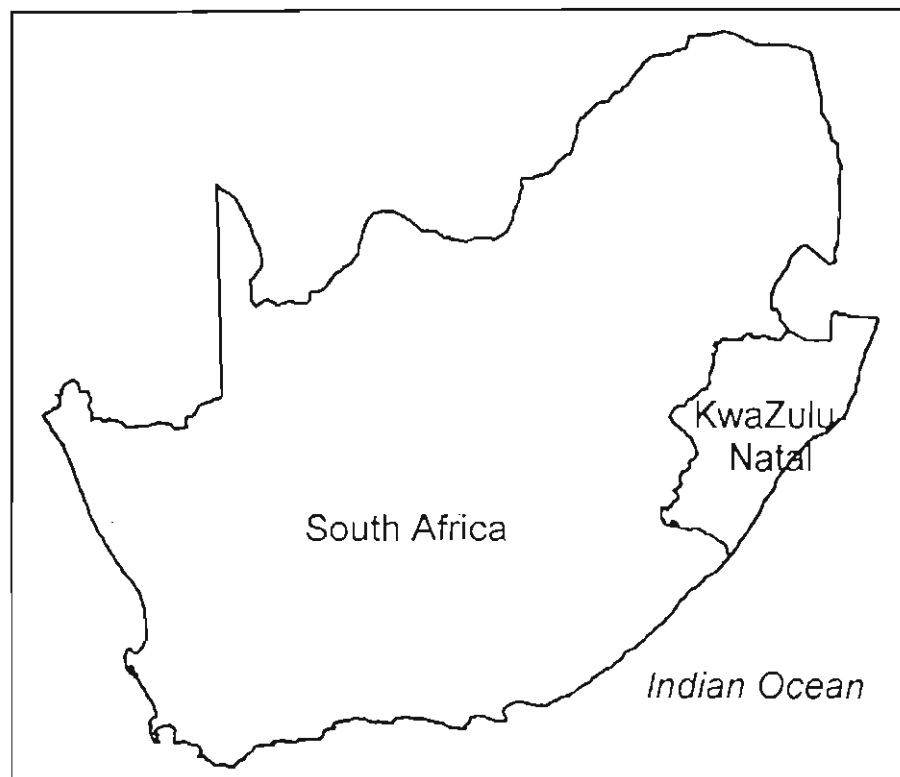
Figure 1.1   Geographic location of the province of KwaZulu-Natal, South
              Africa.

In a review of grassland classifications undertaken in KwaZulu-Natal, Tainton (1984) noted that little effort had been made to refine the components of previous classifications; he also noted that the few refinements that had been produced were poorly co-ordinated and lacked compatibility and concluded that a standardised approach was needed. This comment pointed to a need to plan future descriptive work on grassland communities within an appropriate framework. Woods & Moll (1967) claimed that this could be achieved through addressing key questions such as "What are the objectives of the study?; what descriptive information is lacking?; and what methods are appropriate?". The first and second questions are discussed below, as part of the justification for this study, while the third is explored under the relevant chapter on methods. The criterion of scale is also addressed.

1.2   Objectives

Scheepers (1985) claimed that the overall objective for descriptive work on grasslands was to develop an understanding of "community structure", in order to predict the effects of various perturbations on the grasslands. The studies described below were undertaken with this overall objective in mind. The primary objectives of this study were to produce a classification of the grasslands of the Umtamvuna Nature Reserve (UNR) and to investigate the effects of past management and selected environmental variables on community composition. This constitutes a refinement of previous work on the vegetation of the coastal belt of KwaZulu-Natal (Conlong 1986; Conlong & Van Wyk 1991). Secondary objectives were to:

(a)   become proficient in the classification of coastal grassland

communities;

(b)   provide a map of the grasslands of Umtamvuna Nature Reserve, at an appropriate scale for users such as conservation managers and researchers;

(c)   develop an appropriate monitoring programme to detect temporal change; and

(d)   identify further research on coastal grasslands.

An attempt was made to follow the guidelines of Scheepers (1985), who recommended that vegetation research should address the needs of the end user, make use of robust techniques, evaluate cost effectiveness and ensure that the work constitutes an improvement on existing knowledge.

1.3   Current information on grasslands of KwaZulu-Natal

The impressive record of research on grasslands in southern Africa has, to a large extent, been driven by a need to address grazing management issues because the rangeland resource is widely utilised for the production of domestic livestock, both at the commercial and subsistence levels. Examples of research topics are: (a) improving the management of rangeland for increased production of livestock and/or game (Venter 1969; Mentis & Tainton 1981; Collinson 1982; Boonzaaier & Collinson 1985; Hatch & Tainton 1990); (b) assessment of rangeland condition (Foran *et al.* 1978; Tainton *et al.* 1978; Tainton 1982; Mentis 1983; Heard *et al.* 1986; Hurt & Hardy 1989; Hurt & Bosch 1991); (c) measurement of animal performance on rangelands (Tainton 1982; Turner & Tainton 1989; Barnes & Denny 1991; Owen-Smith

3

1991); (d) the concepts of ecological groups and indicator species (Tainton 1982; Everson 1985; Everson & Clarke 1987; Hurt & Hardy 1989); and (e) the effects of fire on rangelands (Tainton *et al* 1978; Scotcher & Clarke 1981; Everson & Tainton 1984). Aspects of grassland research have, however been criticised. In a review of grazing management recommendations in South Africa, O'Reagain & Turner (1992) argued that untested hypotheses had been assimilated into accepted theory and they recommended that more basic research was needed to increase our understanding of rangeland ecosystems and their responses to management.

A general comment on the literature dealing with the description of grasslands in South Africa was made by Fuls (1992), who noted that research of a descriptive nature is considered by some academics as being "...second-rate research, contributing nothing new to vegetation science". I support the opposite view, expressed by Scheepers (1985) and Fuls (1992), namely that classification and inventory are fundamental components of research and contribute meaningfully towards understanding the structure and dynamics of plant communities. Such understanding also facilitates the prediction of the effects of various forms of land use on plant communities and their component species. This is considered to be a fundamental requirement for responsible management of veld in protected areas.

Despite the wealth of literature covering research into the management of rangelands in KwaZulu-Natal, relatively few detailed descriptive studies have been undertaken, eg. Killick (1958), Conlong (1986) and Walker (1988b). Grasslands of the coastal region have received little attention with respect to

4

descriptive studies or research on rangeland management. The main contributors to local descriptive work have been Conlong (1986) and Conlong & Van Wyk (1991), who produced a classification of the Eastern Shores grasslands in the St Lucia region; McKenzie (1987), who assessed species richness and composition of grasslands near Umtata, Eastern Cape; and Shackleton (1989) and Shackleton *et al.* (1991), who described the grasslands of the Mkambati Nature Reserve in the Eastern Cape Province (formerly Transkei). Other descriptive work, such as the classification of the area between the Mvoti and Lovu rivers, (Woods & Moll 1967) was at a small scale and was derived from very few samples. Some work on changes to the grasslands in the coastal dunes north of Richards Bay was done by Weisser (1978) and Weisser & Marques (1979). According to Tainton (1984), the most widely used vegetation description is that of Acocks (1953) which is unchanged in subsequent revisions, the latest being 1988. In this work the vegetation of the whole of the coastal belt of KwaZulu-Natal was classified as "Veld Type 1a: *Typical Coast-belt Forest in Natal and the Transkei*". A small area in KwaZulu-Natal and southwards to the Eastern Cape was classified as "Veld Type 3: *Pondoland Coastal Plateau Sourveld*". These veld types correspond with Phillips's "Bioclimatic Region 1: *Coast Lowlands*" (Phillips 1973). Apart from the huge areas covered, Acocks's and Phillips's maps are also dated because widespread land transformation has occurred over the past 30 to 40 years, mainly as a result of timber and sugar cane farming (Scheepers 1983).

The coastal grassland communities have been inadequately investigated because (a) they produce low quality forage and therefore have low potential

5

for livestock production (Tainton 1982); (b) the remnants are fragmented and relatively small; and (c) perceptions as to the potential value of the grasslands have been negative (Acocks 1953). These observations are examined in detail below.

1.3.1 Forage quality

The grasslands of the coastal belt have been identified as having a lower capacity for sustained high-level animal production than the cool, moist rangelands of the adjacent interior and drier thornveld to the north (Phillips 1973; Tainton 1982; Acocks 1988). Despite this, coastal grasslands are widely utilised as rangeland, although they are probably of more value to communal farmers than to commercial livestock producers. In parts of KwaZulu-Natal, and much of the Eastern Cape, coastal grasslands are part of a communal grazing system that supports significant numbers of cattle all year round, despite having been subjected to uncontrolled grazing for decades (McKenzie 1984; Forbes & Trollope 1991). The graziers perceive the value of the grassland to be high, as they depend on it to feed their livestock (McKenzie 1984). Another use for coastal grasslands was recognised by Shackleton (1989), who noted that the coastal grasslands of the northern Transkei supported certain wild herbivore species at densities similar to those found in the high altitude, cool moist grasslands.

1.3.2 Fragmentation and size

Most of the grassland communities in the coastal area have been transformed,

primarily for production of sugar cane, bananas and timber (Moll 1987). This has resulted in a significant reduction in the extent of these grasslands, the remnants of which contribute very little towards the total extent of rangelands in KwaZulu-Natal. Consequently, little research has been conducted into rangelands in the coastal region, although much work has been done on assessing the suitability of the land for various forms of cultivation, such as timber production (van der Zel 1989). Many of the smaller grasslands were not delineated in earlier classifications and in some cases, have been considered as part of another vegetation type (Acocks 1953; Scheepers 1985). It is recognised that the smaller components of a particular community are likely to be overlooked in any classification where these components are too small to meet the predefined criterion of a mappable unit (Panagos 1995). However, the size of the mappable unit has in most cases been subjectively determined, which may lead to inconsistencies in the level of attention paid to different vegetation types. Size is also important for long-term conservation of biodiversity and ecological processes within remnants of a particular habitat. Current trends in nature conservation are towards the protection of sites and areas that are poorly represented outside of formally protected areas, in which case the remnants of coastal grassland would qualify as a rare community.

1.3.3 Negative perceptions

The grassland component of the east coast's vegetation has been virtually ignored in the literature, eg. it was classified as part of the 'Coast-belt Forest' by Acocks (1953). Rutherford & Westfall (1986) classified the entire coastal

area as 'subtropical lowland forest'. Acocks (1953) may have inadvertently discouraged research into coastal grasslands by describing the grasslands of his Veld Type 1 as "...secondary grasslands successional to forest.". Edwards (1967) also contributed towards this perception when he noted in his study of the Tugela River Basin, that the only grasslands in the coastal region below 500 m.a.s.l. were "...old lands successional to scrub forest.". Similarly, in their work on the grassland biome, Mentis & Huntley (1982) described the humid coastal grasslands as "...fire climax or false grasslands which are seral to forest.". It is not disputed that the coastal grasslands have the potential to become invaded by woody plants in the absence of fire. However it could be argued that similar conditions prevail in other areas which are also classified as 'false' (fire-maintained) grasslands, yet are not regarded in the literature as potential forests. For instance, Everson (1985) noted that in the Drakensberg grasslands, fire was not likely to have been excluded from extensive tracts of grassland for sufficiently long periods to have allowed overall dominance by woody communities. The same could be said of the coastal grasslands, ie. whether fires were man-induced or naturally ignited, it is probable that these grasslands have been maintained by fire for centuries and are therefor older than popularly believed (McKenzie 1987; Shackleton 1989). Feely (1987) supported this argument by examining evidence of early human settlement and farming practices. He concluded that the eastern grasslands were probably far older and more stable (ie. not anthropogenically derived) than was proposed by Acocks (1953). Similarly, Ellery & Mentis (1992) refuted Acocks's claims through collating palaeobotanical, archaeological and other evidence which showed that most grasslands in South Africa were ancient.

8

Despite his adherence to the forest-climax hypothesis, Acocks (1953) made an exception in the case of grasslands of Veld Type 3: *Pondoland Coastal Plateau Sourveld*, which he considered as a separate entity; he described these grasslands as "...dense and vigorous...", and noted that they were an important transitional area between Fynbos, Transvaal Highveld and subtropical vegetation types. This appears to be inconsistent, especially if it is considered that all the humid coastal grasslands of the eastern seaboard fit the "...dense and vigorous..." description.

It was concluded that research into coastal grasslands has been inadequate because of the emphasis placed on grasslands that have value for commercial livestock production. This has resulted in (a) a poor understanding of the dynamics of coastal grasslands, (b) ignoring their substantial contribution as rangeland to communal graziers and (c) underrating their conservation value.

1.4   Conservation of grasslands

An examination of the past ten years' publications by the Grassland Society of Southern Africa revealed only three papers dealing with the conservation of a particular habitat/system; a further seven dealt with the effects of fire on conserved grasslands and two with the classification of conserved grasslands. The conservation of grasslands in KwaZulu-Natal has been addressed through a variety of topics, such as: mountain catchments, in terms of their importance for water production (Everson 1985; Walker 1988a); vegetation and soil dynamics (Venter *et al.* 1989; Conlong & van Wyk 1991; Nott 1991); and management and classification of rangeland utilised by wild herbivores

(Conlong 1986; Shackleton *et al.* 1991). In an assessment of the status of vegetation conservation in South Africa, Scheepers (1983) recorded that only 21 319 ha (or 0.6%) of the low-altitude eastern portion of grasslands was under formal conservation. It is generally accepted that most of the areas not under conservation have been transformed through intensive land use and that the remaining grasslands have been severely degraded through poor veld management or other forms of human-related disturbance (Moll 1987).

Descriptive and ecological studies of the coastal grasslands of KwaZulu-Natal have not addressed the issue of diversity, although some comment was made by Weisser (1978), and also for the Umfolosi Game Reserve by Venter *et al.* (1989) and the Transkei by McKenzie (1987). Qualitative work on species, with emphasis on taxonomy and rare and/or endemic species and communities was done by Abbott (undated) and Van Wyk (1979). Conservation of grasslands on private or communal land is generally a low priority for land users. It has been argued that the issue of sustainability of certain forms of land use (such as grazing) is of secondary importance to pastoralists, outweighed by short-term profit as the primary motive (Mentis & Tainton 1981). Even in subsistence grazing situations, the 'tragedy of the commons' hypothesis states that the communally owned resource is eventually depleted through over-utilisation (Hardin 1968). Generally, conservation of grasslands has been a low priority, even by those who depend upon them as a resource. Most of the loss of grassland in KwaZulu-Natal has occurred as a result of modern agriculture, with the pace of loss having increased recently with the rapid growth in the timber industry.

1.5   Scope of the study

Differences in the indigenous vegetation of the coastal belt have been attributed to the major geological features occurring to the north and south of the Tugela River (Rutherford & Westfall 1986; Conlong & Van Wyk 1991; Maud 1991). This major river system marks the southern limit of the Zululand (or Mocambique) Coastal Plain, which is at its narrowest point close to the Tugela River, and gradually widens northwards (King 1972; Hobday & Orme 1977). To the north of the Tugela River, the major geological features underlying the grasslands are deep Quaternary yellow sands and recent wind-blown sands (Wolmarans & Du Preez 1986). The northern grasslands have been reported on by workers such as Campbell (1969), Weisser (1978), Conlong (1986) and Conlong & Van Wyk (1991).

To the south of the Tugela River, grasslands occur on shallow soils derived from sandstones of the Natal Group and to a lesser extent on granite derived soils or the deep, compacted red and yellow sands of the Berea Formation (Thomas 1988). A major distinction to the south of the Tugela River is that the coastal area forms a relatively narrow belt which rises steeply westward to the Natal Group Sandstone plateaus, at altitudes ranging from 90 to 500 m.a.s.l. The differences in geological formations and associated topographic features, combined with historic land-use activities, are the major factors influencing vegetation differences to the north and south of the Tugela River (Weisser & Marques 1979; Conlong & Van Wyk 1991). Rutherford & Westfall (1986) supported this rationale in their proposal that nomenclature for biomes should be standardised. In the context of the Tugela split, they used the term

"...subtropical lowland forest...", south of the Tugela and "...tropical lowland forest...", for areas to the north.

1.6   The Umtamvuna Nature Reserve

The Umtamvuna Nature Reserve (UNR) was considered to be suitable for initiating detailed descriptive work on the grasslands south of the Tugela River. The criteria considered in the selection process were the following.

a)   Size. The UNR contains the largest representative remnant of a coastal grassland community south of the Tugela River. Descriptive work on this area could therefore contribute significantly towards a refinement of earlier broad scale descriptive work.

b)   Rarity. It is likely that a remnant of a rare community is represented within the reserve, namely Acocks Veld Type 3, which is one of the smallest grasslands in South Africa. In the 1:1 500 000 map by Acocks (1988) this veld type covered only 76 500 ha, of which 72% occurred in the former Transkei (Eastern Cape) and 18% in KwaZulu-Natal. The last representative fragments of Veld Type 3 probably occur within the UNR, because the remainder is either under cultivation (mainly timber, sugar cane and bananas), or annual cropping and continuous grazing at high stocking rates.

c)   Species diversity. The UNR has a reputedly high plant diversity and is a centre of endemism, which is attributed to the overlap of Fynbos, Transvaal Highveld and subtropical vegetation types (Hilliard 1983; Van Wyk 1979; Acocks 1988).

d)   Lack of descriptive information. Despite considerable plant collecting

12

activity in the UNR, no vegetation map or quantitative description of the plant communities has yet been produced.

e) Access to specimens. The well managed herbarium (with >1300 species) provided sufficient reference material for identification of local flora.

f) Representativeness. Although the parent materials and soils underlying the coastal grasslands vary, many of the larger remnants appear to be associated with the sandstones that are common in KwaZulu-Natal. This would make the findings of the study (including most suitable techniques) applicable to both the UNR and other grasslands of the coastal region.

In conclusion, the UNR was considered to be of a suitable size with a sufficiently reliable foundation of known history and botanical support (such as the well managed herbarium) to meet the objectives of this study. The main products, namely a grassland map and a procedure for monitoring of the grasslands, would contribute towards meeting the management needs, especially for assessing the effects of prescribed burning on the maintenance of the grassland communities.

CHAPTER 2   DESCRIPTION OF THE STUDY AREA

2.1   Size and location

The Umtamvuna Nature Reserve is long and narrow and spans 18.2 km east-to-west, while its width ranges from 300 to 4400 m. The total area covered is 3 257 ha. The reserve lies 230 km south of Durban on the north bank of the Umtamvuna River (Figure 2.1). The geographic co-ordinates are $30^0 09'S$; $31^0 00'E$, and the boundaries are the Umtamvuna River to the south and cultivated farmlands to the north.

2.2   Topography, geology and soils

Three main topographic features were identified, namely gently undulating plateaus, stepped sandstone outcrops and steep-sided valleys. Aspect and associated drainage are predominantly south- and south-westerly. The south-eastern boundary of the reserve lies within three kilometres of the sea and the most distant boundary is 21 km inland, to the north. Altitudes range from 10 to 500 m.a.s.l. Geologically, the area is relatively uniform, characterised by deep Natal Group sandstones, which overlie ancient basement granites (King 1972). Parts of the reserve are steeply incised, giving rise to near-vertical sandstone cliffs up to 200 m in height. The sandstone derived soils on the plateaus are generally shallow, becoming deeper in the vegetated drainage lines which feed into the Umtamvuna River. Common soil forms, using the notation of MacVicar (1991), are Mispah and Clovelly, while soils of wet sites are deeper, with a high clay content and typically fall into the Katspruit form.

