ASPECTS OF THE STRUCTURE AND FUNCTIONING OF THE VEGETATION OF THE HLATIKULU VLEI

by

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DECLARATION

These studies represent original work by the author and have not otherwise been submitted in any form for any degree or diploma to any University. Where use has been made of the work of others it is duly acknowledged in the text.

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ABSTRACT

Hlatikulu Vlei, situated in the foothills of the Natal Drakensberg, is one of the priority wetlands in KwaZulu-Natal, occupying an area of 733 Hectares. The importance of Hlatikulu Vlei lies in its functions to store water, regulate stream flow and attenuate floods, as well as to provide suitable habitat for wildlife and grazing for livestock.

Hlatikulu Vlei is a threatened system and has suffered the effects of human mismanagement. Forty-nine percent of the vlei has been classified as disturbed or destroyed, mainly due to the construction of two large dams and past drainage of vlei to facilitate pasture planting. The effects of grazing and fire on the plant communities has been considerably less.

Vegetation communities at Hlatikulu Vlei have similarities with those at Ntabamhlope Vlei. The main plant communities present at Hlatikulu Vlei are: vlei grassland, sege-meadows, bulrushes and reedswamp. Species compositions of the mixed sedge and grass sedge-meadow community have a notably higher species diversity than similar communities sampled at Ntabamhlope Vlei and the mires at Highmoor.

Soil type and moisture content are shown to be the most significant environmental factors determining the distribution of plant communities and species within the vlei.

A wetland re-establishment and rehabilitation programme in the Hlatikulu Crane and Wetland Sanctuary has been effective in allowing many wetland plants to become re-established. The sanctuary communities bear greater similarity to the sedge and rush sedge-meadow community, than the mixed sedge and grass sedge-meadow communities that were originally present. This is also reflected in the seed bank.

All three Southern African crane species (Blue, Wattled and Crowned Crane) and fourteen species of waterfowl have been recorded in the Hlatikulu Crane and Wetland Sanctuary since the wetland rehabilitation programme. The waterfowl play a role in the dispersal of seeds into the sanctuary, particularly those of *Schoenoplectus decipiens* and

Eleocharis dregeana and are in part responsible for the return of certain wetland plants to the sanctuary.

The flooding of soils, the fluctuating water level and the soil type related to hummocks and to channels are shown to be responsible for the location of *Cyperus denudatus*, *Arundinella nepalensis* and *Aristida junciformis* in differing positions in the channels and on the hummocks and are also responsible for the maintenance and functioning of the hummocks and channels.

Seed banks on the hummocks are similar to seed banks in the channels, however the extant vegetation on the hummocks is distinctly different to that in the channels. Certain species represented in the channel seed bank are being excluded from surviving to maturity.

CONTENTS

CHAPTER 1

INTRODUCTION

'Wetlands are among the most important ecosystems on the Earth'
Mitsch & Gosselink, 1986

On the second of February 1971 the Ramsar Convention on 'Wetlands of International Importance especially as Waterfowl Habitat' was signed in Iran. The conference was ratified by 23 governments and proved to be a significant milestone for obtaining international recognition of the importance of wetland ecosystems (Hook 1988; Cowan 1995). Subsequent ratification of Ramsar (and its amendments) by other governments at the Paris Protocol of 3rd December 1982 and the Conference of Parties on 28th May 1987 have further enhanced its significance in recognising that wetlands are both important and threatened ecosystems. There are now 87 contracting parties ensuring suitable protection throughout the world for 740 key wetlands covering an area of 45 million hectares (Mathews 1993; Grove 1995; Cowan 1995). The Ramsar Convention is the only international environmental convention dealing with a specific habitat and in the light of there not being any other conventions dealing with a specific habitat such as rainforests, deserts or savannahs, the question of why wetland habitats are such important ecosystems that require global recognition and protection, must therefore be answered.

Roggeri (1995) suggests that wetland ecosystems are important and valuable for a variety of reasons but in particular because of the many attributes which they have, the variety of resources that they provide and the vital functions which they are known to perform. It is widely accepted that wetlands throughout the world provide vital natural resources that are utilized for agriculture, fishery, forage, wildlife, natural products, water supply, energy resources, transport, tourism, recreation, research and education (Begg 1988; Madgwick et al. 1994; Roggeri 1995). As well as providing resources, the crucial functions which wetlands perform are known to include; nutrient retention, nutrient export, groundwater recharge and discharge, flood control and flow regulation, drought amelioration, sediment retention, dissipation of erosive forces, salinity control, water treatment, climate stabilization and ecosystem stability (Mitsch & Gosselink 1986; Roggeri 1995). Wetlands are especially critical habitats for wildlife, and exceed all other land types in wildlife productivity (Baldassarre & Bolen 1994; Kent 1994). A majority of wildlife species use wetlands on either a permanent or transitory basis for breeding, food or shelter and the role of wetlands in the life cycles of certain fauna species is essential for their survival (Kent, 1994). Wetlands are also valued for their many attributes, particularly their biological diversity, uniqueness, naturalness, variety and their importance as cultural heritage sites (Roggeri 1995; Hawke & Jose 1996).

Whilst no single wetland provides all the goods and services mentioned above, it would perform more than one function, it would be endowed with several attributes and it would provide many products and services. This means that the value of a wetland in a particular area covers many domains at once (Roggeri, 1995).

Wetlands are also regarded as being amongst the most threatened habitats in the world (Mitsch & Gosselink, 1986). It is estimated that already as much as 50% of the worlds wetlands have been lost and 65% of the most significant tropical wetlands are threatened with degradation in the near future (Whitfield, 1993).

In the past the drainage of land deemed to be 'too wet for agriculture' was seen as a benefit to society. If drained the former marshy areas of wetlands can often be converted to good quality agricultural land as the resulting soils are highly fertile (Denny 1993; Kusler et al. 1994). This is particularly so in drained marshes, swamps and bogs. In northern Europe there has been a long history of bogs being drained and brought into agricultural use (Mitsch & Gosselink 1986). In many temperate and tropical countries, marshes have been drained as they provide a breeding ground for disease-carrying species of insects such as the malaria-carrying Anopheles mosquito (Weller 1987). Practices that cut off wetlands with embankments, diverted their water for other uses, filled them up, built causeways and houses over them and released waste water and effluent into them were common place and raised little opposition. Poor farming methods and other practices that have caused the clogging up of wetlands, due to an increased silt load in rivers and streams similarly remained uncontested, whilst in many wetlands plant invaders have been allowed to strangle and replace the natural vegetation (Levitz 1993).

As a result many wetlands which remain are degraded from channelization, damming, agricultural and urban surface runoff. Wetlands in the developed world are now a shadow of their former expanse, while in developing countries the destruction of wetland habitats continues unabated and practically unopposed, despite a greater understanding than ever before of the value and importance of these systems. Where a slight reduction in the rate of destruction of wetlands has been noted, Kusler et al. (1994) suggest that this is probably due to the fact that there are now fewer wetlands to eliminate than due to effective legislation and policies that protect wetlands.

Although humans have used wetlands since the beginning of recorded history, we have only recently become concerned with their loss (Williams, 1991). The likely consequences of continued wetland destruction could include the loss of valuable natural resources and unique ecosystems, a reduction of global biodiversity, a lowering of the groundwater table, an increased incidence and severity of downstream flooding; river flow cessation, reduced water quality and increased bank erosion (Begg, 1990). In various parts of the world where wetlands have been destroyed and degraded, large scale flooding has powerfully demonstrated the effects of reducing the capacity of wetland systems to absorb excess floodwater. Flooding in the Midwest of the United States of America along the Missouri River was clearly linked to a reduction in the wetland areas of the Missouri River (Kusler et al. 1994). The 1987 Natal Floods highlighted a similar problem in South Africa (Begg 1990). Concern about losses of and threats to wetlands has prompted various conservation organisations throughout the world to push for stricter legislation that will afford greater protection to wetlands. In order to provide effective protection the definition and delineation of wetlands is often required first. These tasks are not as simple as they may seem, as the actual definition and resultant delineation of wetlands has proved to be rather problematic. Wetlands are often as different in their appearance and in the species they host as they are in the range of saturation they experience in the course of a year or season. Their topographical variety and the complexity of their hydrology have made some wetlands difficult to identify and hence, difficult to preserve (Kusler et al. 1994).

What at first seems easily defined - a wetland - is in fact a complex concept. Whilst an accurate definition is fundamental, a clear, precise, unequivocal, and objective definition sometimes is achieved with difficulty. Once conceived definitions change with new information or with a changed social and political context, moreover wetlands themselves are physically and chemically dynamic (Leitch et al. 1994). It may be easy to point at a vlei, swamp or marsh and call it a wetland, it is more difficult to provide a definition that will not only include the variety of wetlands throughout the world but effectively define where they begin and end. These problems will probably never be completely resolved by wetland scientists and managers as few of the definitions adequately describe all types of wetlands and none are universally recognised.

Most definitions distinguish wetlands by the presence of water, seasonally or permanently, where soils are often unique differing from those of adjacent areas and where vegetation is adapted to wet conditions. Wetlands are found at the interface between truly terrestrial and truly aquatic ecosystems and are often considered to be ecotones between the two systems. Thus the crux of many of today's hotly debated wetland issues lies in the subtle distinction between land that is too wet to farm and wetland (i.e., wetLAND and WETland). This is the distinction that policy makers require in establishing effective legislation that will prevent further losses of wetland areas and afford them the required protection (Leitch et al., 1994).

Wetland delineation - identifying wetland boundaries - is primarily a regulatory issue and is essentially concerned with the debate about the delineation of the 'drier end' of wetlands. There is no concern about delineating between wetland and deep water habitats or the 'wetter end' for no one claims that wetlands are dry. The concern is with the distinguishing between wetlands and the adjacent or adjoining dryland. Thus in an area with relatively little topographic relief, tens or hundreds of metres of wetland boundary could easily be in dispute. Wetland delineation thus remains to a large degree subjective. Even when the three factors commonly used to 'identify' wetlands, namely soils, vegetation and hydrology, the objective delineation of the drier end remains elusive and will remain so for some time (Kusler et al. 1994; Leitch et al. 1994).

Attempts to solve the problems associated with wetland definition and delineation have lead to various attempts to classify wetland types that range from regional to national and international. One of the most widely accepted classification of wetlands is the *Classification of Wetlands and Deepwater Habitats of the United States* (Cowardin et al. 1979) and serves as a valuable reference throughout the world (Leitch et al. 1994). In the African context White's (1983) classification of major wetland vegetation provides a basis to define and delineate wetlands in southern Africa (Breen et al. 1993), but Morant's (1983) review of wetland classification in southern Africa concluded that it would be appropriate to adopt, with some small modifications, the system established by Cowardin et al. (1979) for the United States Fish and Wildlife Services (Breen & Begg 1989). This system has not been adopted and little further progress has been made in documenting wetland variability on a broad national scale such that Noble & Hemens' (1978) classification of wetlands in South Africa remains as the broadest classification to date (Breen & Begg 1989). Also since the broad vegetation classification and mapping by Acocks in 1953 very little advance has been made towards more detailed classification and description of vegetation in many areas of southern Africa, particularly of wetlands where few regional and local classifications of the vegetation have been undertaken and include the Pongola floodplain (Furness & Breen 1980), pans of the Orange Free State (Geldenhuys 1981), plant communities of hydrophillic vegetation in the Orange Free State (Fuls et al. 1992) and wetlands in the Pretoria-Witbank-Heidelberg area of the Transvaal (Coetzee et al. 1993).

Although South Africa is a founder signatory of the Ramsar Convention, there has, until comparatively recently, been little interest in the conservation of wetlands. Lake St Lucia and the dune mining controversy thrust wetland issues into the public eye. The St Lucia system, one of the 12 wetland sites in South Africa that are registered with Ramsar and regarded as a wetland of international importance, has escaped (for now) the threat of mining, but has brought greater interest for the conservation of wetlands. Hopefully wetland degradation which has proceeded apace in the past in South Africa will be curbed so that more may be learnt of the nature of existing wetlands and redress the paucity of data on wetlands and wetland species.

In a review of knowledge of and attitudes to wetlands by Breen & Begg (1989) it was shown that conservation organizations in South Africa are generally uninformed about the diversity of wetlands and have disparate approaches to the classification and conservation of wetlands. Also, it is shown that without knowledge of the elements of diversity it is not possible to construct a classification system, and without a classification there is little hope for the formulation of a comprehensive strategy for the conservation of wetlands in South Africa (Breen & Begg 1989). The need for implementation of a conservation strategy is urgent because of the large-scale destruction of wetlands in South Africa by drainage, infilling, channelization, dam construction, mining burning, overgrazing, chemical and nutrient pollution and river regulation (Begg 1990). Also in the light of widespread ignorance of wetland functions, the ineffectiveness of pre-1983 legislation relating to wetland protection, the lack of integrated policy linking government and non-government agencies directly or indirectly involved in water regulation and a fundamental lack of knowledge concerning the conservation requirements of wetlands (without which management strategies cannot be formulated or implemented), the fact that no effective strategy exists to ensure the conservation of South African wetlands implies that it is necessary to convince society and decision makers of the asset value of wetlands to humanity. Emphasis should be placed not on the dependence of an undefined assemblage of plants and animal species upon wetlands, but instead on the bleak prospect of mankind's survival in a future without wetlands. At present decision makers are apparently unaware that the strain on the future fresh water resources of this country means that, in the face of exponential population growth, man's dependence upon wetlands is steadily increasing (Day & Davies 1986; Breen & Begg 1989; O'Keeffe et al. 1989).

Current conservation efforts must not only aim to protect wetlands (Denny, 1993), but should also call for the restoration of degraded wetlands, the replacement of previously extant wetlands and perhaps even the creation of new wetlands (Mitchell, 1994). Much research effort, particularly in the Northern Hemisphere, has been directed towards the fields of wetland restoration, enhancement and wetland creation (Kusler & Kentula 1990; Zuetner 1994), but South Africa remains behind in this regard and research into the field of wetland restoration is required to facilitate the conservation and wise use of these threatened habitats. Whilst some research is presently under way to examine feasibility of cultivating 'artificial' wetlands for the final cleansing of sewage effluent and while artificial wetlands have already been created in some areas for flood control (Day & Davies 1986) wetland resources have been allowed to become so degraded in South Africa that investment in wetland restoration and creation is required to redress past damages to wetland resources (Begg 1990). Where efforts have been made to restore wetlands and improve land use in certain catchments, particularly catchments of KwaKulu-Natal's coastal rivers remarkable success has been achieved (Garland 1989).

Considerable research effort in the Northern hemisphere has aimed at determining the effects of soil stored seed banks on the development of wetland vegetation (Leck 1989; Middleton et al. 1991; ter Heerdt & Drost 1994; Welling et al. 1988a, 1988b). In some wetlands seed banks play an important and well documented role (Thompson, 1992). As the composition of the vegetation following a drawdown can be predicted with reasonable accuracy from a knowledge of the contents of the seed bank (Thompson 1992), the artificial management of water levels is seen to be an essential tool in the management of wetlands as wildfowl habitats (Pederson & van der Valk 1984). Also the understanding of seed bank dynamics in wetlands is considered to have potential for the determining of management strategy for the restoration of degraded wetlands (van der Valk & Pederson, 1989; Keddy & Reznicek 1986). In South Africa, whilst the importance of the role played by the soil seed bank in revegetation is widely recognised (Pierce & Cowling 1991; de Villiers et al. 1994), studies in seed bank ecology has been largely confined to terrestrial systems. The role of seed banks in wetland systems thus requires investigation which could be beneficial to management aimed at the restoration of degraded wetlands.

There are many aspects of wetland ecology which require investigation in order to allow for effective wetland management and wetland rehabilitation. The importance of wetlands to waterfowl is widely known as wetlands provide suitable habitat and breeding sites for a wide variety of waterfowl and other birds, however whilst the feeding habits of waterfowl in southern Africa are known, the role that waterfowl play in the dispersal of wetland plants, and thus their potential role in wetland revegetation, is not well documented. Whilst it is known that wetlands are sensitive to rising and falling water levels which influence their internal character and that they are dependant on the quality and quantity of water, investigations of the effects of various flooding regimes on wetland plants (as conducted in other parts of the world) are required to determine correct management practices.

While the protection, restoration and replacement of wetlands are key issues, the ongoing management of wetlands systems with strategies that maintain their important functions and values is essential. However scientifically sound management of wetlands that satisfies everyone is not easy to achieve. In the past decade, investigators in the United States and Europe have learned much about defining and maintaining wetlands as dynamic features in the landscape. It is hoped that this knowledge could form the basis of workable policies for wetland management (Kusler et al., 1994).

The initial utilization management of South Africa's water resources was based primarily on meeting bulk user demands, mainly agriculture, with scant consideration towards water quality or ecological implications. However, due to more intensive agricultural, mining and industrial development and the resulting ecological problems, an increasing awareness has forced water resource management to recognise the importance of these aspects (Walmsley 1988)

In KwaZulu-Natal attention has been drawn by Begg (1989) to the lack of information regarding the correct measures that ought to be applied in managing wetland vegetation. Knowledge gained by suitable wetland research could then be used to redress this problem. It is also important that the area of wetland reclamation be researched as more information is required concerning the response of wetland vegetation to rehabilitation programmes (Begg, 1990). The success of future reclamations may depend largely on the information gathered from such studies.

Ntabamhlope Vlei is to date the only vlei in the KwaZulu-Natal midlands for which a reasonably thorough description of the vegetation exists (Downing, 1966) and studies of other wetland systems in Kwazulu-Natal are essential to allow for the establishment of sound management strategies and the formulation of conservation policies. As such Hlatikulu Vlei is an important wetland system, recognised as one of the priority wetlands in KwaZulu-Natal about which little is known (Begg, 1989). Clearly it is an important wetland system which requires investigation as, in a qualitative assessment of the functions and values of priority wetlands in the KwaZulu-Natal region, Begg (1989) stresses that Hlatikulu Vlei's value lies in its functions to store water, regulate stream flow and attenuate floods, provide suitable habitat for wildlife and to provide grazing for livestock.

Hlatikulu Vlei is also a threatened system. Certain areas of the vlei have been degraded as a result of mismanagement. The vlei bears the scars of past draining and damming which has resulted in the loss of large portions of vlei vegetation. Unchecked over-grazing by livestock and indiscriminate burning of certain areas of the vlei has resulted in their degradation. Hlatikulu Vlei is further threatened by the afforestation of the surrounding catchment areas of the vlei with plantations of pine trees (Pinus spp.) which could alter the hydrology and functioning of the vlei through a lowering of the water table and affording increased silt loads to the vlei. Whilst the whole of the vlei is privately owned the formation of the Hlatikulu Conservancy will hopefully result in the protection of this valuable system and of its important functions.

The current rehabilitation of a large section of the vlei that had been drained to make way for pastures several decades ago, not only provides an opportunity to monitor the change in vegetation, but hopefully will redress the effects of past degradation. Also with various portions of Hlatikulu Vlei having a reasonably well documented management history, an understanding of the effects which these treatments have had on the vegetation of Hlatikulu Vlei would yield data that is likely to form the basis for improving wetland management in KwaZulu-Natal. This is particularly pertinent in view of the fact that appropriate management regimes for the utilization of wetland habitats in KwaZulu-Natal are largely speculative and by and large following prescriptions developed for surrounding grasslands.

While Hlatikulu Vlei is clearly an important and threatened wetland system in KwaZulu-Natal which requires effective protection and management, the importance of this study lies in the resultant benefits gained from an understanding of the structure and functioning of the vegetation of Hlatikulu Vlei (how it has changed over time, how it has responds to various environmental factors, how it has responded to the various management practices of the past and the rehabilitation programme, how various plant species respond to flooding and burning and the role played by waterfowl in the dispersal of propagules of wetland plants) which will hopefully allow for the formulation of management and conservation policies for Hlatikulu Vlei and other similar wetland systems in KwaZulu-Natal.

CHAPTER 2

OBJECTIVES OF STUDY

Hlatikulu Vlei is a priority wetland in KwaZulu-Natal of considerable size that has not been studied in any detail and about which little is known of the structure and functioning of its vegetation. Although Begg (1989) has dealt with the location, status and function of Hlatikulu Vlei, only brief mention was made of the vegetation of the vlei. In light of Begg's (1990) recommendation that research efforts in wetlands should be targeted towards the improving of wetland mapping and wetland classification for the purpose of tailoring wetland regulations to wetland type, this study aims to classify the wetland vegetation at Hlatikulu vlei and map its extent. Thus the first aim of this project was:

> To describe the major vegetation communities of Hlatikulu Vlei and use various multivariate analysis techniques to classify the vegetation and determine the relative effects of various biotic and abiotic factors on communities.

Whilst the classification of wetland communities of Hlatikulu Vlei may be seen as a primary aim the benefits of comparison of the vegetation communities at Hlatikulu Vlei with those of other vlei's in the region enables the diversity and richness of Hlatikulu Vlei to be evaluated. Thus the vegetation communities of Hlatikulu Vlei are compared with those encountered at Ntabamhlope Vlei and in the wetlands called 'mires' on the Highmoor Plateau. Thus the second aim of this study was:

> To compare the floristic composition of the vegetation of Hlatikulu Vlei with that of Ntabamhlope Vlei and the mires at Highmoor, which are also situated in the uplands of KwaZulu-Natal.

The mapping and delineation of wetlands throughout the world has become an essential management tool for the conservation of these systems. Effective delineation and mapping can lead to effective conservation and protection of wetlands. Thus the third aim of this study was:

> To map the extent of each vegetation community encountered in the vegetation of Hlatikulu Vlei.

The once commonly held idea that 'wetlands are wastelands' has resulted in the conversion of over half of KwaZulu-Natal's wetland resource to cropland, plantations of exotic trees, waste disposal sites and areas overgrazed by stock (Begg, 1989). Hlatikulu Vlei has not escaped the effects of human mismanagement. Degradation of the Hlatikulu Vlei has occurred as a result of various management practices. Thus in order to examine the effects of various management practices a further aim of this study was:

> To assess the gross changes which have taken place in the vegetation communities of Hlatikulu Vlei as a consequence of land management practices over the last 50 years, via comparison of vegetation maps, drawn up from aerial photographs taken in 1944 and 1992.

A common problem in community ecology is to discover how a multitude of species respond to certain environmental variables (ter Braak 1988). The use of ordination techniques provide the means to interpret the community data of different plant communities (Coetzee et al. 1993). Thus a further aim of this study was:

> To determine what environmental factors were responsible for the present floristic patterns of the vegetation at Hlatikulu Vlei.

The joint programme by the South African Crane Foundation and Mondi to rehabilitate the section of Hlatikulu Vlei that had been severely degraded by past draining and planting of pasture grasses provided a unique opportunity to monitor the changes in vegetation to the area. The aim of the programme was to restore wetland vegetation to the area now called the Hlatikulu Crane and Wetland Sanctuary. A further aim of this study was:

To assess the response of vegetation to a wetland rehabilitation programme, executed on a portion of the vlei, and thus to establish patterns of succession within wetlands.

As part of the purpose of rehabilitating the degraded areas of the Hlatikulu Crane and Wetland Sanctuary was to attract cranes and waterfowl to the re-established wetlands, two further aims of this study were:

To census the use of rehabilitated wetland by waterfowl and cranes to determine if suitable habitat has been re-established.

To investigate the role played by waterfowl and other bird species in dispersal and importation of propagules of vlei plants into the rehabilitation area of the vlei.

A feature that characterizes certain areas of Hlatikulu Vlei is the presence of grass covered mounds ('hummocks') and sedge-dominated surrounds ('channels') Begg (1989). Little is known of the structure or functioning of these hummocks and channels and thus the last aim of this study was:

To investigate the maintenance and functioning of 'hummocks and channels' in the dominant plant communities of Hlatikulu Vlei, particularly with reference to the effect of flooding, fluctuating water levels and fire season on the growth of selected wetland plants in controlled experiments.

CHAPTER 3

STUDY AREA

3.1 Introduction

The primary study area for this project is the wetland called Hlatikulu Vlei. To introduce Hlatikulu Vlei brief descriptions of its location, geology, soils, topography, hydrology, climate, fauna, flora and history are given as a foundation for this study. Throughout these descriptions regular reference is made to two other wetlands, namely the mires at Highmoor and the vlei at Ntabamhlope. These references are included to allow for comparisons to be made between Hlatikulu Vlei and these other wetlands. This is particularly relevant in the light of the description and comparison of the floras at Hlatikulu Vlei, Ntabamhlope Vlei and the mires at Highmoor made in Chapter 4.

It is also necessary and relevant here to define the term 'wetland'. Firstly in a global perspective, then to define the types of wetland in South Africa and finally and more parochially to define the specific type of wetlands encountered at Hlatikulu, Highmoor and Ntabamhlope. And ultimately to explain the terms 'vlei' and 'mires'.

3.2 Definition of wetlands

Initially one might assume that the task of establishing a suitable definition of 'wetland' would be fairly simple. Surely as the name 'wetland' indicates, wetlands are simply lands that are wet. Thus one could conclude that any land that is wet would qualify as wetland. Such a clear and simple definition would seem to be all inclusive and workable, but is it really? An immediate response might be to question how wet the land would have to be before it qualified as wetland. Clearly a drop of water in a desert does not turn it into a wetland, nor does a vast ocean of water qualify. The answer lies somewhere between these extremes and should include the vast variety of wetland types such as swamps, marshes, fens, bogs, mires, floodplains, river systems, estuaries, deltas, mangrove swamps and reedbeds. What is required is a definition that is more specific whilst still remaining clear and workable.

The problem is further increased by the conflict between environmentalists and commercial users of the land such as farmers or industrialists who have conflicting views on what land should be used for commercial gain and what should be protected areas of ecological, historical or scientific interest.

In reviewing various definitions of wetlands it is clear that there is no single, correct, indisputable, ecologically sound definition for wetlands (Cowardin, et al., 1979). In general terms wetlands are areas of low-lying land where the water table is at or near the surface for most of the time, resulting in open water habitats and waterlogged land areas. Wetlands are typically found in estuaries, along rivers with little vertical descent or in uplands where natural drainage of the soil may become permanently or seasonally impeded usually resulting from: impermeable underlying bedrock, surface deposits of glacial boulder clay, a basin-like topography from which natural drainage is poor, very heavy rainfall in conjunction with a corresponding low evaporation rate and low-lying land, particularly at estuarine sites at or below sea level (Cowardin et al. 1979; Mitsch & Gosselink 1986; Weller 1987; Hook 1988).

The definition of wetlands as defined at the Ramsar Convention attempts to be as broad as possible and for the purpose of this thesis will be used to define the term wetland. It states that 'Wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water to the depth of which at low tide does not exceed 6 metres' (Roggeri 1995).

In the South African context, Begg (1986) has suggested that wetlands all have one or more of the following features in common: soil that, at least periodically, is saturated with water, soil within which reducing conditions prevail, impeded drainage, occupy a characteristic position in the landscape, distinctive plant and animal communities.

In South Africa, wetlands may, at the broadest level, be separated on the basis of their association with river systems (river source sponges, marshes, swamps and floodplains) and endorheic shallow depressions (pans) in the landscape which are usually not associated with rivers or streams of notable size (Breen, et al., 1993). The wetlands at Hlatikulu, Highmoor and Ntabamhlope all fall within the first category because of their association with river systems. At Hlatikulu and Ntabamhlope the wetlands are marshes, which have developed in the flat reaches of rivers where waterlogging occurs seasonally (locally termed 'vlei', from the Dutch word 'vliet' meaning water course). At Highmoor the wetlands however have not developed in flat reaches of rivers, but rather form river source sponges which are termed 'mires'. These mires are spongy seepage areas on slopes which are seasonally waterlogged. They play an important role in the regulation of the catchment run-off of the local river system (Begg, 1989).

3.3 Location

Hlatikulu Vlei (29° 15'S; 29° 41'E) is situated in the foothills of the Natal Drakensberg about 10 km due east of the Giant's Castle section of the Natal Drakensberg Park in KwaZulu-Natal, South Africa (Figure 3.1). The vlei lies in the upper reaches of the Nsonga catchment, with Mount Lebanon to the east and Hlatikulu Mountain, (from which the vlei takes its name) to the west. The Nsonga catchment is a subcatchment of the Tugela River catchment. The vlei occupies an area of 733 hectares, with a length of circa 7,5 km, an average width of 0.275 km but up to 0.9 km wide in places and a perimeter of 56 km (Begg, 1989).

The Highmoor wetlands (29° 19'S; 29° 36'E), which form the source of the Little Mooi, part of the Mooi River subcatchment, are situated approximately 10 km to the south-west of Hlatikulu Vlei and occupy an area of nearly 120 hectares. The Ntabamhlope Vlei (29° 03'S; 29° 39'E) is situated approximately 24 km to the north of Hlatikulu Vlei on the Klein Boesmans River, part of the Bushmans River subcatchment and occupies more than 100 hectares (Figure 3.2). Both the Mooi and Bushmans rivers are also part of the Tugela River catchment.

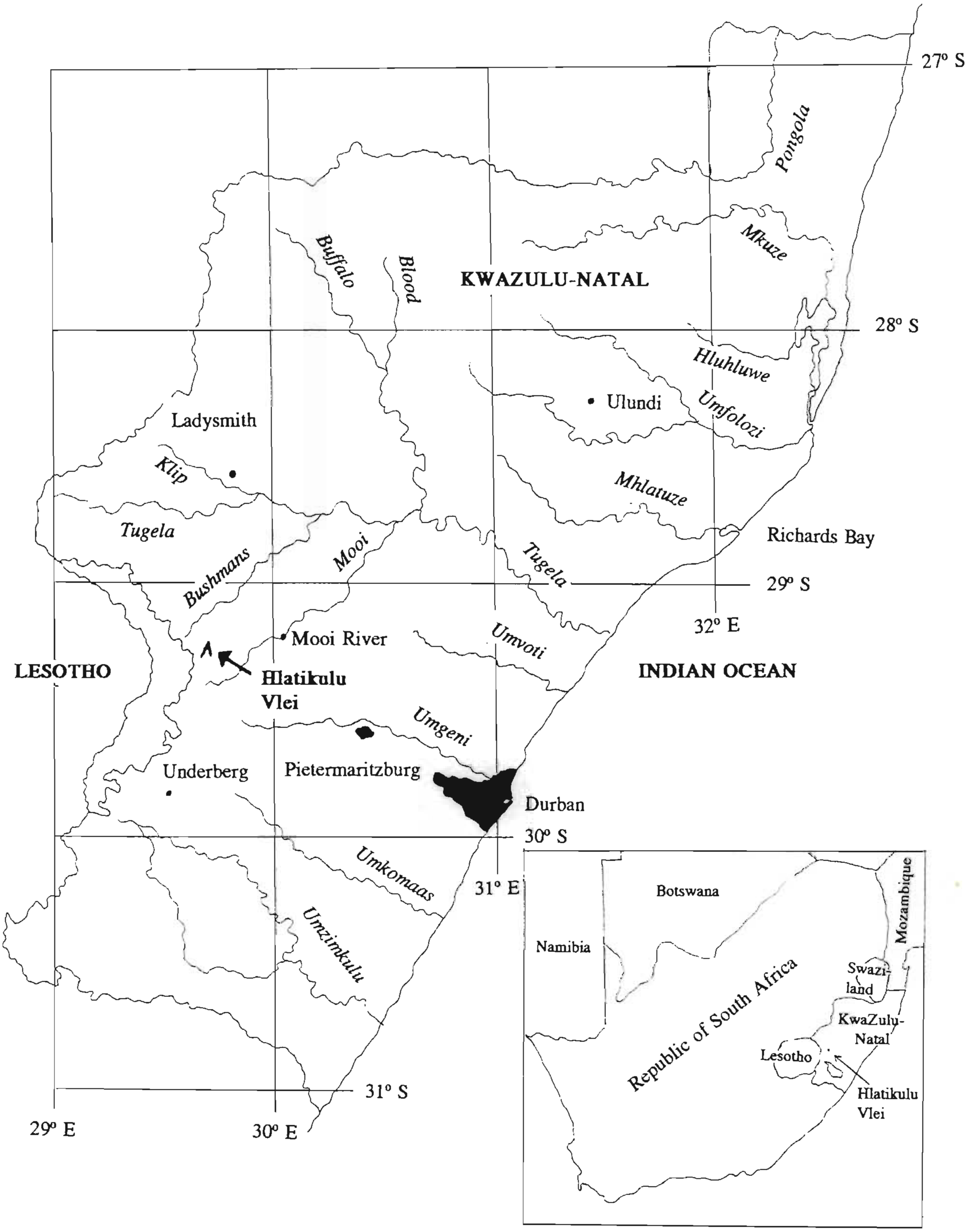


Figure 3.1: Location of Hlatikulu Vlei within KwaZulu-Natal and southern Africa

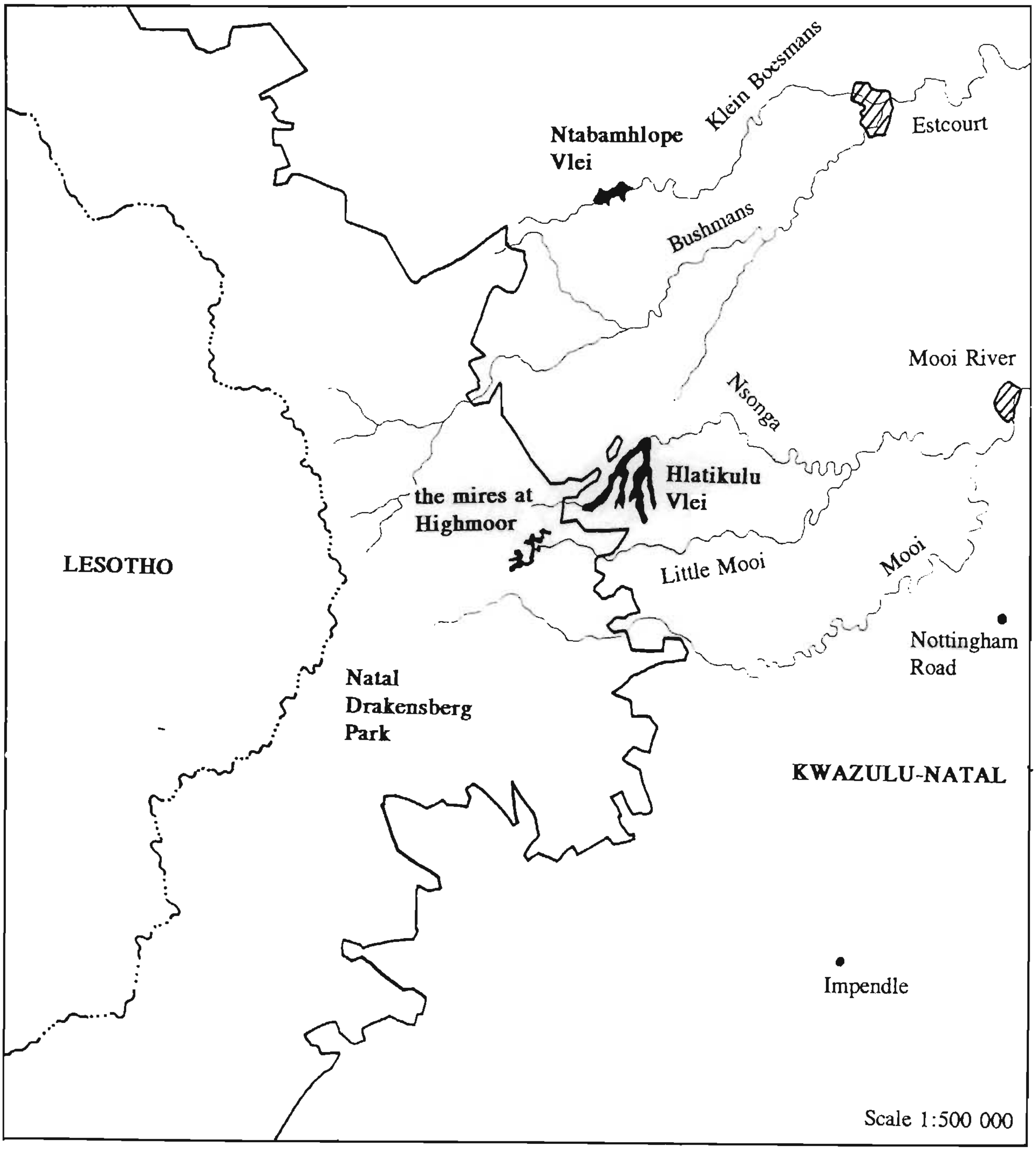


Figure 3.2: **Locations of Hlatikulu Vlei, Ntabamhlope Vlei and the Highmoor mires with respect to the Natal Drakensberg Park.**

3.4 Geology

Hlatikulu Vlei is underlain by mudstone of the Tarkastad formation and by Katberg sandstone, which are sediments of the Beaufort Series of the Karoo System. A small dolerite sill at the outlet of the vlei is the most important geological feature as it forms an underlying erosion resistant rock stratum which has prevented downcutting of the Nsonga River (Begg, 1989). As a result water has been retained in the locality where the vlei has developed and comprises what Begg (1989) has termed the "key point" of the Hlatikulu Vlei and is the primary reason for the existence of the vlei.

The presence of a dolerite sill at the outlet from Ntabamhlope Vlei was similarly responsible for the development of this vlei and it is also underlain by mudstone of the Tarkastad formation and by Katberg sandstone, both are sediments of the Beaufort Series of the Karoo System. The mires at Highmoor are underlain by Basaltic lavas of the Stormberg Series of the Karoo System (Killick, 1990).

3.5 Soils

Due to the permanent water table the dominant soil forms of the vlei are the acid gley soils of the Katspruit and Champagne soil forms. While Katspruit soils are the prevalent soil type in the vlei, Champagne soils, differentiated by their deep black topsoil horizon, are less prevalent through the vlei. MacVicar (1970) states that the saturated, anaerobic conditions that prevail beneath the surface of the soil give rise to an accumulation of organic matter and the formation of mineral acids and gleyed soils. Within both arms of the vlei are found low islands of non-hydric soils of the Pinedene and Clovelly forms (detailed descriptions of the soil types are given in chapter 4). As soils in wetlands are often unique differing from those of adjacent areas and where vegetation is adapted to wet conditions, the diversity of plant communities within Hlatikulu Vlei may be linked to this soil diversity (This is covered in chapter 4).

Soils throughout Ntabamhlope Vlei are of the Katspruit series, while those of the mires at Highmoor are of the Katspruit and Champagne series.

3.6 Topography

Hlatikulu vlei has a 'V' shape with a western and eastern arm (Figure 3.3), separated by a central ridge of land that originally supported grassland. The vlei lies approximately 7 km from the source of the Nsonga River in the foothills of the Drakensberg. The Nsonga river flows through the western arm of the vlei, entering the head of the vlei at an altitude of 1600 m a.s.l. and leaving at the outlet at an altitude of 1561 m a.s.l.. The average slope is of the vlei is 0.468 degrees.

By contrast to Hlatikulu Vlei, Ntabamhlope Vlei is at a lower altitude, with an inlet at 1454 m a.s.l. and the outlet is at 1443 m a.s.l., while the mires at Highmoor are at a higher altitude with an inlet at approximately 2060 m a.s.l. and an outlet at approximately 2000 m a.s.l.. Ntabamhlope Vlei is level wetland, lying in a valley bottom of the Klein Boesmans River. At Highmoor the mires form a dendroid network that cuts into the Highmoor plateau and slopes down towards the north. Although the mires tend to be sloping in nature there are some level areas which are characterised by the presence of raised hummocks surrounded by hollows (called channels) which contain a few centimetres of usually stagnant water. The average slope is of the Ntabamhlope Vlei is 0.44 degrees and 4.15 degrees for the mires at Highmoor.

3.7 Hydrology

Although the streamflow of the Nsonga River has never been gauged, the mean annual run-off from the catchment has been estimated to be 44 million cubic metres (Pitman et al., 1981 in Begg, 1989). In the light of South Africa's impending water crisis, Begg (1989) suggests that as 57 km^2 (38%) of the Nsonga subcatchment is upstream of the vlei, the vlei can be expected to play an important role in the attenuation of floodwater and sediment, storage of water and regulation of streamflow in this portion of the catchment.

The western arm of the vlei contains the Nsonga River thus the water flow is largely contained within the meanders of the river channel (Begg 1989). Although the passage of water through the western arm was initially interfered with by the 'ridge and furrow' drains and dam construction on 'Forest Lodge' (Begg, 1989), diversion of the river to create dams and damlets in the rehabilitation area (Figs. 3.3 & 3.4) has further interfered with the passage of water (pers. obs.). These management practices have undoubtedly had an effect upon wetland vegetation in the western arm of the vlei and the effects are investigated in the Chapters 4 and 6.

The flow of water in the eastern arm of the vlei is more diffuse than in the western arm, with indistinct drainage channels, and the construction of a dam on 'Forest Lodge' has also interfered with the passage of water through this arm (Begg, 1989).

Begg (1989) identifies the drain cut by the Natal Roads Department in the vicinity of the outlet to the vlei as a disruption that could have the most serious consequences to the whole vlei, as it starves the northern most portion of the vlei of water and appears to be eroding at a rate that could endanger not only the road but the also the vlei's 'key point' (described in section 3.4 of this chapter).

The scale of disturbance of the water flow through Hlatikulu Vlei has been far greater than at either Ntabamhlope Vlei or the mires at Highmoor. At Ntabamhlope the weirs are present where the Klein Boesmans River enters the vlei, where other streams enter the vlei and at the outlet of the vlei. The last weir has resulted in the formation of a small dam at the outlet (Downing, 1966). At Highmoor three dams have been constructed for trout at the northern section of the mires with effect on less than 5% of the mires.

3.8 Climate

The mean annual rainfall for Hlatikulu Vlei between 1945 and 1986 as recorded on the farm Tierhoek is 910.15 mm (the standard deviation is 155.81 mm). Annual rainfall

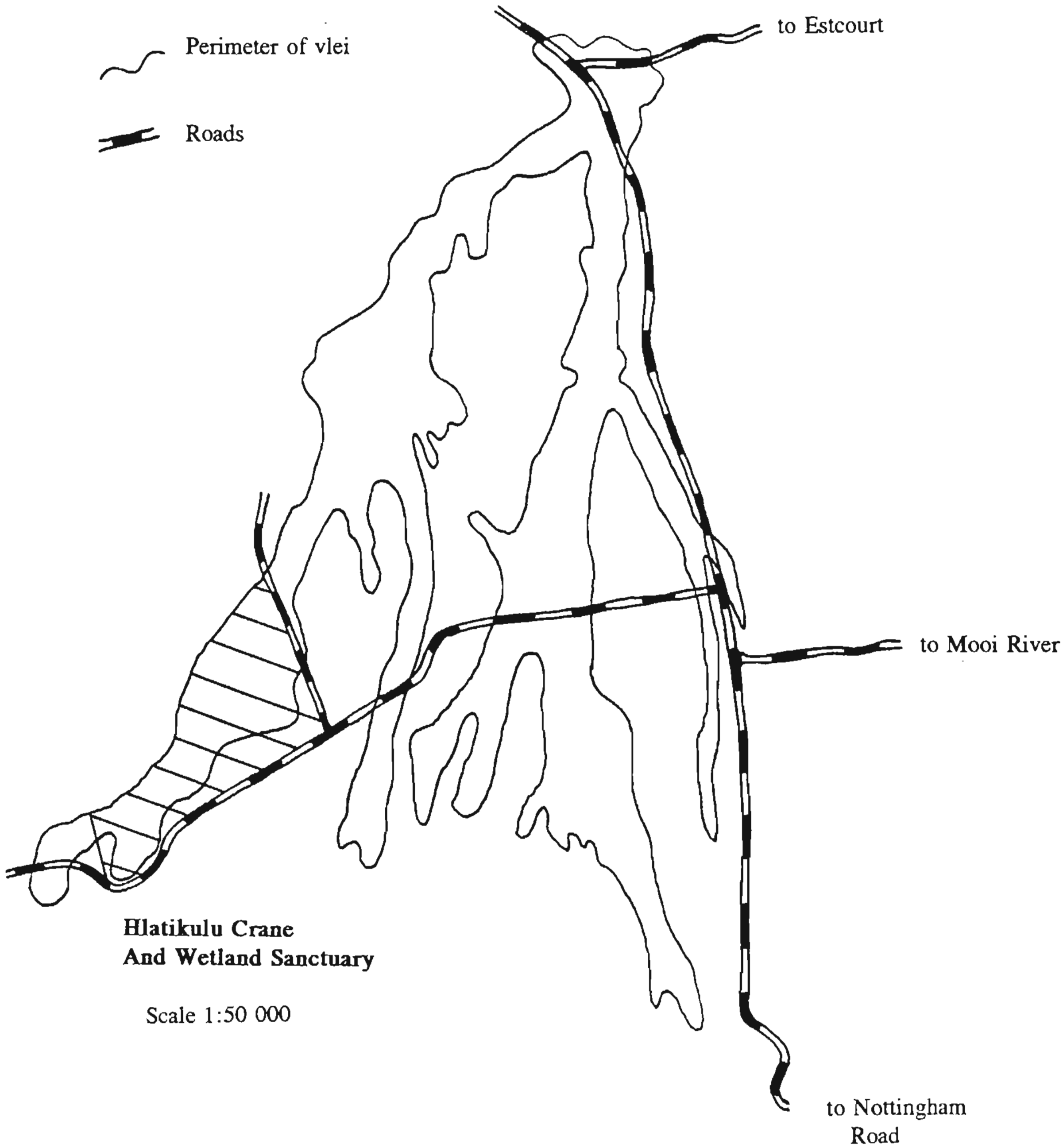
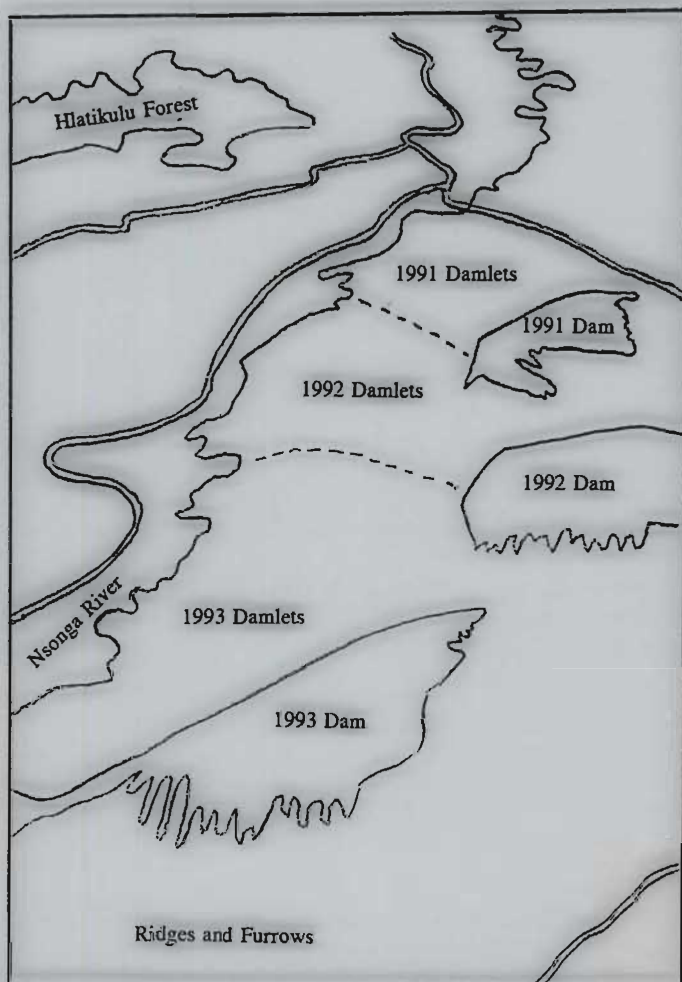


Figure 3.3: Location of the Hlatikulu Crane and Wetland Sanctuary at Hlatikulu Vlei.

Figure 3.4: **Aerial photograph of the dams and damlets within the Hlatikulu Crane and Wetland Sanctuary. Dams and damlets are lablelled on the overlay. Orientation of the photograph is North North East.**

Overlay for Figure 3.4



Overlay for Figure 3.4

Figure 3.4: **Aerial photograph of the dams and damlets within the Hlatikulu Crane and Wetland Sanctuary. Dams and damlets are lablelled on the overlay. Orientation of the photograph is North North East.**

totals for this period are displayed graphically in Figure 3.5. Simulated mean monthly rainfall data, prepared by the Computer Centre for Water Research, for Hlatikulu Vlei, mires at Highmoor and Ntabamhlope Vlei are graphically displayed in Figures 3.6, 3.7 and 3.8 respectively. The highest (simulated) mean annual rainfall of 921.8 mm is at the mires at Highmoor, followed by Hlatikulu with 864.8 mm and Ntabamhlope Vlei with 811.4 mm. Actual mean monthly rainfall data, slightly higher than the simulated data, for Hlatikulu Vlei for the period 1945 to 1986 are displayed in Figure 3.9. At Hlatikulu Vlei, the wet season extends from October to March with the highest monthly mean being January (152.18 mm, the standard deviation is 53.2 mm) and the lowest June (9.29 mm, the standard deviation is 14.31 mm).

