The Restoration of Riparian Plant Communities following Alien Plant Clearing in the Western Cape.

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Chapter 2. Identifying species-environment interactions in riparian plant communities in the Western Cape Province, South Africa – A framework for objective restoration programmes.

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CHAPTER 1:

1. INTRODUCTION:

Plant invasions are a serious threat to natural and managed ecosystems worldwide. This problem will definitely get worse as more species are introduced to new habitats and more existing invaders move into a phase of rapid spread (Hobbs & Humphries, 1995).

Invasiveness, invasibility and environmental stress are all implicated in the spread of alien plants (Alpert *et al.* 2000). Various traits allow a species to invade a new habitat (invasiveness). Another suite of factors determines the susceptibility of a community or habitat to invasion by new species (invasibility), and the effects of alien invaders on resident species and ecological processes (impacts or environmental stress). Invasive alien plants have affected most types of ecosystems all over the world (Richardson, 2001).

Thousands of alien species have been introduced to South Africa, both intentionally and accidentally, some in very large numbers. Only a small sample of these species has become invasive. Table 1.1 lists some of the most widespread alien invaders in South Africa's fynbos biome.

The problem of alien invaders has manifested itself in riparian zones in many parts of the world. One of the best-studied invaders of riparian habitats is *Heracleum mantegazzianum* (giant hogweed). This species was introduced to Britain in 1893 as an ornamental plant, and soon spread along river courses, roads, railways and wastelands over large areas. It is now found from the south coast of England to the Scottish highlands (Anderson, 1994; Lündstrom and Darby, 1994; Sampson, 1994). Another well-studied riparian invader is *Tamarix aphylla*. This species was introduced to North America as an ornamental from its native range in arid parts of Asia Minor, northwestern India, northern and northeastern Africa. It is now one of the dominant woody plants along rivers in the southwestern USA (Brock, 1994; Duncan &

McDaniel, 1998; Griffin *et al.* 1989). *Impatiens glandulifera,* an introduced species in Europe, spreads predominantly in riparian habitats and is becoming increasingly common in the UK (Fowler & Holden, 1994). *Fraxinus ornus*, native to Mediterranean and southern central Europe, has been introduced in southern France where it is highly invasive (Thébaud & Debussche, 1991).

Riparian habitats in South Africa's fynbos biome are heavily invaded by numerous species (some of which are described in Table 1.1.), e.g. *Acacia longifolia, A. saligna, A. mearnsii, Paraserianthes (=Albizia) lophantha* and *Sesbania punicea* (Macdonald & Jarman, 1984).

Table 1.1. Summary of the identity, history and extent of infestations of the most widespread woody alien species in the fynbos biome. (Data from Richardson *et al.* 1992) (see footnotes for explanations of column headings).

SPECIES	ORIGIN	WHEN	WHY	SPREAD	%DISTRIBUTION
Acacia cyclops	Australia	1857	Garden	Timber/sand-stabilization	65
Acacia longifolia	Australia	1827	Horticulture	Sand-stabilization/ Unintentional	42
Acacia mearnsii	Australia	1858	Garden	Tannin/timber	47
Acacia melanoxylon	Australia	1848	Garden	Horticulture/timber	26
Acacia saligna	Australia	1848	Garden	Tannin/timber/sand-stabilization	60
Hakea gibbosa	Australia	1835	Garden	Hedges/sand-stabilization	4
Hakea sericea	Australia	1858	Garden	Hedges/unintentional	30
Leptospermum laevigatum	Australia	1850	Sand-stabilizatio n	Hedges	10
Paraserianthes lophantha	Australia	1835	Garden	Horticulture/ Unintentional	14
Pinus halepensis	Mediterranean	1830	Timber	Timber	?
Pinus pinaster	Mediterranean	1680s	Timber	Timber	30
Pinus radiata	California	1865	Timber	Timber	17

The headings used in the table above are explained as follows:

When? – Date of initial introduction;

Why? – Reason for introduction to South Africa;

Spread? – Mode of human-aided dissemination within South Africa;

% Cover – Extent of distribution in the fynbos biome (% ¼ °grids with presence records in the late 1980s).

Few of the riparian zones of the Western Cape Province, South Africa, can still be described as 'natural', as many, if not all, have been impacted upon in one way or another. They are, therefore, frequently disturbed environments that are highly susceptible to invasion by alien plants. The vegetation of riparian zones controls the flow of water, nutrients and sediments into streams. Plant communities in these habitats are often rich in species, and serve as corridor facilitating the movement of organisms (Hood & Naiman, 2000).

Periodic disturbances, notably flooding, create openings that provide opportunities for seedling establishment (Pyšek & Prach, 1993). Floods scarify the hard-coated seeds of alien species (legumes) and large buoyant fruits and seeds (Richardson *et al.* 1992).

This chapter reviews the structure and functioning of riparian ecosystems, with special reference to factors that influence their susceptibility to alien plant invasions. Particular attention is given to the situation in the Western Cape.

1.1. Riparian Zones: Structure and Dynamics:

Riparian zones are the interfaces between terrestrial and aquatic ecosystems. They have been investigated from many perspectives, resulting in many, sometimes confusing, definitions based on hydrologic, topographic, edaphic and vegetation factors (Gregory *et al.* 1991). Riparian ecosystems occupy a unique position in the catchment landscape (Wissmar & Beschta, 1998), and they support many critically important ecological functions (Goodwin *et al.* 1997). Their vegetation communities offer an abundant and diverse array of food resources for both aquatic and terrestrial consumers (Gregory *et al.* 1991).

Riparian zones comprise sharp gradients of environmental factors, ecological processes, and plant communities. These zones are not easily described, as they comprise mosaics of landforms, communities, and environments within the larger landscape (Gregory *et al.* 1991).

Classification of riparian zones:

River channels comprise a number of morphological units, each of which are related to a particular set of hydro-geomorphic processes and to distinctive vegetation communities. Rowntree (1991) provided a simplified classification of a river in Kwazulu-Natal, South Africa, into six units, namely; the channel bed, channel bar, channel shelf or berm, channel bank, bank edge and flood plain (see Table 1.2). Boucher (1998), working in the Western Cape province, divided riparian zones into an aquatic zone, a wet bank zone and a dry bank zone. The studies in this thesis were done largely in the wet and dry bank zones.

***Vegetation of Riparian Zones*:**

The major physical factors of river catchments that influence the development of riparian corridors are the bedrock geology, geomorphic features (e.g. surface landforms such as erosional features and deposits created by fluvial, landslide and windstorm events), soil character, climate and hydrological regimes (Tabacchi *et al.* 1998). Plant communities are distributed on flood plains in relation to flood depth, duration, and frequency, as well as variation in soils and drainage composition. In North America, some plant species, such as cottonwood *(Populus* sp.), willows (Salix spp.) and silver maple (*Acer saccharinum*) are adapted to colonization of newly deposited sediments and may require very specific patterns of flood recession during a brief period of seed fall to be successful (Morris *et al.* 1978, Rood & Mahoney, 1990; Restoration Working Group, 1998). Although Australian rivers and creeks rarely flood, the different soil and ground water regimes along their banks still produce vegetation that is distinct from that of surrounding upland areas.

Riparian vegetation consists of those plant communities that are restricted to the zone directly influenced by the stream (Hancock *et al.* 1996). Brinson (1990) defined 'riverine forests' as those owing 'their dynamics, structure and composition to river processes of inundation, transport of sediments, or the erosive forces of water and ice movement'.

Species composition of riparian communities varies widely among different habitats, depending on variation in important variables such as current velocity, wave action and soil type. Variation occurs from the scale of local patchiness to one of entire rivers (Nilsson, 1998).

A common feature of riparian ecosystems, is their uniqueness from upland areas with reference to vegetation, because of the greater availability of water in an otherwise water-limited landscape (Fisher, 1995 in Goodwin *et al.* 1997). Water availability is the single most important factor controlling the growth of riparian vegetation. In general, the biomass and species composition of riparian vegetation varies with increasing distance from and elevation above the river.

Riparian plant communities exhibit a high degree of structural and compositional diversity. The distribution and composition of these plant communities reflects histories of both fluvial disturbance regimes of adjacent upland areas, such as fire, wind, plant disease, and insect outbreaks. Soil properties and topography of valley floors are extremely varied, ranging from perennially wet to well-drained soils over short distances (Gregory *et al.* 1991).

Table. 1.2. A list the morphological units of riparian zones identified by Rowntree (1991) with its description (location) and the vegetation types with which its associated, incorporated into Boucher's (1998) classification.

MORPHOLOGICAL UNIT	Rowntree (1991) (For KwaZulu-Natal)	Boucher (1998) (For the Western Cape)
Channel bed	Covered at low mean water level and inundated most of the time; supports - free floating aquatics in water column above the bed.	Aquatic zone-this zone consists of bedrock boulders and is inundated 100% of the time. It supports aquatic species.
Channel bar	Areas of accretion raised slightly above the mean low water level; provides a habitat for herbaceous plants such as reeds and herbs rooted in the substrate.	
Channel shelf or berm	Accretional feature which lies between the low water channel and riverbank; undated 5-25% of the time; provides habitat for herbaceous vegetation and riparian shrubs.	Wet bank zone; This zone is further subdivided into moss, sedge and lower shrub sections. This zone can be submerged during floods.
The river bank	Separates the main channel from the flood plain; slope gradient varies from nearly vertical to gently sloping depending on basal processes and strength of bank materials; steep slopes-devoid of vegetation; moderate to gentle slopes-grass or shrubs	
Bank edge	Strip immediately adjacent to the bank; zone where vegetation has a direct impact on stability and extends for a few meters away from the bank itself.	The dry bank zone is further subdivided into the lower dynamic, tree or upper shrub, and back dynamic zones. These zones are fringed by water during floods and contain many fynbos elements.
Flood plain	More or less level surface which is inundated at frequencies of between 1 and 3 years for rivers in humid areas, possibly less frequently in semi-arid areas; vegetation may include the full range of life forms from herbaceous plants to trees.	

Rowntree (1991) concentrates on the morphological units, whereas Boucher (1998) specifically refers to the type of vegetation occurring in these zones.

1.2. Functions and contributions of Riparian Zones:

Riparian zones provide resources for many species that are not available elsewhere in the environment (see Table 1.3). Many reports have documented the importance of riparian habitats for animals ranging from invertebrates to large vertebrates (Malanson, 1993).

Table 1.3. Functions/values of riparian vegetation in aquatic and terrestrial ecosystems (Adapted from Malanson, 1993).

SITE	COMPONENT	FUNCTION
Aboveground/above channel	Canopy and stems	1) Shade controls temperature and in stream primary production 2) Large and fine plant detritus source 3) Provides food, habitat and building material (beaver) 4) Communication routes for vertebrates (riparian corridor)
In channel	Large debris derived from riparian vegetation	1) Controls routing of water and sediment 2) Shapes habitat and provides cover 3) Substrate for biological activity
Riparian zone	Roots	1) Increases bank stability 2) Provides cover (overhanging) 3) Nutrient uptake from ground and stream water
	Stems and low-lying canopy	Retards movement of sediment, water and organic debris in flood flows
	Ground vegetation	1) Spawning ground for fish & insects 2) Source of detritus 3) Retards nutrients 4) Reduces runoff through evapotranspiration

1.3. The effect of disturbance on riparian zones:

Riparian zones are highly susceptible to human-induced disruption due to urbanization, construction of rail and road networks, dam building, water diversion, channelization, mining, disposal of industrial and domestic wastes, use of pesticides and herbicides, as well as inappropriate land-use leading to increased sediment (Godoy *et al.* 1999). Floods, fire, insects and disease, temperature extremes, and drought are some natural events with the potential to disturb the structure and function of riparian zones (Hobbs & Huenneke, 1992), but those are often modified by human activities (Hobbs, 1991). These systems respond in various ways, depending on their relative stability and resistance (FISRWG, 1998).

Riparian zones are one of the most dynamic portions of the landscape. Frequent disturbance events in these zones create complex mosaics of landforms and associated biological communities that often are more heterogeneous and diverse than those associated with upslope landscapes (Gregory *et al.* 1991). These disturbances will be dealt with under different headings, namely natural, human-induced and plant invasions.

Natural Disturbances:

Natural disturbances can sometimes act as agents of regeneration and restoration. For example, certain species of riparian plants have adapted their life cycle to include the occurrence of destructive, high-energy disturbances, such as floods.

Flooding:

Floods act to reshape earth surface landforms, riparian and channel features. The flood events, along with the accompanying erosion and deposition of materials, also contribute to the formation of different riverine habitats (Tabacchi *et al.* 1998). Periodic disturbances resulting from destructive flooding generally destroy or damage a large part of riparian vegetation.

Flood action usually creates openings that are known to be favourable for colonization by providing suitable habitats for many alien invaders (Thèbaud & Debussche, 1991; Pyšek & Prach, 1993). Flooding is frequent, often annual or even more often, and a single flood may modify hundreds of square kilometres of river valley (Gregory *et al.* 1991). A riparian ecosystem may then take decades to re-establish itself depending on regional climatic conditions (Goodwin *et al.* 1997).

The influence of flooding on species distributions has been a recurring topic in the study of riparian vegetation (Jacob, 1999). Flooding is also an important environmental factor that influences plant composition and plant growth in many parts of the world (Blom *et al.* 1990). Floods control both the physical environment and biotic communities of stream and riparian ecosystems. Immediate effects of floods include widening, filling, deepening, or relocation of the channel; alteration of substrate particle sizes, damage to riparian and aquatic vegetation and addition or removal of organisms from the local communities (Friedman *et al.* 1996). Floods may exert such influence through transport of propagules, the imposition of anaerobic conditions in the root zone or through the direct mechanical work of floodwater in destroying vegetation or modifying substrates.

Anaerobic effects are probably most important in environments where floodwaters remain at high levels for long periods. Mechanical impacts may be important in any environment where floods are of sufficient magnitude to damage plants or rework the surface on which they grow (Jacob, 1999).

The duration of flooding that tree seedlings can endure depends greatly on the time of the year. Siebel & Blom (1998) showed that seedlings of the same species survive total emergence in clear water for most of spring, and then showed variable differences in survival during summer. Siebel *et al.* (1998) showed that tree seedlings could avoid the severe conditions of total submergence by growing rapidly in height above the flood level.

Many plants time important life-cycle events, in order to avoid the adverse effects of submergence (Blom & Voesenek, 1996). It has been said that natural levels of flood disturbance and habitat heterogeneity are important in sustaining the biodiversity of riparian ecosystems (Godoy *et al.* 1999; Bornette & Amoros, 1996).

Human-induced disturbances:

"Human-induced disturbances brought about by land-use activities, undoubtedly have the greatest potential for introducing enduring changes to the ecological structure and functions of stream corridors" (FISRWG, 1998).

a) Erosion:

There is still some controversy surrounding the link between bank characteristics, bank processes and the stable channel geometry. On vegetated banks factors such as the type and density of vegetation and health are also important because they directly control the vegetation influence, which may be either to enhance, or reduce bank stability (Thorne, 1990). An important distinction can be made between grassy and woody vegetation in terms of their effects on bank stability. Grasses and other herbaceous vegetation have a low biomass and are shallow rooting, but tend to have a good surface cover and a dense near-surface root mat.

A good grass cover is most effective against surface scour and enhances stability with respect to shallow slips. The shallow root depth has no effect on stability with respect to deep-seated failures. Trees tend to lack this dense surface root mat and have a poorer ground cover, making the soil surface less resistant against scour. Instead, being deep rooted; trees contribute to the bank material and increase its stability with respect to mass failure (Rowntree, 1991).

Dead vegetation leaves relic roots in the bank. The effectiveness of relic roots in binding the soil decreases with time and eventually the voids and holes left by dead roots may reduce cohesion to a level below that for fallow soil (Thorne, 1990).

However, dead trees in particular tend to pull the bank down due to loss of root associated soil strength. An isolated dead tree in a channel can generate local scour and become a serious source of channel instability (Rowntree, 1991).

In many parts of the woody, invasive alien plants have a major effect on the riverbank stability. For example, Hoffmann & Moran (1988) stated that the presence of *S. punicea* infestations in rivers in the Western Cape obstructs the flow of water, especially during flooding. This often leads to erosion of the water courses, and changes well-defined rivers into a diffuse system of shallow streamlets and trickles with consequent sedimentation, and widening of the stream-bed that creates a perfect substrate for further lateral expansions of the *S. punicea* infestations.

b) Physical disturbance by animals:

Large animals that make use of riparian zones often modify this habitat, as they selectively eat vegetation, burrow and wallow in soils, build dams on streams amongst other activities (Naiman & Rogers, 1997). In many instances, (native) large animals are natural parts of the ecosystem, but alien livestock usually constitute a major disturbance. Grazing of domestic livestock, primarily cattle and sheep, is common across the globe (FISRWG, 1998). In the Western Cape, rural .ivers are increasingly being affected by livestock, usually with destructive consequences. The main impacts that result from grazing of domestic livestock are the loss of vegetation cover and increased erosion of the stream bank.

In areas outside South Africa, beavers pond water and store sediments, creating wetlands, and are able to alter the composition of riparian vegetation, strongly influencing riparian landscapes. Naiman & Rogers (1997) describe in detail the effects of various large mammals on riparian zones, by either browsing (elk, deer and moose), digging of holes (elephant, gemsbok, warthog and baboon) and ponding (hippopotamus and beaver).

Although this is not common in the Western Cape, and not much research has been done on this topic, observations in the field confirm that agricultural activities (involving domestic livestock) have a detrimental impact on river vegetation, as well as water quality.

Plant Invasions in South Africa:

Riparian habitats are highly susceptible to invasion by alien species, because they tend to exhibit small-scale discontinuities in plant cover that allow new plants to become established. This susceptibility increases when this habitat is under stress.

Disturbance seems to facilitate alien invasions for some of the same reasons that it maintains high levels of native species diversity. Human disturbances may introduce alien species to riparian zones and natural disturbances such as flooding may facilitate their spread throughout the drainage network (Hood & Naiman, 2000).

Mechanical control measures against woody alien invaders in South African riparian systems are probably the most intensive undertaken anywhere in the world. The control of invasive alien plants is by far the most expensive and time-consuming task for nature conservation authorities in the fynbos biome. Finding more effective and cheaper solutions to this escalating problem is probably the most urgent challenge facing conservationists in the biome.

Susceptibility of riparian zones to invasion:

The threats to river systems in the Western Cape include over-abstraction of water, invasion by alien plants, alien fish invasions, removal of indigenous vegetation, water pollution, bulldozing of river channels, erosion, dumping of rubble and litter, and the presence of alien water plants, such as water hyacinth (Brown, 1998). Ashton & Mitchell (1989) explained the susceptibility of environments to invasions by proposing three main mechanisms, i.e. disturbance or alteration of habitat, absence of predators, and absence of effective competing species. All these factors apply to riparian zones, but what makes rivers even more susceptible to invasions?

Riparian zones are physically dynamic areas with changes in flows; especially floods, altering riverbeds and exposing bare soil for colonization by weeds. They are also prone to invasion because they are long and narrow and vulnerable to the impact of changes in land-use and cover in adjacent areas. Features of the riparian environment that promote invasion include the easier access to moisture, and periodic disturbances in the form of floods that disperse the seeds, prepare them for germination, provide seed banks, and remove competing plants (Richardson *et al.* 1997,Versfeld *et al.* 1998).
(See Table 1.4).

Riparian zones differ from other systems in that they act as a link between various ecosystems, and thus facilitate the spreading of several species (Planty-Tabacchi *et al.* 1996). Periodic disturbances which result form destructive flooding generally destroy or damage a large part of riparian vegetation, and this creates openings or gaps that provide suitable habitats for alien invaders (Pyšek & Prach, 1993).

Major invaders of riparian zones typically regenerate either from seeds (e.g. *Acacia* species) or from vegetative parts such as roots and branches (e.g. *Populus* spp., *Salix* spp.). South Africa experiences pronounced cycles of wet and dry periods, with floods being common during wet cycles. This is a key invasion opportunity for species that are dispersed by water (Versfeld *et al.* 1998
In many parts of South Africa, including the Western Cape, expert knowledge simply informs that 'all the rivers are invaded' (Versfeld *et al.* 1998). The Western Cape is distinct from other provinces in that major problems with alien invaders occur in both landscapes and rivers, whereas in other provinces riparian invasions tend to dominate. The Western Cape is also the most heavily invaded of all the provinces, especially the wetter catchments of the coastal mountain ranges and broad coastal lowlands in the west and south.

Overall, *Acacia* species are the biggest problem, with a total invaded area of more than 1,6 million hectares and a condensed area of more than 500 000 hectares. Biological control is having a significant impact already (e.g., *Acacia saligna, A. longifolia* and *Sesbania punicea*). Table 1.4 shows the most important riparian invaders in the Western Cape (extracted from Versfeld *et al.* 1998).

Table 1.4. The most important invasive alien trees and shrubs in the Western Cape based on condensed invaded area (r=riparian & l=landscape) (Versfeld *et al.* 1998). The condensed area is the total area adjusted to bring the cover to the equivalent of 100%. Density is the estimated mean cover in the total invaded area.

SPECIES	HABITAT	DENSITY (%)
Acacia saligna	l, r	5.77
Acacia mearnsii	r, l	6.03
Acacia longifolia	r, l	13.04
Prosopis species	r, l	1.49
Sesbania punicea	r	12.68
Leptospermum laevigatum	r, l	3.21
Acacia melanoxylon	r, l	3.74
Acacia mixed species	r, l	54.65

Major alien invaders in South Africa:

The examples of alien invaders discussed below have been chosen based on their invasive success in riparian landscapes, as well as the literature available on these species. *Sesbania punicea*, even though successfully under biological control, was used to illustrate the extent of invasion in the past and the results of successful biological control. *Salix babylonica* was used to illustrate the ease with which this invader has managed to propagate itself along riverbanks, in other biomes (grassland).

a) *Acacia mearnsii* (black wattle)

Acacia mearnsii De Wild., native to Australia, is a widespread plant invader in South Africa, particularly along rivers, streams and ditches (Boucher, 1980, Macdonald, 1991).

Black wattle was introduced to KwaZulu-Natal in the 19th century where it was widely planted. The main features of black wattle include its ability to produce huge numbers of long-lived, viable seeds that are transported down rivers, causing extensive invasion of riparian zones.

Black wattle is an evergreen tree that grows to a height of 5-15m. It enriches the soil via nitrogen fixation; this contributes to its impact as an invasive species in the fynbos biome, where increased nitrogen status of soils is potentially detrimental to the growth of indigenous vegetation, which occurs naturally on nutrient-poor soils (Pieterse & Boucher, 1997; see also Stock & Allsopp (1992) and Musil (1993). This species is shallow-rooted and is readily prone to collapse from bank erosion or in the face of floods. Although not accurately quantified, this species is an expensive water-user (Dye & Poulter, 1995).

b) *Acacia saligna* (Port Jackson willow)

Acacia saligna (Labill.) Wendl., commonly known as Port Jackson willow, was until recently rated the most troublesome invasive alien plant in the fynbos biome of South Africa (Morris, 1997). This shrub or small tree is native to southwestern Australia. It has invaded both disturbed and pristine fynbos and shrublands on a wide variety of substrates, and often forms dense monospecific stands (Milton & Hall, 1981;Henderson, 1995). The success of *A. saligna* is largely attributed to the large number of viable seeds it produces, although little is known of its resource requirements, particularly in terms of nutrients and soil moisture. This invader grows to a height of from 3-10m and overtops the indigenous vegetation that generally attains a height of less than 2m (Witkowski, 1991). After fire, *A. saligna* may also resprout from epicormic buds near to the soil surface, further enhancing its competitive advantage.

Thus, with each successive wild fire, acacia density increases with a concomitant reduction in light availability in the stand. In addition to creating dense shade, *A. saligna* fixes nitrogen and has potential to enhance total soil nitrogen (Holmes & Cowling, 1997). It was introduced during the mid-nineteenth century to stabilize shifting sand dunes. Biological control by an introduced fungus has greatly reduced the density of invasive stands over much of its adventive range in the fynbos biome, and has probably curtailed its potential to invade new areas. Nonetheless, dense stands of this species will constitute a management problem for at least the next few decades.

c) *Sesbania punicea*

Sesbania punicea (Cav.) Benth is native to Argentina, Uruguay and southern Brazil. In the Western Cape this invader is common along rivers and streams, particularly in the southwestern part of the Western Cape and in the Eastern Cape. *Sesbania* is a hardy perennial that seems to spread best in lowland areas wherever water is not a limiting factor (Pienaar, 1980). All parts of this plant are reportedly toxic, especially the seeds.

High seed viability, together with a relatively rapid onset of germination, have allowed this plant to form dense thickets along river banks, in wetlands and in areas of natural vegetation.

This invader is now successfully under biological control, with the florivorous weevil, *Trichapion lativentre* (Hoffmann & Moran, 1991). Another weevil ,*Neodiplogramnus quadrivitattus* (Olivier), destroys older plants by boring into stems, mainly >/= five years old. The combined impact of these two agents has brought about a decline in density of *S. punicea* (Hoffmann & Moran, 1991).

d) *Salix babylonica* (weeping willow)

Salix babylonica, the weeping willow, is naturalised along watercourses, mainly in the grassland biome in southern Africa. The invasion ecology has received little attention. It is easily propagated vegetatively from cuttings or truncheons where conditions are favourable for its dispersal.

During the summer rainfall season, characterised by violent thunderstorms, rivers and streams can flow very swiftly, the force of the water easily breaking off branches and depositing them downstream (Henderson, 1991). *Salix babylonica* was planted for ornament, shade, and fodder and for its sand-binding properties, but its extensive distribution along watercourses is unlikely to be attributed entirely to planting.

1.4. Ecological restoration of riparian zones:

Restoration measures in riparian zones

Restoration of areas invaded by plants and animals usually involves the removal of the invading species in one-way or another. This can be accomplished directly by physical, chemical or biological methods, or indirectly by altering key processes, for instance by altering river flow rates or flood frequencies and intensities. When rehabilitating an area, an integrated approach is required, where a combination of available methods are employed to deal with the problem. These include mechanical methods (such as cutting down, removing or burning weeds); chemical approaches (using environmentally safe herbicides as part of the control operations) and biological control (using species-specific insects and diseases from the alien plants' country of origin).

In South Africa, a project, which is one of the most widely acclaimed under the governments' Reconstruction and Development Programme (RDP), is the Working for Water (WfW) Programme. The former-minister of Water Affairs and Forestry, Kader Asmal, initiated this programme in September 1995. The programme operates countrywide, across several biomes and many vegetation types. The main objectives of this programme, include the enhancement of available water supplies by clearing high water-use alien invasive plants from catchments and streams (Klein, 1997), as well as the conservation of biodiversity through recolonization and recruitment of indigenous flora and fauna following the clearing of alien invasive plants. The main aim of these clearing operations is to restore a sustainable cover of natural vegetation, without which the risk of soil erosion (especially on steep slopes and riverbanks) is increased.

This sustainable cover of indigenous vegetation is also required to ensure that catchment areas continue to deliver high water quality (Gelderblom *et al.* 1997).

Physical rehabilitation:

a) *Mechanical clearing*

Mechanical clearing operations, in which invasive acacias are felled and removed or burnt, normally result in massive seed germination from the soil seed bank (accumulated seeds in the soil). This is due to greater penetration of light, removal of competing vegetation, stimulation of hard seeds by fire, and disturbance of the soil. Most alien invasive plants are characterised by copious seed production and, consequently, these represent the majority of seeds that germinate after clearing (Klein, 1997).

The equipment used in mechanical control ranges from hand-held instruments (such as saws, slashers and axes) to power-driven tools such a chainsaws and brush cutters, and even to bulldozers in some cases (Donald, 1986). Even though invaders are removed or cleared, this may lead to further problems. If measures are not taken to ensure that the site is effectively recolonized by other, preferably native, species, the site may be rendered unstable and open to further physical degradation (for instance if the invading species acted to stabilize stream banks). Similarly, removing an invading species leaves the site open to further invasion, either by the same species or by other unwanted species (Hobbs, 2000).

Clearing invasive trees in riparian zones is very expensive, but is essential, as invasive tree species such as *Acacia mearnsii*, *Eucalyptus grandis* and *Solanum mauritianum* spread rapidly and form dense thickets. This causes disturbance of the soil and damage to the original indigenous vegetation caused during harvesting operations. Versfeld *et al.* (1998) estimated the cost of clearing in South Africa to be about R6.97 billion (with almost half of the cost in the Western Cape).

Eradicating these alien invaders has definite benefits in terms of increasing water resources, but there are many advantages. These include the conservation of biodiversity, easier fire management, increased catchment stability, a greater potential for ecotourism and direct job creation through the control programmes and associated secondary industries (Le Maitre *et al.* 1996).

Klein (1997) suggests three operational stages which are necessary to ensure that the infestations are systematically reduced and the area rehabilitated: i) Initial control, which entails the reduction of the existing plants; ii) follow-up control, involving the removal of seedlings, root suckers and coppice regrowth; and iii) maintenance control, which sustains low alien plant levels and prevents re-infestation.

b) Revegetation (restoration)

Dawson (1991) proposed a number of possible rehabilitation techniques with regard to corridor rehabilitation, their advantages and disadvantages, as well as their relative costs (Table 1.5). Here, 'corridor rehabilitation' is considered to be the recovery or re-establishment of a 'band' of locally indigenous vegetation.

Although no clear reference was made to riparian zones, this table is used to illustrate the general principles of these rehabilitation methods, which could possibly be applied to riparian zones (e.g. natural colonization- could be considered to be similar to a control treatment).

Table 1.5: Possible rehabilitation methods/techniques in riparian zones (Adapted from Hobbs & Mooney, 1993).

METHOD	ADVANTAGES	DISADVANTAGES	SUITABILITY	COST
Natural colonization	Cheapest, Local genetic strains	Slow, need adjacent source. Little control over composition, alien species could be favoured.	Limited	Low
Topsoiling	High seed diversity depending on origin	Limited availability cost of transportation, possible pathogenic transfer, and possible contamination by weed seed.	Limited	Med-high
Planting potted stock	Reliable, immediately visible, can manipulate diversity and spacing.	High cost of maintenance, high losses can result, slow to establish	High	High
Direct seeding	Quick establishment; cheaper than planting, low maintenance costs, greater diversity.	Limited seed availability, not always reliable, not suitable in low rainfall and sandy soil.	High	Medium
Turfing	Immediate cover	Species not suitable, very high cost	Low	High
Hydroseeding	Can treat inaccessible areas, quick, mulching benefits	High cost, water availability, problems with mulch crusts.	Limited	High
Brushwood	Mulching benefits, erosion control	Limited harvest sites	Limited	Medium high

Restoration by means of revegetation is also a good way to restore a disturbed site, as close to its original state as possible. Romhoff (1986) reported on a revegetation study of disturbed areas in the fynbos biome.

Revegetation can imply the return of vegetation to areas that have been disturbed, the rehabilitation of old agricultural lands or rehabilitation of areas invaded by alien plants. One of the most important aspects of revegetation is erosion control. Even though this study was done in terrestrial ecosystems of the fynbos biome, it could be successfully applied to riparian zones.

It is very important to use native species in restoration projects, as introduced species could become potentially invasive, and outcompete indigenous vegetation (Hobbs & Mooney, 1993).

Kraus (1977) showed that by planting trees in rows along rivers, maintenance costs were greatly reduced because weed growth is restricted and banks are less susceptible to erosion. Dawson (1978) outlined a revegetation plan, where trees were planted along the south side of the stream, creating shade, but gaps of approximately 20m in length were left at 70m intervals, to allow for macrophyte growth, which would then ultimately provide shelter for invertebrates and fish.

Riparian communities are often fire-adapted, and thus would recruit after fire in a similar way to fynbos, e.g. *Leucadendron salicifolium*. In areas that have been cleared of alien trees, there are usually species that have been eliminated and rely primarily on resprouting or on seed dispersal, or even on seed dispersal after fire. These species need to be introduced (Holmes, 1998).

Restoration designs should protect existing native vegetation, and restore vegetative structure. However, numerous shrubs and trees have been evaluated as restoration candidates. Selection of vegetative species may be based on the desire to provide habitat for a particular species of interest. The current trend in restoration, however, is to apply a multi-species or ecosystem approach. Existing native vegetation should be retained as well as woody debris and stumps. In addition to providing habitat, erosion and sedimental control, these features provide seed sources and harbour a variety of microorganisms.

As was mentioned previously, riparian sites, which have been degraded by the invasions of aliens, often require extensive rehabilitation of their stream banks. Viljoen & Groenewald (1995) recommended a mixture of three species for getting a quick cover established on bare areas.

They concluded that alien invader plant growth was suppressed by these sown grasses reduced the percentage of bare ground substantially, and would thus suppress the growth of aliens. Emphasis is, however, placed on the fact that grass sowing would not be sufficient and therefore should be combined with regular manual or chemical follow-up control. Hobbs & Mooney (1993) stated that "the use of sterile hybrid grasses, or species with known low reproductive output, as initial stabilizers allows the use of introduced species without the likelihood of them subsequently becoming a problem". Quick-growing species are better able to respond to erosion events. Plants that grow slowly are likely to be attacked and washed out. These species that die back during winter, provide little or no protection, and this is needed, as winter is the season of most significant bank erosion (Thorne, 1990).

According to Thorne (1990), a slope that has a good stand of close-growing vegetation will have a higher resistance to erosion, as compared to an unvegetated slope. The vegetation does not only protect the soil surface directly, but the roots and rhizomes of the plant bind the soil and enhance riverbank stability.

Chemical approaches:

Chemical methods are widely used to control the growth and development of invasive plants, although the use of chemicals is sometimes undesirable in areas set aside for conservation. Control of invasive plants by herbicide application, is usually a short-term term solution directed at individual 'target species'.

The ecological effects on aquatic ecosystems depend on the type of herbicide applied, the treatment level, and the frequency of spraying. Short-term effects could involve a reduction in oxygen, an increase in CO_2, a lowering of pH, an increase in bacterial populations, and a change in the nutrient status of the water and in plant communities, with consequent alteration of habitat for the fauna.

Long-term ecological effects depend on the degree of habitat destruction; the persistence of the herbicide, resulting in suppression of renewed plant growth, and the suitability of any colonizing or non-susceptible plant species in providing a habitat for the fauna.