14
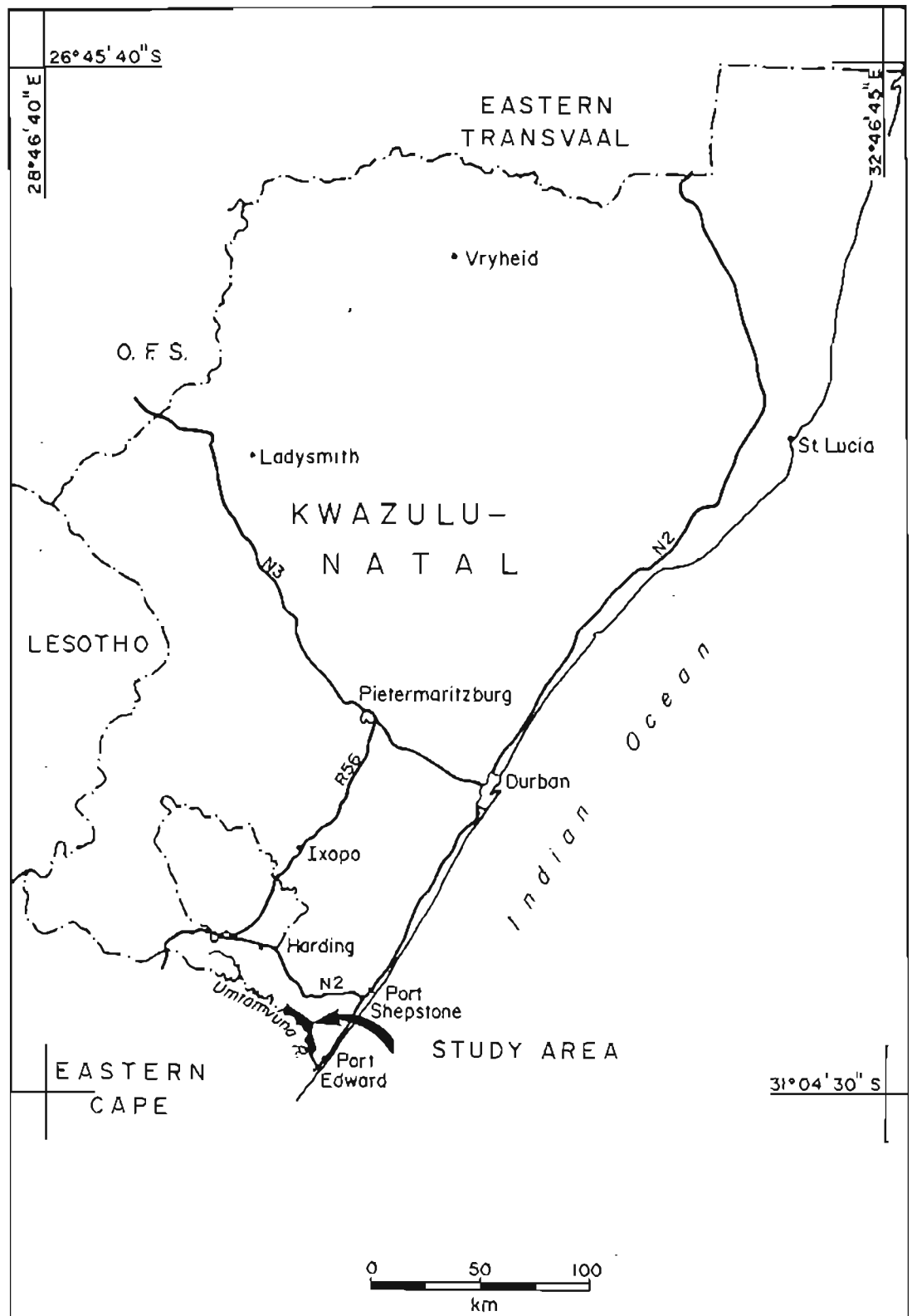
Figure 2.1   Geographic location of KwaZulu-Natal and the Umtamvuna Nature
             Reserve study area.

2.3   Rainfall and climate

Rainfall has been recorded at a single site in the UNR since 1977, at an altitude of 360 m.a.s.l. The annual mean is 1358 mm and the highest annual rainfall was 2223 mm (1987), while the lowest was 667 mm (1992). Records from a site at lower altitude mirrored this pattern, with a mean of 1334 mm (data supplied by Mr E Hooper, Pinedale Farm, Port Edward). Wet and dry rainfall cycles are also a feature, as is the case elsewhere in KwaZulu-Natal (Figure 2.2). Below average rainfall was recorded in the UNR for ten of the 17 years since recording commenced. The monthly distribution of rainfall was also investigated and revealed a distinct summer peak and winter trough, with
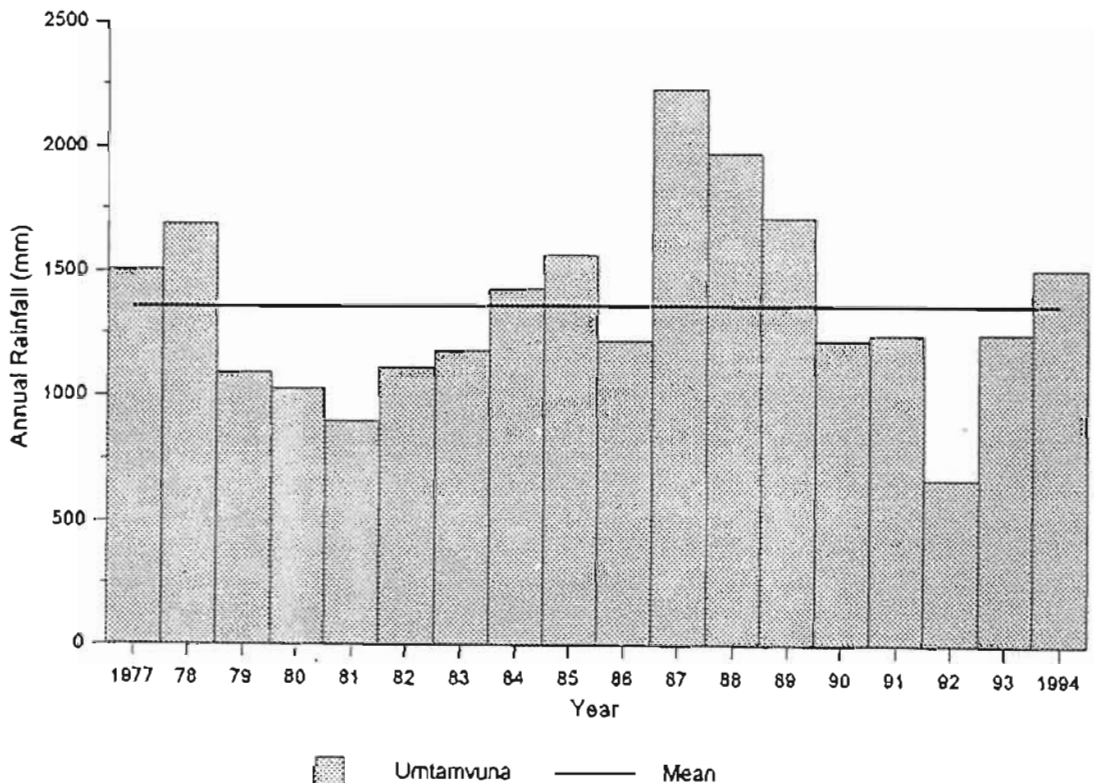
Figure 2.2   Annual rainfall for Umtamvuna Nature Reserve, from 1977 to 1994, showing deviations about the mean of 1358 mm.

most of the rain (81%) occurring in the summer months, between September and March (Figure 2.3). Average monthly rainfall at the lower altitude site did not differ much from the UNR site (Figure 2.3), which indicates that the steep altitudinal gradient has little influence on rainfall. The absence of a rainfall gradient was therefore attributed to the proximity to the sea of the UNR monitoring site (8.2 km). Rainfall is highly variable during winter, with a range of 11 to 233 mm. Rain could be expected to fall in any month of the year, as supported by the observation that, over the past 15 years, < 5 mm for any month has been recorded on only nine occasions.
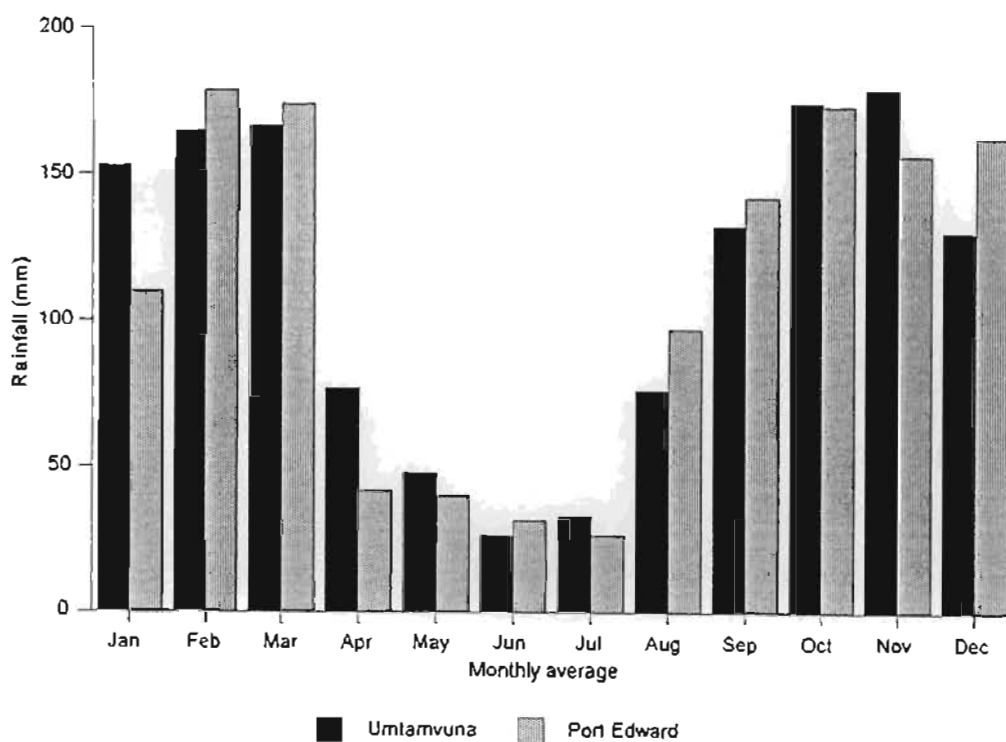
Figure 2.3   Monthly distribution of rainfall in Umtamvuna Nature Reserve, indicating a summer peak and winter trough. A similar pattern was evident closer to the sea (Port Edward).

17

2.4   Vegetation types

The main vegetation types appear to be closely associated with the three major topographic features described earlier (Section 2.2). Thus the gently undulating plateaus support short grasslands, the sandstone outcrops support woody plant communities and the valley slopes, valley bottoms and drainage lines support a variety of forest types. These forests occur at altitudes ranging from 10 to 440 m.a.s.l. and abut, via abrupt ecotones, onto the grasslands. The grassland communities occur only at higher altitudes, from 170 to 490 m.a.s.l.

Numerous small rock outcrops within these grasslands contain assemblages of woody plants which have components of forest as well as species not found elsewhere in the reserve. This feature was also recorded in the Mkambati Game Reserve to the south and is presumed to have arisen as a result of the protection of woody vegetation from fire (Shackleton *et al.* 1991). Two types of protea community also occur: clusters of *Protea roupelliae* are sparsely distributed and mainly associated with rock outcrops, while *P. caffra/P. simplex* communities are more common and appear throughout the grasslands. The UNR is nationally renowned for its plant diversity and as a centre of endemism (Van Wyk 1979), with more than 30 endemic species and 21 type localities recorded to date (Abbott undated). The vegetation of the study area was therefore considered to be sufficiently important to justify further research, the first phase of which was the evaluation of classification techniques, which is dealt with in the next chapter.

CHAPTER 3   METHODS AND PILOT STUDY

3.1   Introduction

The debate surrounding suitable methods for grassland classification has run for decades and is likely to continue (Grunow 1966; Bonham 1974; Kent & Ballard 1988; Fuls *et al.* 1992; Panagos 1995 and many others). The case for using more than one classification technique has also been promoted by many workers (Bonham 1989; Gauch 1982; Neldner & Howitt 1991). Fortunately there is consensus that the objectives of the study should be the primary factor in the process of selecting appropriate methods. In this study it was recognised that, on the one hand it was necessary to produce a classification with adequate scientific detail to contribute towards the knowledge of community composition in a poorly studied grassland, while on the other hand the products of the study were required for management of a conservation area.

The main objectives of the study were to produce a classification of the grasslands and to investigate the effects of past management and environmental variables on community composition. Cognisance was taken of the size of the reserve, the need for development of a grassland monitoring plan, the physiognomic features of the vegetation types, suitability of techniques for use in other coastal grasslands, economy of time and effort and future ecological research (in particular, understanding of the dynamics of the system). Although rangeland managers needed a classification based on objective criteria, it was recognised that the units also needed to be

19

ecologically interpretable (Bonham 1974, 1989).

Many of the early descriptive reports on grassland vegetation in KwaZulu-Natal were qualitative and hence difficult to update, repeat or refine at a later date. Tainton (1984) noted that the methods used by many grassland researchers in South Africa were poorly co-ordinated, difficult to refine and generally not compatible; he urged adoption of a standardised approach, and noted (without making any recommendation) that the Botanical Research Institute had adopted the methods of the Zurich-Montpelier School of Phytosociology. Panagos (1995) noted that the selection of a particular technique is often not adequately justified by authors of papers dealing with classification of vegetation. The literature on grassland research in South Africa indicates that considerable effort has gone into (a) developing and refining methods to assess the potential of rangelands for production of livestock and (b) measuring the response of plant species, or communities, to various forms of management, as discussed in Section 1.3. In some cases, these studies produced descriptions of grassland communities, but the methods used for classification were understandably linked to some form of agricultural objective. This raises the question whether the descriptive and evaluation techniques which were developed for meeting agricultural objectives are applicable for use in general descriptive work on grassland communities. A comprehensive account of vegetation classification techniques was given by Brown (1954) and Greig-Smith (1983), while sampling in grasslands was discussed by Miller & Booysen (1968) and Green (1979). Monitoring of grasslands in South Africa was reviewed by Mentis (1984) and Everson (1985).

Most of the research into grassland classification falls within three broad categories, namely (a) classification based on community structure (eg. Brown 1954; Tainton 1982; Greig-Smith 1983; Tainton 1984; Whittaker *et al.* 1984); (b) assessment of range condition (eg. Tainton 1982, Mentis 1983, Hardy & Hurt 1989, Hurt & Bosch 1991); and (c) monitoring changes in species composition (eg. Mentis 1984; Everson 1985; le Roux & Mentis 1986; Hurt & Hardy 1989). Shackleton (1989) selected the Braun-Blanquet approach for a description of the coastal grassland communities in the Transkei, partly because "...it provides a more comprehensive list of species...". Fuls *et al.* (1992) also used the Braun-Blanquet technique for their description of grasslands in the northern Orange Free State. In the case of the UNR, a comprehensive species list was not required because one had already been compiled. This list, which comprised more than 1 300 species, was produced by searching the area and collecting specimens over many years, ie. no sampling had been undertaken (Abbott undated). In addition, no classification of the vegetation as a whole had been attempted.

3.2   The pilot study

The aims of the pilot study were to:

(a)   determine the efficiency of a variety of sampling techniques;

(b)   obtain the necessary skills to apply various descriptive techniques; and

(c)   evaluate a potentially suitable technique prior to expanding the study to the whole of the UNR.

The following steps were taken in the execution of the pilot study: initial

21

testing of various descriptive techniques; evaluation of their efficiency; selection and stratification of a small pilot study area; application of an efficient technique; data analysis and interpretation; and evaluation of the pilot study. Each of these steps is dealt with separately below. The approach to identification of plants included the compilation of a plant 'identikit' with suitable samples, to assist with identification from vegetative components. This was seen as an essential tool for working in grassland communities, where floral structures (especially among the non-grass plants) are usually short lived.

3.2.1 Evaluation of techniques

Some aspects pertaining to the selection of techniques were criticised by Mentis (1989), albeit in the context of vegetation monitoring, not classification. He argued that researchers have often allowed subjective preferences to override, or have used inefficient techniques because of their preconceptions. Panagos (1995) was also critical of the high level of subjectivity in plant classification efforts; he suggested a quantitative approach whereby the size of a sample site (plot) was determined according to the size of the stratum. While the methods of Panagos (1995) are generally supported for vegetation mapping, the main aim of this study was to classify only the grassland stratum. It was therefore considered essential to apply the principles of a 'cost-benefit' approach (Stalmans & Mentis 1993) for the evaluation of currently preferred techniques, in order that the most appropriate one could be selected. The criterion of efficiency was investigated in order to establish which classification technique was most economical in

terms of producing a description of the grassland communities, bearing in mind that the UNR grasslands have a particularly high species diversity. The key question addressed in this section was that asked by Stalmans & Mentis (1993), namely "What technique requires the minimum effort for maximum return of information?".

The tests of efficiency were conducted using a 50 X 20 m 'Whittaker plot', as described by Shmida (1984), covering the largest area. It was assumed that this technique was effective for producing a comprehensive species list for the plot, which formed the basis for comparing the efficiency of two commonly used techniques. A smaller 20 X 20 m plot was also demarcated in the centre of the Whittaker plot. For the purpose of this study a plot was defined as a sampling unit which has a measurable area. All data were collected between November 1991 and February 1992, because plant identification was easier in the summer months. The following quadrat based and point based techniques were applied on the site:

a)   a 50 X 20 m Whittaker plot, as described by Shmida (1984);

b)   a belt transect one metre wide and 20 m long, subdivided into 20 contiguous 1 m² (100 X 100 cm) quadtrats;

c)   50 randomly placed 1 m² quadrats in the 20 X 20 m plot; and

d)   ten sets of 100 point observations, using the nearest plant method (Foran *et al.* 1978) in the 20 X 20 m plot.

The time taken by a single observer to complete each assessment and the number of species encountered was recorded (Table 3.1). The 20 X 20 m plot within the Whittaker plot was demarcated and comprehensively surveyed to

23

ensure that all species were recorded. A total of 128 species (not all identified to species level) were recorded in the larger Whittaker plot; the time taken for this assessment was six hours. In the smaller 20 X 20 m plot, 119 species were recorded in 290 minutes (Table 3.1). The advantage of the quadrat based techniques for revealing species was clearly demonstrated in this exercise, eg. 30 random 1 m² quadrats revealed 80% of the species

Table 3.1   Efficiency of quadrat and point based sampling in a humid grassland in the Umtamvuna Nature Reserve, using a single observer

Technique	Time per sample (min)	(%)	Species recorded (no.)	(%)
'Whittaker' plot (50 X 20 m) *	360		128	
Smaller (20 X 20 m) plot, for comparison between techniques listed below	290	100	119	100
20 contiguous 1 m² quadrats	105	36	70	59
20 random 1 m² quadrats	117	40	76	64
30 random 1 m² quadrats	171	59	95	80
40 random 1 m² quadrats	219	75	105	88
50 random 1 m² quadrats	256	88	117	98
100 points in 20 x 20 m plot	25	9	23	19
200 points in 20 x 20 m plot	52	18	27	23
300 points in 20 x 20 m plot	75	26	30	25
400 points in 20 x 20 m plot	105	36	33	27
500 points in 20 X 20 m plot	144	50	38	32
600 points in 20 X 20 m plot	178	61	40	34
800 points in 20 X 20 m plot	242	83	41	35
1000 points in 20 X 20 m plot	298	102	43	36

*   The Whittaker plot was used for production of a total species list and for determining the effort (time) required. A 20 X 20 m component of this plot was used for the comparisons.

present in the same time that it took to record 600 point observations, while

the latter revealed only 34% of the species present. Overall, the point based

technique revealed significantly fewer of the species present, but required

considerably less time to complete. The point based data also provided

information on the increase in number of grasses and other species as a

function of sample size (Figure 3.1). Few additional grasses were encountered

beyond 200 points, but the total of all species (grasses and forbs) continued

to increase markedly up to 600 points, then tapered off. The point based

technique was therefore efficient for revealing the presence and proportions
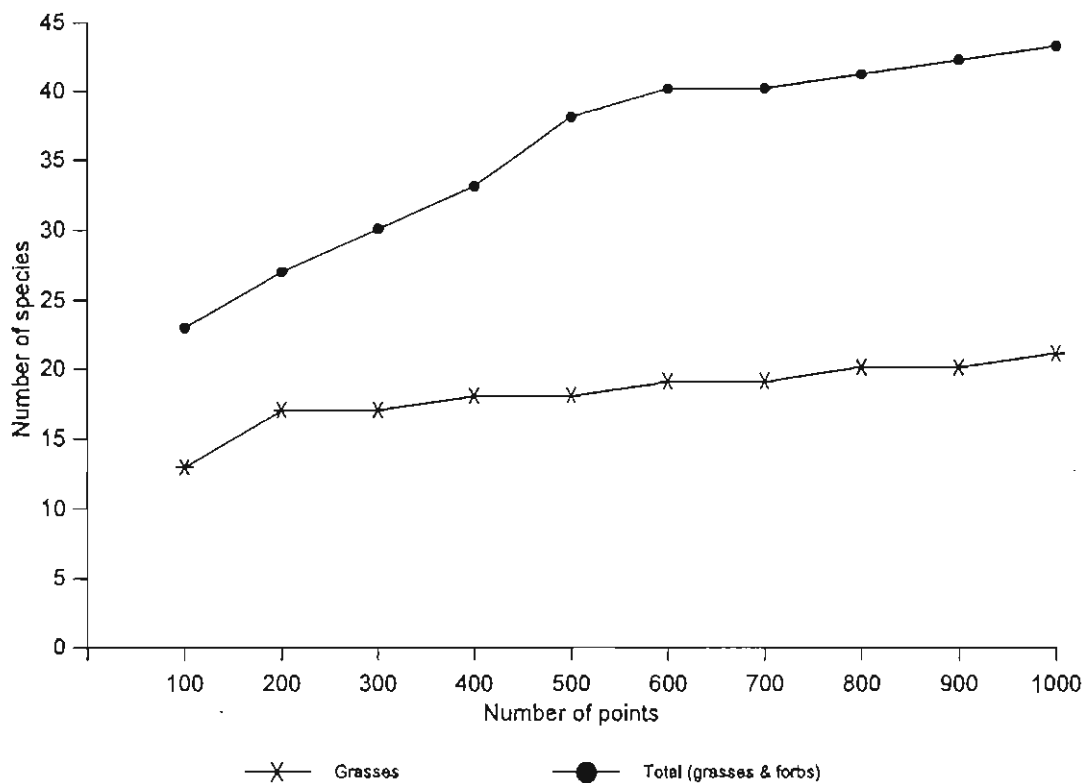
Figure 3.1   Relation between number of point observations and species recorded in a humid grassland in the Umtamvuna Nature Reserve. Few additional grass species were encountered after 200 points; the total of grasses and forbs increased rapidly up to 600 points and thereafter continued to increase at a slower rate.