At Hlatikulu Vlei, the mean annual temperature is 15.2°C with the lowest and highest mean monthly temperatures occurring in July (8°C) and January (25°C) respectively. The highest recorded summer temperature has been 39°C and the lowest winter temperature -8°C (Begg, 1989).

At Ntabamhlope Vlei, the mean annual temperature is 14.6°C with the lowest and highest mean monthly temperatures occurring in July (5.7°C) and January (18.7°C) respectively. The highest recorded summer temperature has been 37.2°C and the lowest winter temperature -15°C (Begg, 1989).

No temperature figures are available for Highmoor (Albertyn, pers. comm.)

3.9 Fauna and Flora

Acocks (1988) describes the grasslands of the eastern slopes and foothills of the Drakensberg as Highland Sourveld grassveld. This grassveld is dominated by *Themeda triandra, Tristachya leucothrix, Trachypogon spicatus, Heteropogon contortus* and *Eragrostis racemosa*, with the dominant dicotyledons being *Acalypha schinzii, Pentanisia prunelloides, Helichrysum pilosellum* and *Haplocarpha scaposa*. These species are however not dominant in the vlei as Begg (1989) stated that while the vlei is

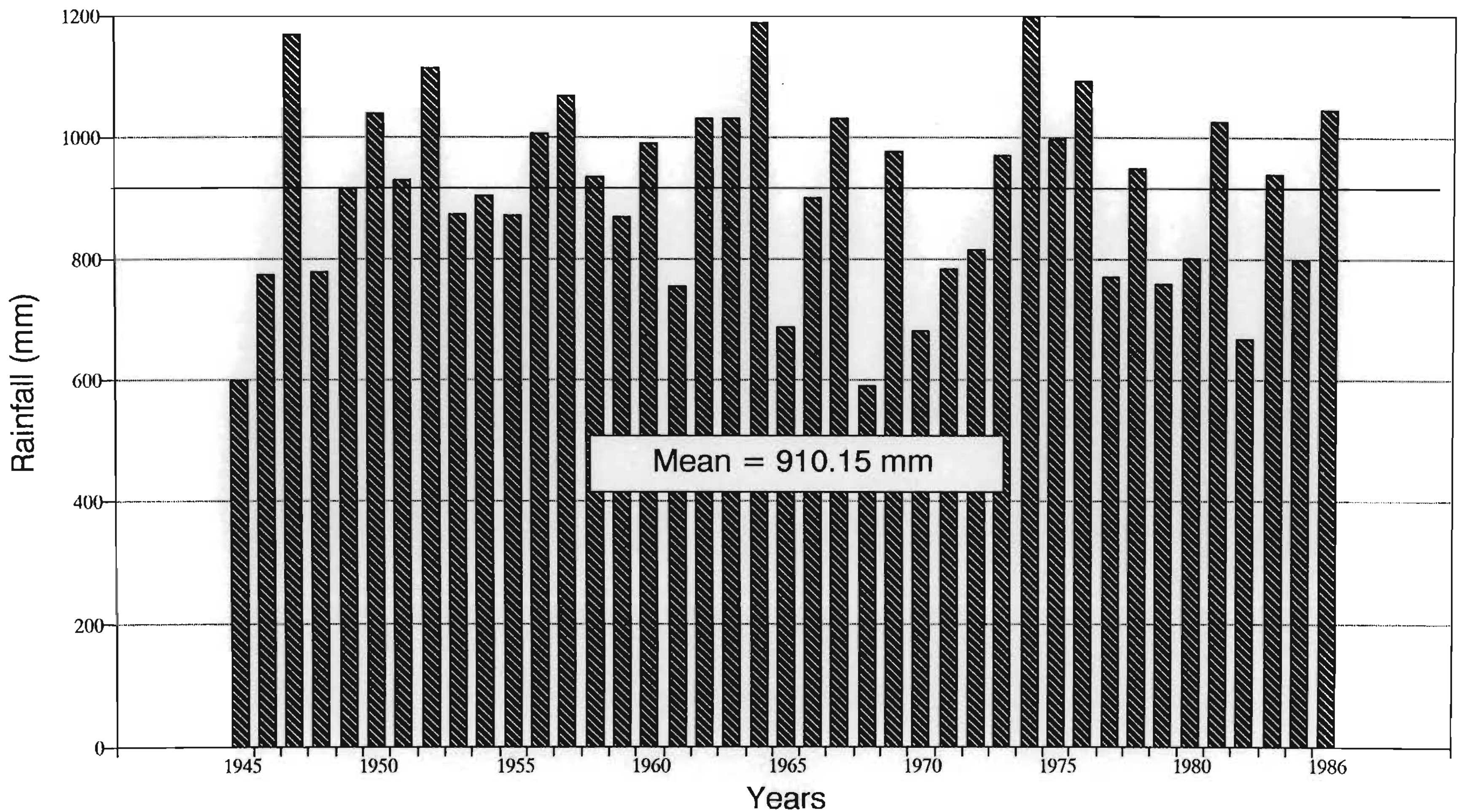


Figure 3.5: Annual rainfall figures for Hlatikulu Vlei (1945-1986).

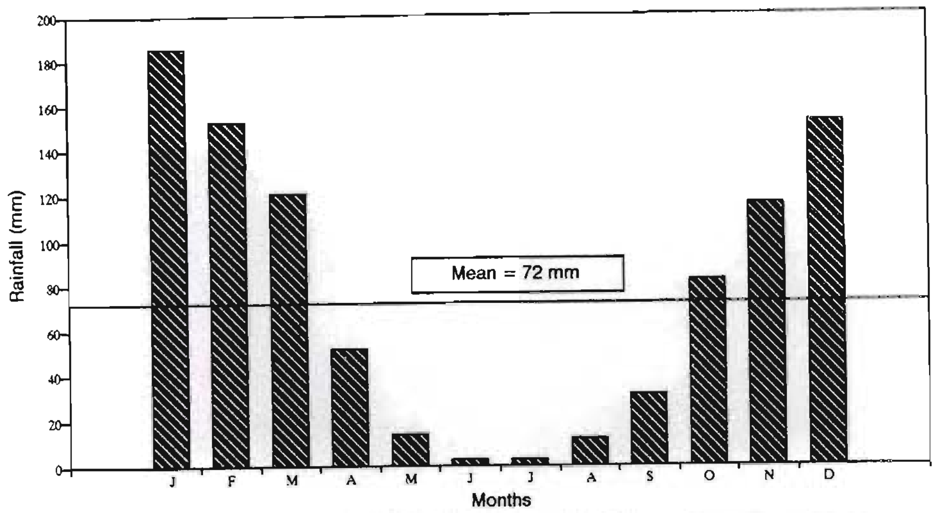


Figure 3.6: Mean monthly rainfall for Hlatikulu Vlei.(simulated by : Computer Centre for Water Research)

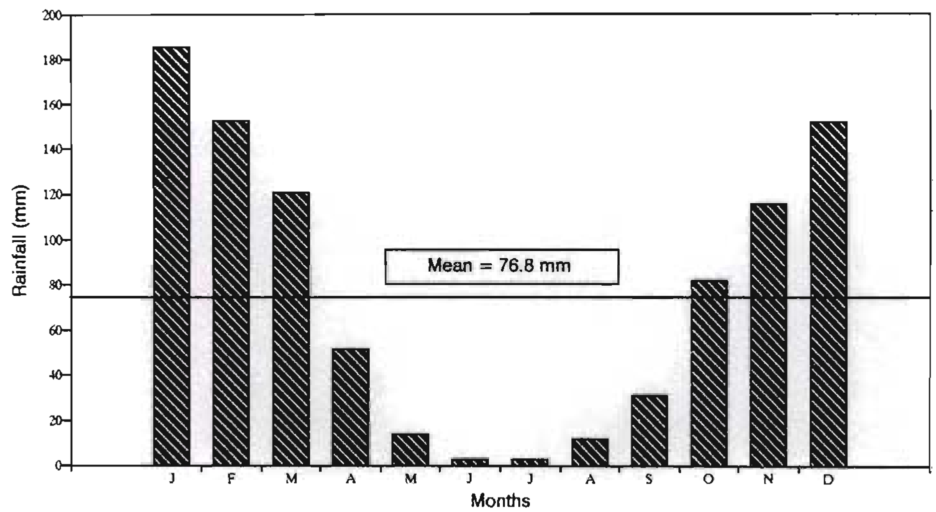


Figure 3.7: Mean monthly rainfall for Highmoor Plateau (simulated by : Computer Centre Water Research)

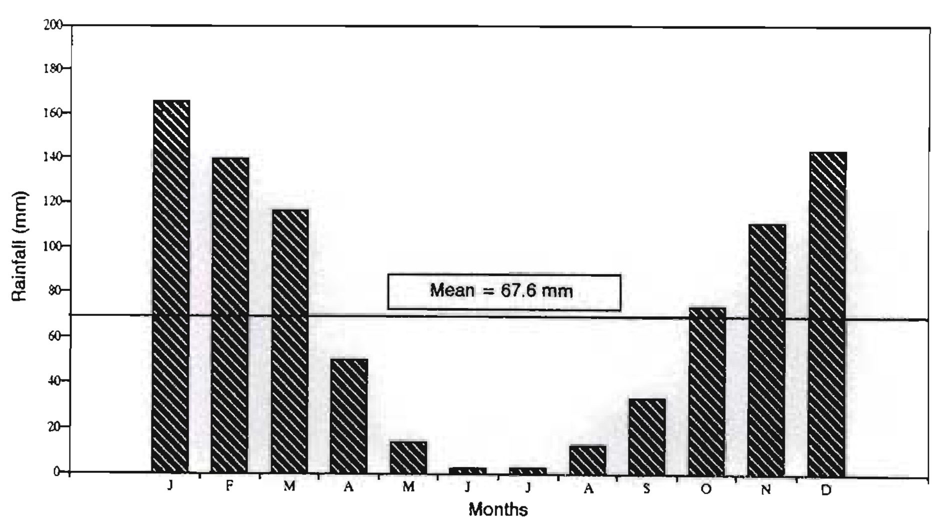


Figure 3.8: Mean monthly rainfall for Ntabamhlope Vlei.(simulated by : Computer Centre for Water Research)

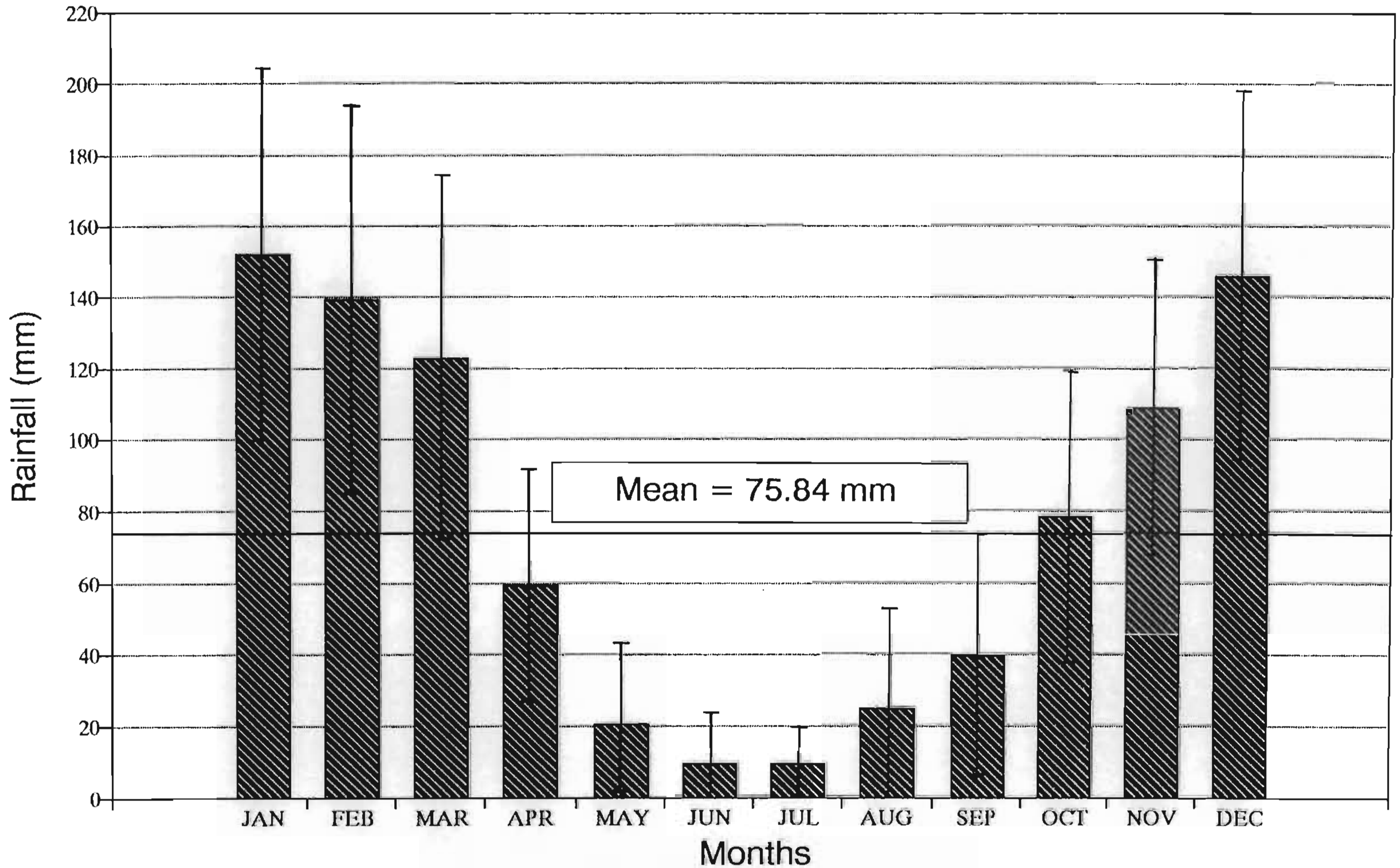


Figure 3.9: **Actual mean monthly rainfall figures (with standard errors transposed on the graph) for Hlatikulu Vlei for the period 1945 to 1986.**

surrounded by *Themeda-Trachypogon* highlands grassland as described by Acocks, the vlei itself is characterised by three main, distinctly distinguishable, plant communities; namely Sedge-meadows, Reedswamp and Bulrush communities (Begg, 1989). While a number of grass species are prevalent in the vlei, the dominant species are sedges, particularly *Cyperus denudatus, C. fastigiatus, Pycreus sp., Isolepis fluitans* and *Carex cognata*. Mapping of vegetation types and detailed descriptions of the plant communities of Hlatikulu Vlei are dealt with in chapters 4 and 5.

While Begg (1989) reports that two pairs of wattled crane (*Grus carunculatus*) are known to breed in the vlei, he notes that the fauna associated with the system is poorly known. As an indication of the biotic diversity of Hlatikulu Vlei and its value as a provider of suitable habitat for various animals, the mammals, birds and frog at the vlei were noted. Their occurence reinforces the need to conserve this vlei.

During the collection of data for this project records were kept of the mammal species observed and in cases captured on the vlei, the wetland dependent or wetland associated bird species and the amphibians associated with the vlei. Species list of mammals, birds and amphibians are contained in Appendices 1, 2 and 3 respectively.

To date 28 species of mammal have been recorded on the Hlatikulu Vlei. Reedbuck (*Redunca arundinum*) and oribi (*Ourebia ourebi*) are the most commonly seen species. Cape clawless otter (*Aonyx capensis*), water mongoose (*Atilax paludinosus*) and banded mongoose (*Mungos mungo*) are the most common smaller mammals and the vlei rat (*Otomys irroratus*), striped mouse (*Rhabdomys pumilio*) and mole-rat (*Cryptomus* sp.) are perhaps the most common rodents.

More than eighty wetland dependent bird species and bird species with strong associations with wetlands have been recorded for Hlatikulu Vlei. Some are resident throughout the year and breed on the vlei such as the hamerkop (*Scopus umbretta*), sacred ibis (*Threskiornis aethiopicus*), Egyptian goose (*Alopochen aegyptiacus*), yellowbilled duck (*Anas undulata*) and spurwinged goose (*Plectropterus gambensis*). Others are rare or endangered species which are reliant on the protection of wetland habitats for their continued survival such as bittern (*Botaurus stellaris*), wattled crane (*Grus carunculata*), whiskered tern (*Chlidonias hybridus*), grass owl (*Tyto capensis*), marsh owl (*Asio capensis*) and cuckoo finch (*Anomalospiza imberbis*).

At least 16 species of frog are found at Hlatikulu Vlei of which the common river frog (*Rana angolensis*) is the most often seen. The rare and little known long-toed tree frog (*Leptopelis xenodactylus*) with a range restricted to upland marshes in KwaZulu-Natal is perhaps the most notable amphibian at Hlatikulu Vlei. Certainly this frog too requires the protection of suitable habitat for its continued survival.

3.10 History of the Area

In KwaZulu-Natal approximately 65% of wetlands are privately owned and of these most are jointly owned by many farmers (Breen, et al, 1993). The Hlatikulu Vlei is privately owned by six owners. The largest portion of the vlei is controlled by Mondi Forests who own most of the farm 'Tierhoek', the uppermost section of 'Tierhoek' having been retained by Mr P.M. Theron, the previous owner. Further substantial portions of the vlei lie within the farms 'Northington' (du Preez), 'Forest Lodge' (Messrs Steyn) and 'Game Wood' (originally a black-owned farm, recently purchased by Messrs Steyn). Two smaller sections of the vlei are contained within 'Jakkalskop' (Harburn) and 'Northington' (Hobson) (Begg, 1989).

The history of the various management treatments that Hlatikulu Vlei has been subjected to during this century is reasonably well documented. As some of these treatments, namely grazing and burning, are routinely carried out on other vleis throughout KwaZulu-Natal, an understanding of the effect which these treatments have had on the vegetation at Hlatikulu Vlei would yield data that is likely to form the basis for improving wetland management in general. Thus a brief history of management of the vlei is given:

In 1880 the farm 'Game Wood' was granted to the 'Native' Sapu and remained under black ownership until 1991 when the land was purchased by Messrs Steyn of 'Forest Lodge'. 'Game Wood' includes the middle portion of the western arm of the vlei, which has been subjected to burning and heavy grazing by black farmers since the land was granted to them (Begg, 1989).

In the mid 1960's the upper portion of the western arm of Hlatikulu Vlei on 'Tierhoek' was drained and developed for pastures using 'ridge and furrow' technique (this technique is described in chapter 7). This was done during Mr Krauss's ownership of the farm, and although the farm changed hands in 1982 when Mr P.M. Theron became the owner, cultivation of pastures for livestock grazing continued until 1989 (Begg, 1989).

In 1990 the greater portion of 'Tierhoek' was purchased by Mondi Forests who proceeded to afforest the land above the vlei and grassland areas on high ground within and between the two arms of the vlei with *Pinus patula*. Consequently, concern was expressed that this could lead to a significant reduction of water entering the wetland, thereby posing a potentially serious threat to the water levels within the vlei that could seriously affect the functioning of and/or cause alterations to the vegetation of the vlei. Mondi responded by embarking upon a joint venture with the Southern African Crane Foundation (S.A.C.F.) to establish the Hlatikulu Crane, Wetland Sanctuary on the formerly drained areas of 'Tierhoek' (Davies, pers comm.).

In 1990 rehabilitation of the wetland commenced. Both Mondi and the S.A.C.F. have contributed towards the cost of the earthworks in the sanctuary portion of Tierhoek in an attempt to restore this portion of the vlei to wetland. During the winters of 1991, 1992 and 1993 three dams and numerous damlets have been constructed to reverse the effect of the 'ridge and furrow' network that drained the wetland. It is hoped that these dams and damlets will raise the water table, allowing wetland plants to become established in the area. The expectation of Mondi and the S.A.C.F. is that the rehabilitated area will become a breeding ground for cranes, especially wattled cranes

(*Grus carunculatus*) which are rare and endangered in southern Africa, waterfowl and other wetland dependent birds.

In 1982 'Forest Lodge' changed hands when Mr P. Young sold to the Steyn cousins (Mrs P. Young, pers comm.). The following year two large dams were constructed on each of the two arms of the vlei causing the flooding of large areas. Also on the high ground that lies between the two arms of the vlei on 'Forest Lodge' a centre-pivot irrigation system was established (Begg, 1989). Since then maize and other crops such as beans and rye grass have been cultivated in this area with water being drawn from the dam on the western arm for irrigation. The wall of this dam was raised by approximately 2 metres in 1993 causing further flooding of vlei areas.

Cattle have been excluded from the lower portion of the vlei on 'Forest Lodge' so that limited grazing only by reedbuck (*Redunca arundinum*) and oribi (*Ourebia ourebi*) has occurred (pers. obs.) and the area is not burnt on a regular annual basis (Begg, 1989).

The farm 'Northington' on the upper portion of the eastern arm of the vlei has been subjected to regular burning and grazing by White farmers from before 1940. Limited draining of certain sections of the vlei on this farm has been conducted.

CHAPTER 4

CLASSIFICATION AND COMPARISON OF WETLAND VEGETATION AT HLATIKULU VLEI, NTABAMHLOPE VLEI AND HIGHMOOR WETLANDS.

4.1 Introduction

Wetlands have a strong ecological function in the landscape as within it they modify the flow of water, nutrients and soil. In performing this function a normal prerequisite is that the vegetation cover should be preserved. As it is generally accepted that any degradation or destruction of wetland vegetation would severely impede the function of that wetland, it is essential that the quality of that vegetation is maintained (Mitsch & Gosselink 1986; Breen & Begg 1989). Whilst the vegetation of a wetland is highly dependent on an adequate supply of water, it is essential to determine what the vegetation of a wetland consists of in terms of plant communities in order to establish effective management practices that ensure the wetland's function and longevity.

The influence of wetlands can generally be regarded as cumulative as the more wetlands that are in a catchment, the greater their modifying influence will be on maintaining water quality, attenuating floods, controlling soil erosion, recharging groundwater and supporting various species of fauna and flora. As ecological management of any area should be based on sound scientific information about the natural resources present in the area (Coetzee et al. 1993), the management of vegetation in wetland systems should be based on such information and not on information from the surrounding grasslands as is so often the case in KwaZulu-Natal (Begg 1990). The necessity to classify, describe and interpret the different plant communities as a natural resource, is well documented by Mentis and Huntley (1982) and classification of wetland vegetation would not only facilitate the adoption of appropriate management practices but also allow for the tailoring of suitable wetland regulations (Begg 1990). Also there is a deficiency of knowledge of African vegetation and in particular of wetland vegetation (Denny 1993).

Classification of wetlands range from broad classifications of wetland types on a national or international scale, where distinctions are drawn between marshes, swamps, bogs, fens etc, (such as the classification of wetlands of the United States in 1979 by Cowardin et al.), to more localised classifications of the vegetation communities within a single wetland (such as Furness and Breen's classification of the vegetation of the Pongola floodplain in 1980). Little is known of the vegetation of wetlands in the Midlands of KwaZulu-Natal, but the ecology of Ntabamhlope Vlei was studied by Downing (1966) who classified the main vegetation communities. The vegetation communities of the Hlatikulu Vlei have not been classified and Begg (1988) contended that, while virtually nothing was then known about the flora of Hlatikulu Vlei, the vlei itself was characterised by three main plant communities, namely sedge-meadows, reedswamp and bulrush communities. Thus the main aim of this section was to classify, describe, and interpret ecologically the wetland plant communities of the Hlatikulu Vlei in order to effectively map theses communities, to facilitate the subsequent establishment of suitable management strategies for the vlei and to determine, as Begg (1988) suggested, which communities have a high species diversity, high quality and uniqueness so that special protection might be afforded to them.

In this regard the following key questions were addressed for Hlatikulu Vlei:

> What are the main plant communities of the Hlatikulu Vlei and what is the species composition of these communities?
>
> What environmental factors are most likely to be responsible for the present pattern of vegetation at Hlatikulu Vlei?
>
> Which vegetation communities at Hlatikulu Vlei are noted for species diversity and uniqueness and thus might require special protection?

Whilst the main priority of this section of this study was to achieve the classification of vegetation communities at Hlatikulu Vlei so that these physiognomically distinguishable plant communities could be suitably mapped, the additional classification of vegetation communities at Ntabamhlope Vlei and the mires at Highmoor facilitates the comparison of vegetation communities encountered at these three wetlands. This allows for an evaluation of how unique the vegetation communities of Hlatikulu Vlei are and indeed how unique the vlei is itself. In this regard the key questions to answer were:

What are the main plant communities of Ntabamhlope Vlei and the mires at Highmoor?

Are the vegetation communities at Hlatikulu Vlei similar to those at Ntabamhlope Vlei and the mires at Highmoor and if so, how, if not, how do they differ?

Are vegetation communities at Hlatikulu Vlei in any way unique or distinctive when compared to communities at other similar wetlands?

Is Hlatikulu Vlei on the whole distinctly different to other wetlands in the midlands of KwaZulu-Natal?

4.2 Study areas

The study areas for this section of the project were the Hlatikulu Vlei, the Ntabamhlope Vlei and the wetlands (mires) of the Highmoor Plateau. Details of these areas are given in Chapter 3.

4.3 Methods

4.3.1 Sample site location

Releves were compiled in random sample plots so that for Hlatikulu Vlei there were 100 plots, for Ntabamhlope Vlei there were 40 plots and for the mires at Highmoor 36 sample plots.

4.3.2 Sampling

Plots of 25m^2 (5 x 5 m) were used as the sampling unit as these were felt to be the most efficient size to allow for the capturing of data to describe the community composition. In each sample plot the floristic composition was recorded such that all species present were rated for cover-abundance according to the Werger's modified Braun-Blanquet scale (Mueller-Dombois & Ellenberg 1974). Taxon and author names conform to Arnold & de Wet (1993). Cover was chosen as a measure of abundance as it is not biased by the distribution and size of the individuals (Floyd & Anderson, 1987). The scale used is given below:

(1)	r	Very rare and with negligible cover (usually just a single individual).
(2)	+	Present but not abundant and with a small cover value (less than 1% of the quadrat size).
(3)	1	Numerous but covering less than 1% of the quadrat area or not so abundant but covering between 1 - 5% of the quadrat area.
(4)	2m	Very numerous covering less than 5% of quadrat area.
(5)	2a	Covering between 5 and 12% of the quadrat area independent of abundance.
(6)	2b	Covering between 13 and 25% of the quadrat area independent of abundance.
(7)	3	Covering between 26 and 50% of the quadrat area independent of abundance.
(8)	4	Covering between 50 and 75% of the quadrat area independent of abundance.
(9)	5	Covering between 75 and 100% of the quadrat area independent of abundance.

All plants were identified to species level from a field herbarium or at the University of Natal's Herbarium in Pietermaritzburg. Collections of each species encountered were made and their identification checked at the Herbarium. Full lists of species collected at Hlatikulu Vlei, the mires at Highmoor and Ntabamhlope Vlei are given in Appendices 4, 5 and 6 respectively.

Sampling of vegetation for Hlatikulu Vlei was conducted during the summer period, December 1992 to April 1993, while at Highmoor and Ntabamhlope sampling of vegetation was conducted during the summer periods, December 1993 to February 1994.

4.3.3 Environmental factors

To assist the classification and description of the plant communities at the three wetlands studied the environmental factors which were thought to be the most likely to be responsible for the present patterns of vegetation were measured.

Soil sampling was conducted at each site at Hlatikulu Vlei, Ntabamhlope Vlei and the mires at Highmoor. Augering to a depth of 1.2 m at each site was done to determine the soil type. Soil profiles were described from auger cores according to their texture and classified using MacVicar et. al. 1991, 'Soil Classification: a taxonomic system for South Africa'. Four soil types were encountered at the three wetlands, namely Champagne, Katspruit, Pinedene and Clovelly. All four of these soil types were encountered at Hlatikulu Vlei, while Katspruit and Champagne soil types were encountered at Ntabamhlope Vlei and the mires at Highmoor.

A profile typical of the Champagne series showed the following characteristics:

Organic O horizon: 0 - 120 cm of fibrous organic material of botanical origin. Dark black 10 YR 3/2 (Munsell, 1990) organic sandy clay loam.

A profile typical of the Katspruit series showed the following characteristics:

Orthic A horizon: 0 - 60 cm of dark black 10 YR 3/1 (Munsell, 1990) silty clay; highly organic with many roots.

G horizon: 60 - 120 cm of grey 7.5 YR 5/2 (Munsell, 1990) silty clay, sometimes with sand, with distinct yellow-brown and blue mottles.

A profile typical of the Pinedene series showed the following characteristics:

Orthic A horizon: 0 - 40 cm of brown 10 YR 3/2 (Munsell, 1990) sandy clay loam with roots.

Yellow-brown Apedal
B horizon: 40 - 120 cm of yellow-brown 10 YR 4/3 (Munsell, 1990) clay, with signs of wetness and small stones.

A profile typical of the Clovelly series showed the following characteristics:

Orthic A horizon: 0 - 45 cm of brown 10 YR 3/2 (Munsell, 1990) fine sandy loam with roots.

Yellow-brown Apedal
B horizon: 45 - 120 cm of yellow-brown 10 YR 4/4 (Munsell, 1990) sandy clay loam on underlying sandstone.

The soil moisture content was recorded at each site every month during the sampling periods given in section 4.3.2. Soil moisture was crudely estimated by eye and touch and was classified into the following categories:

(a) Free standing water (>/= 30 cm)
(b) Free standing water (> 30 cm)
(c) Saturated (water freely drips from soil sample)

(d) Wet (water can be squeezed from soil sample)
(e) Moist (soil sample cohesive when squeezed)
(f) Dry (soil hard or friable)

The degree of utilization by herbivores was also noted at each sample site. Plants in each sample site were observed to determine the severity of grazing so that the amount of damage by livestock to communities could be assessed. The following categories were used as a rough means of quantifying the severity of grazing:

(a) No grazing (no signs of any grazing)
(b) Light (some grasses with signs of grazing)
(c) Moderate (most grasses with signs of grazing)
(d) Heavy (all grasses with signs of grazing, grasses grazed to within 5 - 30 cm of soil surface).
(e) Extreme (grasses grazed to within 5 cm of soil surface).

Finally the presence or absence of hummock and channel features at the sample site was also recorded.

4.4 Data entry

The species abundance estimates for Hlatikulu Vlei, Ntabamhlope Vlei and the mires at Highmoor were processed to create data in a format compatible for analysis using the Two Way Indicator Species Analysis (TWINSPAN) ie. into Cornell condensed format (Gauch, 1982).

4.5 Vegetation Analysis

Over the past 30 years the problems of analysing large amounts of data generated by the floristic description of vegetation to examine plant and community distributions in relation to environmental factors and gradients have resulted in the development of a number of techniques for data reduction. These are usually grouped under the two headings of classification and ordination (Kent & Ballard, 1988). By common consensus in Britain and North America at present, TWINSPAN (Two-Way Indicator Species Analysis) is the most popular method for community classification, while DECORANA (Detrended correspondence analysis or reciprocal averaging) and CANOCO (Canonical correspondence analysis) are the most widely applied methods of ordination (Kent & Ballard, 1988). In this chapter classification methods are used to determine the vegetation communities of the three wetlands studied, while ordination methods are applied to species and environmental data for Hlatikulu Vlei in subsequent chapters.

4.5.1 Classification

Classification is a procedure for categorizing communities in which communities with similar species compositions are grouped together in subsets (Begon et.al., 1990).

4.5.1.1 Two-Way Indicator Species Analysis (TWINSPAN)

Two-Way Indicator Species Analysis (TWINSPAN) (Hill, 1979) is now the most widely used technique for polythetic divisive classification (Kent & Coker, 1992). The method is based on progressive refinement of a single axis ordination from reciprocal averaging or correspondence analysis and employs the idea of the pseudospecies, whereby the presence of a species at different predetermined levels of abundance is used (Kent & Coker, 1992).

A key concept of TWINSPAN and phytosociology is that for each division of a set of quadrats, a dichotomy can be made with a group of quadrats on one side characterised by one set of differential species and a second group on the other side characterised by a set of differential species.

4.6 Sequence of analyses

Two-way indicator species analysis (TWINSPAN) (Hill, 1979) was applied to the floristic data set from all sites at Hlatikulu Vlei, Ntabamhlope Vlei and the mires at Highmoor in order to derive a first approximation of the vegetation types of each of these wetlands. Refinement of the classifications for the three wetlands was done by means of Braun-Blanquet procedures (Bredenkamp et al. 1989). A phytosociological table was produced for each wetland as well as descriptions of each vegetation community for each wetlands.

4.7 Results

Rather than combining all the sample sites at the three wetlands to produce a combined classification of wetland vegetation, separate classifications were produced for each wetland. This allowed for comparisons to be made between the three wetlands on a plant community basis as well as in general terms but also aided in the mapping of vegetation communities at Hlatikulu Vlei (see chapter 5).

The phytosociological tables for Hlatikulu Vlei, Ntabamhlope Vlei and mires at Highmoor are given in Tables 4.1, 4.2 and 4.3 respectively. Lists of species acronyms for Hlatikulu Vlei, Ntabamhlope Vlei and mires at Highmoor are given in Tables 4.4, 4.5 and 4.6 respectively. Species which occur less than three times in a wetland and have low cover abundance values are excluded from the phytosociological tables. For ease of reference and cross reference to vegetation communities described in the

Table 4.1: Phytosociological table of the vegetation communities at Hlatikulu Vlei. (Species acronyms defined in Table 5.4)

		1					
	34443345571133455588995	81555666689123467784669990 13485 6	77 1191334468967799 12	23	21727	78822	2228
	60133920141757836889019	57284570123423224605365778904641752124	1290569485986393745320	880	46639	80779	1561
Community number	A 1.1	A 1.2	A 2.1	A2.2	A2.3	A 3	A 4
Species Group A							
CYP ESC	231-3112---------------	----------1------------------1-----11-	----------------------	---	-----	-----	----
OXA OBL	212--112-1-11----------	-------------------1------------------	--------------------1-	---	-----	-----	----
VER BON	2111-1------1-1----1---	1------------------------------------1	----------------------	---	-----	1----	----
Species Group B							
HYP RAD	22--------------12222--	--11-121-1-11-1-2----1111111-------1--	----------------------	---	-----	-----	----
MON CER	---------2--1--2222222-	-----1-----1-------------11-----------	----------------------	---	-----	-----	----
COM AFR	------1----11---222221-	--1-----------1-12-211-2--22----------	----------------------	---	-----	-----	----
TRI LEU	---------------222-222-	-----1------1-------------------------	----------------------	---	-----	-----	----
OXA COR	--1----------11-11-121-	----------------1-----------1---------	----------------------	---	-----	-----	----
DIC REP	----------------122-11-	-----------------1---1-2-1------------	----------------------	---	-----	-----	----
HYP FIL	1---------------1111111	----1--11-2-1----111------------------	----------------------	---	-----	-----	----
Species Group C							
ERA CHL	1--1----1--11--1-------	---11-1--12----1--------------1------2	----------------------	---	-----	-----	----
ERA CAP	----------22---2-------	1222211--1-2-11-1--111----------------	---1------------------	---	-----	-----	----
GER AMB	---------------1-------	-2--21211---1--11111------------------	----------------------	---	-----	-----	----
LED COO	---------------1-------	12221-2111-1--1-11121-1-111-----------	1-2122--1-------------	---	-----	-----	----
Species Group D							
PAS DIL	-22233233--111-2112--2-	--2111-222-222111-1122-21-122122223333	----------1--------321	---	-----	-----	----
ARI JUN	--------112321132222223	23233333233232222322122-22---112-11--1	2123---1211-1--------2	---	-----	-----	----
ERA CUR	-212-332312--2123223322	--2-1222-2222----11122-21-222-321-2--2	----------1--1--------	---	-----	-----	----
ERA PLA	121-2-111-2-2-22-111-12	---3-1322---22---1---111111---212-----	1------------1--------	---	-----	-----	----
HEL AUR	11112-2-2-22222211-211-	11--1211111-11-1111--2-----11111----22	-1-1---11-1-----------	--1	-----	-----	----
LEE HEX	-1-2---2------11-------	--------21-1----3----111111-----1-1---	----1----11---------1-	-21	1----	-----	----
PSE LUT	---11--11---1-111--11--	----111111-11-11-1-------------1---221	----------1----1-11---	11-	-----	-----	----
CON POD	221---1-1---1-1--------	----111--1----1--11--------1----------	-1----11-----1--------	---	----1	-----	----
Species Group E							
CYP DEN	----1------------------	3232323332333-3-23232132332221-11-2--3	233222112---11-3-3----	1--	-----	-----	----
AND APP	-----------------------	122------2-2-12-23211-222--2------1---	321-221------1--------	---	-----	-----	----
ISO FLU	-----------------------	-222-12122-221-1-21--1211111111-1--1-1	11--1-----1-----------	121	-----	-----	----
PYC UNI	-------------1---------	2----1211-22---1-2-2111111112111-2---1	21-1-1------1--2-2----	---	-----	-----	----
PYN RET	-1-------------1-------	1-1121-111-11-2212-1112-111--1--------	1-1112-222122-11-11---	---	---1-	--1--	----
RHY BRO	-----------1----------1	2--2111212-221-1----11-1-111--1-------	1-2122-11---2----1--1-	---	-----	-----	----
ERA PLN	--11--1------2----11---	--2-21-211222131222211222221-12-212-1-	21----3222-1-2-----132	---	2----	-----	----
HEM ALT	---3-------3-12-1--11--	----1---21-2--21--2311-2-1222--22-212-	------2---21-2-----2-3	---	2-1-2	-----	----
ELI DRE	-------21--------------	-1------2----112-2321--2-122-----3--11	32--2211--2--1-----32-	223	-----	-----	----
JUN EFF	-2--1--1---------------	-1----1--2-1-1--1-1--11111-12211212-2-	21--12-2221--------222	11-	21--1	--11-	----
JUN OXY	----1------------------	111--1-111-111--1----1------21-31----1	1---22---1---------1-1	211	1----	-----	----
SCH DEC	-----------------------	--1----------2----1---------1-1122--2-	-----1-------------2--	3-2	-----	-----	----
Species Group F							
CAR COG	---------------1-------	---------1-1-21-2-2-32212211--1-1-3---	2332223222233333333-31	-2-	112-2	212-1	---1
POL PLE	-1----------------1----	-11---2122-11-1112-1112222221--11-1---	2122-122222-12-121-1--	222	1-112	1121-	---1
Species Group G							
SCH BRA	-----------------------	--------2--1--------------------------	1-------------1-1-----	333	-----	-----	----
Species Group H							
CYP FAS	-----------------------	--1--------------1----2---------------	----21----1-----------	---	33333	-11-1	---1

Table 4.1: Continued

```
                                                               1
            34443345571133455588995   81555666689123467784669990  13485  6 77 1191334468967799 12  23 21727 78822 2228
            60133920141757836889019 57284570123423224605365778904641752124 1290569485986393745320 880 46639 80779 1561

Community
number          A 1.1                   A 1.2                            A 2.1           A2.2 A2.3  A 3   A 4

Species Group I

 TYP CAP    ----------------------- -------------------------------------- ---------------------2 --- 1---1 33333 ---1
 POL KIT    ----------------------- ------------------1--1------------21-- ---------------------1 1-- --1-2 322-1 ----
 MEN AQU    ----------------------- -1-------------1-1-----1-1-1-1-------- -----11---1--1---1---- --- -1--2 121-- ----

Species Group J

 PHR AUS    ----------------------- ----------------------1--------------- ------11-----1-------- --- ----- ----- 3333
 LAR MUS    ----------------------- -------------------------------------- ---------------------- --- ----- ---11 2221

Species Group K

 ARU NEP    ---------33-2232------- ---1-1-------1-22123-3-2-112--2------- ----1113333121-------1 --- ----- ----- ----
 HEL RUG    ---------2-1--2-------- 22---------------------1-1------------ ---------------------- --- ----- ----- ----
 ERA TEF    ---------------2--1---2 -----1-1-1--1------------------------- ---------------------- --- ----- ----- ----
 RUB CUN    ---1--------3-2-------- --1-------------------1--1-----------1 ----------1----------- --- ----- ----- ----
 HEL PIL    ---------221----11-1-1- --2---1----2---11-1-11---------------- -1-------------------- --- ----- ----- ----
 SET PAL    -111-1-21-----1-------- ----1----------1-1-11-1-11-1------1--2 --1-------1----------- --- ----- ----- ----
 SEN CAT    ----------------1--11-- -----12---------1------1-11----------1 1--------------------- --- ----- ----- ----
 CON CHI    --1-------------------- -----------------11--121211--------111 --------1------------1 --- ----- ----- ----
 PYC MAC    -----------1----------- 2----------1---1-2---1------1--2-2---- ---1------------------ --- ----- ----- ----
 PEN SPH    -----1----------------- ----1-----1--1---11---21112----------- ---------------------- --- ----- ----- ----
 SEN TYS    ---------2------------- --1-------------1-1--1-2--21---------- 2--------------------- --- ----- ----- ----
 SPO AFR    -----------1----------1 -------1-------21--------1--------1--- ---------1------------ -1- ----- ----- ----
 APO JUN    ----------------------- -----1122---21---11------------------- ---------------------- -21 ----- ----- ----
 XYR GER    ------------------1---- ---1-1-2-1-22------------------------- ---111---------------- --- ----- ----- ----
 SEN ISA    ---------2------------- --1-------------1-1--1-2--11---------- 2--------------------- --- ----- ----- ----
 SEN BUP    ----------------------- 2-1--------1----11----------------1--- ---11----------------- --- ----- ----- ----
 CON PIN    -------2------1-------- ---------------11--1-1111111-1-------- --------111----------- --- ----- --1-- ----
 DIG DIA    ---------1-1---1------- 2--1--2--12--------------------------- -------------------1-- 1-- ----- ----- ----
 AGR BEG    -1-----------------1--- --------1--------1---1---1--2---11-12- ---------------------2 --- ----- ----- ----
 EUL VIL    ---------2------------- -------------1-21---122-22------------ --2122-2-------------- --- ----- ----- ----
 EPI SAL    ----------------------- -------11---1----11------------------- 1-12---11---1--------1 --- ----- ----- ----
 AGR LAC    --11-------1----------- 1------------111--1---------11-11---21 11--1-1------1-1-1-2-- --- 1---- ----- ----
```

Table 4.2: Phytosociological table of the vegetation communities at Ntabamhlope Vlei. (Species acronyms defined in Table 5.5)

		123	31233 1	134212 12 12	23	1123312233
		6551	150667578	2680230343897	4990	1283471429
Community number		B 1	B 2.1	B 2.2	B2.3	B 3
Species Group A						
	PHR AUS	3333	---------	-------------	----	----------
Species Group B						
	TYP CAP	----	333333222	22221221-22--	----	----------
	CAR CLA	----	33----333	--------21---	----	----------
	CYP DEN	----	-12-2-222	-------2-22-1	-2--	----------
	SCH BRA	----	33----2-1	333333322-122	----	----------
	ERA PLN	----	---------	2332-3222----	----	----------
	JUN OXY	----	------32-	223323--22--1	----	----------
	SCH PAL	----	---------	2-2--32-22---	----	----------
	LSO FLU	----	---------	--------1-122	----	----------
Species Group C						
	CAR AUS	3232	------333	-----322---22	----	----------
	POL PLE	2221	---2-2222	-----2--2122-	----	----------
	CYP FAS	3233	33----2-2	333333322222-	----	----------
Species Group D						
	AGR ERI	----	---------	-------2-2---	2222	----------
	ARU NEP	3-21	---------	-------------	2332	----------
	ASC CAP	----	-------1-	-------------	2-2-	----------
	PYC OAK	2---	---------	-------------	2-21	----------
	RHY BRO	----	---------	-------------	12-2	----------
Species Group E						
	ELE DRE	----	---------	22212333-----	-22-	----------
	HEM ALT	----	---------	-------211222	-222	----------
Species Group F						
	LEE HEX	----	-22221222	2332232333333	3333	----------
Species Group G						
	ARI JUN	----	---------	-------22--2-	2222	3333333333
Species Group H						
	TRI LEU	----	---------	-------------	22-2	333333-333
	AND APP	----	---------	-------------	32-2	3-33333--3
	COM AFR	----	---------	-------------	22-1	---2-22222
	HES BAU	----	---------	-------------	1212	-2-22--22-
	HEL AUR	----	---------	-------2-----	-2--	-22----11-
	MON CER	----	---------	-------------	222-	222222-22-
	PYC RET	----	---------	-------------	22-1	2-21212222
Species Group I						
	PEN SPH	----	---------	-------------	----	-32223-2-2
	PYC MAC	----	---------	-------------	----	2-2-232223
	KYL ERE	----	------2--	-------------	----	--23233222
	CON ALB	----	---------	-------------	----	2-2-2--2-2
	FUI PUB	----	---------	-------------	----	2-2222----
	GER VIR	----	---------	-------------	--2-	-22222-22-
	HEL TUR	----	---------	-------------	----	2-2222-2-2
	PAN SCH	----	---------	-------------	----	2-2-2--22-
	SET PAL	----	---------	-------------	----	3-2-2--222
	AGR HUT	----	---------	-------------	----	--22222222
	GLA PAP	----	---------	-------------	----	-1-1112222
	HYP PAR	----	---------	-------------	----	---3-22222
	KNI ICH	----	---------	-------------	----	--2-222-1-
	LED COO	----	---------	-------------	----	--22-23-2-
	SEB SED	----	---------	-------------	----	-----22222
	TRI LIN	----	---------	-------------	----	2-2-222221
	TUL NAT	----	---------	-------------	----	-1---22212

Table 4.3: Phytosociological table of the vegetation communities at the mires at Highmoor (Species acronyms defined in Table 5.6)

	1111	2211222222	1112 123	333333
	4512382345	791201534867	78906690	124563
Community number	C 1.1(a)	C 1.1 / C 1.1(b)	C 1.2	C 2
Species Group A				
SCA COL	1--222--12	----------11	--------	------
ASC CAP	122-1--211	------------	-1-1----	------
PSE LUT	--1--1--11	------------	--------	------
FUI PUB	2----1-1--	------------	--------	------
COM AFR	--2-2-1---	------------	--------	------
Species Group B				
ARI JUN	3333333333	-2333-233---	----1-1-	----1-
HEL EPA	22-222222-	33222-1221--	---1----	------
ERA CAP	---12--221	--22--21--22	--------	------
JUN OXY	---2222211	1222--222221	--------	------
LOB ERI	1211212212	131212-22-11	--------	----1-
DIE PAU	----222--2	--1----22-21	--------	------
SEN POL	-2221-----	22--2-----1-	----1---	------
GER AMB	---1-2-1--	-2--------1-	--------	------
RAN MUL	-----2----	-----22-----	--------	------
AGR LAC	-------2-2	-----21-1---	--------	------
CYR BRE	12-1-----1	------1-11--	--------	------
Species Group C				
FES CAP	-------1--	23223-333333	3333-333	------
PYC COO	----1-----	31332322-1--	----1-21	------
PEN SPH	----------	---12-2222--	23322333	------
JUN DRE	----------	-121-22---22	---1----	------
JUN EFF	----------	-1--222-----	----21--	--2---
SEN HAR	----------	---1--12--12	------21	--2---
ELI DRE	----------	---------222	--2---2-	------
Species Group D				
CAR COG	----------	--------1---	-2-1--22	12-113
EPI SAL	----------	----1-------	---211-1	-22--2
Species Group E				
AND APP	3-33333233	3333-2223322	-3233-3-	------
Species Group F				
SCH BRA	----------	------------	--------	23-2-1
MEN AQU	----------	------------	--------	-2222-
Species Group G				
ISO FLU	2-22323223	3-3-112--3--	33232-1-	2-32-2
CAR AUS	23-1--1---	31-2333---23	33333122	33333-
HEL COO	2---2-11--	----1------2	---12--2	11-22-
Species Group H				
HYP FIL	---1----2-	-------2----	------1-	------
MEL SCA	--2-1---11	---1---11---	-------1	------
URG MAC	------1-21	--1----22--1	-----2--	------
WAH PAL	-------12-	1---1-------	1-1-22--	------
HES LAC	------11--	--1---------	--------	------
CHI KRE	------1-12	-----1------	--------	------
ARG TUB	12--------	----------1-	----1---	------
STA NAT	-------2--	--------1---	--1-----	------
ISO COS	----------	------233---	--11----	------
HAR FAL	----------	------------	-222----	------
RHY BRO	----------	--12--------	--------	-----2
GUN PER	----------	-----------2	-------3	------
LIM MAI	----------	--22--------	2-------	------
NID ANO	----------	------------	21------	-2----

Table 4.4: List of species acronyms with their full form used in all classification tables and ordination diagrams for Hlatikulu Vlei.