Herbicides either kill on contact, or they can be translocated to the site of action. Total herbicides that kill unselectively (most plants) should, theoretically, be used only where drainage is important, and the risk of flooding is high. Selective herbicides (certain plants targeted) can be used on a wide scale to eradicate nuisance weeds, leaving other non-susceptible plants to grow in their place. In Britain the most widely used herbicides used for controlling bankside vegetation are 2,4-D (amine salt), maleic hydrazide and dalapon with or without paraquatic. These herbicides are not used as aquatic herbicides, but mainly to control broad-and-narrow-leaved species growing on banks by watercourses. Contamination of the water should not occur unless there is considerable run-off form the bank vegetation into the water (Newbold, 1975).

In the Western Cape, the Working for Water teams make use of a Garlon, water and diesel mixture, coloured with blue dye to identify treated areas. Spot spraying is employed in some areas where aliens are selectively sprayed by means of a backpack sprayer.

In more densely invaded areas, large trees are felled, and their stumps are treated (painted) with this mixture to prevent coppicing. It has also been shown that glyphosate (Roundup^{R} and Sting^{R}) can effectively control phyllode acacias after phyllodes have been formed, provided that the application takes place at the right time (Pieterse & McDermott, 1994; Pieterse, 1994).

1. 5. CONCLUSIONS:

Riparian habitats are complex systems. Management of these systems, including restoration following alien plant control, demands a good understanding of the fundamental processes (both biotic and geomorpholic) that drive their functioning (Goodwin *et al.* 1997). As is the case worldwide, riparian systems in the Western Cape, are highly susceptible to alien invasions, and dense stands of alien trees and shrubs are probably the greatest threat to these systems.

Measures (physical, chemical and biological control) have been put in place (notably through the WfW programme) order to control these invaders in the most sustainable manner (Klein, 1997). There are however, still substantial gaps in our knowledge.

This studies that make up this thesis address some of the gaps that have been identified.

The Working for Water Programme, although a proven success has its shortcomings, in that it involves labour-intensive methods of alien clearing and follow-up operations, the results of which are not always clearly apparent. Chapters 3 (sowing in order to rehabilitate) and 4 (sowing to prevent erosion) address follow-up methods, to ensure that this programme operates sustainably, and possibly to make recommendations to this programme to incorporate an alternative follow-up method.

Chapter 2 describes the features of riparian vegetation communities and their relation to various environmental variables. The main aim is to provide benchmarks for restoration projects in other areas. Chapter 3 investigates the effectiveness of different sowing treatments/methods on restoration in riparian zones. Chapter 4 focuses on the effects of the sowing methods employed in Chapter 3, on erosion control following a hot fire through an invaded riparian zone. Chapter 5 provides a general discussion of the research done to date, and gives recommendations regarding future restoration initiatives.

CHAPTER 2: Identifying species-environment interactions in riparian plant communities in the Western Cape, South Africa - A framework for objective restoration programmes.

"There are few rivers in southern Africa that have not been over-exploited, degraded, polluted, or regulated by impoundment/s, and we know of many that were once perennial, but which now flow only seasonally or intermittently" (Davies et al. 1993)

2.1. ABSTRACT:

This study aimed to classify the riparian vegetation along rivers in the Western Cape and to define relationships between the occurrence/abundance of key species and environmental factors. This information is needed to guide restoration efforts in the region, where most rivers have been severely impacted by invasive alien plants and other human-related factors. Six rivers were sampled (total=77 plots); the number and percentage cover for each species was recorded. TWINSPAN classification produced five communities with the following indicator species: 1) *Rhus angustifolia-Metrosideros angustifolia*; 2) *Podocarpus latifolius-Brabejum stellatifolium*; 3) *Prionium serratum-Diospyros glabra*; 4) *Berzelia lanuginosa-Cannamois virgata*; and 5) *Erica inconstans-Brachylaena neriifolia*. Close relationships were found between the various communities and the environmental factors (DCA and CCA). Results showed that environmental variables such as soil depth and altitude are important factors influencing community structure.

KEYWORDS: Braun-Blanquet, CCA, Classification, DCA, TWINSPAN.

2. 2. INTRODUCTION:

Riparian zones are the interfaces between terrestrial and aquatic ecosystems (Gregory *et al.* 1991), and they possess an unusually diverse array of species and environmental processes (Naiman & Décamps, 1997). These zones have great economical, social, cultural and environmental value. Riparian zones perform various functions, from controlling streamflow to habitat availability, to filtering water, ensuring that silt-free water is transported downstream (O'Keeffe, 1986).

Additional functions of these riparian communities include storing water, controlling nutrients and other materials in the stream and providing shade to decrease the deleterious effects of warm water on the biota (O'Keeffe, 1986; FISRWG, 1998).

The classical view of any river is one of a mountain stream-cool and sparkling, cascading down a mountainside. As it enters the foothills and is joined by other tributaries, it gradually slows down and widens. Before reaching its estuary and finally entering the sea, nutrients-rich deposits are made on the floodplain (Davies & Day, 1998).

The mountain stream (headwaters) is characteristically clear and free of silt, except when flooded. It drains land that it is frequently rocky, with very little loose soil (Davies & Day, 1998; O'Keeffe, 1986). Large plants rarely occur in the water or close to the waters edge, because the abrasive movement in the stream normally destroys newly established seedlings. Algae and mosses are present in small quantities (O'Keeffe, 1986).

Western Cape riparian systems are quite characteristic in their structure and function. In the southern coastal region, the geomorphology is dominated by the Cape Fold Belt Mountains, an ancient belt of mountains lying more or less parallel to the coast. Here rivers are short, steep, as well as nutrient-poor, running from, and over high leaded and poorly nutrient-buffered bedrock and soils of the Table Mountain Sandstone (TMS) series. The Storms River is a characteristic example, as it runs through a deeply incised gorge, which comprises mainly headwater and foothill zones, with the floodplains completely lacking in the region (Davies *et al.* 1993).

The upper catchments of these rivers tend to be dominated by species-rich and fire-adapted fynbos. Some of these catchments also exhibit the development of dense Afromontane riparian trees (Davies *et al.* 1993)

Leaving the mountains, flowing through the foothills, the bed widens, as more water arrives from the tributaries. In some areas, trees still line the middle reaches and occasional patches of the palmiet reed, *Prionium serratum*, occur where sufficient sediment accumulates between rocks.

The water quality in this stretch of river is also poorer, because of abiotic processes and activities of the living communities upstream (Davies & Day, 1998; O'Keeffe, 1986). As the river continues its journey, it flows onto a coastal plain, widening further as it is joined by more and more tributaries. The speed of flow decreases, and the river system becomes an ideal environment for the development of dense stands of emergent plants, such as reeds (*Phragmites australis*) and bulrushes (*Typha capensis*).

This river system from the headwaters to the lower reaches has been impacted by human activities, which are brought about by land use activities, some of which are discussed in Chapter 1. In the mountains, rivers are affected by the building of large dams, which alters the water quality, the flow of sediment and organic materials (FISRWG, 1998). In the middle and lower reaches, disturbances like flood control, channelization, road building, urban encroachment and others have major impacts on the functionality of these river systems (FISRWG, 1998; O'Keeffe, 1986) and their related vegetation.

Very little research has been done on riparian zones in the fynbos biome, as apposed to fynbos vegetation, which has been extensively researched (Cowling *et al.* 1997). In mountain catchment areas, specifically, the band of vegetation is usually very narrow and is not always sampled in broader vegetation surveys (McDonald, 1993). Nonetheless, riparian vegetation is very important as a it plays direct role in the functioning of the river systems through its effects on water quality and flow rate. The functions of riparian zones and its related vegetation have been discussed in greater detail in Chapter 1.

A survey of the ecological status of the Western Cape rivers (Brown, 1998) concluded that there are no undisturbed rivers in areas between the foothills and the sea. More than 72% of the rivers covered in this survey were either extensively or seriously modified, or even completely destroyed. These statistics amplify the importance of projects like the Working for Water Programme (WfW), which maximizes on the delivery of water, enhances sustainability by eliminating invading plants, and promotes social equity (job creation) (van Wilgen *et al.* 1998).

Humans have altered much of the natural riparian vegetation, by planting agricultural crops, orchards and plantations and other forms of development (Ferrar, 1989). Past studies (Boucher, 1978; McDonald, 1988; Van Coller, 1992) indicated the importance of species such as *Metrosideros angustifolia, Brabejum stellatifolium and Cannamois virgata* in riparian zones of the Western Cape. Further information is required on the factors that determine the distribution and abundance of these key species.

Considering all of the above, this study was undertaken to provide information of the environmental factors associated with the main communities that exist. Because it is impossible to survey rivers that have not been impacted by alien invaders, I selected six rivers, which had been cleared by Working for Water (WfW) teams in the past and had a relatively broad band of natural riparian vegetation. Riparian vegetation at these sites had not been totally transformed, i.e. the main relationships between species occurrence/abundance and environmental factors are still in evidence. The main relationships between species occurrence/abundance and environmental factors would still be in evidence. Alien invaders were recorded and are included for later discussion.

The main objectives of this chapter are as follows:

- To describe features of non-invaded rivers to provide benchmarks for restoration efforts in other areas.
- To classify the riparian zones into communities, by making use of multivariate techniques.
- To determine whether or not the environmental variables explain the variance in the species data.

2. 3. METHODS:

Study areas:

a) Palmiet and Rooiels Rivers:

The Palmiet estuary is situated between Betty's Bay and Kleinmond (Figure 2.1), about 75km southeast of Cape Town. This estuary is normally open to the sea and receives a large permanent inflow of fresh water from its river. The upper reaches of this estuary are surrounded by apple orchards and forestry plantations (largely *Pinus* spp.). The Palmiet is also known to be the least disturbed of the watercourses in the area (Branch & Day, 1984). The catchment of Palmiet lies in the mountainous Kogelberg, Paarde, Groenland & Hottentots Holland ranges, covering an area of 539 km^2. The Palmiet itself is about 65-70km long, rises in the Kogelberg range, and is joined by two major tributaries and two minor feeder streams before reaching the estuary.

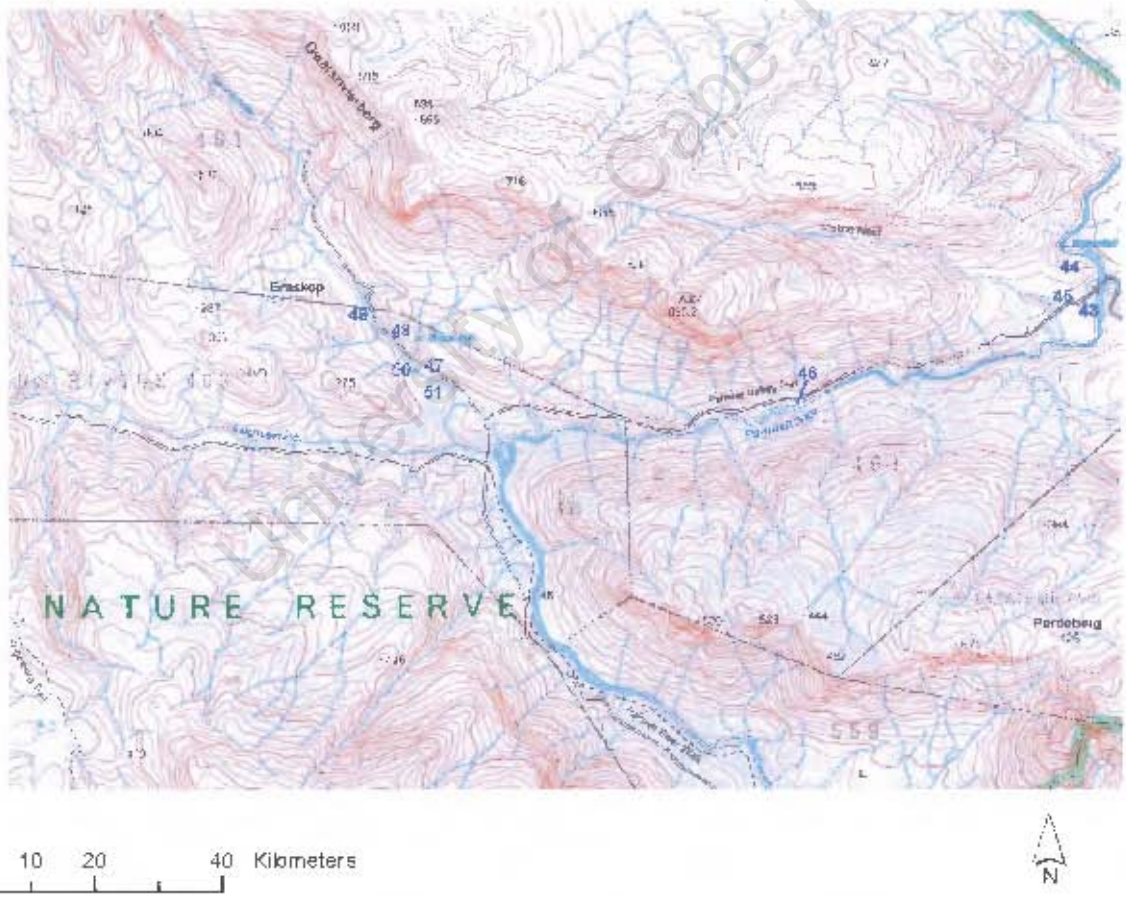

Figure 2.1. Vegetation plots (numbers 43-51) sampled along the Palmiet River, within the Kogelberg Nature Reserve.

The riverbed is very steep, resulting in strong flow. Boucher (1978) did an in depth phytosociological study on the Cape Hangklip area, and describes in detail the geology and topography, as well as the climate of this area. The plots sampled along this river occur between co-ordinates: 34°16'50"S/18°59'25"E & 34°16'75"S/18°55'75"E.

The Rooiels River is also situated within the Kogelberg Nature Reserve and is fed by the sea at high tide (Figure 2.2 & 2.3). The plots sampled along this river occur between co-ordinates: 34°18'S/18°49'20"E & 34°18'S/18°50'7"E.

Figure 2.2. The Rooiels River where it flows to the sea. Water collects in a 'vlei'. The main river is located at the foot of the mountain in the background.

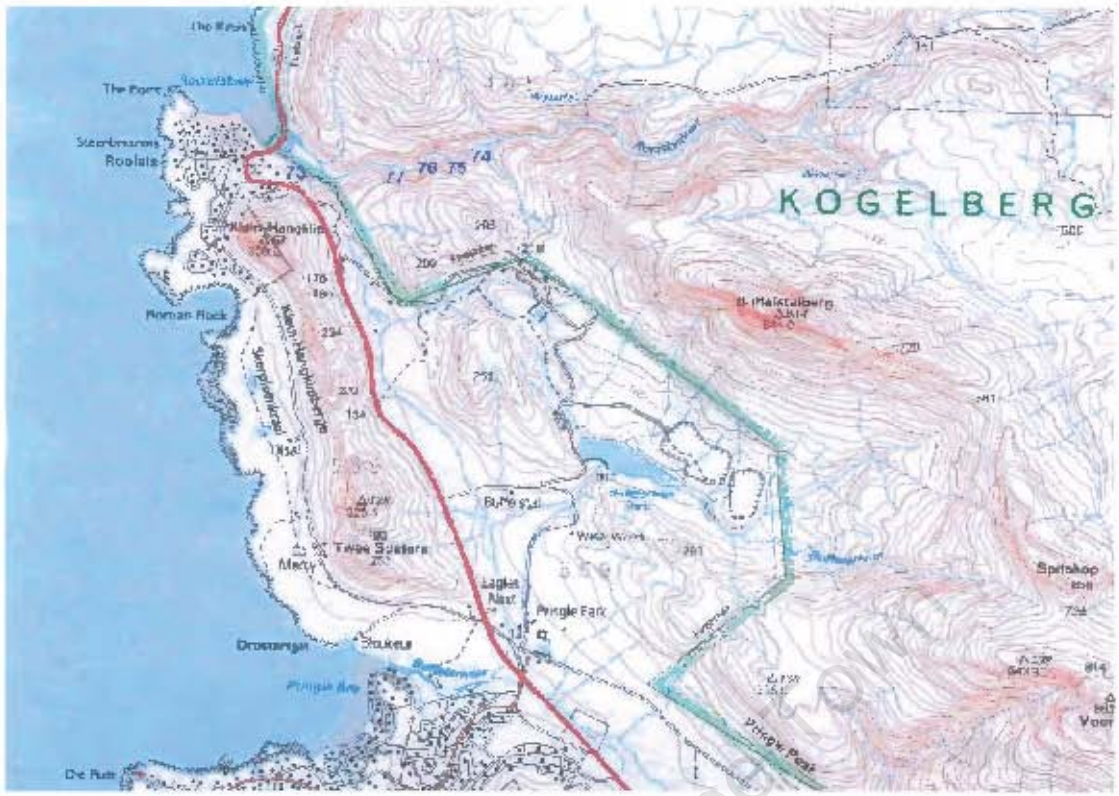

Figure 2.3. Vegetation plots (numbers 73-77) sampled along the Rooiels River in Kogelberg Nature Reserve.

b) Jonkershoek River:

The Jonkershoek River runs down the centre of the Jonkershoek Valley near Stellenbosch (Figure 2.4). Sampling was done in the Jonkershoek State Forest (sampling plots were located between co-ordinates: 33°59'55"/18°58'60"E & 33°58'40"S/18°56'15"E). This river obtains its main water supply from the Jonkershoek valley and then flows past the southern end of town on its way to False Bay (Buys *et al.* 1991). The Jonkershoek ecosystem has been described by Wicht *et al.* (1969). The climate of this area is of the mediterranean type and rainfall in this area averages 1700 mm/a, 1000mm (59%) of which falls between the months of May and August (van Wilgen, 1982; Le Maitre *et al.* 1992). Approximately 83% of the rain falls in a seven-month wet season between April and October in long duration, low density, frontal storm events {Wicht *et al.* (1969) in Scott & van Wyk, 1990}. The soils are derived from sandstone colluvium, occasional shale lenses and deeply

weathered granite. The soils are friable, deep, sandy to silty loams with a clay content of ~ 10%.

Excellent conditions for water infiltration result from their high gravel and rock content, low bulk density (1150 kg.m^{-3}) and high pore volume (55%) (Versfeld, 1981 in Scott & van Wyk, 1990).

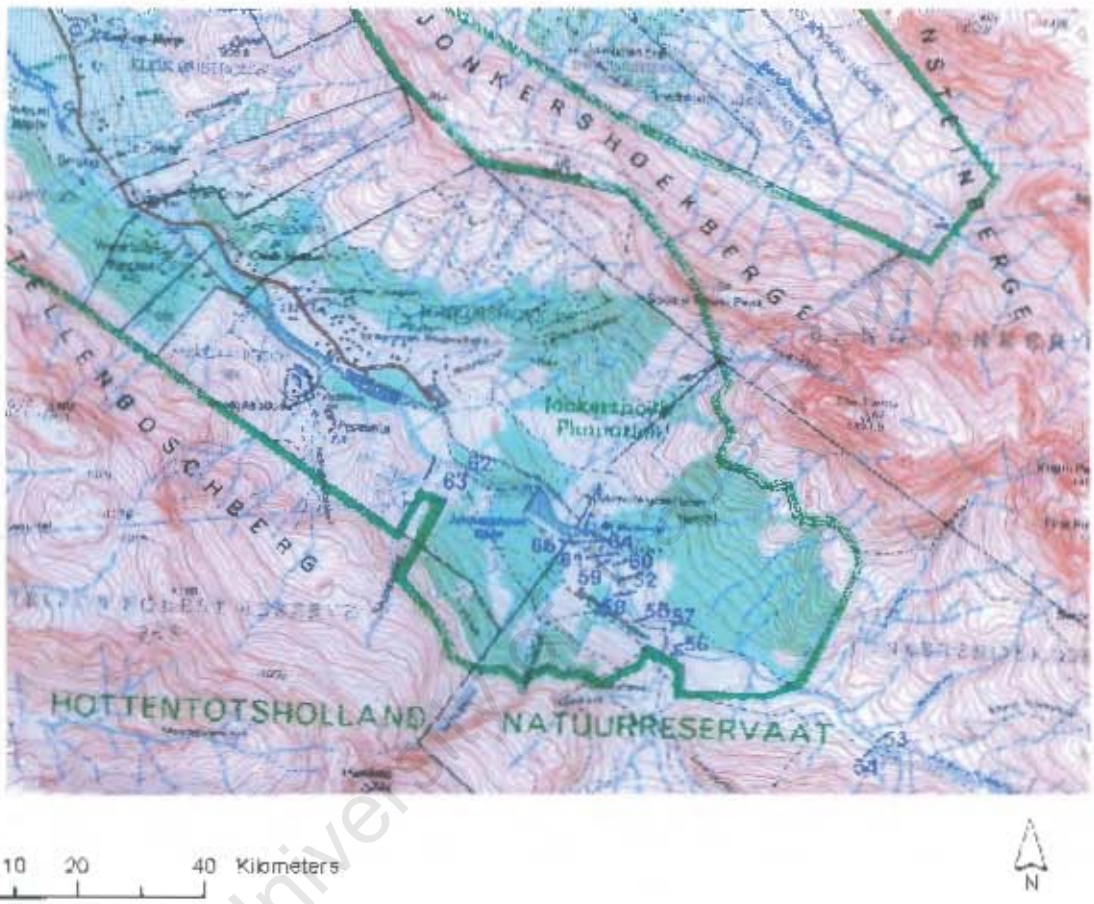

Figure 2.4. Vegetation plots (numbers 52-64) sampled along the Jonkershoek River, running through the Jonkershoek State Forest.

c) Moelenaars River

The Moelenaars River is a perennial river (Figure 2.5 & 2.6) with tributaries such as the Klip River, Krom River and the Elands River (a few plots were sampled in these tributaries). This river is relatively braided in places, with "islands" forming along its length. These "islands" become more apparent during the summer months, when the water level is low, and in the wet season they are submerged. Alien clearing operations have been undertaken in earlier years, evidence (blue dye) of which still occurs.

Sections of the river, especially the tributaries (Elands River and Krom River) have a large percentage of bedrock cover. The plots sampled occur between co-ordinates: 33°42'35"S/19°14'15"E & 33°43'20"S/19°06'75"E.

Figure 2.5. A view of the Moelenaars River, running along the Du Toitskloof Pass, towards Worcester.

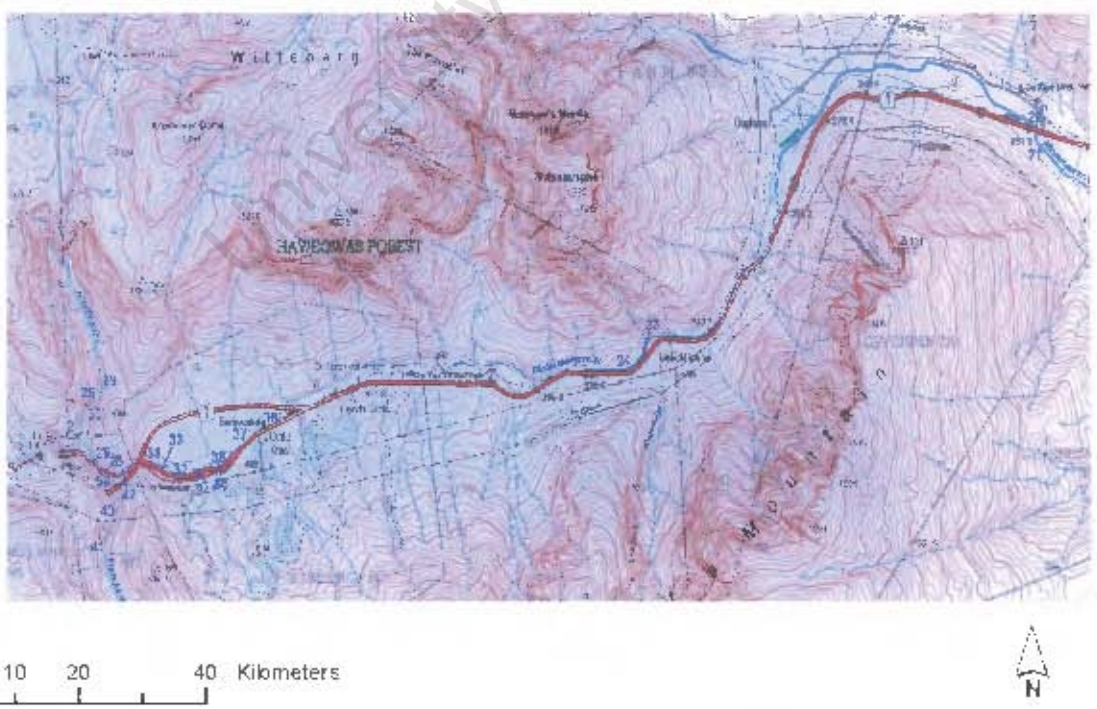

Figure 2.6. The vegetation plots (numbers 21-42) sampled along the Moelenaars River, along the Du Toitskloof Pass, including those sampled along its tributaries.

d) Wit River and Steenbok Rivers:

The Wit River (Figures 2.7 & 2.8) branches off from the Breede River system, and runs along the Bainskloof Pass (between the towns of Wellington and Wolseley). The river dries out in the Slanghoek Mountains. The invasive alien vegetation of this river has also been cleared in sections, however, the riparian vegetation is relatively characteristic between Eerste and Tweede Tol (area sampled). From Tweede Tol towards Ceres, vast sections of the river are infested, mainly with *Acacia mearnsii*. Clearing operations are currently underway on these rivers. The steepness of the slope (accessibility) and the age of the infestation make alien clearing very difficult in this area. The plots sampled occur between co-ordinates: 33°34'15"S/19°08'60"E & 33°37'10"S/19°06'20"E.

The Steenbok River is a perennial tributary of the Wit River, and runs through the Steenbok Park Nature Reserve. Although invasive alien trees have been cleared from this river in the past, sections of the river still have a distinctive band of riverine vegetation, which includes species like *Metrosideros angustifolia, Brabejum stellatifolium* and *Leucadendron salicifolium*. The plots sampled occur between co-ordinates: 33°32'60"S/19°08'35"E & 33°32'50"S/19°07'10"E.

Figure 2.7. A section of the Wit River, between the weir and Tweede Tol (very rocky area).

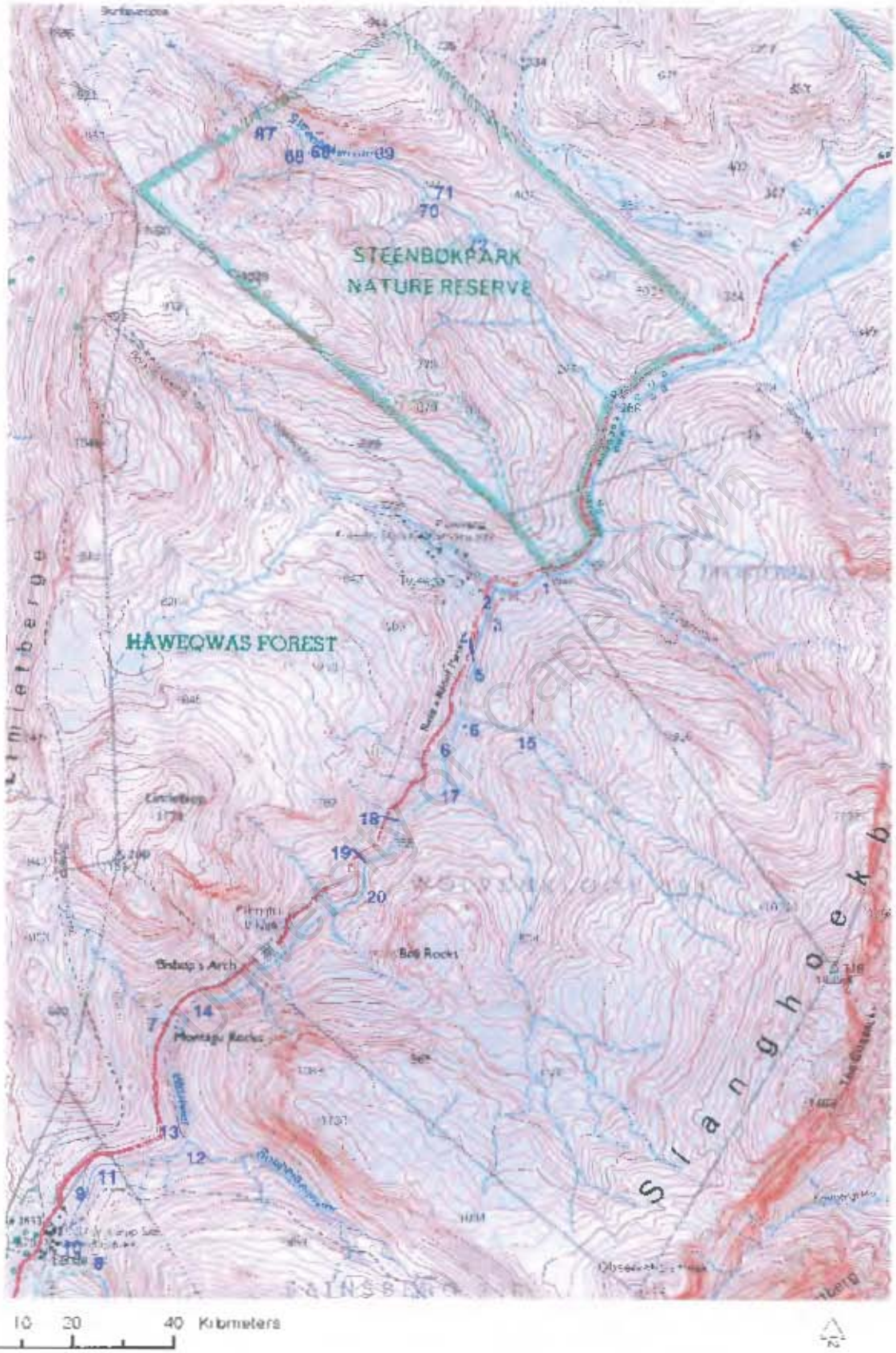

Figure 2.8. The vegetation plots (numbers 1-20) along the Wit River between Eerste and Tweede Tol, along the Bainskloof Pass, as well as the Steenbok River (numbers 66-72), running through the Steenbok Park Nature Reserve.

Table. 2. 1. Principle features of the six sites used in the survey of riparian vegetation.

SITE	SITE CODE	POSITION	LOCATION	ALTITUDE	MAP REF
Wit River	**WR**	Bainskloof Pass	33°34'10"S 19°8;40" E	400-600M	**3319CA** Bainskloof
Steenboks River	**SR**	Bainskloof Pass	33°32'5"S 19°7'0"E	300-500M	**3319CA** Bainskloof
Moelenaars River	**MR**	Du Toitskloof Pass	33°42'25"S 19°14'0"E	400-500M	**3319CA** Bainskloof
Rooiels River	**RR**	Kogelberg State Forest	34°18'15"S 18°49'20"E	0-100M	**3418BD** Hangklip
Palmiet River	**PR**	Kogelberg State Forest	34°16'50"S 18°59'40"E	0-100M	**3418BD** Hangklip
Eerste River	**ER**	Jonkershoek Nature Reserve	33°16'50"S 18°58'30"E	200-400M	**3318DD** Stellenbosch

2. 4. DATA COLLECTION:

It was decided that surveying approximately 80-100 plots would be sufficient to describe the riparian vegetation communities (P.M. Holmes pers. comm.). A total of 77 plots were surveyed.

The sampling unit was a 10 X 5m plot that was used consistently throughout the study, however the plot shape could have been more flexible (Boucher, 1977). The plots were placed 10m parallel to the river and 5m perpendicular to the river. All plots were placed in the wet and dry bank zones. The wet bank zone is usually submerged during floods, while the dry bank zone is fringed by water during, and contains many fynbos elements (Boucher, 1998).

Sampling, done between April and September 1999, involved locating potential sites using 1:50 000 maps and expert knowledge.

Floristic data was gathered by recording all permanently recognizable species and collecting species that could not be identified in the field (McDonald, 1988). Voucher specimens were collected in the field, pressed and clearly marked. Species identification was then carried out in the Guthrie Herbarium at the University of Cape Town, as well as the Compton Herbarium at the National Botanical Institute (NBI). To avoid sampling error owing to seasonality of annuals and many geophytes only perennially identifiable species were recorded. A combined species list (Appendix 2) was compiled for all the study areas (rivers sampled).

The number of individuals of each species in a plot was counted and a percentage cover value was given to each. Cover of each species was estimated to a percentage point in each plot, as the area of ground covered within that specific plot. The percentage values were then converted into Braun-Blanquet scale in order to run a TWINSPAN analysis (Table. 2.2).

Table 2. 2. The Braun-Blanquet cover scale (Kent & Coker, 1992)

VALUE	BRAUN-BLANQUET
+	Less than 1% cover
1	1-5% cover
2	6-25 % cover
3	26-50% cover
4	51-75% cover
5	76-100% cover

Various environmental variables were recorded in each plot namely; aspect, slope, soil depth, soil pH, soil particle size, sand texture, bedrock cover. Table. 2. 3. shows the variables measured and the methods of measurement.

Table 2. 3. The environmental variables measured or estimated for each site and the method used to measure them.

VARIABLE	ABBREV.	UNIT/CLASSES	METHOD
Locality	n/a	Decimal degrees	1:50 000 maps
Altitude	ALT	Metres	1:50 000 maps
Aspect	n/a	N, S, E, W	Estimate/ 1:50 000 maps
Slope angle	n/a	Flat/medium/steep	degree estimate
Soil depth	DEPTH	Metres	Metal rod
Soil pH	pH	pH scale	pH meter
Sand texture	FS, MS, CS	%fine,% medium, % coarse	Appendix 1
Rock cover	RCOV	%	Estimate

Soil depth was measured by hammering a steel rod into the soil at five, randomly selected, points. An average soil depth was established for each plot. A soil sample at random from each site; a few spadefuls of soil were taken just below the soil surface and mixed together. The samples were air-dried and the pH of each sample was measured using a pH meter (WTW 320pH meter. made in Germany). The proportions of coarse, medium, and fine sand in each soil sample were determined using the Bouyoucos Particle size method (Appendix 1).

2. 5. DATA ANALYSIS:

Classification:

The data were analysed using the TWINSPAN statistical programme. TWINSPAN (Two-way Indicator Species Analysis) is a polythetic divisive method of classification, and it is very often used in conjunction with ordination techniques. TWINSPAN is the most widely used data analysis technique in phytosociology (Kent & Coker, 1992). The most significant feature of the programme, is that it first constructs a classification of the samples, and then uses this classification of the species according to their ecological preferences.