25

of only the more abundant species. While the quadrat based technique took significantly more time, it was superior in providing a more comprehensive species list. The investigation provided support for the claim by Mentis (1989) that a cost-benefit analysis was an essential component of the design phase. In this case, it was clear that the relative efficiency of techniques differed greatly and that the grassland classification aims of this study could be economically achieved by using the point based approach. The claim by Hardy & Walker (1991) that the point based technique provided adequate detail for broad-scale community descriptions was therefore supported. However, the high species diversity in the UNR was seen as a complicating factor, and is dealt with below.

3.2.2 Determination of sample size

Hardy & Walker (1991) demonstrated that 100 point based observations per 20 X 20 m plot were adequate for "coarse management scale investigations", which include community description studies. However their sample sites occurred in Acocks's Highland Sourveld, Valley Bushveld and Southern Tall Grassveld in KwaZulu-Natal. The main difference was that these sites contained substantially fewer species (a minimum of eight and maximum of 20, with forbs and sedges grouped together in a single class), compared with 119 species in the 20 X 20 m UNR site (Table 3.1). For this reason it was considered necessary to undertake an independent analysis for determining sample size in the UNR grasslands. The analysis was done using GENSTAT software, adapted to perform the REPSIM analysis, as described by Duckworth & Walker (1988). Replicate similarity is defined as the similarity

between two replicates or sets of N points from the same sample area (Mentis 1984). The procedure for establishing the dependence of replicate similarity on sampling intensity was followed, as outlined by Mentis (1984) and Walker 1988a). A number of point observations, N, were selected using a random number generator, with replacement. This was repeated for N = 10, 20, 30 .... 400 (performed with the assistance of M Graham, 310 Burger St., Pietermaritzburg). The data used for the replicate similarity test comprised two sets of 1000 point observations, collected earlier on two contiguous 20 X 20 m plots. In the initial iteration, the 1000 data points from each of the two plots were treated as separate entities to ascertain to what extent they differed. It was reasoned that, if the differences were small, pooling of the data to provide a larger (2000 point) data set, as used by Duckworth & Walker (1988), would be justified. Mean percentage similarity (mean PS) was calculated as described by Walker (1988a). The results (Figure 3.2) indicated that the difference in species composition between sites was minimal and the two data sets were pooled to form a single sample of 2000 points, with 68 species. All the species were retained in order to compare the full data set with condensed data sets (Figure 3.3). Most southern African workers who have used proportional species composition as a basis for range condition assessment and range monitoring have placed emphasis on the grass species, and have routinely grouped or even excluded forbs and sedges. Combining the total number of forbs and sedges into a single category has become standard practice in studies dealing with grassland monitoring and classification, eg. Tainton (1982); Mentis (1984, 1986); Walker (1988a); Hardy & Walker (1991); Stalmans & Mentis (1993); and many others. While this logic may be supported in grass or livestock production studies, the value of all species as

27

indicators should be more fully explored. Accordingly, all species were included in the REPSIM analysis, followed by a reduction in species, using only those that contributed >10% and >5% respectively (Figure 3.3). The estimated asymptote of the curve was used to determine adequate levels of sampling intensity. With all 68 species included, a relatively low proportion of internal association was retrieved, eg. after 230 points, mean PS = 83%, as opposed to 90 to 92% for the Hardy & Walker sites, which contained far fewer species. The mean PS increased to only 84.4% after 400 points (Table 3.2), indicating that including all species in a species rich community would
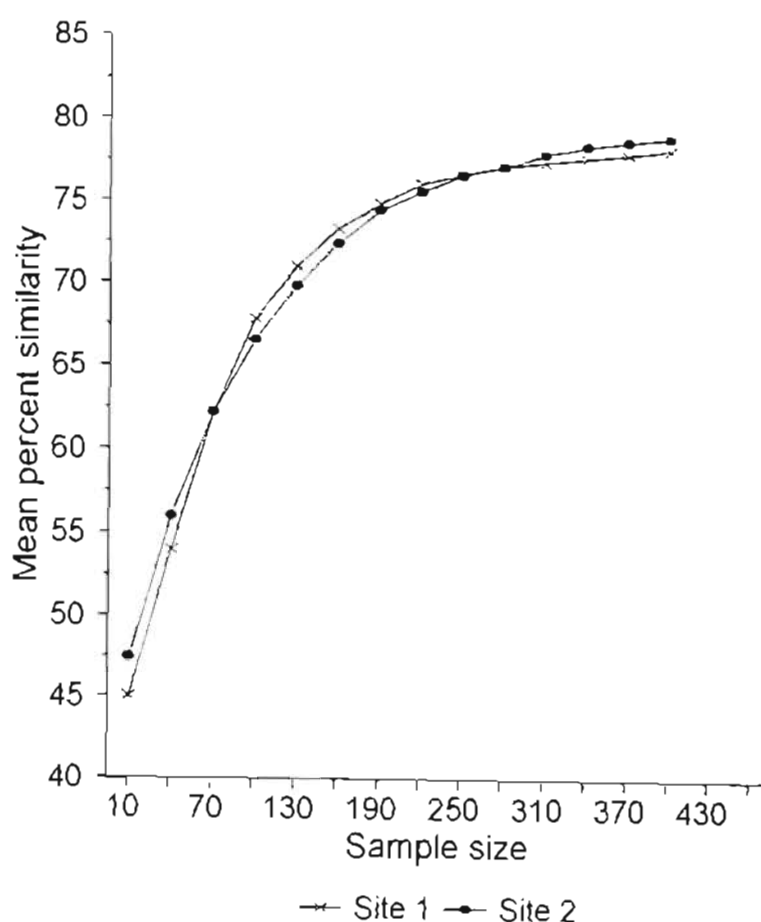
Figure 3.2   Analysis using REPSIM of two data sets representing adjacent sites in the Umtamvuna Nature Reserve. The estimated asymptote is 77% at 250 points, for both sites, which were judged to be sufficiently similar to justify combining the two sets of 1000 points, to form a single 2000 point data set.
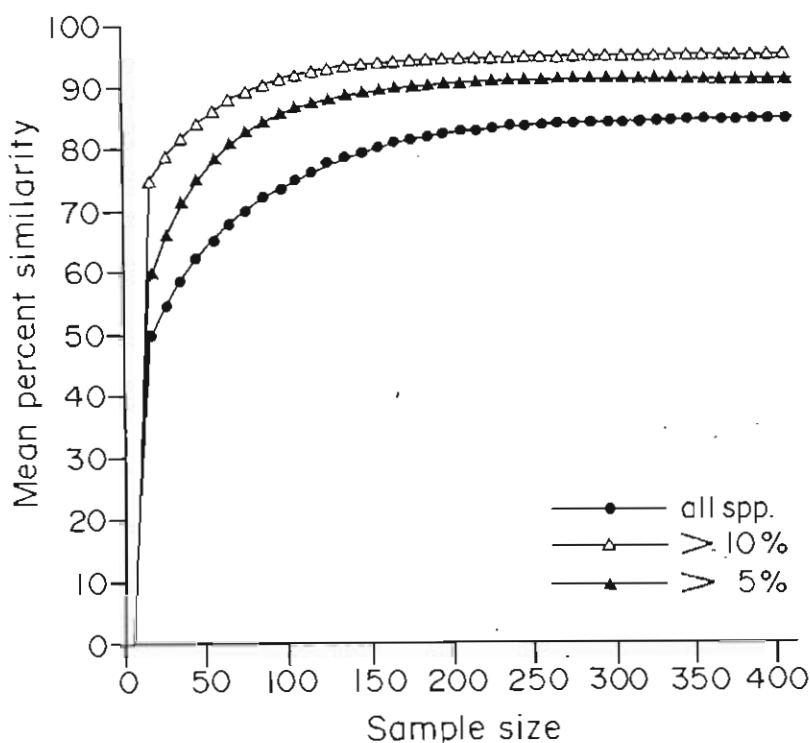
Figure 3.3   The relation between percentage replicate similarity and sample size, using (a) all 68 species, (b) only those species contributing more than 10% and (c) more than 5%, in any one site. Estimated asymptotes are: (a) PS = 83% after 230 points; (b) PS = 90% after 80 points and (c) PS = 86% after 100 points.

require a very large number of point observations to achieve a mean PS of 90% or more. It was however considered important to achieve a higher mean PS, because this is a measure of internal association that reflects how much information is being retrieved, ie. the higher the mean PS value at a given number of point observations, the more representative the sample (Hardy & Walker 1991; Stalmans & Mentis 1993). Although lower levels of internal association have been considered to be adequate, eg. 82% by Bray & Curtis (1957), in this case a direct comparison with the analyses of Hardy & Walker (1991) was desired. Clearly, the 10% level, comprising only four species, was not practical, so attention was focused on the 5% level; this comprised 11

Table 3.2 Mean percentage similarity (PS) values for 100, 200, 300 and 400 point observations in grasslands of the Umtamvuna Nature Reserve. Values were obtained firstly for all **68** species, followed by those contributing > 10% or > 5% in any one plot

No. of species	No. of points			
	100	200	300	400
All 68 species	74.7	82.1	83.9	84.4
Only species contributing > 5 % (11 spp)	86.2	90.1	90.6	90.6
Only species contributing > 10 % (4 spp)	91.3	93.9	94.2	94.3

species (nine grasses and two sedges) and 86.2% of the internal association was recovered after 100 points, compared with 74.7% after 100 points when all 68 species were used (Table 3.2). It was also evident that, at the 5% level, increasing the number of observations from 100 to 200 points would not be efficient; ie. doubling the effort would recover only an additional 4% of the internal association; this supported the findings of Hardy & Walker (1991) and Stalmans & Mentis (1993). Use of the 11 abundant species (at the 5% level) also revealed the dominance of grasses, meaning that the sedges and forbs could be lumped without loss of efficiency. It was concluded from this exercise that the coastal grasslands in the UNR should be added to the list of localities in which 100 point observations could be considered adequate for coarse scale investigations.

3.2.3 Stratification of communities

Ground-based surveys, colour aerial photographs (1985) and orthophotographs (1981), both at a scale of 1:10 000, were used to identify

the major physiographic and physiognomic features of the pilot study area, according to principles expounded upon by various authors (eg. Greig-Smith 1983; Bonham 1974; Neldner & Howitt 1991; Panagos 1995). The five vegetation types initially identified were forest, woodlands, wetlands and grasslands. The grasslands were further stratified visually, using the following criteria: average grass height in mid and late summer, presence of a dominant woody component, eg. proteas, dominant grass species, areas that appeared different as a result of past management, eg. cultivation, and personal knowledge of the reserve. The smallest units which could be mapped were set at 0.25 ha because, at a working-map scale of 1:10 000, this represented a practicable unit measuring 5 X 5 mm. Three grassland strata were recognised, namely short, broadleaf-dominated grassland (S1), short wiregrass-dominated grassland (S2) and short grasslands with a woody component, eg. *Protea roupelliae* (S3). The latter was distinct from units such as bush clumps, forest or riverine vegetation, which had no grass component and were excluded from the study.

3.2.4 Sampling and analysis

Eleven sample plots measuring 20 X 20 m were randomly located in the pilot study area, with a minimum of three plots in each of the designated strata. In each plot, 100 point based observations were made, using the 'wheelpoint' method as described by Foran *et al.* 1978). The resultant pilot study data set comprised a matrix of 11 sample plots and 53 species (26 grasses and 27 forbs and sedges); these data were subjected to analysis using TWINSPAN software, developed by Hill (1979a). The selection of this analytical tool was

31

based on the principle of using cluster analysis for the purpose of classifying communities (van Tongeren 1987). With TWINSPAN, which is a polythetic divisive method, divisions are made on the basis of more than one attribute (species, in this case). A grassland classification derived from species composition data has a major advantage in that the relative abundance values of a suite of indicator species is used to define a particular community. This information can be used in future to assign sites sampled at a later stage to one of the communities derived from the original TWINSPAN analysis (van Tongeren 1987). The analysis was initially made with default settings, meaning that successive hierarchical divisions occurred at the 0, 2, 5, 10, 15 and 20% levels of abundance or 'cut levels', with all species having equal weight as indicators, ie. without downweighting of species. This analysis and the refinement and interpretation of subsequent analyses is discussed in the following section.

3.2.5 Results

The TWINSPAN derived table (Appendix 2) was used to create a dendrogram (Figure 3.4) showing the main communities, eg. community 1 (at the third dichotomy or cut level), dominated by *Aristida junciformis* and *Digitaria setifolia*. The other groupings were not as clearly interpretable and appeared to be of limited value in producing a community description. For example, the first dichotomy (Figure 3.4) indicated that the 'preferential' (most effective) indicator species in site 1 (right hand group) was *Argyrolobium harveyanum*. This species did not contribute more than 2% in any one site and examination of the TWINSPAN species-by-samples table (Appendix 2) revealed that other

32

species, eg. *Festuca costata*, were superior indicators of differences between site 1 and the other 10 sites. The reason for this was attributed to noise, introduced by the rare species and those which occurred at low abundance but were present in many sites (Gauch 1982). The use of default settings
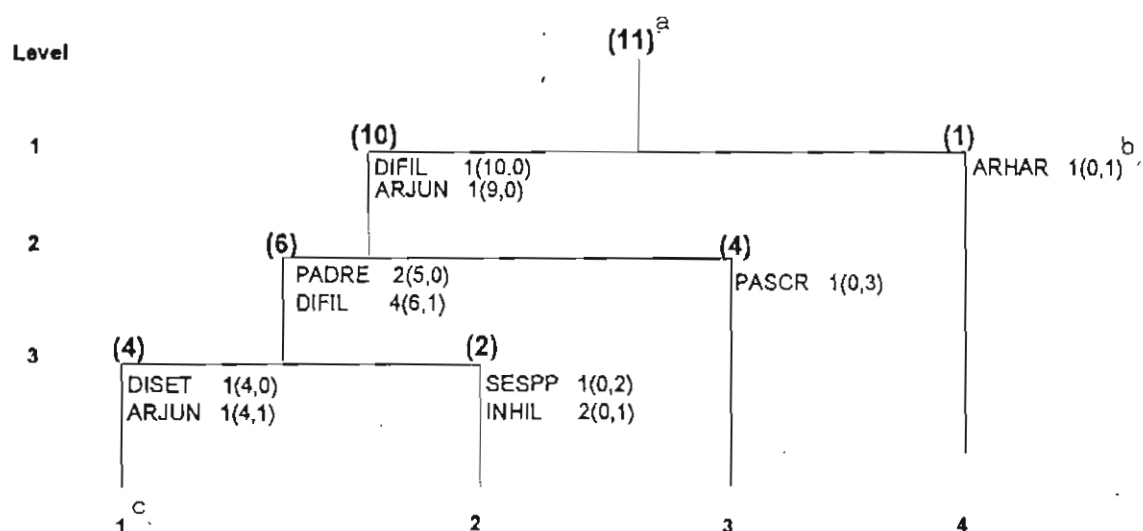
Level

(11)[a]

1   **(10)**   **(1)**
     | DIFIL   1(10.0)   ARHAR   1(0,1) [b]
     | ARJUN   1(9,0)

2   **(6)**   **(4)**
          | PADRE   2(5,0)   PASCR   1(0,3)
          | DIFIL   4(6,1)

3   **(4)**   **(2)**
     | DISET   1(4,0)   SESPP   1(0,2)
     | ARJUN   1(4,1)   INHIL   2(0,1)

          [c]
     1   2   3   4

a   =   Number of sites.
b   =   Preferential (most effective indicator) species - full name supplied below - followed by appropriate cut level and, in brackets, actual number of occurrences on left and right hand side of the dichotomy. In this example, ARHAR 1(0,1), signifies that the indicator species, *Argyrolobium harveyanum*, occurred at the first (2%) cut level, in one sample site on the positive side of the dichotomy and none in the negative side.
c   =   Community type.

DIFIL   *Diheteropogon filifolius*   PASCR   *Paspalum scrobiculatum*
SESPP   *Senecio* species   ARJUN   *Aristida junciformis*
INHIL   *Indigofera hilaris*   ARHAR   *Argyrolobium harveyanum*
DISET   *Digitaria setifolia*   PADRE   *Panicum dregeanum*

Figure 3.4 **A TWINSPAN** derived analysis of Umtamvuna Nature Reserve pilot study data, comprising **53** species in **11** sites. The default settings produced an uninterpretable analysis because all species had the same weighting: species of low abundance were consequently selected as indicators.

to perform the analyses masked the contribution of the more abundant species, a point that was also noted and corrected by Conlong (1986) and Shackleton *et al.* (1991). However, an examination of the data analysis showed that the contribution by more abundant species was not lost, as these could be found by inspection. However, this process was laborious; TWINSPAN was designed to reveal the contributions made by the more significant species through adjustment of cut levels and differential weighting of species (Gauch 1982; ter Braak 1987a), which constituted the next step in the analysis.

The approach of Hill (1979a) was followed for adjusting the default settings as follows:

(a)   the weighting of pseudospecies cut levels were set so that, for the purpose of distinguishing between clusters, pseudospecies corresponding to the higher cut levels (>5%) had twice the weight of those at the lower (<5%) level. This corresponded with the suggestion by Hill (1979a) that each level should represent a meaningful category of abundance, which he described as "absent, a little, a lot, more-or-less dominant". The actual settings selected to reflect these categories were 1, 2, 2, 2, corresponding with cut levels at 5%, 10%, 15% and 20%; and

(b)   the 'indicator potentials' were adjusted so that pseudospecies at the lower cut level (5%) were used in the analysis but not as indicators. The settings used in the analysis to obtain this were 0, 1, 1, 1. No species were initially omitted from the list of potential indicators.

34

In addition to the above adjustments, the data were condensed through grouping some of the common forbs and sedges, such as *Berkheya* (three species), *Cassia* (two species), *Helichrysum* (three species) and *Senecio* (two species), into their respective genera. Replacement of the aforementioned species was effected through entering additional species codes, such as BESPP, CASPP and HESPP (Appendix 1).

The TWINSPAN analysis (Appendix 3) was interpretable and demonstrated that, by reducing noise (through adjusting cut levels and grouping of species) a meaningful classification could be produced (Gauch 1982; van Tongeren 1987). The main advantage of selecting indicator species was in time saving, ie. less time was spent on attempting to identify rare species; also, the more abundant species, which could be sampled with greater precision, contributed most to the analysis (Gauch 1982). The data from the TWINSPAN table were used to construct a dendrogram (cluster diagram) showing the main communities (Figure 3.5), which are described below.

Community 1 : short, 'wiregrass' dominated grassland - the dominant species in this group were *Aristida junciformis* and *Diheteropogon filifolius* (corresponded with stratum S2).

Community 2 : short, mixed grasssland - the dominant species in this group were *Themeda triandra* and wiregrasses. This additional community was revealed by the analysis but was not noted in the visual stratification.

Community 3 : short grassland with high abundance of forbs and *Themeda triandra*, and low abundance of wiregrasses (corresponded with stratum S1).