Species acronym	Full species name	Species acronym	Full species name
AGRBEG	*Agrostis bergiana*	LARMUS	*Largiosiphon muscoides*
AGRLAC	*Agrostis lachnantha*	LEDCOO	*Ledebouria cooperi*
ANDAPP	*Andropogon appendiculatus*	LEEHEX	*Leersia hexandra*
APOJUN	*Aponogeton junceus*	MENAQU	*Mentha aquatica*
ARIJUN	*Aristida junciformis*	MONCER	*Monocymbium ceresiiforme*
ARUNEP	*Arundinella nepalensis*	OXACOR	*Oxalis corniculata*
CARCOG	*Carex cognata*	OXAOBL	*Oxalis obliquifolia*
COMAFR	*Commeliana africana*	PASDIL	*Paspalum dilatatum*
CONCHI	*Conyza chilensis*	PENSPH	*Pennisetum sphacelatum*
CONPIN	*Conyza pinnata*	PHRAUS	*Phragmites australis*
CONPOD	*Conyza podocephala*	POLKIT	*Polygonum kitaibelianum*
CYPDEN	*Cyperus denudatus*	POLPLE	*Polygonum plebeium*
CYPESC	*Cyperus esculentus*	PSELUT	*Pseudognaphalium luteo-album*
CYPFAS	*Cyperus fastigiatus*	PYCMAC	*Pycreus macranthus*
DICREP	*Diclis reptans*	PYCUNI	*Pycreus uniloides*
DIGDIA	*Digitaria diagonalis*	PYNRET	*Pycnostachys reticulata*
ELIDRE	*Eleocharis dregeana*	RHYBRO	*Rhynchospora brownii*
EPISAL	*Epilobium salignum*	RUBCUN	*Rubus cuneifolius*
ERACAP	*Eragrostis capensis*	SCHBRA	*Schoenoplectus brachyceras*
ERACHL	*Eragrostis chloromelas*	SCHDEC	*Schoenoplectus decipiens*
ERACUR	*Eragrostis curvula*	SENBUP	*Senecio bupleuroides*
ERAPLA	*Eragrostis plana*	SENCAT	*Senecio cathcartensis*
ERAPLN	*Eragrostis planiculmis*	SENISA	*Senecio isatideus*
ERATEF	*Eragrostis tef*	SENTYS	*Senecio tysonii*
EULVIL	*Eulalia villosa*	SETPAL	*Setaria pallide-fusca*
GERAMB	*Gerbera ambigua*	SPOAFR	*Sporobolus africanus*
HELAUR	*Helichrysum aureo-nitens*	TRILEU	*Tristachya leucothrix*
HELPIL	*Helichrysum pilosellum*	TYPCAP	*Typha capensis*
HELRUG	*Helichrysum rugulosum*	VERBON	*Verbena bonariensis*
HEMALT	*Hemarthria altissima*	XYRGER	*Xyris gerrardii*
HYPFIL	*Hypoxis filiformis*		
HYPRAD	*Hypochoeris radicata*		
ISOFLU	*Isolepis fluitans*		
JUNEFF	*Juncus effusus*		
JUNOXY	*Juncus oxycarpus*		

Table 4.5: List of species acronyms with their full form used in classification table for Ntabamhlope Vlei.

Species acronym	Full species name	Species acronym	Full species name
AGRERI	*Agrostis eriantha*	PANSCH	*Panicum schinzii*
AGRHUT	*Agrostis lachnantha*	PENSPH	*Pennisetum sphacelatum*
ANDAPP	*Andropogon appendiculatus*	PHRAUS	*Phragmites australis*
ARIJUN	*Aristida junciformis*	POLPLE	*Polygonum plebeium*
ARUNEP	*Arundinella nepalensis*	PYCBET	*Pycreus betschuanus*
ASCCAP	*Ascolepis capensis*	PYCOAK	*Pycreus oakfortensis*
CARAUS	*Carex austo-africana*	PYCMAC	*Pycreus macranthus*
CARCLA	*Carex clavata*	PYCNIT	*Pycreus nitidus*
COMAFR	*Commeliana africana*	PYCRET	*Pycnostachys reticulata*
CONALB	*Conyza albida*	SCHBRA	*Schoenoplectus brachyceras*
CYPDEN	*Cyperus denudatus*	SCHPAL	*Schoenoplectus paludicola*
CYPFAS	*Cyperus fastigiatus*	SEBSED	*Sebaea sedoides*
ELEDRE	*Eleocharis dregeana*	SETPAL	*Setaria pallide-fusca*
ERAPLN	*Eragrostis planiculmis*	TRILEU	*Tristachya leucothrix*
FUIPUB	*Fuirena pubescens*	TRILIN	*Tritonia lineata*
GERVIR	*Gerbera viridifolia*	TULNAT	*Tulbaghia natalensis*
GLAPAP	*Gladiolus papilio*	TYPCAP	*Typha capensis*
HELAUR	*Helichrysum aureo-nitens*		
HELTUR	*Helictotrichon turgidulum*		
HEMALT	*Hesperantha baurii*		
HESBAU	*Hemarthria altissima*		
HYPPAR	*Hypoxis parvifolia*		
ISOFLU	*Isolepis fluitans*		
JUNOXY	*Juncus oxycarpus*		
KNIICH	*Kniphofia ichopensis*		
KYLERE	*Kyllinga erecta*		
LEDCOO	*Ledebouria cooperi*		
LEEHEX	*Leersia hexandra*		
MONCER	*Monocymbium ceresiiforme*		

Table 4.6: List of species acronyms with their full form used in classification table for the mires at Highmoor.

Species acronym	Full species name	Species acronym	Full species name
AGRLAC	*Agrostis lachnantha*	JUNEFF	*Juncus effusus*
ANDAPP	*Andropogon appendiculatus*	JUNOXY	*Juncus oxycarpus*
ARIJUN	*Aristida junciformis*	KNIAUG	*Kniphofia augustifolia*
ARGTUB	*Argyrolobium tuberosum*	MONDEC	*Monopsis decipiens*
ASCCAP	*Ascolepis capensis*	MELSCA	*Melasma scabrum*
CARAUS	*Carex austo-africana*	NIDANO	*Nidorella anomala*
CARCOG	*Carex cognata*	PENSPH	*Pennisetum sphacelatum*
COMAFR	*Commeliana africana*	PSELUT	*Pseudognaphalium luteo-album*
CHIKRE	*Chironia krebsii*	RHYBRO	*Rhynchospora brownii*
CYRBRE	*Cyrtanthus breviflorus*	RANMUL	*Ranunculus multifidus*
DIEPAU	*Dierama pauciflora*	SCACOL	*Scabiosa columbaria*
ELIDRE	*Eleocharis dregeana*	SCHBRA	*Schoenoplectus brachyceras*
ERACAP	*Eragrostis capensis*	SENCAT	*Senecio cathcartensis*
ERAPLC	*Eragrostis planiculmis*	SENHAR	*Senecio harveyanus*
EPISAL	*Epilobium salignum*	SENPOL	*Senecio polyodon*
FUIPUB	*Fuirena pubescens*	STANAT	*Stachys natalensis*
FESCAP	*Festuca caprina*	URGMAC	*Urginea macrocentra*
GERAMB	*Gerbera ambigua*	WAHPAL	*Wahlenbergia pallidiflora*
GUNPER	*Gunnera perpensa*		
HARFAL	*Harpochloa falx*		
HELCOO	*Helichrysum cooperi*		
HELEPA	*Helichrysum epapposum*		
HESLAC	*Hesperantha lactea*		
HYPFIL	*Hypoxis filiformis*		
ISOCOS	*Isolepis costata*		
ISOFLU	*Isolepis fluitans*		
JUNDRE	*Juncus dregeanus*		

followed by the relevant number, all the Ntabamhlope Vlei vegetation communities are labelled with the letter B followed by the relevant number and all the vegetation communities of the mires at Highmoor are labelled with the letter C followed by the relevant number.

4.7.1 Classification and description of vegetation communities at Hlatikulu Vlei

The vegetation communities of the Hlatikulu Vlei have not been classified. In a report on the location, status and function of priority wetlands in KwaZulu-Natal Begg (1988) observed that Hlatikulu Vlei was characterised by three main plant communities which he described as sedge-meadows, reedswamp and bulrush communities. In this study a classification of vegetation communities at Hlatikulu Vlei derived from a TWINSPAN analysis was produced.

The results obtained from the classification answer the key questions posed in the introduction of this chapter such that the main plant communities of the Hlatikulu Vlei are identified and the species composition of these communities is described. Also the environmental factors determining the location of each community within the vlei are given for each community and are discussed later in this chapter.

At Hlatikulu Vlei a total of 168 species were recorded in 100 sample plots located within the 733 hectares of the vlei. There was an average number of 16 species per sample plot. From the final phytosociological table seven plant sub-communities which can be classified under four major communities were identified for Hlatikulu Vlei (Table 4.1) and are listed below as:

A 1. *Aristida junciformis - Paspalum dilatatum* Community

  A 1.1 *Aristida junciformis - Eragrostis curvula* Sub-community

  A 1.2 *Aristida junciformis - Cyperus denudatus* Sub-community

A 2. *Carex cognata* - *Polygonum pleibium* Community

A 2.1 *Carex cognata* - *Cyperus denudatus* Sub-community

A 2.2 *Carex cognata* - *Schoenoplectus brachyceras* Sub-community

A 2.3 *Carex cognata* - *Cyperus fastigiatus* Sub-community

A 3. *Typha capensis* - *Polygonum kitaibelianum* Community

A 4. *Phragmites australis* - *Largiosiphon muscoides* Community

A diagrammatic presentation of the hierarchical classification and associated environmental interpretation of the recognised plant communities for Hlatikulu Vlei is given in Figure 4.1. The floristic and associated environmental attributes for the respective plant communities (Table 4.1) are given below.

A 1. *Aristida junciformis* - *Paspalum dilatatum* Community

This major community is situated on seasonally waterlogged areas of the Hlatikulu Vlei and covers the greatest portion of the total vlei area. The vegetation was subjected to various degrees of grazing ranging from light grazing to heavy overgrazing.

The diagnostic and most conspicuous species in this major community are the tufted perennial grasses *Aristida junciformis* and *Paspalum dilatatum* (species group D, Table 4.1). Other species with high abundance and constancy are the densely tufted grasses *Eragrostis curvula* and *Eragrostis plana* and the perennial forb *Helichrysum aureo-nitens*. This major community is represented by two distinct vegetation sub-communities. Sub-community A 1.1 could by termed vlei grassland as defined by Downing (1966) and sub-community A 1.2 together with community A 2 form the sedge-meadows described by Begg (1988).

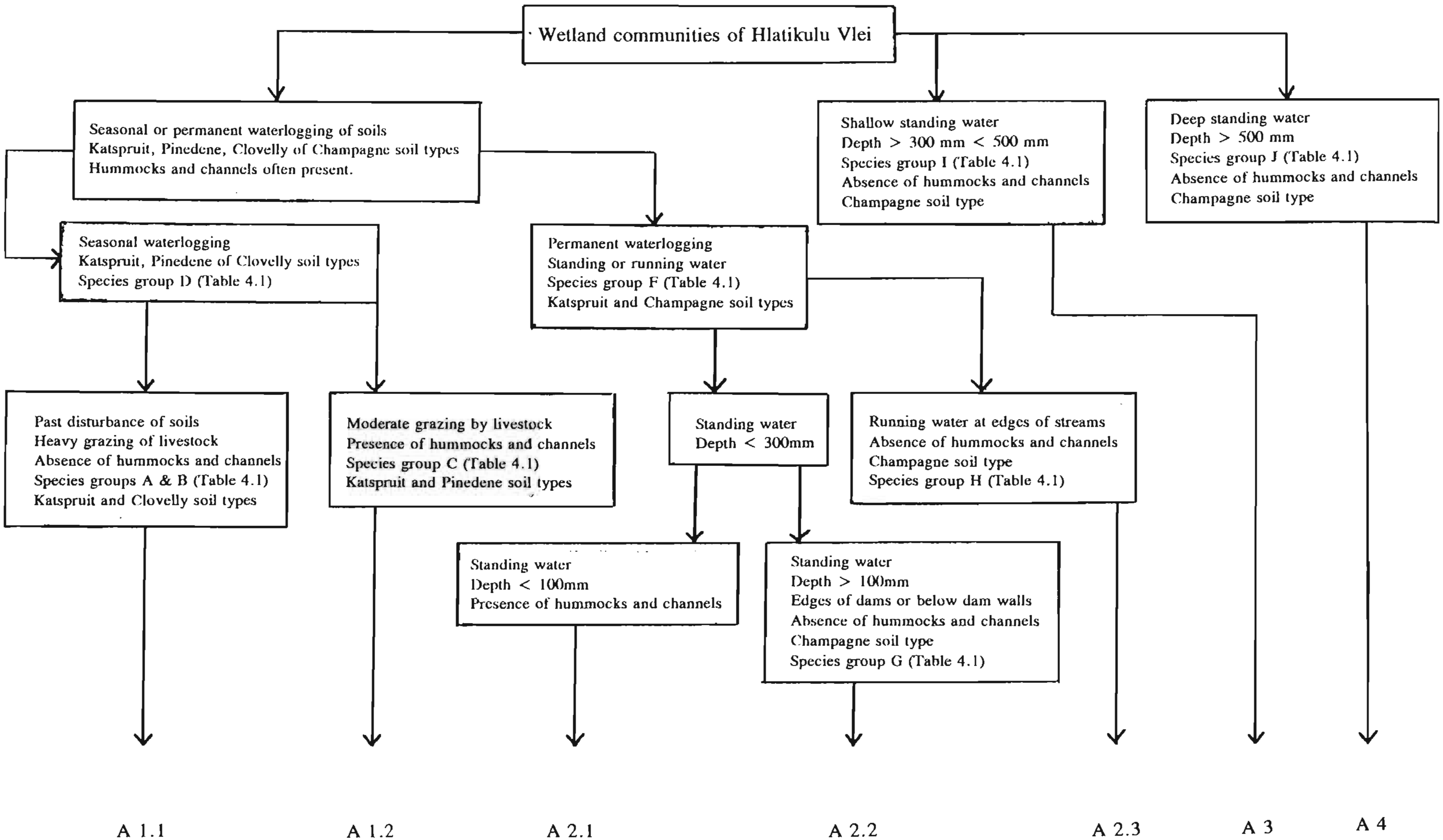


Figure 4.1: The hierarchical classification and environmental interpretation of the vegetation communities at Hlatikulu Vlei. Community numbers correspond to plant community descriptions in the text.

A 1.1 *Aristida junciformis - Eragrostis curvula* Sub-community

This community is found on the fringes of the vlei adjacent to the surrounding grassland in areas that are seasonally waterlogged. In certain areas where this community occurs past disturbances have occurred which may have effected its species composition and diversity. This is particularly so in the Game Wood section on the western arm of the vlei where heavy grazing by livestock has been allowed for much of the past fifty years whilst on the area of 'Tierhoek' (now the Hlatikulu Crane and Wetland Sanctuary) the vlei had been drained, ploughed and cultivated with pasture grasses.

The Katspruit soil form is predominant in this community. The presence of a G-horizon in the soil profile at depths greater than 600mm indicates that the soil is saturated with water for long periods, although the A-horizon is only periodically flooded with water and is often drier than that of community A 1.2.

The most conspicuous and diagnostic species are the grasses *Aristida junciformis* and *Paspalum dilatatum*, while the grasses *Eragrostis curvula* and *Eragrostis plana* and the forb *Helichrysum aureo-nitens* are also diagnostic. There is a conspicuous absence of the sedges *Cyperus denudatus, Isolepis fluitans, Pycreus uniloides* and *Rhynchospora brownii* and the rushes *Juncus effusus* and *Juncus oxycarpus* (species group E, Table 4.1) which separates this community from community A 1.2. This community has a moderate diversity of plant species when compared with other communities within the vlei, with an average of 15 species per sample plot. The absence of these species is most probably due to a drier A-horizon as a result of previous draining of parts of the area. In the areas of the Hlatikulu Crane and Wetland Sanctuary where hummocks and channels are absent the sedge *Cyperus esculentus* and the forbs *Oxalis obliquifolia* and *Verbena bonariensis* are diagnostic (species group A, Table 4.1). In the Game Wood areas, where the heaviest grazing takes place, the soils tend to be more compacted and drier. It is here that the tufted perennial grasses *Monocymbium ceresiiforme* and *Tristachya leucothrix* are diagnostic (species group B, Table 4.1).

A 1.2 *Aristida junciformis - Cyperus denudatus* Sub-community

This community is found in flat areas of the vlei where seasonal flooding occurs and where hummocks and channels features are present in the landscape. These areas have been subjected to livestock grazing of a more limited nature than community A 1.1. although no fencing separates the grassland surrounding these vlei areas from the vlei area occupied by this community.

The Katspruit soil form is the predominant soil type in this community, although pockets of Pinedene soil form are also present. The A-horizon on the hummocks varies from 150mm to 600mm in depth depending on how well formed the hummocks are and is seasonally waterlogged during the summer months and during periods of high rainfall in other seasons. Below the A-horizon of both the hummocks and channels the G-horizon is permanently waterlogged even during drier periods.

The most conspicuous species which are diagnostic for this community, are the widely distributed grasses *Aristida junciformis* and *Paspalum dilatatum*. The sedges *Cyperus denudatus, Isolepis fluitans, Pycreus uniloides* and *Rhynchospora brownii*, the rushes *Juncus effusus* and *J. oxycarpus* and the vlei associated grasses; the tufted perennial river grass *Arundinella nepalensis*, the tufted perennial grass *Eragrostis planiculmis* and the perennial creeping swamp grass *Hemarthria altissima* are also diagnostic (species group E, Table 4.1). This community could be called a mixed sedge and grass sedge-meadow community. The presence of hummocks and channels in the areas of the vlei covered by these communities is the most likely cause for this mixture of sedges and grasses. The hummocks tend to be drier than the waterlogged channels and tend to facilitate the growth of grasses which are able to survive with their roots out of the waterlogged channels, while the channels tend to facilitate the growth sedges and rushes which can survive in waterlogged conditions. These communities support the greatest diversity of plants of all the communities in the Hlatikulu Vlei with an average of 21 species per sample plot.

A 2. *Carex cognata - Polygonum plebeium* Community

This major community is found in low lying, flat and permanently waterlogged areas of the vlei where hummock and channel features are often present. As these areas of the vlei generally occur towards the middle of the vlei or in very wet areas it appears that livestock readily graze these areas and thus this community is less affected by grazing than is community 1. The main soil types are the Katspruit and Champagne soil forms.

The diagnostic species for this community is the sedge *Carex cognata* and the forb *Polygonum plebeium* (species group F, Table 4.1). Three distinct sub-communities were recognised.

A 2.1 *Carex cognata - Cyperus denudatus* Sub-community

This community is found within areas that are permanently waterlogged with free standing water of less than 300mm in depth. Hummocks and channels are still present but less defined than in community A 1.2. The predominant soil types are the Katspruit and Champagne soil forms.

The most conspicuous and diagnostic species is *Carex cognata*, the sedge *Cyperus denudatus* is also diagnostic, but less abundant and visible than *Carex cognata*. Generally fewer species occur in this community per sample plot than community A 1.2, but this is comparatively high for the vlei and the average per sample plot is 17 species. A few grasses are found in this community. *Aristida junciformis* and *Andropogon appendiculatus* tend to occur on the hummocks that are present with *Hemarthria altissima* and *Eragrostis planiculmis* found consistently in the permanently waterlogged channels. This community is characterised by an absence of grasses in species group D (Table 4.1), particularly *Eragrostis curvula, Eragrostis plana* and *Paspalum dilatatum*.

A 2.2 *Carex cognata - Schoenoplectus brachyceras* Sub-community

This community is found in permanently waterlogged areas that are associated with the dams on the vlei, particularly the at edges of the dams where water levels may fluctuate and where winds may cause lapping of water along the edges of the dams. Katspruit and Champagne soils are the predominant soil forms.

The diagnostic species is *Carex cognata* and the most conspicuous species is *Schoenoplectus brachyceras*, with the sedge *Eleocharis dregeanus*, the rush *Juncus oxycarpus* and the perennial forb *Polygonum plebeium* also having a high abundance and consistancy. This community has a low species diversity with an average of 8 species per sample plot. It is also characterised by the absence of grasses.

A 2.3 *Carex cognata - Cyperus fastigiatus* Sub-community

This community is found in permanently waterlogged areas of the vlei particularly the areas immediately below the dam walls where seepage through the dam wall makes the ground sodden and where the water present is often stagnant. This community generally occurs at the lower portions of the vlei in the areas immediately before the outlet of the vlei. Champagne soils are the predominant soil form.

The diagnostic species is *Carex cognata* and the most conspicuous and dominant species is the sedge *Cyperus fastigiatus*. This community has a low species diversity with an average of 5 species per sample plot. The grasses *Eragrostis planiculmis* and *Hemarthria altissima* are less abundant and also occur in this community.

A 3. *Typha capensis - Pòlygonum kitaibelianum* Community

This major community is found in standing water (that is not stagnant) at the edges of dams, generally at depths ranging between 300 and 600mm. At Hlatikulu Vlei this community is largely restricted to the edges of the largest dam on the western arm of the vlei, although small pockets occur elsewhere and are associated with the dams of the vlei. Champagne soils are the dominant soil form of this community.

The diagnostic and dominant species is the bulrush *Typha capensis*. Other sedges occurring regularly in this community are *Cyperus fastigiatus* and *Carex cognata* while the forbs *Polygonum kitaibelianum*, *Polygonum plebeium* and *Mentha aquatica* are also present at lower levels. This community has an average of 5 species per sample plot, making it one of the communities with the lowest species diversity.

A 4. *Phragmites australis - Largiosiphon muscoides* Community

This community is found in deep standing water of the largest dam on the western arm of the vlei, in water of a depth that is greater than 500mm. The soil type is predominately Champagne form.

An average of three species per sample plot was recorded, representing the lowest species diversity of any community encountered on the vlei. The most conspicuous and diagnostic species is the tall perennial reed *Phragmites australis*. This species occurs in nearly pure stands. The only other diagnostic species is the aquatic weed *Largiosiphon muscoides*. The only other non diagnostic species with a high abundance is the bulrush *Typha capensis*. This community is characterised by the absence of any gramminoids, other than *Phragmites australis*.

4.7.2 Classification and description of vegetation communities at Ntabamhlope Vlei

In a study of the ecology of Ntabamhlope Vlei three main plant communities were identified, namely: reedswamps, sedge-meadows and vlei grasslands (Downing, 1966). In this study a total of 40 sample sites were located in an area of over 100 hectares which was within the same area that was studied by Downing (1966). A total of 76 species were recorded in these sites with an average of 15 species per sample plot.

From the final phytosociological table for Ntabamhlope Vlei, six plant sub-communities which can be classified under three major communities were identified (Table 4.2):

B 1. *Phragmites australis - Carex austro-africana* Community

B 2. *Leersia hexandra* Community

B 2.1 *Leersia hexandra - Typha capensis* Sub-community

B 2.2 *Leersia hexandra - Cyperus fastigiatus* Sub-community

B 2.3 *Leersia hexandra - Arundinella nepalensis* Sub-community

B 3. *Aristida junciformis - Tristachya leucothrix* Community

A diagrammatic presentation of the hierarchical classification and associated environmental interpretation of the recognised plant communities for Ntabamhlope Vlei is given in Figure 4.2. The floristic and associated environmental attributes for the respective plant communities (Table 4.2) are given below.

B 1. *Phragmites australis - Carex austro-africana* Community

This plant community can be found in permanently waterlogged areas of the vlei and in area where soils are waterlogged with standing water of up to a depth of 600mm. The soil type is predominately of the Katspruit soil form with some Champagne soil present to a much lesser degree. No evidence of grazing by livestock was noted for this community.

An average of five species per sample plot was recorded, representing the lowest species diversity of any community encountered on Ntabamhlope Vlei. The diagnostic and characteristic species is the tall perennial reed *Phragmites australis*. Other species with high abundance and constancy are the sedges *Carex austo-africana* and *Cyperus fastigiatus* as well as the perennial herb *Polygonum plebeium* (species group C, Table 4.2). The grass *Arundinella nepalensis* is also occasionally present.

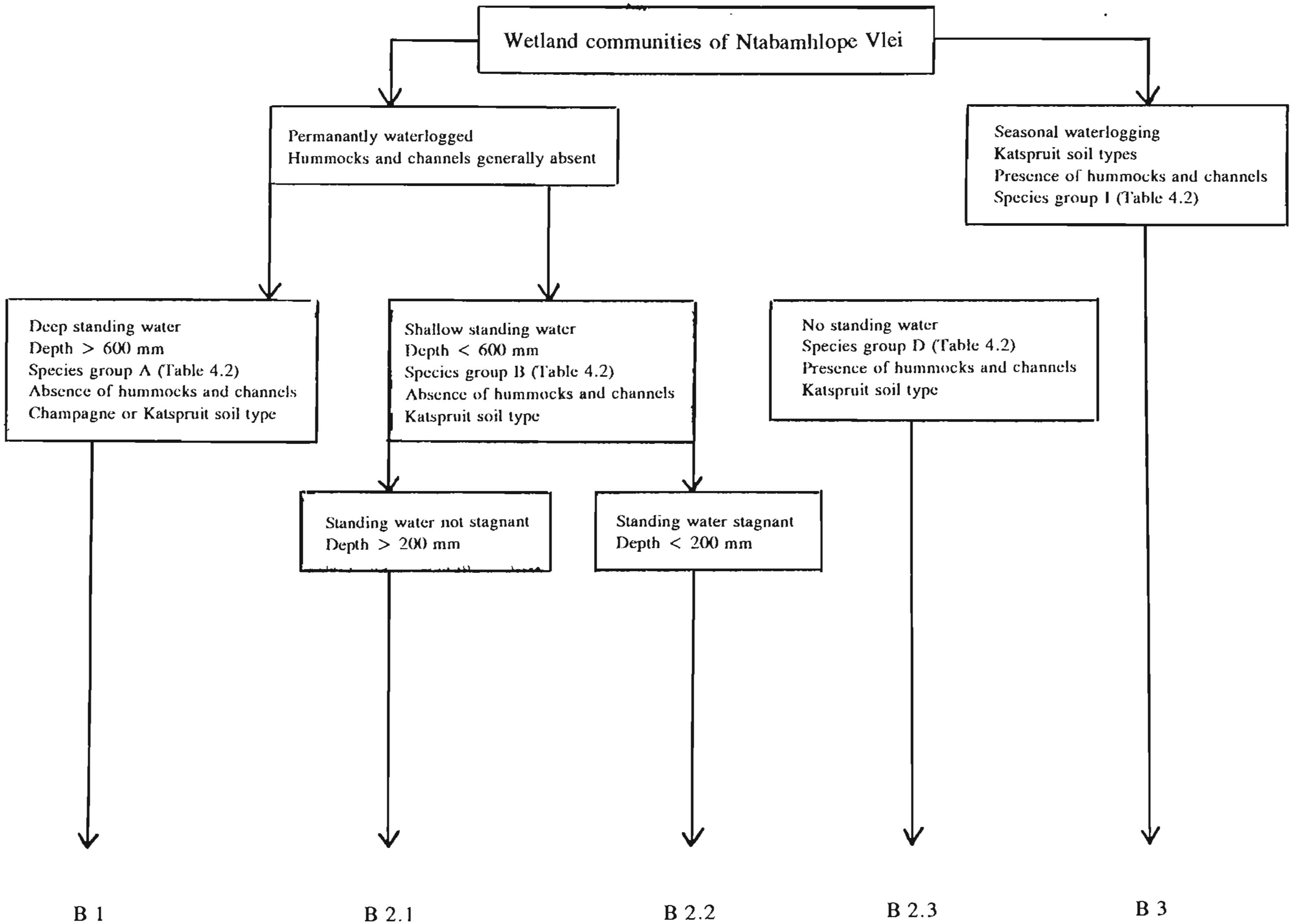


Figure 4.2: The hierarchical classification and environmental interpretation of the vegetation communities at Ntabamhlope Vlei. Community numbers correspond to plant community descriptions in the text.

B 2. *Leersia hexandra* Community

This major community is situated on permanently waterlogged areas of the Ntabamhlope Vlei and covers the greatest portion of the total vlei area. It appears that the vegetation was not subjected to any degree of grazing by livestock. This major community represents the sedge-meadows described by Downing (1966).

The diagnostic and most conspicuous species in this major community is the perennial, hydrophytic grass *Leersia hexandra* which has characteristic creeping rhizomes. Towards the wet extreme of this community bulrushes and sedges have a high abundance and constancy, whilst at the drier extreme certain grasses have a high abundance. This has led to the distinguishing of three sub-communities which are described below. The major community has an average number of 14 species per sample plot.

B 2.1 *Leersia hexandra* - *Typha capensis* Sub-community

This community is found in standing, but not stagnant, water generally at depths greater than 200mm. At Ntabamhlope Vlei this community is found at the edges of streams and dams. Katspruit soils are the dominant soil form of this community.

The diagnostic and dominant species is the bulrush *Typha capensis*, whilst the grass *Leersia hexandra* is characteristic and abundant. Other sedges occurring regularly in this community are *Cyperus denudatus*, *Cyperus fastigiatus* *Carex clavata* and *Carex austro-africana* while the forb *Polygonum plebeium* is also present. This community has the lowest species diversity with an average of 8 species per sample plot.

B 2.2 *Leersia hexandra* - *Cyperus fastigiatus* Sub-community

This community is found in permanently waterlogged areas of the vlei particularly the areas where there is standing water of less than 200mm in depth and where the water is stagnant. Katspruit soils are the predominant soil form.

The diagnostic species is *Leersia hexandra* and the most conspicuous and dominant species is the sedge *Cyperus fastigiatus*. Other species with high abundance and constancy include the sedge *Schoenoplectus brachyceras*, the rush *Juncus oxycarpus* and the grass *Eragrostis planiculmis*. The bulrush Typha capensis is present at lower levels than in community B 2.1. This community has an average of 11 species per sample plot.

B 2.3 *Leersia hexandra - Arundinella nepalensis* Sub-community

This community is found in areas where soils are permanently waterlogged but there tends to be little or no standing or surface water. Katspruit soils are the predominant soil form and both the A and G Horizon are permanently waterlogged.

The diagnostic species is *Leersia hexandra* and the most conspicuous and dominant species is the grass *Arundinella nepalensis*. Other species with high abundance and constancy are the grasses *Aristida junciformis* and *Agrostis eriantha*. This community is characterised by the absence of sedge (*Schoenoplectus brachyceras* and *Cyperus fastigiatus*), rush (*Juncus oxycarpus*) and bulrush (*Typha capensis*) species of species groups B and C (Table 4.2). This community has an average of 16 species per sample plot.

B 3. *Aristida junciformis - Tristachya leucothrix* Community

This major plant community is encountered in areas of Ntabamhlope Vlei, where hummock and channel features are usually present and where soils are seasonally waterlogged. The soil form is predominantly of the Katspruit series.

The most conspicuous and diagnostic species are the perennial tufted grasses *Aristida junciformis* and *Tristachya leucothrix*. The *Aristida junciformis - Tristachya leucothrix* community is defined by the plants in species group I (Table 4.2). Other diagnostic species are the grasses *Andropogon appendiculatus* and *Pennisetum sphacelatum*, the sedge *Pycreus macrantha* and the herb *Pycnostachys reticulata*. Conspicuous is the absence of the grass *Leersia hexandra* and the sedge *Cyperus fastigiatus*. This community has the highest species diversity for communities at Ntabamhlope Vlei with an average of 19 species per sample plot.

4.7.3 Classification and description of vegetation communities at the mires at Highmoor:

The vegetation communities of the mires at Highmoor have not been classified. Killick (1990) has described two types of bog communities in the Drakensberg as those that are found in seepage areas on mountain slopes or those on fairly level areas in the riverheads where rather extensive swampy areas containing hummocks are formed. The mires on the Highmoor Plateaux fall into the second category and are dominated by sedge meadow communities which are associated with hummocks and channels. They are associated with permanently or seasonally waterlogged areas of the Highmoor plateau (where the mires form a dendric shaped pattern at the source of the Little Mooi River). In this classification of wetland vegetation communities at the mires at Highmoor a total of 98 species were recorded in 36 sample plots located within the 120 hectares of wetland. There was an average number of 13 species per sample plot. From the final phytosociological table for the mires at Highmoor, three vegetation sub-communities were identified for two major vegetation communities (Table 4.3):

C 1. *Andropogon appendiculatus - Aristida junciformis* Community

C 1.1 *Aristida junciformis - Juncus oxycarpus* Sub-Community

C 1.1 (a) *Aristida junciformis - Ascolepis capensis* Variant Sub-community

C 1.2 (b) *Festuca caprina - Pycreus cooperi* Variant Sub-community

C 1.2 *Festuca caprina - Pennisetum sphacelatum* Sub-community

C 2 *Carex austro-africana - Schoenoplectus brachyceras* Community

A diagrammatic presentation of the hierarchical classification and associated environmental interpretation of the recognised plant communities for the Highmoor Mires is given in Figure 4.3. The floristic and associated environmental attributes for the respective plant communities (Table 4.3) are given below.

C 1. *Andropogon appendiculatus - Aristida junciformis* Community

This major plant community is encountered in most areas of the mires at Highmoor, where hummock and channel features are usually present and where soils are seasonally or permanently waterlogged. The most conspicuous and diagnostic species are the perennial tufted grasses *Andropogon appendiculatus* and *Aristida junciformis*. This major community had an average number of 15 species per sample plot. The following sub-communities were distinguished within this major plant community:

C 1.1 *Aristida junciformis - Juncus oxycarpus* Sub-community

This sub-community is associated with the seasonally waterlogged edges of the mires adjacent to grassland described by Acocks (1988) as *Themeda - Trachypogon* highlands grassland. The soil form is predominantly of the Katspruit series.

The *Aristida junciformis - Juncus oxycarpus* sub-community is defined by the plants in species group B. The tufted perennial grass *Aristida junciformis* is the most conspicuous and diagnostic species in this community. Other diagnostic species are the

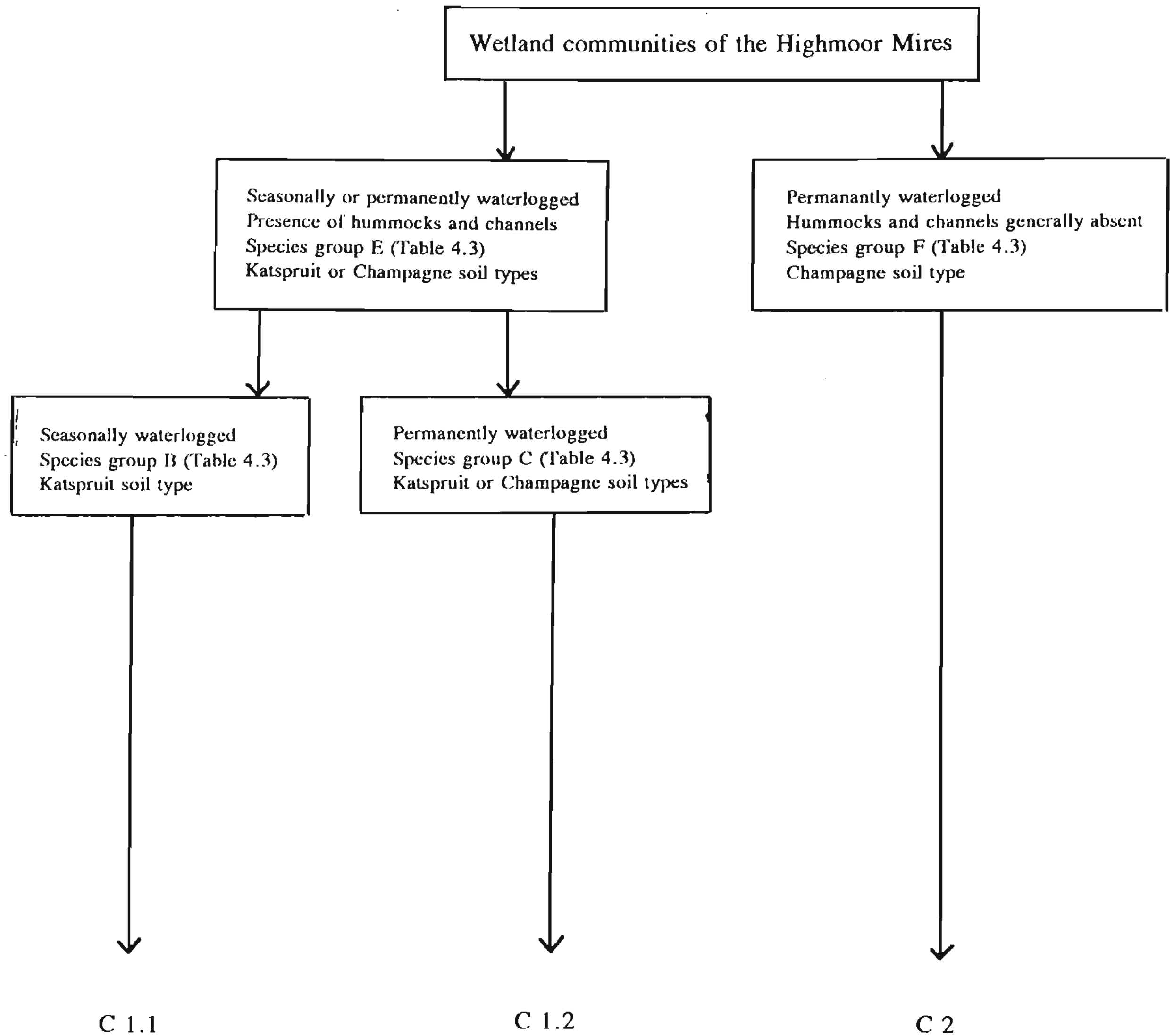


Figure 4.3: The hierarchical classification and environmental interpretation of the vegetation communities at the Highmoor Mires. Community numbers correspond to plant community descriptions in the text.

rush *Juncus oxycarpus*, the herbs *Helichrysum epapposum* and *Lobelia erinus* and the grass *Eragrostis capensis*. The average number of species per sample plot is 14.

C 1.1 (a) ***Aristida junciformis - Ascolepis capensis*** **Variant**

This variant community is defined by the presence of species group A, particularly the sedge *Ascolepis capensis* and the herb *Scabiosa columbaria*. It occurs in areas similar to variant sub-community 1.1.1 (b) by lacks the species in species group C (Table 3.3).

C 1.1 (b) ***Festuca caprina - Pycreus cooperi*** **Variant**

This variant community is defined by the presence of species group C, particularly the grasses *Festuca caprina* and *Pennisetum sphacelatum* as well as the sedge *Pycreus cooperi*. It occurs in areas similar to variant sub-community 1.1.1 (a) by lacks the species in species group A (Table 3.3).

C 1.2 ***Festuca caprina - Pennisetum sphacelatum*** **Sub-community**

This plant community is encountered in permanently waterlogged areas of the mires where hummocks and channels are present. This community tends to encircle or be in close proximity to community 1.2. The predominant soil forms in this community are the Katspruit series and the Champagne series. Where the soils are of the Champagne series the hummock and channel features tend to be less defined.

Diagnostic species with a high constancy in this community include the grasses *Festuca caprina* and *Pennisetum sphacelatum* together with the conspicuous species listed in species group G (Table 3.3). A noteworthy feature of this community is the absence of species listed under species group B (Table 3.3). The average number of species per sample plot is 10.

C 2 ***Carex austro-africana - Schoenoplectus brachyceras*** **Community.**

This plant community is restricted to flat low lying permanently waterlogged areas of the mires and is usually located in the central regions of the mires. There are no hummocks and channels in the area occupied by this community. The predominant soil form in this community is the Champagne series with a dark black organic O-horizon of up to a depth of 90 cm.

The most conspicuous and diagnostic species are the sedges *Carex austro-africana - Schoenoplectus brachyceras*. Other diagnostic species with a high constancy are the sedges *Carex cognata* and *Isolepis fluitans* and perennial herb *Mentha aquatica*. This community is characterised by the absence of grass species perhaps as a result of the absence of hummocks, which in other parts of the mire remain less waterlogged than the surrounding areas and permit the growth of grasses less able to tolerate waterlogging. This community has the lowest species diversity with an average of 8 species per sample plot.

4.8 Discussion of results and comparisons of the vegetation communities at Hlatikulu Vlei, Ntabamhlope Vlei and the mires at Highmoor.

In answer to the key question of what the main plant communities were at Hlatikulu Vlei the results show that seven plant sub-communities, which could be classified under four major communities were identified for Hlatikulu Vlei. These are *Aristida junciformis - Paspalum dilatatum* (Community A 1) which comprised a vlei grassland sub-community (A 1.1 *Aristida junciformis - Eragrostis curvula*) and a sedge-meadow sub-community (A 1.2 *Aristida junciformis - Cyperus denudatus*); the *Carex cognata - Polygonum pleibium* (Community A 2) with three sedge meadow sub-communities (A 2.1 *Carex cognata - Cyperus denudatus*, A 2.2 *Carex cognata - Schoenoplectus brachyceras* and A 2.3 *Carex cognata - Cyperus fastigiatus*) the bulrush community (A 3. *Typha capensis - Polygonum kitaibelianum*) and the reedswamp community (A 4. *Phragmites australis - Largiosiphon muscoides*) [The species compositions of these communities and sub-communities are covered in the results section above].

Also, to assess whether the vegetation communities at Hlatikulu Vlei were similar or dissimilar to those at Ntabamhlope Vlei and the mires at Highmoor their respective plant communities were classified so that the key question of what the main plant communities of Ntabamhlope Vlei and the mires at Highmoor were, was addressed. Six plant sub-communities which could be classified under three main communities were identified for Ntabamhlope Vlei. The three main communities included a reedswamp community (B 1. *Phragmites australis - Carex austro-africana*); the *Leersia hexandra* community (B 2) comprising a bulrush sub-community (B 2.1 *Leersia hexandra - Typha capensis*) and sedge meadow sub-communities (B 2.2 *Leersia hexandra - Cyperus fastigiatus* and B 2.3 *Leersia hexandra - Arundinella nepalensis*) and a vlei grassland community (B 3. *Aristida junciformis - Tristachya leucothrix*). For the mires at Highmoor, three vegetation sub-communities were identified for two main vegetation communities. The main communities included the *Andropogon appendiculatus - Aristida junciformis* community (C 1) which comprised a vlei grassland sub-community (C 1.1 *Aristida junciformis - Juncus oxycarpus*) and a sedge-meadow sub-community (C 1.2 *Festuca caprina - Pennisetum sphacelatum*) and the *Carex austro-africana - Schoenoplectus brachyceras* community (C 2).

It is evident from the resultant classifications that all three wetlands; Hlatikulu Vlei, Ntabamhlope Vlei and the mires at Highmoor were characterised by what may be termed vlei grassland and sedge-meadow communities. Downing (1966) used the term 'vlei grassland' to describe communities in wetlands where grasses are dominant and the term 'sedge-meadows' to describe communities dominated by sedges where sedges and grasses are co-dominant. These terms are applied generally to communities encountered at the three wetlands which were studied as they were a useful aid to facilitate the comparison of similar communities. In general terms the vlei grasslands occur in seasonally waterlogged areas of these wetlands, whilst the sedge-meadows occur in seasonally and permanently waterlogged areas of these wetlands. However, unlike the mires at Highmoor, both Hlatikulu Vlei and Ntabamhlope Vlei have towards their wetter extremes (where standing water occurs on a permanent basis) other communities in the form of bulrush and reedswamp communities. There are no areas with large amounts of standing water (such as a small dam or tarn) at mires at Highmoor and there was a complete absences of bulrush and reedswamps communities. As both the bulrush *Typha capensis* and the reed *Phragmites australis* are known to occur at similar or greater altitude than the mires at Highmoor, the absence of communities characterised by these species at the mires at Highmoor may be as a result of the lack of sufficient standing water on a permanent basis throughout the year, rather than as a result of other factors.

Both Hlatikulu Vlei and Ntabamhlope Vlei have reedswamp in the wettest areas of the vleis where standing water occurs. These communities are dominated by the same reed species (*Phragmites australis*) and do not differ significantly between the vleis except that the extent of reedswamp over each vlei is proportionally greater at Ntabamhlope Vlei than at Hlatikulu Vlei. Also the reed-swamp at Hlatikulu Vlei (community A 4) tends not to have other species present and is almost entirely dominated by the reeds, while at Ntabamhlope the reedswamps (community B 1) have a number of other species which are also present but at low abundances, namely *Carex austro-africana*, *Cyperus fastigiatus* and *Polygonum plebeium*. Even the grass *Arundinella nepalensis* is present in the reedswamp at Ntabamhlope Vlei whereas at Hlatikulu Vlei reedswamp is characterised by the absence of any grass species. The only other species commonly found in reedswamp at Hlatikulu Vlei is the aquatic water weed *Largiosiphon muscoides*.

The bulrush communities encountered at both Hlatikulu Vlei (community A 3) and Ntabamhlope Vlei (sub-community B 2.1) did not differ too significantly in their species composition. While there was a significantly greater portion of the bulrush community at Ntabamhlope Vlei than at Hlatikulu Vlei, many of the other distinguishing species for the communities were common to both vleis, namely the sedge *Cyperus fastigiatus*, some *Carex* species and *Polygonum plebeium*. The rhizomatous grass *Leersia hexandra* was absent at Hlatikulu Vlei's bulrush community, but an abundant species in the bulrush communities of Ntabamhlope Vlei.

Where the difference between the Hlatikulu Vlei and Ntabamhlope Vlei with regard to bulrush and reedswamp communities is immediately apparent is the extent to which each vlei is covered by these communities. Almost 50% of Ntabamhlope Vlei is covered by the *Phragmites australis* and *Typha capensis* dominated communities compared with less the 10% of Hlatikulu Vlei covered by these communities. Thus reedswamp and bulrush communities at Hlatikulu Vlei cannot be noted for their species diversity or uniqueness.

The environmental factors most responsible for the reedswamp and bulrush communities at Hlatikulu Vlei are the moisture and inundation levels. Both these communities only occur in areas where standing water occurs on a permanent basis. It appears that the depth of the standing water at Hlatikulu Vlei determines which of the two communities are able to persist. At depths greater than 500mm the reedswamp dominated by *Phragmites australis* occurs, while the bulrush communities dominated by *Typha capensis* occur in a range of water depths from approximately 300mm to 600mm and not in water that is deeper. The extent of standing water at Hlatikulu Vlei thus determines the extent of reed-swamp and bulrush communities at the vlei and thus should be considered as an important factor in determining the pattern of vegetation communities at Hlatikulu Vlei.

The bulrush and reedswamp communities cover a very small portion of Hlatikulu Vlei where vlei grassland and sedge meadows are the dominant vegetation forms. At the other wetlands, Ntabamhlope has just over 50% covered with vlei grassland and sedge meadows and mires at Highmoor are covered exclusively by vlei grassland and sedge meadows. The composition of these vegetation communities are visually similar at all three wetlands but have differing species compositions which are discussed below.

The terms vlei grassland and sedge meadow are used loosely to describe the grass and sedge dominated communities at the wetlands studied. Vlei grassland occurs in seasonally waterlogged areas of the wetlands and are dominated by various grass species. Some sedges and rushes do occur amongst the grasses but on a lesser scale. The sedge meadows, dominated largely by sedges and rushes, have grasses occurring less frequently or being entirely absent in some cases. Sedge meadows tend to occur where the soils are permanently water logged. The transition from vlei grassland to sedge meadow is difficult to pinpoint with great accuracy as these merge with one another along the gradient from seasonally waterlogged soils to permanently waterlogged soils. The presence of hummock and channel features in both the vlei grassland and sedge meadow communities at all of the three wetlands allowed for species normally associated with the vlei grassland communities to co-exist with species normally associated with sedge meadows. This is due to the nature of the hummock and channel feature. Soils in channels were usually waterlogged throughout the year. During the summer rainfall period the channels usually contained standing or running water usually less than 200mm in depth. Much of this surface water drained away during drier periods, but the soils of the channels remained waterlogged. The soils on the hummocks tended to be seasonally waterlogged (when the channels were full of water) and were not waterlogged during the winter months (when the channels did not contain much surface water).