The two classifications are then used together to obtain an ordered two-way table that expresses the species synecological relations as succinctly as possible (Hill, 1979). This classification was stopped at the 3rd level of division. It was stopped at this point, so as not to end up with groups or communities that are meaningless (Moustafa & Zaghloul, 1996).

Ordination:

Ordination is the tool for the exploratory analysis of community data with no prior information about the environment (ter Braak & Prentice, 1988). Detrended Correspondence Analysis (DCA) was used to group sample sites into communities, according to common floristic characteristics. DCA results are usually superior to other ordination techniques, and it is computationally very efficient (Gauch, 1982). This is an indirect gradient analysis which only ordinates vegetation data.

Canonical Correspondence Analysis (CCA) is a direct gradient analysis technique that is an elegant extension of the indirect gradient analysis technique, Correspondence Analysis. 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 (Kent & Coker, 1992; ter Braak, 1987). CCA is best defined as a method of direct ordinations with the resulting ordination being a product of the variability of the environmental data as well as the variability of the species data. CCA has all the advantages and none of the disadvantages of DCA, and is most suitable where a good set of environmental data is available in addition to the vegetation data (Kent & Coker, 1992).

By using an indirect gradient analysis, attention was first focused on the pattern of variation in community composition, with the environmental data being related to this pattern later (van Coller, 1992). These ordinations (DCA & CCA) appear similar as both give rise to ordination plots, however, they have been shown to be different techniques, which serve different purposes in ecological analysis (Okland, 1996). The program CANOCO, (CANOnical Community Ordination), which is designed for data analysis in community ecology (ter Braak, 1991), was used for all ordination analysis (ter Braak & Šmilauer, 1998).

Species richness and diversity:

The species richness and diversity of the different communities were also calculated (Magurran, 1988). The diversity (H) and evenness (J) of plant communities were calculated using the Shannon-Wiener Index:

$$H = -\Sigma_{Pi}\, 1n\, _{Pi} \quad \text{.....(1),}$$

where Pi is the proportion of individuals in the community, represented by species P.

$$J = H/H_{(max)} \text{.....(2),}$$

where $H_{(max)}$ is the maximum density if all species in the community had an equal number of individuals.

2.6. Results:

Classification:

The TWINSPAN classification discerned five community types. *Metrosideros angustifolia*, is one of the most dominant species through all the plots, followed by *Brabejum stellatifolium*, *Diospyros glabra, Brachylaena neriifolia, Elegia capensis* and *Cannamois virgata*. The results of the TWINSPAN analysis are shown in Table 2.4. The floristic data measured in each of the plots, is shown in Appendix 6.

Community description:

Riparian vegetation in the fynbos biome is normally quite distinctive from the surrounding fynbos vegetation (Boucher, 1978), even though it occurs under similar climatic conditions. These communities (riparian), which have a fynbos affinity, have been described as Closed-Scrub fynbos (Cowling & Holmes, 1992). Dominant species in Closed-Scrub fynbos in the Western Cape are woody plants such as *Metrosideros angustifolia, Brachylaena neriifolia, Salix mucronata, Leucadendron salicifolium and, Cunonia capensis*. (Boucher, 1978; van Wilgen & Kruger, 1985; McDonald, 1988; McDonald, 1993).

Table 2.4. Phytosociological table for the riparian vegetation survey done on six different rivers in the Western Cape Province, South Africa.

No.	Species	Rhus angustifolia COMMUNITY 1														COMMUNITY 2														COMMUNITY 3																													COMMUNITY 4										COMMUNITY 5								
PLOT NO		24	69	76	27	28	31	32	38	39	35	37	40	41	72	61	62	63	64	65	66	65	10	62	60	26	57	58	59	18	67	1	2	3	4	5	9	11	13	17	19	22	83	6	14	21	23	25	29	36	42	43	44	46	70	30	33	77	51	96	98	74	46	47	48	50	75	49	12	15	16	20	7	73	84	8	71
COMMUNITY NO.							1															2																				3																					4								5						
	Rhus angustifolia-Metrosideros angustifolia community (1)																																																																												
128	Rhus angustifolia	5	4	5	3	2	-	3	2	3	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	3	4	-	-	2	4	-	3	-	4	-	-	4	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-
111	Polygonum salicifolium	-	-	-	4	4	3	4	-	-	4	4	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-
1	Acacia longifolia	-	-	-	-	-	-	3	2	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
130	Struthiola myrsinites	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	Restio spp	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	Euryops abrotanifolius	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
47	Elegia cuspidata	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
49	Eragrostis spp	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
82	Hypodiscus aristatus	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Podocarpus latifolius-Brabejum stellatifolium community (2)																																																																														
84	Kiggelaria africana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	4	4	3	4	-	3	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
106	Podocarpus latifolius	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	3	3	-	4	3	-	-	4	4	4	2	4	3	-	-	-	3	-	3	-	3	-	3	-	-	-	-	3	-	-	4	-	-	-	-	-	-	2	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
86	Olea europaea subsp africana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	2	-	3	-	4	2	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
88	Lichtensteinia lacera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
89	Maytenus acuminata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	4	5	4	4	-	-	-	-	-	-	-	-	-	3	-	-	-	-	3	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
115	Protoasparagus rubicundus	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	4	3	-	4	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
143	Tribolium uniolae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	Acacia melanoxylon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
79	Helichrysum cymosum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
100	Oxalis purpurea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
39	Cynodon dactylon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	4	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	Athanasia parviflora	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Prionium serratum-Diospyros glabra community (3)																																																																													
112	Prionium serratum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4	-	-	3	-	4	-	4	3	-	-	-	-	-	-	4	-	5	3	3	-	2	-	4	-	5	5	-	-	5	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	4	4	-	-	-	-	-	-	-	-	-	-	4	-	-
2	Acacia mearnsii	-	-	-	3	-	-	4	2	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	3	3	3	3	4	3	4	-	3	-	4	3	3	-	3	3	-	4	2	-	-	-	3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	3	-
52	Erica caffra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	3	-	-	-	-	-	-	-	3	3	-	3	4	5	4	4	4	3	3	-	4	4	-	3	-	-	3	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	3	4	3	-	-	3	-
44	Driopterus	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	3	-	-	4	-	-	3	4	-	4	3	4	4	3	-	3	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	4	3	-	-	-	-	4
94	Nivenia stokoei	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	3	4	2	-	-	4	3	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	4	-	-	-	-	-	-
71	Pompus spp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	3	-	4	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
41	Kiggelaria africana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
46	Elegia cuspidata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
40	Cyphia spp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
50	Erica spp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
37	Restio cincinatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	Anagallis arvensis var. caerulea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	Anapalina spp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	Anaxeton laeve. Cf	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	Aristida spp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	Athanasia parviflora	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
33	Microloma sagittatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
81	Hypocalyptus spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
83	Juncus punctorius	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	3	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	Ollis africanum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
105	Phylica spicata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
127	Rhus laevigata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
130	Sentella spp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
134	Sonchus oleraceus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
58	Erica longifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
60	Erica plukenetii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
61	Erica scyphagyne	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
65	Ficinia filiformis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
70	Poaceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
74	Halleria elliptica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Species common to 1-3																																																																														
101	Passerina vulgaris	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
120	Rapanea melanophloeos	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
133	Shade tree	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
78	Halleria lucida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Berzelia lanuginosa-Cannomois virgata community (4)																																																																													
87	Leucadendron salicifolium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	4	3	4	4	4	4	4	4	4	4	-	-	-	-	-	-	-	3	5
91	Metalasia muricata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	3	-	3	4	4	2	4	-	-	-	-	-	-	3	3	-
14	Berzelia lanuginosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	4	-	3	4	-	3	3	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	3	4	3	5	5	3	3	4	4	3	3	3	3	3	-	-	4	4
19	Cullumia ciliaris	-	4	2	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	4	3	3	-	-	-	-	3	-	-	-	-	-	-	-	4	2	-
97	Osmitopsis asteriscoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	3	-	-	-	-	3	3	2	-	-	-	-	-	-	-	-	-	-	-
64	Euryops abrotanifolius	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
78	Heisteria muralis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-
28	Cliffortia graminifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
117	Psoralea aphylla	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
54	Erica curvirostris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	3	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-
63	Erica sphaeroides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-
48	Elytropappus glandulosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
51	Erica armata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
123	Restio spp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
125	Restio papery bracts	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	Brunia albiflora	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	3	-	-	-	3	-	-	-	-	-	-	-	-	-	-
56	Erica hirtiflora	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	3	-	-	-	-	-	-	-	-	-	-	-
59	Erica perspicua	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
62	Erica sessiliflora	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
140	Tetraria cuspidata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-
5	Penaea spp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-
32	Cynanchum africanum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-
53	Erica spp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	3	-	-	-	-	-	-	-	-	-
55	Erica gnaphaloides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-
20	Cullumia setosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-
29	Cliffortia polygonifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	3	-	-
85	Leucadendron gandogeri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
86	Leucadendron laureolum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-
102	Pelargonium candicans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-
113	Protea cynaroides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
135	Sonchus oleraceus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-
	Species common to 1-4																																																																													
109	Podalyria calyptrata	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	4	-	4	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-
72	Penaea spp	-	-	-	-	-	3	-	-	-	5	3	-	-	4	3	-	4	-	-	-	-	-	-	-	3	4	4	4	2	-	-	-	-	-	-	-	3	4	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	4	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
31	Clutia pulchella	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	4	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-
122	Restio spp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	3	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-
121	Restio spp	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
78	Hartogiella schinoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	4	3	3	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	Blechnum capense	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	3	-	-	-	-	3	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-
142	Rhamnus prinoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
21	Cannamois spp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	3	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
86	Gnidia oppositifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
116	Pseudobaeckea africana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	3	-	3	-	-	-	-	-	-	-	-	-	-	-	-
131	Sedge	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26	Chironia linoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-
103	Pentaschistis giganticus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	3	-	-	3	-	-	-	-	-	-	-	-	-
137	Stoebe incana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-
73	Hakea sericea	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
114	Protea repens	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-
24	Cassytha ciliolata	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
	Erica inconstans-Brachylaena neriifolia community (5)																																																																													
34	Psoralea aphylla	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-
57	Erica inconstans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	4	3	3	-	-	4	4
67	Restio spp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-
	Species common to 1-5																																																																													
30	Cliffortia ruscifolia	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	2	3	-	2	-	-	-	-	-	-	2	3	-	-	-	4	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	4	-	-	3	-
25	Chironia linoides	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	3	-	4	-	-	-	-	-	-	-	-	-	-	-	4	-	2	-	2	-	-	-	-	-	2	-	-	-	-	-	-	-	-
124	Restio leptostachys	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	3	-	3	-	-	-	3	2	-	3	-	-	-	-	-	-	4	-	-	-	-	3	-	-	-	-	-	-	-	3	-	5	4	-	3	3	-	-	-	-	5	-
141	Tetraria thermalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	4	-	-	-	-
138	Stoebe plumosa	-	-	-	2	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	3	4	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	3	-	-	3	-
136	Stoebe cinerea	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	2	-	-	-	-	-	-	-	3	3	-	-	4	-	-
93	Myrsine africana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-
	Species common to 2-5																																																																													
4	Agathosma spp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-
38	Cynanchum africanum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-
36	Cunonia capensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	4	-	4	5	-	3	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	3	-	-	-	4
118	Psoralea pinnata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	4	3	-	-	-	4	-	3	-	-	-	-	3	-	4	3	-	-	-	-	3	3	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	3	-	-	3	3	4	-	3	-	-	-	-
	Species common to the study area																																																																													
52	Metrosideros angustifolia	-	4	4	4	5	5	5	5	5	5	5	5	5	5	-	4	-	4	-	4	4	4	5	4	4	-	4	4	4	4	4	3	3	4	4	-	4	4	3	5	5	2	3	-	4	4	5	4	4	4	3	4	2	5	3	3	-	-	4	3	-	3	4	3	3	3	-	5	3	4	3	3	-	3	3	4
42	Diospyros glabra	-	-	-	3	2	3	-	3	5	-	-	-	-	-	2	-	2	4	3	3	-	3	3	4	3	-	4	-	3	-	3	-	2	4	-	2	2	3	3	3	4	3	3	3	3	4	4	4	4	4	4	4	4	3	3	2	-	3	3	3	-	-	3	-	-	-	-	3	-	3	-	-	-	-	3	-
16	Brabejum stellatifolium	4	4	-	5	5	5	4	5	4	2	4	3	-	3	5	5	5	5	5	5	5	5	5	5	-	4	5	5	-	4	4	3	4	4	2	3	3	4	-	-	3	5	3	-	5	3	4	4	4	5	5	4	5	5	5	4	-	-	4	4	-	-	2	-	-	-	-	-	-	-	-	-	3	-	2	-
17	Brachylaena neriifolia	-	-	3	-	-	-	-	-	-	-	3	-	-	-	4	4	-	3	-	-	-	2	4	4	4	4	4	-	4	3	4	4	4	4	2	4	4	3	4	4	-	4	-	-	-	3	3	4	4	3	-	-	-	3	-	-	2	-	3	-	-	-	-	3	-	-	3	4	4	3	4	3	-	5	2	-
45	Elegia capensis	4	3	4	2	-	3	3	3	-	-	4	-	-	-	3	-	-	-	-	-	-	-	2	-	-	-	-	-	3	3	2	3	-	2	4	-	-	3	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	3	3	3	-	-	3	4	4	-	-	-	-	-	5	4	3	4	4	2	-	-	3	3
22	Cannamois virgata	4	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	3	-	-	3	3	5	4	3	4	3	4	4	4	-	4	2	3	5	3	2	3	-	-	4	-	-	4	4	2	-	-	-	5	3	4	5	4	5	4	5	-	-	4	-	4	-	3	-	-	3	4
119	Pteridium aquilinum	4	3	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	3	2	3	4	-	2	-	-	-	-	-	-	-	-	-	3	3	3	3	4	-	-	-	-	4	-	4	4	-	-	3	5	4	5	2	-	-	-	4	3	3	-	-	3	-	-	-	-	3	-
	Outliers																																																																													
129	Rubus pinnatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-
132	Senecio spp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-
77	Hoaria argentia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-
69	Otholobium decumbens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-
104	Phylica imberbis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-
110	Polygala myrtifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-
98	Osteospermum ciliatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-
27	Cliffortia strata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	3	-

- **Community 1-***Rhus angustifolia-Metrosideros angustifolia* community:

This community (referred to as the *Rhus* community) occurs at altitudes ranging from 50 to 480m with relatively shallow slopes (5-20°). The soil pH was quite acidic with an average of 4.45 within the community. The soils were relatively shallow with an average soil depth of 364cm, and the average percentage composition of fine, medium and coarse sand are: 13.13, 43.06 & 30.76, respectively. The average bedrock of this community is ±30%. This community occurs mostly on southern aspects. The community is characterized by the following species: *Rhus angustifolia* & *Polygonum salicifolium*. Dominant species of this community include: *Brabejum stellatifolium* & *Metrosideros angustifolia.* The vegetation sampled was mature and the average recorded canopy cover of the community is 88%.

- **Community 2-***Podocarpus latifolius-Brabejum stellatifolium* community:

This community (referred to as the *Podocarpus* community) occurs on northern and southern aspects at altitudes varying from 240 to 550m. The average bedrock cover is ±18%. The slopes are averaged at 11.57° (5-30°) with an average soil depth of 362cm. The average soil pH of this community is 4.64 and the percentage composition of fine, medium and coarse sand are: 11.59, 47.63 and 29.19, respectively. The average canopy cover for this community is 91. This community is characterized *Kiggeleria africana, Olea europea subsp. africana* and *Maytenus acuminata*. The dominant species include: *Brabejum stellatifolium, Diospyros glabra* and *Metrosideros angustifolia.*

- **Community 3-***Prionium serratum-Diospyros glabra* community:

This community (referred to as the *Prionium* community) occurs on slopes that are a bit steeper than communities 1 & 2 ranging from slopes of 5-45 . This community occurs at altitudes ranging from 40 to 500m, and predominantly on northern aspects. The average soil depth is 300cm. The soil pH of this community is on average 4.37, and the percentage composition of fine, medium and coarse sand are: 9.74, 37.72 & 37.02, respectively. The average total canopy cover of this community is 85%, and the average bedrock cover is ±32%.

The characteristic species of this community are: *Prionium serratum, Driopterus* sp. and *Erica caffra*. Dominant species occurring in this community include: *Metrosideros angustifolia, Diospyros glabra, Brachylaena neriifolia, Elegia capensis, Cannamois virgata* and *Pteridium aquilinum*.

- **Community 4**-*Berzelia lanuginosa-Cannamois virgata* community:

This community (referred to as the *Berzelia* community) occurs on relatively sandy soils, and on mostly northerly aspects. The altitudes range from 50-520m. This community occurs on a similar average slope as the *Rhus angustifolia-Metrosideros angustifolia* community (9.50°: range from 2 to 30°). The soil pH is quite acidic (3.67), with the average percentage composition of fine, medium and coarse sand being: 22.42, 35.10 and 21.18, respectively. This community has a greater soil depth than the previous three communities 556cm, and this corresponds well with the low bedrock cover.

The characteristic species of this community are: *Berzelia lanuginosa, Leucadendron salicifolium, Metalasia muricata* & *Cullumia ciliaris*. Dominant species of this community include: *Cannamois virgata, Metrosideros angustifolia* and *Pteridium aquilinum*. This community has an average canopy cover of 92.5%.

- **Community 5**-*Erica inconstans-Brachylaena neriifolia* community:

This community (referred to as the *Erica* community) occurs on a very sandy substrate (very little bedrock cover), and at altitudes in the range of 320-560m. Its average soil depth is 115cm, which does not correspond with its very low bedrock cover.

The average slope is also the lowest of all the communities sampled and ranges from 0-40° (average=8°). The soil is also the most acidic with an average of 3.32. The average percentage composition of fine, medium and coarse sand are: 11.8, 36.64 and 25.24, respectively. This community has an average total canopy cover of 85%, and occurs on predominantly northern aspects.

The characteristic species of this community is *Erica inconstans*. Dominant species recorded in this community are: *Berzelia lanuginosa, Metrosideros angustifolia, Brachylaena neriifolia* and *Elegia capensis*.

- **Alien species:**

Throughout the survey of the different rivers, several invader species were identified. These included *Acacia longifolia*, *Acacia melanoxylon*, *Acacia mearnsii* and *Hakea sericea*. *Acacia mearnsii* was the most frequently recoded alien species - in 24 of the 77 sampling plots. *Acacia longifolia* was noted in five, *Hakea sericea* in three, and *Acacia melanoxylon* in two.

As mentioned previously, none of the rivers were 'pristine' and had each undergone clearing by the WfW teams, to some extent.

Ordination:

- *Detrended Correspondence Analysis (DCA):*

The results of the DCA (indirect gradient analysis) of the riparian vegetation is shown in Figure 2.9. This analysis was used to determine species and site assemblages within the data set. The eigenvalues of axes 1 and 2 of the DCA for the sites were 0.521 and 0.356, respectively. Sites belonging to the five communities have been classified by TWINSPAN were clustered in the ordination.

The 77 sites were arranged into three main groups consisting of the *Berzelia* and *Erica* community, which was slightly separated from the other, the *Podocarpus* community and the 3rd group consisting of the *Rhus* & *Prionium* communities, the latter two communities were largely overlapping.

- *Canonical Correspondence Analysis (CCA):*

The eigenvalues of the CCA axes were lower than for the DCA axes (axis 1= 0.32 and axis 2= 0.24). The total inertia is 9.433. The F-ratio for the first canonical axis is 2.312, with a resulting P-value of 0.03, indicating that the 1st canonical axis is not significant. The F-ratio of the sum of all canonical eigenvalues (the trace) is 1.462. The resulting P-value is 0.0050, demonstrating that the relation between the species and the environmental variables is highly significant ($P<0.01$).

Figure 2.10 displays the CCA ordination diagram for the site and environmental scored. The environmental variables are represented by arrows pointing in the direction of maximum variation, with their length proportional to the rate of change (ter Braak, 1986; Moustafa & Zaghloul, 1996).

The *Berzelia* community is situated on the far right of the diagram and is closely related to the %FS, pH and less closely correlated with depth. The *Rhus* community is predominantly located in the upper left-hand corner of the diagram, and is closely related to pH, altitude and %CS. It overlaps quite a bit with the *Prionium* community. The *Podocarpus* community is closely related to %MS, pH, %FS, rock cover, altitude, % CS and slope. This is a very broad community as it relates to most of the environmental variables. The *Prionium* community overlaps quite a bit with the other communities, and is closely related to all environmental variables, except depth, total cover and %FS. The *Erica* community was quite widely dispersed, and is not very closely related to any of the environmental variables. However, it overlapped quite a bit with the *Prionium* community.

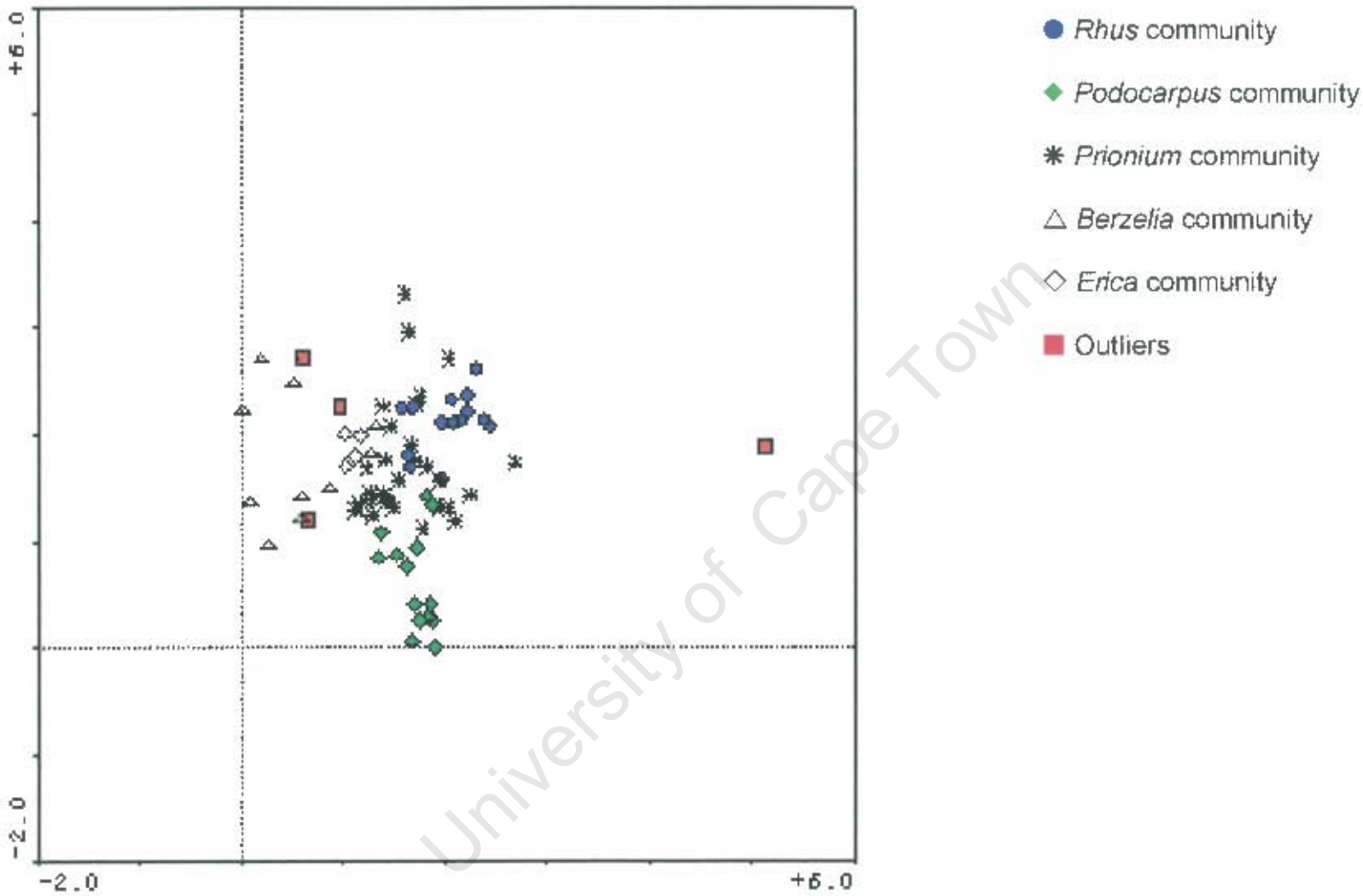

Figure 2.9. Detrended Correspondence Analysis (DCA) ordination diagram of 77 sites plotted on the 1st and 2nd axis. The groups of sites associated with each of the five communities are shown with symbols (see legend).

Species richness and diversity:

Table 2.5 displays the species richness, diversity and evenness of the different rivers sampled. The species richness of the Wit, Palmiet, Steenbok and Rooiels Rivers were a similar range (11.9-13.05), while that of Moelenaars and Jonkershoek was calculated at 6.7 & 8.79, respectively.

Table:2.5. Mean vegetation variables at six different sites (rivers) in a riparian vegetation survey.						
Plot locations	**Wit River: Baainskloof**	**Moelenaars River: Du Toits Kloof**	**Palmiet River Kogelberg NR**	**Jonkershoek River Jonkershoek NR**	**Steenbok River Steenbok Park NR**	**Rooiels River Kogelberg NR**
Vegetation variables						
Mean number of individuals	98.55 (42.4)	26 (19)	109.5 (39.1)	40.6 (16.3)	116 (80.2)	57.4 (52.7)
Species richness (50m^2)	13.05 (3.38)	6.7 (3.8)	12 (3.32)	8.79 (1.89)	11.9 (6.72)	12.8 (8.3)
Diversity (H)	-0.78 (0.33)	-0.64 (0.27)	-0.8 (0.12)	16.7 (24.4)	116 (80.2	57.4 (52.7)
Evenness (J)	-0.71 (0.28)	-0.8 (0.24)	-0.8 (0.06)	18.3 (25.6)	104 (51.8)	49.1 (32.6)
Total Canopy cover (%)	0.83 (0.15)	0.85 (0.13)	0.92 (0.11)	0.89 (0.07)	0.91 (0.06)	0.98 (0.03)

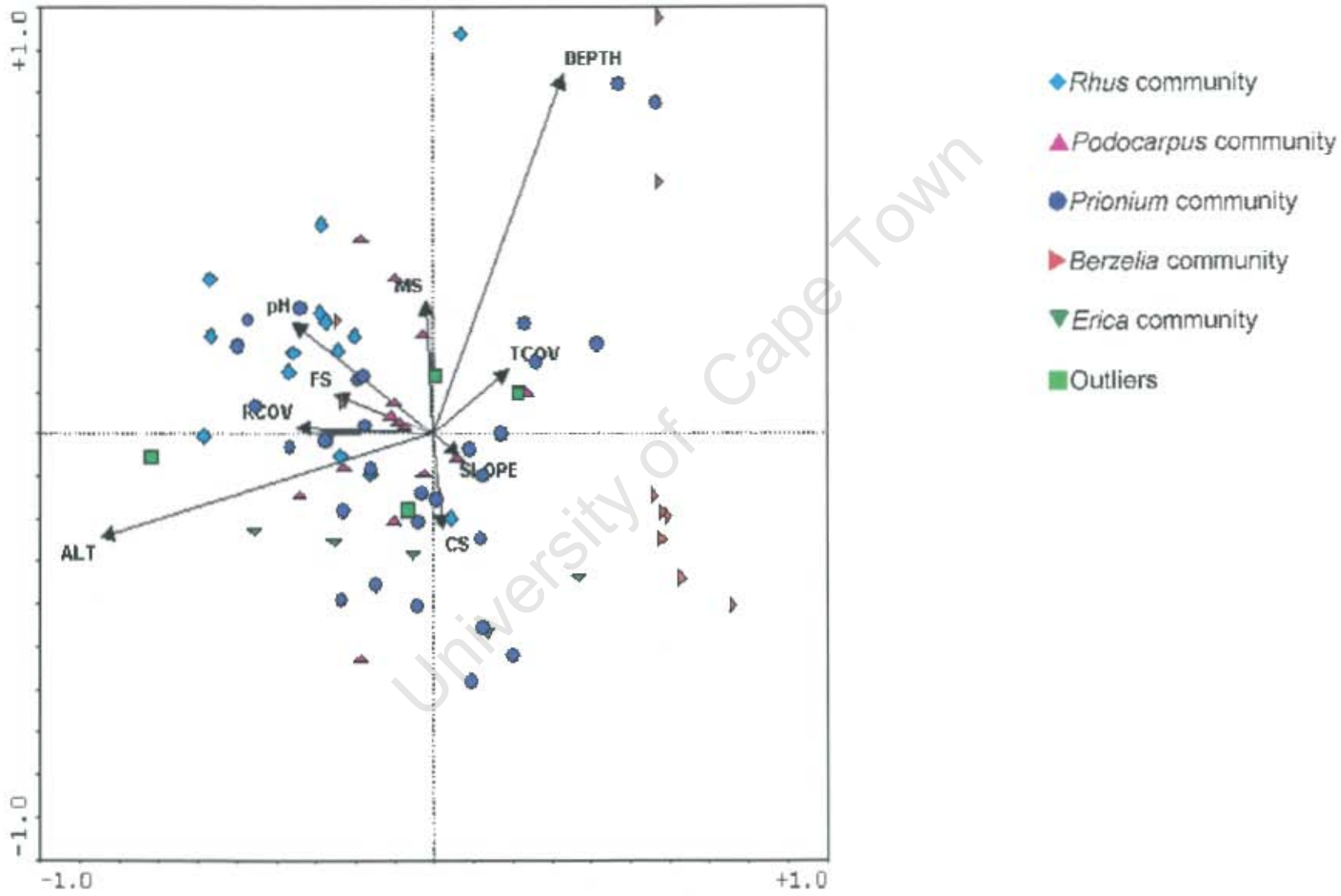

Figure 2.10. Canonical Correspondence Analysis (CCA) of the site scores for the 77 sites and the entire set of environmental variables on the first 2 CCA axis. The groups of sites associated with each of the five communities are classified by different symbols, see legend. Refer to Table 2.3 for a full description of

2.7. Discussion:

Vegetation classification:

The TWINSPAN analysis divided the vegetation along the six different rivers into five communities. These communities are broadly equivalent to riparian communities described by Boucher (1978) and McDonald (1988).

The vegetation sampled in this survey is a mix of fynbos and forest elements. Species such *Brabejum stellatifolium, Metrosideros angustifolia*, *Brachylaena neriifolia, Pteridium aquilinum,* and *Erica caffra* are very dominant in the plots that were sampled. Presence of aliens such as *Acacia mearnsii* and *Acacia melanoxylon*, prove that the rivers surveyed are not pristine. There are however rivers such as the Palmiet, Jonkershoek and Steenbok rivers, which all run through nature reserves, and are devoid of alien vegetation (regular follow-up).

Most of the areas sampled, occurred in narrow bands along the river, however, it is felt that in some areas a larger plot size could have been used. The plot size ($50m^2$) was kept consistent throughout the study. This size is adequate for phytosociological studies in fynbos (Bond, 1981; Taylor, 1996). However, in a study conducted in Jonkershoek by McDonald (1988), $50m^2$ plots were used in fynbos, while $200m^2$ plots were used in riparian and forest communities. The sites were located subjectively in areas of homogenous environment that appeared to be typical of the environment class being sampled. Previous vegetation studies in South Africa (Boucher, 1978; Taylor, 1984) have used plot sizes ranging from 4 to $200m^2$. However, the choice of plot size has largely depended on floristic richness and the structure of the communities sampled (Mustart *et al.* 1993).

Vegetation-environment relationships:

The relationship between vegetation and environmental factors was assessed with both DCA and CCA ordinations. Environmental factors with long arrows are more strongly correlated with the ordination axes than those with short arrows, and so more closely related to the pattern of community variation shown in the ordination (ter Braak, 1987).

At a broad scale, the ordination analysis provided an indication of the major environmental determinants of the vegetation. The two main compositional gradients (community changes across the landscape) were strongly correlated with gradients of factors such as altitude for the first axis and soil depth for the second axis. The importance of soil depth shows us that riparian vegetation is readily adapted to being able to extend its root network through bedrock, in order to reach the available water. This also relates to the importance of soil volume and texture (Richards *et al.* 1995). Altitude is one of the most important factors affecting vegetation composition, and has been analysed in many studies (Campbell, 1983, 1986). It affects the amount of precipitation, which increases linearly with elevation, and there is usually a temperature decrease of about 0.8°C per 100m elevation (Moustafa & Zaghloul, 1996). Factors that are responsible for the strong effect of elevation include moisture availability, flood disturbances, seed dispersal by water and possibly nutrient availability (Friedman *et al.* 1996).

The other variables that influenced the vegetation to a lesser extent were pH, %MS, rock cover and %CS. The importance of pH is evidence of the key role of soil chemical characteristics. Although most of the communities were related to some of the environmental variables to some extent, and very closely related in some cases, the *Berzelia* community proved to be relatively unaffected.

Species richness:

Generally, riparian zones are said to have a high plant species richness, which can be explained by various factors, specifically regular floods (Hood & Naiman, 2000; Nilsson *et al.* 1994). However, this same factor can contribute to making this zone susceptible to invasion by alien plants. The species richness was calculated for the six different community groups, and it was found that the species richness was high in most sites.

Aliens have also impacted on these rivers, and are aliens such as *Acacia mearnsii* and *Acacia melanoxylon* are present in low to medium numbers. There is proof that these aliens reduce species richness in fynbos (Richardson *et al.* 1989) and also has the ability to change the community structure (Holmes & Cowling, 1997). Other studies have shown that an increase in alien plant cover results in a decline in species richness. in Large numbers of *Acacia mearnsii* were found primarily at the Wit and Moelenaars Rivers.

2.8. Conclusions:

The distinct communities present in this study showed compositional gradients that were strongly correlated with environmental factors. This is evidence of the crucial role of environmental factors in determining species distributions in riparian zones.

The TWINSPAN method, although subjective, was very useful in obtaining useful communities from the data collected. Ordination was also equally effective in relating the above-mentioned communities to the environmental factors recorded.