Grasslands with a protea component (stratum S3) were not revealed by the

classification, meaning that the data did not reveal any effect of proteas on herbaceous species composition, despite the visual dominance of proteas. This applied to both the dense, shrubby stands of *P. simplex/P. caffra* (grouped because of the difficulty in identification without flowers) and the
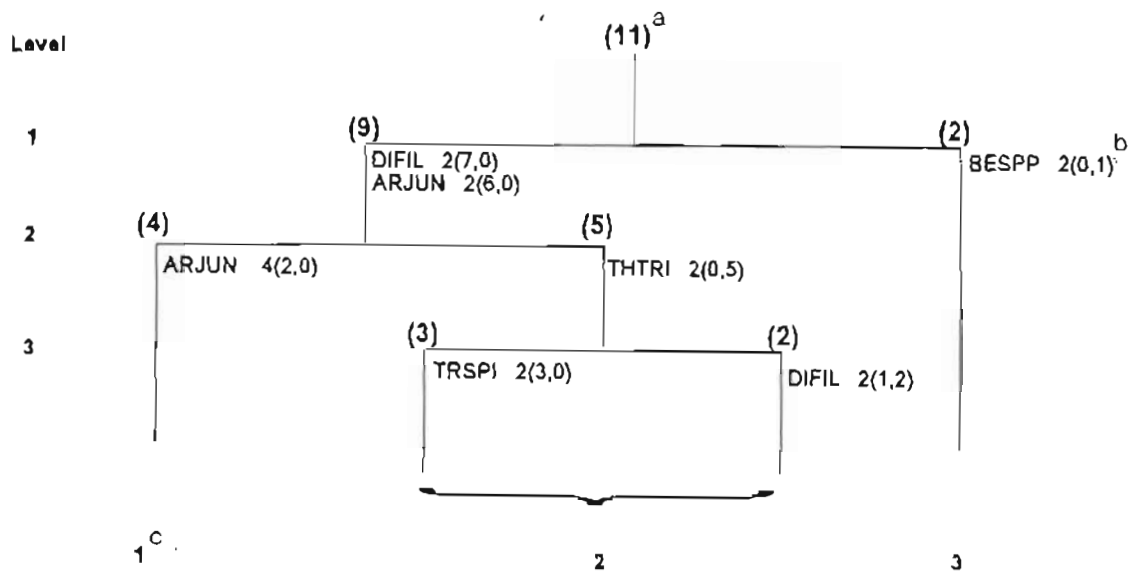
a	=	Number of sites.
b	=	Preferential (most effective indicator) species - full name supplied below - followed by cut level and, in brackets, actual number of occurrences on left and right hand side of the dichotomy. In this example, DIFIL 2(7,0), signifies that the indicator species, *Diheteropogon filifolius*, occurs at the second (10%) cut level), in seven samples on the negative side and none on the positive side of the dichotomy.
c	=	Community types

DIFIL	*Diheteropogon filifolius*	THTRI	*Themeda triandra*
ARJUN	*Aristida junciformis*	TRSPI	*Trachypogon spicatus*
BESPP	*Berkheya* species lumped		

Figure 3.5 **A TWINSPAN derived classification of Umtamvuna Nature Reserve** pilot study data, comprising 53 species in 11 sites. An interpretable analysis was produced after adjusting the cut levels to 0, 10, 15 and 20%, downweighting of rare species and lumping of non-grass species into their respective genera.

sparse stands of the taller *P. roupelliae*. Although proteas did not appear to influence the composition of the herbaceous layer, protea communities were considered important for the classification and were accordingly retained as a separate community type (Protea Woodland).

3.3   Conclusion

The pilot study contributed substantially towards:

(a)   the development of essential skills in community description, such as selection and application of appropriate techniques and plant identification;

(b)   an evaluation of the efficiency of a variety of classification techniques prior to embarking on the extended study;

(c)   a justification for using an objective approach in selecting sampling techniques and determining appropriate sample size;

(d)   experience gained in the use of the TWINSPAN package, in particular the interpretation of the data analysis.

It was concluded that the point based method, using 100 points per site and analysis of the data using TWINSPAN, was an adequate first step towards producing a classification of the grassland communities of the UNR. The analyses in this study supported similar claims (Mentis 1986; Hardy & Walker 1991) and provided a basis for expanding the study to the remainder of the UNR.

37

CHAPTER 4   THE EXPANDED STUDY

4.1 Introduction

The pilot study provided a framework for the development of a classification of the grasslands of the UNR. However, it was recognised that a larger data set would provide opportunities for additional exploration, such as the use of gradient analysis. The aims of the expanded study were:

(a) to produce a map of the grassland communities of the UNR;

(b) to determine whether environmental gradients could be inferred through indirect gradient analysis; and

(c) to examine the effects of environmental variables and past management on community composition.

This chapter describes the results of the stratification, the classification by TWINSPAN, the DCA-derived samples and species ordinations and the investigation of effects of environmental variables on species.

4.2 Methods

The procedure outlined under 3.2.3 for the pilot study was followed for the expanded study, commencing with a physiognomic stratification of all major vegetation types of the entire reserve, followed by stratification of the grasslands. From the subjective stratification of plant communities, a map was produced, at a scale of 1:10 000 for the entire 3 257 ha of the UNR. More intensive work was then done on stratification of the grasslands, using aerial photographs and ground-based observations to map community types,

38

which were described by their visually dominant component species. Particular attention was paid to identifying vegetation units at a scale which is practical for meeting the needs of the end-user (Green 1979). As discussed earlier, the smallest sized mapping units were 0.25 ha because, this measured 5 X 5 mm on a working map at a scale of 1:10 000.

The concept of proportional representation was followed (Brown 1954), where a minimum of five 20 X 20 m sampling plots were located in each of the grassland strata. Only two plots were located in the old croplands; this was considered adequate because the stratum was small (<5 ha) with distinct boundaries. *Eragrostis curvula* was visually the most abundant species. A total of 48 plots were assessed, with 100 point observations per plot, using the nearest plant method of Foran *et al.* (1978).

Additional environmental data were collected in each plot. These were soil depth, soil form, slope, aspect, altitude and distance from the sea. The latter variable was included because the sites sampled in the UNR ranged from very near (3 km) to quite far (21 km) from the sea. It was reasoned that this variable might have had an influence on species with low salt tolerance. Soil types were classified at each sample site, using the system of MacVicar (1991). These variables were selected because they were most likely to have affected the pattern (community composition), as shown by Cowling (1983) and Shackleton *et al.* (1991). The variables were tested for correlations with scores of each site along the ordination axes, in order to assist in providing ecological insight into community characteristics, as elaborated by ter Braak (1987a).

4.3 Results and discussion

4.3.1 Stratification

The 1:10 000 scale colour aerial photographs were the most useful for detecting boundaries between physiognomically distinct units, such as forest edges, grasslands and protea woodlands. Six vegetation types were delineated, namely mature forests (along with their linear extensions into the grasslands), mature forest patches measuring 0.25 to 5.0 ha, low scrub forest, wetlands (including swamp forest), protea woodlands (>0.25 ha) and grasslands. Steep slopes and cliffs with variable vegetation were classified as such, pending further investigation. The subsequent stage of stratification of the grassland communities from aerial photographs required two steps; firstly, visual differences were recorded on transparent overlays. This step was adequate for indicating different patches, but a more intensive ground based examination was required to ensure that the distinctions were justifiable. For instance, old croplands and wetlands appeared to be very similar on the photographs; also, areas that had been burnt in the previous spring appeared to be similar to the wetlands. Colour variations were evident within the same grassland community, where recently burnt patches appeared to differ from moribund patches. Elimination of these anomalies required considerable walking and mapping on site. Boundaries between grasslands and other habitats, such as forests, forest patches, rock outcrops and cliffs, were usually distinct; conversely, gradients between grassland communities were often 20 to 40 m wide. Five grassland strata were delineated and these were named according to their visually dominant species, as follows:

40

-       Old croplands, dominated by *Eragrostis curvula;*

-       *Tristachya leucothrix* community;

-       *Themeda triandra* community;

-       *Diheteropogon filifolius* community; and

-       *Aristida junciformis* community.

The stratification exercise, in which the five grasslands and five other plant communities were mapped, was followed by analysis and interpretation of the point data, as described below.

4.3.2 Analysis of point data using TWINSPAN

A total of 93 species (39 grasses and 44 forbs and sedges) were encountered in 48 plots (Appendix 5). The ten plants that were not identified because they were either too small or had inadequate diagnostic material, were assigned codes (Appendix 1). The data were subjected to analysis by TWINSPAN (Hill 1979a), with downweighting of rare species and cut levels adjusted to 0, 10, 15 and 20%, as described earlier under Section 3.2.5. The TWINSPAN derived species-by-sites table (Appendix 4) was examined and six communities (S1 to S6) were identified. A dendrogram depicting the cut levels and communities was produced (Figure 4.1) and is discussed below.

(a)   Interpretation of the TWINSPAN analysis. The first dichotomy in the analysis, ie. at cut level 1 (Figure 4.1), split the two old croplands sites, 34 and 38, from the remaining sites. Of interest was that the old cropland sites (community S1) contained a distinctive suite of species, seven of which were exclusive to this community (Appendix 4). The split at the second cut level (Figure 4.1) separated the *T. leucothrix*

41

dominated sites from the *T. triandra*/wiregrass dominated sites (the

wiregrass species being *A. junciformis* and *D. filifolius*). Two divisions

occurred at cut level 3: one separated communities with high *L.*

simplex (S2) from those with high *T.leucothrix* (S3); the other
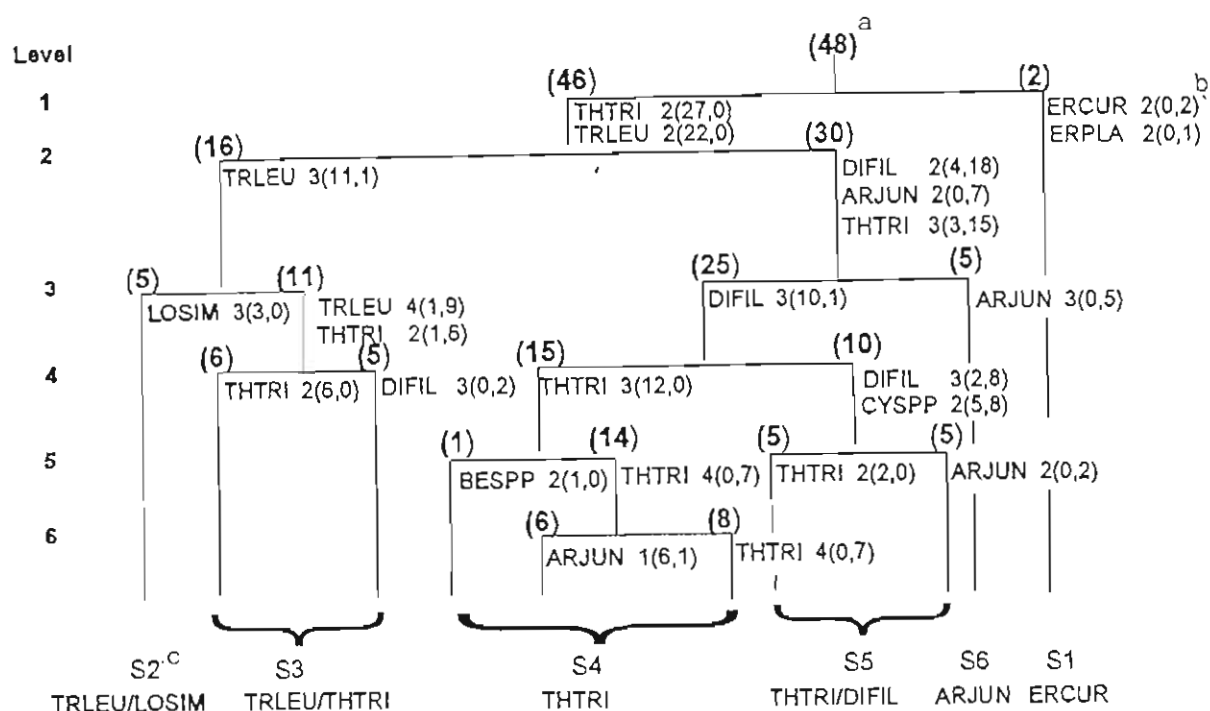
a = Number of sites.
b = Preferential (most effective) indicator species - full name supplied
below - followed by cut level and, in brackets, actual number of
occurrences on left and right hand side of the dichotomy. Example:
ERCUR 2(0,2) signifies that the indicator species, *Eragrostis curvula*,
occurs at the second (10%) cut level, in two samples on the positive
side of the dichotomy and none on the negative side.
c = Community types

ERCUR	*Eragrostis curvula*	ARJUN	*Aristida junciformis*
ERPLA	*Eragrostis plana*	LOSIM	*Loudetia simplex*
THTRI	*Themeda triandra*	CYSPP	*Cyperus* species grouped
TRLEU	*Tristachya leucothrix*	BESPP	*Berkheya* species grouped
DIFIL	*Diheteropogon filifolius*		

Figure 4.1   A TWINSPAN derived classification of 48 sites and 93 species in the
Umtamvuna Nature Reserve. Cut levels were adjusted to 0, 10, 15
and 20% and rare species downweighted. Six grassland communities,
labeled S1 - S6, were recognised.

N

LEGEND

- Fire Exclusion Areas
- Forest
- Swamp Forest
- Closed Scrub Forest
- Steep Rocky Slopes – not classified
- Protea Communities
- Alien Plants
- Wetland
- Grassland

S1 = Old crop lands (*Eragrostis curvula*/*E. plana*)
S2 = *Tristachya leucothrix*/*Loudetia simplex*
S3 = *Tristachya leucothrix*
S4 = *Themeda triandra*
S5 = *Themeda triandra*/*Diheteropogon filifolius*
S6 = *Aristida junciformis*

- 23 = Sample sites
- M6 = Monitoring sites

Reserve Boundary

Boundary separating grassland communities

0 1 2 3 4 5
Km

NATAL PARKS BOARD

FIGURE 4.2

UMTAMVUNA
NATURE RESERVE:

GRASSLAND COMMUNITIES
AND OTHER MAJOR VEGETATION TYPES

Compiled by: N.P. le Roux
Draughted by: Ian G. Gordon   Date: 20 July 1995

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Umtamvuna River

INDIAN OCEAN

separated sites with high *D. filifolius* from those with high *A. junciformis* (S6). At cut level 4, a split between sites with high *T. triandra* and high *D. filifolius* was indicated, but the dominance of higher order species indicated that the 11 sites could be combined to form community S3, dominated by *T. leucothrix* and *T. triandra* (Figure 4.1). This was not the case in the other level 4 split, which revealed a strong distinction between the *T. triandra* dominated sites with low levels of wiregrasses (S4) and those with abundant wiregrasses (*D. filifolius*, community S5). Lower order splits, at cut levels 5 and 6, were not considered to be sufficiently distinctive to warrant delineation of additional communities, but have been indicated in Figure 4.1 for completeness.

(b)   When comparing the stratification with the TWINSPAN classification, it was evident that the stratification had increased the efficiency of the quantitative sampling exercise.

From the interpretation of the TWINSPAN derived classification, the following grassland communities were identified and mapped at a scale of 1:10 000 (Figure 4.2):

S1   Old croplands, dominated by *Eragrostis curvula;*

S2   *Tristachya leucothrix/Loudetia simplex* community;

S3   *Tristachya leucothrix/T. triandra* community;

S4   *Themeda triandra* community;

S5   *T. Triandra/Diheteropogon filifolius* community; and

S6   *Aristida junciformis* community.

The results of the TWINSPAN derived classification of grasslands of the nearby (30 km south) Mkambati Game Reserve (MGR), undertaken by Shackleton (1989), were compared with the results of this study. It was found that the *T. leucothrix/L.simplex* (S2) community in the UNR was also identified by Shackleton (1989). However, a major proportion (84%) of his study site comprised of this community, whilst it was uncommon in the UNR. Shackleton's (1989) classification contained sites dominated by tall grasses, mainly of the genera *Cymbopogon* and *Digitaria*, while in the UNR, these were rare and too small to map. None of the other communities identified in the two studies appeared to be similar, but *T. triandra* was seen to be an abundant or indicator species in sites of both study areas, although more common in the UNR than in the MGR. From these observations it was tentatively concluded that the grasslands of the MGR differed substantially from those of the nearby UNR.

4.3.3 Indirect gradient analysis

The question addressed in this section was "Which major environmental variables or past management activities affected species composition?". The first step was to investigate methods of indirect gradient analysis, to which the data were suited. Detrended correspondence analysis (DCA) is used primarily in indirect gradient analysis, ie. to discover underlying gradients in the data, in this case environmental (Gauch 1982; ter Braak 1987a; Wartenberg *et al.* 1987). Although some authors (Wartenberg *et al.* 1987) were critical of the technique, others have defended the use of DCA, mainly because of its value for elucidating multidimensional gradients or gradients of

44

unknown dimensions (ter Braak 1987a; Peet *et al.* 1988). However, Jackson & Somers (1991) subsequently pointed out that DCA-derived ordinations of sample site data were highly sensitive to the number of segments selected, with a danger of contradicting interpretations. The division of the first axis of the correspondence analysis is an essential step towards detrending, ie. removal of the arch in the first two axes of the ordination (Gauch 1982). The DCA default setting uses 26 segments, but Jackson & Somers (1991) showed that significant movement of sites can occur along the second axis if 24 or 25 segments were selected instead; they concluded that DCA was sensitive to segment selection, although it was useful in providing insight into one of many possible results. This cautionary note was borne in mind during interpretation of the DCA analysis.

DCA ordinations, using CANOCO (ter Braak 1988, 1991), with default settings for the number of segments, were used to assist with the ecological interpretation of the data. Following the guidelines of Hill (1979b) and Gauch (1982), the 'outliers', comprising two old croplands (sites 34 and 38), were omitted. These sites differed substantially from the rest and, when included in the analysis, caused a compression of the remaining sites towards the left (Y-axis) of the diagram. After removing the outliers, the resulting DCA ordination (Figure 4.3) was effective in revealing the arrangement of the sample sites of communities S2 to S6, ie. the TWINSPAN derived classification. This step was justified on the basis that DCA has often been used for facilitating a community description (Hill & Gauch 1980; Gauch 1982; Peet *et al.* 1988; ter Braak 1988). The lines on the DCA diagram (Figure 4.3) were subjectively inserted for ease of interpretation (assisted by

CD Morris, Agricultural Research Council, Range and Forage Institute, University of Natal, Pietermaritzburg). Overlapping of some sites representing different communities was evident, but this was considered to be typical for a vegetation community which is part of a continuum (Miles 1979; Neldner
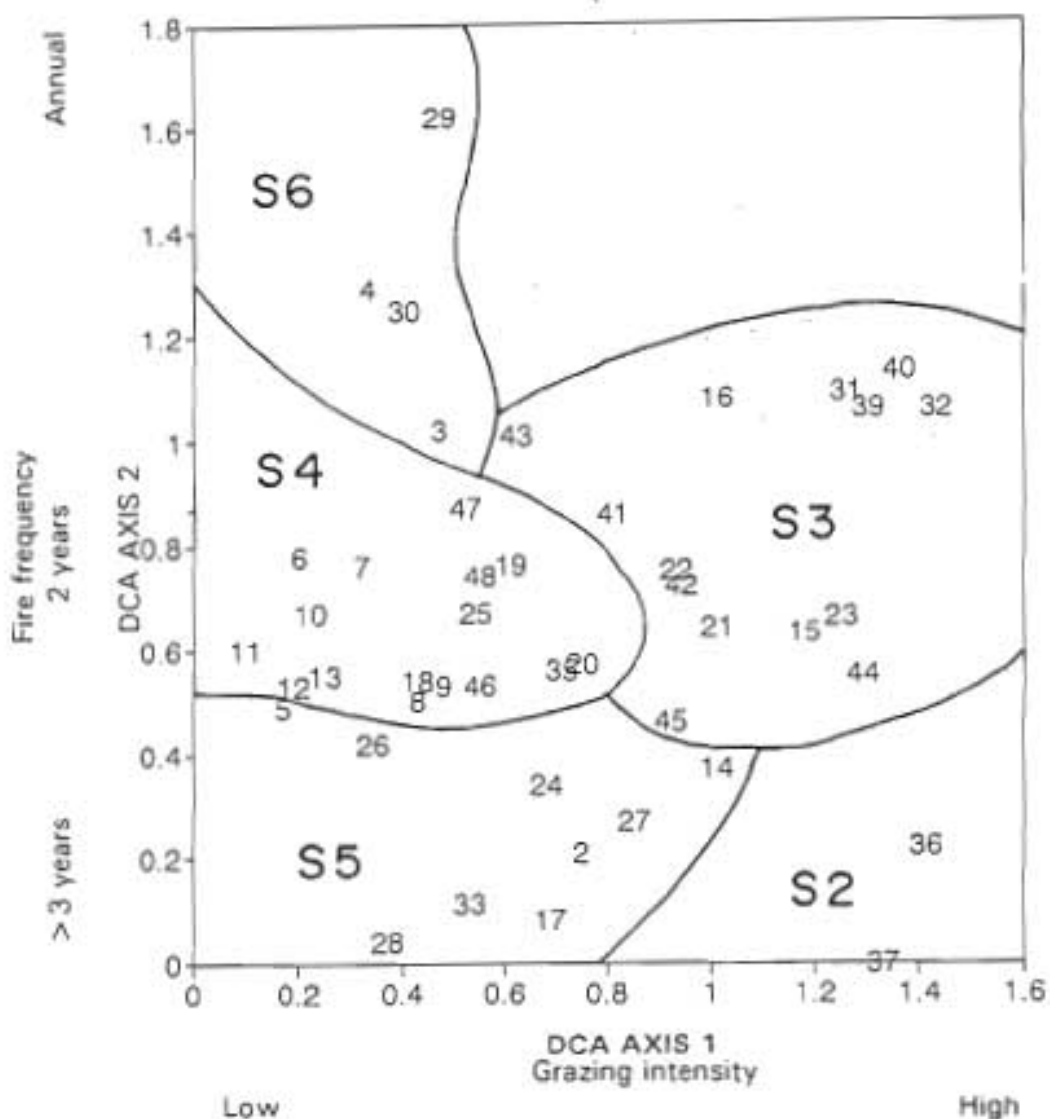
Figure 4.3   A DCA derived analysis of 46 sample sites in the Umtamvuna Nature Reserve. Numbers represent sites and subjectively drawn lines indicate the grouping of sites into their TWINSPAN derived communities (S2 to S6). The old croplands sites (34 & 38), classified as community S1, were omitted because they caused a compression of the remaining site information on Axis 1. The omission reduced the eigenvalue of Axis 1 from 0.408 to 0.104. Postulated gradients were grazing intensity on axis 1 and fire frequency on axis 2.