The communities at Hlatikulu Vlei that may be called sedge-meadow communities are the *Aristida junciformis - Cyperus denudatus* sub-community (sub-community A 1.2) and the *Carex cognata - Polygonum pleibium* community (community A 2 [with its three sub-communities: the *Carex cognata - Cyperus denudatus* sub-community, the *Carex cognata - Schoenoplectus brachyceras* sub-community and the *Carex cognata - Cyperus fastigiatus* sub-community]). These communities are described in section 4.7.1 above. The sedge meadows at Ntabamhlope Vlei are represented by sub-communities B 2.2 and B 2.3, the *Leersia hexandra - Cyperus fastigiatus* sub-community and the *Leersia hexandra - Arundinella nepalensis* sub-community, whilst the *Festuca caprina - Pennisetum sphacelatum* sub-community (sub-community C 1.2) and the *Carex austro-africana - Schoenoplectus brachyceras* community (community C 2) at the mires at Highmoor could be termed sedge-meadow communities.

The dominance of sedges in the sedge-meadows varies from communities that are almost exclusively composed of sedges to those that are mixed sedge and grass communities. Those communities that are almost exclusively composed of sedges include the *Carex cognata* - *Schoenoplectus brachyceras* sub-community (sub-community A 2.2) and the *Carex cognata* - *Cyperus fastigiatus* sub-community (sub-community A 2.3) at Hlatikulu Vlei, the *Leersia hexandra* - *Cyperus fastigiatus* sub-community (sub-community B 2.2) at Ntabamhlope Vlei and the *Carex austro-africana* - *Schoenoplectus brachyceras* community (community C 2) at the mires at Highmoor. Sub-community A 2.2 at Hlatikulu Vlei is similar to community C 2 at Highmoor. Both communities have a low species diversity and are dominated by the large sedges *Schoenoplectus brachyceras*, either one or two species of *Carex* (*C. cognata* and *C. austro-africana*) and the smaller sedge *Isolepis fluitans*. Both occur in areas where the soils are usually permanently waterlogged and differ mainly in terms of the composition of these dominant sedges and in terms of the occurrence of other less abundant species within the communities. In this regard the Hlatikulu Vlei community (A 2.2) has a distinct rush (*Juncus effusus* and *J. oxycarpus*) component lacking in the mires at Highmoor community (C 2). Thus in terms of being noted for species diversity and uniqueness the *Carex cognata* - *Schoenoplectus brachyceras* sub-community (sub-community A 2.2) at Hlatikulu Vlei has a low species diversity and does not display any particular or peculiar uniqueness.

With regard to the *Carex cognata* - *Cyperus fastigiatus* sub-community (sub-community A 2.3) at Hlatikulu Vlei and the *Leersia hexandra* - *Cyperus fastigiatus* sub-community (sub-community B 2.2) at Ntabamhlope Vlei which are both dominated by the sedge *Cyperus fastigiatus* the Hlatikulu Vlei community (sub-community A 2.3) is almost exclusively dominated by this sedge and has a very low species diversity, whilst the Ntabamhlope Vlei community (sub-community B 2.2) has a higher species diversity that includes the grasses *Leersia hexandra* and *Eragrostis planiculmis*, the sedge *Schoenoplectus brachyceras*, the rush *Juncus oxycarpus* and the bulrush *Typha capensis*. Thus in terms of being noted for species diversity and uniqueness the *Carex cognata* - *Cyperus fastigiatus* sub-community (sub-community A 2.3) at Hlatikulu Vlei does not display any particular uniqueness nor does it have a high diversity of plant species when compared to a similar community at Ntabamhlope Vlei.

Due to the presence of hummocks some communities in sedge- meadows in the wetlands studied were not almost entirely composed of sedges but rather were characterised by a co-dominance of sedges and grasses. These communities included the *Aristida junciformis - Cyperus denudatus* sub-community (sub-community A 1.2) and the *Carex cognata - Cyperus denudatus* (sub-community A 2.1) at Hlatikulu Vlei, the *Leersia hexandra - Arundinella nepalensis* sub-community (B 2.3 sub-community) at Ntabamhlope Vlei and the *Festuca caprina - Pennisetum sphacelatum* sub-community (sub-community C 1.2) at the mires at Highmoor. The common link between these communities is the presence of hummock and channel features which allow for the presence of a variety of grass species on the hummocks and a variety of sedge species in the channels. The dominant grass species at Hlatikulu Vlei's communities (A 1.2 and A 2.1) and Ntabamhlope Vlei's community (B 2.3) was *Aristida junciformis* which was typically found on the hummocks, whilst the dominant grass species at mires at Highmoor were *Festuca caprina, Pennisetum sphacelatum* and *Andropogon appendiculatus*. Also the other grasses *Paspalum dilatatum* and *Eragrostis planiculmis* with high abundances in the Hlatikulu communities were not dominant at Ntabamhlope where *Agrostis eriantha, Arundinella nepalensis* and *Leersia hexandra* had high abundances. The dominant sedges at Hlatikulu Vlei's communities were *Cyperus denudatus, Isolepis fluitans* and *Carex cognata*. None of these species were dominant at Ntabamhlope Vlei's community where the channels were dominated by *Ascolepis capensis, Pycreus oakfortensis* and *Rhyncospora brownii* and the grass *Leersia hexandra*. This grass species was dominant in the channels at Ntabamhlope Vlei's community B 2.3 unlike Hlatikulu Vlei's communities A 1.2 and A 2.1 where *Cyperus denudatus* was dominant in the channels. At the mires at Highmoor *Isolepis fluitans* and *Carex cognata* were the dominant sedges in the channels and *Cyperus denudatus* was completely absent. Thus when compared with similar communities at Ntabamhlope Vlei and mires at Highmoor the A 1.2 and A 2.1 communities did differ to a large degree and were found to have a higher species diversity, particularly sub-communities A 1.2. This community (sub-communities A 1.2) thus should be noted for species diversity and uniqueness in the Hlatikulu Vlei and afforded special attention in management strategies and may even require special protection to protect it. With regard to species diversity in sedge-meadow communities, many dicotyledons (particularly the Asteraceae: *Helichrysum aureo-nitens, H. cephaloideum, H. cooperi, H. epapposum, H. glomeratum, H. herbaceum, H. mundtii, H. natalitum, H. pilosellum, Senecio bupleuroides, S. cathcartensis, S. caudatus, S. decurrens, S. glabberimus, S. harveyanus, S. inornatus, S. isatideus, S. macrocephalus, S. tysonii*) and various monocotyledons (*Kniphofia linearifolia, Tulbaghia natalensis, Ledebouria cooperi, Nerine prancratioides, Brunsvigia grandiflora, Cyrtanthus breviflorus, Rhodohypoxis milloides, Hesperantha baurii, H. lactea, Dierama pauciflora*, *Gladiolus papilio*, the terrestrial orchids; *Habenaria dives, Satyrium cristatum, S. hallackii ocellatum, S. trinerve, Schizochilus zeyheri, Disa chrysostachya, D. versicolor* and *Disperis tysonii*) are encountered at low abundance levels, particularly in communities A 1.2 and A 2.1 at Hlatikulu Vlei. These have on the most been eliminated from the phytosociological tables due to their low abundance values, but contribute to the high species diversity of sedge meadow communities particularly community A 1.2. As many of these species are often sensitive to disturbance by heavy grazing and would be eliminated by ploughing or crop cultivation and thus for their protection and continued survival in these sedge-meadows communities at Hlatikulu Vlei these sedge-meadow communities should be afforded special protection.

The final group of plant communities from the three wetlands that could commonly be termed vlei grassland were the *Aristida junciformis - Eragrostis curvula* sub-community (sub-community A 1.1) at Hlatikulu Vlei, the *Aristida junciformis - Tristachya leucothrix* community (community B 3) at Ntabamhlope Vlei and the *Aristida junciformis - Juncus oxycarpus* sub-community (C 1.1 sub-community) at the mires at Highmoor. All these communities share the dominant grass *Aristida junciformis* as a distinguishing species which has a high abundance throughout and these communities tend to lack the hummock and channel features of the sedge-meadow communities which facilitate the co-dominance of sedges and grass. Where sedges occur they are less abundant and do not have a high constancy or dominance. It is significant to note that much of the vlei grassland community at Hlatikulu Vlei (sub-community A 1.1) has the weedy *Cyperus esculentus* present as the only sedge and tends to be degraded with a high abundance of pasture grasses *Eragrostis curvula* and *Paspalum dilatatum* and various weedy species, particularly the grass *E. plana* and the herbs *Verbena* *bonariensis, Pseudognaphalium luteo-album, Conyza podocephala* and *Oxalis obliquifolia*. Only where the grassland has not been degraded through pasture planting or overgrazing do grassland species such as *Tristachya leucothrix* and *Monocymbium ceresiiforme* (which also occur at Ntabamhlope Vlei's vlei grassland community) occur in any abundance. Only the vlei grassland community of the mires at Highmoor has a marked presence non-grass species such as the rush *Juncus oxycarpus* and the sedges *Isolepis fluitans* and *Carex austro-africana*. Certainly the vlei grassland community at Hlatikulu Vlei (sub-community A 1.1) cannot be noted for its uniqueness or high diversity of plant species but the weedy elements and pasture grasses do distinguish it from the wetlands at Ntabamhlope and Highmoor. Further degradation of vlei grassland must be avoided at Hlatikulu Vlei and areas where this vlei grassland community are presently in good condition should be monitored so that further degradation through overgrazing or ploughing of lands for pasture and other crops may be prevented.

It is significant to note that the two characteristic species, *Aristida junciformis* and *Paspalum dilatatum* of community A 1 at Hlatikulu Vlei (the *Aristida junciformis - Paspalum dilatatum* community) are classed as species which invade natural veld, particularly moist areas (Gibbs Russell et al. 1991; van Oudtshoorn 1992). *A. junciformis* is a very unpalatable grass, utilised by stock only to a limited degree and only at a young stage (van Oudtshoorn 1992) It used to indicate of mismanagement of veld due to its capability of increasing in natural veld as a result of severe overgrazing (Gibbs Russell et. 1991). The fact that this species is so dominant in community A 1 at Hlatikulu Vlei indicates that these areas of the vlei are being mismanaged through over grazing. Also as this species, once established, is known to be virtually impossible to eliminate by normal grazing practices suggests that future management practices should be developed to prevent the increase of this species within this community.

The grass *P. dilatatum*, a common invader (Gibbs Russell et. al. 1991) which has become naturalised in South Africa but which originated from South America, is palatable (unlike *A. junciformis*) and is often planted as pasture, particularly on damp soils. This species was planted for pasture in various parts of the Hlatikulu Vlei in the past, particularly the area that now is called the Hlatikulu Crane and Wetland Sanctuary. As a result this grass now occurs in all but the wettest areas of the Hlatikulu Vlei. As it is reasonably resilient to heavy grazing and is known to increase with moderate grazing (van Oudtshoorn 1992) its dominant presence in the vlei, particularly community A 1, should raise concern because as with *A. junciformis*, the presence of *P. dilatatum* at high levels in the vlei indicates that the these areas of the vlei have been mismanaged in the past. Future management practices should thus strive to prevent further increases in the abundance of this species within the vlei and should aim to limit and reduce presence in the vlei particularly as it is an alien species. *P. dilatatum* is entirely absent from the mires at Highmoor and is present at very low abundances at Ntabamhlope Vlei such that it was excluded from the phytosociological table for that vlei because it was regarded as a rare species.

In regard to the question of which environmental factors are most likely to be responsible for the present pattern of vegetation at Hlatikulu Vlei, it is clear that the single most important factor in determining the present pattern of vegetation at Hlatikulu Vlei is the amount of water present in a particular area from year to year. The degree of wetness ranges from areas where soils are seasonally waterlogged to areas where not only are soils permanently waterlogged but are constantly covered with water of depths of more than a metre. Thus the variety of conditions at the vlei range from the truly terrestrial (non-wetland areas ie. the grassland which surrounds the vlei) to truly aquatic (in the deeper sections of the larger dams) where only aquatic plants survive. Certain communities such as the bulrush and reedswamp communities are restricted to areas where standing water at depths between 400mm and 2000mm occurs on a permanent basis and are not found in areas that are seasonally waterlogged or even in areas where soils are permanently waterlogged but lack standing water. The waterlogging of soils on a permanent or seasonal basis is also largely responsible for the distribution of vlei grasslands (in seasonally waterlogged areas) and sedge-meadows (seasonally and permanently waterlogged areas) of Hlatikulu Vlei, but other factors are also important.

The amount of water present in parts of the vlei is not the only factor determining the present pattern of vegetation at Hlatikulu Vlei. The soil type, degree of grazing and what could be termed the micro-topography (ie. the presence or absence of hummocks and channels) are *inter alia* important factors. As ordination techniques provide the medium with which to summarize community data, to relate community variation to environmental gradients and to foster an understanding of community structure, they are used as an additional means of explaining the vegetation patterns encountered at Hlatikulu Vlei. These techniques are dealt with in chapter 6.

4.9 Conclusion:

Although Begg (1988) contended that Hlatikulu Vlei was characterised by three main plant communities; sedge-meadows, reedswamp and bulrush communities, this study identifies four main plant communities for the vlei that include in addition to sedge-meadows, reedswamp and bulrush communities a vlei grassland community. These vegetation communities at Hlatikulu Vlei were not distinctly different in appearance to other wetlands in the midlands of KwaZulu-Natal as it all were common to other wetlands. Where the differences did occur was in respect to the species composition of each community and to the extent of each community within Hlatikulu Vlei. In terms of diversity of vegetation communities those at Hlatikulu Vlei are superficially most similar to those at Ntabamhlope Vlei and contain vlei grassland, sedge-meadows, bulrush and reedswamp communities. The proportions of the communities differed greatly as Ntabamhlope Vlei has a higher proportion of bulrush and reedswamp communities (which dominate the vlei) than has Hlatikulu Vlei. Hlatikulu Vlei has a very small portion of it covered by bulrush and reedswamp communities and is rather dominated by vlei grassland and sedge-meadows as are the Mires at Highmoor. Also although lacking in reedswamp and bulrush communities at the mires at Highmoor, its vlei grassland and sedge-meadow communities are superficially similar to those at Hlatikulu Vlei. Where the major differences occur this relates to the actual species composition of the various communities. The A 1.2 *Aristida junciformis - Cyperus denudatus* sub-community and the A 2.1 *Carex cognata - Cyperus denudatus* sub-community at Hlatikulu Vlei which are sedge-meadow communities are distinctly different to sedge-meadow communities at Ntabamhlope Vlei and the mires at Highmoor and have higher species diversity. These sedge-meadows communities (A 1.2 and A 2.1) also have a higher species diversity than other communities at Hlatikulu Vlei. In the light of Begg's (1989) suggestion that plant communities noted for their high diversity and uniqueness should be identified and should there warrant special protection these communities are recommended for special protection.

Within farm and conservation management programmes for Hlatikulu Vlei, wetland communities should be regarded as distinct management units. It is of special importance to fence off the wetlands from the rest of the grassland, especially in grazing programmes as, due to the more palatable vegetation of the wetlands (Tainton 1981), these areas are more subjected to overgrazing and therefore ecologically more sensitive than the rest of the grassland. The overgrazing of these areas will result in deterioration of the wetland ecosystems, particularly the vlei grassland and the sedge-meadow communities. It is of major concern at present, in South Africa and all over the world, that man has succeeded in irreversibly degrading vast areas of wetland and seasonal wetland by development and poor land-use practices (Walmsley 1988) and, in spite of the relatively low plant species diversity encountered in the wetlands, specific species are restricted to these habitats. Also these habitats are of special importance for the survival of many animal species (particularly birds and amphibians) and thus special care should be taken in management programmes to conserve these areas and prevent further degradation. This is particularly pertinent for Hlatikulu Vlei where further degradation must be avoided to ensure longevity of the vlei's vegetation and functioning.

CHAPTER 5

VEGETATION MAPPING

5.1 Introduction

The mapping and delineation of wetlands throughout the world has become an essential management tool for the conservation of these systems. Without effective delineation and mapping, continued practices within wetlands such as; widespread ploughing, livestock grazing pressure, increased run-off and erosion as well as the liberal use of fertilizer and pesticides within catchment areas will further contribute to watercourse and wetland degradation (Fuls *et al.* 1992). As large sections of wetlands and indeed whole systems are modified, degraded or destroyed there is a greater need for scientists, managers, farmers, industrialists and others to be provided with the clear delineation of the extent and whereabouts of wetlands within their area of operation. This will be effectively achieved only when there is agreement on what portion of the landscape is to be included and excluded as wetland (Begg 1989) so that effective protection of wetland areas may result.

As in most parts of the world, wetlands in South Africa have been extensively modified by agriculture (Breen, et al. 1993). By 1965 as much as 34% of wetlands in the Tugela Basin (of which Hlatikulu Vlei is a part) had been destroyed as a result of overgrazing, sheet erosion or drained by gully erosion, and losses may now have doubled (Breen, *et al.*, 1993). For Hlatikulu Vlei Begg (1988) contended that despite a high degree of proximal disturbances to and the construction of dams on the vlei, the remaining vlei areas remain relatively undisturbed and one of the first research requirements for the vlei should be the mapping and analysis of land-use data. It is imperative that future land-use planning, management and conservation strategies are based on sound plant ecological principles (Fuls *et al.* 1992). To follow the classification of vegetation communities at Hlatikulu Vlei in Chapter 4 the mapping of these vegetation communities within the boundaries of the Hlatikulu Vlei in this chapter was seen as a natural progression.

The principle aim of vegetation mapping at Hlatikulu Vlei is to clearly delineate the various vegetation communities so that any communities that are unique or have high species diversity may be identified to hopefully ensure that they are afforded suitable protection in future management programmes. However, with the use of historical aerial photographs the production of a map showing the past vegetation patterns at Hlatikulu Vlei is not only possible, but should allow for the comparison with present day vegetation patterns. Such comparisons should not only show how the vegetation patterns at Hlatikulu Vlei have changed over time, but also show what effects various management practises at the vlei have had on the vegetation over the past 50 years. In light of the fact that various of these land management practices (outlined in chapter 3) are reasonably documented for the past fifty years an assessment of these practices might also provide a basis for the formulation of future management plans for the vlei.

5.2 Study Area

The study area for this section of the project is the Hlatikulu Vlei and the grassland that immediately surrounds it. Details of the study area are given in Chapter 3.

5.3 Methods

Two vegetation maps were produced for Hlatikulu Vlei. The first map was prepared from colour aerial photographs taken by the Natal Parks Board on the 26 January 1992 (NPB Job number 3 for Hlatikulu Vlei; Strip numbers 1/1, 2/1, 1/2, 2/2, 1/3, 3 and 1/4; Scale 1:10 000). Using the classification of vegetation communities described for Hlatikulu Vlei in Chapter 4, the existing and proximal vegetation associations of the vlei were identified and their extent determined with the aid of a Wild 46728 stereoscope. From an aerial photograph scale of 1 : 10 000 the first map (Figure 5.1) was produced at a reduced scale of 1 : 30 000. After the initial mapping from these aerial photographs, the borders of the vegetation communities were more precisely defined through on site analysis.

After reviewing historic aerial photographs for Hlatikulu Vlei the earliest photographs (Job 60/1944; Strip numbers 14394, 14395, 14396, 14397, 14398, 14399, 14400, 14662, 14663, 14664, 14665, 14666, 14667, 14668, 15001, 15002, 15003, 15004 and 15005; Scale 1: 20 000) taken as part of a government survey of the area in May 1944 were selected to produce the second map (Figure 5.2). As no drainage or damming of the vlei had yet been undertaken on the vlei in 1944 it was anticipated that a map produced from these photographs would provide a an acceptable beginning point for comparison with present day vegetation patterns. With the aid of a stereoscope and the 1992 aerial photographs and first vegetation map as references, the 1944 (black and white) aerial photographs were used to map vegetation communities in which probably existed in 1944. From an aerial photograph scale of 1 : 20 000 the map was produced with a reduced scale of 1 : 30 000. Unlike the first vegetation map the disadvantage in producing this second vegetation map from historical aerial photographs was the inability to check on the ground and more precisely define the borders of the vegetation communities through on site analysis after the initial mapping. This was an unavoidable situation which must be borne in mind when the vegetation maps are compared. A further problem concerns the species composition of the communities making up the vegetation in 1944 as there is no means of accurately describing what these were, thus in order to facilitate comparison between the 1944 vegetation communities and the 1992 vegetation communities general terms such as reedswamp or vlei grassland are applied to the communities as these have remained fairly constant. Definitions of these terms are given in Section 5.4 below. Comparison of the extent of each community (ie total extent of a particular community in 1944 compared with the total extent of the community in 1992) was used to assess the effects of various management practises that have been applied to the vegetation of Hlatikulu Vlei over the past 50 years.

After the vegetation maps were drawn up they were digitised by staff at the Institute for Natural Resources in Pietermaritzburg. A third map (Figure 5.3) was also produced to show the survey sites used for the classification and ordination of the vegetation communities at Hlatikulu Vlei (discussed in Chapters 4 and 6 respectively).

From the vegetation maps the total area covered by each community was measured on the maps and tabulated so that the changes in the physical sizes of each vegetation community could be determined.

5.4 Definition of plant communities in vegetation maps

As one cannot assume that the species compositions of the various communities at Hlatikulu Vlei have remained constant since 1944, the names given to present day communities in the classification in chapter 4 (for example *Aristida junciformis - Cyperus denudatus* sub-community) may not necessarily apply to those communities that were present in 1944, thus general names such as vlei grassland, bulrush or reedswamp have been used instead to facilitate comparison. The terms used are defined below and reference is made in each case to the names given to communities in the classification in Chapter 4.

(a) **Dry grassland community**: This community is essentially not part of the Hlatikulu Vlei and not described in the vegetation classification in chapter 4. This is the vegetation type that surrounds the vlei and is called *Themda-Trachypogon* grassland (Acocks 1988). It is dominated by the grasses *Themeda triandra, Trachypogon spicatus, Tristachya leucothrix, Aristida junciformis, Heteropogon contortus, Eragrostis racemosa, Eragrostis plana*, and *Monocymbium ceresiiforme*. Occurring less abundantly amongst these grasses were other species namely, particularly *Helichrysum pilosellum, Hypoxis rigidula, Wahlenbergia pallidiflora* and *Senecio tysonii*.

(b) **Disturbed dry grassland**: This is part of the dry grassland community described above, but has been disturbed and degraded by mechanical means (i.e. ploughing) or excessive grazing by livestock that has caused erosion. This community tends to have a large weedy element which includes: *Cyperus esculentus, Eragrostis curvula, Paspalum dilatatum, Rumex acetosella, Trifolium repens, Conyz albida, C. chilensis, C. podocephala* and *Cirsium vulgare*.

(c) **Vlei grassland**: This vegetation type occurs in seasonally waterlogged areas of the vlei where grasses are the dominant species and where hummock and channel features are generally absent. This name refers to the *Aristida junciformis - Eragrostis curvula* sub-community (A 1.1) in the vegetation classification in Chapter 4 where a description of species composition of this community may be found.

(d) **Sedge-meadow** community: This community occurred in areas of the vlei where grasses and sedges are co-dominant or where sedges are dominant. These areas tended to be associated with hummock and channel features in the landscape. Four sub-communities of sedge-meadows were designated for Hlatikulu Vlei and include the following:

i) **Mixed sedge and grass** sedge-meadow community: This occurs in seasonally flooded areas where hummocks and channels present. This name refers to the *Aristida junciformis - Cyperus denudatus* sub-community (A 1.2) in the vegetation classification in Chapter 4 where a description of species composition of this community may be found. This community supported the greatest species diversity of all the plant communities in the Hlatikulu.

ii) ***Carex* and *Cyperus*** sedge-meadow community: This occurs in permanently waterlogged areas of the vlei where hummock and channel features are often present. This name refers to the *Carex cognata - Cyperus denudatus* sub-community (A 2.1) in the vegetation classification in chapter 4 where a description of species composition of this community may be found.

iii) **Sedge and rush** sedge-meadow community: This community is found in permanently waterlogged areas that are associated with the dams on the vlei.

iv) ***Cyperus fastigiatus*** sedge-meadow community: This community is found in permanently waterlogged areas of the vlei where the water present is often stagnant. This name refers to the *Carex cognata - Cyperus fastigiatus* sub-community (A 2.3) in the vegetation classification in Chapter 4 where a description of species composition of this community may be found.

(e) **Disturbed sedge-meadow** community: This refers to mixed sedge and grass sedge-meadow community that has been disturbed by various management practices such as the creation of drainage ditches, ploughing and excessive grazing. This community is part of the *Aristida junciformis - Cyperus denudatus* sub-community (A 1.2) in the vegetation classification in Chapter 4.

(f) **Bulrush** community: This community is dominated by the bulrush *Typha capensis*. (Community A 3. *Typha capensis - Polygonum kitaibelianum* in Chapter 4)

(g) **Reedswamp** community: A community where the most conspicuous and diagnostic species is the tall perennial reed *Phragmites australis* which occurs in virtually pure stands. (Community A 4. *Phragmites australis - Largiosiphon muscoides* in chapter 4)

Also marked on either or both of the vegetation maps are features such as dams, pine plantations, wattle stands, maize, beans, various buildings, roads, rivers, an air strip and the rehabilitation area of the Hlatikulu Crane and Wetland Sanctuary.

5.5 Results:

The vegetation maps, produced from the 1944 and 1992 aerial photographs, of the various plant communities at Hlatikulu Vlei are given in Figures 5.1 and 5.2 respectively. A third map with the survey sites used for the classification, ordination and refinement of the mapping of vegetation communities at Hlatikulu Vlei (discussed in Chapters 4 and 6 respectively) is given in Figure 5.3.

From the vegetation maps the total area covered by each community was calculated and tabulated in Table 5. The total extent of each vegetation community for 1944, 1992 and the resultant differences in size are given in hectares. The management practices

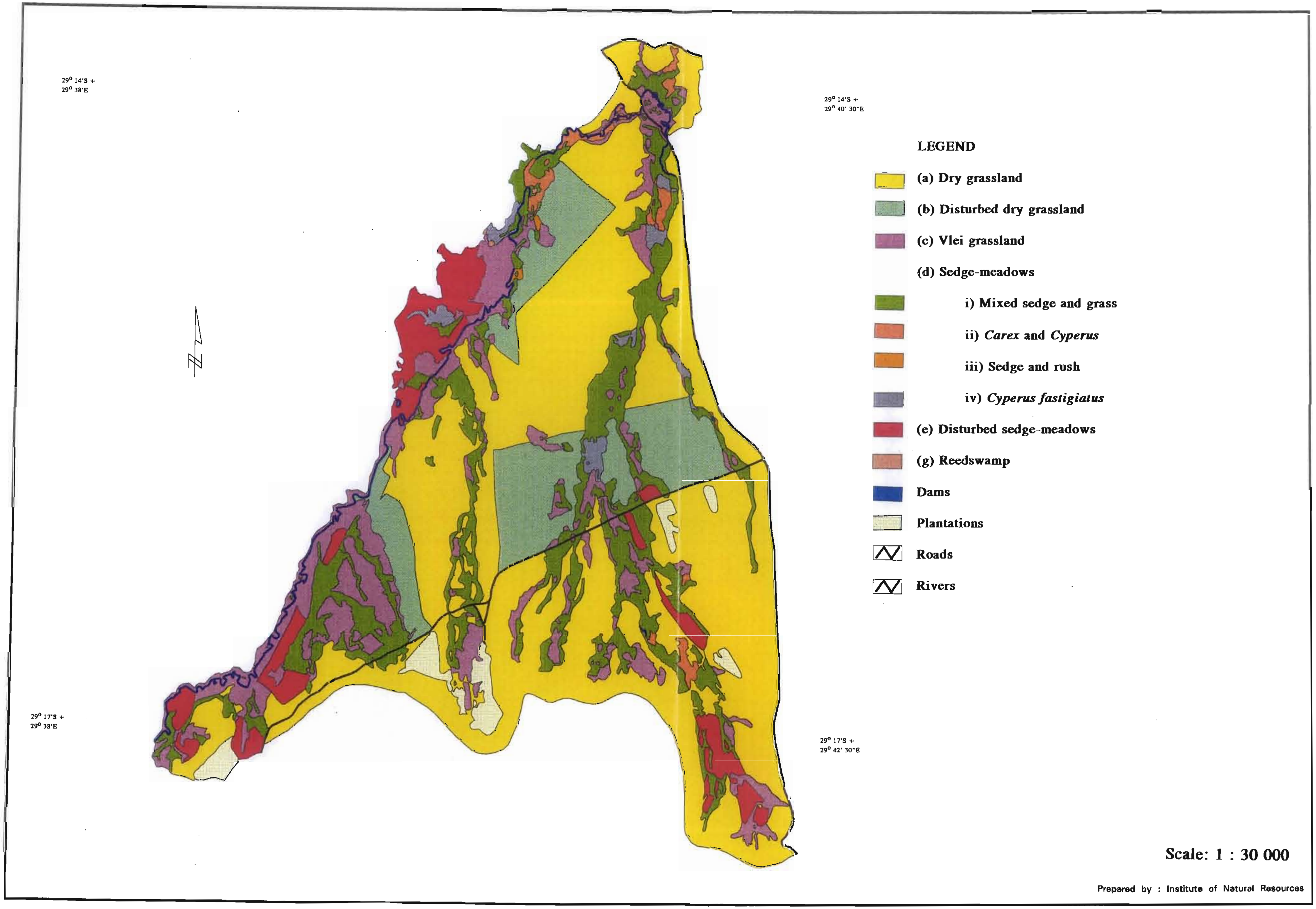


Figure 5.1: The 1944 Vegetation map for Hlatikulu Vlei.

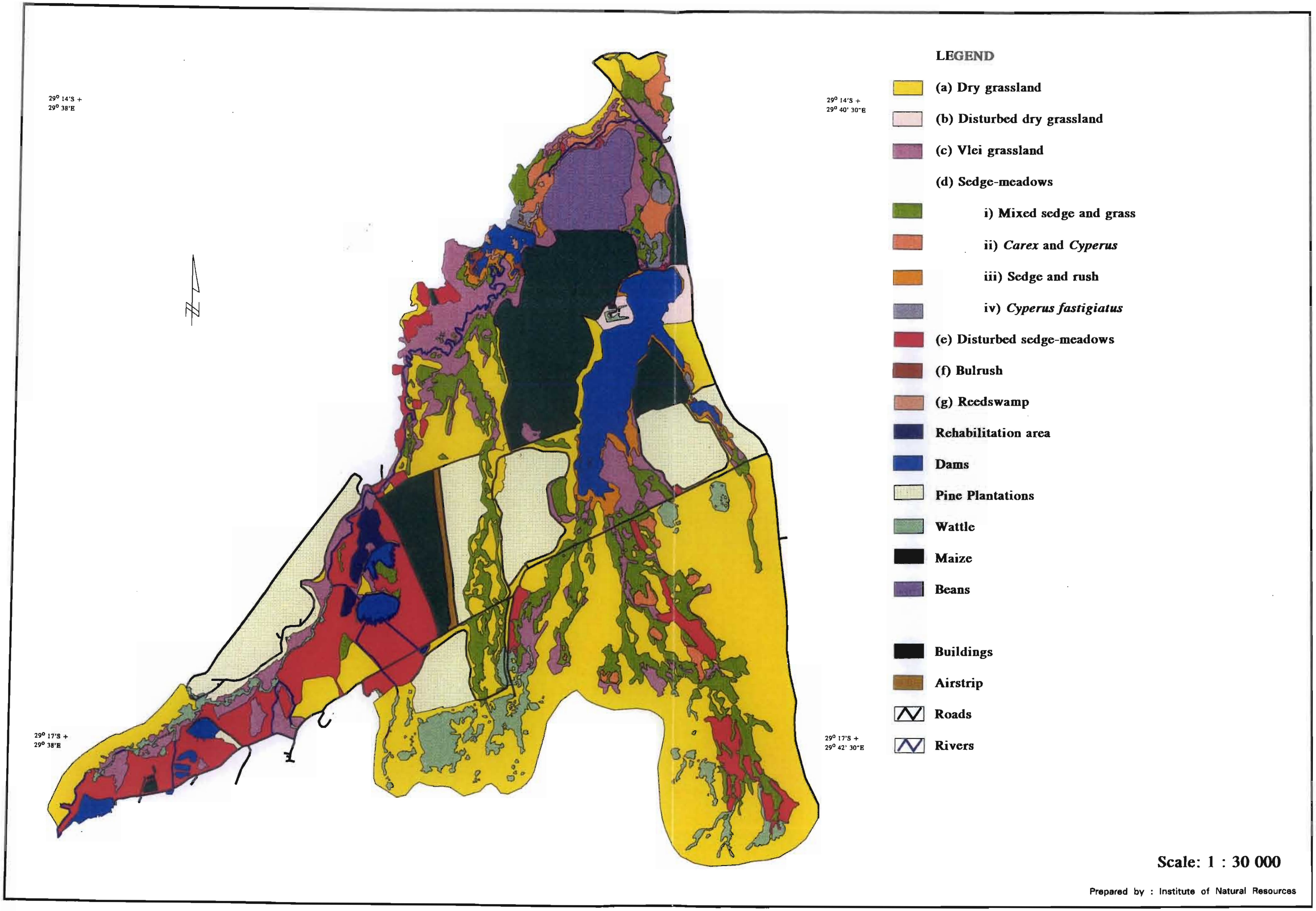


Figure 5.2: The 1992 Vegetation map for Hlatikulu Vlei.

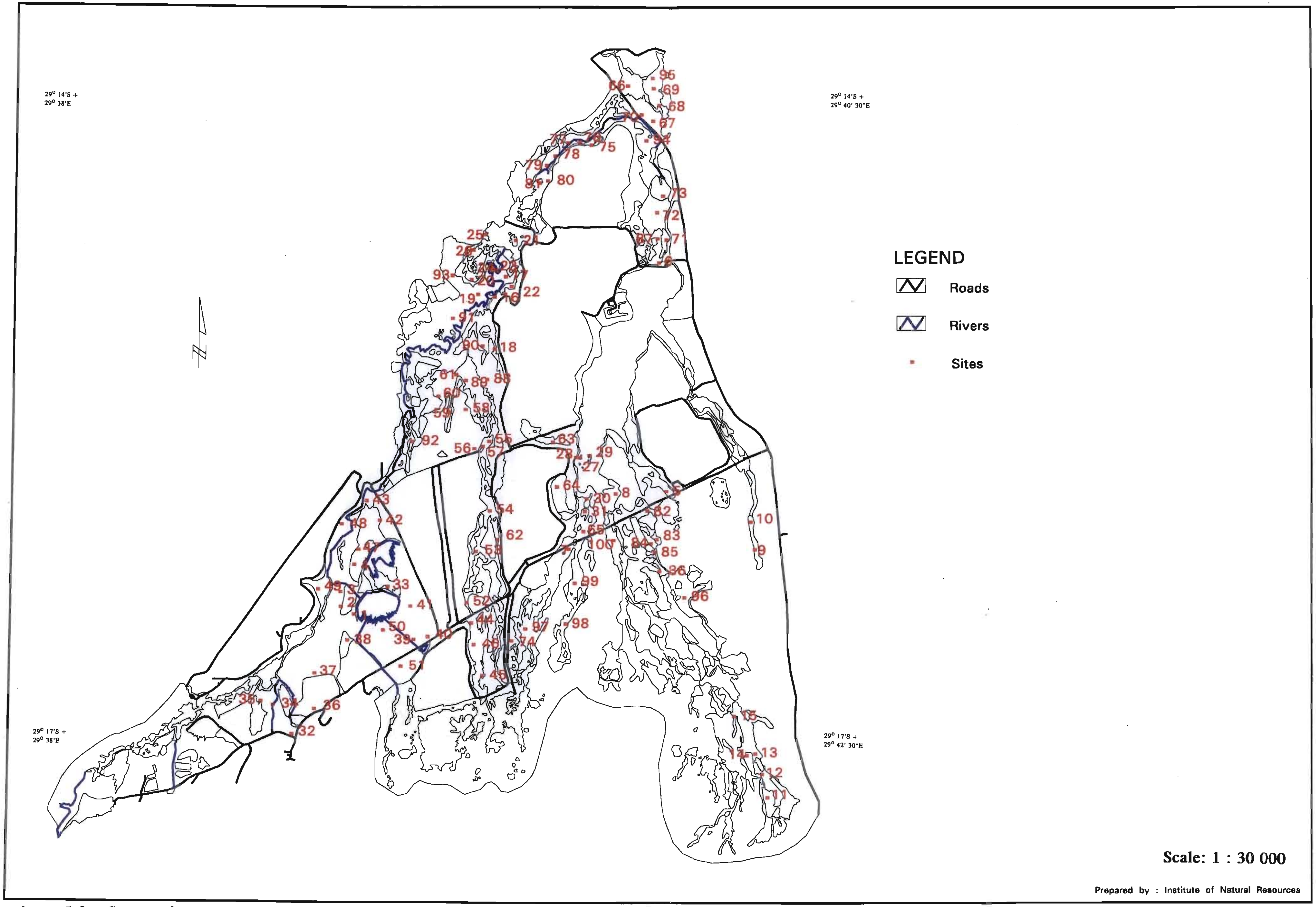


Figure 5.3: Survey sites transposed on an outline of the 1992 Vegetation map for Hlatikulu Vlei.

Table 5: The total extent of each vegetation community at Hlatikulu Vlei for the years 1944 and 1992.

Vegetation Community	Total extent in 1944 (ha)	Total extent in 1992 (ha)	Difference	Causes of change in the extent of each community
Dry grassland	452	161	-291	1 & 2
Vlei grassland	191	101	-91	2 & 8
Disturbed grassland	183	15	-168	1
Disturbed mixed sedge and grass	135	156	+21	4,5 & 8
Mixed sedge and grass	242	168	-74	4,5 & 8
Carex and Cyperus	19	22	+3	6
Sedge and rush	3	13	+10	6
Cyperus fastigiatus	21	8	-13	3 & 8
Reedswamp	0.5	3.5	+3	7
Bulrush	0.1	3	+2.9	7

Causes of the change in the extent of each community as a result of various management practices (See final column of Table 5).

1: Afforestation (*Pinus patula*).
2: Cultivation of various food crops.
3: Inundation by water in dams that caused the destruction of these communities.
4: Drainage of wetland areas
5: Cultivation of pasture grasses.
6: Increase in habitat along the perimeter of dams that favour this community.
7: Increase in habitat within and associated with dams that favour this community.
8: Grazing pressure by livestock.

that have caused changes to the size covered by each community at Hlatikulu Vlei are also given and refer to Section 3.10 in chapter 3.

From Table 5 it is clear that there have been considerable changes to the size of most vegetation communities at Hlatikulu Vlei which has resulted from the various management practices that have occurred over the period from 1944 to 1992. Of the various plant communities at Hlatikulu Vlei the vlei grassland community has been reduced in size by 91 hectares (a loss of 47 % of this community), the mixed sedge and grass sedge-meadows have been reduced in size by 74 hectares (a loss of 30 % of this community), the *Cyperus fastigiatus* sedge-meadows have been reduced in size by 13 hectares (a loss of 60 % of this community) and the areas of disturbed mixed sedge and grass sedge-meadows have been increased in size by 21 hectares (a degradation of a further 8 % of mixed sedge and grass sedge-meadows). Certain communities have extended their range in the vlei, the *Carex* and *Cyperus* sedge-meadow community has increased in extent by 3 hectares (an increase of 16 %), the sedge and rush sedge-meadow communities have increased in extent from 3 hectares to 13 hectares (an increase of over 300 %) and the bulrush and reed-swamp communities have increased from 0.1 to 3 hectares and 0.5 to 3.5 hectares respectively. Also of interest are the significant decreases in the dry grassland and disturbed dry grassland communities which surround the vlei. Areas of dry grassland have decreased by 291 hectares (a loss of 64 %) and areas of disturbed have decreased by 168 hectares (a loss of 91 %).

As the 1944 aerial photographs were taken prior to the draining (by the 'ridge and furrow' technique) of the upper portion of the western arm of Hlatikulu Vlei on 'Tierhoek' and the subsequent development of the area for pastures, it is possible to establish that this area was covered predominantly by mixed sedge and grass sedge-meadow and vlei grassland communities. The draining and development of fields for pastures caused a reduction of the mixed sedge and grass sedge-meadow community from an area of 59 ha in 1944 to an area of 4.5 ha in 1992, while the vlei grassland has been reduced from an initial area of 79 ha to 29.5 ha. Clearly the draining and planting of pastures in the areas covered by these communities has effectively destroyed the wetland vegetation that was present and replaced it with species depauperate pasture lands. Also the construction of two large dams on each of the two arms of the vlei (Figure 5.2) in 1983 caused the flooding of large areas. The eastern dam flooded an area of 75 ha destroying 39 ha of mixed sedge and grass sedge-meadow community, 6 ha of *Cyperus fastigiatus* sedge-meadow community and 4.5 ha of vlei grassland. A further 5.5 ha of mixed sedge and grass sedge-meadow community, 4 ha of vlei grassland and 1 ha of *Cyperus fastigiatus* sedge-meadow community has been replaced by sedge and rush sedge-meadow communities along the margins of the dam.

The western dam flooded an area of 14 ha inundating 7 ha of vlei grassland, 3.5 ha of *Cyperus fastigiatus* sedge-meadow community (representing a further loss of 16.6% of area covered in 1944 by this community) and 2.5 ha of mixed sedge and grass sedge-meadow community. However the construction of this dam has allowed the expansion of *Phragmites australis* dominated communities from 0.5 ha in 1944 to 3.5 ha in 1992, an increase in *Typha capensis* dominated communities for less than 0.1 hectares in 1944 to 3 ha in 1992 and the establishment of a further 4.5 ha of sedge and rush sedge-meadow community.

Less substantial changes were detectable on the middle portion of the western arm of the vlei (part of 'Game Wood'), that has been subjected to burning and heavy grazing by Black farmers since 1880, here 3 ha of *Cyperus fastigiatus* sedge-meadow community have been lost since 1944 and the area remains dominated by vlei and disturbed grassland.

The areas least affected by previous management practices are the lower portions of the vlei on 'Forest Lodge' where cattle have been excluded and the upper portion of the eastern arm of the vlei ('Northington') which has been subjected to light burning and grazing by White farmers from before 1940. In these areas there have been no substantial losses of wetland vegetation or large changes in the types of plant communities present.

Of the dry grassland present within and between the two arms of the vlei in 1944, approximately 134 ha were afforested in 1991 with *Pinus patula* by Mondi Forests, who have not afforested any wetland areas. A further 225 ha of this grassland on 'Forest Lodge' was converted in 1983 to croplands where maize, beans and rye grass have been cultivated. Although these areas were never wetland *per se* the effects that these changes may have on the hydrology of the vlei are not known.

5.6 Discussion

In 1988 Begg observed that, despite the high degree of proximal disturbances (the construction of storage dams within the vlei and the establishment of rye-grass pastures at the head of the western arm) most of Hlatikulu Vlei was in a relatively undisturbed condition.

However when comparing the areas that could be classified as disturbed, altered, degraded or even destroyed by various land management practices prior to and since 1944, it is clear that, whereas in 1944 less than 20% of the total vlei area could be classified as such, by 1992 the figure had risen to almost half (49,4%) the vlei. This use of historical aerial photographs to produce maps of past and present vegetation patterns at Hlatikulu Vlei allows an accurate assessment of the effects of these proximal disturbances observed by Begg (1988). Clearly the construction of storage dams within the vlei and the establishment of pastures at the head of the western arm have resulted in the greatest destruction of wetland vegetation and caused many changes to the extent of various communities in the vlei. The remaining areas of the vlei remain relatively undisturbed.

Where cattle have been excluded from wetland communities and where burning is not conducted on an annual basis, such as the lower portion of the vlei on 'Forest Lodge' or certain areas of the farm 'Northington' on the upper portion of the eastern arm of the vlei which has been subjected to greater controls over burning and grazing, communities have a higher species diversity than other communities in other areas of the vlei.

The farm 'Game Wood' includes the middle portion of the western arm of the vlei, which has been subjected to burning and heavy grazing by black farmers since before 1944 is described by Begg (1988) as the most vulnerable portion of the vlei. This is due to the excessively high numbers of people that presently occupy this farm where it is probable that the overgrazing of the area by cattle and indiscriminate cultivation within the vlei will lead to serious degradation in the long term. Here both vlei grassland and sedge and grass sedge-meadow communities have a lower species diversities than other areas of vlei where the same communities occur. This implies that continued pressure by livestock and regular burning cause a reduction in the species diversity of wetland communities. Also the soils in these areas tended to be compacted, drier and the hummock and channel feature characteristic of the sedge and grass sedge-meadow communities tended to be degraded and in certain areas erosion is prevalent. The high prevalence of the invader grasses *Aristida junciformis* and *Paspalum dilatatum* in these areas is also a concern. The unpalatablity of *Aristida junciformis* can only result in subsequent increases of this species and the decline and exclusion of other species. Although palatable the grass *Paspalum dilatatum* is an alien species which is classed as an increaser (van Oudtshoorn 1992) and one can expect that this species will also cause a decline in the species diversity of these communities as various indigenous species are reduced and ultimately become extinct.

The 1991 purchase by Messrs Steyn (of 'Forest Lodge') of portions of 'Game Wood' farm may halt this degradation through a degreased grazing pressure on, and less frequent burning of wetland vegetation. Tragically, further areas of wetland vegetation will be destroyed or largely altered by the raising of the level of the dam wall on the western part of the vlei by approximately two metres in 1993. Subsequent flooding of further vlei areas on both 'Forest Lodge' and 'Game Wood' farms will mean that more than 50% of the vegetation of Hlatikulu Vlei will have been destroyed or degraded, a situation which should not be allowed to happen.

The vlei grassland and sedge and grass sedge-meadow communities of Hlatikulu Vlei have the highest species diversity. Clearly they should be afforded suitable protection in future management programmes not flooded. Continued loss of wetland vegetation will ultimately cause a lowering of the water table, a reduced carrying capacity of the land and a restriction and destruction of the functioning of the vlei as a whole.

The effects of afforestation of grassland surrounding on the wetland areas of Hlatikulu Vlei is not known. Much debate has been generated by conservation bodies who are concerned that a significant reduction of water entering the wetland from the surrounding catchment areas posed a potentially serious threat to the water levels within the vlei that could seriously affect the functioning of the vlei and could cause alterations to the vegetation of the vlei. The response by Mondi to embark upon a joint venture with the Southern African Crane Foundation to establish the Hlatikulu Crane and Wetland Sanctuary on the formerly drained areas of 'Tierhoek' and to re-establish wetland in this area does not however address the effects of afforestation and no research into this aspect is being conducted at Hlatikulu Vlei.

Whilst the re-establishment and rehabilitation of wetland in the Hlatikulu Crane and Wetland sanctuary is investigated in Chapter 7, the expectations of Mondi and the S.A.C.F. were that the re-establishment and rehabilitation of wetland vegetation will encourage the breeding of cranes, waterfowl and other wetland dependent birds.

The effects of the additional reduction of grassland between the two arms of the vlei on the farm 'Forest Lodge' to allow for the cultivation of maize, beans and other crops on the vlei is also unknown.

5.7 Conclusions

The delineation of the extent of wetland and the various wetland vegetation communities at Hlatikulu Vlei should provide the basis of any further management programmes at the vlei.

The major source of disturbance, degradation and destruction of the various plant communities at Hlatikulu Vlei were the creation of a number of dams in the vlei since

1944 (particularly on the farm 'Forest Lodge') and the draining of a large area of 'Tierhoek' for the planting of pasture grasses. These have resulted in the inundation or loss of major portions of the dominant plant communities, namely vlei grassland and sedge and grass sedge-meadow communities.

The effects of grazing and fire on the plant communities of Hlatikulu Vlei have been considerably less, with the exception of areas of wetland on 'Game Wood' farm most of the remaining areas of wetland vegetation are relatively well preserved and degradation is minimal. Certain areas of 'Game Wood' farm show signs of erosion and the species diversity is lower than other areas where similar plant communities occur. Also there is a marked increase in weedy alien species which one may assume were not originally part of the species composition of these communities.

Continued mismanagement of this area should be prevented and controls of grazing and burning should be implemented. The fencing of these wetland areas should be a priority to prevent further degradation. In the light of the raising of the wall of the western dam on 'Forest Lodge' by approximately two metres which has caused the further flooding wetland vegetation, the likelihood of these areas being protected seems remote.