Though riparian zones, of varied maturities were surveyed, the noticeable presence of alien plants proves that regular follow-up is still paramount, in order to ensure that riparian zones remain natural.

How can this information be used in the future?

- Managers, e.g. WfW team managers, have a poor idea of what communities (assemblages of species) to aim for in restoration. This study may be used as a guide in future restoration projects. When doing surveys of invaded/non-invaded rivers, managers can use these results, as a guide for determining which species will occur on which type of substrate.
- The study also confirms that a plot size of $200m^2$ should be used to avoid undersampling in the future (monitoring purposes). There were certain drawbacks to using the plot size $50m^2$, one of which was loss of important species data (undersampling).

- Environmental factors can also be used as a guideline in determining the presence or absence of species. Altitude for example, can be used as a guide and a link can be made in terms of species presence.
- Alien invasive plants were also included in the survey. These results can also be used to indicate to researchers/managers what they can expect in terms of "invasive spread" in the area.

The remainder of this thesis looks at rehabilitation by revegetation/sowing along riparian zones and the effects of these treatments on erosion.

CHAPTER 3: Assessment of the relative effectiveness of three different sowing methods for restoring vegetation cover and reducing soil erosion in riparian zones following invasion by alien trees and clearing in the Western Cape, South Africa.

3.1. ABSTRACT:

Paired catchments at Oaklands near Wellington in the Western Cape were burnt in February 1998 while being cleared of invasive alien trees, mainly *Acacia mearnsii*, *Eucalyptus* spp. and *Pinus pinaster*. Working for Water teams were felling alien trees in one catchment when the fire occurred, resulting in two "treatments", namely "burn standing" (BS) and " fell and burn" (FB). These are the two most widely used methods for controlling invasive alien trees and shrubs in the Western Cape. This study set out to use this "natural experiment" to explore options for alien invasive plant control along Western Cape Rivers.

Three sowing treatments were applied (20 plots on each catchment): 1) Fynbos mix only (FYN); 2) Fynbos mix and grass (MIX) and 3) Fynbos mix with grass placed in terraces (TER). The recruitment of native and alien plants, as well as the effect of the sowing treatments on the soil movement, was monitored for 1 year.

Species richness was higher in the FB treatment. The fynbos mix proved an effective option for restoring an indigenous plant cover. The repeated-measures ANOVA performed on soil-loss data revealed no significant interaction between soil erosion and plant.

Keywords: *Acacia mearnsii*, biological invasions, fire, recruitment, restoration, soil erosion.

3. 2. INTRODUCTION:

Riparian zones throughout the world have been adversely affected by invasive alien plants (Knopf *et al.* 1988, Hood & Naiman, 2000). These zones are prone to invasion by alien plants because they act as primary dispersal corridors for many plants, and they are continually disturbed by flooding events (Naiman & Décamps, 1997). Invasive alien organisms are important agents of land transformation, disrupters of ecosystem functioning, and a threat to biodiversity, and these threats have increased rapidly over the last 200 years throughout the world (Richardson *et al.* 1997).

There are various natural disturbances that disturb the structure and functions of riparian systems. These disturbances, including floods, fire, insects and disease, temperature extremes and droughts, can also be agents of regeneration and restoration, and some species of riparian plants have managed to adapt their life cycles to cope with such natural disturbances (FISRWG, 1998; Blom *et al.* 1990; Blom *et al.* 1993).

Alien plants have become a major problem along Western Cape Rivers (Brown, 1998; Versfeld *et al.* 1998), as they have a huge impact on stream flows (Dye & Poulter, 1995; Prinsloo & Scott, 1999). The main options that are available to managers for removing stands of alien invasive alien trees are 1) burn standing, 2) fell & burn and 3) fell, remove & burn (Holmes *et al.* 2000). To ensure that an integrated approach to control invasive plants is taken, managers also have the option of making use of herbicides (Garlon & Roundup) and biocontrol. Fire is an important management tool in mountain fynbos and very important part of the control of alien invaders (specifically woody invaders) (Richardson & van Wilgen, 1986). One of the most damaging aspects of alien clearing is a fire that occurs unexpectedly through a dense alien stand/felled material (Holmes, 2001).

There are various advantages and disadvantages of using these different clearing/control treatments. Burn standing does not hold the danger of extremely hot fires, but after the fire, managers are left with dead tress that have to be manually removed.

Fell & burn- this treatment has the advantage of allowing a controlled burn in designated areas (some cases), which destroys alien seedlings or stimulates germination that can facilitate follow-up. In some cases of accidental fires, extreme heat can result in major damage of the seed bank (Richardson & van Wilgen, 1986), as well as erosion of the riverbanks (Scott & van Wyk, 1992). Fell, remove & burn has the advantage of clearing the area, and removing the potential threat of fire, at the same time exposing soil to further invasion (unless area followed-up).

Along most rivers and catchment areas in South Africa, the main objective is to clear and control alien plants, and then link this control with successful recruitment of indigenous species. Various restoration attempts have been undertaken following disturbances such as road construction (Romhoff, 1986; Levitt, 1997), mining (Holmes, 1996), as well as reservoir building (Peterson, 1988).

During most restoration projects it is also very important to consider erosion effects of clearing on riverbanks. In some cases, it may be necessary to revegetate in order to restore ecosystem function after alien clearing, because functions such as streambank stability and the delivery of good quality of water may be compromised. In the short-term, it may be desirable to use quick-growing annuals to protect the banks against surface scour (Rowntree, 1991; Holmes *et al.* 1998). Pimentel & Kounang (1998) rank soil erosion as one of the most serious environmental problems in the world. Its effects are pervasive, and its damages are long lasting. The amount of soil loss/movement could also be attributed to the degree of water repellency experienced by soils. Soils normally show a strong attraction for water, making them completely wettable; the opposite effect is known as water repellency (Scott, unpublished). Fire-induced water repellency in soil was first noted in 1949 in the chaparral area of California (De Bano, 1969). Versfeld (1981) further states that soils with poor infiltration rates are most likely to exhibit overland flow, which in turn will result in soil erosion.

Thorne (1990) says that a slope that is covered with a good stand of close-growing vegetation, compared to one that is unvegetated will be resistant to erosion. Revegetating along rivers should however take the season into account, as seedlings need to be protected from floods, in order to establish (Blom *et al.* 1990).

In October 1995 the Department of Water Affairs and Forestry launched a far-reaching campaign to control invasive alien plants: The Working for Water Programme (http://www-dwaf.pwv.gov.za/wfw/). This programme's mission statement reads: "The WfW programme will sustainably control invading alien species, to optimise the potential use of natural resources through a process of economic empowerment and transformation...". It operates specifically in water catchment areas and river courses, using labour-intensive methods of clearing alien plants (Gelderblom *et al.* 1997). This initiation of control operations across large areas, resulted in the initiation of more projects, hence this study (investigating clearing methods).

This study made use of a "natural experiment" that was created when an unplanned summer fire burnt through a paired catchment at Oaklands near Wellington, where Working for Water teams were busy clearing. Alien trees in one catchment had been felled before the fire, but the teams had not yet felled trees in the other catchment. The unplanned fire, thus, provided the opportunity to monitor – in similar catchments - regeneration and erosion effects of different restoration treatments following the widely used "fell and burn" and "burn standing" methods.

This chapter aims to investigate:

1. The effectiveness of sowing a mixture of seeds of indigenous plant species on the recovery of vegetation density and cover;
2. Whether sowing grasses will suppress or have a negative effect on the native vegetation;
3. Whether the treatments have different effects on the recruitment of indigenous species;
4. The effects of sowing different mixtures of seeds of indigenous plant species on soil erosion patterns;
5. Whether a fast-growing annual stabilizes stream banks successfully and decreases soil erosion.

3.3. METHODS:

3.3.1. Study area

This study was conducted on the farm Oaklands, situated at the foot of the Groenberg near Wellington in the Western Cape (33°36'80"S/19°5'30"E). The vegetation in this catchment is mountain fynbos. The annual rainfall at the study site ranges from 900 to 1200 mm. Soils are derived from deeply weathered granites, with colluvial sandstone material in the upper soil layers (Le Maitre *et al.* 1998).

The whole catchment was invaded by black wattle (*Acacia mearnsii*) and *Eucalyptus grandis* (Figure 3.1). Black wattles occur mostly in the riparian zones (Prinsloo & Scott. 1999), whereas the eucalypts occupy the outer edges of the riparian zone and the ridges. Black wattle trees formed a closed canopy with an average crown height of 10-15m. Some very large individuals (diameter at breast height >400mm) occurred in the riparian zones (CSIR, 1998). There were also a number of large self-sown *Pinus pinaster* trees in the area, but these were mostly further than 20m from the stream (Le Maitre *et al.* 1998). The invaded area extended about 20m to the east and 30m to the west of the watercourse.

Figure 3.1 Dense stands of invasive alien trees, mainly *Acacia mearnsii* (note the thick stumps). This picture was taken prior to clearing the catchment at Oaklands.

Hydrological experiment

The Oaklands site was chosen by the CSIR for a hydrological experiment to confirm the results of riparian clearfelling reported from other parts of the country. Two adjacent catchments on the lower slopes of Groenberg and a similar site just below the Du Toitskloof Pass were selected. This allowed for a paired catchment analysis of the impacts of clearing, where one catchment was kept as the control and the other was cleared. The flow data from the catchments before clearing started was used to calculate the relationship between the flow in the control and the treated catchments (CSIR, 1998).

Clearing Treatments

The streamflow was measured for a short calibration period, and then the riparian zone in one of each pair of catchments was cleared of woody weeds (mostly black wattle), and monitored. The area cleared at Oaklands was 47 ha in extent, with a mean slope angle of roughly 57% (29°). About 250m upstream from the weir a dry stream branched out in a southwesterly direction, and was also densely invaded with black wattle.

The weir was placed on this catchment by CSIR to measure streamflow. The riparian zone, 20m on either side of both main stream course and the branching channel was cleared. Alien plants (mainly eucalypts) on the ridge between the two stream channels were also cleared (CSIR, 1998).

Clearfelling was mainly done in March and April of 1997, but the operation was only completed in May 1997. The slashed material was spread over the area that was cleared, while the tree boles were left where they fell. A wildfire, which started in Bainskloof on 15 February 1998, swept through Oaklands, burning all litter and live vegetation in both catchments. Thus, this paired catchment, provided two clearing treatments, namely burn standing (BS) and fell & burn (FB).

Setbacks

The plan was to use NO herbicides in the clearing treatments. However, due to a misunderstanding, herbicides were applied by the Working for Water teams (standard follow-up procedure) at the BS site. "Spot-spraying" was done, using a mixture of Garlon and diesel applied from a 20L backpack sprayer unit.

The following mixture was applied: i) 3X caps of Garlon, ii) 1 spoon of dye (blue), iii) 2 caps of liquid soap and iv) ±10L of water (to fill up the 20L backpack An assessment of the extent of herbicide application was made soon after the incident (April 1999) by surveying the $1m^2$ quadrats and the entire plot (5X10m){Appendix 5}.

Seed collecting

A mixture of seeds of fynbos species (hereafter "the fynbos mix) was used in this study, based on its successes in other restoration projects in the Western Cape (Holmes, 1998, 2000; Holmes *et al.* 2000). This mixture of fynbos elements greatly improves structural composition of the vegetation, and increases indigenous plant density. Seeds were collected on the farm Oaklands to ensure that appropriate species and genotypes were used. Seeds for this purpose were handpicked in late March 1998 from several unburned patches of mature fynbos on the farm (approximate post-fire age: 1.5 years) (Figure 3.2). The seed was sun-dried for a few days, to allow for seed release (especially important for serotinous seeds). Seeds were then sorted into 30X10kg potato bags.

The fynbos mix consisted of the following species: *Euryops abrotanifolius* (L.) DC, *Rhus angustifolia* L., *Diospyros glabra* (L.), *Protea repens* (L.) L., *Protea laurifolia* Thunb., *Leucadendron salignum* Bergius., *Pentaschistis curvifolia* (Schrader) Stapf., *Athanasia* spp., *Stoebe* spp., *Tribolium* spp., *Montinia* spp., and *Helichrysum* spp. Riparian species like *Berzelia lanuginosa* (L.) Brongn, *Leucadendron salicifolium* (Salisb.) I. J. Williams. and *Brabejum stellatifolium* L. were collected from an unburnt valley in Bainskloof. Table 3.1 shows the volume of seeds used for the sowing treatments. *Anthospermum aethiopicum* L. collected from the same unburnt patches on the farm was used as mulch, to hold the sown seed during rainy or windy conditions and as another source of seed. Seed of two grass species, *Eragrostis tef* and *Avena fatua,* was purchased from the commercial seed distributor Agricol (Pty) Ltd in Brackenfell, Cape Town. These grass species were sown at one third of the agricultural recommended rate.

Figure 3.2. One of the various unburned patches at Oaklands, where the majority of the fynbos mix was handpicked

Table 3. 1. Table of seed volumes (e.g. no. of cones, handfuls, grams) sown per plot.

SPECIES	VOLUME
Protea repens (L.) L.	14 cones
Protea laurifolia Thunb.	5 cones
Leucadendron salignum Bergius.	20 heads
Leucadendron salicifolium (Salisb.) I. J. Williams.	30 heads
Berzelia lanuginosa (L.)	2 handfuls
Brabejum stellatifolium L.	27 fruits
Fynbos mix (indigenous seed mix)	4 handfuls
GRASSES	
Avena fatua L.	400g
Eragrostis tef (Zucc.) Trotter	50g

Site preparation

Oaklands experienced a wildfire, on 15 February 1998. The site was investigated as a possible experimental site soon after the fire. In the interim (between fire and site visit), the debris from the burnt standing site (BS) was stock piled (Figure 3.3). These piles were later removed by the Working for Water teams to set up twenty 50m^2 plots, for the sowing experiment. These debris piles left behind a significant amount of litter, mainly as pine needles, dead acacia leaves and tree bark.

The site that was felled and burned (FB) was relatively bare after the fire, but the first species to recruit after the fire was *Pteridium aquilinum* (bracken). Bracken (Figure 3.4), although a native fern in the fynbos, is a well-known "weed" in many parts of the world (e.g. in the U.K. Pakeman *et al.* 1997, 2000). It is also one of the first plant species to regenerate following fire in more mesic conditions in fynbos, and its dominance in these situations may hinder the regeneration of other fynbos plants (D.M. Richardson, pers. comm.) The density of bracken was reduced at the site, to prevent the dominance of this species at the expense of other species (sown and seed bank).

Figure 3.3. Stockpiling of the woody debris left behind after the fire, prior to setting up the plots.

Figure 3.4. *Pteridium aquilinum* (bracken) recruited at the FB site soon after the fire in February 1998.

There are various options for controlling bracken, but these were not considered, as it is a concern that vegetation development after aerial spraying (one option) is slow, patchy and unpredictable (Pakeman *et al.* 2000). Since bracken is rhizomatous, and handpulling would cause considerable disturbance to the site, this was also ruled out as a clearing option. Rather, a slasher was used to clear most of the canopy cover of bracken, leaving the roots in tact. This initiative was used to allow for easier sowing and initial establishment, as well as using the root system for additional soil stabilization.

Experimental design

Twenty plots were set up in each catchment. The plots were placed 5m parallel to the river, and 10m perpendicular to the riverbank. The size of each plot was 50m^2.

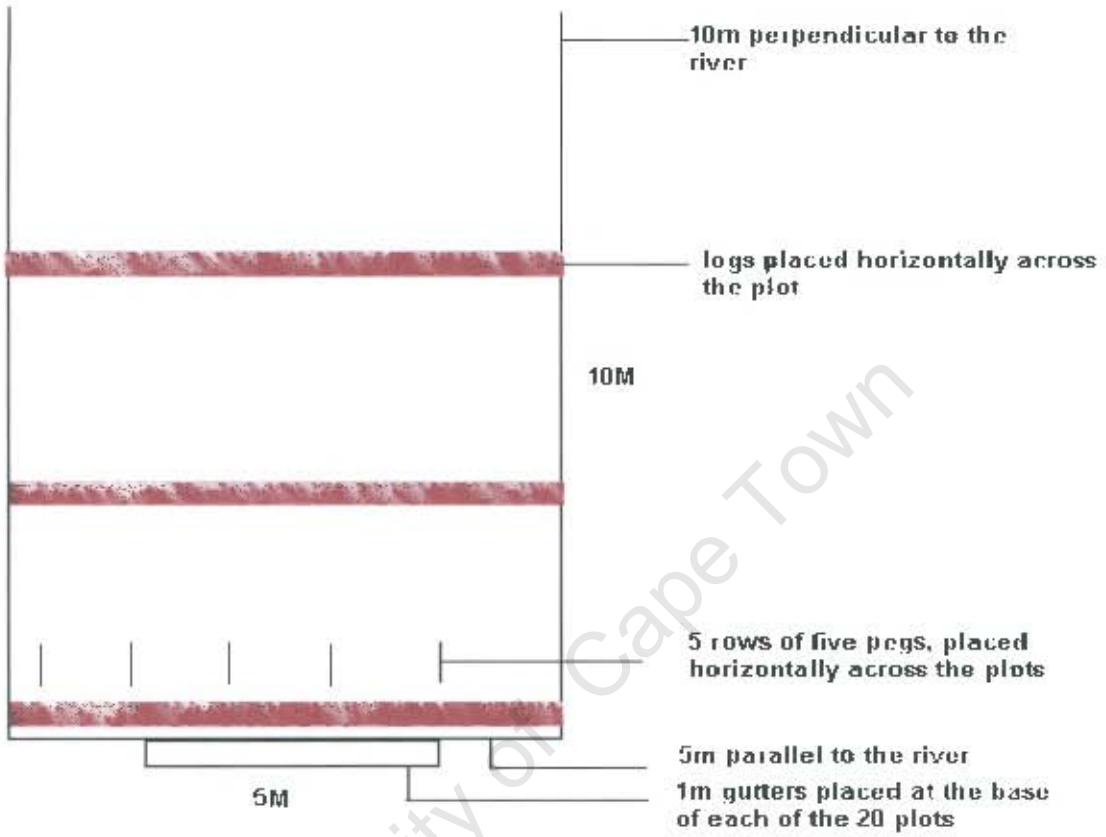

Figure 3.5. Plot layout at the Oaklands experimental site. Logs and gutters were only placed at the one site, as erosion measurements were taken there

As an additional stabilization technique, to slow run-off and reduce erosion, three logs were fixed horizontally on each plot (Figure 3.6). This technique was only applied to the felled site, as it was quite steep.

Figure 3.6. Three logs placed horizontally across the plots in the catchment that was "felled and burned", as an additional stabilization technique.

Sowing experiment

These plots (FB & BS) were placed within the burned area and no controls were established. There were no controls available at Oaklands, as the whole catchment had been burned

Three sowing treatments were applied to each catchment: 1) Fynbos mix only **(FYN)**; 2) Fynbos and grass **(MIX)** and 3) Fynbos mix, with grass sown in terraces **(TER)**, as well as a control (**CON**-plots covered in mulch only). In the **MIX** treatment, fynbos mix and grass were broadcast across the plots as evenly as possible. In the TER treatment, the grass was separated and sown in the terraces, while the fynbos mix was sown between the terraces. These three mixes were used to monitor recruitment of indigenous seedlings.

The potential benefits of these treatments are as follows: 1) Fynbos only provided a substantial indigenous vegetation cover; 2) the addition of grass, allowed us to monitor the effect of competition on indigenous recruitment; 3) the separation of grass from fynbos by terracing, would show how well fynbos does without interference and 4) the control enabled us to monitor what came up from the seed bank without any intervention.

The seeding treatments were allocated to the plots at random, whilst ensuring that each site supported five replicates of each treatment. The seed was applied on 31 April 98 (FB) and 14 May 98 (BS), by broadcasting over the entire plot as evenly as possible. Mulch was added to each plot immediately to prevent seed loss and to retain moisture following rainfall events.

Erosion measures:

Two techniques for measuring erosion were used to test the effectiveness of the four sowing treatments:

1. Five rows of five steel pegs (Figure 3.7) were placed on eight of the 20 plots (2 replicates). The five rows were 1.5m apart, and the pegs were placed 1m apart. Pegs were hammered into the ground until they were relatively stable (to prevent pegs from washing away in heavy rain). The exposed length of the peg was measured (initial measurement).

2. One-meter long gutters were placed on each of the twenty plots (Figure 3.8). These plots were placed approximately in the middle, at the base of each plot. The amount of sediment accumulated in the gutters was measured to estimate sediment movement taking place in the plots.

Figure 3.7 Layout of the steel pegs used to measure soil erosion and accumulation over time.

Figure 3.8: One-meter long gutters placed on all 20 plots at the FB site.

3.3.2. Data Collection:

Monitoring/Vegetation sampling

The recruitment and survival of all growth forms was monitored frequently in the early stages (see censuses1&2). Five separate censuses were done: 5 (1,2 & 8/10/98), 6 (17-19/11/98), 9 (23, 24 & 28/02/99), 13 (1-3/6/99) and 15 (4-6/10/99) months after sowing. In each of the 40 plots, four $1m^2$ permanent quadrats were established. These plots were marked with four steel pegs to ensure that monitoring took place in the same area at each census.

The following variables were measured in each quadrat:

a) Species were classified into nine growth-form guilds: ericoids, proteoids, alien forbs, indigenous forbs, alien grasses, indigenous grasses, broad-leaved shrubs, bracken and geophytes. Counts of all the individuals (i. e. plant density) were made for each growth-form guild. After 15 months, the vegetation was too dense for counts to be done in the quadrats and projected plant cover for each species was estimated over the entire plot.

b) Canopy cover for each growth-form guild was estimated to the nearest percentage point ('ocular estimate'), and the total canopy cover for all species within each group was then summed.

c) Species richness was calculated for the final vegetation census, which was done by species. This value was determined by assessing the number of species within the $50m^2$ plot.

The diversity (H) and evenness (J) of plant communities were calculated using the Shannon-Wiener Index:

$$H = -\Sigma_{Pi}\, 1n\, _{Pi} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1),$$

Where Pi is the proportion of individuals in the community, represented by species P.

$$J = H/H_{(max)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2),$$

Where $H_{(max)}$ is the maximum density if all species in the community had an equal number of individuals.

Throughout the trial, all flowering specimens were collected and most were identified in order to compile a complete species list for the site (Appendix 2). Some of the slower-maturing plants could not be identified to species level by the end of the monitoring period.

Soil collection

1. The gutters were put in place on 6 July 1998. Monitoring started immediately after the next rain (8 July 1998). Grab-sampling was done every two or three months after every significant rainfall event (>5mm). This involved collecting all the soil accumulated in the gutters. Data collection took place at various points during the rainy season. After each rainfall event, the eroded soil and all other material trapped in the gutters were collected. The oven-dry mass and volume was determined for each sample.
2. The pegs were measured every month, whether it rained or not, as events besides rainfall (e.g. wind) also cause erosion. The exposed length of the pegs was measured to monitor movement of soil across the plot. Increases over time indicated erosion, whereas decreases indicated soil accumulation.

Alien control

The Oaklands farm was being cleared by the Working for Water teams, but to prevent disturbance to the sites, clearing was initially excluded. After the first heavy rains, the dense regeneration of black wattle seedlings started to become a problem. Without intervention, these seedlings would have smothered seedlings of the native species, confusing the results of the study. It was therefore important to exclude fast-growing alien invasive plants

Due to time and capacity constraints, I decided to use only hand pulling (Figure 3.9) to remove regenerating seedlings of alien trees. This operation was undertaken in January 1999. Because *Acacia mearnsii* (primary invader) resprouts vigorously after cutting, it was necessary to pull seedlings out by the roots. However, this had to be done very carefully, as this method could be quite damaging to surrounding indigenous seedlings.

Figure 3.9. *Acacia mearnsii* saplings being handpulled at the BS site, Oaklands, Wellington.

3.4. Data analysis:

Sowing experiment:

The main aim of the statistical analysis was to investigate if there were any differences between sowing methods compared to the control. It was also important to investigate whether any effects that have taken place over time, depended on the sowing method.

Data collected in this study consisted mostly of the total counts of the various growth forms in the four quadrats, and the percentage cover (alien, indigenous and total).

An attempt was made to use a Generalized Linear mixed model (GLMM) (Schall, 1991), but some numerical problems were encountered due to the high variability of the data in some cases. This approach was therefore abandoned. The data were transformed to stabilize the variance, and a repeated measures analysis of variance (ANOVA) was used. The square root transformation was used for the total quadrat counts and the arc sin transformation was used for the percentage covers (Miller, 1966; Morrison, 1967).

A repeated measures analysis of variance (ANOVA) of the transformed data was used to compare the sowing methods over time. It was decided to make pairwise comparisons of the sowing and time means that were shown to be significantly different by the ANOVA. Bonferroni t-statistics were used in these multiple comparisons. The overall significance level was set at 5%, and the individual comparisons made at the 0.08% level.

The repeated measures ANOVA results are given in the Appendix 4. Significant effects are in bold. Details of the Bonferroni multiple t-tests are summarized in Table 3.2.

Finally, Detrended Correspondence Analysis (DCA) was used to assess patterns in the treatments and controls (ter Braak & Šmilauer, 1998). The sum of the density values was used. The same analysis was performed on the final vegetation census, which was done by species. This multivariate analysis was conducted using the program Canoco for Windows.

Erosion experiment:
a) Correlation:

Correlations were used to test the relationship between two variables, namely plant cover (total, alien, indigenous, bracken) and soil loss (Sokal & Rohlf, 1987).

Correlations were performed using Statistica 5 (version 5.5) for the various censuses (1-4) to test whether erosion/soil loss was correlated to plant cover. For each census, a correlation analysis was performed for soil loss vs. total plant cover, alien cover and indigenous cover. The final vegetation census gave a cover value for bracken and a similar analysis was performed to clarify what type of relationship exists between soil loss and bracken cover.

Daily rainfall for the nearest weather station (Paarl) to the study site was obtained from the weather bureau and was plotted for the months in which the greatest amounts of rain fell.

Table 3.2: Bonferroni multiple comparisons showing significant differences between the sowing and time effects (using the transformed scale).
Significant differences are indicated in bold.

						Transformed means				Bonferroni multiple comparisons					
Variable	**Factor**	**d.f.**	**Fprob**	**t**	**SED**	**Time1**	**Time2**	**Time3**	**Time4**	**1-2**	**1-3**	**1-4**	**2-3**	**2-4**	**3-4**
Time effects:															
Total counts															
FBProtTots	Time	3	0.003	2.521	0.1873	2.505	2.363	2.022	1.769	0.76	**2.58**	**3.93**	1.82	**3.17**	1.35
BSEricaTots	Time	3	<0.001	2.528	0.664	14.19	10.65	10.8	6.74	**5.33**	**5.11**	**11.22**	-0.23	**5.89**	**6.11**
FBEricaTots	Time	3	<0.001	2.558	0.738	13.09	9.29	8.64	7.75	**5.15**	**6.03**	**7.24**	0.88	2.09	1.21
FBGrindTots	Time	3	<0.001	2.535	1.028	10.8	6.89	6.46	5.53	**3.80**	**4.22**	**5.13**	0.42	1.32	0.90
BSForbinTots	Time	3	0.005	2.528	0.338	2.81	2.26	1.51	2.64	1.63	**3.85**	0.50	2.22	-1.12	**-3.34**
FBForbinTots	Time	3	<0.001	2.553	0.452	7.81	6.55	5.4	8.15	**2.79**	**5.33**	-0.75	**2.54**	**-3.54**	**-6.08**
BSGralienTots	Time	3	0.027	2.548	1.169	5.48	5.55	7.27	9.01	-0.06	-1.53	**-3.02**	-1.47	**-2.96**	-1.49
FBGralienTots	Time	3	0.024	2.548	1.096	2.48	4.04	4.23	6.38	-1.42	-1.60	**-3.56**	-0.17	-2.14	-1.96
FBForbalTots	Time	3	<0.001	2.535	0.618	8.02	8.85	5.65	10.1	-1.34	**3.83**	**-3.37**	**5.18**	-2.02	**-7.20**
BSBrdlvTots	Time	3	0.037	2.539	0.1262	0.854	0.78	1.159	0.844	0.59	-2.42	0.08	**-3.00**	-0.51	2.50
FBBrdlvTots	Time	3	<0.001	2.501	0.381	3.42	4.35	5.07	4.02	-2.44	**-4.33**	-1.57	-1.89	0.87	**2.76**
BSBrackTots	Time	3	<0.001	2.51	0.513	9.54	9.85	8.66	5.61	-0.60	1.72	**7.66**	2.32	**8.27**	**5.95**
FBBrackTots	Time	3	0.02	2.631	0.2415	2.449	2.699	1.997	1.808	-1.04	1.87	**2.65**	**2.91**	**3.69**	0.78
BSGeoTots	Time	3	0.054	2.577	0.2013	1.255	1.02	0.71	1.283	1.17	**2.71**	-0.14	1.54	-1.31	**-2.85**
FBGeoTots	Time	3	0.004	2.62	0.544	3.47	3.09	2.71	0.86	0.70	1.40	**4.80**	0.70	**4.10**	**3.40**
Averages															
BSTotalAvgs	Time	3	<0.001	2.539	0.0288	0.373	0.54	0.548	0.537	**-5.80**	**-6.08**	**-5.69**	-0.28	0.10	0.38
FBTotalAvgs	Time	3	<0.001	2.61	0.0608	0.783	1.013	0.693	0.982	**-3.78**	1.48	**-3.27**	**5.26**	0.51	**-4.75**
FBAlienAvgs	Time	3	<0.001	2.518	0.0353	0.412	0.58	0.303	0.389	**-4.76**	**3.09**	0.65	**7.85**	**5.41**	-2.44
BSIndigAvgs	Time	3	<0.001	2.532	0.0252	0.298	0.4343	0.4801	0.4629	**-5.40**	**-7.22**	**-6.54**	-1.82	-1.13	0.68
FBIndigAvgs	Time	3	0.028	2.539	0.0485	0.413	0.389	0.406	0.537	0.49	0.14	**-2.56**	-0.35	**-3.05**	**-2.70**
Sowing effects						**CON**	**FYN**	**MIX**	**TER**	**CON-FYN**	**CON-MIX**	**CON-TER**	**FYN-MIX**	**FYN-TER**	**MIX-TER**
BSProtTots	Sow	3	<0.001	2.693	0.5758	1.022	5.307	4.194	4.371	**-7.44**	**-5.51**	**-5.82**	1.93	1.63	-0.31
BSGralienTots	Sow	3	<0.001	2.693	2.049	1.03	1.03	16.71	8.54	0.00	**-7.65**	**-3.67**	**-7.65**	**-3.67**	**3.99**
FBGralienTots	Sow	3	<0.001	2.693	1.936	0.74	1.33	10.53	4.54	-0.30	**-5.06**	-1.96	**-4.75**	-1.66	**3.09**
BSAlienAvgs	Sow	3	0.007	2.693	0.0348	0.0837	0.0753	0.2028	0.1374	0.24	**-3.42**	-1.54	**-3.66**	-1.78	1.88

Legend:

BS-Burn standing	Gralien-Alien grasses	Prot-Proteas	
FB- Fell and burn	Brdlvd-Broad leaved shrubs	Grind-Indigenous grasses	
Forbin-Indigenous Forbs	Forbal-Alien Forbs		
Brack-Bracken	Geo-Geophytes		

b) Peg analysis:

A repeated-measures ANOVA was performed on the pegs data (erosion) using the *GenStat* statistical programme (Payne, 2000: *GenStat* Release 4.2).

3.5. Results:

Sowing experiment:

For all growth forms, the F probabilities and the overall p value given by the Bonferroni method (p= 0.05) are shown in Table 3.2. The transformed mean values are also given in Table 3.2. The observed average counts from the four quadrats are presented below, underlined means are those shown not to be significantly different in the transformed analysis.

The treatment effects were rarely significant during the study. The only instances where significant differences occurred between treatments was Proteas (BS), Alien grasses (BS and FB) and Alien and Indigenous cover (BS). The rest of the treatments showed no significance. Table 3.2 clearly shows that significant differences occurred between the different times throughout the study. These results were confirmed by looking at the untransformed means. This data has not been repeated in the thesis due to its length.

Graphical representation:

Box-and-whisker plots were used to illustrate the performance of each growth form (ericoids, proteoids, alien forbs, indigenous forbs, alien grasses, broad leaved shrubs, bracken, geophytes) in each sowing treatment during the four vegetation censuses (Appendix 3). This type of statistical categorized graphs does not assume normality and shows the great number of zeros present in the data. The box-and-whisker plots are especially useful when we wish to compare two or more sets of data, in which case the plots are drawn side-by-side to the same scale (Underhill & Bradfield, 1994).

Recruitment of growth forms over time:

Recruitment was low for the first census, however, the mulch (*Anthospermum aethiopicum*), recruited very well soon after the first rains. Despite this, at the first census there was an average percentage cover (all plants) of 30% for the FB site and 70% for the BS site. The commercial grasses were also quite quick to germinate, especially after the first heavy rains.

The BS site, however, experienced heavy grazing disturbance by cows, pigs and baboons, retarding the germination. Cows heavily grazed the terraces. The pigs also cleaned out some of these terraces. therefore the alien grass estimates would be lower. Terraces at the FB site were quite evident, however, due to the slope of the site, some of the grass seed were unfortunately washed outside of the plots. The projected canopy cover peaked during the second census (6 months) when there were both perennial and ephemeral species present, irrespective of the setbacks encountered.

As expected, the cover then decreased, because of the dieback of the above-mentioned species (Figure 3.11).

A graphical presentation of the alien, indigenous and total cover during the four censuses is shown in Figure 3.11. In the FB treatment the total cover increased distinctively after the first census and then levelled out. The same was the case for the indigenous cover. Where alien cover was concerned, great variation occurred due to various reasons, namely clearing treatment. A drastic decrease occurred in the third census, and once again became level, except in the case of the mix treatment showing a dramatic increase.

In the BS treatment, much variation occurred throughout the various covers. Total cover increased as expected and then dropped in the third census, after which it experienced an increase again. The indigenous cover experienced variable changes throughout the sowing experiment. There was a marked increase in the control at the second census, and a dramatic decrease in the third. Alien cover showed a general trend of increasing in the second census and decreasing in the third. The control treatment however decreased.