& Howitt 1991). In general, the clusters of sites fitted the community description adequately; however, the S2 sites were relatively widely dispersed (eg. sites 31, 32, 36 & 37), despite having been separated from S3 sites in the early stages (cut level 3) of the TWINSPAN analysis (Figure 4.1). The eigenvalues of 0.104 for DCA Axis 1 and 0.071 for Axis 2, indicated that Axis 1 revealed 8.4% of the variance in the data, while Axis 2 revealed 5.7%. Subsequent axes indicated successively weaker gradients.

The positions of sites along Axes 1 and 2 were also used for inferring gradients. The sites occurring to the right of Axis 1 (community S2, Figure 4.3) had been subjected to continuous grazing (stocking rates unknown) by cattle until 1991. The S3 sites (with the exception of site 23) had been subjected to grazing by cattle at varying intensities in the past, while most of the sites to the left of DCA Axis 1 have almost certainly not been utilised in the past 20 years. The gradient on Axis 1 was thus interpreted as a grazing intensity gradient, from zero utilisation (left) to some utilisation (centre right), to heavy utilisation (far right). Axis 2 revealed a separation of two wiregrass communities, S5 and S6 (Figure 4.3). The S5 sites (bottom of Axis 2) had a high abundance of *D. filifolius*, while the S6 sites (top of Axis 2) were dominated by *A. junciformis*. In grazing management literature (eg. Tainton 1982), both these wiregrass species are classed as Increaser III, ie. species which increase with selective grazing. The ecological group that most closely resembles the high rainfall communities in the UNR grasslands is Acocks's Highland Sourveld (Acocks 1953). Following this logic, it was expected that the S5 and S6 sites would be more closely grouped in the ordination (Figure 4.3). Community S4, dominated by *T. triandra*, was interspersed between

communities S5 and S6, suggesting that the S4 communities could change to either S5 or S6, in response to some environmental or management factor. Considering that the sites in question, ie. all on the left hand side of Axis 1, were apparently not utilised by grazers, the major agent of defoliation was likely to have been fire. Accordingly burning history was investigated, through examining past management records of fires in the UNR. A fire-frequency gradient was inferred from the distribution of sites along DCA axis 2 (Figure 4.3). Annually burnt sites occurred at the top of axis 2: site 29 was in a firebreak and sites 4 and 30 were burnt annually until 1986. Of the 15 sites classified as community S4, at least 11 had a history of biennial burns. Of the ten sites in community S5, (bottom of axis 2) five were burnt infrequently, averaging three to five years between burns, while the burning history of the remaining five was not clear. It is therefore inferred that DCA Axis 2 represents a fire frequency gradient, with *A. junciformis* (S6) dominant on annually burnt sites, *T. triandra* (S4) dominant on biennially burnt sites and *D. filifolius* dominant on less frequently burnt sites. The interpretation of the postulated gradients was also facilitated by the species ordination, which is discussed below.

4.3.4 Species ordination

A DCA derived scatter diagram of species was produced (Figure 4.4); only the more abundant species, as revealed by the TWINSPAN analysis, were evaluated, including those that contributed > 10% in at least one sample site. To the left of DCA Axis 1 (Figure 4.4), *E. curvula* (ERCUR) and *Paspalum scrobiculatum* (PASCR) indicated stratum S1 (old croplands), which has been

excluded from the site ordination because of its extreme position on the ordination diagram. The arrangement of abundant species on Axis 1 partially supported the hypothesis that Axis 1 represents a grazing gradient. For instance, indicator species for the postulated grazing gradient on DCA Axis 1 (Figure 4.4) were the Increaser II, *E. racemosa* (ERRAC), which was dominant in the most heavily grazed sites, and the Decreaser, *T. triandra* (THTRI), which appeared to be correctly positioned to the centre of the gradient (moderately utilized sites). However, *T. leucothrix* (TRLEU) an Increaser I, and *L. simplex* (LOSIM), an Increaser III, occurred to the right of Axis 1 and it was difficult to explain the presence of *D. filifolius* (DIFIL), which
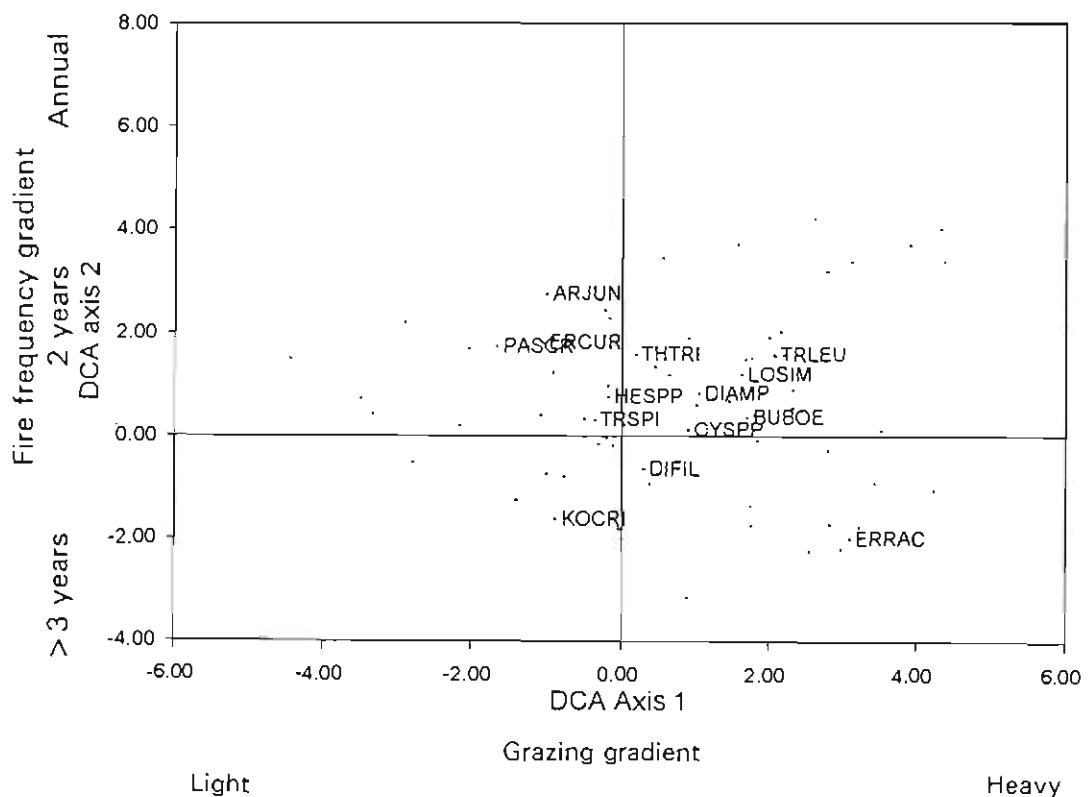
Figure 4.4 A DCA derived ordination of species in the Umtamvuna Nature Reserve; points represent their relative position along the DCA axes. Only the 14 most abundant species' codes have been inserted (full names are given in Appendix 1). Axis 1 accounted for 57.5% of the variance and Axis 2, 17.9%.

49

is also an Increaser III, to the centre of the gradient. While it must be accepted that Axis 1 might not represent a grazing gradient, two alternative explanations require discussion. These are: (a) that the response of species to grazing in warm moist grasslands differ from that recorded in Highland Sourveld (eg. Tainton 1982); or (b) that the combined effects of fire and grazing have had the greatest effect on species composition. In the case of (a), the species ordination could assist in redefining the increaser and decreaser categories for coastal grasslands, as this has not been attempted. However, this exercise is of limited value because these categories are used mainly for developing scores when assessing veld condition in commercial grazing systems. In the case of (b), the following effects could be postulated from Figure 4.4: *A. junciformis* increases with frequent burning, irrespective of grazing intensity; *E. racemosa* dominates under heavy grazing and infrequent burning; *T. leucothrix* and *L. simplex* increase under moderate grazing and biennial burning; *D. filifolius* increases under moderate grazing and infrequent burning; and *D. amplectens*, *T. triandra* and *T. spicatus* increase under moderate grazing and biennial burning. The position of *Koeleria cristata* (KOCRI) at the bottom of the axis required further investigation. Examination of the TWINSPAN matrix (Appendix 4) showed that this species was common, but occurred at low abundance, in all communities excepting for S1 and S3. It was concluded that *K. cristata*, a filiform or wiregrass species, was probably a good indicator of infrequently burnt veld. Although some sedges, eg. the genera *Bulbostylis* and *Cyperus*, were abundant, they tended to occur at similar levels in many communities and thus did not contribute as meaningfully as the grasses towards the DCA ordination. The species arrangement on the DCA axes also indicated that community S2 (Figure 4.3)

could be split into two communities, the one represented by sites 36 and 37 (dominated by *E. racemosa*), and the other by sites 31 and 32 (dominated by *L. simplex*). This split was evident at cut level 3 in the TWINSPAN analysis (Appendix 4) and was strongly indicated by the DCA ordination (Figure 4.3). For the purpose of this classification, however, the number of sites was considered to be too small to argue that two distinct communities should be recognised.

4.3.5 Environmental variables

The key question addressed in this section was "What are the effects of measurable environmental variables on community composition?". The reason for incorporating this question into the analysis was that, after establishing which variable contributed most to a species' presence or absence, it may be possible to predict a species' response from observing/measuring that variable. This is particularly useful in nature conservation (as in agriculture), where predicting the potential for species' appearance or disappearance may be required. A common example is found in the question "What effect does soil depth have on a particular species, eg. *T. triandra* ?". Descriptions of the range of suitable analytical techniques were provided by ter Braak (1987a), who noted that this approach was a form of direct gradient analysis, using explicit environmental data. Similar procedures for investigating correlations were used by Cowling (1983), who attempted to determine which environmental variables affected the distribution of C_3 and C_4 grasses in the Cape fynbos.

Initially, consideration was given to arranging some of the variables such as slope and soil depth into categories, but it was reasoned that use of available quantitative information which reflected a continuum of variables, would probably provide a more interpretable data set (Cowling 1983). Six variables were selected because they were likely to affect species' distributions, as shown in other studies, eg. Shackleton (1989) and Cowling (1983). These were soil depth, soil form, slope angle, aspect, altitude and distance from the sea (Table 4.1). Soil chemistry was not determined because of the uniformity of the sandstone derived soils over most of UNR. Soil depth was measured with a soil auger. Altitude, expressed in metres above sea level, was calculated from the contour lines on the 1:10 000 survey map. Distance from the sea was estimated to the nearest 50 m by measuring a straight line trajectory on the 1:10 000 survey map, from a point in the centre of the mouth of the Umtamvuna River, directly inland to each sample site.

To facilitate the analysis, the descriptive (nominal) variables, namely soil form and aspect, were defined as 'dummy variables' (ter Braak 1987b), as follows: 1 = Clovelly, 2 = Mispah, 3 = Glenrosa and 4 = Katspruit. Slope angle was estimated from the contour intervals on the 1:10 000 survey map, using the following trigonometric calculation: angle of slope (in degrees) = $\sin^{-1}$ of the contour interval (a constant) over the hypotenuse. Aspect was determined from the survey map at the same time that the contour distance measurements were being made for each site and was simply recorded as east, south-east, west, north-west, etc., or as level where the slope was < 4 degrees. Following the rationale of Schulze (1975) concerning the correlation between slope and soil temperature, dummy variables representing 'heat

52

Table 4.1   Environmental variables recorded in 48 sampling sites in the Umtamvuna Nature Reserve. Dummy (numerical) variables were created for soil form and aspect, in order to facilitate the regression analysis.

Site No.	Soil depth (cm)	Soil Form	Slope (degrees)	Aspect	Altitude (m)	Dist.from sea (m)
1	>120	Clovelly	30	S	340	8 470
2	50	Mispah	10	W	330	8 820
3	55	Mispah	17	N	340	9 005
4	75	Glenrosa	4	S	390	9 240
5	40	Mispah	24	NW	350	9 350
6	35	Mispah	9	N	370	9 480
7	45	Mispah	17	W	380	9 670
8	45	Mispah	13	W	350	10 010
9	>120	Clovelly	30	W	260	8 500
10	>120	Clovelly	5	W	330	8 000
11	35	Mispah	8	S	170	3 150
12	25	Mispah	4	S	200	3 640
13	30	Mispah	5	W	250	3 480
14	35	Mispah	5	W	490	20 300
15	20	Mispah	19	NW	380	19 050
16	25	Mispah	6	S	490	20 750
17	15	Mispah	5	W	380	9 600
18	25	Mispah	12	SE	410	9 220
19	25	Mispah	6	N	350	9 820
20	30	Mispah	5	W	410	18 350
21	75	Clovelly	14	W	390	18 050
22	35	Mispah	5	S	380	10 850
23	20	Mispah	6	N	390	10 380
24	50	Mispah	4	SE	400	9 260
25	30	Mispah	4	S	330	7 330
26	20	Mispah	9	SE	360	8 550
27	20	Mispah	30	SE	290	8 200
28	>120	Clovelly	42	SE	280	7 850
29	40	Glenrosa	5	W	350	8 750
30	30	Mispah	5	W	350	8 740
31	25	Mispah	13	SW	420	20 350
32	25	Mispah	10	W	410	20 450
33	95	Clovelly	14	E	360	9 850
34	>120	Clovelly	5	W	380	10 000
35	45	Mispah	19	W	140	9 450
36	25	Mispah	17	NW	390	10 600
37	20	Mispah	24	W	340	10 010
38	>120	Katspruit	7	NE	410	9 700
39	20	Mispah	5	N	410	16 400
40	30	Mispah	11	W	380	16 200
41	25	Mispah	11	W	420	15 600
42	25	Mispah	5	W	470	14 350
43	40	Mispah	14	W	370	13 350
44	>120	Clovelly	7	W	380	19 400
45	30	Mispah	6	S	470	19 950
46	30	Mispah	12	SW	330	8 600
47	25	Mispah	10	S	380	8 800
48	20	Mispah	5	E	410	9 970

classes' were assigned to each aspect. These were designated as follows: 1 = SE (coolest slope), 2 = S, 3 = SW, 4 = E, 5 = W, 6 = NE, 7 = N and 8 = NW (hottest slope). Correlations between the six environmental variables and the DCA ordination axes are discussed in the next section.

4.3.6 Analysis of environmental variables

4.3.6.1. Correlation

Tests were undertaken to detect correlations between each of the DCA axes 1 to 4 and the six measured environmental variables. Spearman's rank correlation coefficient (r_s) is an efficient technique for testing for 'associations' between variables (Neave & Worthington 1988). Environmental variables were used as independent variables and the DCA axes as dependent variables. The statistical package STATGRAPHICS (Anon 1988) was used for the analysis (with 46 degrees of freedom in all cases). The correlation coefficients derived from this type of test lie between -1 and +1, where +1 represents extreme evidence of positive correlation, ie. perfect agreement (Neave & Worthington 1988). No objective method exists for selecting the value that would denote significant or meaningful correlations and a subjective decision is therefor required. Neave & Worthington (1988) noted that, where N is large, even a small value of r_s (such as 0.4) may be significant, indicating that at least "...some relationship does exist.". Thus the test is not a test of significance, but "...judges whether or not the null hypothesis of zero correlation is consistent with the data." (Neave & Worthington 1988). Accordingly, r_s values of 0.4 and higher are discussed below.

54

Correlations were detected between certain environmental variables, namely soil depth/soil form (see (a) below) and elevation/distance from the sea (see (b) below).

(a)   The correlation between soil depth and soil form ($r_s = $ -0.46, $P < 0.002$) was expected, because the Clovelly soils were all deep (> 120 cm), while the Mispah soils were considerably shallower (mean $= 30.4$ cm; range $= 20$ to 50 cm).

(b)   A strong within-variable correlation was evident between altitude and distance from the sea ($r_s = 0.80$, $P < 0.001$). This was to be expected, as it revealed the nature of the topography, namely increasing altitude with distance from the sea.

(c)   Altitude was correlated with DCA axis 1 ($r_s = 0.55$, $P < 0.002$). I was unable to translate this into any form of predictive value, because the species on both the left and the right extremes of axis 1 occurred at similar altitudes.

(d)   Soil depth was correlated with DCA axis 1 ($r_s = $ -0.40, $P < 0.008$), which indicated a weak gradient from deeper soils (characterised by species such as *Paspalum scrobiculatum* and *E. curvula*), to shallower soils characterised by *E. racemosa* (ie. left to right of DCA axis 1, Figure 4.4). While *E. racemosa* is clearly associated with shallow soils, the species gradient inferred from this correlation is potentially misleading, because the species associated with deep soils occurred as a result of past management (recent cultivation) and therefore do not reflect soil depth *per se*.

The analyses described thus far indicated that past management appeared to

be the most important factor affecting pattern or community composition in the UNR grasslands. The analyses were of some value in developing the capacity to determine past land use through recognising key species (such as *P. scrobiculatum* and *E. curvula*), or conversely, being able to predict which species were likely to dominate in response to a particular management action (such as *E. racemosa* on heavily grazed sites). The study also provided some insight into the responses of the coastal grasslands to two management variables, namely fire and grazing. Other analytical approaches that are considered to be useful for a further evaluation of the response of species to environmental gradients are reported upon below.

4.3.6.2 Canonical ordination

Canonical ordination is the form of ordination that integrates regression and ordination into multivariate direct gradient analysis (ter Braak 1987b; 1988). This approach is mostly used to detect pattern (variation in species composition); it is also used to detect the main relations between species and a number of observed environmental variables (Gauch 1982; ter Braak 1987b; 1988). Canonical correspondence analysis (CCA) is used to test the effect of a set of particular environmental variables on species composition, thus providing a form of direct gradient analysis (ter Braak 1987a). The computer program CANOCO is a form of CCA commonly used for this purpose (ter Braak 1991); the main attraction of CANOCO being that it also permits the testing of the significance of relations between species and environmental variables. Another important feature of CANOCO is that it is an extension of DCA, meaning that the analysis also reveals the pattern of variation (ter Braak

1987a). After the removal of the 'outliers', ie. old cropland sites (34 and 38, which were also removed for the DCA analysis) the data set comprised 46 sites and 86 species. The environmental variables were the same as those listed in Table 4.1, with dummy variables created for the two explanatory (nominal) variables, namely soil form and aspect, as described under 4.3.5. Default settings were used for the CANOCO analysis.