Currently the *Aristida junciformis* - *Cyperus denudatus* (Sub-community A 1.2) and the *Carex cognata* - *Cyperus denudatus* (Sub-community A 2.1) of the sedge-meadow communities have the highest species diversities for the vlei and should be suitably protected in management practices which prevent overgrazing and restrict the regularity of fires. To ensure that the variety of vegetation communities at Hlatikulu Vlei is not destroyed smaller communities such as the *Cyperus fastigiatus* sedge-meadows care should be taken to locate and protect these areas too.

Further losses of vlei vegetation should be avoided at all cost if Hlatikulu Vlei is to remain a functioning priority wetland in KwaZulu-Natal.

CHAPTER 6

THE RELATIONSHIPS BETWEEN SPECIES AND CERTAIN ENVIRONMENTAL VARIABLES IN THE VEGETATION COMMUNITIES OF HLATIKULU VLEI

6.1 Introduction

A common problem in community ecology is to discover how a multitude of species respond to external factors such as environmental variables (ter Braak 1988). Whilst the classification and description of vegetation communities of wetlands is regarded as a necessary step to provide an objective representation of the vegetation, the use of ordination techniques provide the means to interpret the community data of different plant communities (Coetzee *et al.* 1993).

Ordination is the collective term used to describe multivariate techniques that arrange sites along axes on the basis of data on species composition (Jongman et al., 1987). The objective of ordination is in generating hypotheses about the relationships between composition of vegetation and the environmental or other factors which determine it (Greig-Smith 1983).

We may view ordinations as transfer systems in which information flows from raw data to ordination co-ordinates. Naturally we may expect from such transfer systems certain peculiar properties: 1) Different results by different techniques of transfer, 2) Information loss under most circumstances, 3) Optimal performance confined to specific objectives.

The ordination techniques with differences in their handling of the data, are expected to produce different results. Their differences, however, need not lead to radically different ecological interpretations. On the contrary ordinations are quite robust in that they have a strong tendency toward convergence of the ecological information which they reveal (Orloci, 1978).

The most recent development in ordination techniques is canonical correspondence analysis (CCA) developed by ter Braak (1988). Application of this technique has been greatly aided by the availability of the CANOCO computer programme (ter Braak, 1988). Unlike previous ordination methods which are indirect in that the species data alone is first analysed and then the environmental interpretation is made by superimposing environmental data on the ordination plots and then looking for correlations and patterns, canonical correspondence analysis incorporates the correlation and regression between floristic data and environmental factors within the ordination itself (Kent & Ballard, 1988). Thus the input to canonical correspondence analysis consists not just of a data matrix of species x quadrats but also a second matrix of environmental factors x quadrats. Canonical correspondence analysis is thus best defined as a method of direct ordination with the resultant ordination being a product of the variability of the environmental data as well as the variability of the species data.

This approach of using both species and environmental data in the actual ordination process is known as a form of canonical analysis. Thus the resulting ordination diagram expresses not only patterns of variation in floristic composition, but also the principal relationships between the species and each of the environmental variables.

The exact process by which canonical correspondence analysis works is rather complex and a detailed explanation may be obtained in ter Braak (1986; 1987). In brief however, the method uses multiple regression to select the linear combination of environmental variables that explains most of the variation in the species scores on each axis. In CCA a multiple regression, using the iterative approach of correspondence analysis (CA), is carried out between the quadrat ordination scores for an axis (the dependent variable) and various combinations of the environmental variables (the independent variables). Then the calculated best fit values for quadrats for the combinations of environmental variables which give the highest explained variance in the original axis scores are taken as an improved estimate of those quadrat ordination axis scores. The CCA iteration will then continue by performing another multiple regression to improve the fit on the next iteration and continues on until eventually the scores stabilise (Kent & Coker, 1992).

The influence of various environmental factors on the location of plant communities within Hlatikulu Vlei may be determined through CCA ordination techniques such that the key question of what environmental factors are responsible for the present floristic patterns of the vegetation at Hlatikulu Vlei may be answered.

6.2 Methods

6.2.1 Sample site location

One hundred sample sites were located within the various plant communities of the vlei. Sites were chosen so that all the plant communities of the vlei, from the drier extremes to the most saturated conditions, were represented. The location of the sites are given in Figure 5.3 as an overlay for the 1992 vegetation map (Figure 5.2).

6.2.2 Environmental factors

To determine what environmental factors were most likely to be responsible for the present patterns of vegetation, various environmental factors were recorded for use in the ordination.

Soil sampling was conducted at each site at Hlatikulu Vlei in the same way as described in Section 4.3.3 of Chapter 4. The four soil types encountered at the vlei, namely Champagne, Katspruit, Pinedene and Clovelly soil forms, recorded for each site.

The soil moisture content was recorded at each site every month during the sampling period, December 1992 to April 1993. Soil moisture was crudely estimated by eye and touch and was classified into the following categories:

(a) Free standing water (>/= 30 cm)
(b) Free standing water (> 30 cm)
(c) Saturated (water freely drips from soil sample)
(d) Wet (water can be squeezed from soil sample)
(e) Moist (soil sample cohesive when squeezed)
(f) Dry (soil hard or friable)

The altitude and aspect of each site was extracted from 1:10 000 orthophoto maps of the area printed in 1985 by the Department of the Interior, KwaZulu. The names and numbers of the maps were as follows: KwaMakonjane 2929 BA 24, Yorkville 2929 BA 25, Louisdaal 2929 BC 3 and Tierhoek 2929 BC 4.

The severity of grazing was estimated by a visual assessment of the amount of damage by livestock to communities at each site and were classified into the following categories:

(a) No grazing (no signs of any grazing)
(b) Light (some grasses with signs of grazing)
(c) Moderate (most grasses with signs of grazing)
(d) Heavy (all grasses with signs of grazing, grasses grazed to within 5 - 30 cm of soil surface).
(e) Extreme (grasses grazed to within 5 cm of soil surface).

Finally the presence or absence of hummock and channel features at the sample site was also recorded.

6.2.3 Sampling

The sampling units used for the collection of data were quadrats of 25m^2 (5 x 5 m) as this is an efficient size for studies in grasslands and marshes (Westhoff & van der Maarel, 1978). Within each quadrat all the species present were rated for cover/abundance according to Werger's modified Braun-Blanquet scale. The methods utilised are described in section 4.3.2 in chapter 4. The sampling for this phase of the study was conducted during the summer period, December 1992 to April 1993.

6.3 Data entry

The species abundance estimates and the environmental data for Hlatikulu Vlei were processed into Cornell condensed format for use in the Canonical Correspondence Analysis (CANOCO)(Gauch, 1982).

Initially all the data from all sites at Hlatikulu Vlei sampled were analysed and ordinations produced using CCA. Anomalous sites and outlier species were checked for and removed from the subsequent analysis. Having removed the outlier sites, the data was again analysed using CCA, the effects of environmental variables were then determined and species ordination produced in a species-environment biplot.

6.4 Results

The complete set of species and environmental data for Hlatikulu Vlei sites was analysed using CCA. The results of the initial analysis are presented in Table 6.2 and Figure 6.1. The weighted correlation matrix of all environmental variables is shown in Table 6.3 and the correlation matrix for all environmental variables with species axes for all sites is shown in Table 6.4.

Table 6.1: List and description of environmental variables taken for each site sampled.

Name of Variable	Description of variable
Clo	Clovelly soil form
Pin	Pinedene soil form
Kat	Katspruit soil form
Cha	Champagne soil form
Cov	Percentage total cover at site
Gra	Severity of grazing
Moi	Soil moisture
Hum	Presence of hummocks and channels
Alt	Altitude as height above sea level (m)

Table 6.2: Ordination axes, corresponding eigenvalues, species-environment correlations, percentage variance accounted for and fraction of variance explained by CCA for all sites.

Axis	Eigen-value	Species - environment correlation	Cumulative % Variance accounted for by axis	Fraction of variance explained
1	0.4388	0.8120	35.7	0.337
2	0.2271	0.7152	54.2	0.185
3	0.1750	0.7678	68.4	0.142
4	0.1447	0.7225	80.2	0.118

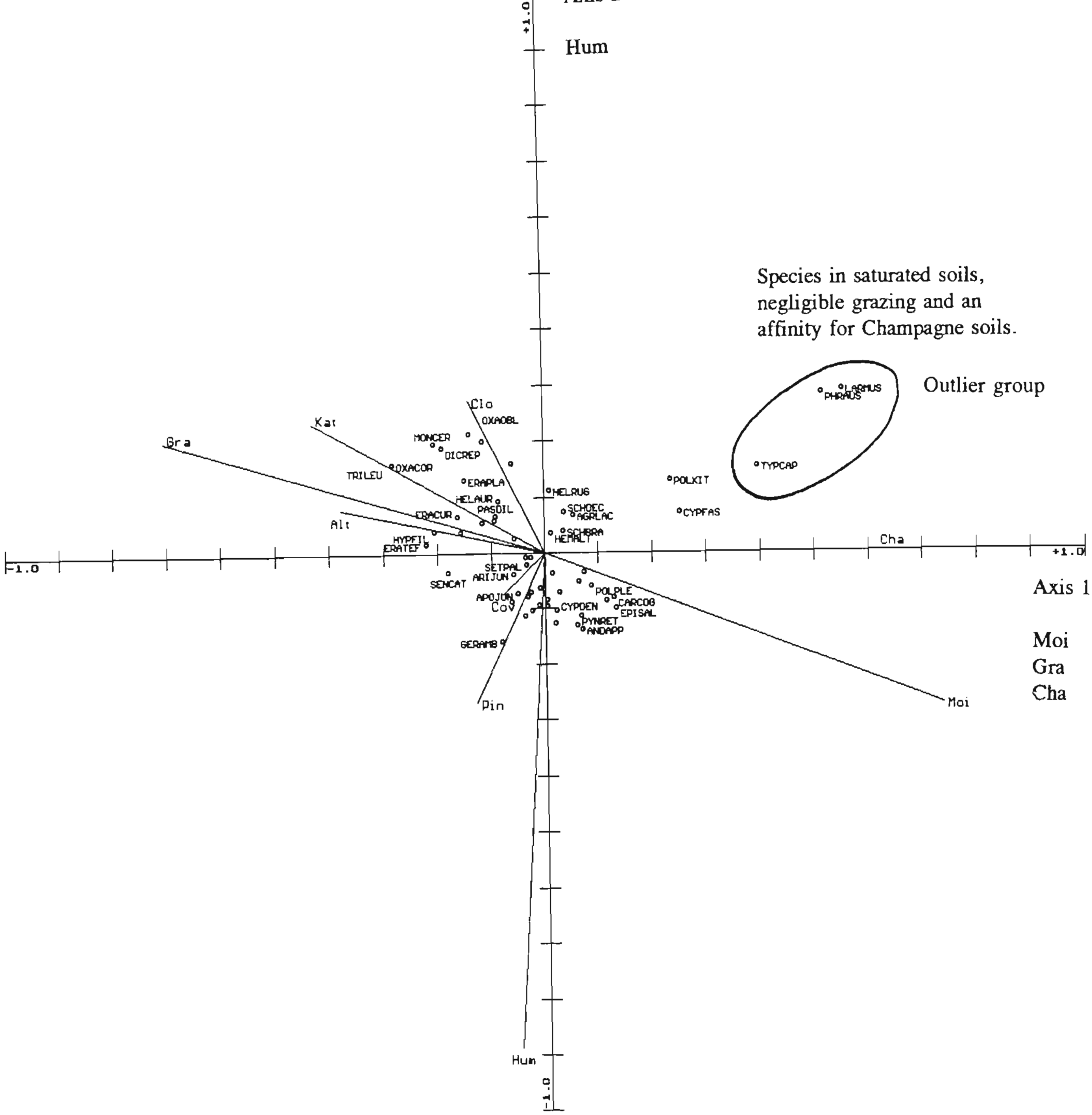


Figure 6.1: Biplot of species and environmental variables for all sites at Hlatikulu Vlei

Species acronyms as per Table 4.4 in Chapter 4, variable acronyms as per Table 6.1. Variables significantly correlated with axes, listed under respective axes.

Table 6.3: Weighted correlation matrix for correlations between all environmental variables (rows) with each other (columns), for all sites (Variables significantly correlated with each other are highlighted in bold).

Clo	1.00								
Pin	-0.15	1.00							
Kat	-0.07	**-0.59**	1.00						
Cha	-0.07	**-0.57**	-0.27	1.00					
Cov	0.11	-0.03	-0.02	0.03	1.00				
Gra	0.10	0.14	0.15	-0.37	0.08	1.00			
Moi	0.23	0.06	0.19	-0.34	0.13	0.32	1.00		
Hum	-0.18	-0.13	0.13	0.08	0.11	-0.10	-0.36	1.00	
Alt	-0.16	0.16	-0.08	-0.17	0.32	0.27	0.37	-0.19	1.00
	Clo	Pin	Kat	Cha	Cov	Gra	Moi	Hum	Alt

Table 6.4: Correlation matrix for correlations between all environmental variables (rows) with species ordination axes (columns) for all sites. (Variables significantly correlated with each other are highlighted in bold. Variable acronyms explained in Table 5.7).

SPEC AX1	1.00			
SPEC AX2	0.21	1.00		
SPEC AX3	-0.01	-0.06	1.00	
SPEC AX4	-0.11	-0.16	0.07	1.00
Clo	-0.11	0.20	-0.09	0.27
Pin	-0.10	-0.19	0.25	0.28
Kat	-0.35	0.16	-0.16	-0.34
Cha	**0.53**	0.00	-0.12	-0.08
Cov	-0.06	-0.05	-0.70	0.24
Gra	**-0.58**	0.14	-0.10	-0.26
Moi	**-0.59**	0.20	0.07	0.35
Hum	-0.04	**-0.64**	-0.15	-0.22
Alt	-0.31	0.06	-0.18	0.31
	SPEC AX1	SPEC AX2	SPEC AX3	SPEC AX4

Table 6.2 presents the ordination axes, the corresponding eigenvalues, the species-environment correlations, the percentage variance accounted for and fraction of variance explained by the CCA analysis for all sites. The first and second axes have the highest eigenvalues of 0.4388 and 0.2271 respectively, whilst the third and fourth axes have eigenvalues of 0.1750 and 0.1447 respectively. With regard to the species-environment correlations the first and second axes have correlations of 0.8120 and 0.7152 respectively, whilst the third and fourth axes have correlations of 0.7678 and 0.7225 respectively. The cumulative percentage variance accounted for by all axes is 80.2 %, by the first three axes 68.4 %, by the first two axes 54.2 % and by the first axis 35.7 %. The fraction of variance explained by the first axis was 0.337, by the second axis 0.185, by the third axis 0.142 and by the fourth axis 0.118.

The weighted correlation matrix for all environmental variables with each other for all sites shown in Table 6.3 show that Katspruit and Champagne soils were significantly correlated with Pinedene soils with correlation values of -0.59 and -0.57 respectively.

The correlation matrix for all environmental variables with species axes for all sites in Table 6.4 show that the environmental variables significantly correlated with species axis 1 were Champagne soils with a value of 0.53, severity of grazing with a value of -0.58 and moisture levels with avalue of -0.59. Also the environmental variable significantly correlated with species axis 2 was the presence or absence of hummocks and channels with a value of -0.64.

The biplot of species and environmental variables for all sites at Hlatikulu Vlei as presented in Figure 6.1 shows a group of outlier species namely, *Phragmites australis, Largiosiphon muscoides* and *Typha capensis*. These are outliers because they either represent rare species or they occur at the extreme end of the scale. The sites in which these species occurred were removed from the data set.

Having removed the outlier sites, the data were again analysed using CCA. The results of this analysis are presented in Table 6.5 and Figure 6.2, with the correlation matrix

Table 6.5: Ordination axes, corresponding eigenvalues, species-environment correlations, percentage variance accounted for and fraction of variance explained by CCA for all sites excluding the outlier sites.

Axis	Eigen-value	Species - environment correlation	Cumulative % Variance accounted for by axis	Fraction of variance explained
1	0.318	0.842	29.2	0.292
2	0.207	0.807	48.2	0.19
3	0.159	0.786	62.8	0.146
4	0.136	0.845	75.3	0.125

Table 6.6: Weighted correlation matrix for correlations between all environmental variables (rows) with each other (columns), for all sites excluding the outlier sites (Variables significantly correlated with each other are highlighted in bold).

Pin	1.00							
Kat	**-0.64**	1.00						
Cha	**-0.60**	-0.23	1.00					
Cov	0.07	-0.05	-0.04	1.00				
Gra	0.23	-0.03	-0.32	0.01	1.00			
Moi	-0.19	-0.08	0.24	-0.14	-0.22	1.00		
Hum	-0.42	0.28	0.23	-0.03	-0.16	0.43	1.00	
Alt	22	-0.15	-0.13	0.31	0.24	-0.30	-0.25	1.00
	Pin	Kat	Cha	Cov	Gra	Moi	Hum	Alt

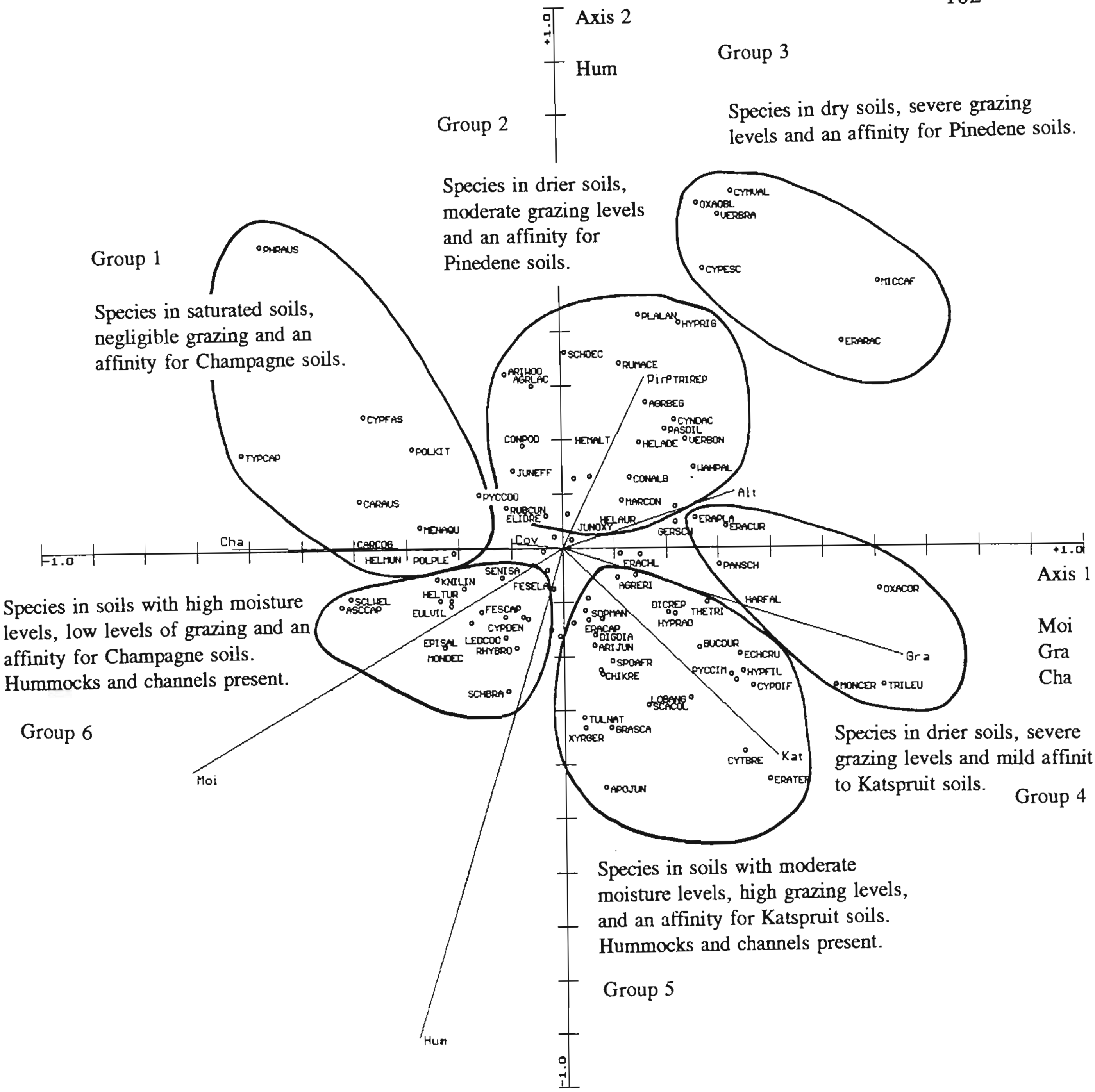


Figure 6.2: Biplot of species and environmental variables for all sites at Hlatikulu Vlei excluding outlier sites.

Species acronyms as per Table 4.4 in Chapter 4, variable acronyms as per Table 6.1. Variables significantly correlated with axes, listed under respective axes.

of all environmental variables shown in Table 6.6. Environmental variables that are significantly correlated with species axes are shown in Table 6.7.

Table 6.5 presents the ordination axes, the corresponding eigenvalues, the species-environment correlations, the percentage variance accounted for and fraction of variance explained by the CCA analysis for all sites. The first and second axes have the highest eigenvalues of 0.318 and 0.207 respectively, whilst the third and fourth axes have eigenvalues of 0.159 and 0.136 respectively. With regard to the species-environment correlations the first and second axes have correlations of 0.842 and 0.807 respectively, whilst the third and fourth axes have correlations of 0.786 and 0.845 respectively. The cumulative percentage variance accounted for by all axes was 75.3 %. The percentage variance accounted for by the first three axes, the first two axes and the first axis were 62.8 %, 48.2 % and 29.2 % respectively. The fraction of variance explained by the first, second, third and fourth axes were 0.292, 0.19, 0.146 and 0.125 respectively.

As with the weighted correlation matrix for all environmental variables with each other for all sites shown in Table 6.3, the weighted correlation matrix for all environmental variables with each other for all sites excluding the outlier sites shown in Table 6.6 show that Katspruit and Champagne soils were significantly correlated with Pinedene soils with correlation values of -0.64 and -0.60 respectively.

The correlation matrix for all environmental variables with species axes for all sites excluding the outlier sites are shown in Table 6.7 and show similar results to those presented in Table 6.4. The environmental variables significantly correlated with species axis 1 were Champagne soils with a value of -0.53, severity of grazing with a value of -0.55 and moisture levels with a value of -0.60. The environmental variable significantly correlated with species axis 2 was presence or absence of hummocks and channels with a value of -0.73. The biplot of species and environmental variables for all sites at Hlatikulu Vlei excluding outlier sites as presented in Figure 6.2 shows six groupings of species related to the various environmental variables.

Table 6.7: Correlation matrix for correlations between all environmental variables (rows) with species ordination axes (columns) for all sites excluding outlier sites. (Variables significantly correlated with each other are highlighted in bold. Acronyms for environmental variables are explained in Table 5.7).

SPEC AX1	1.00			
SPEC AX2	-0.07	1.00		
SPEC AX3	**0.54**	-0.05	1.00	
SPEC AX4	0.11	-0.08	-0.04	1.00
Pin	0.13	0.25	0.29	0.00
Kat	0.35	-0.31	-0.31	-0.12
Cha	**-0.53**	0.00	-0.04	0.13
Cov	-0.08	0.00	-0.02	0.53
Gra	**-0.55**	-0.16	-0.26	0.25
Moi	**-0.60**	-0.33	-0.22	-0.03
Hum	-0.24	**-0.73**	0.12	-0.15
Alt	-0.28	0.08	0.37	0.66
	SPEC AX1	SPEC AX2	SPEC AX3	SPEC AX4

Group 1 species showed an affinity for sites with saturated soils, where the effects of grazing were negligible and where Champagne soils were present. Group 2 species showed an affinity for sites with drier soils, where grazing levels were moderate and where Pinedene soils were usually present. Group 3 species showed an affinity for sites with dry soils, where the severity of grazing were amongst the harshest for the vlei and where Pinedene soils were usually present. Group 4 species showed an affinity for sites with drier soils, where the harshest grazing levels were found and where soils tended to be Katspruit soils. Group 5 species showed an affinity for sites with soils that had moderate moisture levels, where grazing levels were high and where Katspruit soils were present and where the hummock and channel feature was present. Group 6 species showed an affinity for sites where soils had high moisture levels, there were low levels of grazing, Champagne soils were present, and where the hummock and channel feature was present.

6.5 Discussion

The biplot of species and environmental variables presented in Figure 6.1 shows an outlier group of species which are distinctly dissimilar to the majority of species at all sites sampled for Hlatikulu Vlei. These species, *Phragmites australis*, *Largiosiphon muscoides* and *Typha capensis* are dominant in areas where the soils have high (saturated) soil moisture contents, specifically Champagne soils, where there is little or no grazing and where the hummock and channel features are absent. These species may be considered to be outlier species due to their location at the edge of the ordination diagram. It is standard practice to consider that the species found at the edge of ordination diagrams either are rare species, lying there either because they prefer extreme (environmental) conditions or because their occurrences happen to be at sites with extreme conditions (ter Braak, 1987). In this case these species occurred in saturated sites, located within and at the edges of the large dams on the 'Forest Lodge' section of the Hlatikulu Vlei, where soil moisture levels represented the extreme end of the scale. These sites and not the species were viewed as outliers and were subsequently removed from further analysis.

It is possible to split the species that are characteristic at these sites into two groups. One group, identified in chapter 4 as the *Phragmites australis - Largiosiphon muscoides* community, was found at sites in the deeper parts (depths of 1,5 to 3 m) of the western Forest Lodge dam (see Figure 6.2). Here the reed, *Phragmites australis,* was the dominant species rooted in the soil beneath the water surface, with *Largiosiphon muscoides* floating amongst the reed stems. This group occurred where Champagne soils were present and where soil moisture was at the extreme end of the scale. The other group, identified in chapter 4 as the *Typha capensis - Polygonum kitaibelianum* community, occurred on sites in both the dams on 'Forest Lodge' farm, rooted at depths between 0.5 and 2 metres. The dense growth of Typha capensis at these sites tended to prevent other species from co-habiting the sites. *Largiosiphon muscoides* and *Polygonum kitaibelianum* were present at these sites too, but with cover values less than 5%. This group also occurred where Champagne soils were present and where soil moisture levels were at the extreme end of the scale, though not to the degree of the *Phragmites australis - Largiosiphon muscoides* community.

As the occurrence of these species at Hlatikulu Vlei was not limited to those sites representing these extreme conditions but other sites too (where they were not the dominant species), rather than removing the outlier species, the outlier sites were removed. Further analysis, to allow for a better dispersion of the majority of species and sites and hence interpretation of the response to environmental gradients, was then conducted after the removal .

There are several environmental variables significantly correlated with species axes (Table 6.4). Here of primary interest are the variables correlated with the first two axes as these axes account for 66.59 % of the variability in the complete data set. The major environmental variables affecting species distributions are those most strongly correlated with the species axes in the analysis. In this case the first axis strongly correlated with soil moisture, the severity of grazing and Champagne soil type, while the second axis is strongly correlated to the presence (or absence) of hummocks and channels at the sites. In this first analysis, the single most important environmental variable which is most likely to determine where certain species will grow in the

Hlatikulu Vlei is the amount of water present in or covering the soil. The moisture levels in the soils ranged from dry soils to saturated soils and beyond that to areas where free standing water of up to 3 metres occurred. This result could be expected in the light of wetland definitions that describe wetlands as 'lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water' (Cowardin, 1979)

Also there is a positive correlation of Champagne and Katspruit soils with the Pinedene soils. This may be explained by the nature of the soil types within the vlei, for within the dominant Katspruit and Champagne soil forms, patches of Pinedene soil types are found. This would explain the positive correlation of Champagne and Katspruit soils with Pinedene soils.

The removal of outlier sites from the data set before the second analysis has allowed for a clearer representation of the relationship between species and environmental variables. In the biplot of species and environmental variables in Figure 6.2 distinct groupings of species in relation to the environmental variables are exhibited. In CCA it is standard that groupings of similar species are near each other in the ordination diagram, whilst 'dissimilar' species are further apart in the ordination diagram (Gauch, 1982). While the first two axes account for less variability in the data set than in the first ordination (52.5 %), as in the first analysis, the first axis is again strongly correlated with soil moisture, the severity of grazing and Champagne soil type, while the second axis is again strongly correlated to the presence (or absence) of hummocks and channels at the sites. Six group were identified from the biplot in Figure 6.2. Each group could be related to several of the environmental variables. Each group is discussed with reference to these environmental variables to show which are most responsible for the present pattern of vegetation at Hlatikulu Vlei.

As in the initial analysis there is again a positive correlation between Champagne and Katspruit soils with the Pinedene soils. This is as a results of there being patches of Pinedene soils within the Champagne and Katspruit soils.

The relationships between species and certain environmental variables for group 1 in Figure 6.2 are discussed below. At high soil moisture levels (free standing water $\geqslant$ 30 cm) and very low level of grazing, sites lacking the presence of hummocks and channel features in the landscape are dominated by *Phragmites australis, Typha capensis, Cyperus fastigiatus, Carex austro-africana, Carex cognata, Pycreus cooperi, Polygonum kitaibelianum, Polygonum plebeium, Mentha aquatica* and *Helichrysum mundtii*. These species are thus found in the wetter extremes of Hlatikulu Vlei and occur in species poor sites that are dominated by one or two species with very few other species co-occurring. At sites where either *Phragmites australis, Typha capensis* or *Cyperus fastigiatus* occur, they tend to be dominated by that particular species. Where *Carex austro-africana* and/or *Carex cognata* occur as the dominant species *Pycreus cooperi, Polygonum kitaibelianum, Polygonum plebeium, Mentha aquatica* and *Helichrysum mundtii* less common and abundant. These are the dominant species in the *Phragmites australis, Typha capensis, Cyperus fastigiatus* sedge-meadow and *Carex* and *Cyperus* sedge-meadow communities mapped in Figure 5.2.

The relationships between species and certain environmental variables for group 6 in Figure 6.2 are discussed below. Where high moisture levels and low grazing levels occur but where hummock and channel features occur in the landscape and where soils are either Champagne or Katspruit types, the sites are dominated by the grasses *Eulalia villosa* and *Festuca caprina*; the sedges *Scleria welwitschii, Cyperus denudatus, Rhynchospora brownii, Schoenoplectus brachyceras* and *Ascolepis capensis* and other species including *Ledebouria cooperi, Epilobium salignum* and *Senecio tysonii* are dominant species with *Helictotrichon turgidulum, Kniphofia linearifolia* and *Monopsis decipiens* being less abundant. *Kniphofia linearifolia* is rare at these sites and thus also rare at Hlatikulu Vlei. These dominant species are typical of the wetter mixed sedge and grass sedge-meadow community of the vlei.

The relationships between species and certain environmental variables for group 5 in Figure 6.2 are discussed below. Where soil moisture levels are tending to be more in the middle of scale and grazing levels high, but where Katspruit soils occur with hummocks and channels, the sites are dominated by the grasses *Eragrostis capensis,* *Digitaria diagonalis, Aristida junciformis, Sporobolus africanus* and *Eragrostis tef*. Other species, less dominant include, *Xyris gerrardii, Aponogeton junceus, Diclis reptans* and *Hypochoeris radicata*. *Sopubia manii, Chironia krebsii, Tulbaghia natalensis, Cyrtanthus breviflorus, Graderia scabra, Buchnera dura, Pycreus cimicinus* and *Cyperus difformis* are less abundant species. These species are typical of the drier mixed sedge and grass sedge-meadows and the vlei grassland communities of Hlatikulu Vlei.

The relationships between species and certain environmental variables for group 4 in Figure 6.2 are discussed below. At low soil moisture levels, where grazing is severe and Katspruit soils lack the hummock and channel features, *Eragrostis curvula, Eragrostis plana, Tristachya leucothrix, Monocymbium ceresiiforme* are the dominant grasses. *Panicum schinzii, Harpecloa falx* and *Themeda triandra* are less abundant grasses as are *Oxalis corniculata* and *Geranium schlecteri*. These are species which typify parts of the rehabilitation area in the Hlatikulu Crane and Wetland sanctuary, the disturbed grassland and disturbed mixed sedge and grass sedge-meadow communities.

The relationships between species and certain environmental variables for group 3 in Figure 6.2 are discussed below. At the low extreme of the soil moisture gradient at the vlei, where grazing is intense, the grasses *Eragrostis racemosa, Cymbopogon validus* and *Microchloa caffra* are characteristic. These areas lack the hummock and channel feature and tend to have Pinedene soils. These are more characteristic of the disturbed vlei grassland community where over-grazing is common.

The relationships between species and certain environmental variables for group 2 in Figure 6.2 are discussed below. At drier soil moisture levels and moderate grazing, *Paspalum dilatatum, Agrostis bergiana, Agrostis lachnantha* and *Hemarthria altissima* are the dominant grasses. There are no hummocks and channels and soils tend to be of the Pinedene type. Here, a weedy element includes *Cyperus esculentus, Oxalis obliquifolia, Rubus cuneifolius, Verbena bonariensis, Rumex acetosella, Trifolium repens, Conyza albida* and *Conyza podocephala*, while the dominant sedges are: *Eleocharis dregeana, Schoenoplectus decipiens* and *Mariscus congestus*; and *Juncus* *effusus* and *Juncus oxycarpus* the dominant rushes. These species characterise parts of the rehabilitation area in the Hlatikulu Crane and Wetland sanctuary and the disturbed grassland and disturbed mixed grass and sedge sedge-meadow communities and sedge and rush sedge-meadow communities.

To a certain extent one is able to predict the occurrence of certain species in a particular areas of the vlei if the particular set of environmental variables is known. Clearly in drier areas bulrush and reedswamp communities will not occur, nor will certain grasses or sedges occur in the wettest extremes of the vlei. Thus, with some understanding of the relationships between species and certain environmental variables, for each of the groups identified in Figure 6.2 a reasonable judgement may be made as to where a particular species might be found growing at Hlatikulu Vlei.

6.6 Conclusion:

The influence of various environmental factors on the location of plant species within vegetation communities at Hlatikulu Vlei has been determined using CCA ordination techniques. Thus in answer to the key question of what environmental factors are responsible for the present floristic patterns of the vegetation at Hlatikulu Vlei it is evident that there are several environmental factors which are responsible.

Of these, soil moisture content and inundation depths are the most significant factors affecting the distribution of species within the vlei. Generally in wetlands throughout the world the soil moisture content is one of the most important factors affecting the location of wetland vegetation and thus wetland specific species. The type of soil encountered is also a significant variable in determining vegetation patterns as certain species show distinct affinities for certain soil types. This too could to a large degree be expected in wetlands as soil type is often a characteristic used in the definition of wetlands and is linked largely to the soil moisture content. Wetlands are often defined by the presence of wetland soils.

The presence or absence of hummock and channel features within the landscape at Hlatikulu Vlei is another variable which clearly affects where species occur within the vlei. Many species are reliant on the variety of niches created by these hummock and channel features which are responsible for maintaining a higher species diversity than areas that lack these features. Finally the severity of grazing is a less significant variable affecting where species occur within the vlei and is linked to soil moisture. It is clear that the less saturated areas of the vlei, where vlei grassland and sedge and grass sedge-meadows occur, are more favoured by livestock than the saturated reedswamps, bulrush communities and wetter sedge-meadows.

The results obtained in this chapter do allow for the limited prediction of what plant species should be able to grow in a particular area of the vlei depending on the environmental variables which are present. This is particularly relevant for the following chapter which deals with the wetland rehabilitation programme in the Hlatikulu Crane and Wetland Sanctuary.

CHAPTER 7

EFFECTS OF A WETLAND RE-ESTABLISHMENT AND REHABILITATION PROGRAMME ON THE VEGETATION AND SEED BANK DYNAMICS IN THE HLATIKULU CRANE AND WETLAND SANCTUARY

7.1 Introduction

A consequence of human mismanagement of wetland resources throughout the world has been the destruction of numerous wetland areas (Williams 1991). Many of the wetlands which now remain are degraded from channelization, damming, agricultural practices and urban surface run-off (Kent 1994). While in the past drainage of wetlands was seen as a benefit to society, many individuals and organisations are now aware of the benefits of wetlands and the need to preserve them. In addition to preservation there is an increasing emphasis being placed on the rehabilitation, replacement and creation of wetlands (Kusler & Kentula 1990). Wetland rehabilitation usually refers to the restoration of wetlands that may be degraded or hydrologically altered and often involves re-establishing the hydrologic regime and vegetation (Mitch & Gosselink 1993). Replacement involves the development of a wetland in an area that once was wetland, whilst creation of wetlands involves the establishment of a wetland where none existed before (Leitch 1994).

In 1990 the Hlatikulu Crane and Wetland Sanctuary was established on a portion of the farm 'Tierhoek' by Mondi and the Southern African Crane Foundation. This portion of the farm had, in the mid-1960's, been subjected to a 'ridge and furrow' development which had caused the vlei areas to be drained. Subsequently this area was ploughed and planted with pasture grasses for livestock. This 'development' in effect destroyed most of the wetland vegetation in this area and severely altered the hydrologic regime.

During the 1960's, when the draining took place, wetlands were regarded in a vastly different light to what they are today. They were considered to be areas of limited agricultural potential where the soils impeded drainage. As the water-table in wetlands, throughout or during part of the year, was too high for optimum production of crops, pasture or timber wetlands were thus regarded as 'wastelands' (Hill *et al*, 1981). These agriculturally unproductive wetlands could however 'be developed' using the 'ridge and furrow' system to drain the wetlands. The concept of draining wetlands to make way for agriculture is age old, and has been used in various continents down the ages to convert so-called unproductive wetlands.

On the African continent the practice of draining wetlands using 'ridge and furrow' methods was particularly popular in the post-war period and was extensively used (Hill et al. 1981). The 'ridge and furrow' system may be described as the ploughing of wetland in a prescribed 'herring-bone' pattern to gather soil onto ridges and to excavate furrows so that maximum drainage of water from the system may be achieved (Hill et al. 1981). Thus the wetland is shaped, according to a preselected pattern into ridges which are freed from waterlogging and furrows which act as drains to channel away excess water. In such a manner wetlands are destroyed to make way for other uses of the land by agricultural. In South Africa, wetlands have been extensively modified by agriculture, many having been drained by 'ridge and furrow' techniques (Breen et al., 1993). In the 'Tierhoek' case the wetland was drained to make way for pastures of *Eragrostis curvula*, *Paspalum dilatatum* and various species of *Lolium* (Theron, pers comm.).

The drainage and destruction of wetlands were accepted practices prior to the mid-1970's and in certain parts of the world were actively encouraged by government (Mitch & Gosselink, 1986). These trends have gradually been (and still are being) reversed as knowledge of the value of wetlands has increased. While the destruction of wetlands still continues throughout the world, their importance has been realised at government and non-government level so that there is increasing trend towards the protection, restoration, enhancement and even the replacement and creation of wetlands. In South Africa very few wetlands are contained within formal conservation areas. The

Conservation of Agricultural Resources Act of 1983 specifically provides for the 'protection of vleis, marshes, water sponges and water courses' and in essence forbids the drainage or cultivation of wetlands (or land within 10 m horizontally from the 1:10-year flood line of a water course) by any land-user throughout South Africa without written permission from the South African Department of Agricultural Economics and Marketing (Breen & Begg, 1989).

In KwaZulu-Natal a number of reserves protect specific wetlands. Lake St. Lucia the largest wetland lies within the protected area of the Greater St Lucia Wetland Park, while smaller reserves exist to protect specific wetlands such as the Umgeni Vlei, Umvoti Vlei, and The Swamp. Also the Natal Drakensberg Park, while not specifically a wetland park has numerous upland wetlands within its boundaries (Dely, pers comm.). Despite these reserves most of the wetlands in KwaZulu-Natal lie outside formal reserves and little has been done to rehabilitate wetland areas that were subjected to degradation and destruction in the past. Thus the joint venture between the S.A.C.F. and Mondi Forests that aims to re-establish wetland in the areas where wetland had previously existed and to rehabilitate the remnant wetland areas on 'Tierhoek' farm (now the Hlatikulu Crane and Wetland Sanctuary) is one of the few programmes in KwaZulu-Natal and in fact in southern Africa as a whole, that seeks to re-establish wetland in an area where wetland once existed.

The programme, initiated in 1991, sought to raise the water table of the sanctuary area (ie. to re-establish the original hydrologic regime) so as to facilitate the return and re-establishment of wetland plants. It is also envisioned that as wetland does become re-established the area will provide suitable habitat for wetland birds, particularly cranes and waterfowl.

This programme to raise the water table consisted of three construction phases. In each phase a number of damlets and a larger dam were constructed along the furrows to retard the flow of water out of the sanctuary and allow for a subsequent rise in the water table. In this way, over the three-year period of the programme the entire ridge and furrow network in the sanctuary area was blocked with nearly 500 damlets and 3 larger dams.

As each phase of the construction was undertaken during the winters of 1991, 1992 and 1993 the possibility of monitoring the effect of the wetland re-establishment and rehabilitation programme changes in vegetation surrounding the damlets over quantifiable periods of time became apparent. Monitoring would provide an indication of what vegetational changes are taking place as a result of the changes to the hydrologic regime. It would also give an idea of the successional processes at work amongst wetland plant communities through the monitoring of changes to vegetation in the sanctuary. These factors would be a vital component in understanding the structure and functioning of the Hlatikulu Vlei.

While the monitoring of the changes to vegetation as a result of a programme was considered to be a vital part of this project, the effects of the soil stored seed bank could not be ignored. Seed banks play a major role in the vegetation dynamics and the distribution of plants in wetlands (Poiani & Johnson, 1988). A 'seed bank' may be 'defined as an aggregation of ungerminated seed potential capable of replacing existing adult plants', and thus any disturbance which alters the composition of the adult plants may eventually alter the composition of the seed bank (Baker, 1989). Thus the effects of the wetland re-establishment and rehabilitation programme on the soil stored seed bank, and indeed the effects of the seed bank on the programme were also monitored and assessed.

Under usual conditions, wetlands have three attributes in common which undoubtably affect the composition of the soil stored seed bank. These are flooded or saturated soils (for at least part of the growing season), hydric soils and vegetation adapted to a particular hydrological regime (Leck, 1989). However, with the destruction of the wetland vegetation in the sanctuary area and the fact that the wetland has been drained for a period of nearly thirty years, the seed bank will inevitably have undergone considerable change as the maintenance of seed banks depends on the dynamics of both the seed bank and the vegetation. These factors in turn, depend on recruitment from the seed bank, survival to reproductive age, dispersal, predation and viability of the seeds themselves (Leck, 1989).

The study of the effects of the wetland re-establishment and rehabilitation programme thus has a dual nature in that the vegetation and the seed banks were monitored to answer the a number of questions.

With regard to the vegetation the foolwing questions were posed:

What vegetation was present in the sanctuary prior to the draining in the mid-1960's?

What vegetation was present in the sanctuary prior to the wetland re-establishment and rehabilitation programme?

What vegetation is present now in the sites where dams were constructed in 1991?

What vegetation is present now in the sites where dams were constructed in 1992?

What vegetation is present now in the sites where dams were constructed in 1993?

Is there a significant difference between species composition in the 1991, 1992 and 1993 sites in the sanctuary?

Is the wetland re-establishment and rehabilitation programme allowing for the return of wetland vegetation present in the area prior to draining of the area in the mid-1960's?

With regard to the seed banks, the following questions were posed:

What might the seed bank composition of the sanctuary area have been prior to 1960?

What are the present seed bank compositions in various areas of the sanctuary?

Is there a difference between the pre-drainage seed bank composition and the extant seed banks?

Is there a difference between the seed banks in the areas of the sanctuary where damlets have been present for differing periods of time?

How might the present seed banks in the sanctuary affect the re-establishment of wetland to this area?

7.2. Methods

7.2.1 Vegetation sampling in the Hlatikulu Crane and Wetland Sanctuary

7.2.1.1 Vegetation prior to draining of sanctuary

From the vegetation map for 1944 (see Chapter 5) one is able to establish that the dominant vegetation community that occupied the sanctuary prior to draining was a mixed sedge and grass sedge-meadow community. Much of the Hlatikulu Vlei is covered by this vegetation community. Thus sampling in areas where this community was present was seen to be a reliable method by which to determine what the species composition of the vegetation in the sanctuary might have been prior to the draining of this area in the 1960's. This method however can only give an approximation of previous vegetation compositions and can never be entirely accurate.

Thus to determine the composition of these mixed sedge and grass sedge-meadow communities, three sites (sites 7, 46 and 57 in Figure 5.3) were selected within these communities. At each site 100, 1x1 m quadrats were sampled in an area of 25 x 25m ($625m^2$). As each site was dominated by 'hummocks and channels' half of the quadrats were located on hummocks and the other half were located in the channels. Each quadrat was divided into a grid of 100, 10x10 cm squares and the frequency percentage for each species was determined.

7.2.1.2 Vegetation prior to the wetland re-establishment and rehabilitation programme

After the drainage of the sanctuary, pasture grasses were planted to replace the previous wetland vegetation. In order to monitor the effects on the vegetation by the wetland re-establishment and rehabilitation programme on the sanctuary, the composition of the vegetation prior to the initiation of the programme needs to be determined. There were areas in the sanctuary that had not yet been affected by the rehabilitation programme. This was so because all the stages of the rehabilitation programme had not yet been implemented. Thus these areas were chosen for sampling so that the composition of the vegetation prior to the establishment of the rehabilitation programme might be determined. In each of three sites (37, 41 and 50 in Figure 5.3) in these areas 100, 1x1 m quadrats were sampled in an area of $625m^2$. Once again each quadrat was divided into a grid of 100, 10x10 cm squares so that the frequency percentage for each species could be determined.

7.2.1.3 Extant vegetation in the sanctuary

As the damlets in the sanctuary were constructed at yearly intervals over a three year period, the comparison of vegetation of a quantifiable ages (ie; 3 years old, 2 years old and 1 year old) was conducted. Thus a total of 81 damlets at 27 sites were sampled. The 27 sites were positioned in the sanctuary so that nine sites were located in the area where damlets were constructed in 1991 and the vegetation age was three years old, nine sites were located in the area where damlets were constructed in 1992 and the vegetation age was two years old, nine sites were located in the area where damlets were constructed in 1993 and the vegetation age was one year old.

Also to assess the effect of a south to north and a east to west downward slope (called gradient 1 and gradient 2 respectively) through the sanctuary the nine sites in each of the three vegetation age categories were arranged in a 3 x 3 site grid to allow for comparison between sites along Gradient 1 and along Gradient 2 respectively (Figure 7.1 indicates the position of the sites).

At each damlet three transects were positioned from the damlet wall through the damlet to the grass areas at the top of the damlet. In each transect 5, 1x1 m quadrats sampled were sampled so that Locality 1 was on the damlet wall, locality 2 was at the bottom area of the damlet, Locality 3 was at the middle area of the damlet, Locality 4 was at the top area of the damlet and Locality 5 was in the grass area at the top of the damlet wall (Figures 7.2 and 7.3).

As each quadrat had a grid of 100, 10 x 10 cm squares the frequency percentage of each species was determined by counting the number of squares in which a particular species was present.

The data for each species were analysed using multi-factor ANOVA to determine if there was a significant difference in the frequency percentages of the species due to the different factors affecting species abundances in the sanctuary (*i.e.*: Between vegetation of one, two or three years of age, between sites at the top, middle and bottom of gradient 1, between sites at the top, middle and bottom of gradient 2, between the 5 localities along the transects and between the three transects).