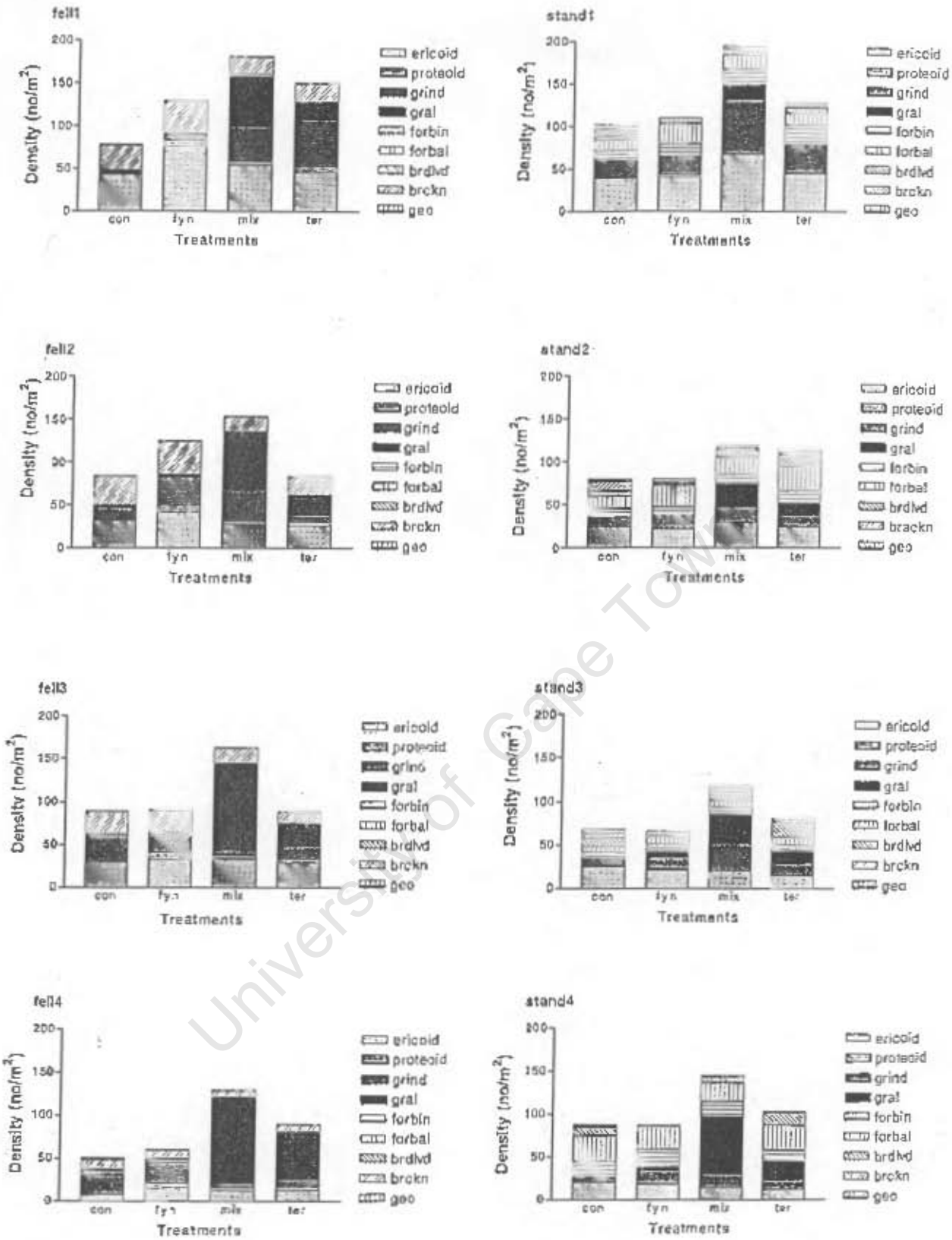

Figure 3.10. The growth-form distribution in the FB and BS treatments, after applying sowing treatments Control (CON), Fynbos mix only (FYN), Fynbos mix and grass (MIX) and Fynbos mix with grass sown in terraces (TER).

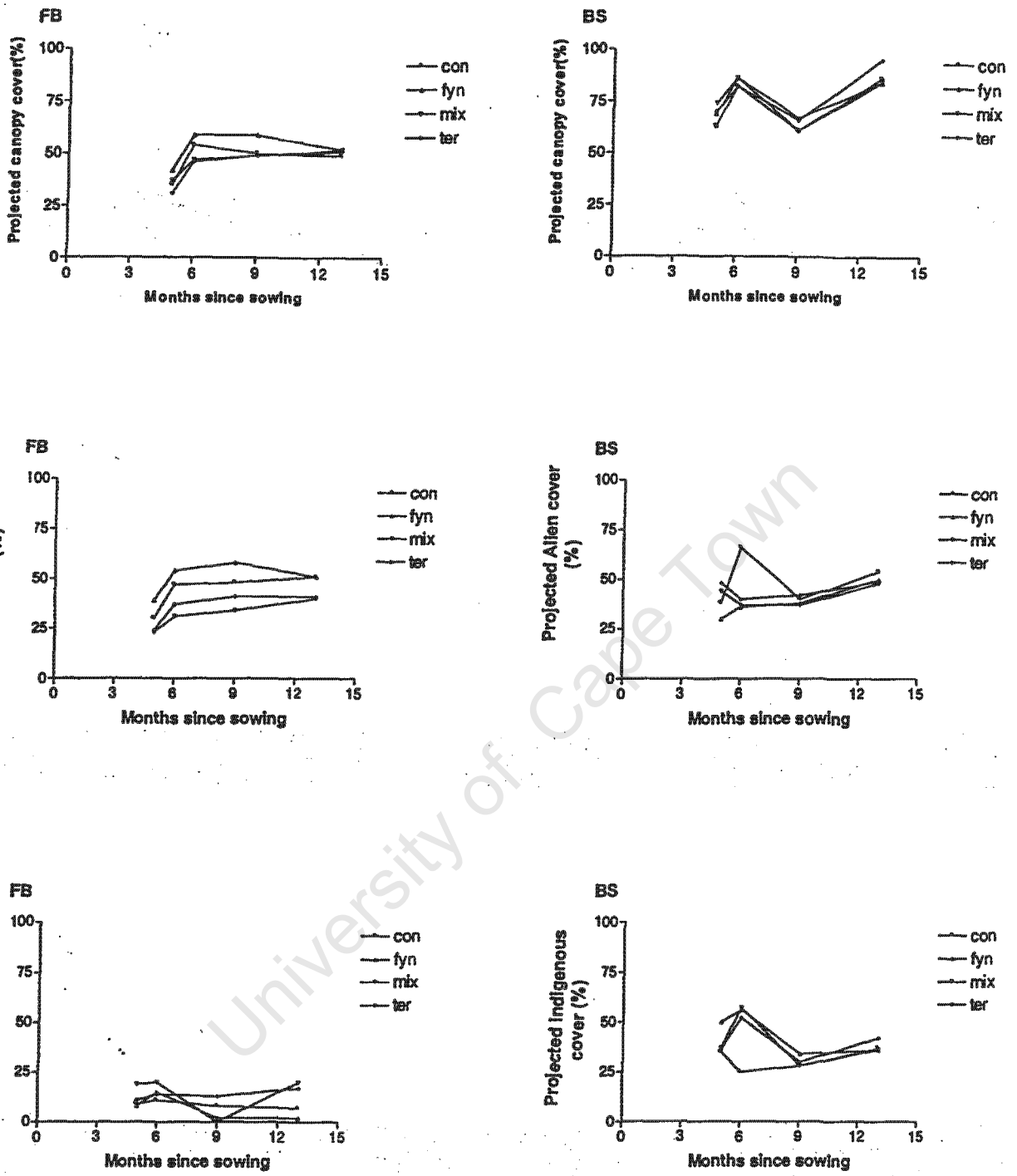

Figure 3.11. Projected plant canopy cover during the experimental period with the various sowing treatments (CON, FYN, MIX & TER); a) total, b) indigenous and c) alien.

Changes in the density of the nine growth-form guilds differed among the different sowing treatments over time. Trends were apparent in the various clearing treatments over time and the nine different growth-form guilds. In the FB treatment, alien grasses increased steadily over the four censuses, whereas ericoids 'boomed' at the first census and generally decreased in density towards the end of the sowing experiment (Figure 3.10). In the BS treatment there was quite a large amount of variation over the four censuses, and this can be directly related to season (pers obs). Ericoids, as in the FB treatment also decreased in number over the census. This can be ascribed to the fact that as the ericoids matured; the numbers seemed to decrease as the canopy increased.

Effects of seed treatments:

In the FB treatment, the addition of the fynbos mix with or without grasses increased the density and cover values. The CON treatment showed an initial increase at the 6th month, but levelled out during the rest of the census. This was due to the quick rate of germination of the mulch. Differences in density of the various growth forms were evident (Figure 3.10).

The controls in both the FB and BS treatments had a relatively low density in each growth-form guild. Ericoids, as well as, bracken were encountered from the first census. Proteoids in both FB and BS treatments had low densities throughout the entire survey. Alien grasses had a high density in the FB treatment in all vegetation censuses. In the BS treatment, alien grasses density did not increase as fast as in the FB treatment (Figure 3.10).

The total (d.f.=3; F=0.724) and indigenous plant cover (d.f.=3; F=0.79) did not show any significant differences in the FB treatment. In the BS treatment variability in the canopy cover occurred throughout the sowing study (Figure 3.11). However, the variability (difference) was not significant (Table 3.2). When comparing the time effects within the BS and FB treatments, there were significant differences.

Species richness:

Species richness was calculated for the final vegetation census only, as the first four censuses were done by growth form. Table 3.3 shows the species richness, calculated diversity, evenness and total canopy cover amongst the various treatments, CON, FYN, MIX and TER.

When comparing the different clearing treatments, the species richness of the different sowing treatments do not vary significantly from one another. The same applies to the diversity. However, in the FB site, the CON site showed the highest diversity (2.54±7.24). This is quite unusual, as the control plot did not receive any seed mix; it was covered by mulch only. It was thus evident that the seed bank still contains quite a large amount of seed.

Table 3.3: Means of vegetation variables of four sowing treatments applied on a felled and burnt(FB) and burnt standing (BS) sites (clearing treatments) on Oaklands study site. The standard deviation is indicated in brackets.

Vegetation variables	Sowing and clearing treatments							
	BS	(n=4)			FB	(n=4)		
	CON	FYN	MIX	TERR	CON	FYN	MIX	TERR
Total number of individuals	177 (35.3)	160 (41.8)	136 (52.1)	145 (56.6)	135 (85.9)	186 (37.9)	131 (58)	138 (43.2)
Species richness (1m²)	9.4 (3.44)	9.4 (1.34)	10 (2.74)	7.4 (2.3)	10.4(6.23)	10.2 (3.7)	11.2 (3.7)	10.6 (4.16)
Diversity (H)	-0.8 (.23)	-0.8 (0.09)	-0.8 (0.12)	-0.7 (0.13)	2.54 (7.24)	-0.7 (0.23)	-0.8 (0.12)	-0.8 (0.16)
Evenness (J)	-0.8 (0.12)	-0.8 (0.04)	-0.9 (0.06)	-0.9 (0.03)	3.89 (10.2)	-0.7 (0.12)	-0.8) (0.06)	-0.8 (0.08)
Total Canopy cover (%)	89 (31)	85 (18.1)	84.6 (23.7)	85.2 (26.9)	73.8 (19.5)	74.2 (21.8)	71.2 (30.6)	111 (21.7)
LEGEND								
Sowing Treatments:								
CON	Control							
FYN	Fynbos mix only							
MIX	Fynbos mix and grass, broadcast							
TERR	Fynbos mix with grass sown in terraces							
Clearing Treatments								
FB	Fell and burn							
BS	Burnt standing							

Detrended Correspondence Analysis (DCA):

The Eigenvalues for the first and second axes are 0.71 and 0.25, respectively. The length of the gradient is a measure of how unimodal the species responses are along an ordination axis. The first axis of the final vegetation census data has a length of 3.262 SD thus; the final vegetation census shows a modest amount of unimodality.

Results of the DCA analysis indicated that the FB and BS treatments varied from one another (Figure 3.12). Both the BS and FB treatments formed separate groups, with no resulting overlap. This clearly indicates that each site (BS and FB) is unique. No significant comparisons were made between the BS & FB treatments, as there were not enough replicates available (only one site). The DCA was used to show how unique the vegetation at both the BS & FB sites were.

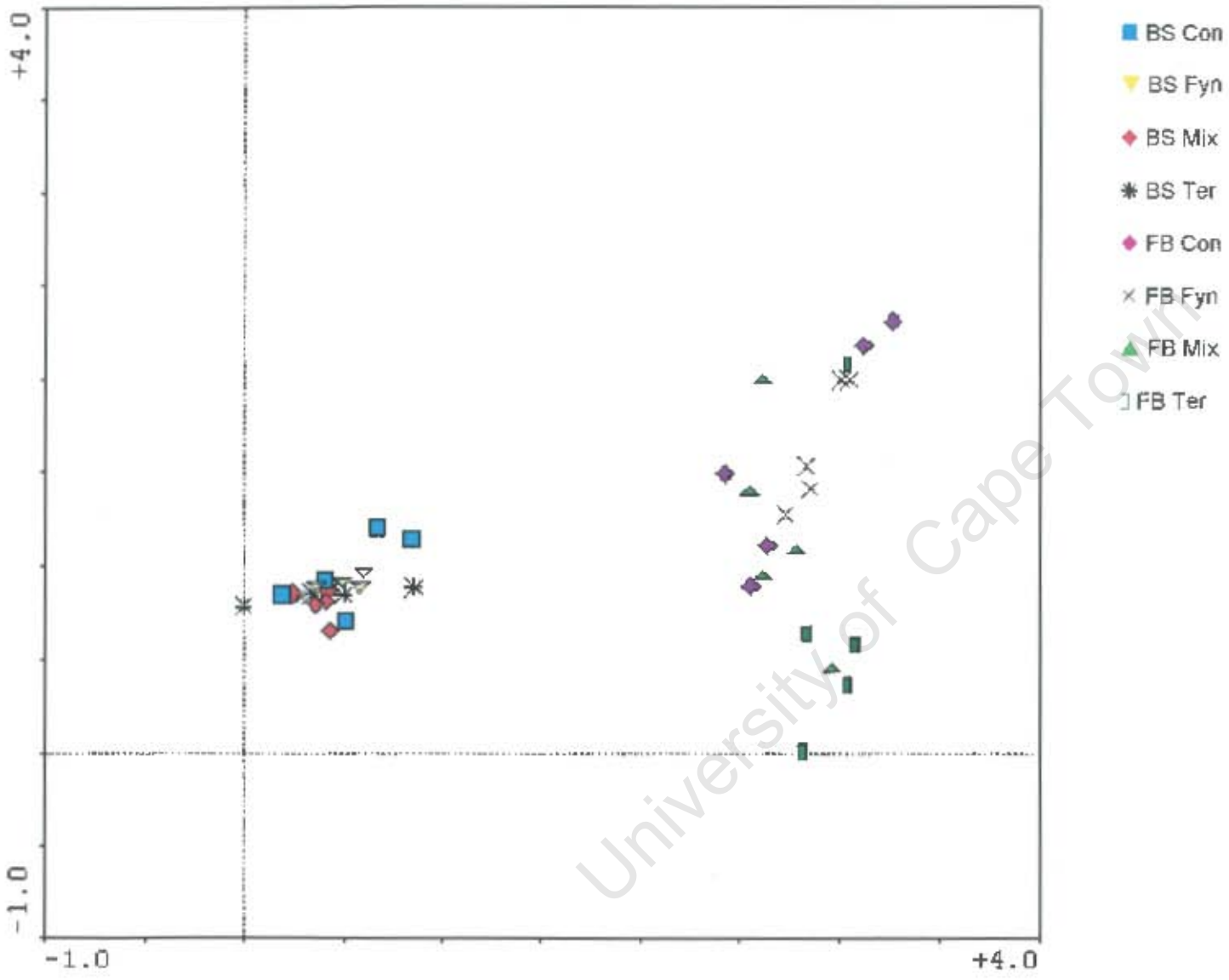

Figure 3.12: Detrended Correspondence Analysis (DCA) ordination of the clearing and sowing treatments at Oaklands. This was the final vegetation census which was done by species. See text for explanation of abbreviations used in the legend.

Erosion measurements:

Correlations

When comparing the correlations between the four censuses for indigenous, alien and total plant cover, no clear relationship was evident between soil movement and plant cover. Correlation (r) values are represented in Table 3.4 for each census.

Table 3.4: Correlation coefficients (Pearson r) for three categories of plant cover and soil loss at different stages after all treatments (p value is indicated in brackets).

	CENSUS 1 (Oct 98)	CENSUS 2 (Dec 98)	CENSUS 3 (Feb 99)	CENSUS 4 (June 99)
INDIGENOUS	0.22 (0.34)	-0.15 (0.53)	0.22 (0.34)	0.15 (0.51)
ALIEN	-0.42 (0.06)	0.23 (0.32)	-0.15 (0.52)	-0.31 (0.18)
TOTAL	0.12 (0.61)	-0.13 (0.59)	0.07 (0.77)	-0.06 (0.80)

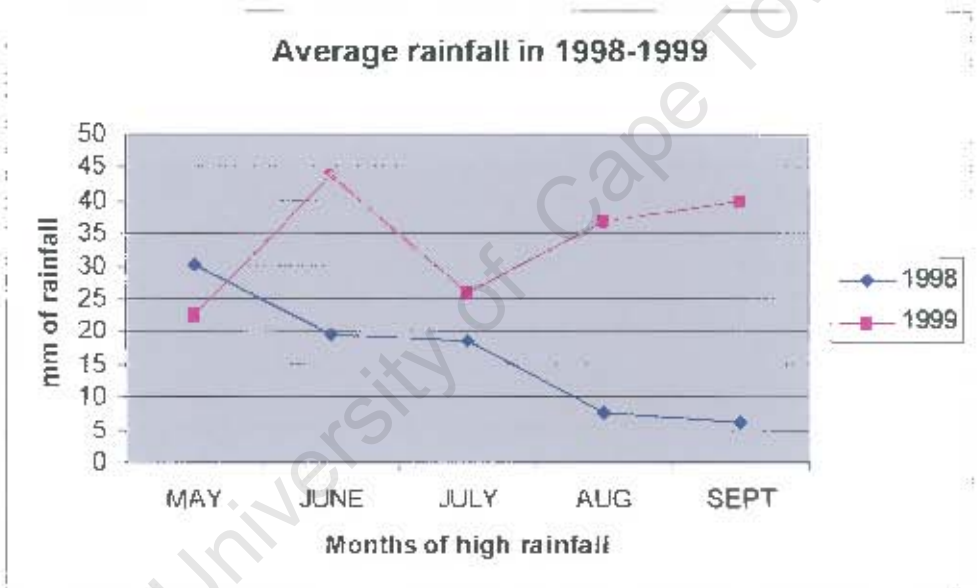

Figure 3.13. Average rainfall in Paarl, plotted for May, June, July, August and September. the months of heaviest rainfall for 1998 and 1999.

The graph plotted for rainfall (Figure 3.13) showed that 1999 received more rainfall than 1998. It was to concentrate on months from May to September, as they were the months in which most rainfall occurred. In 1999, peaks of ±45mm of rainfall were recorded, as apposed to peaks of 30mm in 1998. These values will be discussed later when looking at the pegs data.

Peg analysis

There is no statistically significant interaction between the Time and the Treatment factors in these erosion measurements. However the F statistics for the Time factor (d.f.=3; F=0.03) is statistically significant at the 95% confidence level. No significant difference occurred between the different sowing treatments (d.f.=3; F=0.72). This means that there are significant differences in the erosion measurements over time but no significant difference is evident between the sowing treatments (Fig 3.14).

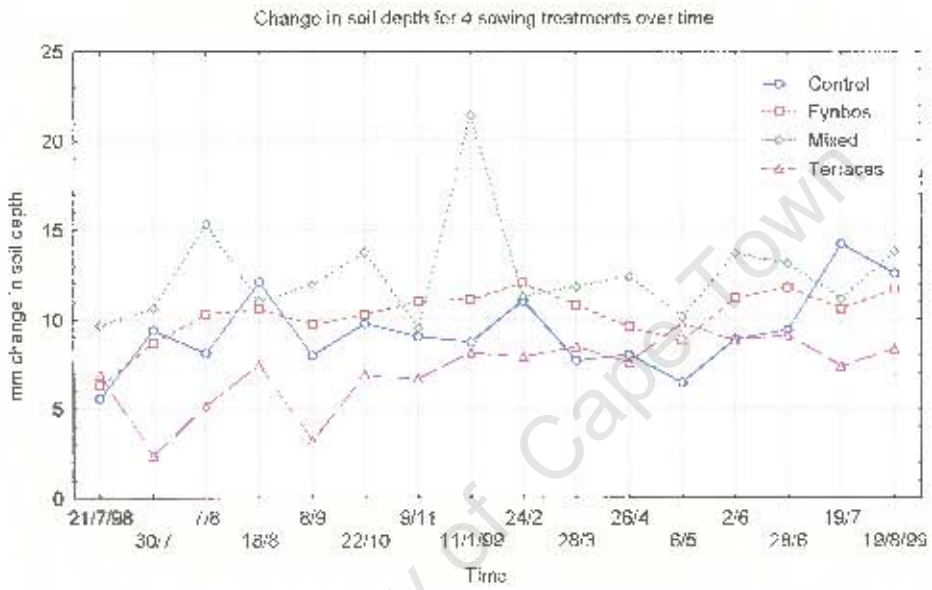

Figure 3.14. Graph showing the mean peg differences for the three sowing treatments and control over time.

The graphical presentation shows that there is not a large amount of variability between sowing treatments and the control. A high measurement or an increase in the peg measurement over time indicates an increase in soil loss. A decrease in the measurement or a low measurement indicates a build-up of soil (i.e. no soil loss). Observing the trend of each sowing treatment over time individually, shows that there is a degree of variability over time (d.f.=3; F=0.03).

Pegs were hammered into the ground to stabilize them, thereby preventing them from becoming dislodged in heavy rainfall. There are consistent trends in each of the sowing treatments and controls.

Figure 3.14 clearly shows that soil loss occurs consistently at approximately the same time (rainfall event) between the different sowing treatments. It should be noted that soil collection did not take place while it was raining, usually soon after, therefore, rainfall that would have affected the measurement would have occurred 1-3 days earlier.

3.6. DISCUSSION:

Sowing experiment:

- *Density, cover and species richness:*

In summary, the sowing experiment implied that introducing a mixture of indigenous seed to a riparian zone with a history of infestation increases the indigenous vegetation cover; it has the potential to increase the species richness of the invaded area, and also has a stabilizing effect on eroding riverbanks.

Statistical comparisons could not be made between the two clearing treatments, as there were not enough replicates (Prof. Juritz, pers comm.). Therefore normal (observed) comparisons were made between the FB and BS treatments.

When comparing the two clearing treatments, and looking at their impact on density and cover of plants, the density did not differ significantly within the various sowing treatments (Table 3.3). There was, however, a difference in the densities of the individual growth forms, e.g. In the FB treatment, bracken was present throughout the first three censuses in quite large numbers. Only at the fourth census did the numbers drop. This could have been due to the summer heat, as browning of the plants was observed. Pakeman *et al* (2000) stated that it is well known (in the U.K.) that bracken will eventually shade out almost all the established vegetation by the time it has fully recovered from treatment. This was not the case at Oaklands as the recruitment of fynbos vegetation was relatively rapid, and the extent of invasion of the bracken was short-term.

In the BS treatment, the bracken density was almost non-existent. It should be noted, that at the FB site, the first plant species to recruit was bracken (Figure 3.10), as the site was bare. However, the BS site still had a large amount of debris, which needed to be removed.

This could have been the reason for the low cover of this species. Friedman *et al* (1996) showed that litter can reduce seedling establishment by preventing seeds from reaching the sediment, by shading or physically obstructing those seedlings that do germinate, or by changing light quality.

Ericoids were also prominent from the first vegetation census. Densities (seedling numbers) were as high as 80/m^2, specifically in the FYN treatment. Significant differences occurred over time in the BS (d.f.=3; F=<0.001) and FB (d.f.=3; F=<0.001) treatments. These numbers however, decreased over time. Indigenous grasses also showed varied dominance during the four censuses. Alien grasses were the most prominent in the MIX treatment at the FB site. Due to the amount of disturbance at the BS site (pigs, cows and baboons and especially pigs), alien grasses established slowly. The same amount of disturbance did not occur at the FB site, and therefore the alien grasses were able to establish successfully. There were significant differences between the alien grasses when observing the sowing methods in the BS (d.f.=3; F=<0.001) and the FB (d.f.=3; F=<0.001) treatments. Significant differences occurred over time as well. These differences can be attributed to the different intensity of disturbances that took place at the two different sites.

At the BS site, accidental herbicide spraying took place, which may have had a negative effect on the results (recruitment). This incident occurred in April 1999, prior to the fourth vegetation census. Looking at the results, Figure 3.10 indicates no clear effect on the recruitment of any of the plant species.

The results (no/m^2) shown in this sowing study, suggest that a fynbos mix is effective as it restores a suitable vegetation cover. However, alien grass proliferation could become a problem (out competing native vegetation) in the future, as seen in the MIX and TER treatments at the FB site. It could be that the amount of the seed sown should be decreased to avoid it becoming a competitor with the native plant species.

- *Recruitment of fynbos and riparian elements:*

From the recruitment results, it was observed that the introduction of the seed mix aids in the facilitation of indigenous recovery. The CON treatment (covered with mulch only) showed positive recruitment, irrespective of it not being applied with a sowing treatment.

All the sowing treatments showed good indigenous recruitment. These mixes took into account various factors such as the heat intensity of the fire (killing indigenous seed close to the soil surface), the age of infestation, as well as the absence of riparian elements along alien-invaded riparian zones (e.g. Oaklands). Growth forms such as proteoids and broad-leaved shrubs, form an important part of fynbos communities, and it was therefore seen as an essential component (Cowling & Holmes, 1992). Riparian elements such as *Brabejum stellatifolium, Leucadendron salicifolium* and *Berzelia lanuginosa*, were also sown to ensure representivity (absent at Oaklands). Only after the sowing, it was discovered that this riparian species (*Brabejum)* preferred to be buried (shade), in order to establish successfully (P.M. Holmes, pers. comm). This factor, together with the disturbance caused by pigs and baboons, explains the low species richness in the BS treatment, compared to the FB treatment.

Fortunately, at the FB site, due to the steepness of the slope, some of the *Brabejum* seeds rolled under the logs, and managed to germinate. At the, evidence that pigs cleared out much of the Brabejum seeds was clear. Kotanen (1995) states that feral pigs are omnivorous, and a substantial portion of their diet is obtained by grubbing in search of roots, bulbs and other background material. This type of disturbance was evident at Oaklands soon after the seed mixes were applied. However, when looking at the total projected canopy cover throughout the census, the BS (d.f.=3; F=0.39) compared to the FB (d.f.=3; F=0.72) was not significantly different. Closer inspection of the growth-form guilds showed that alien grasses at the BS site were less than the FB site (same quantity sown).

The most successful and dominant recruitment was that of the mulch, *Anthospermum aethiopicum.*

There was no significant difference (d.f.=3; F>0.05) between the different sowing treatments at the two sites. The most noticeable difference was the presence of the alien grasses, and its dominance. The main reason for including alien grasses was to facilitate a quick cover to act as soil stabilization feature. This was very successful, however, it may have implications at a later stage.

Dawson (1991) undertook a similar study with four different sowing treatments; however, this was not specifically applied to a riparian zone. This included the introduction of alien grasses. This study concluded that alien grasses will recruit in competition with indigenous vegetation, and this method of sowing is only justified on steep slopes, where the main aim/benefit is soil stabilization.

The most favourable option was the revegetation of locally indigenous vegetation, as it restores what should be there. This method could however be considered a disadvantage if the required species were unavailable. Oberholzer (1995) started a similar experiment, and managed to transform a section of the Hout Bay River from a convenient storm water channel to a landscaped amenity for the whole community.

Erosion measurements:

Correlations:

The correlation coefficients throughout the census were not significantly different from one another. However, the raw data showed that, during months of no rain, no soil loss was recorded. This concludes that the time of vegetation census did not coincide with the amount of soil loss. The correlations of these soil erosion measurements do not successfully support the hypothesis, that an increase in vegetation cover decreases the amount of soil loss.

It is known that soil erosion potential increases if the soil has no or very little vegetation cover of plants (Pimentel & Kounang, 1998; Thorne, 1990). This however, depends on the type, extent and quantity of cover. Vegetation not only protects the soil surface directly, but the roots and rhizomes of plants bind the soil and introduces extra cohesion over and above that which the bank material may have (Thorne, 1990; Woo *et al.* 1997).

Soil erosion may be a slow process that can continue relatively unnoticed or it may occur at an alarming rate causing donga and gully formation (pers. obs).

An alien clearing operation took place in January 1999. This, however, did not have a marked effect on soil loss in the plots. This proves that the indigenous vegetation had established substantially enough to act as a stabilizer of the soil.

Heede *et al* (1998) stated that litter cover is more important in controlling erosion than is slope angle, because litter cover increases infiltration and reduces overland flow, thus reducing erosion. At Oaklands, the fire in 1998 removed most of the litter, but dense patches of bracken quickly established.

Peg analysis:

The CON and TER treatments showed the least soil loss over time (peg measurement), however the measurements were extremely variable. Another point to consider is the placement of the logs on the plots. This site underwent a 'fell and burn" treatment, thus leaving behind charcoaled stumps in various places. We tried as far as possible to be consistent in placing the logs, however, this was not always possible when having to avoid logs. Thus the rows of pegs were placed above or below the logs in places. This could also have had an effect on the build-up or erosion of soil, e.g., pegs above a log, would have experienced soil movement with natural influences (e.g., roots, twigs, etc.), however, those below the logs were protected and thus did not experience natural erosion or build-up. This however, is an effective method of measuring soil movement across a plot, over a period of time. From the results we see that there is a significant difference at the 95% confidence level when looking at the time and treatment factors separately.

Although the statistical comparisons between the sowing treatments showed no significant differences, there was a great amount of variability. A good example is shown in the above-mentioned figure, where a distinct peak is shown in the MIX treatment, in January 1999. This is directly related to the alien clearing operation that was undertaken. At the same time (11/01/99), the other sowing treatments remained stable.

Thus, the type of sowing treatment employed has a significant impact on the soil loss. The time (season) at which the measurement was taken is also significant, as rainfall has an effect on soil loss.

3.7. Conclusions:

Sowing experiment:

From this study, the difference in species presence is quite obvious, amongst the BS and FB site. It is common knowledge that once a clearing treatment is applied, a follow-up, as well as revegetation or sowing treatment should be applied to make sure that re-invasion does not occur. Both the above were successfully applied at Oaklands with positive results. It is also recommended that a detailed investigation is undertaken of the site to make sure that disturbances such as those experienced at Oaklands (pigs and cows) are written into the experimental design.

The results of the sowing treatments imply that adding alien grass to the mix could have detrimental impacts in the future. There is a possibility that these alien grasses could become a permanent feature in riparian zones, and outgrow the indigenous vegetation (Holmes, 1998). Thus, an alternative (with the same attributes-quick growing) should be considered, that would not prevent the colonization of indigenous species.

Erosion measurements:

Soil erosion is a critical environmental problem, and if not managed correctly may have major implications. It has been concluded that an increase in plant cover will decrease the amount of soil movement, by protecting the soil from raindrop splash, which if not protected could result in removal of soil from the land surface.
Wind energy also plays an important role in soil erosion, as it dislodges soil particles and carries them off land (Pimentel & Kounang, 1998).

For future projects, it may be more practical to sow prior to the start of the rainy season, so to allow some vegetation cover to establish, playing a better protective role. Larson *et al.* (1997) confirms that strategically placed buffer strips of grasses or woody species placed in riparian areas (Oaklands), on foot slopes, are extremely effective if properly designed for trapping sediment and nutrients.

Where bracken (*Pteridium aquilinum*) is concerned, this dominant fern may also have had a major impact on the amount of soil movement at Oaklands. The fibrous roots of these plants have strong binding effect and decreases surface erosion (Luk *et al.* 1997). One could speculate that if the bracken was not present, increases in soil movement would have taken place, as the site would have been bare after the fire. Further studies should be done to investigate soil erosion without the influence of bracken.

Chapter 4: General conclusions

This thesis explores aspects of the plant communities of riparian zones in the Western Cape, South Africa, with specific emphasis on options for restoring these communities following invasion by invasive alien trees and management aimed at clearing dense stands. Although many studies have looked at the classification of fynbos (e.g., McDonald, 1988; Boucher, 1978; Boucher & Stindt, 1992; van Wilgen & Kruger, 1985), most of these have either ignored, or at best paid scant attention to characterizing the plant communities associated with riparian habitats. This is perhaps understandable, given the spectacular richness of the fynbos flora and its high levels of endemism. Riparian communities, which are typically relatively species-poor, clearly do not hold the same fascination for phytosociologists and biogeographers. Given the extent of threat to these communities, this was identified as a major gap, and this study was the first to give special attention to riparian plant assemblages in the fynbos biome. The aim was specifically to provide benchmarks for future restoration projects in riparian zones.

This chapter examines the main findings of the study, and uses these to make suggestions for future restoration projects.

The specific aims of the study were to:

1. To describe (define) riparian zones in the Western Cape, looking at worldwide examples: A literature review;
2. To classify riparian vegetation in the Western Cape and provide benchmarks for future restoration projects;
3. To investigate the effects of clearing treatments, as well as sowing (revegetation) treatments on the rehabilitation of riparian zones;
4. To assess the effects of the different sowing treatments in arresting/preventing soil erosion;

Findings:

Benchmarks: Riparian vegetation classification:

Clear benchmarks have been laid in Chapter 2, with dominant and characteristic species like *Brabejum stellatifolium, Metrosideros angustifolia, Diospyros glabra, Cannamois virgata,* and *Berzelia lanuginosa,* defining the community types. Strong relationships between environmental variables such as pH, % fine, medium or course sand, rock cover and altitude, gives an indication of where these species can be found.

Where such species are absent or poorly represented due to the past effects of invasion and management actions, demonstrated links between environmental factors and species occurrence could be used to guide restoration efforts.