The product of the analysis was a biplot, being a joint plot showing the relation between species and environmental variables (Figure 4.5a). Eigenvalues were 0.104 and 0.071 for the X and Y axes respectively. Initially the sites were labelled according to their respective TWINSPAN derived communities, and were superimposed on the biplot. The information was cluttered as a result of a large proportion of species and sites being close to the centroid. This was unchanged even when the less abundant species were omitted. Changes were made to the scale, but this was unsatisfactory because some of the outlying sites were then omitted. As a compromise, a second biplot was produced, showing the effects of environmental variables on sites (Figure 4.5b). The arrow representing an environmental variable points in the direction of maximum change of the variable across the biplot. The direction of the arrow indicates the direction in which the corresponding species increases most (ter Braak 1987a), while the length of the arrow indicates the rate of change in that direction (length being proportional to the rate of change). The cosine of the angle between the arrow and the axis (cos $0° = 1$; cos $90° = 0$) is a measure of the extent of correlation, ie. the smaller the angle the stronger the correlation. Therefor for Axis 1 of Figure 4.5a, Distance > Altitude > Aspect > Depth > Slope.

The significance (at the 5% level, t > 1.96) of the relation between environmental variables and the CCA axes, was also calculated (Table 4.2). The only strong correlation was between Axis 1 and the variable distance from the sea (r = 0.83). On inspection of Figures 4.5a and 4.5b, together with the information in Table 4.2, it was seen that sites with a high abundance of
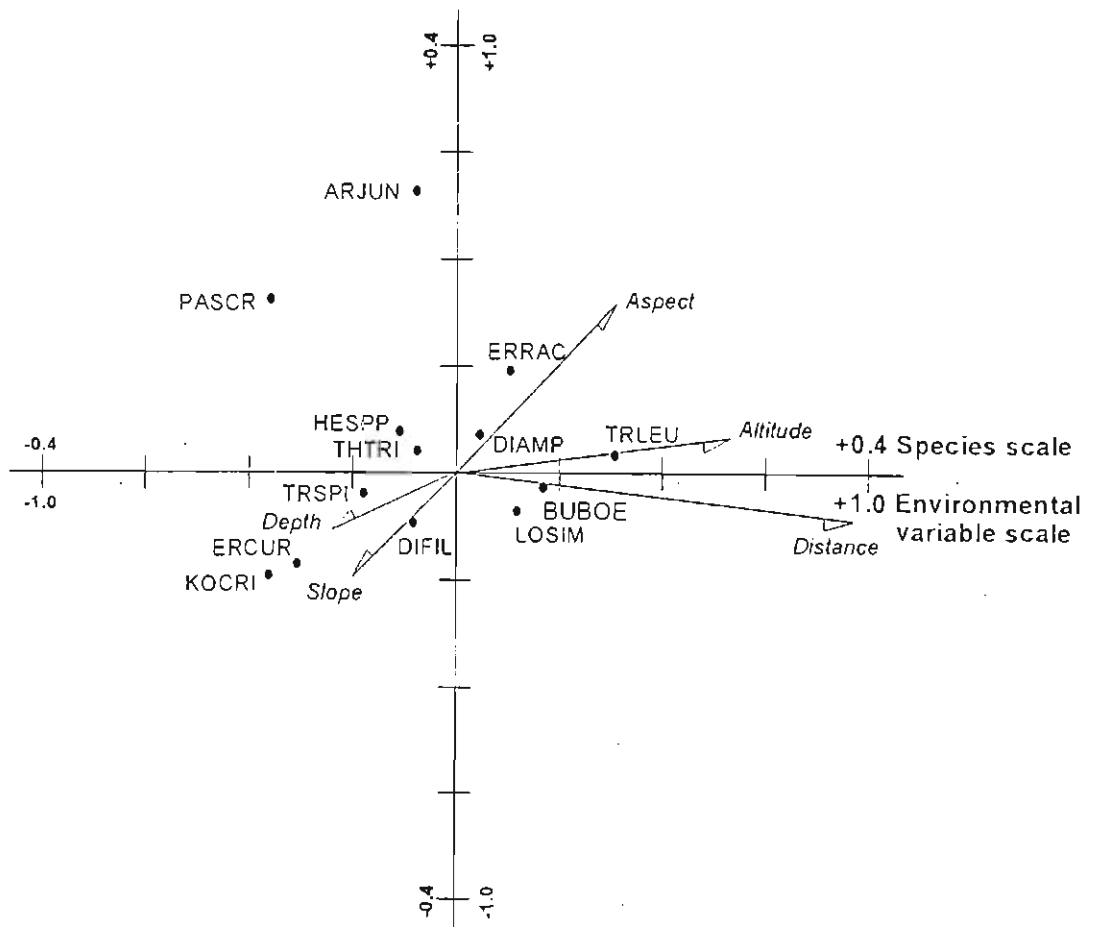
Figure 4.5a   A CANOCO derived biplot of the UNR data showing the 13 most abundant species (full species names in Appendix 1) and five most important environmental variables (arrows). Scales are unequal: 0.4 units on the species scale equals 1.0 unit on the environmental variable scale. The X axis accounted for 41.8% of the variance and the Y axis 28.5%. *T. leucothrix* was strongly correlated with distance from the sea and *A. junciformis* was weakly correlated with aspect.

T. leucothrix occurred to the right of Axis 2, and it was inferred that *T. leucothrix* increased in abundance with increasing distance from the sea. A weak correlation was evident between Axis 2 and altitude, which indicated that *A. junciformis* was most abundant on the warmer (northerly) slopes. The eigenvalues (which are a measure of the biological relevance of the DCA axes) were low, at 0.104 and 0.71 for axes 1 and 2 respectively. Low eigenvalues indicate that the selected environmental variables are not predicting the main variation in species composition. However, it was pointed out by ter Braak
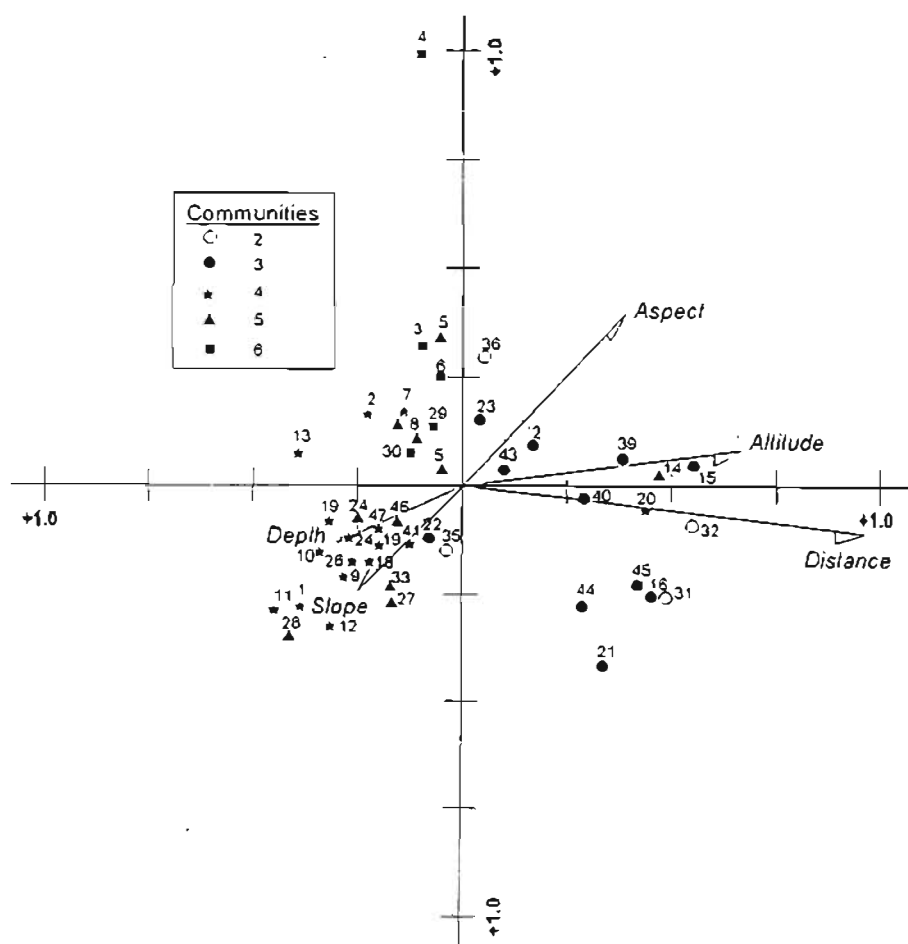
Figure 4.5b   A CANOCO derived biplot of the UNR data showing the relation between sites (numbers), five TWINSPAN derived communities (symbols) and five important environmental variables (arrows). Scaling of sites and variables is the same. The X axis accounted for 41.8% of the variance and the Y axis, 28.5%. Sites of community 1 (old croplands) were omitted from the analysis.

(1987b) that, despite low eigenvalues, the variables showing a strong correlation with one of the CCA axes were in effect predicting a substantial part of the remaining variation. This suggests that the higher eigenvalues in the first and second axes of the DCA ordination were a measure of the main gradients, postulated earlier to be grazing and fire gradients respectively.

Table 4.2   Umtamvuna Nature Reserve: relation between eight environmental variables and four CCA axes, tested for significance at the 5% level (t > 1.96)

Variable	Axis 1	Axis 2	Axis 3	Axis 4
Distance from sea	+0.83	-0.16	-0.11	n.s.
Altitude	n.s.	+0.09	-0.45	n.s.
Aspect	n.s.	+0.34	-0.17	-0.30
Soil: Clovelly	n.s.	-0.32	-0.31	n.s.
Soil: Mispah	n.s.	-0.04	n.s.	n.s.
Soil: Glenrosa	n.s.	n.s.	n.s.	n.s.
Slope	n.s.	n.s.	-0.20	-0.36
Soil depth	n.s.	n.s.	n.s.	+0.23

Other variables have been evaluated in similar studies, eg. in the MGR grasslands study, Shackleton *et al.* (1991) revealed strong correlations between plant community distribution and soil conductivity, and plant community distribution and organic matter. Variables describing soil chemistry were excluded from my analysis because the sandstone-derived soils in the UNR were considered to be fairly uniform, as was evident from the soil forms described earlier (Table 4.1).

4.4   Conclusion

The objectives of producing a classification of the UNR grasslands, of developing an understanding of grassland community structure and the mapping of grasslands at a scale of 1:10 000 (Figure 4.2), were achieved. The classification of grassland communities was achieved primarily by interpreting the TWINSPAN derived ordination, but valuable additional information was provided by subjecting the data to detrended correspondence analysis (DCA) and canonical correspondence analysis (CCA). The DCA derived analysis of species and sites contributed towards the determination of possible environmental gradients related to past management, ie. fire and grazing. The CCA derived gradient analysis was useful in that it revealed the extent to which a number of selected environmental variables affected species distribution; this exercise also accounted for the remaining variation not measured by the indirect gradient analysis. The weak correlations between most of the environmental variables and species abundance may have been an indication of relative uniformity of the study area; however, this is hypothetical and indicates a need to evaluate other variables, such as organic content and chemistry of the soil. Further work on this aspect, as well as detecting additional grassland communities, is recommended. Investigations by way of hypothesis testing are recommended, especially with regard to the postulated gradients of grazing and fire frequency.

The experience gained through achieving the above objectives contributed significantly towards meeting the objective of developing a monitoring programme, which is dealt with in the next chapter.

CHAPTER 5   MONITORING

5.1   Introduction

While no single definition of monitoring is likely to be universally accepted, it is widely recognised that the aim of monitoring should be to detect change over time (Mentis 1984, 1989). It is understood that establishing the cause of change is not necessarily part of the monitoring exercise, but represents a separate step (Green 1979; Mentis 1984). A general definition of monitoring, as suggested by Green (1979) and supported by Mentis (1984, 1986), is: "To test the null hypothesis of no change over time in predefined properties of a system...". This definition has been adopted for the purpose of this chapter. Siegfried & Davies (1982) claimed that monitoring was one of the most important yet most neglected criteria in the management of ecosystems. They made a strong appeal that monitoring operations should be undertaken "...as a rule..." in protected areas; without this, conservation efforts could not be evaluated, nor could remedial action be planned. In assessing the attainment of nature conservation goals, Siegfried & Davies (1982) claimed that a monitoring programme should be designed in such a way that it would assist in establishing the effects of management actions on the vegetation. This was also noted by O'Connor (1985), who claimed (in the context of the grass layer in savanna ecosystems) that without monitoring, there was a risk that models of system functioning would be incorrect. Aucamp *et al.* (1992) claimed that the basis for managing conserved areas "...must be the conservation of the floral element on which all other objectives rely." Monitoring therefore had to determine whether temporal

protected areas would place greatest emphasis on assessing the effects of management actions, such as fire, on elements of diversity, such as species and habitats (Mentis 1984; Siegfried & Davies 1982). This requires that monitoring be designed to measure predetermined levels of change, with due consideration for both *species* and *communities*.

In the context of managing conserved grasslands, Mentis (1984) suggested that it was important to detect the direction and extent of change in species composition along a recognised gradient. Thus, he suggested an ordination approach for monitoring grasslands that have been maintained by fire, through detecting a shift of sites along the DCA axis that has been interpreted as a fire frequency gradient. This approach was considered for the UNR, but was inappropriate because the fire gradient referred to in Figure 4.3 was inferred from historical burning treatments with different fire frequencies from those currently being applied.

The possibility of resampling permanently marked plots, as advocated by Austin (1981), was also considered. While this approach may reduce the number of samples, the statistical requirement of independence of samples is violated; ie. the mean and variance are not independent of each other in subsequent surveys (Greig-Smith 1983). Mentis (1986) investigated methods to detect change on permanent plots and noted that a prerequisite was the initial random location of plots. Thereafter, random observations within the plots would address the requirement of statistical independence; however, this constitutes a form of pseudoreplication (Hurlbert 1984). Swaine and Greig-Smith (1980) suggested an ordination approach (partial principal

64

components analysis) whereby a sequence of observations from the same plots could be analyzed. In his review of 'temporal fluctuation', Austin (1981) argued that assessing change by using data from a sample of vegetation was problematic because of the assumption that the sites were of equivalent potential at the onset of monitoring. He noted that increasing the sample size could offset the problem, but no comment was made on the additional expense this would involve. It was further claimed by Austin (1981) that randomly located quadrats can only determine mean changes and therefore the detection of changes in the spatio-temporal mosaic required permanent quadrats.

The evaluation of commonly used techniques for monitoring of the herbaceous layer revealed a divergence of opinions, primarily between point based and area (quadrat) based approaches. Accordingly, these have been discussed below under separate headings.

5.2.1 Point based techniques

Point based techniques are those that are used to collect data by the random or systematic placement of a number of points (spike or wheelpoint), and identifying the nearest living plant to the point. This method was first described by Tidmarsh & Havenga (1955) and modified by Foran *et al.* (1978). Although point data can be collected along a line (line intercept), the most common approach is to randomly locate plots (usually 30 X 30 m or 20 X 20 m in size) and to collect a predetermined number of point observations in each plot (Mentis 1984). The point based techniques were evaluated for

65

their efficiency in monitoring of changes in *community composition* and *species diversity*, as discussed below.

5.2.1.1 Community composition

their efficiency in monitoring of changes in *community composition* and *species diversity*, as discussed below.

5.2.1.1 Community composition

Community composition is determined from the measurement of proportional species composition, usually expressed as a percentage contribution by each species. Differences in proportional composition are commonly detected by the analytical tool TWINSPAN (Hill 1979a), as elaborated upon in Chapter 3. Community composition is a widely used parameter in grazing management literature. Its acceptance has developed from an animal production perspective, leading to the conventional wisdom that community composition data efficiently indicate the capacity of the veld to sustain animal production (Tainton 1982). The potential for adapting this technique for monitoring grasslands was explored by Mentis (1984, 1986), who concluded that point data reflecting community composition were efficient for detecting change and for relating such changes to key variables, such as grazing or fire frequency.

The use of point based data for analysis of community composition has been most strongly supported by researchers working in the humid grasslands areas of South Africa (especially in KwaZulu-Natal), eg. Mentis (1986), Holton (1987), Walker (1988a) and Hardy & Walker (1991). It was suggested by Hardy & Walker (1991) that as few as 200 points might be adequate for monitoring; however, their tests for establishing acceptable levels of replicate similarity were based on data from sites with few grass species, ranging from

eight to 20. Forbs and sedges were placed in a single group. Mentis (1984), Holton (1987) and Walker (1988b) also advocated the use of point data for monitoring, but provided no justification for their choice. McKenzie (1987) claimed that point data were adequate for establishing community diversity or 'inter-community pattern', an important criterion in nature conservation.

Stalmans & Mentis (1993) favoured proportional species composition for monitoring grasslands in a nature reserve in the north eastern Transvaal (now Mapumalanga); they identified species composition as the only parameter of concern and dismissed other 'arbitrarily chosen techniques' as being unlikely to meet the stringent requirements of statistical credibility and cost-effectiveness. Stalmans & Mentis (1993) required only 87 point observations to achieve a mean $PS = 90\%$ in their 20 X 20 m plots; this increased to 142 points required to achieve a mean $PS = 95\%$. Unfortunately, the number of species contained in their data set was not mentioned, but it was likely to have been small. Walker (1988a) pointed out that the higher the PS value, the better the estimate of internal association. However, in the UNR (Table 3.2) it was clear that it would be impractical to increase the number of point observations until a mean PS of say 95% could be attained, as was proposed by Hardy & Walker (1991) for monitoring studies. It was demonstrated earlier (section 3.2.2) that, when all 68 species were used, a low percentage replicate similarity ($PS = 84.4\%$) was obtained after as many as 400 points. However, by excluding all species contributing < 5% in any single plot, the replicate similarity increased considerably ($PS = 90.1\%$, after only 200 points). This demonstrated that, in the UNR case, point data would suffice for measuring changes at the community level. This approach was also favoured

because the important step of establishing replicate similarity in the species rich UNR grasslands had already been undertaken. However, the practicality and cost of randomly locating an adequate number of plots in each stratum (as discussed under Sections 4.2 and 4.3) needed to be determined. Walker (1988a) calculated that, in the Drakensberg grasslands, 30 random plots (and 200 points per plot) were required per stratum, while Stalmans & Mentis (1993) required 25 plots (and 142 points per plot). The approximate costs of applying similar techniques in the UNR were calculated, in an attempt to provide a comparison of costs (Table 5.1). Complicating factors, such as the greater number of points required for areas with high species diversity, have been excluded, so the illustration was probably conservative when applied to the UNR. Although not quantified here, more time would be required for the sophisticated analyses of point derived data, as advocated by Mentis (1984;

Table 5.1   A comparison of the efficiency of point based and quadrat based techniques, for monitoring grasslands in the Umtamvuna Nature Reserve, assuming that all data were collected by the same observer.

Technique (Author)	No. samples required for retrieval of 95% of internal association (per stratum)	Time* required per stratum (hours)	Information provided
Point (Stalmans & Mentis 1993)	25 random plots; 142 points/plot = 3550 points	14.45	Community composition
Point (Walker 1988a)	30 random plots; 200 points/plot = 6000 points	20.00	Community composition
Quadrat (Proposed by le Roux 1995)	47 random placements	4.50	Community composition and Alpha diversity

* Calculated from averages as recorded in Table 3.1

68

1986). The efficiency of quadrats was clear from this exercise, and is discussed in detail in Section 5.2.2.

5.2.1.2 Species diversity

Point based techniques appear to be adequate for the measurement of species richness or alpha diversity, because the data reflect both the species present in a site and the relative abundance of the set of species, for a given site. The arguments in favour of using point based techniques for monitoring diversity have not been strongly challenged by grassland researchers, although McKenzie (1987) pointed out that his 200 points per 0.1 ha plot provided "...poor information on species diversity and no information on intra-community pattern...". In my study (Chapter 3, section 3.2.1), it was demonstrated that the point based technique efficiently measured only the abundant species. While I argued earlier that this was adequate for meeting the aim of producing a classification, it cannot be considered to be efficient for monitoring changes in alpha diversity; eg. from Table 3.1, it was seen that only 34% of the species in the study site had been encountered after 600 point observations and 36% after 1000 points. By extrapolation (with a known species count of 119), it could be expected that in excess of 2000 points per plot would be required to capture a reasonable amount of the species diversity. The time taken per 2000 points would be about nine to ten hours, indicating a potentially high cost. It was concluded that, where the plant community is species rich and where alpha diversity is one of the important parameters, the claim of superior efficiency of the point based method by Stalmans & Mentis (1993) can be refuted.

69

It was evident from the above investigation that the concept of community composition is well understood and its use is widely supported, because it has merit for a variety of investigations in grasslands. However, there is little evidence to support the case for using point based techniques for monitoring any parameter other than the proportional composition of the most abundant species. Opinions on the most efficient method of obtaining the data vary considerably, depending in most cases on the vegetation type and researchers' affiliations. Workers in semi-arid areas with a grassland component have been critical of measuring community composition with point based techniques; however, they have not agreed on an alternative. Snyman *et al.* (1990) suggested proportional biomass as an alternative; Peel *et al.* (1991) used a belt transect technique; O'Connor (1991) used 50 X 50 cm quadrats; and Eckhardt *et al.* (1993) and Panagos (1995) applied the Braun-Blanquet approach.