Using Canonical correspondence analysis (CCA), described in Section 6.1 in Chapter 6, the data for all the sites in existing vegetation in the sanctuary was analysed to

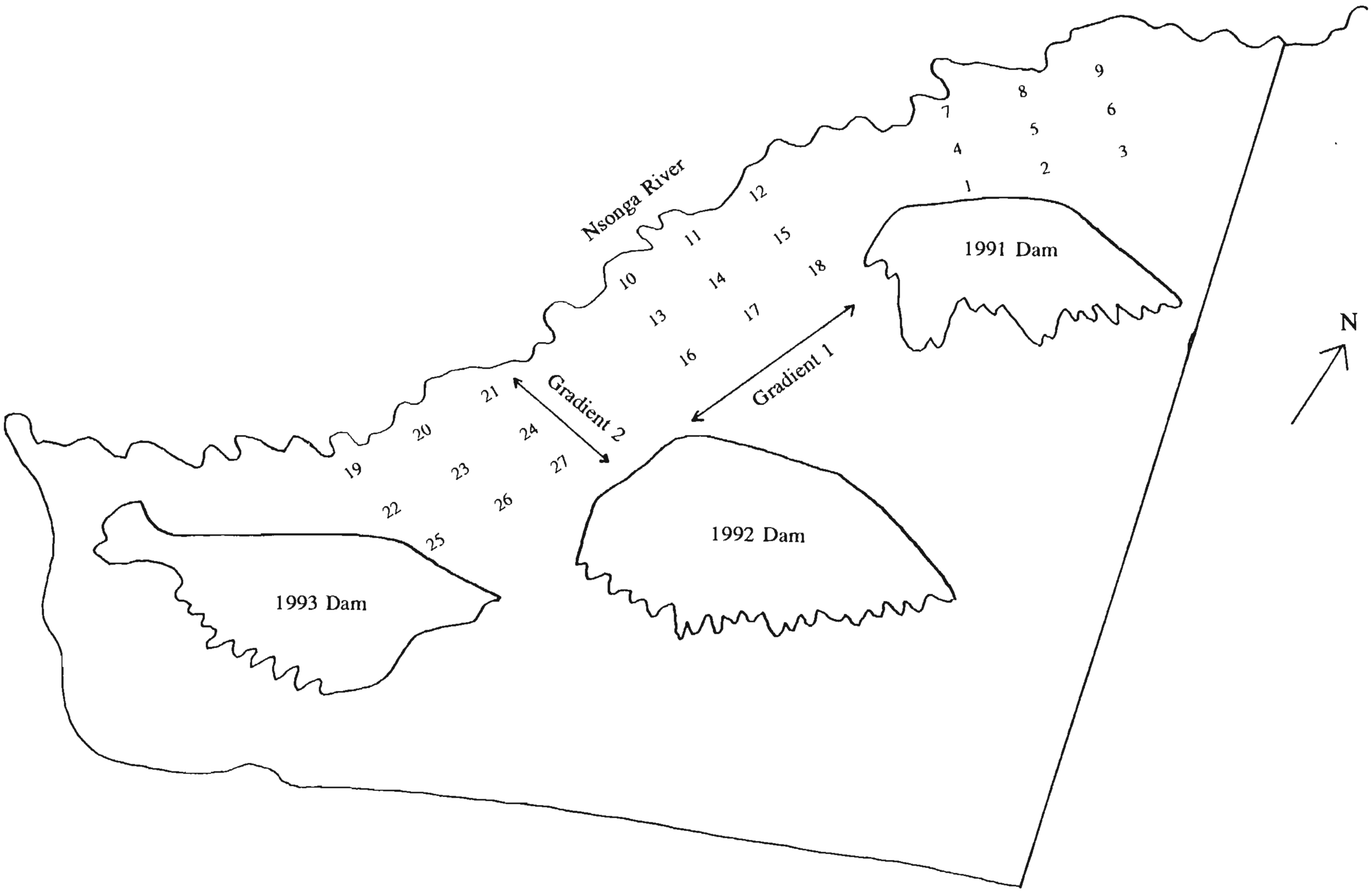


Figure 7.1: The locality of sample sites in the Hlatikulu Crane and Wetland Sanctuary. (Sites 1 to 9 are in the area where damlets were constructed in 1991, sites 10 to 18 are in the area where damlets were constructed in 1992, sites 10 to 18 are in the area where damlets were constructed in 1993. Gradients 1 and 2 are described in section 6.2.1.3).

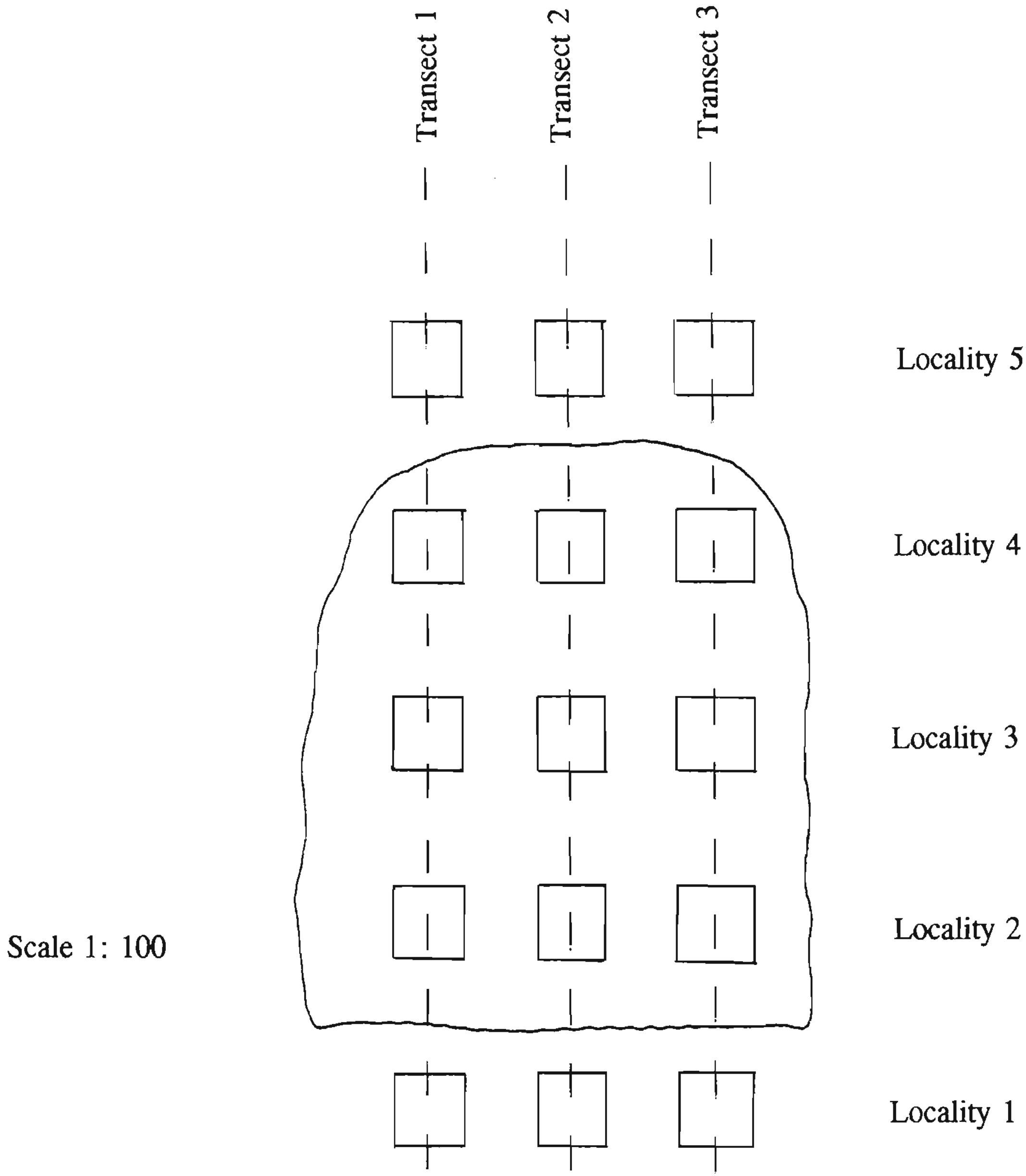


Figure 7.2: Diagram showing the locations of transects through a generalised damlet as viewed from above the damlet. There are five quadrat localities at each the three transects. (Locality 1 is on the damlet wall, locality 2 is at the bottom of the damlet in water depths greater than 0.5 m, locality 3 is in the middle of the damlet at depths from between 0.25 and 0.5 m, locality 4 is at the top of the damlet on depths of water from 0.01 m to 0.25 m and locality 5 is in the area adjacent to the top of the damlet.)

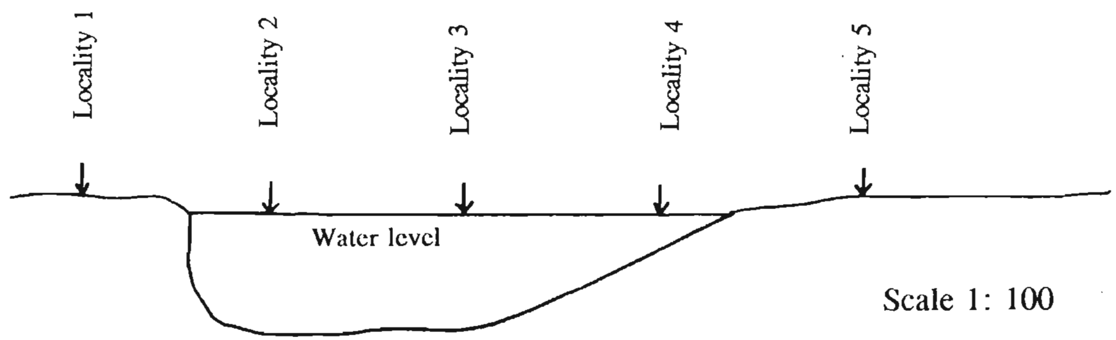


Figure 7.3: Diagram showing the placement of quadrats at five localities along the transect through a cross-section of a generalised damlet. (Locality 1 is on the damlet wall, locality 2 is at the bottom of the damlet in water depths greater than 0.5 m, locality 3 is in the middle of the damlet at depths from between 0.25 and 0.5 m, locality 4 is at the top of the damlet on depths of water from 0.01 m to 0.25 m and locality 5 is in the area adjacent to the top of the damlet.)

determine the effects of environmental variables by ordinating the species in a species-environment biplot. Here the following environmental variables were used:

The age of a damlet was designated in terms of time elapsed between construction so that those constructed in 1991 were three years old, those constructed in 1992 were two years old and those constructed in 1993 one year old.

The position of the damlet along gradient 1 was rated as 1, 2 and 3 to reflect its position at the top, middle and bottom of the gradient respectively. Likewise the position of the damlet along gradient 2 was rated as 1, 2 and 3 to reflect its position at the top, middle and bottom of the gradient respectively. The position of quadrats within the damlet were designated the following values according to the degree of saturation:

Locality 1 on the damlet wall was taken to represent the second driest locality and given a value of 2, Locality 2 was at the bottom area of the damlet in depths greater than 0.5 m, representing the most saturated locality was given a value of 5, Locality 3 at the middle area of the damlet at water depths ranging between 0.25 and 0.5 m was given a value of 4, Locality 4 at the top area of the damlet in water depths ranging between 0.01 and 0.25 m was given a value of 3 and Locality 5 in the grass area at the top of the damlet wall, representing the driest locality, was given a value of one.

7.2.2 Soil stored-seed bank sampling

Considerable research has been conducted in the Northern Hemisphere on seed banks in wetlands (Leck 1989). Methodology in establishing the composition and size of wetland seed banks varies greatly among authors. Thus certain researchers have concentrated on the evaluation of methods used in determining seed bank composition and size. When evaluating the seedling emergence method and the flotation method for determining seed bank size, both methods had inherent problems (de Villiers *et al.* 1994). However, the seedling emergence method used to determine wetland seed bank composition was found to be generally accurate and widely used (Poiani & Johnson, 1988).

Sampling of seed banks has been found to be a useful tool for management and restoration of natural vegetation (van der Valk & Pederson, 1989) and the prediction of changes in plant communities (Keddy & Reznicek, 1982, 1986). Also the potential for the development of wetland vegetation from the seed bank after drawdowns is recognised (Welling et al. 1988a, 1988b; ter Heerdt & Drost, 1994).

If, in the Hlatikulu Crane and Wetland Sanctuary one is able to establish what the seed bank was prior to the draining of the wetland area and if one is able to establish what the seed bank was prior to the initiation of the wetland re-establishment and rehabilitation programme, then various important comparisons may be made. Not only may the data gathered about seed banks prior to the events described above be compared with data on current seed banks, but the changes to the seed banks that have resulted from the disturbances to the area may be determined.

To determine the seed bank composition in the Hlatikulu Crane and Wetland Sanctuary for the following conditions: prior to draining of the sanctuary in the mid-1960's; prior to the establishment of the wetland re-establishment and rehabilitation programme and the present situation in the sanctuary, soil cores were collected from appropriate sites described in Sections 7.2.2.1, 7.2.2.2 and 7.2.2.3 below.

The soil cores were collected at the sites described below in tubes 12.5 cm in length and a surface area of 80 cm^2 so that the total volume was 1000 cm^3. These tubes were cut from standard PVC plumbing pipes with a diameter of 11cm. The soil was placed in seed trays (185 x 270 x 75mm) and maintained in greenhouses in the Department of Botany. The soil was watered regularly to prevent it from becoming dry to allow for the germination of seedlings. Seedlings were counted and given code names until representatives, which were grown to flowering stage, could be identified. These soil cores were collected during February, June and October 1993 and February 1994. The seedling germination of each soil core was monitored for 12 months after the date of collection.

7.2.2.1 Seed bank prior to draining of sanctuary

From aerial photographs taken in 1944 one is able to establish that the dominant vegetation community that occupied the S.A.C.F.'s portion of Tierhoek was the sedge and grass sedge-meadow community. This community has the greatest species diversity of all communities in the Hlatikulu Vlei and is characterised by the presence of 'hummocks and channels'. The hummocks have a greater species diversity than the channels, with the dominant grasses being; *Aristida junciformis*, *Andropogon appendiculatus*, *Eragrostis capensis* and *Arundinella nepalensis*, the dominant sedges being; *Rhynchospora brownii* and *Cyperus denudatus* and many herbs, the dominant species being; *Ledebouria cooperi*, *Tulbaghia natalensis*, *Gerbera ambigua*, *Chironia krebsii*, *Satyrium trinerve*, *Commelina africana*, *Pycnostachys reticulata* and *Cyrtanthus breviflorus*. The channels are almost exclusively dominated by one sedge *Cyperus denudatus*, with other sedges and rushes such as *Isolepis fluitans*, *Carex austro-africana*, *Carex cognata*, *Juncus effusus* and *Juncus oxycarpus* being much less abundant. All species recorded on the hummocks and in the channels are given in Tables 7.1 and 7.2 respectively.

Having established that the type of vegetation likely to have been present in the sanctuary prior to its being drained was that of the mixed sedge and grass sedge-meadow community, which still covers much of the Hlatikulu Vlei outside of the sanctuary, it was possible to sample the seed bank in these areas to obtain a reasonable idea of what the seed bank in the sanctuary might have been prior to it being drained.

To determine the composition of the seed bank in this sedge and grass sedge-meadow community, 30 soil cores were taken at each of three sites (sites 7, 46 and 57 in Figure 5.3). As each site is dominated by 'hummocks and channels' half of the cores were taken from on top of hummocks and the other half were taken from the channels.

7.2.2.2 Seed bank prior to the wetland re-establishment and rehabilitation programme

In order to monitor the effects on the seed bank by the wetland re-establishment and rehabilitation programme on the sanctuary, the composition of the seed bank prior to the initiation of the rehabilitation programme was determined. This was achieved through sampling in areas of the sanctuary where the rehabilitation programme had not yet been implemented. In each of three sites (37, 41 and 50 in Figure 5.3) 30 soil cores were collected and placed in seed trays to allow for the germination of seed from the soils.

7.2.2.3 Extant seed banks in the sanctuary

At three sites within the Hlatikulu Crane and Wetland Sanctuary, 90 soil cores were collected. Thirty soil cores were taken in areas where damlets were constructed in 1991, 30 cores in areas where damlets were constructed in 1992 and 30 in areas where damlets were constructed in 1993. To obtain 30 soil cores in each of these areas described above, 15 soil cores were taken from within the damlets and 15 soil cores were taken from the grassland adjacent to the dams. In this way each of the areas affected by the respective phases of damlet construction in 1991, 1992 and 1993 were sampled. The soil cores were placed in seed trays to allow for the germination of seed from the soils.

7.3 Results

7.3.1 Vegetation sampling in the Hlatikulu Crane and Wetland Sanctuary

7.3.1.1 Vegetation prior to draining of sanctuary

As mixed sedge and grass sedge-meadow communities were known to exist in the Hlatikulu Crane and Wetland Sanctuary prior to its draining in the mid-1960's, the species composition of the vegetation in the Sanctuary prior to its draining is assumed to be similar to the species composition found in areas currently supporting mixed sedge and grass sedge-meadow communities. Thus from the sampled areas (Section 7.2.1.1) 53 species were recorded on the hummocks and 19 were recorded in the channels in the mixed sedge and grass sedge-meadow community. The species are listed and ranked according to their mean frequency percentages in Tables 7.1 and 7.2 respectively. Most species on the hummocks have mean frequency percentages of less than 4 % but 9 species have mean frequency percentages of more than 4 %. *Aristida junciformis* has the highest mean frequency percentage of 38.2 % whilst *Andropogon appendiculatus, Ledebouria cooperi, Eragrostis capensis, Rhynchospora brownii, Tulbaghia natalensis, Gerbera ambigua, Chironia krebsii* and *Cyperus denudatus* have mean percentage frequencies of 31.5 %, 28.2 %, 18.8 %, 17.6 %, 9.3 %, 6.1 %, 6.5 % and 5.8 % respectively.

7.3.1.2 Vegetation prior to the wetland re-establishment and rehabilitation programme

From sampling in areas that had not been subjected to the rehabilitation (section 7.2.1.2) it was possible to establish what the species composition of vegetation in the sanctuary was prior to the initiation of the wetland re-establishment and rehabilitation programme. The species, their mean frequency percentages and their rankings are given in Table 7.3. In all 36 species were recorded but the vegetation was dominated

Table 7.1: Hummock species in sedge and grass sedge-meadow communities with the mean frequency percentages for each species.

Rank	Species	Mean frequency %
1	*Aristida junciformis*	38.2
2	*Andropogon appendiculatus*	31.5
3	*Ledebouria cooperi*	28.2
4	*Eragrostis capensis*	18.8
5	*Rhynchospora brownii*	17.6
6	*Tulbaghia natalensis*	9.3
7	*Gerbera ambigua*	6.1
8	*Chironia krebsii*	6.5
9	*Cyperus denudatus*	5.8
10	*Satyrium trinerve*	3.9
11	*Commelina africana*	3.5
12	*Pycnostachys reticulata*	3.2
13	*Cyrtanthus breviflorus*	3.1
14	*Arundinella nepalensis*	2.9
15	*Pseudognaphalium luteo-album*	2.9
16	*Sebaea sedoides*	2.6
17	*Senecio tysonii*	2.6
18	*Digitaria diagonalis*	2.2
19	*Eulalia villosa*	1.8
20	*Graderia scabra*	1.8
21	*Eragrostis curvula*	1.7
22	*Hypochoeris radicata*	1.7
23	*Nerine prancratioides*	1.7
24	*Senecio cathcartensis*	1.5
25	*Monocymbium ceresiiforme*	1.4
26	*Sopubia manii*	1.2
27	*Eragrostis planiculmis*	1.2
28	*Panicum schinzii*	1.1
29	*Helichrysum epapposum*	1.1
30	*Agrostis lachnantha*	0.9
31	*Pennisetum sphacelatum*	0.9
32	*Pycreus uniloides*	0.9
33	*Schizochilus zeyheri*	0.8
34	*Conyza pinnata*	0.8
35	*Helichrysum aureonitens*	0.8
36	*Ranunculus multifidus*	0.7
37	*Argyrolobium tuberosum*	0.6
38	*Hypoxis rigidula*	0.6
39	*Ophiglossum polyphyllum*	0.6
40	*Pycreus macrantha*	0.6
41	*Wahlenbergia pallidiflora*	0.6
42	*Conyza podocephala*	0.5
43	*Helichrysum pilosellum*	0.3
44	*Aristea cognata*	0.3
45	*Disperis tysonii*	0.3
46	*Drosera burkeana*	0.3
47	*Hesperantha lactea*	0.2
48	*Juncus effusus*	0.2
49	*Lobelia erinus*	0.1
50	*Mimulus gracilis*	0.1
51	*Polygonum plebeium*	0.1
52	*Ascolepis capensis*	0.1
53	*Monopsis decipiens*	0.07

Table 7.2: Channel species in sedge and grass sedge-meadow communities with the mean frequency percentages for each species.

Rank	Species	Mean frequency %
1	*Cyperus denudatus*	92.4
2	*Isolepis fluitans*	8.1
3	*Carex austro-africana*	3.4
4	*Carex cognata*	2.6
5	*Juncus effusus*	1.7
6	*Juncus oxycarpus*	1.7
7	*Eleocharis dregeana*	1.2
8	*Polygonum plebeium*	1.2
9	*Pycreus flavescens*	0.9
10	*Juncus tenuis*	0.8
11	*Eragrostis planiculmis*	0.6
12	*Juncus dregeanus*	0.6
13	*Limosella maior*	0.6
14	*Rhynchospora brownii*	0.6
15	*Utricularia prehensilis*	0.6
16	*Aponogeton junceus*	0.5
17	*Schoenoplectus decipiens*	0.3
18	*Agrostis lachnantha*	0.1
19	*Schoenoplectus brachyceras*	0.08

Table 7.3: Species recorded in areas of the Hlatikulu Crane and Wetland Sanctuary which as yet were unaffected by the wetland re-establishment and rehabilitation programme. The mean frequency precentage is given for each species.

Rank	Species	Mean frequency %
1	*Paspalum dilatatum*	54.2
2	*Eragrostis curvula*	33.6
3	*Eragrostis plana*	12.4
4	*Conyza pinnata*	7.6
5	*Oxalis corniculata*	6.8
6	*Arundinella nepalensis*	6.3
7	*Leersia hexandra*	6.1
8	*Cymbopogon validus*	5.6
9	*Eragrostis planiculmis*	4.3
10	*Cyperus esculentus*	4.1
11	*Helichrysum aureonitens*	3.7
12	*Setaria pallide-fusca*	3.1
13	*Oxalis corniculata*	1.3
14	*Lolium multiflorum*	1.2
15	*Conyza chilensis*	0.9
16	*Verbena bonariensis*	0.8
17	*Helichrysum glomeratum*	0.7
18	*Hemarthria altissima*	0.5
19	*Aristida junciformis*	0.3
20	*Echinocloa crus-galli*	0.3
21	*Bromus catharticus*	0.3
22	*Cynodon dactylon*	0.2
23	*Agrostis lachnantha*	0.2
24	*Rumex acetosella*	0.2
25	*Conyza podocephala*	0.2
26	*Pseudognaphalium luteo-album*	0.1
27	*Juncus effusus*	0.1
28	*Cirsium vulgare*	0.1
29	*Verbena bonariensis*	0.1
30	*Rubus cuneifolius*	0.1
31	*Agrostis eriantha*	0.1
32	*Mariscus congestus*	0.05
33	*Wahlenbergia undulata*	0.03
34	*Hypochoeris radicata*	0.03
35	*Pycreus uniloides*	0.02
36	*Echinocloa crus-galli*	0.02

almost entirely by the grasses *Paspalum dilatatum, Eragrostis curvula* and *Eragrostis plana* with mean frequency percentages of 54.2 %, 33.6 % and 12.4 % respectively.

7.3.1.3 Extant vegetation in the sanctuary

A total of forty-five species were recorded in the sites sampled in the sanctuary (Table 7.4). Three species were dominant with mean frequency percentages greater than 10 % (*Paspalum dilatatum* with 32.6 %, *Setaria pallide-fusca* with 12.7 % and *Eleocharis dregeana* with 12.4 %), eleven species had mean frequency percentages greater than 1 % and the rest (31 species) had frequency percentages less than 1 %.

When comparing Tables 7.3 and 7.4, not only is it apparent that the dominant species prior to the wetland re-establishment and rehabilitation programme have smaller mean frequency percentages, *Paspalum dilatatum* (the dominant species prior to the rehabilitation programme and after its inception) declining from 54.2 % to 32.6 %, *Eragrostis curvula* declining from 33.6 % to 4.9 % and *Eragrostis plana* from 12.4 % to less than 1 %, but there are a number of wetland species recorded in the sanctuary. These include the sedges; *Eleocharis dregeana, Schoenoplectus decipiens, Cyperus denudatus, Cyperus flavescens, Isolepis fluitans, Fuirena pubescens, Pycreus uniloides* and *Carex cognata*; the reed *Phragmites australis*; the rush; *Juncus oxycarpus* and other wetland plants; *Polygonum plebeium, Aponogeton junceus* and *Helichrysum mundtii* which were not recorded in the sanctuary prior to the initiation of the rehabilitation programme.

The mean frequency percentages for each species for the 1993 damlets, 1992 damlets and the 1991 damlets are given in Table 7.5 for comparison. The grasses *Paspalum dilatatum, Setaria pallide-fusca, Panicum schinzii* and *Eragrostis curvula* have their highest frequencies in the youngest damlets and show a marked reduction in frequency as the damlets get older. The species *Eleocharis dregeana, Hemarthria altissima, Schoenoplectus decipiens, Eragrostis planiculmis, Agrostis lachnantha, Juncus effusus* and *Cyperus denudatus* have their highest frequencies in the oldest dams and show a marked reduction in frequency as the damlets get younger. Only the 14 dominant

Table 7.4: Species recorded in vegetation and seed bank of the Hlatikulu Crane and Wetland Sanctuary. The mean frequency percentage and the total number of seedlings that germinated from soil cores are given for each species.

Rank	Species	Mean frequency %	Seedling number
1	*Paspalum dilatatum*	32.6	4296
2	*Setaria pallide-fusca*	12.7	3131
3	*Eleocharis dregeana*	12.4	886
4	*Hemarthria altissima*	7.7	1269
5	*Panicum schinzii*	6.9	3592
6	*Schoenoplectus decipiens*	6.0	1323
7	*Cyperus difformis*	5.9	1345
8	*Eragrostis planiculmis*	5.8	1040
9	*Eragrostis curvula*	4.9	648
10	*Agrostis lachnantha*	4.4	845
11	*Juncus effusus*	4.0	755
12	*Echinocloa crus-galli*	2.4	1298
13	*Leersia hexandra*	1.1	476
14	*Cyperus denudatus*	1.1	646
15	*Cyperus esculentus*	0.8	5669
16	*Juncus oxycarpus*	0.8	238
17	*Cyperus flavescens*	0.7	225
18	*Cynodon dactylon*	0.7	215
19	*Polygonum plebeium*	0.4	149
20	*Agrostis eriantha*	0.4	125
21	*Rumex angiocarpus*	0.3	88
22	*Isolepis fluitans*	0.3	0
23	*Pseudognaphalium luteo-album*	0.2	1846
24	*Mariscus congestus*	0.2	63
25	*Fuirena pubescens*	0.1	0
26	*Arundinella nepalensis*	0.1	35
27	*Pycreus uniloides*	0.1	35
28	*Oxalis corniculata*	0.1	649
29	*Commelina africana*	0.1	26
30	*Trifolium repens*	0.1	31
31	*Eragrostis plana*	0.1	193
32	*Wahlenbergia undulata*	0.04	0
33	*Conyza podocephala*	0.03	1166
34	*Carex cognata*	0.02	0
35	*Verbena bonariensis*	0.02	72
36	*Crassula pellicida*	0.02	6
37	*Cirsium vulgare*	0.01	54
38	*Conyza pinnata*	0.01	0
39	*Aponogeton junceus*	0.01	5
40	*Phragmites australis*	0.01	0
41	*Cymbopogon validus*	0.01	3
42	*Rubus cuneifolius*	0.01	94
43	*Helichrysum mundtii*	0.01	0
44	*Hypochoeris radicata*	0.01	0
45	*Poa binata*	0.003	0

Table 7.5: Mean frequency percentages for species recorded in the 1991, 1992 and 1993 damlets in the Hlatikulu Crane and Wetland Sanctuary.

Rank	Species	1993	1992	1991
1	*Paspalum dialatatum*	40.51	36.91	20.48
2	*Setaria pallide-fusca*	20.85	13.43	3.68
3	*Eleocharis dregeana*	0	9.33	28.01
4	*Hemarthria altissima*	0	5.85	17.11
5	*Panicum schinzii*	13.77	6.31	0.84
6	*Schoenoplectus decipiens*	0	2.10	15.97
7	*Cyperus difformis*	3.52	14.02	0
8	*Eragrostis planiculmis*	1.73	4.05	11.57
9	*Eragrostis curvula*	8.74	3.27	3.12
10	*Agrostis lachnantha*	0	4.78	8.70
11	*Juncus effusus*	0	0.85	11.57
12	*Echinocloa crus-galli*	1.71	3.51	2.03
13	*Leesia hexandra*	0.51	2.18	0.67
14	*Cyperus denudatus*	0	0.37	2.98

Table 7.6: Mean frequency percentages for species recorded in the five localities of the damlets in the Hlatikulu Crane and Wetland Sanctuary.

Rank	Species	1	2	3	4	5
1	*Paspalum dialatatum*	47.23	0	0	37.67	78.15
2	*Setaria pallide-fusca*	34.83	0	0	5.30	23.16
3	*Eleocharis dregeana*	1.55	16.02	19.85	16.07	8.71
4	*Hemarthria altissima*	16.76	0	1.65	5.95	13.90
5	*Panicum schinzii*	17.82	0.14	0.54	5.33	11.03
6	*Schoenoplectus decipiens*	0	10.12	11.5	8.05	0.42
7	*Cyperus difformis*	15.01	0	0	4.29	9.95
8	*Eragrostis planiculmis*	5.48	0	0	11.03	12.41
9	*Eragrostis curvula*	9.56	0	0	1.79	13.16
10	*Agrostis lachnantha*	13.54	0	0.78	3.90	4.57
11	*Juncus effusus*	1.2	1.7	0	15.32	3.24
12	*Echinocloa crus-galli*	7.35	0	0.2	3.9	0.63
13	*Leesia hexandra*	3.48	0	0	0.87	1.27
14	*Cyperus denudatus*	0	0.29	1.01	3.51	0.79

species each with a mean frequency percentage greater than 1 % are presented in Table 7.5 (Figure 7.1).

The mean frequency percentages for each species for five localities along the transects are given in Table 7.6 for comparison (Figures 7.2 and 7.3). Most species are absent from the localities within the damlets (localities 2 & 3), but are present on the dam wall (locality 1) and the edges of the damlets (localities 4 & 5). These include *Paspalum dilatatum, Setaria palide-fusca, Cyperus difformis, Eragroatis planiculmis, E. curvula* and *Leersia hexandra*. Other species are found predominately in the damlets (localities 2 & 3) and are absent or less frequently found on the dam wall (locality 1) and the edges of the damlets (localities 4 & 5). These include *Eleocharis dregeana, Schoenoplectus decipiens* and *Cyperus denudatus*.

The statistically significant differences in frequency percentages for the various factors influencing plant abundances in the Hlatikulu Crane and Wetland Sanctuary are given in Table 7.7. Here the differences in frequency percentages for the 1, 2 and 3 year old vegetation and the differences in frequency percentages for the localities 1, 2, 3, 4 and 5 at the each damlet are highly significant. The differences in frequency percentages for gradient 1 and gradient 2 are only highly significant for *Panicum schinzii* and the differences in frequency percentages for the transects is not highly significant.

Of the 14 dominant species in the damlets sampled in the sanctuary 12 species show a statistically significant difference in frequency percentage from younger damlets to older damlets (Table 7.7). The dominant grasses of 1990 show declines in the mean frequency percentages from younger damlets to older damlets. In Table 7.5 *Paspalum dilatatum*, the dominant grass in 1990, shows a decrease of its mean frequency percentage of 40% in and around the youngest damlets constructed in 1993 to 21% in and around damlets constructed in 1991. Other grassland species show similar declines, such as *Setaria pallide-fusca*, *Panicum schinzii* and *Eragrostis curvula*.

Some species such as *Cyperus difformis*, *Echinocloa crus-galli* and *Leersia hexandra* have mean frequency percentages which tend to increase and then drop off with

Table 7.7: Statistically significant differences (from Analysis of Variance) in the frequency percentages of species within various factors influencing their abundances in the Hlatikulu Crane and Wetland Sanctuary.

Rank	Species	Age of vegetation	Gradient 1	Gradient 2	Locality	Transects
1	*Paspalum dilatatum*	**			**	
2	*Setaria pallide-fusca*	**			**	
3	*Eleocharis dregeana*	**		*	**	
4	*Hemarthria altissima*	**			**	*
5	*Panicum schinzii*	**	**	**	**	
6	*Schoenoplectus decipiens*	**			**	
7	*Cyperus difformis*	**			**	
8	*Eragrostis planiculmis*	**	*		**	*
9	*Eragrostis curvula*	**			**	
10	*Agrostis lachnantha*	**			**	
11	*Juncus effusus*	**			**	
12	*Echinocloa crus-galli*				**	
13	*Leersia hexandra*	**	*	*	**	
14	*Cyperus denudatus*		*			

* = significant, ** = highly significant

increasing damlet age. The damlets constructed in 1992 have the greatest mean frequency percentages for these species than the 1991 damlets. The sedges *Eleocharis dregeana* and *Schoenoplectus decipiens* have their highest mean frequency percentages at locality 2 (bottom area of the damlets at depths of greater than 0.5 m) and locality 3 (middle area of the damlets at depths of between 0.25 and 0.5 m) showing that these species grow best in moist and saturated conditions. Most of the other species have small frequency percentage for these localities (Table 7.6).

Other species such as *Juncus effusus*, *Echinocloa crus-galli* and *Cyperus denudatus* grow best on the edges of the damlets at locality 4 (at the top area of the damlet where water depths are from 0.01 to 0.25 m) where soils are moist and less saturated than in the damlets themselves (Table 7.6).

Most of the dominant species (*Paspalum dilatatum, Setaria pallide-fusca, Hemarthria altissima, Panicum schinzii, Cyperus difformis, Eragrostis planiculmis, Eragrostis curvula, Agrostis lachnantha* and *Leersia hexandra*) grow best at localities 1 (on the damlet wall) and 5 (at the top of the damlet) where soils, while still moist, are not saturated and represent the drier end of the scale (Table 7.6).

7.3.1.3.1 Ordination of species in extant vegetation in the sanctuary

The results of the ordination are given in Figure 7.4 and Table 7.8. The correlation matrix of the environmental variables are shown in Table 7.9. The correlation matrix for all environmental variables with species axes are shown in Table 7.10.

The respective age of the damlet, the location of species within the damlets and the position of the damlet in relation to gradient 1 are the variables significantly correlated with the first two axes (see Table 7.10).

In the ordination in Figure 7.4 three groupings are identified. *Eleocharis dregeana, Juncus oxycarpus, Schoenoplectus decipiens* and *Cynodon dactylon* occur at saturated

Table 7.8: Ordination axes, corresponding eigenvalues, species-environment correlations, percentage variance accounted for and fraction of variance explained by CCA for all sites in the Hlatikulu Crane and Wetland Sanctuary.

Axis	Eigen-value	Species - environment correlation	Cumulative % Variance accounted for by axis	Fraction of variance explained
1	0.582	0.918	19.5	0.195
2	0.240	0.822	27.6	0.081
3	0.055	0.639	29.4	0.018
4	0.337	0.000	40.7	0.113

Table 7.9: Weighted correlation matrix for all environmental variables with each other, for all sites (Variables significantly correlated with each other are highlighted in bold).

Year	1.0000			
Location	0.3482	1.0000		
Gradient 1	**-1.0000**	-0.3482	1.0000	
Gradient 2	-0.0500	0.0251	0.0500	1.0000
	Year	Location	Gradient 1	Gradient 2

Table 7.10: Correlation matrix for all environmental variables with species axes for all sites. (Variables significantly correlated with each other are highlighted in bold).

SPEC AX1	1.00			
SPEC AX2	0.12	1.00		
SPEC AX3	-0.12	-0.04	1.00	
SPEC AX4	-0.18	-0.08	0.25	1.00
Year	**-0.74**	0.48	-0.06	0.00
Location	**-0.76**	-0.46	-0.01	0.00
Gradient 1	**0.74**	-0.48	0.06	0.00
Gradient 2	-0.05	0.01	**0.63**	0.00
	SPEC AX1	SPEC AX2	SPEC AX3	SPEC AX4

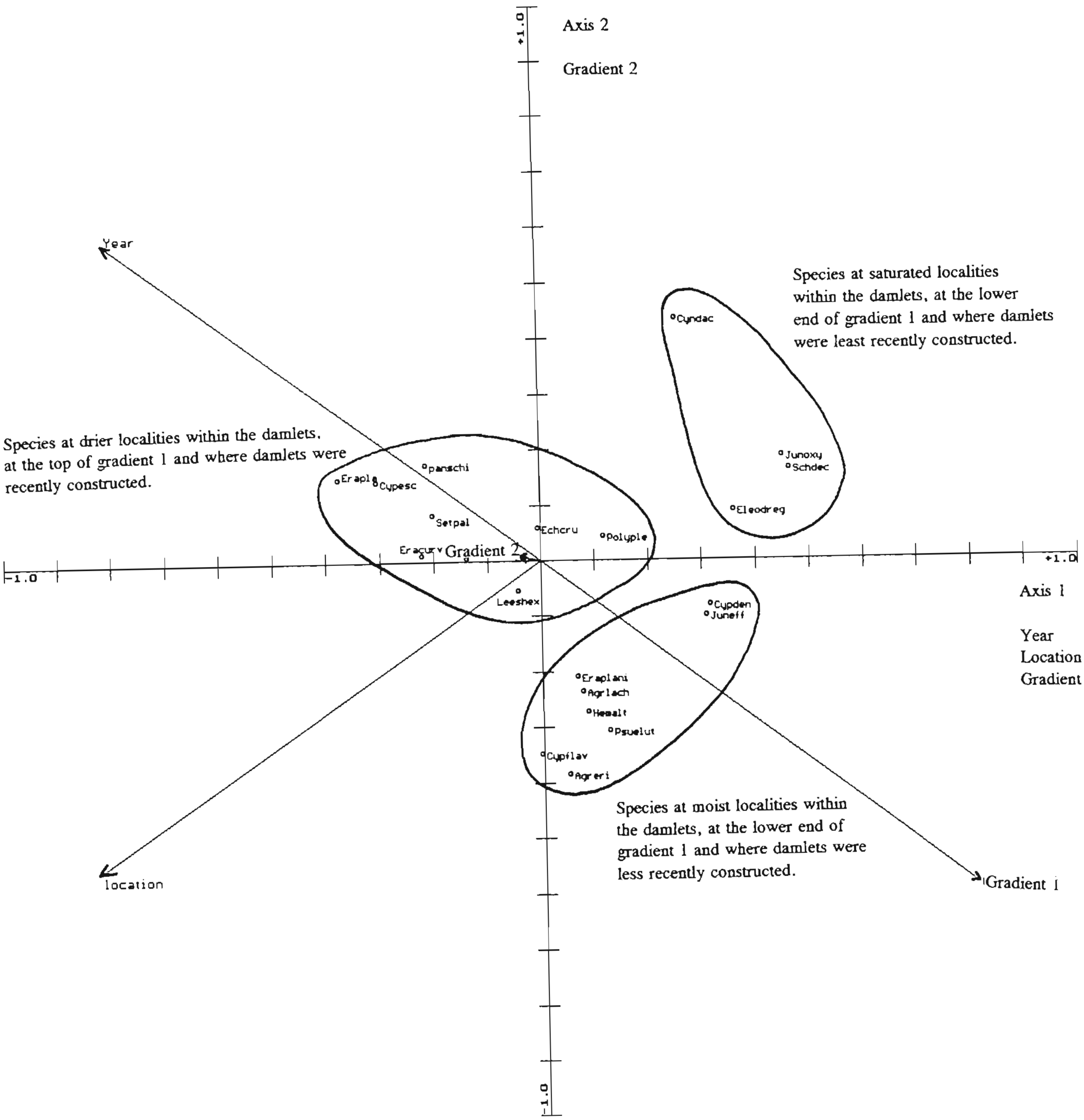


Figure 7.4: Biplot of species and environmental variables for all sites at the Hlatikulu Crane and Wetland Sanctuary.

(Species acronyms per Table 7.11. Variables significantly correlated with axes, listed under respective axes.)

Table 7.11: List of species names and acronyms used in the ordination diagram (Figure 7.4) for the Hlatikulu Crane and Wetland Sanctuary.

Species acronym	Full species name
Agreri	*Agrostis eriantha*
Agrlach	*Agrostis lachnantha*
Cyndac	*Cynodon dactylon*
Cypden	*Cyperus denudatus*
Cypesc	*Cyperus esculentus*
Cypflav	*Cyperus flavescens*
Echcru	*Echinochloa crus-galli*
Eleodreg	*Eleocharis dregeana*
Eracurv	*Eragrostis curvula*
Erapla	*Eragrostis plana*
Eraplani	*Eragrostis planiculmis*
Hemalt	*Hemarthria altissima*
Juneff	*Juncus effusus*
Junoxy	*Juncus oxycarpus*
Leeshex	*Leersia hexandra*
Panschi	*Panicum schinzii*
Polyple	*Polygonum plebeium*
Psuelut	*Pseudognaphalium luteo-album*
Schdec	*Schoenoplectus decipiens*
Setpal	*Setaria pallide-fusca*

localities within damlets that tend to be at the lower end of gradient 1, where damlets are the oldest.

In drier locations within the damlets that have been recently constructed and at the top of gradient 1, *Eragrostis plana, Cyperus esculentus, Panicum schinzii, Setaria pallide-fusca, Eragrostis curvula, Echinocloa crus-galli, Paspalum dilatatum, Polygonum plebeium* and *Leersia hexandra* occur.

Where localities are moist, the damlets at the lower end of gradient 1 and where damlets are older, *Cyperus denudatus, Juncus effusus, Eragrostis planiculmis, Agrostis lachnantha, Hemarthria altissima, Pseudognaphalium luteo-album, Cyperus flavescens* and *Agrostis eriantha* occur.

7.3.2 Soil stored seed bank

7.3.2.1 Seed bank prior to draining of sanctuary

The possible seed bank composition of the Hlatikulu Crane and Wetland sanctuary prior to draining is given in Table 7.12. Here 5197 seedlings representing 30 species germinated from soil cores taken in hummocks and channels in sedge and grass communities were similar to those that were present prior to the draining of the area in the mid 1960's. Greater numbers of seedlings germinated from the channel soil.

The seed bank of the area now forming the Hlatikulu Crane and Wetland Sanctuary would have, prior to being drained, been representative of the extant vegetation at that time. In Table 7.12 the possible seed bank composition is given showing that seed banks in the sedge and grass communities of Hlatikulu Vlei are extensively representative of the extant vegetation. What is worth noting is the intrusion into the present day seed bank of sedge and grass sedge-meadow communities by species that are not well represented in the extant vegetation such as *Cyperus esculentus, Pseudognaphalium luteo-album, Oxalis corniculata* and *Conyza podocephala*. These

Table 7.12: Possible seed bank composition of the Hlatikulu Crane and Wetland Sanctuary taken from sedge and grass communities similar to those that would have been found in the Hlatikulu Crane and Wetland Sanctuary prior to its being drained in the mid 1960's. Seedling totals represent seedling germination from 90 soil cores, 45 taken on hummocks and 45 taken in channels.

Rank	Species name	Hummock seedlings	Channel seedlings	TOTAL
1	Lobelia erinus	607	650	1257
2	Cyperus denudatus	242	854	1096
3	Schoenoplectus decipiens	85	737	822
4	Conyza pinnata	218	281	499
5	Pseudognaphalium luteo-album	271	227	498
6	Oxalis corniculata	158	96	254
7	Cyperus esculentus	73	107	180
8	Aristida junciformis	86	58	144
9	Eragrostis curvula	62	52	114
10	Conyza podocephala	17	65	82
11	Juncus effusus	8	52	60
12	Ledebouria cooperi	26	17	43
13	Cyperus difformis	2	24	26
14	Digitaria diagonalis	18	3	21
15	Panicum schinzii	20	1	21
16	Agrostis lachnantha	12	2	14
17	Echinocloa crus-galli	2	11	13
18	Eleocharis dregeana	0	11	11
19	Eragrostis capensis	8	0	8
20	Senecio cathcartensis	0	6	6
21	Paspalum dilatatum	0	6	6
22	Setaria pallide-fusca	4	1	5
23	Aponogeton junceus	0	4	4
24	Monopsis decipiens	0	3	3
25	Eragrostis plana	0	2	2
26	Satyrium trinerve	2	0	2
27	Cirsium vulgare	2	0	2
28	Cyrtanthus breviflorus	2	0	2
29	Mimulus gracilis	1	0	1
30	Helichrysum pilosellum	1	0	1
	TOTAL	1924	3268	5197

species are usually regarded as pioneer or weedy species which have probably been dispersed into these areas from neighbouring areas where lands have been disturbed and their growth there has occurred.

7.3.2.2 Seed bank prior to the wetland re-establishment and rehabilitation programme

The seed bank composition of the Hlatikulu Crane and Wetland sanctuary prior to the initiation of the wetland re-establishment and rehabilitation programme, is given in Table 7.13. Here 3501 seedlings representing 25 species germinated from soil cores taken in areas of the sanctuary that were not subjected to the wetland re-establishment and rehabilitation programme.

The seed bank of the Hlatikulu Crane and Wetland Sanctuary prior to the initiation of the wetland re-establishment and rehabilitation programme was heavily dominated by *Paspalum dilatatum, Eragrostis curvula, Setaria pallide-fusca, Cyperus esculentus* and *Panicum schinzii* which are species that were well represented in the vegetation prior to the programme. Many of the wetland species that would have originally occurred in the area had disappeared and fewer species are represented by the germinated seedings (Table 7.13).

7.3.2.3 Extant seed banks in the sanctuary

In the Hlatikulu Crane and Wetland Sanctuary 43 species were represented by 33390 seedlings that germinated from all the soil cores taken. In areas where damlets were constructed in 1991, 5804 seedlings representing 37 species germinated from soil cores taken in the damlets and 5538 seedlings representing 37 species germinated from soil cores taken in areas adjacent to the damlets. In areas where damlets were constructed in 1992, 4576 seedlings representing 31 species germinated from soil cores taken in the damlets and 11123 seedlings representing 31 species germinated from soil cores taken in areas adjacent to the damlets. In areas where damlets were constructed in 1993, 2093 seedlings representing 27 species germinated from soil cores taken in the damlets and

Table 7.13: **Composition of the seed bank prior to the initiation of the wetland re-establishment and rehabilitation programme in the Hlatikulu Crane and Wetland Sanctuary. Seedling totals represent seedling germination from 90 soil cores.**

Rank	Species name	Total seedlings
1	Paspalum dilatatum	1123
2	Eragrostis curvula	545
3	Setaria pallide-fusca	378
4	Cyperus esculentus	279
5	Panicum schinzii	242
6	Hemarthria altissima	201
7	Cyperus difformis	185
8	Oxalis corniculata	154
9	Eragrostis planiculmis	79
10	Cyperus flavescens	77
11	Agrostis lachnantha	47
12	Conyza podocephala	34
13	Eragrostis plana	33
14	Mariscus congestus	24
15	*Leersia hexandra*	23
16	Polygonum plebeium	17
17	Arundinella nepalensis	13
18	Cirsium vulgare	12
19	Pseudognaphalium luteo-album	11
20	Wahlenbergia undulata	7
21	Juncus effusus	6
22	Verbena bonariensis	5
23	Helichrysum pilosellum	3
24	Cymbopogon validus	2
25	Rubus cuneifolius	1
	TOTAL	3501

3446 seedlings representing 24 species germinated from soil cores taken in areas adjacent to the damlets. Table 7.12 lists the species recorded for each area where damlets were constructed and the numbers of seedlings germinating per species.

While the composition of the present seed banks in the Hlatikulu Crane and Wetland Sanctuary still shows a dominance by *Cyperus esculentus, Paspalum dilatatum, Panicum schinzii* and *Setaria pallide-fusca*, there is a notable reappearance and increase in certain wetland species. *Eleocharis dregeana, Schoenoplectus decipiens* and *Cyperus denudatus* have reappeared and the proportions of *Hemarthria altissima, Agrostis lachnantha, Juncus effusus* and *Leersia hexandra* in the seed bank are greater. Of the 6 species that were recorded in the seed bank and not in the extant vegetation at the sanctuary, namely *Hypoxis rigidula, Plantago lanceolata, Lobelia erinus, Polygonum kitaibelianum, Aristida junciformis* and *Digitaria diagonalis* (Table 7.14 gives the seedling numbers recorded for each species), only *Digitaria diagonalis* has been recorded in proportionally large numbers.

7.4 Discussion

The purpose of the joint wetland re-establishment and rehabilitation programme of the South African Crane Foundation and Mondi is to rehabilitate and replace wetland vegetation in the sanctuary area. Whilst it has been possible to determine that the wetland vegetation in the Hlatikulu Crane and Wetland Sanctuary originally was that of the mixed sedge and grass sedge-meadow community, this vegetation community was largely destroyed when the wetland areas of the sanctuary were drained in the mid-1960's. The species of the original vegetation community were replaced by other species so that by 1990 prior to the commencement of the wetland re-establishment and rehabilitation programme the area was dominated by a few species namely *Paspalum dilatatum, Eragrostis curvula* and *Eragrostis plana*. Since the initiation of the wetland rehabilitation programme, there have been a number of changes to the structure of the vegetation at the Hlatikulu Crane and Wetland Sanctuary.