Sowing and erosion experiments:

This study showed no significance between the sowing treatments applied to the plots at Oaklands. However, there were significant differences over time, which suggests that sowing will increase vegetative cover over time quite significantly. No clear guidance can therefore be given with regards to the type of sowing treatment, which will be most successful, as several factors (cows, pigs, baboons, and human disturbance) played a vital role in the outcome of this study.

Peg measurements/differences also showed no significant difference between the treatments. There was, however, a significant difference over time. We can therefore conclude that as plant cover increases, so soil movement will decrease. In the case of this study, a longer monitoring period may have resulted in significant differences between the various treatments.

Soil collected in the gutters over time also showed no significant difference between sowing methods. Correlation analysis in fact showed very weak relationships between plant cover and soil movement. This is contrary to the hypothesis. This could be ascribed to several outliers (extreme values) that may have 'skewed' the data.

Recommendations for future restoration projects:

One of the key lessons learned in undertaking these studies, was the importance of the proper experimental design, including a clear idea of what type of analysis would be appropriate for the type of data that will be collected. These studies yielded lots of data, but when it came to analysing data, insufficient replicates were available to make statistical comparisons, between sites, as was the intention.

Another, limiting factor, which could have been avoided by a better experimental design, was the separation and sowing of the fynbos mix, and other indigenous plant species. Not knowing the quantities of seed inputs is one of the biggest limitations of this study. However, it would be recommended that substantial refinement be done in future restoration projects. For example, instead of just broadcasting the *Protea* cones (which is what happens naturally), it would be very valuable for ecologists, as well as conservation managers, to know before-hand, the amount of seedlings necessary to provide a good vegetative cover.

In the erosion experiment, more research needs to be done with regards to movement of soil, after applying seed mixes. Variable results were shown and this should be measured over a longer period to determine more of a pattern. At Oaklands, gutters were used to monitor soil movement across steep banks. The two techniques used to measure soil erosion were both very effective, but monitoring took place at random depending on the occurrence of rain. It might be a good idea to monitor at fixed times so that we can get a regular pattern of how rainfall and the increase of ground cover affects soil erosion on steep slopes.

Research gaps:

In the initial phase of this project, the aim was to investigate sites (rivers) that have been cleared by WfW teams. Plots were established before alien clearing, recording the density and canopy cover. Once cleared, the aim was to return and monitor the recruitment.

This phase was set aside, due tc time constraints. It is however, a very important aspect for further work. This study has provided useful information that managers can use immediately to determine which key woody riparian species should be present at a given site (based on environmental data). This information could be used to guide re-introduction of species, or to encourage natural succession. However, very little is known of the regeneration dynamics of these key components of the main riparian communities. Studies are urgently needed in this regard.

Other studies have been undertaken with regards to re-introduction of locally indigenous species, by using an indigenous fynbos mix, and have had varying degrees of success (Holmes, 1998).

The study at Oaklands could not prove statistically that one treatment was more effective than the other in ensuring efficient fynbos restoration, as there were not enough replicates. Thus, comparisons were made between observations made in the field.

These strongly suggested that the use of a fynbos mix in rehabilitation projects definitely has the potential to establish a good, functional vegetation cover. The only setback was the introduction of the commercially available grasses (introduced at a third of the recommended sowing rate), as these species became quite dominant. More research is needed to determine the longer-term implications of introducing these species.

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Appendix 1:

Determination of soil texture by the Bouyoucos Particle Size Method:

The clay, silt and sand proportions were determined using the Bouyoucos Particle size method (Bouyoucos, 1962). 100 ml of H_2O_2 was added to soils containing organic material. This soil was then boiled to remove excess hydrogen peroxide, and was allowed to stand overnight. After drying at 110 C, 50g were weighed into a jar with 50ml of 10% CALGON solution (10g of sodium hexametaphosphate per 100ml of H_2O_2), and were allowed to stand for 30 minutes. The pH of the soils treated with H_2O_2, were adjusted to 9 by adding 4% of NaOH solution after the CALGON. To each sample 150ml of tap water was added, and the solution was stirred for approximately five minutes, after which it was transferred to a litre measuring cylinder, which was topped up to the 1000ml mark. A blank was also prepared by diluting 50ml CALGON solution to 1Litre in another measuring cylinder. These were then left to stand overnight in a room with constant temperature. Shaking was commenced by inverting each cylinder numerous times (for approximately one minute), and the sediments were allowed to settle out for seven minutes, before taking the "silt + clay" reading. The readings were taken using a hydrometer. After the first reading was taken, the samples were allowed to stand for seven hours (settling time) before taking the "clay" reading.

Sand Fractions:

After the clay reading was taken, the cylinders were shaken again, and allowed to settle for seven minutes, after which the silt + clay suspension was decanted. This procedure was repeated until the soil was free of silt and clay. This soil was then dried at 110°C and a screen analysis was performed by sieving the dry sand through 500 and 212 micron sieves. The different fractions that were left behind in the various sieves were classified as coarse (>500 micron); medium (500 –212 micron) and fine sand (<212 micron) and were weighed on an electronic balance.

Appendix 2: Joint species list

Species List For the Classification Study:

SPECIES	*FAMILY*
Acacia mearnsii	**FABACEAE**
Acacia longifolia	**FABACEAE**
Acacia melanoxylon	**FABACEAE**
Agathosma spp.	**RUTACEAE**
Anagallis arvensis var. caerulea	**PRIMULACEAE**
Anapalina spp.	**IRIDACEAE**
Anaxeton laeve	**ASTERACEAE**
Aristida spp.	**POACEAE**
Athanasia parviflora	**ASTERACEAE**
Berzelia lanuginosa	**BRUNIACEAE**
Blechnum spp.	**BLECHNACEAE**
Brabejum stellatifolium	**PROTEACEAE**
Brachylaena neriifolia	**COMPOSITAE**
Brunia albiflora	**BRUNIACEAE**
Cullumia ciliaris	**ASTERACEAE**
Cullumia setosa	**ASTERACEAE**
Cannamois virgata	**RESTIONACEAE**
Cassinopsis illicifolia	**ICACINACEAE**
Cassytha ciliolata	**LAURACEAE**
Chironia linoides	**GENTIANACEAE**
Cliffortia atrata	**ROSACEAE**
Cliffortia polygonifolia	**ROSACEAE**
Cliffortia graminiflora	**ROSACEAE**
Cliffortia ruscifolia	**ROSACEAE**
Clutia pulchella	**EUPHORBIACEAE**
Cunonia capensis	**CUNONIACEAE**
Cynanchum aficanum	**ASCLEPIADACEAE**
Cynodon dactylon	**POACEAE**
Cyphia spp.	**LOBELIACEAE**
Dipogon lignosus	**FABACEAE**
Diospyros glabra	**EBENACEAE**
Driopterus	
Elegia capensis	**RESTIONACEAE**
Elegia cuspidate	**RESTIONACEAE**
Elytropappus glandulosus	**ASTERCACEAE**
Eragrostis spp.	**POACEAE**
Erica armata	**ERICACEAE**
Erica caffra	**ERICACEAE**
Erica curvirostris	**ERICACEAE**
Erica gnaphaloides	**ERICACEAE**
Erica hirtiflora	**ERICACEAE**
Erica inconstans	**ERICACEAE**
Erica longifolia	**ERICACEAE**
Erica perspicua	**ERICACEAE**

Erica plukenetti	**ERICACEAE**
Erica scyphagyna	**ERICACEAE**
Erica sessiflora	**ERICACEAE**
Erica sphaeroides	**ERICACEAE**
Euryops abrotanifolius	**ASTERACEAE**
Ficinia filliformes	**CYPERACEAE**
Galium spp.	**RUBIACEAE**
Gnidia oppositifolia	**THYMELIACEAE**
Hakea sericea	**PROTEACEAE**
Halleria elliptica	**SCROPHULARIACEAE**
Halleria lucida	**SCROPHULARIACEAE**
Hartogiella schinoides	**CELASTRACEAE**
Heeria argentea	**ANACARDIACEAE**
Helichrysum cymosum	**ASTERACEAE**
Hypocalyptus spp.	**FABACEAE**
Hypodiscus aristatus	**RESTIONACEAE**
Juncus punctorius	**JUNCACEAE**
Kiggeleria africana	**FLACOURTIACEAE**
Leucadendron gandojeri	**PROTEACEAE**
Leucadendron laureolum	**PROTEACEAE**
Leucadendron salicifolium	**PROTEACEAE**
Maytenus acuminata	**CELASTRACEAE**
Maytenus oleoides	**CELASTRACEAE**
Metalasia muricata	**ASTERACEAE**
Metrosideros angustifolia	**MYRTACEAE**
Muraltia heisteria	**POLYGALACEAE**
Myrsine africana	**MYRSINACEAE**
Nivenia stokoei	**IRIDACEAE**
Olea europea subsp. africana	**OLEACEAE**
Osmitopsis asteriscoides	**ASTERACEAE**
Osteospermum ciliatum	**ASTERACEAE**
Otholobium decumbens	**FABACEAE**
Passerina vulgaris	**THYMELIACEAE**
Penaea sp.spp.	**PENAEACEAE**
Pentachistis giganticus	**POACEAE**
Pelargonium candicans	**GERANIACEAE**
Phylica imberbis	**RHAMNACEAE**
Phylica spicata	**RHAMNACEAE**
Pittosporum undulatum	**PITTOSPORACEAE**
Plecostachys serpyllifolia	**RESTIONACEAE**
Podalyria calyptrata	**FABACEAE**
Podocarpus latifolius	**PODOCARPACEAE**
Polygala myrtifolia	**POLYGALACEAE**
Polygonum salicifolium	**POLYGONACEAE**
Protea cynaroides	**PROTEACEAE**
Protea repens	**PROTEACEAE**
Protosparagus rubicundus	**ASPARAGACEAE**
Prionium serratum	**JUNCACEAE**

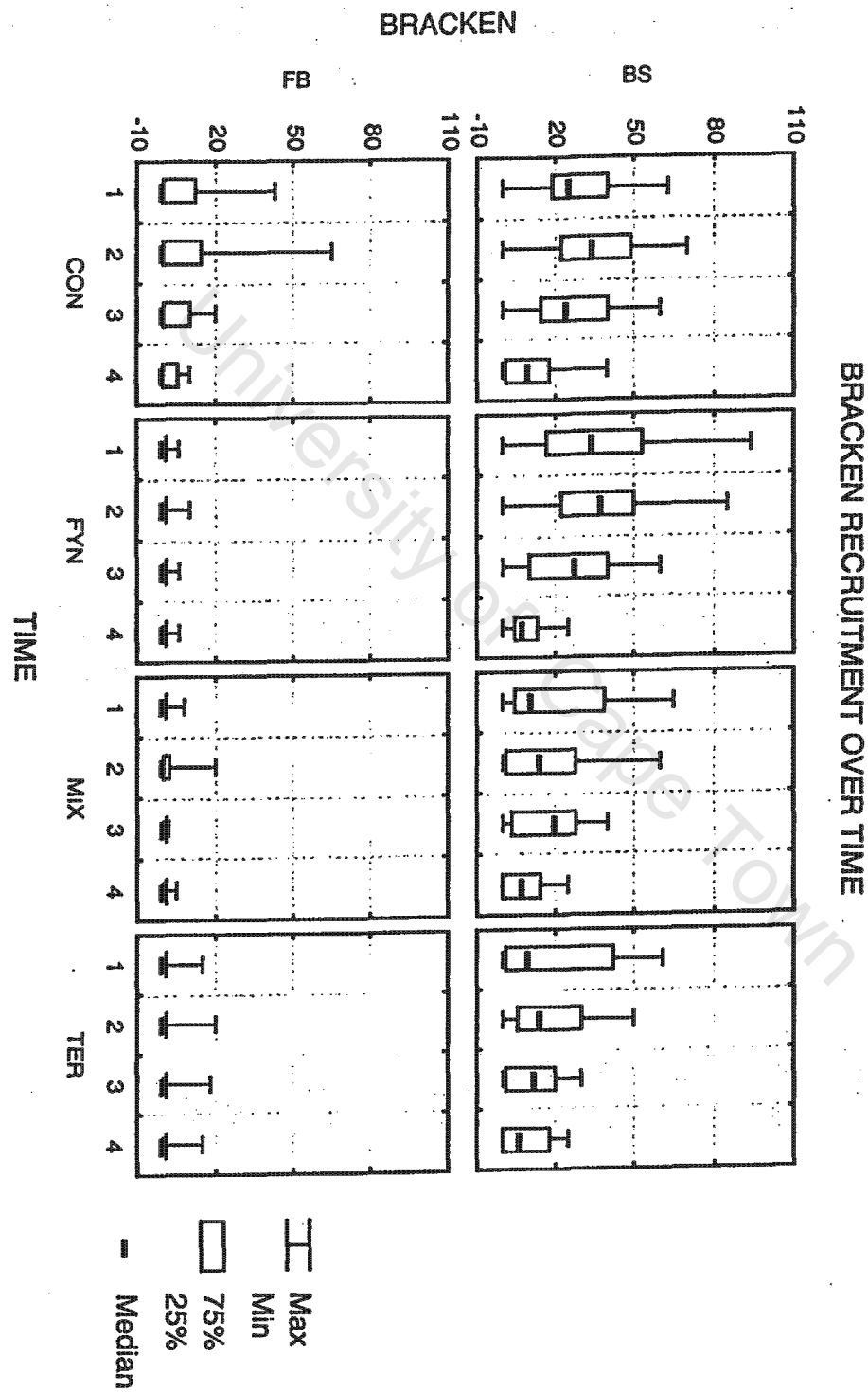
Pseudobaeckia africana	**BRUNIACEAE**
Psoralea aphylla	**FABACEAE**
Psoralea pinnata	**FABACEAE**
Pteridium aqulinum	**DENNSTAEDTIACEAE**
Rapanea melanophloeos	**MYRSINACEAE**
Restio cincinata	**RESTIONACEAE**
Restio leptostchys	**RESTIONACEAE**
Rhamnus prinoides	**RHAMNACEAE**
Rhus angustifolia	**ANACARDIACEAE**
Rhus laevigata	**ANACARDIACEAE**
Rhus tomentosa	**ANACARDIACEAE**
Rubus pinnatus	**ROSACEAE**
Santella sp.	**APIACEAE**
Senecio sp.	**ASTERACEAE**
Sonchus oleraceus	**ASTERACEAE**
Stoebe cinerea	**ASTERACEAE**
Stoebe incana	**ASTERACEAE**
Stoebe plumosa	**ASTERACEAE**
Struthiola myrsinites	**THYMELAEACEAE**
Tetraria ustulata	**POACEAE**
Tertraria thermalis	**POACEAE**
Thesium viridifolium	**SANTELACEAE**
Tribolium uniolae	**POACEAE**
Virgilia oroboides	**FABACEAE**

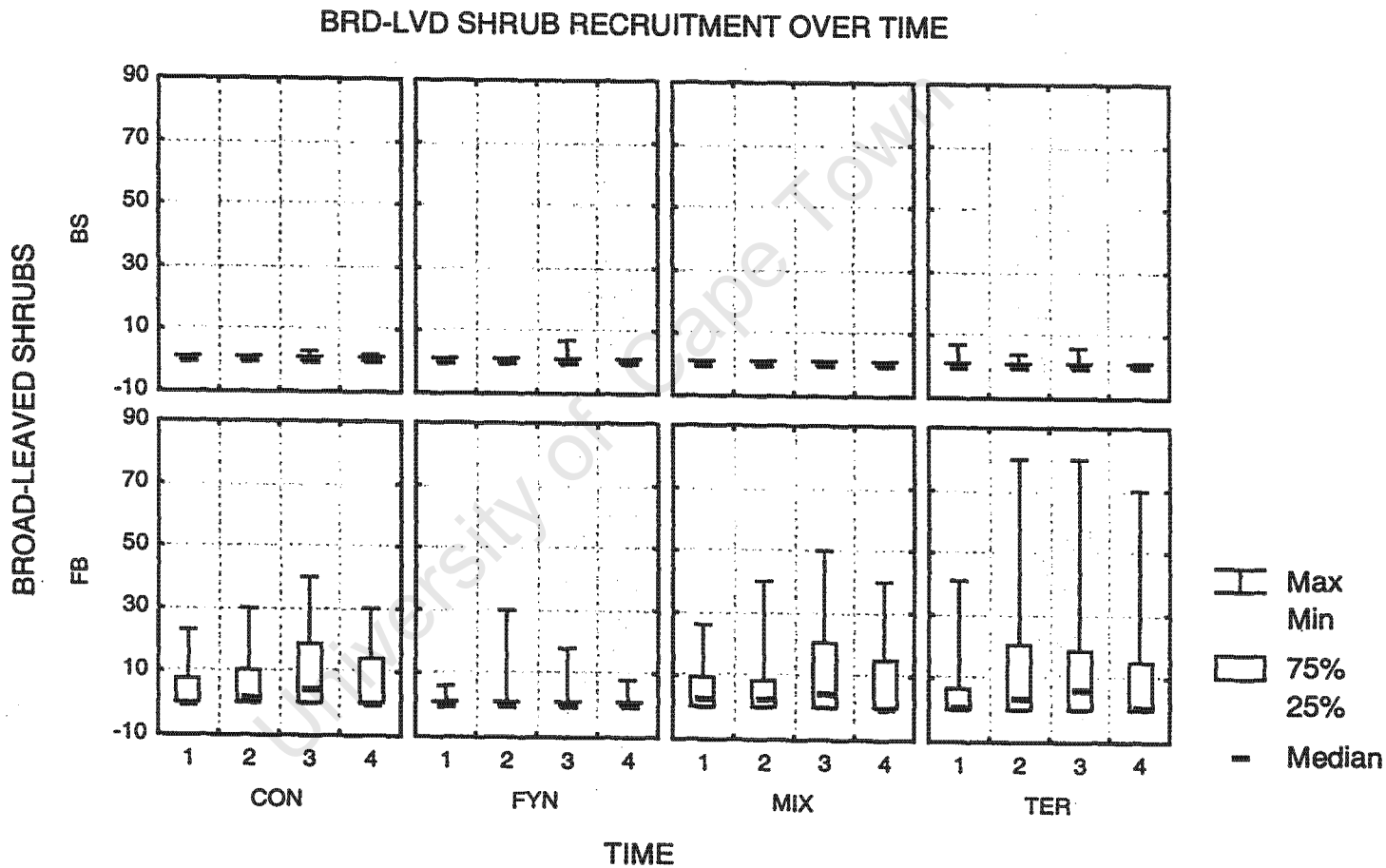
Species list for Oaklands:

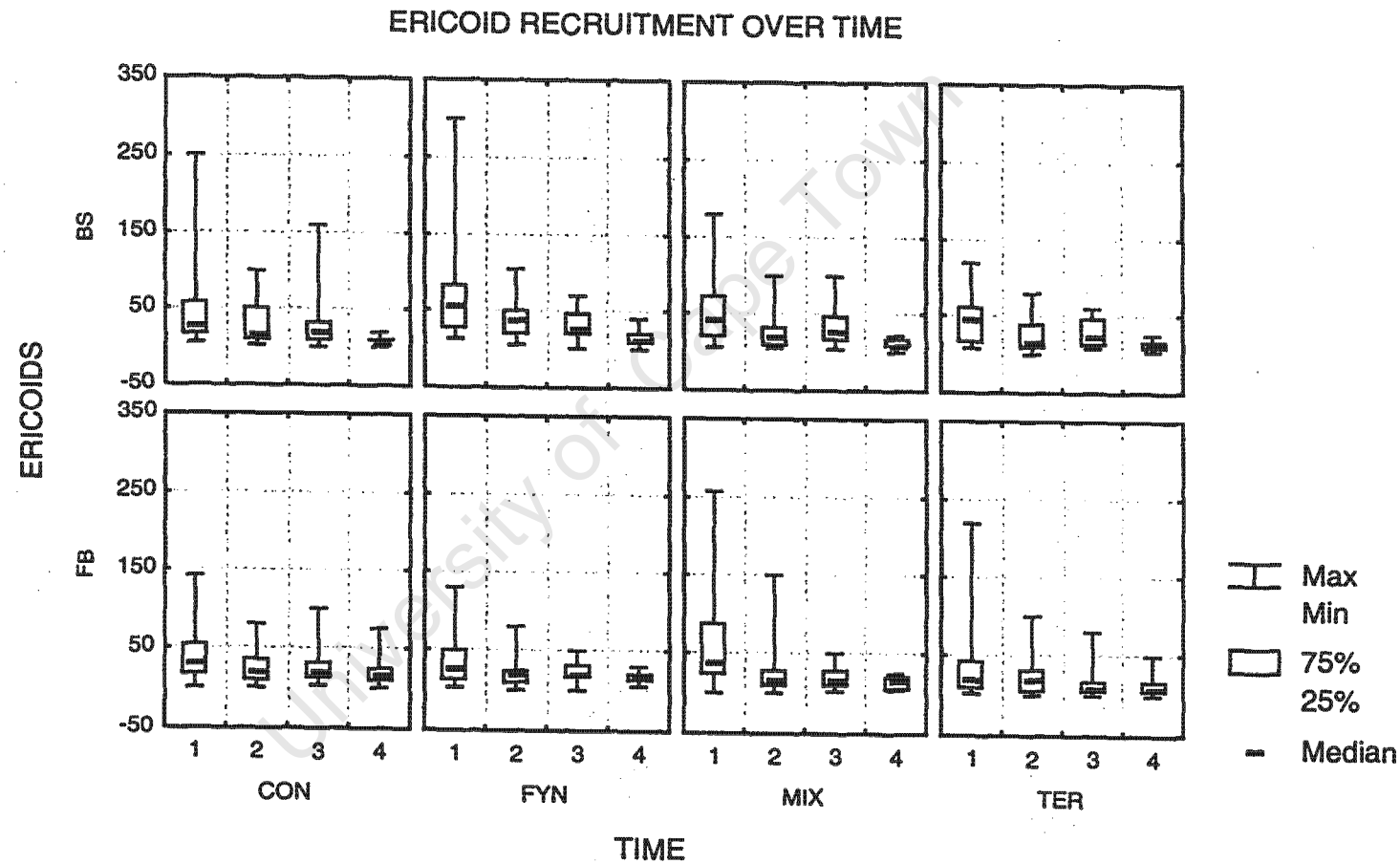
SPECIES	*FAMILY*
Acacia mearnsii	**FABACEAE**
Anagallis arvensis var. *caerulea*	**PRIMULACEAE**
Anthospermum aethiopicum	**ASTERACEAE**
Athanasia parviflora	**ASTERACEAE**
Avena fatua	**POACEAE**
Berzelia lanuginosa	**BRUNIACEAE**
Blechnum capensis	**BLECHNACEAE**
Bolusafra bituminosa	**FABACEAE**
Brabejum stellatifolium	**PROTEACEAE**
Brachylaena neriifolia	**COMPOSITAE**
Briza maxima	**POACEAE**
Chrysanthemoides monilifera	**ASTERACEAE**
Cliffortia ruscifolia	**ROSACEAE**
Cyanela hyacinthoides	**TECOPHILACEAE**
Diospyros glabra	**EBENACEAE**
Elytropappus glandulosus	**ASTERCACEAE**
Eragrostis teff	**POACEAE**
Erica sp.	**ERICACEAE**
Ficinia filliformes	**CYPERACEAE**

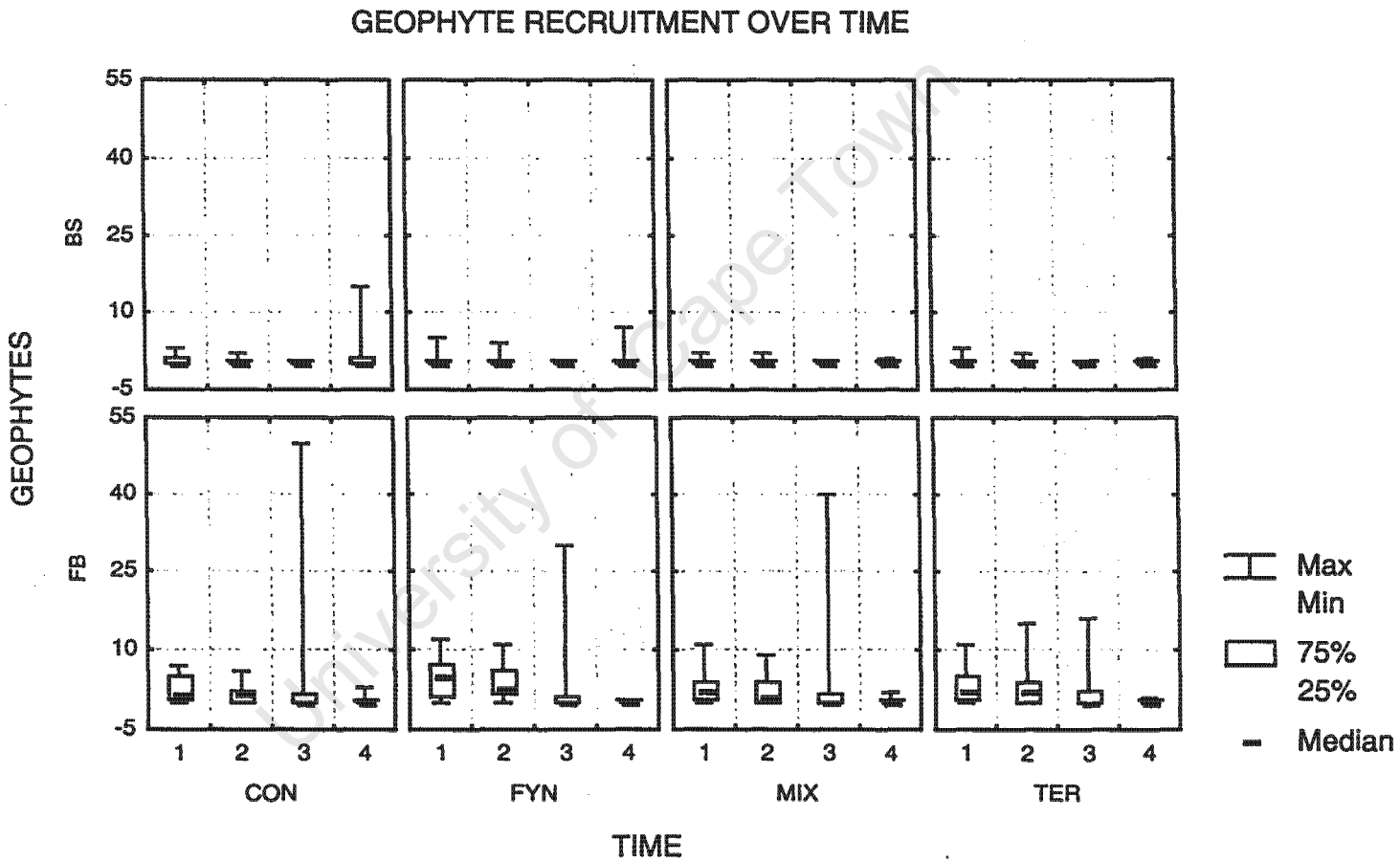
Ficinia nigrescens	**CYPERACEAE**
Geranium incanum	**GERANIACEAE**
Helichrysum orbuculare	**ASTERACEAE**
Hermanii multiflora	**STERCULIACEAE**
Hibiscus trionium	**MALVACEAE**
Hieracium sp.	**ASTERACEAE**
Leucadendron salicifolium	**PROTEACEAE**
Leucadendron lauriolum/gandogeri	**PROTEACEAE**
Lichsteinia lacera	**APIACEAE**
Metalasia muricata	**ASTERACEAE**
Muraltia ericoides	**POLYGALACEAE**
Oftia africanum	**SCROPHULARIACEAE**
Olea europea subsp. Africana	**OLEACEAE**
Osteospermum ciliatum	**ASTERACEAE**
Oxalis purpurea	**OXALIDACEAE**
Pelargonium capitatum	**GERANIACEAE**
Plantago lanceolata	**PLANTAGINACEAE**
Podylaria calyptrata	**FABACEAE**
Protea repens	**PROTEACEAE**
Protosparagus rubicundus	**ASPARAGACEAE**
Psoralea asarina	**FABACEAE**
Pteridium aquilinum	**DENNSTAEDTIACEAE**
Pterocelastrus tricuspidatus	**CELASTRACEAE**
Rhus angustifolia	**ANACARDIACEAE**
Rhus laevigata	**ANACARDIACEAE**
Rubus sp.	**ROSACEAE**
Rumex cordatus	**POLYGONACEAE**
Senecio sp.	**ASTERACEAE**
Solanum nigrum	**SOLANACEA**
Sonchus oleraceus	**ASTERACEAE**
Stoebe plumose	**ASTERACEAE**
Tribolium uniolae	**POACEAE**
Ursinia crithmoides var. palcaea	**ASTERACEAE**
Vicia sativa	**FABACEAE**

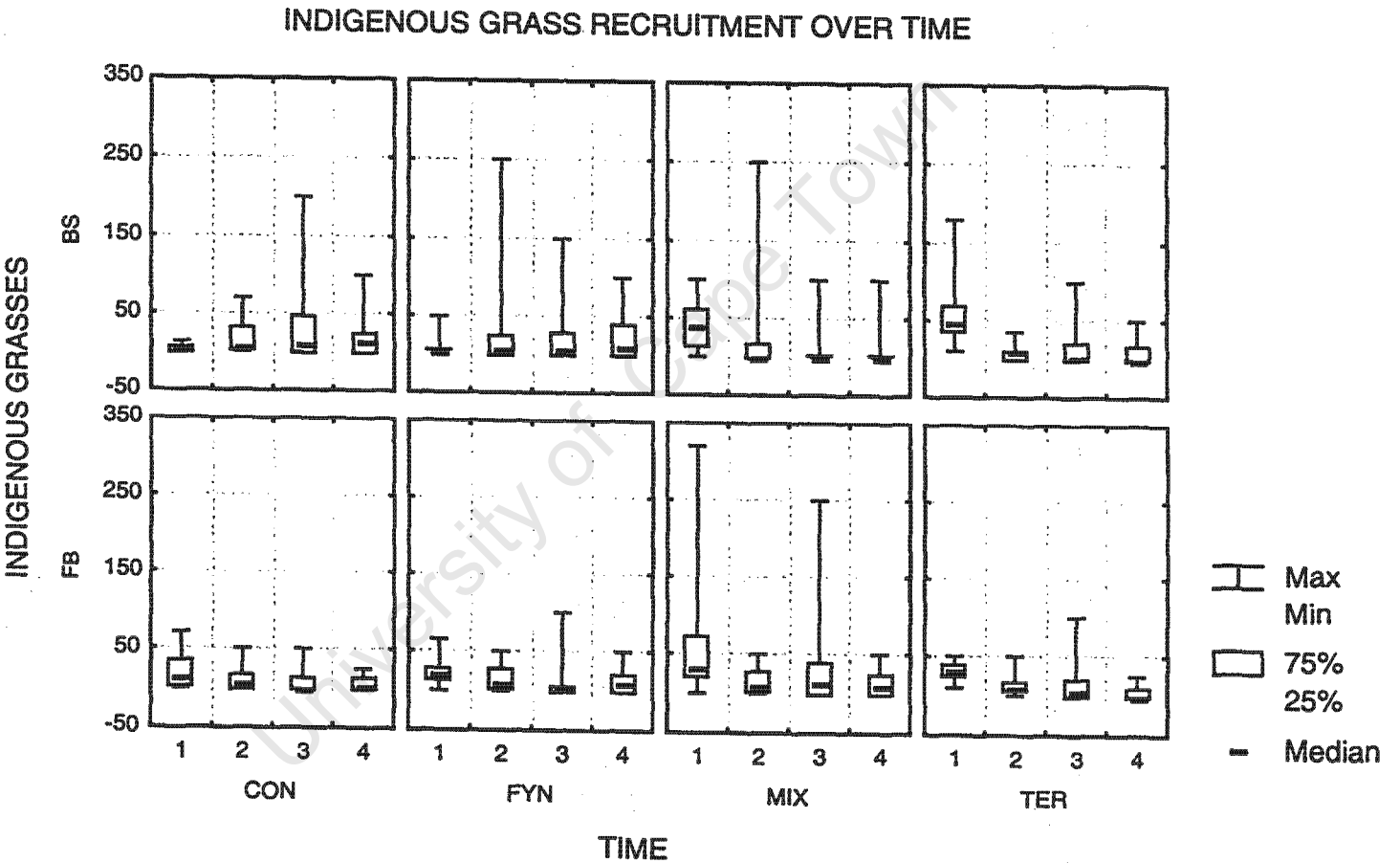
Appendix 3: Box and whisker plots for sowing study.