Researchers have favoured point based techniques mainly for the following reasons: (a) the ease of data collection; (b) the repeatability of the technique; (c) the statistical validity of the data; (d) the low cost of equipment, such as a spike in stead of a wheel point apparatus, as shown by Everson & Clarke (1987); and (e) the ease with which a single operator can collect the data. The question of how point based techniques compare with the more widely used quadrat based techniques, is addressed the following section.

5.2.2 Quadrat based techniques

Quadrats are used primarily for the measurement of *frequency*, which is

usually expressed as the proportion of samples in which a species occurs (Greig-Smith 1983). Quadrats are the unit of measurement and should not be confused with the sample plots referred to earlier, within which point observations are made for obtaining species composition data. Reports on the use of quadrats to measure frequency in communities with a grassland component include those by McKenzie (1987), Venter *et al.* (1989) and Panagos (1995). Quadrats were also used by O'Connor (1991), who measured species composition, expressed as the "...percentage of total number...", as well as individual species' responses to experimental treatments. Workers who have compiled species lists and measured alpha diversity have relied on quadrats, with the Braun-Blanquet and Whittaker plot methods being most popular. However, these methods do not provide the quantitative floristic data that are a prerequisite for monitoring (Aucamp *et al.* 1992).

In anticipation of assessing the efficiency of quadrats, I had earlier used a quadrat to collect frequency data in the 'intensive' study site, referred to under section 3.2.1. These data were collected in the same 20 X 20 m plot that provided the information in Table 3.1, and comprised 50 randomly located quadrats measuring 100 X 100 cm, in which all species were recorded with each quadrat placement. Time taken to complete the exercise was also recorded. The exercise revealed that most of the alpha diversity of the site could be captured by quadrats, eg. the first 39 quadrats captured 88%, while 47 quadrats captured 98% of the species present, on a site with very high alpha diversity (119 species in total). Data collection was terminated at 50 quadrats, once it was clear that, beyond 47 quadrats, sampling had

reached the level where most of the species had been recorded. Clearly, fewer quadrats are likely to suffice in less diverse sites, eg. O'Connor (1991) found 20 to be adequate in a study site with <30 species of grasses and forbs. While the 100 X 100 cm quadrats were shown to be superior for detecting nearly all of the species present in the UNR site, it was evident from Table 3.1 that this technique was also expensive in terms of time (50 quadrats required just under five hours). Apart from the expertise required for identifying all the species in the sward, considerable time was taken in searching for and identifying all species occurring in each quadrat. However, the time factor was placed in perspective by calculating the time required for collecting an adequate sample of quadrat based data, and comparing this with an adequate sample of point based data; for the latter calculation the sample sizes provided by Hardy & Walker (1991) and Stalmans & Mentis (1993) were used (Table 5.1). When using the time required to collect the data as the major criterion of efficiency, the quadrat based technique is clearly more efficient, requiring about one third of the time to collect an adequate sample. Additional information is also supplied by the quadrat data, in the form of a measure of alpha diversity. The cost of equipment (quadrat versus a spike) was considered to be equally low in both cases, as was the ease with which a single operator can collect the data. A prerequisite for monitoring with quadrats is that the worker must be able to identify most of the plants in the sward; however, this is an obvious requirement if the aim of monitoring is to detect change at the species level.

The efficiency of quadrats is accentuated when a monitoring exercise requires data on species, such as when measuring alpha diversity or species'

72

responses to a treatment (eg. O'Connor 1991). An assessment of the minimum number of quadrats per stratum can be undertaken as a routine operation, during the collection of the baseline data. The cut-off could be simply determined as follows: the 100 X 100 cm quadrat was earlier seen to be efficient for detecting nearly all species occurring in a species rich site; thus, when no additional species are encountered, it may be assumed that sufficient samples have been collected. What will also have to be determined for each stratum is the minimum number of quadrats required for revealing community composition, but this should not exceed 47, as this was determined in a site with very high alpha diversity. It was clear that a monitoring procedure could be designed in a variety of ways, not all of which were appropriate for meeting the requirements of efficiency for monitoring in the UNR. The main issues are summarised below.

(a)   Gradient analysis (ordination) techniques were not applicable for monitoring in the UNR, because the difference between annual and biennial burns (the only current forms of management) represents a weak gradient.

(b)   The case for permanent plots was convincingly presented by Austin (1981), but he made no contribution with regard to the techniques of data collection and analysis. Also, potential problems with statistical validity have been recognised, when using permanent plots (Hurlbert 1984; Hardy & Walker 1991).

(c)   Mentis (1986) and Stalmans & Mentis (1993) provided a recipe type of approach, using randomly located plots and point based species composition data. The statistical soundness of this approach is not questioned for detecting changes in species composition; however,

two concerns were: (i) the high cost of meeting the requirements of random location and the minimum number of plots per stratum; and (ii) the emphasis on abundant species only, with inadequate sensitivity for detecting change at the species level.

(d)   Randomly located quadrats provided an efficient method of monitoring both community composition and species diversity.

The above overview revealed that, by using a quadrat based approach, it was possible to produce a sampling design that meets the criteria of repeatability, statistical rigour, sensitivity to predetermined levels of change, and cost-effectiveness. The latter point is of course relative, because all monitoring carries a cost, but quadrats were superior in providing the most information for the lowest cost. The costs of equipment and locating sites were considered to be nearly equal for both methods, so no detailed comparisons were made. A pitfall in attempting to meet all the criteria of monitoring is that the programme could be designed as an academic exercise, thus rendering it practically useless because it is too expensive or complicated to implement (Aucamp *et al.* 1992). This was borne in mind in the following section, which deals with the design of an appropriate monitoring programme for the UNR.

5.3   Recommendations for a monitoring programme

Earlier in this study it became evident that the grasslands of the UNR were characterised by a number of features, the major ones being the lack of structural diversity and high within-community (alpha) diversity. In addressing the question "What do we need to monitor, and why?", a subset of questions

74

was also addressed, namely "What levels of change do we wish to detect?" and "What are acceptable levels of change?". In the context of managing conserved grasslands, answers are not as clear as, for instance, in a livestock production system that focuses on profit. It was suggested earlier that the most important consideration in monitoring vegetation in a protected area is the detection of the effects of management actions on species and communities; apart from cost effectiveness, the spatial and temporal scales at which such actions are applied are also major criteria affecting the selection of a monitoring technique. In this study, the main management activity affecting the grasslands of the UNR is fire, usually applied at a spatial scale of 10 to 200 ha and a temporal scale of one to three years. It was considered that monitoring the effects of fire at both the species and the community levels would be of importance to reserve managers. From the evidence in section 5.2, it was clear that the point based technique would suffice for monitoring change only at the community level and that it would be too insensitive to measure species' responses, apart from the most abundant species. In his experimental treatments, O'Connor (1991) demonstrated that as few as 20 quadrats of 50 X 50 cm were suitable (a) for providing a species list, (b) for measuring community composition and (c) for assessing the response of species to treatments.

An examination of the vegetation map (Figure 4.2) showed that the six communities classified earlier were widely scattered and that resampling each portion of a community would be impractical. It was therefore considered that the most efficient approach would be to monitor representative portions of each community. To illustrate the concept, the old lands community (S1) was

75

represented by one large and two small sites; the larger of these was selected as a 'typical' site, ie. the representative compartment in which to monitor change. Similarly, typical sites were selected for each of the other five strata. This was done by referring to the DCA ordination (Figure 4.2) and the TWINSPAN classification (Appendix 4), from which typical sites could be identified. The size and configuration of monitoring sites varied, especially in the case of old lands (S1) where even the largest of the sites was small. The selected sites were designated M1 to M6, the number in each case corresponding with the community number; the locality and extent of all monitoring compartments were indicated in Figure 4.2. Having established earlier that 47 quadrats were adequate for capturing almost all (98%) of the species diversity, it was assumed that at most 50 random quadrat placements would be required per monitoring site. It is recognised that each of the sites may require a different number of quadrats, but this could be ascertained while collecting the baseline data, using the logic of establishing a cut-off when no new species are encountered. With regard to sampling frequency, O'Connor (1985) suggested that the intensity of sampling should be related to the time span within which the variable can change. In the case of the UNR, circumstantial evidence has indicated that in fire maintained sites, the rate of change is likely to be slow; hence, where monitoring annually or biennially burnt sites, a frequency of five years should be adequate. However, in fire exclusion sites, a more rapid change has been observed and it is recommended that these sites be re-assessed every three years. The following approach is recommended for monitoring grasslands in the UNR.

(a)   Obtain baseline data by randomly locating a number of 100 X 100 cm quadrats in each of the six typical compartments identified in the map

(Figure 4.2). A maximum of 50 quadrats will probably be required in the most diverse sites, but the exact number will be established per sample site, once no further species are encountered.

(b)   Record the presence of each species found in each placement of the quadrat and produce a summary list of species.

(c)   Calculate species' frequency (abundance) and proportional composition for each compartment.

(d)   On a follow-up survey (suggested interval is five yearly in biennially burnt areas, and three yearly in fire-exclusion experiments), repeat the above procedure and perform a chi-squared analysis on the baseline and follow up data, for each species. This analysis will test the null hypothesis of no change in species' abundances between successive surveys. The same analysis should be done for detecting changes in proportional composition.

(e)   Present the results of the analysis as tables, noting where differences are significant at the 90% and 95% confidence intervals. Two levels are suggested because both are commonly used in statistical analyses (Greig-Smith 1983).

The information derived from the above approach would be adequate to reveal significant differences (if any) between baseline and follow up surveys. Only an experimental approach (with treatments and controls), would provide comparative data to assist in establishing whether or not these changes were in response to some form of management, eg. fire. Finally, the *extent of change* to be regarded as being of practical importance, ie. on which to base decisions, needs to be predetermined. This is a subjective step (Aucamp *et al.*

77

1992) and the cost of achieving the desired level of sensitivity is often the most important factor.

The techniques that were recommended following a series of grassland monitoring workshops in the mid-1980s do not appear to have been widely implemented. It is possible that workers have been put off by the time required to produce the large number of randomly derived samples per stratum and by the relatively sophisticated data analyses, as advocated by Mentis (1984, 1989). In contrast, the quadrat based technique produces more information and is more efficient, but requires considerable plant identification skills pertinent to the plant community being studied.

CHAPTER 6   CONCLUDING DISCUSSION AND RECOMMENDATIONS

6.1   Discussion

The primary objective of the study was to contribute towards the description of grassland communities of the coastal region of KwaZulu-Natal, as a refinement of earlier descriptive work. The Umtamvuna Nature Reserve was suitable for this study because it contains the largest remnant of protected coastal grassland south of the Tugela River and no previous attempt has been made to describe and map these communities. The pilot study provided essential information to justify the selection of an appropriate classification technique. The classification objective was met through the use of TWINSPAN, which demonstrated that this technique was able to handle a fairly large data set with ease. With regard to the secondary objectives, the investigation into the cost of various techniques showed that the point based approach was effective for producing a classification, through providing a data set which could be analyzed by a variety of established statistical and ordination techniques. The point based approach was not effective for studies where species inventories and/or information on alpha diversity are required. It was shown that a very large number of point observations would be required to measure the diversity of a species rich site such as the UNR. No work has been done to establish the levels of alpha diversity at which the point derived data become inadequate and this would be a useful avenue for further research. The claim by authors such as Stalmans & Mentis (1993) that proportional composition derived from point data was the only parameter worthy of measurement, was not supported in the context of meeting the

objectives of this study.

The additional steps of collecting data on environmental variables and relating these to species' distributions, required considerable effort. A prior assessment of the need for this information is essential, especially in studies where a classification of grassland communities is the primary requirement. However, where further ecological insight is required, the additional information provides a sound basis for determining effects of variables, such as abiotic components or past management, on community composition.

It was a considerable challenge to develop a suitable monitoring technique, because of the strong bias in the recent South African grassland literature towards using species composition data for monitoring. This is mainly as a result of the agricultural bias that has influenced the direction of grassland research, and of the small number of studies on assessing the suitability of other monitoring techniques. No consensus was reached regarding the suitability of grassland monitoring techniques at the monitoring workshops conducted in the mid-1980s, which were reported on by Mentis (1984, 1986). The arguments presented at these workshops were not resolved and preferences appear to have become entrenched at various institutions. Consequently, many authors have used point data for studies ranging from descriptive to monitoring and research (eg. Everson & Clarke 1987; Stalmans & Mentis 1993; Zacharias 1994), while others have preferred quadrats (eg. O'Connor 1991; Peel *et al.* 1991). Apart from my observations supporting the efficiency of point data for classification of grasslands, Hardy & Hurt (1989), Panagos (1995) and others have commented that point data are the most

sensitive for obtaining an index of veld condition. However, this study has shown that the point based approach may have been extended beyond the practical limits for which it was designed. My argument that monitoring data derived from quadrats are preferable to point based data, because they provide a measure of both community composition and species diversity, requires investigation in other humid grassland types.

Finally, the time constraints for field observations for this study resulted in certain aspects receiving inadequate attention. The grassland communities of the UNR are probably more diverse than have been indicated by the relatively small number of sample sites. This is probably of little relevance to a reserve manager concerned with managing a physiognomically uniform herbaceous layer, but may be of value in a nature reserve of major botanical importance. In particular, the intuitive capacity gained from spending much time in the study area, has led me to postulate that the UNR grasslands are in fact far more diverse than revealed by my analyses. A further gap in our knowledge is that the dynamics of these grasslands is poorly understood. There is circumstantial evidence that the high rainfall/high temperature coastal grasslands respond rapidly to the exclusion of fire, and that a significant loss of diversity (mainly in grass species) occurs within four or five years of protection from fire. This loss is offset by a small gain in woody plant diversity, which represents the early stages of invasion by fire sensitive woody pioneers. The process is not well understood nor documented, yet this knowledge is vital for meeting the conservation aim of maintaining alpha diversity within the grassland communities.

6.2   Recommendations

1.   The monitoring plan outlined in section 5.3 should be incorporated in the reserve's management plan and be implemented within the next two years. The timing is important, because baseline data could be obtained by using local expertise in the form of local amateur botanists.

2.   As a rule, the cost of equipment required, as well as the time taken for data collection, analysis and reporting, should be recorded for future cost-benefit studies.

3.   The priorities for further investigative work should include the following.

    (a)   A study on the *dynamics of coastal grasslands*, with emphasis on the effects grazing intensity and fire frequency on species and community diversity. This should be aimed at developing a predictive capability, which will contribute towards the production of a decision support system for management of coastal grasslands.

    (b)   A refinement of the UNR vegetation map, with emphasis on the woody and wetland components.

    (c)   A study of the techniques currently in use for classification and monitoring of grasslands, and testing of their efficiency in various climatic regions. Of particular importance is a comparison of cost effectiveness over a range of grasslands with varying levels of alpha diversity.

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Appendix 1 Plant names and codes for species identified in 48 sites in Umtamvuna Nature Reserve. Nomenclature according to Ross (1972).

ABLAE	*Abrus laevigatus* E.Mey.	CYSPP	*Cyperus* species lumped
ACPED	*Acalypha peduncularis* E.Mey ex Meisn.	CYSPE	*Cyanotis speciosa* (L.f.) Hassk.
ALLON	*Alepidea longifolia* E.Mey	DEDRE	*Desmodium dregeanum* Benth.
ALSEM	*Alloteropsis semialata* (R.Bir.) Hitch. var *eckloniana* (Nees) Pilg.	DESPP	*Desmodium* species lumped
ARJUN	*Aristida junciformis* Trin. & Rupr.	DIAMP	*Diheteropgon amplectens* (Nees) W.D. Clayton
ARHAR	*Argyrolobium harveyanum* Oliv.	DIFIL	*Diheteropogon filifolius* (Nees) W.D. Clayton
ARRUP	*Argyrolobium rupestre* subsp. *rupestre* (E.Mey.) Walp.	DIERI	*Digitaria eriantha* Steud.
		DISET	*Digitaria setifolia* Stapf
ASLAR	*Asparagus laricinus* Burch.	DISP1	*Digitaria* - unidentified species
ATPHY	*Athrixia phylicoides* DC.	ELMUT	*Elionurus muticus* Nees
BEOBO	*Becium obovatum* (E. Mey. ex Benth.)N.E. Br.	ERCAP	*Eragrostis capensis* (Thunb.) Trin.
BERHA	*Berkheya rhapontica* (DC.) Hutch. & Burtt Davy	ERCUR	*Eragrostis curvula* (Schrad.) Nees
BESET	*Berkheya setifera* DC	ERRAC	*Eragrostis racemosa* (Thunb.) Steud.
BESPE	*Berkheya speciosa* DC	ERPLA	*Eragrostis plana* Nees
BESPP	*Berkheya* species lumped	ERSAL	*Eriosema salignum* E.Mey.
BEUMB	*Berkheya umbellata* DC	EUALB	*Eugenia albanensis* Sond.
BRSER	*Brachiaria serrata* (Thunb.) Stapf	EUERI	*Euphorbia ericoides* Lam.
BUBOE	*Bulbostylis boeckeleriana* (Schweinf.) Beetle	EUVIL	*Eulalia villosa* (Thunb.) Nees
		FECOS	*Festuca costata* Nees var. *costata*
CACAP	*Cassia capensis* Thunb.	GEAMB	*Gerbera ambigua* (Cass.) Sch. Bip.
CAPLU	*Cassia plumosa* (E.Mey.) Vogel	HEDEC	*Helichrysum decorum* DC
CASPP	*Cassia* species lumped	HELON	*Helichrysum latifolium* (Thunb.) Less.
CAPHY	*Cassinia phylicifolia* (DC.) Wood	HEPAL	*Helichrysum pallidum* DC
CEASI	*Centella asiatica* (L.) Urban	HESPP	*Helichrysum* species lumped
COAFR	*Commelina africana* L.		
CTCON	*Ctenium concinnum* Nees	HECON	*Heteropogon contortus* L.
CYEXC	*Cymbopogon excavatus* (Hochst.) Stapf ex Burtt Davy	HYFIL	*Hyparrhenia filipendula* (l.) Stapf

HYSPP	*Hypoxis* - unidentified species
INHIL	*Indigofera hilaris* Eckl. & Zeyh.
KOCRI	*Koeleria cristata* (L.) Pers.
LESPP	*Leucospermum* sp. Strey
LOSIM	*Loudetia simplex* (Nees) C.E. Hubb.
MICAF	*Microchloa caffra* Nees
MOCER	*Monocymbium ceresiiforme* (Nees) Stapf
OLSP1	*Oldenlandia* - unidentified species
OPOBL	*Ophrestia oblongifolia* (E. Mey.) H.M. Forbes var. *oblongifolia*
OPSP1	*Ophrestia* - unidentified species
OXSPP	*Oxalis* - unidentified species
PAAEQ	*Panicum aequinerve* Nees
PADRE	*Panicum dregeanum* Nees
PAECK	*Panicum ecklonii* Nees
PANAT	*Panicum natalense* Hochst.
PAURV	*Paspalum urvillei* Steud.
PASCR	*Paspalum scrobiculatum* (Lam.) Stapf
PASP1	*Paspalum* - unidentified species
PASP2	*Paspalum* - unidentified species
PEANG	*Pentanisia angustifolia* Hochst.
PRCAF	*Protea simplex/caffra* lumped
PTAQU	*Pteridium aquilinum* (L.) Kuhn
REALT	*Rendlia altera* (Rendle) Chiov.
RHNER	*Rhynchelytrum nerviglume* (Franch.) Chiov.
RHREP	*Rhynchelytrum repens* (Willd.) C.E. Hubb.
RHSET	*Rhynchelytrum setifolium* (Stapf) Chiov.
RHTOT	*Rhynchosia totta* (Thunb.) DC var. *totta*
SEOXY	*Senecio oxyriifolius* DC
SERHY	*Senecio rhyncholaenus* DC
SESPP	*Senecio* species lumped
SESPH	*Setaria sphacelata* Stapf & C.E. Hubb. ex M.B Moss
SENIG	*Setaria nigrirostris* Nees
SPAFR	*Sporobolus africanus* (Poir.) Robyns & Tournay
SPPYR	*Sporobolus pyramidalis* Beauv.
TEKRA	*Tephrosia kraussiana* Meisn.
TECAP	*Tephrosia capensis* (Jacq.) Pers.
TESPP	*Tephrosia* species lumped
THATR	*Thunbergia atriplicifolia* E. Mey.
THDRE	*Thunbergia dregeana* Nees
THSPP	*Thunbergia* species lumped
THTRI	*Themeda triandra* Forsk.
TRLEU	*Tristachya leucothrix* Nees
TRSPI	*Trachypogon spicatus* (L.f.) Kuntze
UNFOR	Unidentifiable forbs (too little material) lumped
UNGRA	Unidentifiable grasses (too little material) lumped
URAGR	*Urelytrum agropyroides* Hack.
URSQU	*Urelytrum squarrosum* Hack.
WADEN	*Watsonia densiflora* Bak.
SP095	Specimen not identified
SP103	Specimen not identified
SP105	Specimen not identified
SP110	Specimen not identified
SP116	Specimen not identified