Table 7.14: Composition of the seed banks at the Hlatikulu Crane and Wetland Sanctuary for 1991, 1992 and 1993 damlets and areas adjacent to 1991, 1992 and 1993 damlets. Seedling totals represent seedling germination from 90 soil cores, 45 taken in damlets and 45 taken in areas adjacent to damlets for each damlet age group.

	Year of damlet construction	1991	1991	1992	1992	1993	1993
Rank	Location of sample Species name	adjacent	damlet	adjacent	damlet	adjacent	**damlet**
1	Cyperus esculentus	1033	1451	2401	243	253	289
2	Paspalum dilatatum	821	432	1222	130	1064	626
3	Panicum schinzii	583	1013	1128	477	251	140
4	Setaria pallide-fusca	290	85	1534	358	595	269
5	Pseudognaphalium luteo-album	591	374	692	106	14	69
6	Cyperus difformis	42	172	852	3	209	67
7	Echinocloa crus-galli	152	305	593	212	0	36
8	Hemarthria altissima	318	0	0	374	215	362
9	Conyza podocephala	213	41	806	35	28	43
10	Eragrostis planiculmis	312	2	21	231	69	405
11	Schoenoplectus decipiens	45	760	22	172	45	9
12	Eleocharis dregeana	6	565	5	245	2	65
13	Agrostis lachnantha	274	87	374	57	112	8
14	Juncus effusus	225	33	86	342	366	67
15	Oxalis corniculata	62	33	309	24	0	109
16	Eragrostis curvula	79	59	90	6	32	48
17	Digitaria diagonalis	67	14	348	186	23	0
18	*Leersia hexandra*	105	47	279	0	0	13
19	Cyperus denudatus	98	33	90	147	89	73
20	Juncus oxycarpus	33	48	0	100	0	57
21	Cyperus flavescens	109	0	0	19	47	8
22	Cynodon dactylon	0	145	70	0	9	0
23	Eragrostis plana	66	29	9	37	0	5
24	Polygonum plebeium	8	10	13	45	2	64
25	Agrostis eriantha	78	14	0	31	0	2
26	Rubus cuneifolius	2	0	90	0	1	0
27	Rumex angiocarpus	0	0	76	0	0	12
28	Verbena bonariensis	6	49	21	1	14	43
29	Aristida junciformis	4	0	16	1	18	0
30	Mariscus congestus	43	1	0	5	0	1
31	Cirsium vulgare	5	4	11	6	0	13
32	Polygonum kitaibelianum	44	0	0	2	15	0
33	Pycreus uniloides	15	0	0	20	0	0
34	Arundinella nepalensis	20	5	25	0	0	0
35	Trifolium repens	0	25	0	1	0	0
36	Commelina africana	3	0	0	0	0	0
37	Lobelia erinus	26	0	14	0	0	0
38	Pycreus flavescens	7	0	0	0	0	0
39	Plantago lanceolata	10	1	1	0	0	0
40	Crassula pellicida	6	0	0	6	0	0
41	Conyza pinnata	0	0	5	0	0	0
42	Cymbopogon validus	0	0	0	0	3	0
43	Hypoxis rigidula	0	0	1	0	0	0

It is evident that the hydrologic regime in the sanctuary has been greatly altered by the construction of dams and damlets as part of the rehabilitation programme in an attempt to re-establish the original hydrological regime of the area. This is the first stage in the rehabilitation of a wetland which is usually followed by the re-establishment of the original wetland vegetation (Mitch & Gosselink 1993). In this case however there has been no active cultivation of any wetland vegetation in the sanctuary area, any wetland vegetation that has re-established in the sanctuary has occurred as a result of natural processes which have allowed for its growth.

Having established that the dominant vegetation community in the sanctuary, prior to its being drained and planted with pasture grasses, was that of the mixed sedge and grass sedge-meadow community, one is able to establish whether the rehabilitation programme has favoured the return of the species that are associated with this community. Clearly at this stage of the programme, the species from this community are not being favoured by the changed hydrologic regime but rather other species are being favoured. The most notable wetland plants which have higher mean frequency percentages in the current vegetation of the sanctuary than were recorded in the vegetation prior to the commencement of the rehabilitation programme are *Schoenoplectus decipiens, Hemarthria altissima, Cyperus difformis, Agrostis lachnantha, Juncus effusus* and *Cyperus denudatus*. These species are more characteristic of the sedge and rush sedge-meadow communities described in section 4.7.1 of Chapter 4.

However, while the species of the mixed sedge and grass sedge-meadow community may not be returning to the sanctuary area as might be desired or expected, the rehabilitation programme has resulted in an increase of wetland species in and around damlets of the sanctuary, particularly the older damlets where species have had a longer period in which to become established. The wetland grasses *Hemarthria altissima*, *Eragrostis planiculmis* and *Agrostis lachnantha* show an increase in their mean frequency percentages, particularly in the older damlets. Also the sedges, *Eleocharis dregeana*, *Schoenoplectus decipiens* and *Cyperus denudatus* and the rush *Juncus effusus* all show an increase in their mean frequency percentages in and around damlets. Once again this is particularly so in and next to the older damlets.

It is evident that the age of the damlets in the sanctuary and the location of the particularly species in relationship to the damlet are the two most important factors affecting where species grow in the sanctuary and their frequency percentages. Clearly the older damlets support more wetland species at high abundances, whilst the wetter sites within the damlets also support more wetland species again at higher abundances. The wetland favouring species, *Eleocharis dregeana, Juncus oxycarpus, Schoenoplectus decipiens* and *Cynodon dactylon* occur at saturated localities within damlets that tend be most abundant in the oldest damlets. At moist localities within the damlets the wetland species, *Cyperus denudatus, Juncus effusus, Eragrostis planiculmis, Agrostis lachnantha, Hemarthria altissima, Cyperus flavescens* and *Agrostis eriantha* occur and also tend to be abundant in older damlets.

It should be remembered that seed banks play a major role in the vegetation dynamics and the distribution of plants in wetlands (Poiani & Johnson, 1988). It is clear that the seed bank of the sanctuary area has changed significantly since the destruction of the sedge and grass sedge-meadow communities that were present in the sanctuary prior to the draining of the area in the mid-1960's. While the original seed bank would have contained species from the sedge and grass sedge-meadow communities the current seed bank is dominated by species not generally found in the sedge and grass sedge-meadow communities.

Clearly the seed bank composition of the Hlatikulu Crane and Wetland sanctuary prior to the initiation of the wetland re-establishment and rehabilitation programme was heavily dominated by *Paspalum dilatatum, Eragrostis curvula, Setaria pallide-fusca, Cyperus esculentus* and *Panicum schinzii* which are species that were well represented in the vegetation prior to the programme. This dominance remains in the most recent samples of the present seed banks' composition, but there is a notable reappearance and increase in certain wetland species *Eleocharis dregeana, Schoenoplectus decipiens* and *Cyperus denudatus* and an increase in the proportions of *Hemarthria altissima, Agrostis* *lachnantha, Juncus effusus* and *Leesia hexandra* in the seed bank. This means that there are a greater number of species currently represented in the seed bank in the Hlatikulu Crane and Wetland Sanctuary than before the initiation of the wetland re-establishment and rehabilitation programme. However, the present seed bank is only likely to affect the re-establishment of wetland to the area by reinforcing the species that are already present in the area (Leck 1989) as there are few species recorded in the seed bank that are not also present in the extant vegetation with their numbers making up a small proportion of the total seed bank.

Changes that occur to the vegetation will eventually become apparent in the seed bank (Leck 1989) so one could expect that as more wetland species become present to a greater degree in the vegetation of the Hlatikulu Crane and Wetland Sanctuary so too will the seed bank reflect these changes.

7.5 Conclusion

It thus appears that the wetland re-establishment and rehabilitation programme has been effective in allowing many wetland species to become re-established in the Hlatikulu Crane and Wetland Sanctuary. The oldest damlets not only have the highest frequency percentages for wetland species, but the least frequency percentages for the non-wetland species which indicated that over time all the damlets will encourage the establishment of a greater number of wetland species than non wetland species.

Although wetland plants are being re-established in the Hlatikulu Crane and Wetland Sanctuary, the wetland being established is greatly different to the vegetation of the sedge and grass community found in the area originally. This sedge and grass sedge-meadow community would have been dominated by the grass; *Aristida junciformis, Andropogon appendiculatus* and *Eragrostis capensis* on the hummocks and almost entirely by the sedge *Cyperus denudatus* in the channels. None of these species are dominant in the sanctuary at present, *Cyperus denudatus* has a mean frequency percentage of 1.1 % and the other species are not yet represented. Also many of the hummock species in the sedge and grass community are also not presently recorded in the sanctuary, e.g. the grasses *Digitaria diagonalis, Eulalia villosa* and *Monocymbium ceresiiforme*; the geophytes *Ledebouria cooperi, Tulbaghia natalensis, Satyrium trinerve, Cyrtanthus breviflorus, Nerine prancratioides, Schizochilus zeyheri, Hypoxis rigidula, Aristea cognata, Disperis tysonii* and *Hesperantha lactea*; the dicotyledons; *Gerbera ambigua, Chironia krebsii, Commelina africana, Pycnostachys reticulata, Sebaea sedoides, Senecio tysonii, Graderia scabra, Senecio cathcartensis, Sopubia manii, Helichrysum epapposum, Argyrolobium tuberosum, Wahlenbergia pallidiflora* and *Mimulus gracilis*. Also certain sedges and rushes, that are found in the channels of the sedge and grass sedge-meadow community but which are also lacking from the sanctuary are *Carex austo-africana, Rhynchospora brownii, Juncus tenuis* and *Juncus dregeanus*.

In the seed bank too, while remaining dominated by non-wetland species and despite the relatively high proportion of seedlings of the wetland species; *Schoenoplectus decipiens, Hemarthria altissima, Eragrostis planiculmis, Eleocharis dregeana, Agrostis lachnantha, Juncus effusus, Leersia hexandra* and *Cyperus denudatus*, most of the species recorded in the sedge and grass community that originally occurred in this area are yet to become re-established.

Thus, although wetland is being re-established in the Hlatikulu Crane and Wetland Sanctuary it bears greater similarity to the sedge/rush community characterised by *Schoenoplectus decipiens, Isolepis fluitans, Eleocharis dregeana, Juncus effusus* and *Juncus oxycarpus* which occurs at the edges of the large dams on 'Forest Lodge' section of the vlei (Section 4.7.1 in Chapter 4 and Figure 5.2) than to the vegetation communities that originally occurred.

CHAPTER 8

USE OF THE HLATIKULU CRANE AND WETLAND SANCTUARY BY CRANES AND WATERFOWL AND THEIR ROLE IN THE DISPERSAL OF PLANT PROPAGULES

'Living birds can hardly fail to be highly effective agents in the transportation of seeds.'

Charles Darwin, 1859

8.1 Introduction

Wetlands form the primary natural habitat for wildlife (Baldassarre & Bolen, 1994). The Hlatikulu Crane and Wetland Sanctuary exists primarily to protect and to provide suitable habitat for the three species of crane found in southern Africa. In providing suitable habitat for cranes the sanctuary also provides suitable habitat for a wider variety of species usually associated with wetlands.

Apart from providing suitable habitat and breeding sites for cranes, wetlands are known to support a remarkable abundance and diversity of bird species (Langley, 1987). Approximately 20 per cent of the 900 species recorded in southern Africa are associated in some way with wetland habitats. Of these species, those that depend almost entirely on wetland areas for their survival number approximately 120 and can be regarded as true 'wetland birds' while 60 or so 'wetland associated birds' utilize both the terrestrial and wetland environments (Langley, 1987).

Many of these birds are reliant on plant material (seeds and vegetative parts) for food. This is particularly so for many species of waterfowl. As consumers of large quantities of seed waterfowl are important dispersers of seeds to wetlands. This concept that waterfowl play an important role in the dispersal of plant propagules, especially seeds, is not new. In 1930 Ridley published a tome of considerable size and scope entitled 'Dispersal of plants throughout the world' in which the role played by waterfowl in the dispersal of plant propagules is clearly documented. Many wetland plants particularly those of the families Cyperaceae, Juncaceae and Poaceae are documented as having their seeds dispersed by ducks and geese (Ridley, 1930). Clearly the concept is not new and in his classic work Ridley (1930) stressed the importance of ducks as a whole class and states that:

> 'It will be readily seen of what vast importance these birds are to dispersal of marsh and aquatic plants, and notably of the Cyperaceae. Ducks fly over the whole world area, from arctic regions to the antarctic and travel at a very rapid rate. They are very voracious and swallow large quantities of seed. Many dive to the bottom of the water and pick up non-floating seed. They are often attacked and torn to pieces by large falcons, eagles and foxes, so that the seeds they have swallowed may be scattered far from where they picked them up. Many seeds and small aquatics, as well as portions of larger ones, adhere to their bodies and feet, and are so transported. It is to these wandering birds that we undoubtedly owe most of the extremely wide distribution of the marsh and pool sedges and grasses and aquatic plants.'

Although much is known of the habits and diet of waterfowl in the northern hemisphere, Siegfried (1971) complained that there was a lack of information concerning the feeding habits of ducks in southern Africa. This situation has improved in recent times with a number of publications in southern Africa dealing with waterfowl feeding habits (Tarboton, 1993). However details of which species are preferred as food sources remain scant as do the role of waterfowl in the dispersal of plant propagules in southern African wetlands.

With the initiation of the wetland re-establishment and rehabilitation programme by the S.A.C.F. and Mondi Forests in the Hlatikulu Crane and Wetland Sanctuary the possibility of not only determining which species of crane and waterfowl have returned to the sanctuary and the numbers in which they occur, but also the possibility of determining the role played by waterfowl in importing and dispersal of plant propagules from other areas to the sanctuary, arose.

The aim of this section of the project was to monitor the return of cranes and waterfowl to the Hlatikulu Crane and Wetland Sanctuary through regular censusing. Also of importance is the investigation of the role played by certain waterfowl in the dispersal of plant propagules into the area from other areas of the vlei.

8.2. Methods

8.2.1 Censii of crane and waterfowl

As 'birds are counted for a wide variety of reasons by a bewildering range of methods' (Bibby et al., 1992) the purpose of these censii was to document the species of crane and waterfowl which were in the sanctuary and their numbers over the summer periods of 1992/1993 and 1993/1994.

A census was conducted monthly from December 1992 to April 1993 and December 1993 to April 1994 at the sanctuary so that 10 months in all were censused. Each census was conducted an hour after sunrise for each particular month, during which the same route through the sanctuary was followed that allowed for maximum coverage of the sanctuary dams and damlets. Individual numbers of crane and waterfowl species were logged and the totals tallied at the end of each census. A pair of Nikon 9 x 25 CFIII binoculars (Manufacturer: The Nikon Corporation, Tokyo, Japan) were used to view species and aided in their identification.

8.2.2 Role of waterfowl in the dispersal of plant propagules

As waterfowl are known to be the dispersal agents for many wetland plants (Ridley, 1930) it is then not only essential to monitor their use of the sanctuary area after the initiation of the wetland re-establishment and rehabilitation programme but also to determine which plant species are being transported to and within the sanctuary either in the droppings of waterfowl or in being attached to their feet and feathers.

Initially the option of shooting birds to collect their crop and gut contents was considered. From the few birds shot it became apparent that although their crop contained a great number of seeds, the amount of seeds surviving the gizzard and stomach action and passed out as droppings were considerably less. Thus options of capturing live birds or collecting the droppings from waterfowl resting places remained. However, despite locating and disguising a large trap in the sanctuary and despite copious amounts of crushed maize within the trap, waterfowl remained wary of the trap for several months and thus the option of collecting droppings was chosen.

From the observation of waterfowl in the sanctuary and initial censii results, three waterfowl species were selected for this study due to their almost continual presence in the sanctuary. These were the spurwinged goose, Egyptian goose and the yellowbilled duck. Resting places for the birds were observed and fresh droppings collected at each site for each species on a daily basis during the summer period 1992/1993. Only fresh droppings were collected to ensure that they were from the recently flushed birds. These droppings were placed in sterile soil in seed trays in greenhouses in the Department of Botany. Trays were kept moist to encourage seedling germination. Seedling germination was monitored for 12 months after dropping collections. The seedlings that emerged from the droppings were coded and counted. Representatives of each coded species were grown to maturity so that identifications could be made to species level.

8.3 Results

8.3.1 Censii of cranes and waterfowl

The results of the censii conducted are given in Table 8.1. All three southern African crane species, the wattled, the blue and the crowned were recorded in the Hlatikulu Crane and Wetland Sanctuary. A total of 14 waterfowl species were also recorded in the sanctuary during ten censuses. Only three species were present at each census, the yellowbilled duck (*Anas undulata*), the spurwinged goose (*Plectropterus gambensis*) and

Table 8.1: Censii data for cranes and waterfowl for ten dates from December 1992 to April 1993.

SPECIES \ CENSUS NUMBER	1	2	3	4	5	6	7	8	9	10
Blue crane (*Anthropoides paradisea*)			2							
Southern crowned crane (*Balearica regulorum*)	4	23	23		2		5	12		6
Wattled crane (*Grus carunculata*)				3				3		
African black duck (*Anas sparsa*)				3					2	
Cape shoveller (*Anas smithii*)	3	5	5	2		6		12	1	4
Cape teal (*Anas capensis*)	3					9	1			
Egyptian Goose (*Alopochen aegyptiacus*)	21	15	33	5	14	17	5	19	2	4
Hottentot teal (*Anas hottentota*)		6								
Knobbilled duck (*Sarkidiornis melanotos*)								5		
Maccoa duck (*Oxyura maccoa*)					3			2		
Redbilled teal (*Anas erythrorhyncha*)	12	3	7	21	6		17	2	2	
South African shelduck (*Tadorna cana*)		4							6	
Southern pochard (*Netta erythrophthalma*)	1	3	3		1		1		1	
Spurwinged goose (*Plectropterus gambensis*)	4	23	17	34	16	41	12	3	11	5
Whitebacked duck (*Thalassornis leuconotus*)			2	2	2					
Whitefaced duck (*Dendrocyna viduata*)		2		5						
Yellowbilled duck (*Anas undulata*)	62	78	31	54	12	77	35	54	47	39

Key to Censii dates:

1 = 19 December 1992
2 = 15 January 1993
3 = 10 February 1993
4 = 16 March 1993
5 = 17 April 1993
6 = 10 December 1993
7 = 18 January 1994
8 = 15 February 1994
9 = 11 March 1994
10= 15 April 1994

recorded in the censii, these three species were on average, the three most observed waterfowl species in the sanctuary.

8.3.2 Role of waterfowl in the dispersal of plant propagules

The seedlings which germinated from the crop and gut contents of two yellowbilled duck shot in the sanctuary are given in Table 8.2. The percentage of seeds in the gut gives an indication of how few seeds survive to be passed out into the droppings of these birds. Of the nine species of plant seed found in the crop, seven were also found occurring in the gut, but at much reduced levels. This is largely due to the destruction of seeds in the gizzard of the bird where they are ground up with stones sand and grit to break them up for digestion. There were more than ten seeds of the sedge *Schoenoplectus decipiens*, the grasses *Echinocloa crus-galli* and *Paspalum dilatatum* and *Polygonum plebeium* in the gut contents.

The numbers of seedlings which germinated from the droppings of spurwinged geese, Egyptian geese and yellowbilled duck are given in Table 8.3. Fourteen species were recorded in 2.614 kg of droppings collected from spurwinged geese, seven species were recorded in 2.193 kg of droppings collected from Egyptian geese and fourteen species were recorded in 0.738 kg of droppings collected from yellowbilled ducks. Large numbers of the sedges *Schoenoplectus decipiens* and *Eleocharis dregeana* germinated from spurwinged goose and yellowbilled duck droppings.

8.4 Discussion

With all three South African crane species and 14 species of waterfowl having been recorded in the Hlatikulu Crane and Wetland Sanctuary in recent years, it is apparent that the establishing of dams and damlets in the sanctuary has been effective in fostering the return of these birds to the area. The occurrence of uncommon waterfowl, such as the Maccoa duck, the South African shelduck, the whitebacked duck and the knobbilled the Egyptian goose (*Alopochen aegyptiacus*). Also, of all the birds recorded in the censii, these three species were on average, the three most observed waterfowl species in the sanctuary.

8.3.2 Role of waterfowl in the dispersal of plant propagules

The seedlings which germinated from the crop and gut contents of two yellowbilled duck shot in the sanctuary are given in Table 8.2. The percentage of seeds in the gut gives an indication of how few seeds survive to be passed out into the droppings of these birds. Of the nine species of plant seed found in the crop, seven were also found occurring in the gut, but at much reduced levels. This is largely due to the destruction of seeds in the gizzard of the bird where they are ground up with stones sand and grit to break them up for digestion. There were more than ten seeds of the sedge *Schoenoplectus decipiens*, the grasses *Echinocloa crus-galli* and *Paspalum dilatatum* and *Polygonum plebeium* in the gut contents.

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8.4 Discussion

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Table 8.2: Number of seedlings which germinated from the crop and gut of two yellowbilled duck from the Hlatikulu Crane and Wetland Sanctuary.

(Mass of crop contents 0.1274 kg, mass of gut contents 0.236 kg)

PLANT SPECIES / ORIGIN OF CONTENTS	Crop	Gut	Percentage in gut
POACEAE			
Digitaria diagonalis	56	0	0
Paspalium dialatatum	237	15	6.3
Echinocloa crus-galli	463	37	7.9
Agrostis bergiana var. laevisulca	16	1	6.3
Eragrostis plana	142	3	2.1
CYPERACEAE			
Schoenoplectus decipiens	273	42	15.4
POLYGONACEAE			
Polygonum plebeium	364	43	11.8
ASTERACEAE			
Conyza podocephala	67	3	4.5
Cirsium vulgare	4	0	0

Table 8.3: The number of seedlings which germinated from waterfowl droppings collected at the Hlatikulu Crane and Wetland Sanctuary from December 1993 to March 1994.

(Masses of dropping collected; Spurwinged goose: 2.614 kg, Egyptian goose: 2.193 kg, Yellowbilled duck: 0.738 kg)

PLANT SPECIES / BIRD SPECIES	Spurwinged goose	Egyptian goose	Yellowbilled duck
POACEAE			
Digitaria diagonalis	0	0	94
Paspalium dialatatum	37	21	106
Echinocloa crus-galli	28	147	31
Agrostis bergiana var. laevisulca	114	162	13
Agrostis lachnantha	3	0	17
Eragrostis curvula	0	0	36
Eragrostis plana	151	17	2
Cynodon dactylon	32	11	0
	2	0	0
CYPERACEAE			
Cyperus denudatus	0	0	25
Cyperus esculentus	37	81	14
Pycreus macranthus	3	0	0
Schoenoplectus decipiens	267	43	327
Eleocharis dregeana	42	0	169
POLYGONACEAE			
Rumex acetosella	46	0	0
Polygonum plebeium	69	0	138
ASTERACEAE			
Conyza podocephala	18	0	2
Cirsium vulgare	0	0	3

whitebacked duck (*Thalassornis leuconotous*) and the knobbilled duck (*Sarkidiornis melanotos*), indicated that the sanctuary is effective in providing a place of refuge for such birds. This is an encouraging sign as it suggests that the Hlatikulu Crane and Wetland Sanctuary is provides suitable habitat for these birds.

It is also apparent that waterfowl do play a role in the dispersal of seeds to the sanctuary. In light of the large numbers of seedlings of *Schoenoplectus decipiens* and *Eleocharis dregeana* germinating from the droppings, and having observed waterfowl moving from areas adjacent to the two large dams on Hlatikulu Vlei to the sanctuary where the sedge and rush sedge-meadow community occurs [which has *Schoenoplectus decipiens* and *Eleocharis dregeana* as dominant species (see section 4.7.1 in Chapter 4)], one can speculate that the spurwinged geese, Egyptian geese and yellowbilled ducks are in part responsible for the return of certain wetland plants to the sanctuary.

Due to the limited data in this section no statistical testing has been conducted.

8.5 Conclusion

The Hlatikulu Crane and Wetland Sanctuary does provide suitable habitat for the three species of crane found in southern Africa as well as providing suitable habitat for a wider variety of species usually associated with wetlands.

The investigation of the role played by yellowbilled duck, Egyptian geese and spurwinged geese in the dispersal of plant propagules into the sanctuary from other areas of the vlei reveals that a number of wetland species are transported by these birds. Certainly the data are small and more research is required in this field before any wider conclusions are drawn.

CHAPTER 9

ASPECTS OF THE FORMATION, MAINTENANCE AND FUNCTIONING OF HUMMOCKS AND CHANNELS AT HLATIKULU VLEI

9.1 Introduction

A noticeable feature of the sedge and grass community of Hlatikulu Vlei are the numbers of 'hummock' and 'channel' structures present. These features are not unique to Hlatikulu Vlei and have been noted at Ntabamhlope Vlei (Downing, 1966) and in the mires at Highmoor (pers obs.). To date no conclusive explanations have been offered for the formation and maintenance of these structures and thus the investigation of these features was undertaken.

Downing (1966), has suggested that cattle are responsible for hummock and channel formation in the sedge meadows at Ntabamhlope Vlei. Through trampling by cattle, the wet, clay soil is depressed into paths which form a close criss-cross pattern or network through the sedge meadows. The vegetation in the paths is killed and, in the course of time, as the cattle continue to use the same paths, the paths deepen to form channels. The hummocks then are the untrampled areas between the channels. This may partially explain the creation of these features in the landscape.

At Hlatikulu Vlei a similar pattern of hummocks and channels are found in the sedge and grass sedge-meadow communities. The hummocks in the Hlatikulu vlei vary in size from area to area, but are on average approximately 50 cm in diameter. These hummocks are surrounded by channels which are on average approximately 40 cm in width. When the areas of sedge and grass community are flooded the channels act as drains through the vlei. Thus hummock and channel sedge-meadows are subject to a wide range of soil moisture conditions. Hummocks are wet during the rainy season, but remain moist during the dry season. Channels are saturated or even flooded by up to 10 cm depth of water during the rainy season and remain wet during the dry season. The hummock soil profile shows a humic horizon approximately 15 cm thick that overlays a predominately clay horizon. The channel soil profile shows a poorly drained clay horizon.

Hummocks support different vegetation to the channels. The channels tend to be dominated by a single species *Cyperus denudatus* with other species such as *Isolepis fluitans*, *Carex austro-africana*, *Carex cognata*, *Juncus oxycarpus* and *Juncus effusus* occurring less abundantly. The hummocks tend to be dominated by the grass species; *Aristida junciformis*, *Andropogon appendiculatus*, *Eragrostis capensis* and *Arundinella nepalensis*, but support a great variety of other species including; *Ledebouria cooperi*, *Cyrtanthus breviflorus*, *Tulbaghia natalensis*, *Gladiolus papilio*, *Satyrium trinerve*, *Hypoxis filiformis*, *Nerine prancratioides*, *Pycnostachys reticulata*, *Ranunculus multifidus*, *Gerbera ambigua*, *Senecio cathcartensis*, *Diclis reptans*, *Mimulus gracilis*, *Mentha aquatica*, *Monopsis decipiens*, *Lobelia erinus*, *Epilobium salignum* and *Melasma scabrum*.

This section of the study determines what factors are responsible for the maintenance and functioning of hummocks and channels in the sedge and grass community. In this regard the following key questions are asked:

1) What factors are responsible for the distinct difference in vegetation between hummocks and channels?

2) Are the seed banks in the channels similar to those on the hummocks or are they as distinctly different as is the extant vegetation.

The study is divided into two sections, a flooding experiment which looks at the effects of various degrees of flooding and fluctuating water levels, soils and fire season on selected wetland plants and a seed bank study which documents the seed banks of hummocks and of channels in the Hlatikulu Vlei.

9.2 Methods

9.2.1 Flooding and fluctuation of water levels

The effects of controlled water regimes on various wetland species have been studied in various parts of the world (McKee & Mendelssohn, 1989; Hellings & Gallager, 1992 and Kirkman & Sharitz, 1992), but little is known of the effects of flooding various species in wetlands in KwaZulu-Natal.

As the various floodings of plant species, the fluctuating of water levels, the effects of differing soils and fire season may be factors which are partly responsible for determining where certain plant species grow in relation to hummocks and channels, the following experiment was designed to test their effects.

9.2.1.1 Soil

The simplest method for the direct determination of soil water content is the gravimetric method, which in principle involves the measurement of water lost by weighing a soil sample before and after it is dried at 105-110°C in the oven (Tan, 1996). Thus to determine whether soils on the hummocks were sufficiently different to soils in the channels, undisturbed soil cores were taken from the hummocks and from the channels to test their water retentivity. After initial saturation soils were subjected to differing matric potentials. The water content was calculated and water retention curves plotted for the hummock and the channel soils.

The results of this initial investigation are given in Figure 9.1 and show a clear distinction between the soils. The channels soils which appear to have more clay when crudely sampled in the hand, and have a higher water content at higher matric potentials than the hummock soils which appear to have a greater humus content. For this reason the factor of soil was included in the flooding experiment.

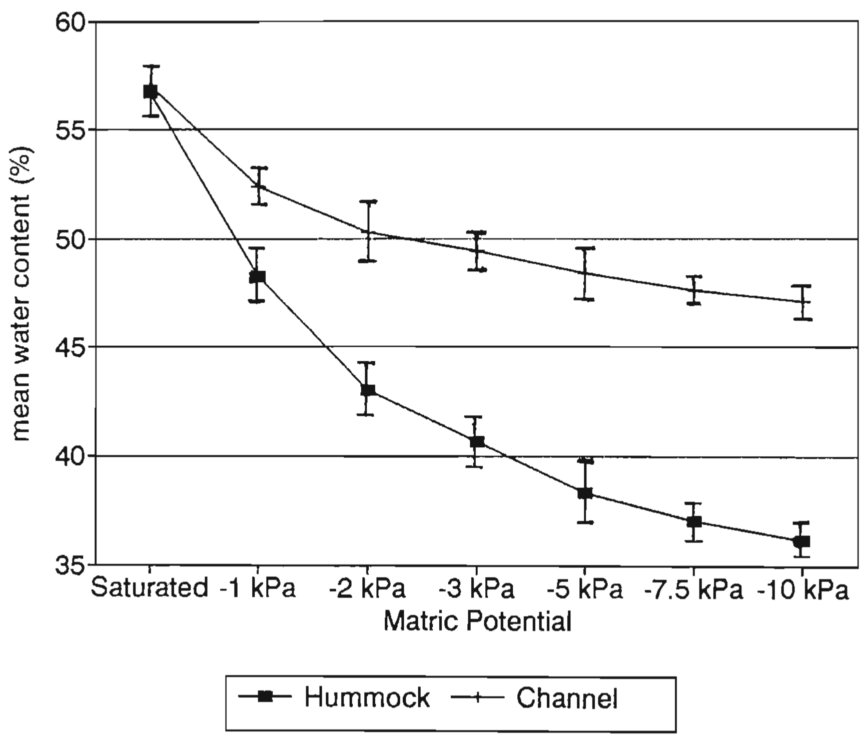

Figure 9.1: **Graph showing the mean water content for undisturbed hummock and channel soil cores subjected to various matric potentials after initial saturation.**

9.2.1.2 Plant species selected

Three species were selected for treatment in this experiment. They were *Aristida junciformis* (usually associated with the tops of the hummocks), *Arundinella nepalensis* (usually associated with the lower hummocks) and *Cyperus denudatus* (usually associated with the channels).

For the flooding experiment 108 plansts of each of the three species given above were grown in polyvinyl chloride (P.V.C.) tubes (diameter 110 mm and length 400 mm). The tillers for each species were required to be clones of each other so that any competitive advantage that might be due to differing genetic material could be eliminated. To obtain the large number of tillers a large plant of each of the three species was collected. Each plant was divided into as many tillers as possible and potted to allow for more tillers to be produced. Eventually when 108 plants for each species were available the experiment was begun.

Thus, for the flooding experiment, 108 plants of each of the three species were grown in polyvinyl chloride (P.V.C.) tubes. Half the P.V.C. tubes contained undisturbed soil cores collected from channels in the vlei and the other half contained soil cores collected from hummocks in the vlei. The P.V.C. tubes were divided equally and proportionally between 18 halved 210 litre drums (the flooding and fluctuating treatments associated with each drum are described in sections 9.2.1.4 and 9.2.1.5 in this chapter) so that each drum contained 18 P.V.C. tubes as detailed in Table 9.1. Open P.V.C. tubes were selected instead of pots to allow the free movement of water in the soils.

9.2.1.3 Fire treatment

As burning of the Hlatikulu Vlei occurs usually in spring or autumn (Theron pers. comm.) to remove moribund plants, the following fire treatments were included in the experiment.

Table 9.1: Species cultivated, the soil source and the fire treatment for each of the 18 P.V.C. tubes in each drum.

P.V.C. Tube number	Species name	Soil source	Fire time
1	Cyperus denudatus	Channel	May
2	Cyperus denudatus	Channel	September
3	Cyperus denudatus	Channel	Not burnt
4	Cyperus denudatus	Hummock	May
5	Cyperus denudatus	Hummock	September
6	Cyperus denudatus	Hummock	Not burnt
7	Arundinella nepalensis	Channel	May
8	Arundinella nepalensis	Channel	September
9	Arundinella nepalensis	Channel	Not burnt
10	Arundinella nepalensis	Hummock	May
11	Arundinella nepalensis	Hummock	September
12	Arundinella nepalensis	Hummock	Not burnt
13	Aristida junciformis	Channel	May
14	Aristida junciformis	Channel	September
15	Aristida junciformis	Channel	Not burnt
16	Aristida junciformis	Hummock	May
17	Aristida junciformis	Hummock	September
18	Aristida junciformis	Hummock	Not burnt

A third of the plants in each drum were subjected to an autumn (May 1994) and a spring (September 1994) burn, while the remaining third were not subjected to a fire treatment. These treatments are detailed for each species and the soil type in which they were grown in Table 9.1. For each burn the relevant tubes were removed from their drums and buried in the vlei with their soils level with the ground so that the plants in these tubes were be subjected to the same fire treatment as the surrounding vlei vegetation. Once the fire treatments were complete the tubes were returned to their original drums.

9.2.1.4 Flooding

Nine 210 litre drums were cut in half so that each end could be filled with water. Each half drum was fitted with a ball-cock to control the water level in the drum and the drums connected to a water supply. A third of the drums were used for the saturated treatment, a third for the moist treatment and the remaining third for the dry treatment. The PVC tubes were stood on bricks in the drums such that each tube was at its prescribed water level.

In the saturated treatment the tubes were completely submerged in water so that the top of the soil was at the surface of the water. This allowed for the aerial portion of the plants to remain above the water level, while the roots in the soil were totally saturated with water. In the moist treatment the tubes were placed in the water so that the upper 15 cm of the tube protruded above the water level. In the dry treatment the tubes were placed so that the bottom of the tube was in contact with the water. The flooding treatment for each drum is detailed in Table 9.2.

9.2.1.5 Fluctuating water levels

Nine of the 18 drums were subjected to fluctuating water levels. Every 12 weeks the drums were drained and kept dry for 6 weeks before being refilled to the original level. This cycle was continued for the entire period of the experiment which was from January 1994 to February 1995.

Table 9.2: Flooding and fluctuating treatments for each of the 18 drums.

Drum number	Water level	Fluctuating level
1	Saturated	Yes
2	Moist	Yes
3	Dry	Yes
4	Saturated	Yes
5	Moist	Yes
6	Dry	Yes
7	Saturated	Yes
8	Moist	Yes
9	Dry	Yes
10	Saturated	No
11	Moist	No
12	Dry	No
13	Saturated	No
14	Moist	No
15	Dry	No
16	Saturated	No
17	Moist	No
18	Dry	No

9.2.1.6 Data collection and analysis

The number of tillers and inflorescences of each plant was recorded every week to monitor the progress of the experiment. When the experimental period (January 1994 - February 1995) had elapsed the plants were destructively harvested and dried. Their final tiller number, inflorescence number and dry mass were recorded.

The data were analyzed using multifactor ANOVA (Statgraphics) to determine if there were significant differences between the final masses, tiller numbers and inflorescence number as a result of the various treatments administered to the plants.

9.2.2.1 Soil stored seed bank sampling

The various methods for soil seed bank sampling are discussed in section 6.2.2 of Chapter 6. However for this section of the study the following procedure was conducted.

Soil cores were collected at sites 7, 46 and 57 (see Figure 5.3) in PVC tubes 12.5 cm in length and a surface area of 80 cm^2 so that the total volume was 1000 cm^3. To determine the composition of the seed bank in this sedge and grass community, 30 cores were taken at each of three sites. The sites were dominated by 'hummocks and channels' so at each site half (15) of the cores were taken from on top of hummocks and the other half were taken from the channels. The soil from each core was placed in a seed tray and the seed trays kept in greenhouses. Soils were kept moist to allow for the germination of seedlings. Seedlings that germinated were counted and given code names until representative seedlings could be grown to flowering stage and identifications made to species level. Soil cores were collected every four months from February 1993 to February 1994 and seedling germination for each collection monitored for 12 months from the date of collection.

9.3 Results

9.3.1 Flooding experiment

The results of the flooding experiment are given in Tables 9.3 and 9.4 and Figures 9.2, 9.3, 9.4 and 9.5. Table 9.3 gives the mean dry mass in grams of the harvested *Cyperus denudatus, Arundinella nepalensis* and *Aristida junciformis* plants for the treatments in the experiment and Table 9.4 gives a summary of the multiple factor analysis of variance testing for significant differences between various of the treatments. There are significant differences in the mass of harvested plants of *Cyperus denudatus* and *Aristida junciformis* between the fluctuating and non-fluctuating and hummock soil and channel soil treatments. There are significant differences in the mass of harvested plants of *Arundinella nepalensis* and *Aristida junciformis* between the saturated and moist treatments. There are significant differences in masses of harvested plants of all three species between the saturated and dry treatments.

Figures 9.2, 9.3, 9.4 and 9.5 graphically display the mean dry masses of *Cyperus denudatus, Arundinella nepalensis* and *Aristida junciformis* plants for saturated, moist and dry; fluctuating and non-fluctuating; hummock soil and channel soil and fire treatments respectively. In Figure 9.2 all three species have similar results in the moist condition, but *Cyperus denudatus* is favoured over the other species in the saturated condition, while *Aristida junciformis* is favoured over the others in the dry condition.

In Figure 9.3 *Cyperus denudatus* is favoured over the other species in the non-fluctuating condition, while *Aristida junciformis* is favoured over the others in the fluctuating condition.

In Figure 9.4 *Cyperus denudatus* is favoured over the other species in the channel soil condition, while *Aristida junciformis* is favoured over the others in the hummock soil condition.

Table 9.3: Mean dry masses (grams) of plants harvested at the end of the experiment period for the various treatments applied. (Standard Errors in brackets)

Species Treatment	*Cyperus denudatus*	*Arundinella nepalensis*	*Aristida junciformis*
Non-fluctuating	46.98 (6.97)	23.97 (3.67)	21.94 (3.40)
Fluctuating	27.79 (3.06)	22.32 (2.49)	40.81 (4.59)
Saturated	58.29 (9.14)	9.00 (0.94)	9.01 (0.82)
Moist	30.01 (4.78)	33.25 (4.69)	29.77 (1.39)
Dry	23.86 (1.83)	27.18 (2.45)	55.35 (3.48)
May fire	34.30 (2.16)	14.50 (1.97)	26.65 (2.44)
September fire	27.68 (4.91)	18.88 (3.50)	24.59 (3.13)
No fire	40.58 (1.68)	34.38 (2.39)	38.74 (4.27)
Channel	42.87 (3.45)	20.32 (3.79)	23.11 (1.74)
Hummock	31.90 (2.59)	25.97 (2.29)	39.65 (2.42)

Table 9.4: Summary of multiple factor analysis of variance testing for significance of difference between treatments in the flooding experiment.

Contrast	*Cyperus denudatus*	*Arundinella nepalensis*	*Aristida junciformis*
Fluctuating-Non-fluctuating	**		**
Saturated-Moist	*	**	**
Moist-Dry	*		**
Saturated-Dry	**	**	**
May fire-September fire		*	
May fire-No fire		*	*
September fire-No fire	*	*	*
Channel-Hummock	**	*	**

** $p < 0.0001$ (Highly significant)
* $P < 0.0075$ (Significant)

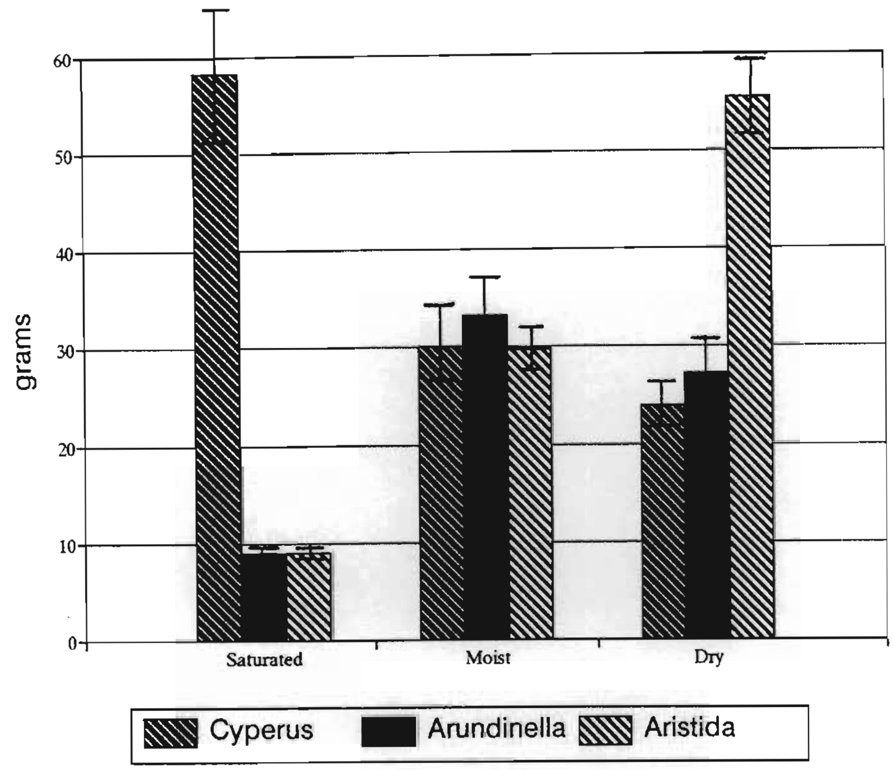

Figure 9.2: **Mean dry masses (grams) of *Cyperus denudatus, Arundinella nepalensis* and *Aristida junciformis* for saturated, moist and dry flooding treatments.**

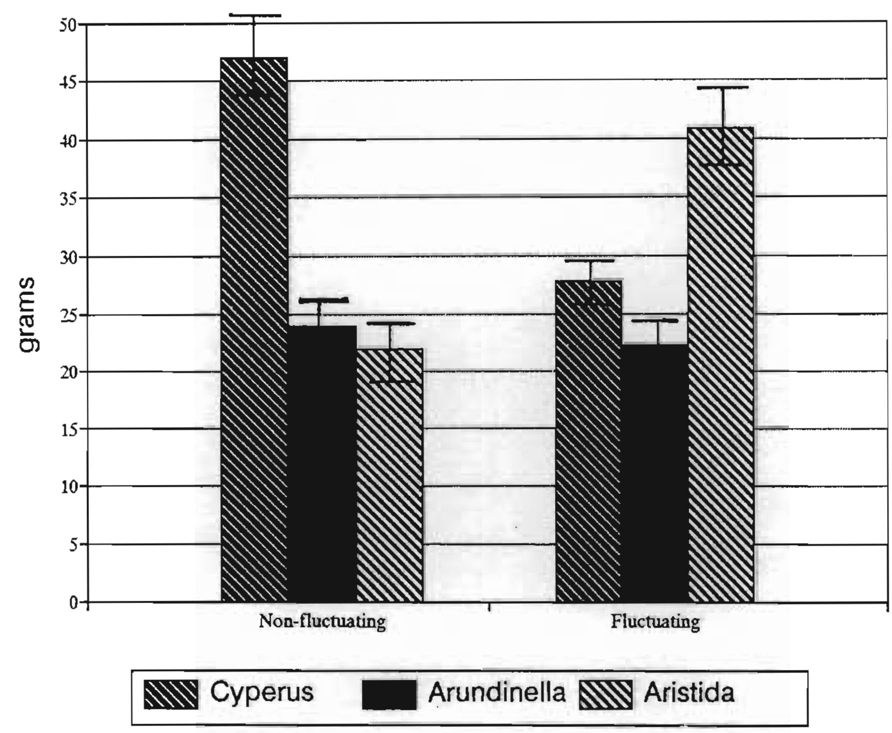

Figure 9.3: **Mean dry masses (grams) of *Cyperus denudatus, Arundinella nepalensis* and *Aristida junciformis* for fluctuating and non-fluctuating treatments.**

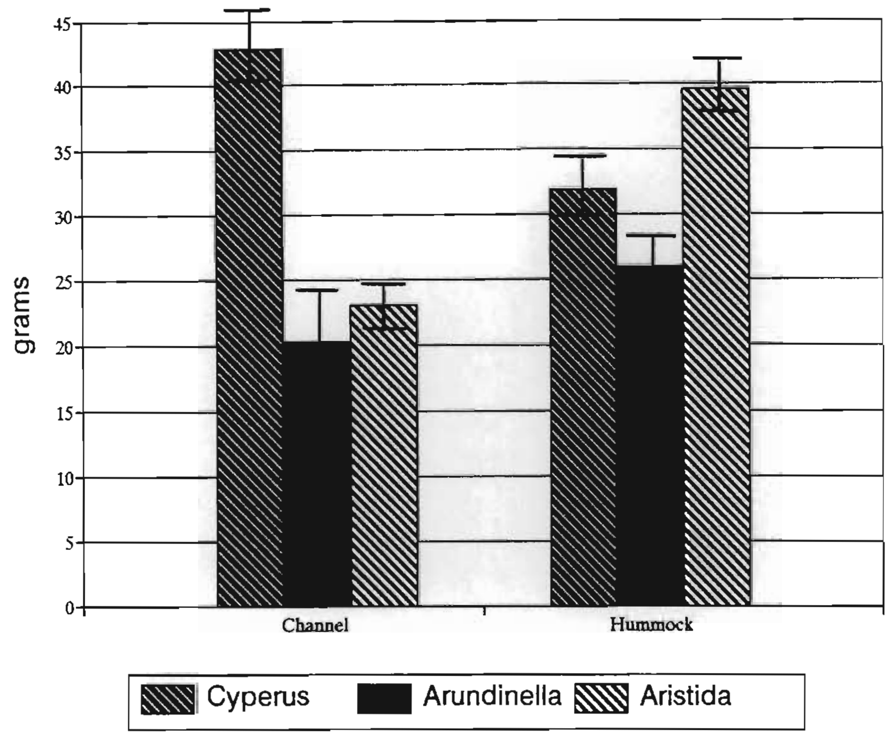

Figure 9.4: **Mean dry masses (grams) of *Cyperus denudatus, Arundinella nepalensis* and *Aristida junciformis* for channel and hummock soils.**

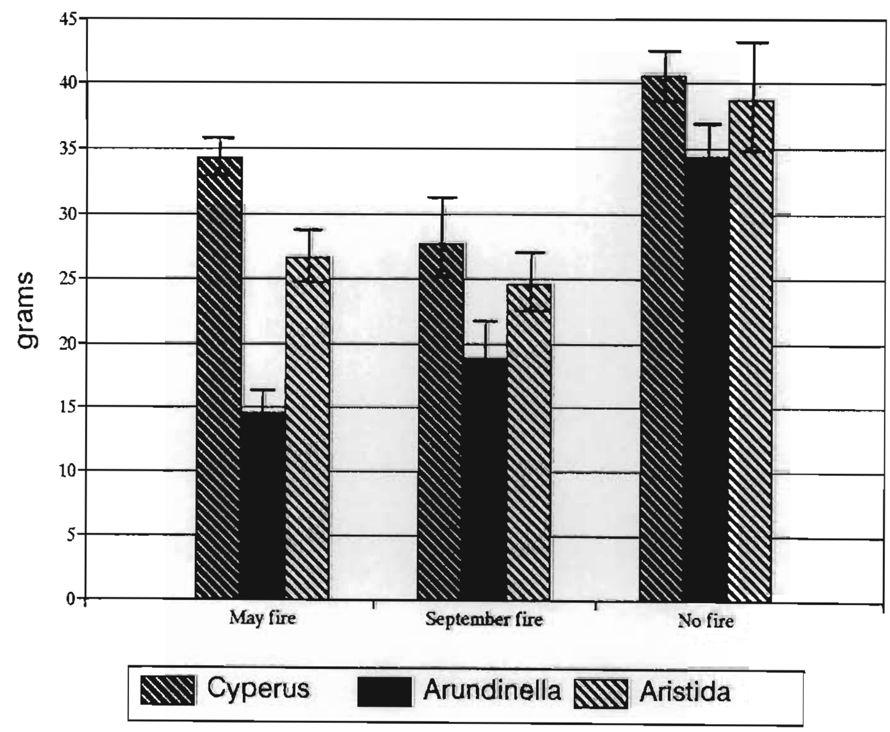

Figure 9.5: **Mean dry masses (grams) of *Cyperus denudatus, Arundinella nepalensis* and *Aristida junciformis* for May and September fire treatments and for no fire treatment.**

In Figure 9.5 all three species have best results for no fire treatment, but *Cyperus denudatus* and *Aristida junciformis* fare worst in the September fire treatment, while *Arundinella nepalensis* fares worst in the May fire treatment.