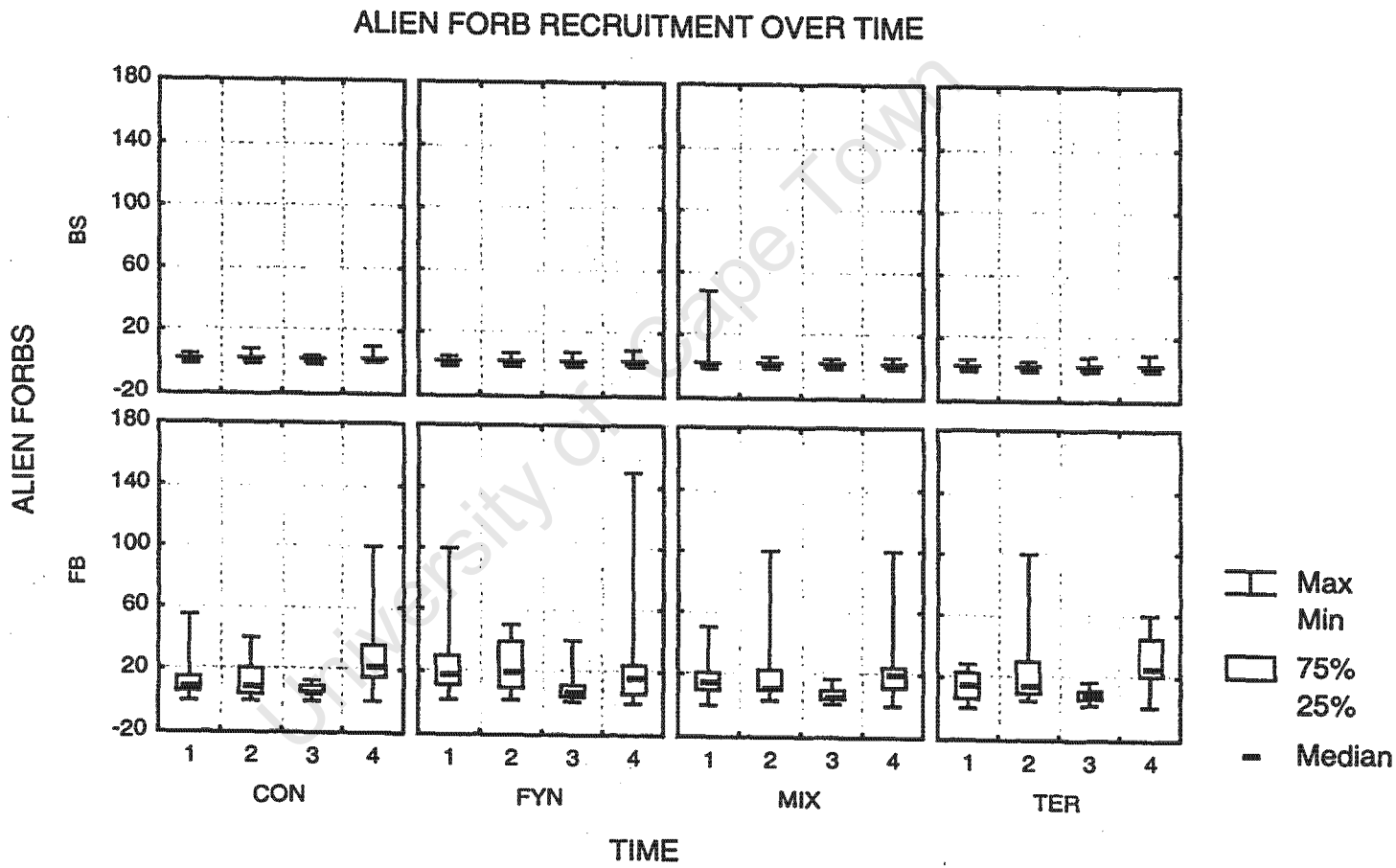


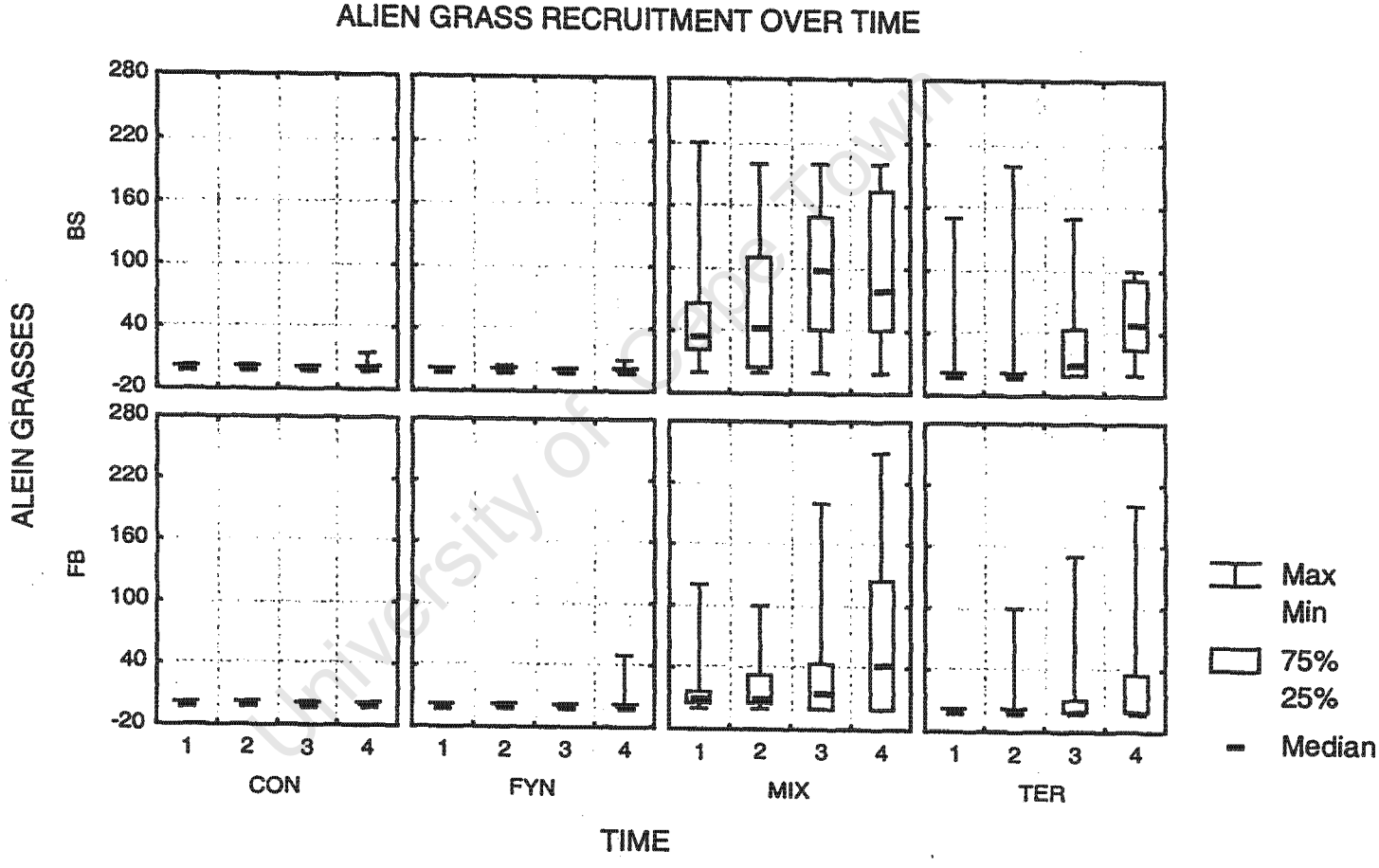


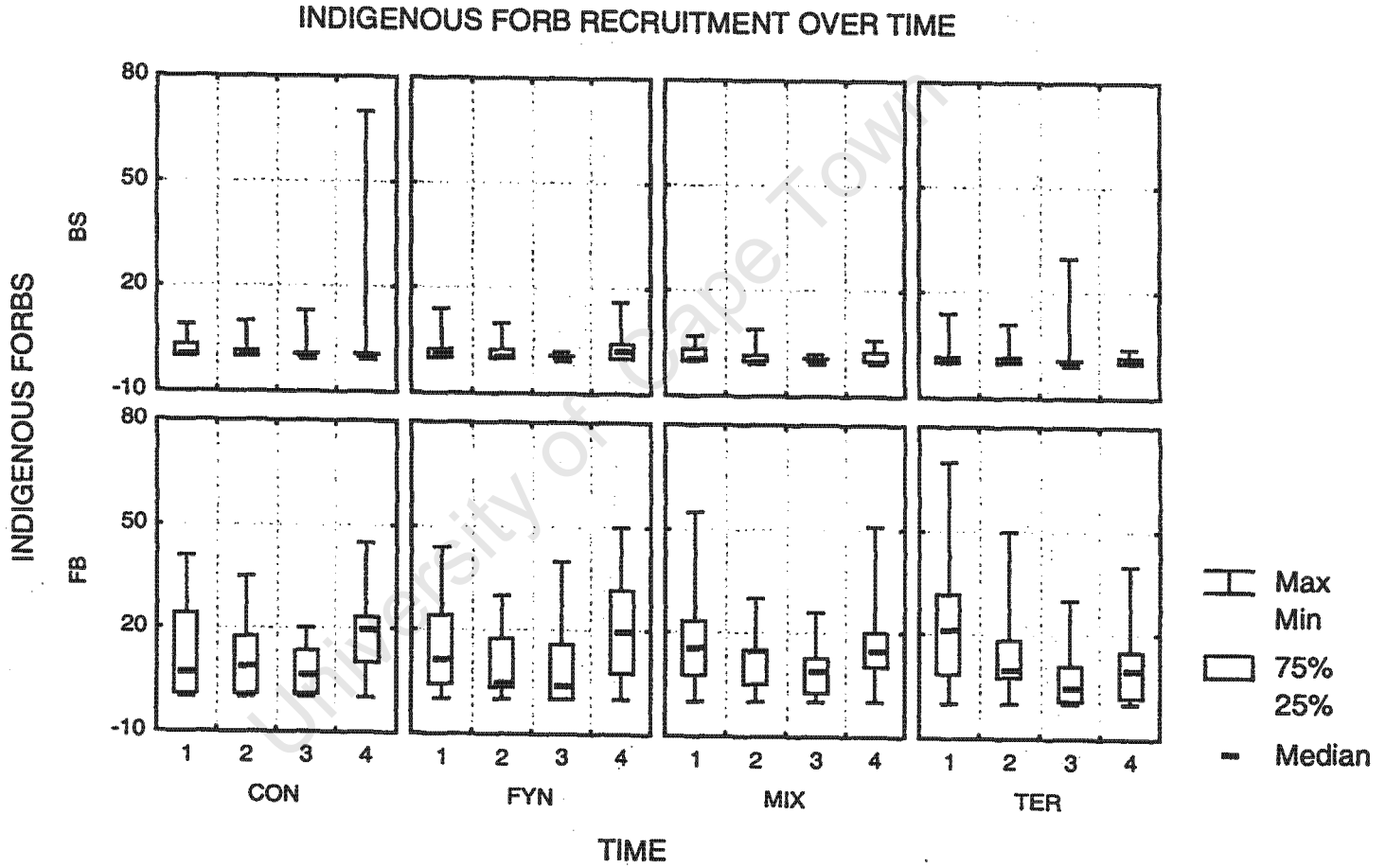


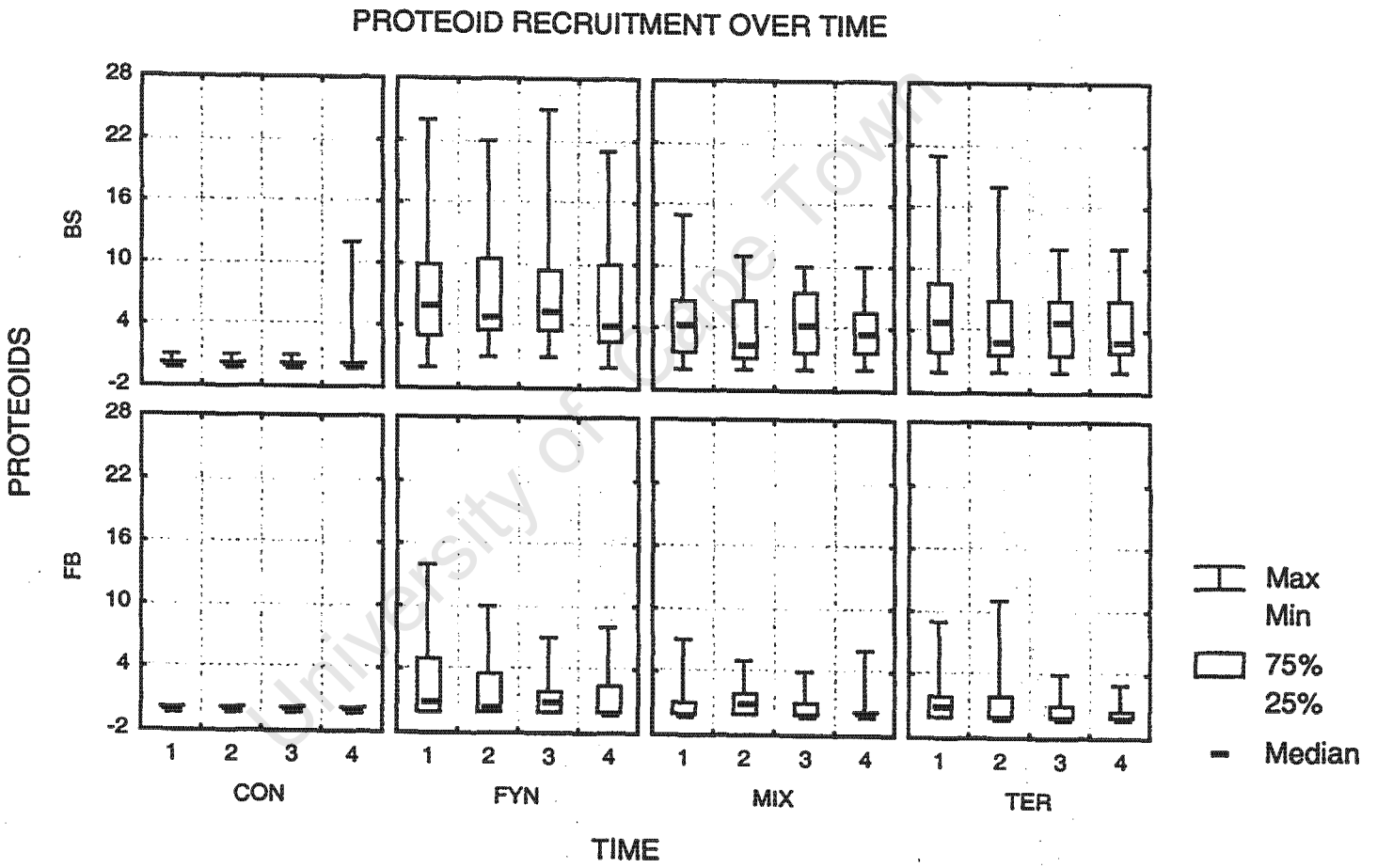


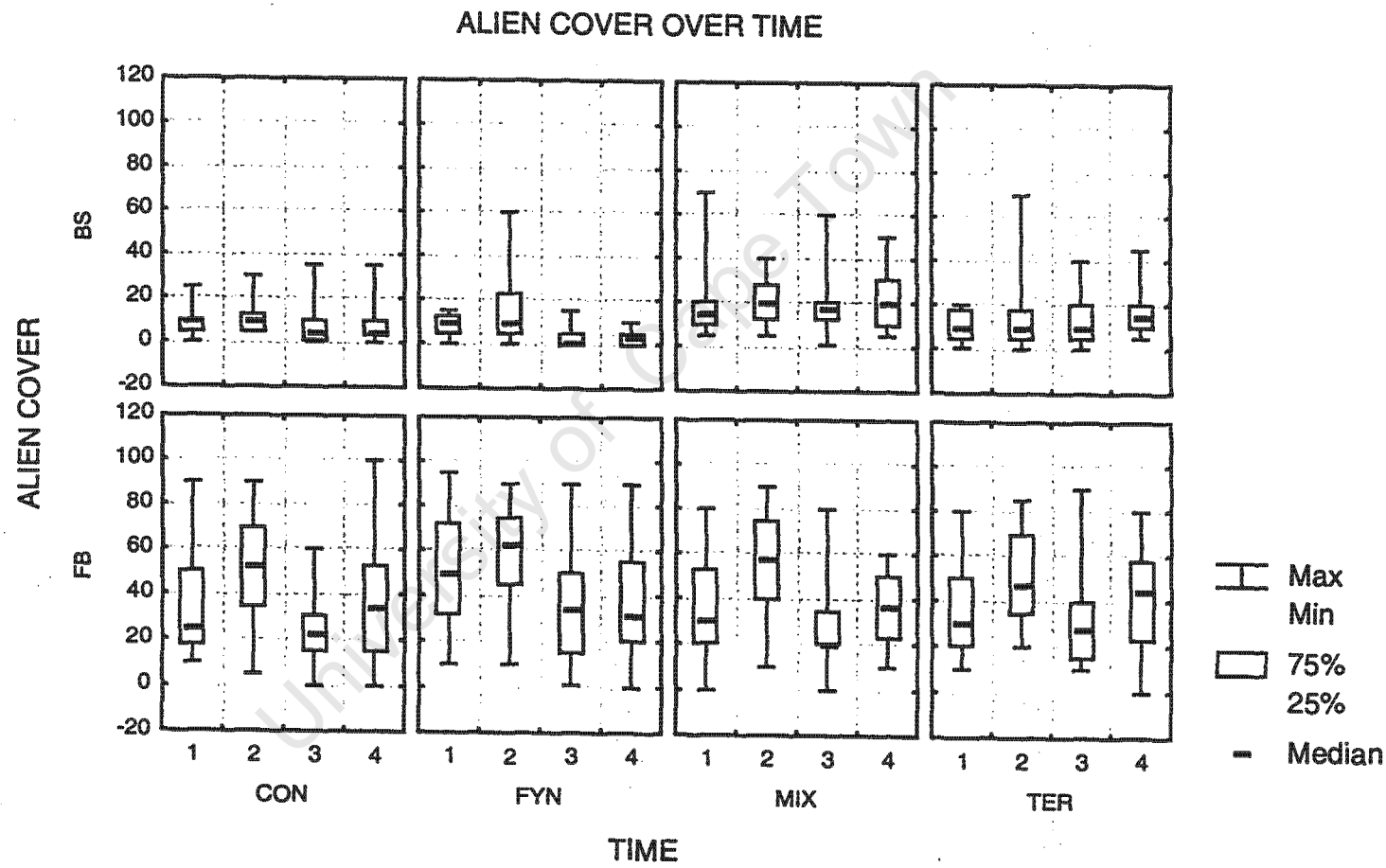

INDIGENOUS GRASS RECRUITMENT OVER TIME
INDIGENOUS GRASSES
BS
FB
350
250
150
50
-50
1
2
3
4
CON
FYN
MIX
TER
TIME
Max
Min
75%
25%
Median

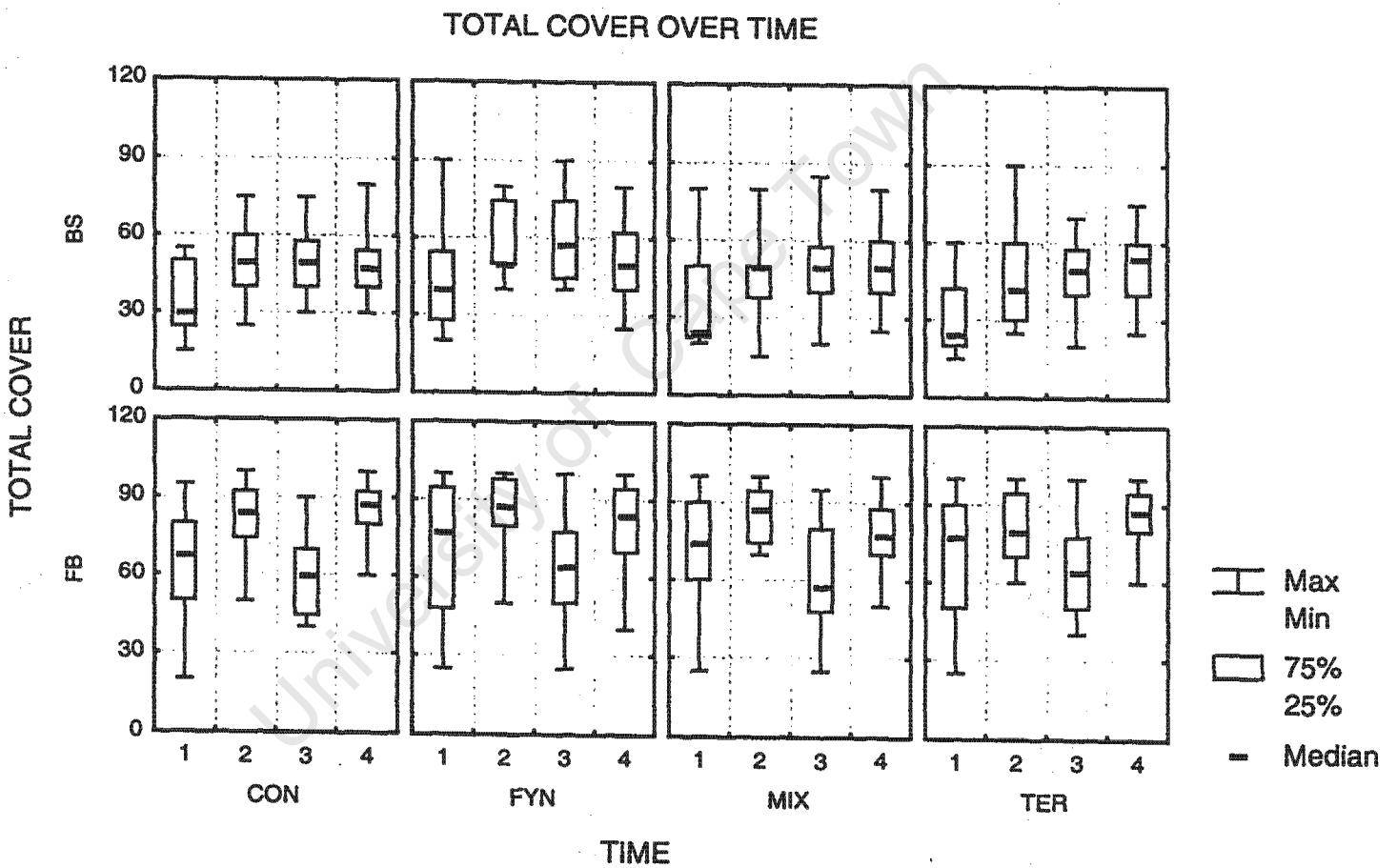


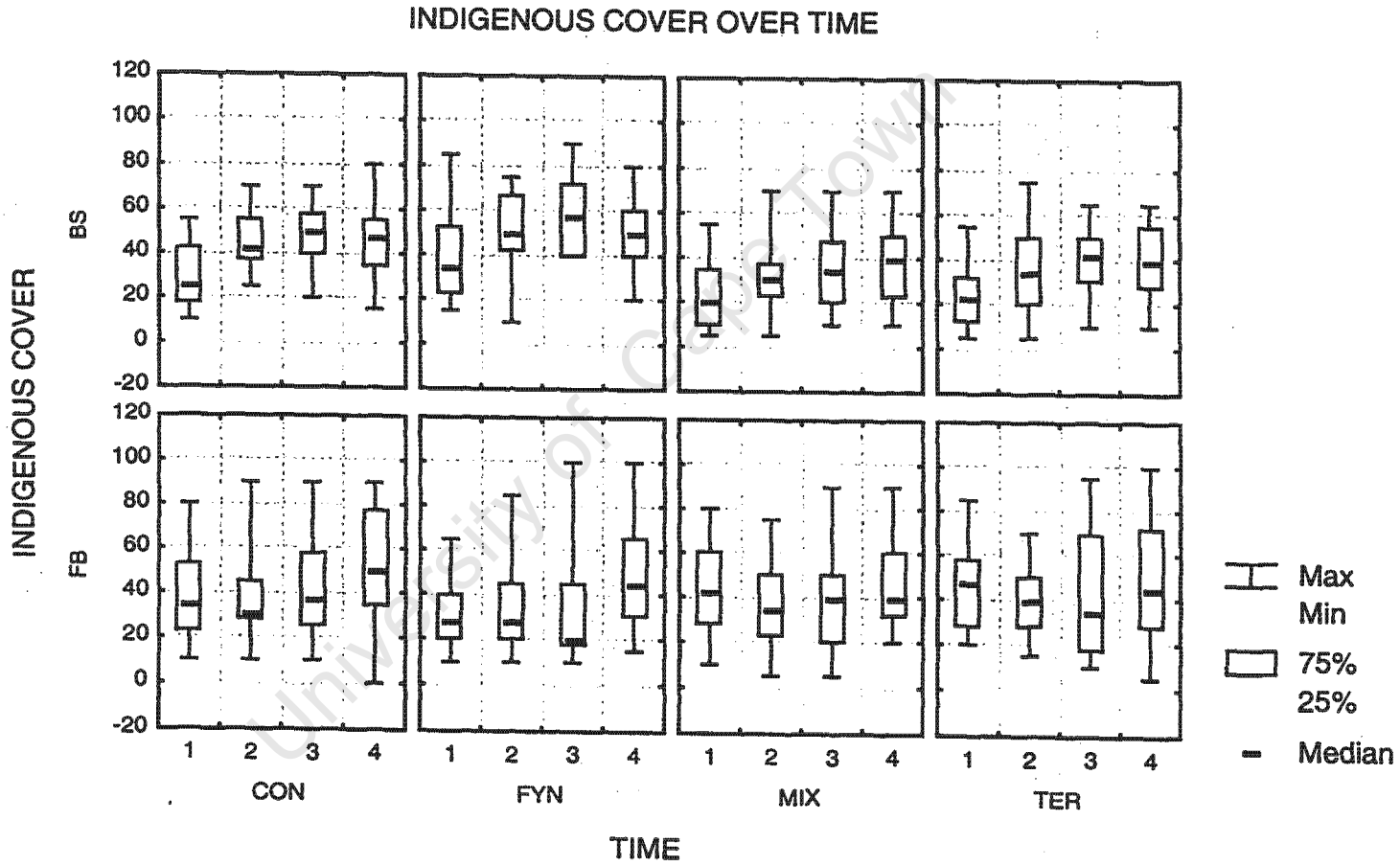



INDIGENOUS FORB RECRUITMENT OVER TIME
INDIGENOUS FORBS
BS
FB
80
50
20
-10
1 2 3 4
CON
FYN
MIX
TER
TIME
Max
Min
75%
25%
Median


PROTEOID RECRUITMENT OVER TIME
PROTEOIDS
BS
FB
28
22
16
10
4
-2
1 2 3 4
CON
FYN
MIX
TER
TIME
Max
Min
75%
25%
Median







Appendix 4: Results of Repeated measures ANOVA

```
BSTotalAvgs
  54  calculate RTime1=arcsin(TimeA1/100)
  55  calculate RTime2=arcsin(TimeA2/100)
  56  calculate RTime3=arcsin(TimeA3/100)
  57  calculate RTime4=arcsin(TimeA4/100)
  58  pointer[values=RTime1,RTime2,RTime3,RTime4]RTime
  59 arepmeasures[treatmentstructure=Sow;print=corr,epsilon;aprint=aov,means;fpr
     ob=
  60 yes;pse=differences]RTime[]
 *** Correlation matrix ***
      RTime1       1.0000
      RTime2       0.7373       1.0000
      RTime3       0.4084       0.1902       1.0000
      RTime4       0.5466       0.4741       0.6096       1.0000
                   RTime1       RTime2       RTime3       RTime4

 Common correlation 0.4673

 *** Greenhouse-Geisser epsilon  0.6777     ***

***** Analysis of variance *****
Source of variation      d.f.        s.s.        m.s.     v.r.  F pr.
Subject stratum
Sow                         3    0.118280    0.039427     1.06  0.395
Residual                   16    0.596688    0.037293     4.51
Subject.Time stratum
d.f. correction factor 0.6777
Time                        3    0.427906    0.142635    17.25  <.001
Time.Sow                    9    0.055694    0.006188     0.75  0.617
Residual                   48    0.396956    0.008270
Total                      79    1.595524
d.f. are multiplied by the correction factors before calculating F probabilities

***** Tables of means *****
Grand mean  0.499
     Time         1         2         3         4
              0.373     0.540     0.548     0.537
      Sow       CON       FYN       MIX       TER
              0.486     0.564     0.484     0.464
     Time       Sow       CON       FYN       MIX       TER
        1                 0.354     0.438     0.383     0.317
        2                 0.549     0.630     0.490     0.489
        3                 0.530     0.645     0.510     0.508
        4                 0.511     0.545     0.552     0.541

 *** Standard errors of differences of means ***
 Table                    Time          Sow          Time
                                                      Sow
 rep.                       20           20             5
 s.e.d.                 0.0288       0.0611        0.0788
 d.f.                    32.53           16         36.44
 Except when comparing means with the same level(s) of
  Sow                                              0.0575
  d.f.                                              32.53
 Correction factors have been applied to residual d.f.
 (see analysis-of-variance table for details)
   60  DELETE [REDEFINE=yes] _XDev
   61  CALC _XDev = 0 + 1*EDT(0.992;33)
   62  PRINT [IP=*] ':  Student''s T Equivalent Deviate = ',_XDev;F=1;SKIP=0
 :  Student's T Equivalent Deviate = 2.539
  @@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
```

```
FBTotalAvgs
 114  calculate RTime1=arcsin(TimeA1/100)
 115  calculate RTime2=arcsin(TimeA2/100)
 116  calculate RTime3=arcsin(TimeA3/100)
 117  calculate RTime4=arcsin(TimeA4/100)
 118  119  pointer[values=RTime1,RTime2,RTime3,RTime4]RTime
 120
arepmeasures[treatmentstructure=Sow;print=corr,epsilon;aprint=aov,means;fprob=
yes;pse=differences]RTime[]
 *** Correlation matrix ***
      RTime1       1.0000
      RTime2       0.8096       1.0000
      RTime3      -0.7134      -0.5529       1.0000
      RTime4      -0.1584      -0.2203       0.3949       1.0000
                   RTime1       RTime2       RTime3       RTime4

 Common correlation -0.06481
*** Greenhouse-Geisser epsilon  0.4663     ***

***** Analysis of variance *****
Source of variation      d.f.       s.s.        m.s.     v.r.  F pr.
Subject stratum
Sow                         3    0.03740     0.01247     0.45  0.724
Residual                   16    0.44749     0.02797     0.76
Subject.Time stratum
d.f. correction factor 0.4663
Time                        3    1.43797     0.47932    12.97  <.001
Time.Sow                    9    0.13411     0.01490     0.40  0.813
Residual                   48    1.77445     0.03697
Total                      79    3.83142
d.f. are multiplied by the correction factors before calculating F probabilitie

***** Tables of means *****
Grand mean  0.867
     Time         1         2         3         4
              0.783     1.013     0.693     0.982
      Sow       CON       FYN       MIX       TER
              0.840     0.877     0.856     0.897
     Time       Sow       CON       FYN       MIX       TER
        1                 0.701     0.775     0.839     0.817
        2                 0.982     1.042     1.035     0.991
        3                 0.650     0.726     0.656     0.738
        4                 1.027     0.963     0.894     1.044

 *** Standard errors of differences of means ***
 Table                    Time          Sow          Time
                                                      Sow
 rep.                       20           20             5
 s.e.d.                 0.0608       0.0529        0.1178
 d.f.                    22.38           16         32.23
 Except when comparing means with the same level(s) of
  Sow                                              0.1216
  d.f.                                              22.38
 Correction factors have been applied to residual d.f.
 (see analysis-of-variance table for details)
  121  DELETE [REDEFINE=yes] _XDev
  122  CALC _XDev = 0 + 1*EDT(0.992;22)
  123  PRINT [IP=*] ':  Student''s T Equivalent Deviate = ',_XDev;F=1;SKIP=0
 :  Student's T Equivalent Deviate = 2.610
  @@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
```

BSAlienAvgs

```
 170  calculate RTime1=arcsin(TimeA1/100)
 171  calculate RTime2=arcsin(TimeA2/100)
 172  calculate RTime3=arcsin(TimeA3/100)
 173  calculate RTime4=arcsin(TimeA4/100)
 174  175  pointer[values=RTime1,RTime2,RTime3,RTime4]RTime
 176
arepmeasures[treatmentstructure=Sow;print=corr,epsilon;aprint=aov,means;fprob=
yes;pse=differences]RTime[]
 *** Correlation matrix ***
       RTime1      1.0000
       RTime2      0.4965      1.0000
       RTime3      0.3817      0.4400      1.0000
       RTime4      0.3728      0.3787      0.8249      1.0000
                   RTime1      RTime2      RTime3      RTime4

 Common correlation 0.4549
*** Greenhouse-Geisser epsilon  0.7209     ***

176.....................................................................
***** Analysis of variance *****
Source of variation     d.f.       s.s.       m.s.     v.r.  F pr.
Subject stratum
Sow                        3   0.207651   0.069217     5.71  0.007
Residual                  16   0.193962   0.012123     4.34
Subject.Time stratum
d.f. correction factor 0.7209
Time                       3   0.020102   0.006701     2.40  0.102
Time.Sow                   9   0.035635   0.003959     1.42  0.233
Residual                  48   0.134149   0.002795
Total                     79   0.591499
d.f. are multiplied by the correction factors before calculating F probabilities

***** Tables of means *****
Grand mean  0.1248
     Time        1        2        3        4
            0.1178   0.1515   0.1099   0.1200
      Sow      CON      FYN      MIX      TER
           0.0837   0.0753   0.2028   0.1374
     Time      Sow      CON      FYN      MIX      TER
        1               0.0854   0.0831   0.1941   0.1086
        2               0.1053   0.1469   0.2044   0.1493
        3               0.0709   0.0350   0.2081   0.1257
        4               0.0732   0.0360   0.2044   0.1662

*** Standard errors of differences of means ***
Table                  Time         Sow        Time
                                                Sow
rep.                     20          20           5
s.e.d.              0.01672     0.03482     0.04528
d.f.                  34.61          16       37.49
Except when comparing means with the same level(s) of
 Sow                                        0.03344
 d.f.                                         34.61
Correction factors have been applied to residual d.f.
(see analysis-of-variance table for details)
 177  DELETE [REDEFINE=yes] _XDev
 178  CALC _XDev = 0 + 1*EDT(0.992;16)
 179  PRINT [IP=*] ':  Student''s T Equivalent Deviate = ',_XDev;F=1;SKIP=0
:  Student's T Equivalent Deviate = 2.693
```