Analysis using TWINSPAN of Umtamvuna Nature Reserve pilot study data, comprising 11 sites and 52 species. Default cut levels 0, 2, 5, 10 and 20%, were used, with no downweighting of species.

```
                    13
               35682947001

46 KOCR I     1322-3--2-1   0000
 9 ATPH Y     ----1------   000100
 7 ARRU P     --1--------   000101
17 COAF R     ---1-------   000101
18 CTCO N     1----------   000101
30 ERCU R     1----------   000101
56 PADR E     22223-1----   000101
25 DIFI L     4444551432-   00011
26 DISE T     1323----21-   00011
28 ELMU T     23222222-1-   00011
 6 ARJU N     5454-24324-   001000
36 EUVI L     ---2---1---   001000
90 UNGR A     -2-1---1-1-   001000
 1 ABLA E     ----1--1---   001001
15 CASS P     -1------1--   001001
16 CEAS I     ---1-----1-   001001
23 DIAM P     4233222232-   001001
32 ERRA C     --111-1-11-   001001
39 HECO N     --2-21--12-   001001
70 RHTO T     -----1---1-   001001
87 TRLE U     4333234324-   001001
29 ERCA P     -------1---   00101
38 GEAM B     -------11--   00101
41 HYHI R     -------1---   00101·
83 THAT R     -----1--21-  ·00101
13 BUBO E     32224322221   0011
48 LOSI M     3-232222231   0011
20 CYSP P     34344333434   0100
85 THTR I     112-4554444   0100
88 TRSP I     2-441344443   0100
51 OLSP P     -2211-1-212   0101
89 UNFO R     -2121221212   0101
 8 ASLA R     -21-------1   011
44 INHI L     1---21----1   011
67 RHNE R     221-22111-2   011
 4 ALSE M     2211-1-1213   1000
22 DESP P     111---1--12   1000
27 DISP 1     1---------1   1000
82 TESP P     -1--1-----1   1000
 5 ARHA R     ---------1    1001
24 DIER I     ---------1    1001
37 FECO S     ---------3    1001
63 PEAN G     ---------1    1001
93 WADE N     ---------1    1001
 2 ACPE D     --------2-3   101
40 HESP P     32212134213   101
91 URAG R     -------1-1    101
10 BESP P     ---11111214   110
71 SESP P     ----2111112   110
55 PAAE Q     ---------21   111
59 PASC R     ------1-211   111
73 SESP H     --------2-1   111

               00000000001
               0000001111
               000011
```

Analysis by **TWINSPAN** of Umtamvuna Nature Reserve pilot study data, comprising 11 sites and 52 species. A meaningful classification was produced after cut levels were adjusted to 0, 10, 15, 20 %, with downweighting of rare species.

```
                      3   1
                35684702910

    1 ABLA E    -----1-1---    0000
    9 ATPH Y    -------1---    0000
   29 ERCA P    -----1-----    0000
   41 HYHI R    -----1-----    0000
   45 KOCA P    --------1--    0000
   70 RHTO T    ------1-1--    0000
   16 CEAS I    ---1--1----    00010
   28 ELMU T    111111111--    00010
   36 EUVI L    ---1-1-----    00010
   90 UNGR A    -1-1-11----    00010
   56 PADR E    11111--1---    000110
    7 ARRU P    --1--------    000111
   17 COAF R    ---1-------    000111
   18 CTCO N    1----------    000111
   30 ERCU R    1----------    000111
    6 ARJU N    4242313-1-1    001
   23 DIAM P    211111111-1    001
   25 DIFI L    233312144-1    001
   87 TRLE U    211121211-1    001
   39 HECO N    --1---111-1    01000
    4 ALSE M    1111-11-111    010010
   22 DESM O    111-1-1--1-    010010
   13 BUBO E    11111112111    010011
   32 ERRA C    --111-11--1.   010011
   40 HELS P    111111211111   010011
   48 LOSI M    1-111111111    010011
   67 RHNE R    111-11-1111    010011
   88 TRSP I    1-222321112    010011
   89 UNFO R    -1111111111    010011
   71 SENS P    ----1111111    0101
   85 THTR I    111-4332432    0101
   26 DISE T    1111--1---1    011
   46 KOCR I    1111----111    011
   20 CYPS P    12121112122    1000
   51 OLSP P    -1111-11-11    1000
    8 ASLA R    -11------1-    1001
   15 CASS P    -1--------1    1001
   27 DISP P    1--------1-    1001
   82 TEPH R    -1-----1-1-    1001
   44 INHI L    1------111-    101
   83 THAT R    ------1-1-1    1100
   10 BERK H    ---11111121    1101
   38 GEAM B    -----1----1    1101
   55 PAAE Q    ------1--1-    1101
   59 PASC R    ----1-1--11    1101
    2 ACPE D    ---------11    111
    5 ARHA R    ---------1-    111
   24 DIER I    ---------1-    111
   37 FECO S    ---------1-    111
   63 PEAN G    ---------1-    111
   73 SESP H    ---------11    111
   91 URAG R    ---------11    111
   93 WADE N    ---------1-    111

                00000000011
                000011111
                  00011
```

Analysis by TWINSPAN of Umtamvuna Nature Reserve data comprising 48 sites and 93 species, with cut levels adjusted to 0, 10, 15 & 20% and downwheighting of rare species. A classification of six grassland communities was produced from the analysis.

```
          3333323414412244  11114 1122244 1412  232   2333
          1256729062351345170123898905617276475843836490 48

53 OPSP P  ------------------------------1-------------  000000
58 PANA T  -------------------------------1-----------  000000
68 RHRE P  ------------------------------1------------  000000
78 SP11 6  --------------------------------1----------  000000
34 EUAL B  -------------------------1-----------------  000001
37 FECO S  ---------------1--------------------------  000001
41 HYFI L  ----------------1-------------------------  000001
45 KOCA P  -----------------------1---------------------  000001
52 OPOB L  ------------------------1------------------  000001
63 PEAN G  ---------------1-------------------------  000001
73 SESP H  ----------------1-1--1------1----1----------  000001
76 SP10 5  -------------------------1----------------  000001
80 SP09 5  ------------------111-------1-------------  000001
84 THSP P  ----------------------1-------------------  000001
93 WADE N  ---------------1----1---------------------  000001
38 GEAM B  -----------1--1-11111-------1------------  00001
 7 ARRU P  -------------------------------------1-----  000100
 8 ASLA R  ---------------1----------------1----1-----  000100
16 CEAS I  -------------------------------1-------1--  000100
43 HYSP P  -------------------------------------1---  000100
22 DESP P  -------------1--1-------------1-1-1---111111--  000101
 1 ABLA E  -------1---------1-1-1---------1--1--------1---  000110
10 BESP P  -----1-----111--211111-1-1--11-11111-11----1-1--  000110
46 KOCR I  11111----------1-12111111111-1-111111111111-----  000110
82 TESP P  ----1---------1---------1----11---1--------  000110
83 THAT R  -----------1-----11---1---1-1---------------1--  000110
92 URSQ U  -----------1------------1---1-----1-----------  000110
 4 ALSE M  --1-1-11------1111111111111-1-1-----11-1111-11--  000111
88 TRSP I  --1--1--11111111113211111131311-111111-212312212--  000111
25 DIFI L  --11111111212134-211212411113214342333244231111-  00100
 3 ALLO N  -1-----------------------1-----------------  001010
85 THTR I  1131123232211--133233323444244442-2--1-11-11443--  001010
 2 ACPE D  1-1--1-111------1-1---1--1---1----1---------1---  001011
13 BUBO E  1211121-1112112111111111111--11221211111-11111--  001011
15 CASP P  ---1------1-1-1----1111---------1---1---1-------  001011
23 DIAM P  11121-1111111111-1111111111111111111111-21111--  001011
26 DISE T  ---1--111--111----11111-1-111-1----11111111--1--  001011
27 DISP 1  ---------1------1---------------------1------  001011
28 ELMU T  --111----11-1111-1-11111-1-111111--11111111111--  001011
32 ERRA C  ---321111--1-----1--1--1------11-11-11---11-1--  001011
36 EUVI L  11---111-11-1-11-1------111--11-1-11-1-1--------  001011
44 INHI L  -1-11---11----111---11-1-11-1--11-1------11------  001011
48 LOSI M  34311-12-111111-1111-1111112111111-1-111211111--  001011
56 PADR E  1111-111111111-1------1-11111111111111111111----  001011
67 RHNE R  --1-111--111-111111--1-111-1111111111-11-1111---  001011
70 RHTO T  1------1--------------1--------------1-----1--  001011
 5 ARHA R  -1----111--1---11----1----1--1--------1---------  001100
 9 ATPH Y  -----------1--1-----------1-1---------------  001100
17 COAF R  ------1----------------------------1----------  001100
75 SP10 3  ------1---1--------------1---1----------------  001100
11 BEOB O  1-111-11-----------------1-----------1---1---  001101
18 CTCO N  -11---11------1----------1--------1----11------  001101
21 CYSP E  ---11-1--1----1-----1-------1----------1----1---  001101
50 MOCE R  ---11---11-------------1-------1--------------  001101
87 TRLE U  43-2144442244444-111111112112111122111-121232--  001101
33 ERSA L  11----------------------------------------  001110
54 OXSP P  ----1--------------------------------------  001110
57 PAEC K  ----1-------1------------------------------  001110
64 PRCA F  --111-------------------------------------  001110
```

```
65 PTAQ U    1--------------------------------------------------------  001110
66 REAL T    --1-----------------------------------------------------  001110
91 URAG R    --111--1-1-1111-1-1-------------------------------------  001110
14 CAPH Y    -----------1--------------------------------------------  001111
35 EUER I    -----1--------------------------------------------------  001111
47 LESP P    ------1-------------------------------------------------  001111
49 MICA F    ------11-11---------------------------------------------  001111
69 RHSE T    -----------1---1----------------------------------------  001111
77 SP11 0    -----1--------------------------------------------------  001111
79 SP11 6    -----1--------------------------------------------------  001111
81 SPPY R    --------1-----------------------------------------------  001111
24 DIER I    ----------------1------------------1----1-----11        01000
40 HESP P    11-111111111--1112111111111111111-1111-111111111        01000
51 OLSP P    1---1--1-1------1-11-11------11111---11-1--11-111       01000
90 UNGR A    1---1-----------1--11-----------1-11-------111          01000
20 CYSP P    2112111132122131212111-12313111212222244111-112        01001
39 HECO N    11--111111--1-11--111111--1--1-1---11-------1--11-      01001
71 SESP P    1----1-11111-11-1111-111111--1111-1---11---1-1-1       01001
89 UNFO R    11111--1111111111111111111111111-1-111---11-1-1        01001
 6 ARJU N    11-1-11-1-1-------1111111--------1111221--44343-1       0101
59 PASC R    ---------------1-1--1------------1-----1--11121         0101
29 ERCA P    ------11-11------1----------------------------11        0110
55 PAAE Q    --------11-------1-----------------------1--------11-1   0110
60 PASP 1    ----1-----------------------------------------------11  0110
74 SPAF R    1---1-----------------------------------------------11  0110
19 CYEX C    -------------------------------1------------------------1  0111
30 ERCU R    1---------1--------111-----1-------------1----33       10
12 BRSE R    ------------------------------------------------------1-  11
31 ERPL A    -----------------------------------------------------21  11
42 HYSP P    -----------------------------------------------------1-  11
61 PASP 2    -----------------------------------------------------1-  11
62 PAUR V    -----------------------------------------------------11  11
72 SENI G    -----------------------------------------------------11  11
86 THDR E    ------------------------------------------------------1-  11
```

```
          00000000000000000000000000000000000000000000000000011
          00000000000000011111111111111111111111111111111
          00000111111111110000000000000000000000000011111
          00111000000111110000000000000000011111111100111
              0001110001101111111111111000001111
                000000111111110001100001
```

Appendix 5

Umtamvuna Nature Reserve point data: abundance of 93 species in 48 sites. Full species names are given in Appendix 1.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	35	36	37	39	40	41	42	43	44	45	46	47	48
ABLAE	0	1	0	0	0	0	1	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
ACPED	7	0	0	0	0	0	0	0	0	3	0	0	0	1	0	1	0	0	2	0	0	1	0	0	0	0	0	0	2	0	3	0	0	2	0	0	0	1	1	1	0	0	0	0	0	1
ALLON	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ALSEM	6	0	2	0	2	1	1	1	1	2	2	4	2	0	0	0	0	3	1	1	0	0	0	0	0	1	0	3	1	1	1	0	0	2	1	0	3	3	1	0	0	0	2	3	2	2
ARHAR	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	1	0	0	1	0	0	0	4	0	0	0	0	0	1	0	0	0	0	0	1	1	2	0	0	0	1	0	0	0	0
ARJUN	0	0	21	18	14	20	6	11	3	4	5	6	4	2	0	6	2	0	0	0	2	0	1	0	0	1	0	1	22	16	3	2	0	2	0	1	0	0	9	0	0	7	0	0	0	7
ARRUP	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ASLAR	1	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ATPHY	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0
BESPP	11	1	0	1	0	0	1	1	1	2	2	3	4	2	3	0	2	0	3	0	1	3	6	1	0	4	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	0
BEOBO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	2	0	2	0	0	2	2	1	1	2	0	0	0	0	0	0	0	0	0
BRSER	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BUBOE	1	13	5	3	2	2	4	4	8	3	2	2	2	13	10	3	10	6	6	7	1	10	8	6	0	0	2	0	2	2	9	13	4	2	5	5	6	0	8	3	1	14	4	8	4	6
CAPHY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CASPP	0	0	0	0	1	0	0	0	0	1	6	1	3	0	1	0	2	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0
CEASI	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
COAFR	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
CTCON	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	4	1	0	0	1	0	1	0	0	2	1	0	0	0	0	1	0	0	0	0
CYEXC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CYPSP	10	10	6	5	10	9	5	10	5	10	7	8	7	10	14	17	9	12	15	9	11	9	9	20	18	9	12	4	0	6	11	7	21	9	10	6	2	5	4	10	6	15	9	11	9	0
CYSPE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	1	4	2	0	2	1	0	1	0	1	0	0	9
DESPP	2	0	1	1	1	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DIAMP	0	2	10	4	3	6	4	5	2	8	4	3	5	5	2	4	4	5	3	6	8	0	4	4	2	3	3	0	5	4	5	5	3	8	11	4	3	5	3	8	4	1	4	8	4	3
DIERI	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DIFIL	0	28	11	1	17	15	13	19	20	8	6	12	9	10	6	1	15	8	4	7	13	9	5	14	5	19	18	34	1	4	0	0	20	8	4	7	6	5	12	9	11	18	24	22	3	12
DISET	0	0	1	0	8	4	0	5	0	2	2	2	4	0	1	2	0	1	0	5	2	0	1	5	8	1	7	3	0	1	0	0	3	0	2	0	3	1	0	0	0	0	0	0	2	2
DISPI	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
ELMUT	0	4	2	2	7	4	4	3	2	0	4	4	4	0	0	0	2	0	1	0	3	0	3	4	3	2	3	5	2	1	0	6	9	2	1	0	0	3	1	1	1	2	1	0	3	3
ERCAP	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	2	0	1	1	0	0	0	0
ERCUR	0	0	1	0	0	0	0	0	0	0	2	2	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
ERPLA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ERRAC	0	1	0	1	0	1	0	1	0	1	0	0	0	1	3	3	1	6	1	0	0	0	2	0	1	0	0	2	0	0	1	0	0	0	0	0	15	11	3	1	0	0	0	0	0	0
ERSAL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EUALB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EUERI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EUVIL	0	0	0	0	0	0	1	2	0	0	0	0	0	1	0	0	1	1	2	1	4	2	0	0	0	0	1	0	0	0	2	5	1	0	0	0	3	1	1	1	3	2	1	0	2	0
FECOS	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GEAMB	0	0	0	0	0	0	1	0	0	1	2	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	3	0	0	0	0
HECON	0	4	0	0	0	2	0	0	1	1	5	4	3	5	0	1	0	0	0	5	2	1	0	0	0	3	0	0	2	5	1	0	0	0	2	1	5	1	2	0	2	5	0	0	0	2
HESPP	7	3	7	6	3	2	11	1	1	4	2	6	2	4	1	3	9	8	2	2	0	6	0	0	3	2	2	3	2	1	2	1	1	0	2	1	1	1	1	4	5	1	3	0	1	1
HYHIR	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HYSP1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HYSPP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

INHIL	1	2	1	0	0	0	0	0	1	0	0	2	1	7	0	1	1	0	1	2	0	0	0	0	0	1	0	2	0	0	0	1	0	0	1	5	0	0	0	3	0	1	2	0	0	0
KOCAP	1	0	1	0	6	2	0	3	7	3	10	7	5	2	0	0	3	2	1	2	0	0	0	0	5	2	8	4	4	0	0	1	1	1	3	3	3	0	0	0	0	0	0	4	4	3
LENAT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
LOSIM	1	2	7	4	0	3	3	6	2	2	3	0	1	0	1	0	6	1	2	4	3	0	3	5	11	3	6	12	8	6	18	26	4	15	5	8	4	11	5	8	7	8	0	8	5	9
MICAF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	0	5	3	0	0	0	0	0
MOCER	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	0	0	0	1	0	0	0	0
OLSPP	4	1	0	1	2	2	0	1	0	2	2	0	1	0	0	0	1	0	0	0	0	0	0	0	0	4	0	0	0	1	1	0	2	0	0	1	0	1	2	1	0	0	0	0	1	2
OPOBL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OPSPP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OXSPI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
PAAEQ	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
PADRE	0	5	4	1	2	2	0	3	0	0	0	0	0	0	1	6	1	5	4	2	1	6	2	2	4	2	2	4	3	0	0	2	4	8	6	1	0	1	3	2	3	6	0	2	4	2
PAECK	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
PANAT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PASCR	1	0	0	1	0	0	0	0	0	0	2	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PASP1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
PASP2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PAURV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PEANG	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PRCAF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	1	0	0	0	0	0
PTAQU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
REALT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
RHNER	2	3	2	1	3	1	1	0	4	1	0	0	0	1	7	3	0	1	2	8	0	0	9	4	2	3	4	3	0	3	0	0	0	6	3	0	5	1	0	4	1	2	2	3	2	0
RHREP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RHSET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
RHTOT	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	2	0	0	0	0
SESPP	3	2	0	1	0	0	1	0	1	1	2	0	2	1	3	1	1	2	3	1	0	2	1	1	0	0	0	0	1	1	0	1	0	0	0	0	1	4	2	3	1	0	0	0	0	1
SENIG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SESPH	1	0	0	0	0	0	0	0	0	0	3	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1	0
SPAFR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
SP103	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	4	0	1	0	0	0	0
SP105	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SP110	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SP115	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SP116	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SPP95	0	0	0	0	0	0	0	0	0	0	4	2	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SPPYR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TESPP	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
THATR	0	0	0	0	0	0	0	0	0	1	2	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0
THSPP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
THTRI	19	11	1	21	1	2	15	0	21	14	17	15	14	0	6	16	0	22	25	10	7	14	0	7	22	23	0	0	20	18	6	9	2	15	9	9	19	13	21	10	13	0	5	12	35	15
TRDRE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TRLEU	0	3	12	14	9	7	7	7	8	3	4	6	6	13	26	30	1	1	4	13	21	20	34	6	7	6	14	3	19	14	21	19	0	0	14	6	27	29	11	11	10	26	22	4	7	8
TRSPI	5	1	3	12	0	11	17	12	8	14	4	7	8	5	6	4	9	17	8	18	8	5	9	8	9	6	5	17	3	11	0	0	12	5	0	0	0	0	8	8	1	4	8	8	9	
UNFOR	3	1	0	2	3	1	1	2	2	2	1	2	2	1	3	2	1	1	1	2	1	0	1	2	2	1	0	0	1	2	2	0	4	2	4	0	2	1	2	3	2	1	0	2	1	
UNGRA	0	0	0	0	2	0	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0
URAGR	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	2	0	8	0	0	0	0	0	0	0	0	0	1	4	3	0	1	0	1	0	0	0	0	0	0
URSQU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
WADEN	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0