9.3.2 Seed banks

The seed bank composition of sedge and grass communities sampled at Hlatikulu Vlei are given in Table 9.5. Seedlings germinating from the hummock soils totalled 1924 from 24 species and seedlings germinated from the channel soil totalled 3268 from 24 species.

Although there were a greater number of seedlings of *Cyperus denudatus* and *Schoenoplectus decipiens* recorded in the channel soil than the hummock soils, most of the other species had similar numbers of seeds in each soil type. This means that despite the distinctly different vegetation on the hummocks to that in the channels (described in section 4.3 of Chapter 4 and section 5.6.1.1 of Chapter 5), the seed banks of the hummocks and channels are to a large extent similar.

9.4 Discussion

It is clear from this experiment that the saturated treatment favours *Cyperus denudatus*, the moist treatment favours *Arundinella nepalensis* and the dry treatment favours *Aristida junciformis*. These results are to be expected in view of *Cyperus denudatus* plants usually being found in saturated conditions of the channels in the vlei, *Arundinella nepalensis* usually being associated with the moister conditions of the lower hummock and *Aristida junciformis* usually being found in the drier conditions of the hummock top.

While the fluctuating of water levels does not cause a significant difference between the dry mass of *Arundinella nepalensis* plants subjected to fluctuating and non-fluctuating

Table 9.5: **Seed bank composition of sedge and grass communities sampled at Hlatikulu Vlei. Seedling totals represent seedling germination from 90 soil cores, 45 taken on hummocks and 45 taken in channels.**

Rank	Species name	Hummock seedlings	Channel seedlings	TOTAL
1	Lobelia erinus	607	650	1257
2	Cyperus denudatus	242	854	1096
3	Schoenoplectus decipiens	85	737	822
4	Conyza pinnata	218	281	499
5	Pseudognaphalium luteo-album	271	227	498
6	Oxalis corniculata	158	96	254
7	Cyperus esculentus	73	107	180
8	Aristida junciformis	86	58	144
9	Eragrostis curvula	62	52	114
10	Conyza podocephala	17	65	82
11	Juncus effusus	8	52	60
12	Ledebouria cooperi	26	17	43
13	Cyperus difformis	2	24	26
14	Digitaria diagonalis	18	3	21
15	Panicum schinzii	20	1	21
16	Agrostis lachnantha	12	2	14
17	Echinocloa crus-galli	2	11	13
18	Eleocharis dregeana	0	11	11
19	Eragrostis capensis	8	0	8
20	Senecio cathcartensis	0	6	6
21	Paspalum dilatatum	0	6	6
22	Setaria pallide-fusca	4	1	5
23	Aponogeton junceus	0	4	4
24	Monopsis decipiens	0	3	3
25	Eragrostis plana	0	2	2
26	Satyrium trinerve	2	0	2
27	Cirsium vulgare	2	0	2
28	Cyrtanthus breviflorus	2	0	2
29	Mimulus gracilis	1	0	1
30	Helichrysum pilosellum	1	0	1
	TOTAL	1924	3268	5197

treatments, it is clear that *Cyperus denudatus* is not favoured by fluctuating conditions where soils are allowed to dry for periods after initial flooding, but *Aristida junciformis* is favoured by the drying of soils during the fluctuating treatments.

It is also clear that hummock soils favour the growth of *Aristida junciformis* and *Arundinella nepalensis* rather than channel soils, while channel soils favour the growth of *Cyperus denudatus* rather than hummock soils. This indicates the importance of soil in determining the location of these plants species with regard to the hummocks and channels in the vlei.

All species were favoured by the absence of fire treatments. The September burn had a harsher effect on *Cyperus denudatus* and *Aristida junciformis*, while the May fire had a harsher effect on *Arundinella nepalensis*. These results suggest that alteration of the fire season may be required to prevent certain species continually being favoured over others. Also as none of the species had yet become moribund during the experiment, no species were favoured by fire treatments. However should certain species become moribund the situation could well change with fire treatments required to remove excess dead material and allow for the emergence of new tillers.

Despite the distinctly different vegetation on the hummocks to that in the channels the seed banks of the hummocks and channels are to a large extent similar. This suggests that either seeds or seedlings of hummock plants are being excluded from the channels at a later stage by the environmental conditions in the channels or from competition from the existing vegetation. Possibly a combination of both these factors could be the answer.

9.5 Conclusion

The flooding of soils, the fluctuating of water level and the soil type related to hummocks and to channels are largely responsible for the location of *Cyperus denudatus*, *Arundinella nepalensis* and *Aristida junciformis* in differing positions in the channels and on the hummocks and thus also largely responsible for the maintenance and functioning of the hummocks and channels. It is the degree to which soils are saturated in the channels and the hummocks that ensures a distinct difference in the species found in the channels and on the hummocks. This saturation may be due largely to the fluctuation of water levels in the hummocks and channels with seasonal precipitation and has distinct effects on the plants grown in this flooding experiment.

Seed banks on the hummocks are similar to seed banks in the channels and are not distinctly different from each other as is the extant vegetation on the hummocks to that in the channels. Certain species represented in the channel seed bank are being excluded from surviving to maturity.

CHAPTER 10

CONCLUSIONS

There is no doubt that wetlands are amongst the most threatened habitats in the world (Mitsch & Gosselink, 1986). As greater concern for the plight of wetlands is generated on a global scale, the mapping and delineation of wetlands has become essential to allow for suitable conservation of these eco-systems through effective management programmes. Research efforts in wetlands should be targeted towards the improving of wetland mapping and wetland classification for the purpose of tailoring wetland regulations to wetland type so that management programmes are effective.

In this study the description of the major vegetation communities of Hlatikulu Vlei using TWINSPAN showed that the vlei is characterised by four main plant communities; vlei grassland, sedge-meadows, reedswamp and bulrush communities. This allowed for the delineation and mapping of these communities at Hlatikulu Vlei. This delineation of the various wetland vegetation communities at Hlatikulu Vlei should provide the basis of any further management programmes at the vlei.

Comparisons of the floristic composition of vegetation communities at Hlatikulu Vlei were made with communities at Ntabamhlope Vlei and the mires at Highmoor. The vegetation communities at Hlatikulu Vlei were not distinctly different in appearance to Ntabamhlope Vlei and the mires at Highmoor and all communities encountered were common to other wetlands in KwaZulu-Natal. Differences did occur in respect to the species composition of each community but the vegetation communities at Hlatikulu Vlei are most similar to those at Ntabamhlope Vlei.

Unlike Ntabamhlope Vlei which has large areas covered by bulrush and reedswamp communities dominating the vlei, Hlatikulu Vlei has very few areas covered by bulrush and reedswamp communities. The dominant communities at Hlatikulu Vlei are vlei grassland and sedge-meadow communities. The mires at Highmoor, which lack in reedswamp and bulrush communities, have vlei grassland and sedge-meadow communities that are superficially similar to those at Hlatikulu Vlei.

The A 1.2 *Aristida junciformis* - *Cyperus denudatus* sub-community and the A 2.1 *Carex cognata* - *Cyperus denudatus* sub-community at Hlatikulu Vlei (which are sedge-meadow communities) are distinctly different from, and have a higher species diversity than the sedge-meadow communities at Ntabamhlope Vlei and the Highmoor Mires as well as having a higher species diversity than any other vegetation community at Hlatikulu Vlei. These vegetation communities are identified as requiring special protection to preserve their unique character and richness.

Over half of KwaZulu-Natal's wetland resource has been degraded (Begg, 1989). Hlatikulu Vlei has not escaped the effects of human mismanagement and the assessment of the gross changes to the vegetation communities of Hlatikulu Vlei reveals that more than 50 % of the vlei has been degraded as a consequence of the various land management practices over the past 50 years. Degradation and destruction of the vegetation at Hlatikulu Vlei was largely caused as a result of the construction of an number of dams which flooded the vegetation and as a result of the draining of wetland areas to facilitate the planting of pastures. The effects of regular over-grazing and too frequent burning of the plant communities of Hlatikulu Vlei has also resulted in the degradation of certain areas, but the effects have been considerably less than damage caused as a result of dam construction and the drainage of wetland areas.

Further losses of vlei vegetation should be avoided if Hlatikulu Vlei is to remain a functioning priority wetland in KwaZulu-Natal. Wetland communities should be regarded as distinct management units and should be fenced off from the rest of the grassland, especially in grazing programmes to prevent the more palatable vegetation of the wetlands being overgrazed and degraded (Tainton 1981).

A common problem in community ecology is to discover how a multitude of species respond to certain environmental variables (ter Braak 1988). In answer to the question in this study as to which environmental factors were responsible for the present floristic patterns of the vegetation at Hlatikulu Vlei it is evident that there were several. Soil moisture content is the most significant environmental factor affecting the distribution of species within the vlei. The type of soil encountered is also a significant variable in determining vegetation patterns as certain species show distinct affinities for certain soil types as wetlands are often defined by the presence of wetland soils. A further feature which is an important environmental factor determining vegetation patterns within the vlei is the presence or absence of hummocks and channels within the landscape at Hlatikulu Vlei. Many species are reliant on the variety of niches created by these features and it seems that hummocks and channels are responsible for maintaining a higher species diversity in certain communities.

Whilst it is important to protect wetlands, current conservation efforts should also call for the restoration of degraded wetlands and the replacement of wetlands in areas where they previously existed (Mitchell, 1994). The rehabilitation of a large section of Hlatikulu Vlei, that had been severely degraded by past draining and planting of pasture grasses, aimed to re-establish wetland vegetation in an area where it previously existed.

Many wetland species had become re-established in this rehabilitation area. Where damlets had been constructed to restore the original hydrological regime of Hlatikulu Crane and Wetland Sanctuary being rehabilitated, wetland species were encountered in their highest numbers in the oldest damlets. Also where these older damlets occurred there were a lower abundances of non-wetland species. Although the rehabilitation programme had not yet been effective in returning the vegetation originally occurring in the wetland (*i.e*: the sedge and grass sedge-meadow communities) to the Hlatikulu Crane and Wetland Sanctuary, it was effective in encouraging the growth of species common in sedge and rush sedge-meadow communities.

It is known that in wetlands, seed banks play an important and well documented role (Thompson, 1992). In the rehabilitation areas of Hlatikulu Vlei, wetland species were also recorded in higher abundances in the seed banks as a result of the creation of suitable habitat for wetland plants within these areas.

Wetlands are especially critical habitats for wildlife (Baldassarre & Bolen 1994; Kent 1994). Census results showed that the Hlatikulu Crane and Wetland Sanctuary did provide suitable habitat for the three species of crane found in southern Africa as well as a wider variety of bird species, particularly waterfowl, that are usually associated with wetlands. Yellowbilled duck, Egyptian geese and spurwinged geese were found to be responsible for the dispersal of limited amounts of seed of certain wetland plant species to the Hlatikulu Crane and Wetland Sanctuary. Thus their role in aiding the re-establishment of wetland species in the Hlatikulu Crane and Wetland Sanctuary must also be acknowledged.

The growth of certain plant species in relationship to the hummock and channel feature in certain areas of Hlatikulu Vlei was related to the flooding of soils, the fluctuating of water level and the particular type of soil. *Cyperus denudatus* preferred saturated conditions in channel soils, *Arundinella nepalensis* preferred moist conditions in hummock soils and *Aristida junciformis* preferred drier conditions in hummock soils. Saturation of soils is largely as a result of the fluctuation of water levels in channels depending upon seasonal precipitation. This has distinct effects on certain plant species and determines where they are able to survive.

Despite the fact that the vegetation on the hummocks was distinctly different to that in the channels, the species in seed banks of the hummocks were similar to those in the seed banks in the channels. The saturation levels in the hummocks and the channels must prevent all species in the soil seed banks from surviving to maturity, thus maintaining the different species on the hummock vegetation and in the channel vegetation.

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APPENDIX 1 A List of Mammals recorded at Hlatikulu Vlei (Nomenclature after Skinner & Smithers, 1990)

Chacma baboon (*Papio ursinus*)
Scrub hare (*Lepus saxatilis*)
Common mole-rat (*Cryptomus hottentotus*)
Cape porcupine (*Hystrix africaeaustralis*)
Vlei rat (*Otomys irroratus*)
Striped mouse (*Rhabdomys pumilio*)
Water rat (*Dasymys incomtus*)
Pygmy Mouse (*Mus minutoides*)
Natal multimammate mouse (*Mastomys natalensis*)
White-tailed mouse (*Mystromys albicaudatus*)
Caracal (*Felis caracal*)
African wild cat (*Felis lybica*)
Serval (*Felis serval*)
Domestic cat (*Felis catus*)
Black-backed jackal (*Canis mesomelas*)
Cape clawless otter (*Aonyx capensis*)
Spotted-necked otter (*Lutra maculicollis*)
Large-spotted genet (*Genetta tigrina*)
White-tailed mongoose (*Ichneumia albicauda*)
Water mongoose (*Atilax paludinosus*)
Banded mongoose (*Mungos mungo*)
Rock dassie (*Procavia capensis*)
Aardvark (*Orycteropus afer*)
Common Duiker (*Sylvicapra grimmia*)
Oribi (*Ourebia ourebi*)
Grey Rhebok (*Pelea capreolus*)
Eland (*Taurotragus oryx*)
Reedbuck (*Redunca arundinum*)

Reference:

SKINNER, J.D. & SMITHERS, R.H.N., 1990. The mammals of the southern African subregion. University of Pretoria, Pretoria.

APPENDIX 2 A list of wetland dependent birds recorded at Hlatikulu Vlei 1992-1994 (Nomenclature after Maclean, 1993)

Dabchick (*Tachybaptus ruficollis*)
Whitebreasted cormorant (*Phalacrocorax carbo*)
Reed cormorant (*Phalacrocorax africanus*)
Darter (*Anhinga melanogaster*)
Grey heron (*Ardea cinerea*)
Purple heron (*Ardea purprea*)
Great white egret (*Egretta alba*)
Little egret (*Egretta garzetta*)
Yellowbilled egret (*Egretta intermedia*)
Blackcrowned night heron (*Nycticorax nycticorax*)
Bittern (*Botaurus stellaris*)
Hamerkop (*Scopus umbretta*)
Black stork (*Ciconia nigra*)
Sacred ibis (*Threskiornis aethiopicus*)
Glossy ibis (*Plegadis falcinellus*)
African Spoonbill (*Platalea alba*)
Whitefaced duck (*Dendrocygna viduata*)
Whitebacked duck (*Thalassornis leuconotus*)
Egyptian goose (*Alopochen aegyptiacus*)
South African shelduck (*Tadorna cana*)
Yellowbilled duck (*Anas undulata*)
African black duck (*Anas sparsa*)
Cape teal (*Anas capensis*)
Hottentot teal (*Anas hottentota*)
Redbilled teal (*Anas erthyrorhyncha*)
Cape shoveller (*Anas smithii*)
Southern pochard (*Netta erythrophthalma*)
Spurwinged goose (*Plectropterus gambensis*)
Maccoa duck (*Oxyura maccoa*)
African fish eagle (*Haliaeetus vocifer*)
African marsh harrier (*Circus ranivorus*)
Wattled crane (*Grus carunculata*)
Southern Crowned crane (*Balearica regulorum*)
African rail (*Rallus caerulescens*)
Black crake (*Amaurornis flavirostris*)
Redchested flufftail (*Sarothrura rufa*)
Purple gallinule (*Porphyrio porphyrio*)
Moorhen (*Gallinula chloropus*)
Redknobbed coot (*Fulica cristata*)
Painted snipe (*Rostratula benghalensis*)
Ringed plover (*Charadrius hiaticula*)
Kittlitz's plover (*Charadrius pecuarius*)
Threebanded plover (*Charadrius tricollaris*)

Blacksmith plover (*Vanellus armatus*)
Wattled plover (*Vanellus senegallus*)
Common sandpiper (*Tringa hypoleucos*)
Wood sandpiper (*Tringa glareola*)
Marsh sandpiper (*Tringa stagnatilis*)
Greenshank (*Tringa nebularia*)
Curlew Sandpiper (*Calidris ferruginea*)
Little stint (*Calidris minuta*)
Ruff (*Philomachus pugnax*)
Ethiopian snipe (*Gallinago nigripennis*)
Avocet (*Recurvirostra avosetta*)
Blackwinged stilt (*Himantopus himantopus*)
Whiskered tern (*Chlidonias hybridus*)
Grass owl (*Tyto capensis*)
Marsh owl (*Asio capensis*)
Pied kingfisher (*Ceryle rudis*)
Giant kingfisher (*Ceryle maxima*)
Halfcollared kingfisher (*Alcedo semitorquata*)
Malachite kingfisher (*Alcedo cristata*)
Brownthroated martin (*Riparia paludicola*)
Banded martin (*Riparia cincta*)
African marsh warbler (*Acrocephalus baeticatus*)
Cape reed warbler (*Acrocephalus gracilirostris*)
Yellow warbler (*Chloropeta natalensis*)
African sedge warbler (*Bradypterus baboecala*)
Broadtailed warbler (*Schoenicola brevirostris*)
Levaillants cisticola (*Cisticola tinniens*)
Cape wagtail (*Motacilla cinerea*)
Cuckoo finch (*Anomalospiza imberbis*)
Red bishop (*Euplectes orix*)
Golden bishop (*Euplectes afer*)
Yellowrumped widow (*Euplectes capensis*)
Redshouldered widow (*Euplectes axillaris*)
Redcollared widow (*Euplectes ardens*)
Longtailed widow (*Euplectes progne*)
Common waxbill (*Estrilda astrild*)
Orangebreasted waxbill (*Sporaeginthus subflavus*)

Reference:

MACLEAN, G.L., 1993. Roberts' birds of southern Africa. The Trustees of the John Voelcker Bird Book Fund, Cape Town.

APPENDIX 3 A List of Frogs recorded at Hlatikulu (Nomenclature after Passmore & Carruthers, 1979)

Common platanna (*Xenopus laevis*)

Guttural toad (*Bufo gutteralis*)

Raucous toad (*Bufo rangeri*)

Penther's rain frog (*Breviceps adspersus pentheri*)

Bullfrog (*Pyxicephalus adspersus*)

Common river frog (*Rana angolensis*)

Cape river frog (*Rana fuscigula*)

Clicking stream frog (*Rana grayii*)

Striped stream frog (*Rana fasciata*)

Striped grass frog (*Ptychadena porosissima*)

Snoring puddle frog (*Phrynobatrachus natalensis*)

Common caco (*Cacosternum boettgeri*)

Bronze caco (*Cacosternum nanum*)

Long-toed tree frog (*Leptopelis xenodactylus*)

Bubbling kassina (*Kassina senegalensis*)

Rattling kassina (*Kassina wealii*)

Reference:

PASSMORE, N.I. & CARRRUTHERS, V.C., 1979. South African frogs. Witwatersrand University Press, Johannesburg.

APPENDIX 4: PLANTS OF THE HLATIKULU VLEI

PTERIDOPHYTA

OPHIGLOSSACEAE

Ophiglossum polyphyllum A. Br. ex Seubert

SCHIZAEACCEAE

Mohria caffrorum (L.) Desv.

CYATHEACEAE

Cyathea dregei Kunze

DENNSTAEDTIACEAE

Pteridium aquilinum (L.) Kuhn

ADIANTHACEAE

Cheilanthes viridis (Forssk.) Swartz

ANGIOSPERMS
MONOCOTYLEDONS

TYPHACEAE

Typha capensis (Rohrb.) N.E. Br.

APONOGETONACEAE

Aponogeton junceus Lehm. ex Schlechtd. subsp. *junceus*

HYDROCHARITACEAE

Largiosiphon muscoides Harv.

POACEAE

Ischaemum fasciculatum Brongn.
Hemarthria altissima (Poir) Stapf & C.E. Hubb.
Elionurus muticus (Spreng.) Kunth
Miscanthus capensis (Nees) Anderss.
Eulalia villosa (Thunb.) Nees
Andropogon appendiculatus Nees
Andropogon eucomis Nees
Cymbopogon validus (Stapf) Stapf ex Burtt Davy
Hyperrhenia hirta (L.) Stapf
Monocymbium ceresiiforme (Ness) Stapf
Trachypogon spicatus (L. f.) Kuntze
Heteropogon contortus (L.) Roem. & Schult.
Diheteropogon filiformis (Nees) Clayton
Themeda triandra Forssk.
Digitatia diagonalis (Nees) Stapf var. *diagonalis*
Paspalum dilatatum Poir.
Paspalum urvillei Steud.
Echinocloa crus-galli (L.) Beauv.
Panicum maximum Jacq.
Panicum schinzii Hack.
Setaria pallide-fusca (Schumach.) Stapf & C.E. Hubb
Pennisetum clandestinum Chiov.
Pennisetum sphacelatum (Nees) Dur. & Schinz
Pennisetum villosum R. Br. ex Fresen.
Leersia hexandra Swartz
Arundinella nepalensis Trin.
Tristachya leucothrix Nees
Helictotrichon turgidulum (Stapf) Schweick.
Merxmuellera macowanii (Stapf) Conert
Phragmites australis (Cav.) Steud.
Agrostis bergiana Trin. var. *laevisulca* Stapf
Agrostis eriantha Hack. var. *eriantha*
Agrostis lachnantha Nees var. *lachnantha*
Aristida junciformis Trin & Rupr. subsp. *junciformis*
Sporobolus africanus (Poir.) Robyns & Tournay
Eragrostis capensis (Thunb.) Trin.
Eragrostis chloromelas Steud.
Eragrostis curvula (Schrad.) Nees
Eragrostis plana Nees
Eragrostis planiculmis Nees
Eragrostis racemosa (Thunb.) Steud.
Eragrostis tef (Zucc.) Trotter
Microchloa caffra Nees
Rendlia altera (Rendle) Chiov.
Cynodon dactylon (L.) Pers.
Harpechloa falx (L. f.) Kuntze

Eleusine coracana (L.) Gaertn. subsp. *africana* (K.-O'Byrne) Hilu & De Wet
Koeleria capensis (Steud.) Nees
Dactylis glomerata L.
Poa binata Nees
Festuca caprina Nees
Festuca elator L.
Bromus catharticus Vahl.
Lolium multiflorum Lam.
Lolium perenne L.

CYPERACEAE

Ascolepis capensis (Kunth) Ridley
Cyperus denudatus L.f.
Cyperus difformis L.
Cyperus esculentus L.
Cyperus fastigiatus Rottb.
Pycreus cimicinus (Presl) Pfeiffer [= *P. niger* (Ruiz. & Pav.) subsp. *elegantulus*]
Pycreus cooperi C.B. Cl.
Pycreus flavescens (L.) Reichb.
Pycreus macranthus (Boeck.) C.B. Cl.
Pycreus uniloides (R.Br.) Urb.
Mariscus congestus (Vahl.) C.B. Cl.
Kyllinga erecta Schumach.
Kyllinga puchella Kunth.
Ficinia sp. nov.
Fuirena pubescens (Poir.) Kunth.
Schoenoplectus brachyceras (A.Rich.) K. Lye.
Schoenoplectus decipiens (Nees) J. Raynal
Isolepis fluitans (L.) R.Br.
Eleocharis dregeana Steud.
Bulbostylis schoenoides (Kunth) C.B.Cl.
Rhynchospora brownii Roem. & Schult.
Scleria dregeana Kunth.
Scleria welwitschii (Ridley) C.B. Cl.
Carex austro-africana (Kuekenth.) Raymond
Carex cognata Kunth. var. *cognata*

ARACEAE

Zantedeschia aethiopica (L.) Spreng.
Zantedeschia albomaculata (Hook.) Baill. subsp. *albomaculata*

XYRIDACEAE

Xyris capensis Thunb.
Xyris gerrardii N.E.Br.

ERIOCAULACEAE

Eriocaulon dregei Hochst. var *dregei*

COMMELINACEAE

Commeliana africana L. var. *africana*

JUNCACEAE

Juncus dregeanus Kunth
Juncus effusus L.
Juncus oxycarpus E. Mey. ex Kunth
Juncus tenuis Willd.

ASPODELACEAE

Kniphofia linearifolia Bak.
Kniphofia breviflora Harv. ex Bak.
Kniphofia ichopensis Bak. ex Schinz var. *ichopensis*

ALLIACEAE

Agapanthus campanulatus Leighton subsp. *patens* Leighton
Tulbaghia natalensis Bak.

HYACINTHACEAE

Ornithogalum graminifolium Thunb.
Scilla natalensis Planch.
Ledebouria cooperi (Hook. f.) Jessop

AMYRYLLIDACEAE

Scadoxus puniceus (L.) Friis & Nordal
Nerine prancratioides Bak.

Brunsvigia grandiflora Lindl.
Cyrtanthus breviflorus Harv.
Cyrtanthus tuckii Bak. var. *viridilobus* Verdoon

HYPOXIDACEAE

Hypoxis filiformis Bak.
Hypoxis rigidula Bak. var. *rigidula*
Rhodohypoxis milloides (Bak.) Hilliard & Burtt

IRIDACEAE

Moraea inclinata Goldblatt
Morea stricta Bak.
Aristea cognata N.E. Br. ex Weim.
Aristea woodii N.E. Br.
Schizostylis coccinea Backh. & Harv.
Hesperantha baurii Bak. subsp. baurii
Hesperantha lactea Bak.
Dierama latifolium N.E. Br.
Dierama pauciflora Wolley-Dod
Crocosmia aurea (Pappe ex Hook.) Planch. var *aurea*
Gladiolus crassifolius Bak.
Gladiolus ecklonii Lehm. subsp. *ecklonii*
Gladiolus papilio Hook. f.
Watsonia lepida N.E. Br.

ORCHIDACEAE

Habenaria dives Reichb. f.
Habenaria dregeana Lindl.
Satyrium cristatum Sond. var. *longilabiatum* A.V. Hall
Satyrium hallackii H. Bol. subsp. *ocellatum* (H. Bolus) A.V. Hall
Satyrium longicauda Lindl. var. *jacottetianum* (Kraenzl.) A.V. Hall
Satyrium longicauda Lindl. var. *longicauda*
Satyrium trinerve Lindl.
Schizochilus zeyheri Sond.
Disa chrysostachya Swartz.
Disa stachyoides Reichb. f.
Disa versicolor Reichb. f.
Disperis tysonii H. Bol.
Eulophia foliosa (Lindl.) H. Bol.
Eulophia ovalis Lindl. subsp. *ovalis*

DICOTYLEDONS

SALICACEAE

Salix babylonica L.

POLYGONACEAE

Rumex acetosella L. subsp. *angiocarpus* (Murb.) Murb.
Rumex sagittatus Thunb.
Rumex steudelii Hochst ex. A. Rich.
Polygonum kitaibelianum Sadler
Polygonum meisnerianum Cham. & Schlechtd.
Polygonum plebeium R. Br.

PHYTOLACCACEAE

Phytolacca octandra L.

RANUNCULACEAE

Ranunculus multifidus Forssk.

BRASSICACEAE

Raphanus raphanistrum L.

DROSERACEAE

Drosera burkeana Planch.

CRASSULACEAE

Crassula pellicida L. subsp. *marginalis* (Dyrand. in Ait.) Tolken.
Crassula vaginata Eckl. & Zeyh. subsp. *vaginata*

ROSACEAE

Rubus cuneifolius Pursh.
Rubus ludwigii Eckl. & Zeyh. subsp. *spatiosus* C.H. Stirton

Rubus rigidus Smith
Duchesnea indica (andr.) Focke
Alchemilla natalensis Engl.
Leucosidea sericea Eckl. & Zeyh.
Cliffortia nitidula (Engl.) Fries & Fries subsp. *pilosa* Weim.

FABACEAE

Acacia dealbata Link.
Acacia mearnsii D. Wild.
Lotononis corymbosa (E. Mey.) Benth.
Argyrolobium pilosum Harv. [*A. amplexicaule* (E. Mey.) Duemmer]
Argyrolobium tuberosum Eckl. & Zeyh.
Melilotus alba Desr.
Trifolium pratense L. var. *pratense*
Trifolium repens L. var. *repens*

GERANIACEAE

Geranium schlecteri Kunth
Pelargonium luridum (Andr.) Sweet

OXALIDACEAE

Oxalis corniculata L.
Oxalis obliquifolia Steud ex. Rich.
Oxalis semiloba Sond.

POLYGALACEAE

Polygala ohlendorfiana Eckl. & Zeyh.

EUPHORBIACEAE

Acalypha punctata Meisn.

MALVACEAE

Hibiscus trionum L.

CLUSIACEAE

Hypericum aethiopicum Thunb. subsp. *sonderi* (Bredell) Robson
* *Hypericum lalandii* Choisy

ONAGRACEAE

Epilobium salignum Hausskn.
* *Oenothera biennis* L.
* *Oenothera jamesii* Torr. & Gray
* *Oenothera rosea* Ait.

HALORAGACEAE

* *Gunnera perpensa* L.

APIACEAE

* *Sium repandum* Welw. ex Hiern

PRIMULACEAE

Anagallis huttonii Harv.

LOGANIACEAE

Buddleja salviifolia (L.) Lam.

GENTIANACEAE

Sebaea filiformis Schinz
Sebaea sedoides Gilg.
Chironia krebsii Griseb.

ASCLEPIADACEAE

Xysmalobium stockenstromense Scott Elliot
Periglossum angustifolium Decne.
* *Asclepias fruticosa* L.

CONVOLVULACEAE

Ipomoea purpurea (L.) Roth.

VERBENACEAE

Verbena bonariensis L.
Verbena brassiliensis Vell.

LAMIACEAE

Leonotis leonurus L. (R. Br.)
Stachys natalensis Hochst. var. *natalensis*
Mentha aquatica L.
Pycnostachys reticulata (E. Mey.) Benth.

SOLANACEAE

Solanum retroflexum Dun.
Datura stratimonium L.

SCROPHULARIACEAE

Diclis reptans Benth.
Phygelius aequalis Harv. ex Hiern
Mimulis gracils R. Br.
Limosella maior Diels
Melasma scabrum Berg.
Alectra sessiliflora (Vahl.) Kuntze var. *sessiliflora*
Graderia scabra (L. f.) Benth.
Sopubia manii Skan. var *tenuifolia* (Engl. & Gilg) Hepper
Sopubia simplex (Hochst.) Hochst.
Buchnera dura Benth.

LENTIBULARIACEAE

Utricularia arenaria A. DC.
Utricularia livida E. Mey.
Utricularia prehensilis E. Mey.

PLANTAGINACEAE

Plantago lanceolata L.
Plantago virginica L.

RUBIACEAE

Anthospermum herbaceum L.f.
Anthospermum rigidum Eckl. & Zeyh. subsp. *pumilum* (Sond.) Puff

DIPSACACEAE

Cephalaria oblongifolia (Kuntze) Szabo
Scabiosa columbaria L.

CUCURBITACEAE

Cucumis hirsutus Sond.

CAMPANULACEAE

Wahlenbergia pallidiflora Hilliard & Burtt
Wahlenbergia undulata (L. f.) A. DC.

LOBELIACEAE

Lobelia angolensis Eckl. & Diels
Lobelia erinus L.
Monopsis decipiens (Sond.) Thulin

ASTERACEAE

Felicia muricata (Thunb.) Nees subsp. *muricata*
Nidorella anomala Steetz
Conyza albida Spreng.
Conyza chilensis Spreng.
Conyza pinnata (L. f.) Kuntze
Conyza podocephala DC.
Dekenia capensis Thunb.
Pseudognaphalium luteo-album (L.) Hilliard & Burtt
Helichrysum adenocarpum DC. subsp. *adenocarpum*
Helichrysum aureonitens Sch. Bip.
Helichrysum cephaloideum DC.

Helichrysum cooperi Harv.
Helichrysum epapposum H. Bol.
Helichrysum glomeratum Klatt
Helichrysum herbaceum (Andr.) Sweet
Helichrysum mundtii Harv.
Helichrysum natalitum DC.
Helichrysum pilosellum (L.f.) Less.
Helichrysum rugulosum Less.
Bidens formosa (Bonato) Sch. Bip.
Bidens pilosa L.
Tagetes minuta L.
Anthemis arvensis L.
Phymaspermum acerosum (DC.) Kallersjo
Senecio bupleuroides DC.
Senecio cathcartensis O. Hoffm.
Senecio caudatus DC.
Senecio decurrens DC.
Senecio glabberimus DC.
Senecio harveyanus MacOwan
Senecio inornatus DC.
Senecio isatideus DC.
Senecio macrocephalus DC.
Senecio madagascariensis Poir.
Senecio tysonii MacOwan
Haplocarpha scaposa Harv.
Gazania krebsiana Less. subsp. *krebsiana*
Berkheya multijuga (DC.) Rossl
Cirsium vulgare (Savi) Ten.
Gerbera ambigua (Cass.) Sch. Bip.
Hypochoeris radicata L.
Taraxacum officinale Weber sens. lat.
Sonchus asper (L.) Hill subsp. *asper*

ANGIOSPERMS
MONOCOTYLEDONS

TYPHACEAE

Typha capensis (Rohrb.) N.E. Br.

APONOGETONACEAE

Aponogeton junceus Lehm. ex Schlechtd. subsp. *junceus*

POACEAE

Elionurus muticus (Spreng.) Kunth
Miscanthus capensis (Nees) Anderss.
Eulalia villosa (Thunb.) Nees
Andropogon appendiculatus Nees
Andropogon eucomis Nees
Themeda triandra Forssk.
Digitatia diagonalis (Nees) Stapf var. *diagonalis*
Setaria sphacelata (Schumach.) Moss
Pennisetum sphacelatum (Nees) Dur. & Schinz
Arundinella nepalensis Trin.
Tristachya leucothrix Nees
Merxmuellera macowanii (Stapf) Conert
Agrostis lachnantha Nees var. *lachnantha*
Aristida junciformis Trin & Rupr. subsp. *junciformis*
Eragrostis capensis (Thunb.) Trin.
Eragrostis planiculmis Nees
Renldia altera (Rendle) Chiov.
Harpechloa falx (L. f.) Kuntze
Festuca costata Nees
Festuca elator L.

CYPERACEAE

Ascolepis capensis (Kunth) Ridley
Pycreus cooperi C.B. Cl.
Fuirena pubescens (Poir.) Kunth.
Schoenoplectus brachyceras (A.Rich.) K. Lye
Schoenoplectus decipiens (Nees) J. Raynal
Isolepis costata (Boeck.) A. Rich. var *macra* (Boeck.) B.L. Burtt

Isolepis fluitans (L.) R.Br.
Eleocharis dregeana Steud.
Rhynchospora brownii Roem. & Schult.
Scleria welwitschii (Ridley) C.B. Cl.
Carex austro-africana (Kuekenth.) Raymond
Carex cognata Kunth. var. cognata
Carex glomerabilis Krecz.

XYRIDACEAE

Xyris capensis Thunb.

ERIOCAULACEAE

Eriocaulon abyssinicum Hochst.
Eriocaulon dregei Hochst. var *dregei*

COMMELINACEAE

Commeliana africana L. var. *africana*

JUNCACEAE

Juncus dregeanus Kunth
Juncus effusus L.
Juncus oxycarpus E. Mey. ex Kunth

ASPODELACEAE

Kniphofia augustifolia (Bak.) Codd
Kniphofia breviflora Bak.
Kniphofia ichopensis Schinz var. *ichopensis*

ALLIACEAE

Agapanthus campanulatus Leighton subsp. *patens* Leighton

HYACINTHACEAE

Urginea macrocentra Bak.
Ledebouria cooperi (Hook. f.) Jessop

AMYRYLLIDACEAE

Cyrtanthus breviflorus Harv.

HYPOXIDACEAE

Hypoxis filiformis Bak.
Hypoxis ludwigii Bak.

IRIDACEAE

Aristea grandis Weim.
Hesperantha baurii Bak. subsp. *baurii*
Hesperantha lactea Bak.
Dierama pauciflora Wolley-Dod
Gladiolus ecklonii Lehm.
Gladiolus papilio Hook. f.
Watsonia lepida N.E. Br.

ORCHIDACEAE

Habenaria dregeana Lindl.
Satyrium longicauda Lindl. var. *longicauda*
Disa versicolor Reichb. f.
Disperis tysonii H. Bol.

DICOTYLEDONS

RANUNCULACEAE

Ranunculus multifidus Forssk.
Ranunculus meyeri Harv.

DROSERACEAE

Drosera burkeana Planch.

FABACEAE

Argyrolobium tuberosum Eckl. & Zeyh.

Trifolium burchellianum Ser. subsp. *burchellianum*
Trifoliun pratense L. var. *pratense*

GERANIACEAE

Geranium pulchrum N.E. Br.

OXALIDACEAE

Oxalis semiloba Sond.

ONAGRACEAE

Epilobium salignum Hausskn.

HALORAGACEAE

Gunnera perpensa L.

GENTIANACEAE

Sebaea filiformis Schinz
Sebaea sedoides Gilg.
Chironia krebsii Griseb.

LAMIACEAE

Stachys natalensis Hochst. var. *natalensis*
Mentha aquatica L.

SCROPHULARIACEAE

Limosella maior Diels
Melasma scabrum Berg.
Alectra sessiliflora (Vahl) O. Kuntze var. *sessiliflora*

LENTIBULARIACEAE

Utricularia livida E. Mey.

DIPSACACEAE

Scabiosa columbaria L.

CAMPANULACEAE

Wahlenbergia pallidiflora Hilliard & Burtt
Wahlenbergia undulata (L. f.) A. DC.

LOBELIACEAE

Lobelia erinus L.
Monopsis decipiens (Sond.) Thulin

ASTERACEAE

Felicia muricata (Thunb.) Nees subsp. *muricata*
Nidorella anomala Steetz
Conyza pinnata (L. f.) Kuntze
Pseudognaphalium luteo-album (L.) Hilliard & Burtt
Helichrysum aureonitens Sch. Bip.
Helichrysum cooperi Harv.
Helichrysum epapposum H. Bol.
Helichrysum mundtii Harv.
Senecio cathcartensis O. Hoffm.
Senecio harveyanus MacOwan
Senecio tysonii MacOwan
Senecio polyodon DC. var *polyodon*
Gerbera ambigua (Cass.) Sch. Bip.

PTERIDOPHYTA

CYATHEACEAE

Cyathea dregei Kunze

DENNSTAEDTIACEAE

Pteridium aquilinum (L.) Kuhn

ANGIOSPERMS
MONOCOTYLEDONS

TYPHACEAE

Typha capensis (Rohrb.) N.E. Br.

APONOGETONACEAE

Aponogeton junceus Lehm. ex Schlechtd. subsp. *junceus*

HYDROCHARITACAE

Largiosiphon major (Ridl.) Moss ex Wager

POACEAE

Ischaemum fasciculatum Brongn.
Hemarthria altissima (Poir) Stapf & C.E. Hubb.
Elionurus muticus (Spreng.) Kunth
Miscanthus capensis (Nees) Anderss.
Andropogon appendiculatus Nees
Cymbopogon validus (Stapf) Stapf ex Burtt Davy
Monocymbium ceresiiforme (Ness) Stapf
Themeda triandra Forssk.
Digitatia diagonalis (Nees) Stapf var. *diagonalis*
Digtaria ternata (A. Rich.) Stapf
Paspalum dilatatum Poir.

Paspalum urvillei Steud.
Echinocloa crus-galli (L.) Beauv.
Panicum schinzii Hack.
Sacciolepis chevalieri Stapf
Setaria nigrirostis (Nees) Dur. & Schinz
Setaria pallide-fusca (Schumach.) Stapf & C.E. Hubb
Pennisetum clandestinum Chiov.
Pennisetum sphacelatum (Nees) Dur. & Schinz
Pennisetum thunbergii Kunth
Leersia hexandra Swartz
Arundinella nepalensis Trin.
Tristachya leucothrix Nees.
Helictotrichon turgidulum (Stapf) Schweick.
Phragmites australis (Cav.) Steud.
Agrostis continuata Stapf
Agrostis eriantha Hack. var. eriantha
Agrostis lachnantha Nees. var. *lachnantha*
Agrostis montevidensis Spreng. ex Nees
Aristida junciformis Trin & Rupr. subsp. *junciformis*
Eragrostis capensis (Thunb.) Trin.
Eragrostis chloromelas Steud.
Eragrostis curvula (Schrad.) Nees
Eragrostis heteromera Stapf
Eragrostis plana Nees
Eragrostis planiculmis Nees
Harpechloa falx (L. f.) Kuntze
Eleusine coracana (L.) Gaertn. subsp. *africana* (K.-O'Byrne) Hilu & De Wet
Koeleria capensis (Steud.) Nees
Stibarus alopecuroides (Hack.) Stapf
Poa binata Nees
Festuca caprina Nees
Lolium rigidum Gaudin

CYPERACEAE

Ascolepis capensis (Kunth) Ridley
Cyperus denudatus L.f.
Cyperus difformis L.
Cyperus esculentus L.
Cyperus fastigiatus Rottb.
Cyperus semitrifidus Schrad. *semitrifius*
Pycreus betschuanus (Boeck.) C.B. Cl. subsp. *elegantulus*
Pycreus flavescens (L.) Reichb.
Pycreus macranthus (Boeck.) C.B. Cl.
Pycreus nitidus (Lam.) J. Raynal
Pycreus oakfortensis C.B. Cl.
Pycreus uniloides (R.Br.) Urb.

Mariscus congestus (Vahl.) C.B. Cl.
Kyllinga alba Nees
Kyllinga erecta Schumach.
Fuirena pubescens (Poir.) Kunth.
Schoenoplectus brachyceras (A.Rich.) K. Lye.
Schoenoplectus paludicola (Kunth) Palla ex J. Raynal
Isolepis fluitans (L.) R.Br.
Eleocharis dregeana Steud.
Eleocharis palustris R. Br.
Fimbristylis complanata (Retz.) Link
Fimbristylis dichotoma (L.) Vahl
Bulbostylis schoenoides (Kunth) C.B.Cl.
Rhynchospora brownii Roem. & Schult.
Scleria dieterlenii Turrill
Scleria dregeana Kunth.
Scleria welwitschii (Ridley) C.B. Cl.
Schoenoxiphium ecklonii Nees.
Carex acutiformis Ehrh.
Carex austro-africana (Kuekenth.) Raymond
Carex clavata Thunb.
Carex cognata Kunth. var. *cognata*

LEMNACEAE

Lemna sp.

XYRIDACEAE

Xyris capensis Thunb.

ERIOCAULACEAE

Eriocaulon dregei Hochst. var *dregei*

COMMELINACEAE

Commeliana africana L. var. *africana*

JUNCACEAE

Juncus effusus L.
Juncus exsertus Buchen. subsp. *exsertus*
Juncus oxycarpus E. Mey. ex Kunth

Juncus tenuis Willd.

ASPODELACEAE

Trachyandra asperata Kunth var. *stenophylla* (Bak.) Oberm.
Kniphofia breviflora Harv. ex Bak.
Kniphofia ichopensis Bak. ex Schinz var. *ichopensis*
Kniphofia tysonii Bak. subsp. *tysonii*

ALLIACEAE

Agapanthus campanulatus Leighton subsp. *patens* Leighton
Tulbaghia natalensis Bak.

HYACINTHACEAE

Ornithogalum graminifolium Thunb.
Scilla natalensis Planch.
Ledebouria cooperi (Hook. f.) Jessop

AMYRYLLIDACEAE

Cyrtanthus breviflorus Harv.

HYPOXIDACEAE

Hypoxis parvifolia Bak.
Hypoxis rigidula Bak. var. *rigidula*

IRIDACEAE

Aristea woodii N.E. Br.
Hesperantha baurii Bak. subsp. *baurii*
Hesperantha lactea Bak.
Dierama medium N.E. Br.
Tritonia lineata (Salsb.) Ker-Gawl. var. *lineata*
Gladiolus crassifolius Bak.
Gladiolus papilio Hook. f.

ORCHIDACEAE

Schizochilus zeyheri Sond.
Disa chrysostachya Swartz.
Disa polygonoides Lindl.
Disperis tysonii H. Bol.

DICOTYLEDONS

SALICACEAE

Salix babylonica L.

POLYGONACEAE

Polygonum plebeium R. Br.

RANUNCULACEAE

Ranunculus meyeri Harv.
Ranunculus multifidus Forssk.

BRASSICACEAE

Rorippa narsturtum-aquaticum (L.) Hayck

DROSERACEAE

Drosera burkeana Planch.

CRASSULACEAE

Crassula pellicida L. subsp. *marginalis* (Dyrand. in Ait.) Tolken.
Crassula natans Thunb. var. *natans*
Crassula vaginata Eckl. & Zeyh. subsp. *vaginata*

ROSACEAE

Rubus cuneifolius Pursh.
Agrimonia bracteata E. Mey. ex C.A. Mey.
Cliffortia linearifolia Eckl. & Zeyh.

FABACEAE

Argyrolobium tuberosum Eckl. & Zeyh.
Trifolium repens L. var. *repens*
Vigna frutescens A. Rich. subsp. *frutescens* var. *frutescens*

OXALIDACEAE

Oxalis obliquifolia Steud ex. Rich.

EUPHORBIACEAE

Acalypha ciliata Forssk.
Euphorbia striata Thunb. var. *cuspidata* (Boiss.) N.E. Br.

MALVACEAE

Hibiscus trionum L.

LYTHRACEAE

Rotala tenella (Guill & Perr.) Hiern

CLUSIACEAE

Hypericum lalandii Choisy

HALORAGACEAE

Gunnera perpensa L.

APIACEAE

Sium repandum Welw. ex Hiern

GENTIANACEAE

Sebaea sedoides Gilg.
Chironia krebsii Griseb.

ASCLEPIADACEAE

Schizoglossum nitidum Schltr.
Periglossum angustifolium Decne.

VERBENACEAE

Verbena bonariensis L.
Verbena officinalis L.

LAMIACEAE

Mentha aquatica L.
Pycnostachys reticulata (E. Mey.) Benth.

SOLANACEAE

Datura stratimonium L.

SCROPHULARIACEAE

Diclis reptans Benth.
Limosella maior Diels
Melasma scabrum Berg.
Sopubia simplex (Hochst.) Hochst.
Buchnera dura Benth.
Buchnera glabrata Benth.

LENTIBULARIACEAE

Utricularia australis R. Br.
Utricularia inflexa Forssk.
Utricularia livida E. Mey.
Utricularia prehensilis E. Mey.

ACANTHACEAE

Thunbergia natalensis Hook.

PLANTAGINACEAE

Plantago lanceolata L.

CAMPANULACEAE

Wahlenbergia krebsii Cham. subsp. *krebsii*
Wahlenbergia undulata (L. f.) A. DC.

LOBELIACEAE

Lobelia erinus L.
Monopsis decipiens (Sond.) Thulin

ASTERACEAE

Virnonia hirsuta (DC.) Sch. Bip.
Nidorella anomala Steetz
Conyza albida Spreng.
Conyza podocephala DC.
Dekenia capensis Thunb.
Pseudognaphalium luteo-album (L.) Hilliard & Burtt
Helichrysum aureonitens Sch. Bip.
Helichrysum pilosellum (L.f.) Less.
Bidens formosa (Bonato) Sch. Bip.
Bidens pilosa L.
Tagetes minuta L.
Senecio caudatus DC.
Senecio erubescens Ait. var. *crepidifolius* DC.
Senecio glabberimus DC.
Senecio paucicalyculatus Klatt
Gazania krebsiana Less. subsp. *krebsiana*
Cirsium vulgare (Savi) Ten.
Gerbera viridifolia (DC.) Sch. Bip. subsp. *natalensis* (Sch. Bip.) H.V. Hansen
Hypochoeris radicata L.