FBAlienAvgs

```
 229  calculate RTime1=arcsin(TimeA1/100)
 230  calculate RTime2=arcsin(TimeA2/100)
 231  calculate RTime3=arcsin(TimeA3/100)
 232  calculate RTime4=arcsin(TimeA4/100)
 233  234  pointer[values=RTime1,RTime2,RTime3,RTime4]RTime
arepmeasures[treatmentstructure=Sow;print=corr,epsilon;aprint=aov,means;fprob=
yes;pse=differences]RTime[]
 *** Correlation matrix ***
       RTime1      1.0000
       RTime2      0.5301      1.0000
       RTime3      0.2303      0.4615      1.0000
       RTime4      0.5156      0.8492      0.4429      1.0000
                   RTime1      RTime2      RTime3      RTime4

 Common correlation 0.5021
*** Greenhouse-Geisser epsilon  0.8196     ***

***** Analysis of variance *****
Variate: _['DATA']
Source of variation     d.f.       s.s.       m.s.     v.r.  F pr.
Subject stratum
Sow                        3   0.06056    0.02019     0.32  0.809
Residual                  16   1.00357    0.06272     5.03
Subject.Time stratum
d.f. correction factor 0.8196
Time                       3   0.80876    0.26959    21.63  <.001
Time.Sow                   9   0.08445    0.00938     0.75  0.636
Residual                  48   0.59815    0.01246
Total                     79   2.55549
(d.f. are multiplied by the correction factors before calculating F probabilitie
s)

***** Tables of means *****
Grand mean  0.421
     Time        1        2        3        4
            0.412    0.580    0.303    0.389
      Sow      CON      FYN      MIX      TER
            0.392    0.466    0.410    0.415
     Time      Sow      CON      FYN      MIX      TER
        1               0.366    0.528    0.383    0.369
        2               0.551    0.608    0.612    0.550
        3               0.267    0.353    0.282    0.308
        4               0.382    0.374    0.364    0.434

*** Standard errors of differences of means ***
Table                  Time         Sow        Time
                                                Sow
rep.                     20          20           5
s.e.d.              0.0353      0.0792      0.1001
d.f.                 39.34          16       35.61
Except when comparing means with the same level(s) of
 Sow                                        0.0706
 d.f.                                         39.34
Correction factors have been applied to residual d.f.
(see analysis-of-variance table for details)
 236  DELETE [REDEFINE=yes] _XDev
 237  CALC _XDev = 0 + 1*EDT(0.992;16)
 238  PRINT [IP=*] ':  Student''s T Equivalent Deviate = ',_XDev;F=1;SKIP=0
:  Student's T Equivalent Deviate = 2.693
```

BSIndigAvgs

```
 287  calculate RTime1=arcsin(TimeA1/100)
 288  calculate RTime2=arcsin(TimeA2/100)
 289  calculate RTime3=arcsin(TimeA3/100)
 290  calculate RTime4=arcsin(TimeA4/100)
 291  292  pointer[values=RTime1,RTime2,RTime3,RTime4]RTime
 arepmeasures[treatmentstructure=Sow;print=corr,epsilon;aprint=aov,means;fprob=
 yes;pse=differences]RTime[]
 *** Correlation matrix ***
       RTime1      1.0000
       RTime2      0.8673      1.0000
       RTime3      0.5740      0.5643      1.0000
       RTime4      0.6016      0.6952      0.7089      1.0000
                   RTime1      RTime2      RTime3      RTime4
Common correlation 0.6614
*** Greenhouse-Geisser epsilon  0.7295     ***

***** Analysis of variance *****
Source of variation      d.f.       s.s.       m.s.    v.r.  F pr.
Subject stratum
Sow                         3   0.460667   0.153556    2.74  0.078
Residual                   16   0.897380   0.056086    8.81
Subject.Time stratum
d.f. correction factor 0.7295
Time                        3   0.410742   0.136914   21.52  <.001
Time.Sow                    9   0.045222   0.005025    0.79  0.594
Residual                   48   0.305433   0.006363
Total                      79   2.119443
d.f. are multiplied by the correction factors before calculating F probabilities

***** Tables of means *****
Grand mean  0.4188
     Time        1        2        3        4
            0.2980   0.4343   0.4801   0.4629
      Sow      CON      FYN      MIX      TER
            0.4463   0.5283   0.3290   0.3717
     Time      Sow      CON      FYN      MIX      TER
        1               0.3069   0.4018   0.2363   0.2470
        2               0.4857   0.5442   0.3179   0.3896
        3               0.5093   0.6337   0.3511   0.4262
        4               0.4834   0.5335   0.4106   0.4242

*** Standard errors of differences of means ***
Table                  Time         Sow        Time
                                                Sow
rep.                     20          20           5
s.e.d.              0.02523     0.07489     0.08670
d.f.                  35.02          16       27.30
Except when comparing means with the same level(s) of
 Sow                                         0.05045
 d.f.                                          35.02
Correction factors have been applied to residual d.f.
(see analysis-of-variance table for details)
 294  DELETE [REDEFINE=yes] _XDev
 295  CALC _XDev = 0 + 1*EDT(0.992;16)
 296  PRINT [IP=*] ':  Student''s T Equivalent Deviate = ',_XDev;F=1;SKIP=0
:  Student's T Equivalent Deviate = 2.693
 297  DELETE [REDEFINE=yes] _XDev
 298  CALC _XDev = 0 + 1*EDT(0.992;35)
 299  PRINT [IP=*] ':  Student''s T Equivalent Deviate = ',_XDev;F=1;SKIP=0
:  Student's T Equivalent Deviate = 2.532
```

FBIndigAvgs

```
 350  calculate RTime1=arcsin(TimeA1/100)
 351  calculate RTime2=arcsin(TimeA2/100)
 352  calculate RTime3=arcsin(TimeA3/100)
 353  calculate RTime4=arcsin(TimeA4/100)
 354  355  pointer[values=RTime1,RTime2,RTime3,RTime4]RTime
 arepmeasures[treatmentstructure=Sow;print=corr,epsilon;aprint=aov,means;fprob=
 yes;pse=differences]RTime[]
 *** Correlation matrix ***
       RTime1      1.0000
       RTime2      0.0387      1.0000
       RTime3     -0.1583      0.5661      1.0000
       RTime4     -0.2100      0.4816      0.6492      1.0000
                   RTime1      RTime2      RTime3      RTime4

 Common correlation 0.2497
*** Greenhouse-Geisser epsilon  0.6969     ***

***** Analysis of variance *****
Source of variation      d.f.       s.s.       m.s.    v.r.  F pr.
Subject stratum
Sow                         3    0.05736    0.01912    0.35  0.790
Residual                   16    0.87613    0.05476    2.33
Subject.Time stratum
d.f. correction factor 0.6969
Time                        3    0.27581    0.09194    3.91  0.028
Time.Sow                    9    0.08081    0.00898    0.38  0.891
Residual                   48    1.12736    0.02349
Total                      79    2.41747
d.f. are multiplied by the correction factors before calculating F probabilities

***** Tables of means *****
Grand mean  0.436
     Time        1        2        3        4
            0.413    0.389    0.406    0.537
      Sow      CON      FYN      MIX      TER
            0.445    0.396    0.433    0.471

     Time      Sow      CON      FYN      MIX      TER
        1              0.391    0.305    0.460    0.493
        2              0.400    0.365    0.383    0.411
        3              0.417    0.376    0.383    0.449
        4              0.572    0.540    0.505    0.530

*** Standard errors of differences of means ***
Table                  Time         Sow        Time
                                                Sow
rep.                     20          20           5
s.e.d.              0.0485      0.0740      0.1119
d.f.                 33.45          16       46.69
Except when comparing means with the same level(s) of
 Sow                                         0.0969
 d.f.                                         33.45
Correction factors have been applied to residual d.f.
(see analysis-of-variance table for details)
 357  DELETE [REDEFINE=yes] _XDev
 358  CALC _XDev = 0 + 1*EDT(0.992;33)
 359  PRINT [IP=*] ':  Student''s T Equivalent Deviate = ',_XDev;F=1;SKIP=0
:  Student's T Equivalent Deviate = 2.539
```

```
BSGeoTots
880  pointer[values=RTime1,RTime2,RTime3,RTime4]RTime
 881
arepmeasures[treatmentstructure=Sow;print=corr,epsilon;aprint=aov,means;fprob=yes;ps
e=differences]RTime[]
 *** Correlation matrix ***
       RTime1      1.0000
       RTime2      0.8401      1.0000
       RTime3      0.0000      0.0000      0.0000
       RTime4      0.5965      0.4295      0.0000      1.0000
                   RTime1      RTime2      RTime3      RTime4

 Common correlation 0.3242

 *** Greenhouse-Geisser epsilon  0.5479     ***

881.....................................................................
***** Analysis of variance *****
Variate: _['DATA']
Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.
Subject stratum
Sow                        3     2.8841     0.9614    0.81  0.505
Residual                  16    18.9207     1.1825    2.92
Subject.Time stratum
d.f. correction factor 0.5479
Time                       3     4.2332     1.4111    3.48  0.054
Time.Sow                   9     3.5603     0.3956    0.98  0.450
Residual                  48    19.4491     0.4052
Total                     79    49.0473
(d.f. are multiplied by the correction factors before calculating F probabilitie
s)

***** Tables of means *****
Variate: _['DATA']
Grand mean  1.067
     Time        1        2        3        4
             1.255    1.020    0.710    1.283
      Sow      CON      FYN      MIX      TER
            1.314    1.188    0.863    0.903
     Time      Sow      CON      FYN      MIX      TER
        1                1.348    1.550    1.044    1.078
        2                1.088    1.166    0.884    0.942
        3                0.710    0.710    0.710    0.710
        4                2.110    1.326    0.812    0.884

*** Standard errors of differences of means ***
Table                   Time        Sow       Time
                                                Sow
rep.                      20         20          5
s.e.d.                0.2013     0.3439     0.4897
d.f.                  26.30         16      40.05
Except when comparing means with the same level(s) of
 Sow                                        0.4026
 d.f.                                       26.30
Correction factors have been applied to residual d.f.
(see analysis-of-variance table for details)
 882  DELETE [REDEFINE=yes] _XDev
 883  CALC _XDev = 0 + 1*EDT(0.992;26)
 884  PRINT [IP=*] ':  Student''s T Equivalent Deviate = ',_XDev;F=1;SKIP=0
:  Student's T Equivalent Deviate = 2.577
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
```

```
FBGeoTots
 932  pointer[values=RTime1,RTime2,RTime3,RTime4]RTime
 933
arepmeasures[treatmentstructure=Sow;print=corr,epsilon;aprint=aov,means;fprob=yes;ps
e=differences]RTime[]
 *** Correlation matrix ***
       RTime1      1.0000
       RTime2      0.8890      1.0000
       RTime3      0.1804      0.2065      1.0000
       RTime4      0.1117     -0.0178     -0.3032      1.0000
                   RTime1      RTime2      RTime3      RTime4

 Common correlation 0.1304

 *** Greenhouse-Geisser epsilon  0.4464     ***

933.....................................................................
***** Analysis of variance *****
Variate: _['DATA']
Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.
Subject stratum
Sow                        3      0.598      0.199    0.04  0.988
Residual                  16     75.740      4.734    1.60
Subject.Time stratum
d.f. correction factor 0.4464
Time                       3     80.314     26.771    9.05  0.004
Time.Sow                   9      4.465      0.496    0.17  0.953
Residual                  48    142.044      2.959
Total                     79    303.161
(d.f. are multiplied by the correction factors before calculating F probabilitie
s)

***** Tables of means *****
Variate: _['DATA']
Grand mean  2.53
     Time        1        2        3        4
             3.47     3.09     2.71     0.86
      Sow      CON      FYN      MIX      TER
            2.41     2.65     2.56     2.52
     Time      Sow      CON      FYN      MIX      TER
        1                3.11     3.97     3.39     3.43
        2                2.62     3.45     3.01     3.30
        3                2.97     2.47     2.84     2.55
        4                0.94     0.71     0.99     0.81

*** Standard errors of differences of means ***
Table                   Time        Sow       Time
                                                Sow
rep.                      20         20          5
s.e.d.                 0.544      0.688      1.167
d.f.                  21.43         16      36.48
Except when comparing means with the same level(s) of
 Sow                                        1.088
 d.f.                                       21.43
Correction factors have been applied to residual d.f.
(see analysis-of-variance table for details)
 934  DELETE [REDEFINE=yes] _XDev
 935  CALC _XDev = 0 + 1*EDT(0.992;21)
 936  PRINT [IP=*] ':  Student''s T Equivalent Deviate = ',_XDev;F=1;SKIP=0
:  Student's T Equivalent Deviate = 2.620
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
```

BSBrackTots

```
 777  pointer[values=RTime1,RTime2,RTime3,RTime4]RTime
 778
arepmeasures[treatmentstructure=Sow;print=corr,epsilon;aprint=aov,means;fprob=yes;ps
e=differences]RTime[]
 *** Correlation matrix ***
       RTime1      1.0000
       RTime2      0.8583      1.0000
       RTime3      0.7904      0.7652      1.0000
       RTime4      0.8307      0.8113      0.7197      1.0000
                   RTime1      RTime2      RTime3      RTime4

 Common correlation 0.7661

 *** Greenhouse-Geisser epsilon  0.8835     ***

778.....................................................................
***** Analysis of variance *****
Source of variation      d.f.       s.s.       m.s.    v.r.  F pr.
Subject stratum
Sow                         3    145.497     48.499    1.30  0.307
Residual                   16    594.939     37.184   14.10
Subject.Time stratum
d.f. correction factor 0.8835
Time                        3    225.096     75.032   28.46  <.001
Time.Sow                    9     36.289      4.032    1.53  0.176
Residual                   48    126.540      2.636
Total                      79   1128.360
(d.f. are multiplied by the correction factors before calculating F probabilitie
s)

***** Tables of means *****
Grand mean  8.42
     Time        1        2        3        4
                9.54     9.85     8.66     5.61
      Sow      CON      FYN      MIX      TER
                9.44    10.05     6.99     7.18
     Time      Sow      CON      FYN      MIX      TER
        1                10.54    11.71     7.78     8.12
        2                11.20    12.43     7.29     8.50
        3                10.12     9.94     7.78     6.80
        4                 5.88     6.14     5.12     5.30

*** Standard errors of differences of means ***
Table                    Time         Sow        Time
                                                  Sow
rep.                       20          20           5
s.e.d.                  0.513       1.928       2.123
d.f.                    42.41          16       23.14
Except when comparing means with the same level(s) of
 Sow                                            1.027
 d.f.                                           42.41
Correction factors have been applied to residual d.f.
(see analysis-of-variance table for details)
 779  DELETE [REDEFINE=yes] _XDev
 780  CALC _XDev = 0 + 1*EDT(0.992;42)
 781  PRINT [IP=*] ':  Student''s T Equivalent Deviate = ',_XDev;F=1;SKIP=0
:  Student's T Equivalent Deviate = 2.510
 @@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
```

FBBrackTots

```
829  pointer[values=RTime1,RTime2,RTime3,RTime4]RTime
 830
arepmeasures[treatmentstructure=Sow;print=corr,epsilon;aprint=aov,means;fprob=yes;ps
e=differences]RTime[]
 *** Correlation matrix ***
       RTime1      1.0000
       RTime2      0.9840      1.0000
       RTime3      0.9535      0.9475      1.0000
       RTime4      0.9194      0.9025      0.9597      1.0000
                   RTime1      RTime2      RTime3      RTime4

 Common correlation 0.8831

 *** Greenhouse-Geisser epsilon  0.4259     ***

830.....................................................................
***** Analysis of variance *****
Variate: _['DATA']
Source of variation      d.f.       s.s.       m.s.    v.r.  F pr.
Subject stratum
Sow                         3     98.8992    32.9664    1.81  0.186
Residual                   16    291.2847    18.2053   31.21
Subject.Time stratum
d.f. correction factor 0.4259
Time                        3     10.0005     3.3335    5.72  0.020
Time.Sow                    9      9.4482     1.0498    1.80  0.169
Residual                   48     27.9972     0.5833
Total                      79    437.6298
(d.f. are multiplied by the correction factors before calculating F probabilitie
s)

***** Tables of means *****
Variate: _['DATA']
Grand mean  2.238
     Time        1        2        3        4
                2.449    2.699    1.997    1.808
      Sow      CON      FYN      MIX      TER
                4.127    1.261    1.846    1.717
     Time      Sow      CON      FYN      MIX      TER
        1                4.696    1.348    2.038    1.712
        2                5.096    1.404    2.484    1.810
        3                3.800    1.216    1.160    1.810
        4                2.914    1.078    1.700    1.538

*** Standard errors of differences of means ***
Table                    Time         Sow        Time
                                                  Sow
rep.                       20          20           5
s.e.d.                 0.2415      1.3493      1.4126
d.f.                    20.44          16       19.09
Except when comparing means with the same level(s) of
 Sow                                            0.4830
 d.f.                                           20.44
Correction factors have been applied to residual d.f.
(see analysis-of-variance table for details)
 831  DELETE [REDEFINE=yes] _XDev
 832  CALC _XDev = 0 + 1*EDT(0.992;20)
 833  PRINT [IP=*] ':  Student''s T Equivalent Deviate = ',_XDev;F=1;SKIP=0
:  Student's T Equivalent Deviate = 2.631
 @@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
```

FBProtTots

```
 51  pointer[values=RTime1,RTime2,RTime3,RTime4]RTime
arepmeasures[treatmentstructure=Sow;print=corr,epsilon;aprint=aov,means;fprob=yes;
pse=differences]RTime[]
 *** Correlation matrix ***
       RTime1      1.0000
       RTime2      0.6492      1.0000
       RTime3      0.3654      0.2896      1.0000
       RTime4      0.6651      0.4264      0.6273      1.0000
                   RTime1      RTime2      RTime3      RTime4

Common correlation 0.4880
 *** Greenhouse-Geisser epsilon  0.7905     ***

***** Analysis of variance *****
Source of variation     d.f.      s.s.       m.s.    v.r.  F pr.
Subject stratum
Sow                        3    9.2936     3.0979    1.83  0.182
Residual                  16   27.0228     1.6889    4.81
Subject.Time stratum
d.f. correction factor 0.7905
Time                       3    6.6482     2.2161    6.32  0.003
Time.Sow                   9    3.3529     0.3725    1.06  0.407
Residual                  48   16.8437     0.3509
Total                     79   63.1612
(d.f. are multiplied by the correction factors before calculating F probabilities)

***** Tables of means *****
Grand mean  2.164
     Time       1        2        3        4
            2.505    2.363    2.022    1.769
      Sow     CON      FYN      MIX      TER
            2.107    2.737    1.881    1.933
     Time     Sow      CON      FYN      MIX      TER
        1            2.120    3.326    2.086    2.488
        2            2.120    2.740    2.254    2.336
        3            2.120    2.500    1.856    1.610
        4            2.070    2.380    1.326    1.298

*** Standard errors of differences of means ***
Table                   Time          Sow         Time
                                                   Sow
rep.                      20           20            5
s.e.d.                0.1873       0.4110       0.5236
d.f.                   37.94           16        36.23
Except when comparing means with the same level(s) of
 Sow                                            0.3747
 d.f.                                            37.94
Correction factors have been applied to residual d.f.
(see analysis-of-variance table for details)
  53  DELETE (REDEFINE=yes) _XDev
  54  CALC _XDev = 0 + 1*EDT(0.992;38)
  55  PRINT [IP=*] ':  Student''s T Equivalent Deviate = ',_XDev;F=1;SKIP=0
:  Student's T Equivalent Deviate = 2.521
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
```

BSProtTots

```
 102  pointer[values=RTime1,RTime2,RTime3,RTime4]RTime
 103  arepmeasures[treatmentstructure=Sow;print=corr,epsilon;aprint=aov,means;fprob=
    yes;pse=differences]RTime[]
 *** Correlation matrix ***
       RTime1      1.0000
       RTime2      0.7847      1.0000
       RTime3      0.6819      0.7892      1.0000
       RTime4      0.5263      0.7654      0.6054      1.0000
                   RTime1      RTime2      RTime3      RTime4

 Common correlation 0.6854

 *** Greenhouse-Geisser epsilon  0.8277     ***

103..............................................................................
***** Analysis of variance *****
Variate: _['DATA']
Source of variation     d.f.      s.s.       m.s.    v.r.  F pr.
Subject stratum
Sow                        3  208.8606    69.6202   21.00  <.001
Residual                  16   53.0529     3.3158    9.72
Subject.Time stratum
d.f. correction factor 0.8277
Time                       3    1.1606     0.3869    1.13  0.341
Time.Sow                   9    4.3173     0.4797    1.41  0.227
Residual                  48   16.3813     0.3413
Total                     79  283.7726
(d.f. are multiplied by the correction factors before calculating F probabilitie
s)

***** Tables of means *****
Variate: _['DATA']
Grand mean  3.724
     Time       1        2        3        4
            3.915    3.636    3.736    3.608
      Sow     CON      FYN      MIX      TER
            1.022    5.307    4.194    4.371
     Time     Sow      CON      FYN      MIX      TER
        1            0.812    5.432    4.450    4.966
        2            0.914    5.370    3.994    4.264
        3            0.914    5.486    4.320    4.224
        4            1.450    4.940    4.010    4.030

*** Standard errors of differences of means ***
Table                   Time          Sow         Time
                                                   Sow
rep.                      20           20            5
s.e.d.                0.1847       0.5758       0.6588
d.f.                   39.73           16        26.39
Except when comparing means with the same level(s) of
 Sow                                            0.3695
 d.f.                                            39.73
Correction factors have been applied to residual d.f.
(see analysis-of-variance table for details]
 104  DELETE [REDEFINE=yes] _XDev
 105  CALC _XDev = 0 + 1*EDT(0.992;16]
 106  PRINT [IP=*] ':  Student''s T Equivalent Deviate = ',_XDev;F=1;SKIP=0
:  Student's T Equivalent Deviate = 2.693
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
```

BSEricaTots

```
153  pointer[values=RTime1,RTime2,RTime3,RTime4]RTime
arepmeasures[treatmentstructure=Sow;print=corr,epsilon;aprint=aov,means;fprob=yes;
pse=differences]RTime[]
 *** Correlation matrix ***
       RTime1      1.0000
       RTime2      0.5850      1.0000
       RTime3      0.8338      0.8239      1.0000
       RTime4      0.7089      0.3178      0.6178      1.0000
                   RTime1      RTime2      RTime3      RTime4

 Common correlation 0.5786

 *** Greenhouse-Geisser epsilon  0.7487     ***

154.....................................................................
***** Analysis of variance *****
Variate: _['DATA']
Source of variation      d.f.       s.s.       m.s.    v.r.  F pr.
Subject stratum
Sow                         3     76.929     25.643    0.89  0.465
Residual                   16    458.581     28.661    6.49
Subject.Time stratum
d.f. correction factor 0.7487
Time                        3    556.414    185.471   42.01  <.001
Time.Sow                    9     31.930      3.548    0.80  0.586
Residual                   48    211.934      4.415
Total                      79   1335.787
(d.f. are multiplied by the correction factors before calculating F probabilitie
s)

***** Tables of means *****
Variate: _['DATA']
Grand mean  10.59
     Time         1         2         3         4
                14.19     10.65     10.80      6.74
      Sow       CON       FYN       MIX       TER
                9.57     12.12     10.75      9.93
     Time       Sow       CON       FYN       MIX       TER
        1                12.33     16.87     14.61     12.95
        2                10.38     12.56     10.25      9.40
        3                10.15     11.40     11.31     10.33
        4                 5.42      7.66      6.84      7.05

*** Standard errors of differences of means ***
Table                   Time       Sow      Time
                                                Sow
rep.                      20        20         5
s.e.d.                 0.664     1.693     2.047
d.f.                   35.94        16     31.24
Except when comparing means with the same level(s) of
 Sow                                          1.329
 d.f.                                         35.94
Correction factors have been applied to residual d.f.
(see analysis-of-variance table for details)

 155  DELETE [REDEFINE=yes] _XDev
 156  CALC _XDev = 0 + 1*EDT(0.992;36)
 157  PRINT [IP=*] ':  Student''s T Equivalent Deviate = ',_XDev;F=1;SKIP=0
:  Student's T Equivalent Deviate = 2.528
 @@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
```

FBEricaTots

```
 205  pointer[values=RTime1,RTime2,RTime3,RTime4]RTime
arepmeasures[treatmentstructure=Sow;print=corr,epsilon;aprint=aov,means;fprob=yes;
pse=differences]RTime[]
 *** Correlation matrix ***
       RTime1      1.0000
       RTime2      0.6481      1.0000
       RTime3      0.4998      0.7146      1.0000
       RTime4      0.4399      0.5464      0.8033      1.0000
                   RTime1      RTime2      RTime3      RTime4

 Common correlation 0.5038

 *** Greenhouse-Geisser epsilon  0.6138     ***

206.....................................................................
***** Analysis of variance *****
Variate: _['DATA']
Source of variation      d.f.       s.s.       m.s.    v.r.  F pr.
Subject stratum
Sow                         3     35.073     11.691    0.42  0.739
Residual                   16    441.565     27.598    5.06
Subject.Time stratum
d.f. correction factor 0.6138
Time                        3    332.057    110.686   20.30  <.001
Time.Sow                    9     49.707      5.523    1.01  0.432
Residual                   48    261.712      5.452
Total                      79   1120.114
(d.f. are multiplied by the correction factors before calculating F probabilitie
s)

***** Tables of means *****
Variate: _['DATA']
Grand mean  9.69
     Time         1         2         3         4
                13.09      9.29      8.64      7.75
      Sow       CON       FYN       MIX       TER
                10.07      9.58     10.44      8.67
     Time       Sow       CON       FYN       MIX       TER
        1                12.25     12.21     15.55     12.36
        2                 9.31      8.80     10.11      8.95
        3                 9.89      8.98      8.72      6.95
        4                 8.82      8.34      7.39      6.44

*** Standard errors of differences of means ***
Table                   Time       Sow      Time
                                                Sow
rep.                      20        20         5
s.e.d.                 0.738     1.661     2.097
d.f.                   29.46        16     34.08
Except when comparing means with the same level(s) of
 Sow                                          1.477
 d.f.                                         29.46
Correction factors have been applied to residual d.f.
(see analysis-of-variance table for details)
 207  DELETE [REDEFINE=yes] _XDev
 208  CALC _XDev = 0 + 1*EDT(0.992;29)
 209  PRINT [IP=*] ':  Student''s T Equivalent Deviate = ',_XDev;F=1;SKIP=0
:  Student's T Equivalent Deviate = 2.558
 @@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
```

BSGrindTots

```
 256  pointer[values=RTime1,RTime2,RTime3,RTime4]RTime
 257
arepmeasures[treatmentstructure=Sow;print=corr,epsilon;aprint=aov,means;fprob=yes;ps
e=differences]RTime[]
 *** Correlation matrix ***
       RTime1       1.0000
       RTime2       0.5465       1.0000
       RTime3       0.1157       0.4689       1.0000
       RTime4       0.1884       0.4725       0.9212       1.0000
                    RTime1       RTime2       RTime3       RTime4

 Common correlation 0.4350

 *** Greenhouse-Geisser epsilon  0.6750     ***

257.................................................................................
***** Analysis of variance *****
Variate: _['DATA']
Source of variation     d.f.        s.s.        m.s.    v.r.  F pr.
Subject stratum
Sow                        3       29.69        9.90    0.16  0.922
Residual                  16      990.98       61.94    4.08
Subject.Time stratum
d.f. correction factor 0.6750
Time                       3       58.51       19.50    1.28  0.291
Time.Sow                   9      726.28       80.70    5.32  <.001
Residual                  48      728.72       15.18
Total                     79     2534.19
(d.f. are multiplied by the correction factors before calculating F probabilitie
s)

***** Tables of means *****
Variate: _['DATA']
Grand mean  7.23
     Time          1         2         3         4
                8.59      7.23      6.80      6.29
      Sow        CON       FYN       MIX       TER
                6.87      7.61      6.44      7.99
     Time        Sow       CON       FYN       MIX       TER
        1                 2.97      4.35     12.18     14.87
        2                 6.95      9.59      7.15      5.24
        3                 9.02      8.19      3.34      6.65
        4                 8.55      8.32      3.08      5.21

*** Standard errors of differences of means ***
Table                     Time          Sow          Time
                                                      Sow
rep.                        20           20             5
s.e.d.                   1.232        2.489         3.278
d.f.                     32.40           16         38.03
Except when comparing means with the same level(s) of
 Sow                                                2.464
 d.f.                                               32.40
Correction factors have been applied to residual d.f.
(see analysis-of-variance table for details)

@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
```

FBGrindTots

```
 305  pointer[values=RTime1,RTime2,RTime3,RTime4]RTime
 306
arepmeasures[treatmentstructure=Sow;print=corr,epsilon;aprint=aov,means;fprob=yes;ps
e=differences]RTime[]
 *** Correlation matrix ***
       RTime1       1.0000
       RTime2       0.2922       1.0000
       RTime3       0.6019       0.3995       1.0000
       RTime4       0.0568       0.5859       0.0939       1.0000
                    RTime1       RTime2       RTime3       RTime4

 Common correlation 0.3289

 *** Greenhouse-Geisser epsilon  0.7130     ***

306.................................................................................
***** Analysis of variance *****
Variate: _['DATA']
Source of variation     d.f.        s.s.        m.s.    v.r.  F pr.
Subject stratum
Sow                        3      199.63       66.54    2.13  0.137
Residual                  16      500.29       31.27    2.96
Subject.Time stratum
d.f. correction factor 0.7130
Time                       3      322.99      107.66   10.19  <.001
Time.Sow                   9       99.18       11.02    1.04  0.417
Residual                  48      506.95       10.56
Total                     79     1629.03
(d.f. are multiplied by the correction factors before calculating F probabilitie
s)

***** Tables of means *****
Variate: _['DATA']
Grand mean  7.42
     Time          1         2         3         4
               10.80      6.89      6.46      5.53
      Sow        CON       FYN       MIX       TER
                5.66      7.00      9.98      7.03
     Time        Sow       CON       FYN       MIX       TER
        1                 8.06      8.76     15.02     11.35
        2                 5.74      6.97      8.06      6.77
        3                 4.76      4.97      9.97      6.15
        4                 4.10      7.29      6.88      3.86

*** Standard errors of differences of means ***
Table                     Time          Sow          Time
                                                      Sow
rep.                        20           20             5
s.e.d.                   1.028        1.768         2.509
d.f.                     34.22           16         43.82
Except when comparing means with the same level(s) of
 Sow                                                2.055
 d.f.                                               34.22
Correction factors have been applied to residual d.f.
(see analysis-of-variance table for details)
 307  DELETE [REDEFINE=yes] _XDev
 308  CALC _XDev = 0 + 1*EDT(0.992;34)
 309  PRINT [IP=*] ':  Student''s T Equivalent Deviate = ',_XDev;F=1;SKIP=0
:  Student's T Equivalent Deviate = 2.535
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
```

BSForbinTots

```
 356  pointer[values=RTime1,RTime2,RTime3,RTime4]RTime
 357
arepmeasures[treatmentstructure=Sow;print=corr,epsilon;aprint=aov,means;fprob=yes;ps
e=differences]RTime[]
 *** Correlation matrix ***
       RTime1      1.0000
       RTime2      0.6873      1.0000
       RTime3      0.3674      0.2959      1.0000
       RTime4      0.5651      0.3240      0.5733      1.0000
                   RTime1      RTime2      RTime3      RTime4

 Common correlation 0.4359

 *** Greenhouse-Geisser epsilon  0.7534     ***

357.....................................................................
***** Analysis of variance *****
Variate: _['DATA']
Source of variation      d.f.       s.s.       m.s.     v.r.  F pr.
Subject stratum
Sow                         3      2.997      0.999     0.21  0.886
Residual                   16     74.855      4.678     4.09
Subject.Time stratum
d.f. correction factor 0.7534
Time                        3     20.073      6.691     5.85  0.005
Time.Sow                    9      8.549      0.950     0.83  0.566
Residual                   48     54.899      1.144
Total                      79    161.374
(d.f. are multiplied by the correction factors before calculating F probabilitie
s)

***** Tables of means *****
Variate: _['DATA']
Grand mean  2.30
     Time         1         2         3         4
                2.81      2.26      1.51      2.64
      Sow       CON       FYN       MIX       TER
                2.43      2.45      1.97      2.36
     Time       Sow       CON       FYN       MIX       TER
        1                 3.00      3.00      2.52      2.73
        2                 2.18      2.34      2.06      2.45
        3                 1.48      1.09      1.30      2.16
        4                 3.07      3.37      2.02      2.08

*** Standard errors of differences of means ***
Table                   Time       Sow      Time
                                                Sow
rep.                      20        20         5
s.e.d.                 0.338     0.684     0.901
d.f.                   36.16        16     38.83
Except when comparing means with the same level(s) of
 Sow                                       0.676
 d.f.                                      36.16
Correction factors have been applied to residual d.f.
(see analysis-of-variance table for details)
 358  DELETE [REDEFINE=yes] _XDev
 359  CALC _XDev = 0 + 1*EDT(0.992;36)
 360  PRINT [IP=*] ':  Student''s T Equivalent Deviate = ',_XDev;F=1;SKIP=0
:  Student's T Equivalent Deviate = 2.528
 @@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
```

FBForbinTots

```
 408  pointer[values=RTime1,RTime2,RTime3,RTime4]RTime
 409
arepmeasures[treatmentstructure=Sow;print=corr,epsilon;aprint=aov,means;fprob=yes;ps
e=differences]RTime[]
 *** Correlation matrix ***
       RTime1      1.0000
       RTime2      0.8653      1.0000
       RTime3      0.7543      0.7308      1.0000
       RTime4      0.3935      0.6222      0.5607      1.0000
                   RTime1      RTime2      RTime3      RTime4

 Common correlation 0.6372

 *** Greenhouse-Geisser epsilon  0.6268     ***

409.....................................................................
***** Analysis of variance *****
Variate: _['DATA']
Source of variation      d.f.       s.s.       m.s.     v.r.  F pr.
Subject stratum
Sow                         3      3.303      1.101     0.07  0.977
Residual                   16    262.909     16.432     8.03
Subject.Time stratum
d.f. correction factor 0.6268
Time                        3     94.936     31.645    15.46  <.001
Time.Sow                    9     32.030      3.559     1.74  0.150
Residual                   48     98.273      2.047
Total                      79    491.451
(d.f. are multiplied by the correction factors before calculating F probabilitie
s)

***** Tables of means *****
Variate: _['DATA']
Grand mean  6.98
     Time         1         2         3         4
                7.81      6.55      5.40      8.15
      Sow       CON       FYN       MIX       TER
                6.69      7.09      7.23      6.91
     Time       Sow       CON       FYN       MIX       TER
        1                 6.53      7.41      8.37      8.94
        2                 6.43      6.10      6.79      6.88
        3                 5.27      5.80      5.45      5.09
        4                 8.52      9.06      8.31      6.72

*** Standard errors of differences of means ***
Table                   Time       Sow      Time
                                                Sow
rep.                      20        20         5
s.e.d.                 0.452     1.282     1.502
d.f.                   30.09        16     28.11
Except when comparing means with the same level(s) of
 Sow                                       0.905
 d.f.                                      30.09
Correction factors have been applied to residual d.f.
(see analysis-of-variance table for details)
 410  DELETE [REDEFINE=yes] _XDev
 411  CALC _XDev = 0 + 1*EDT(0.992;30)
 412  PRINT [IP=*] ':  Student''s T Equivalent Deviate = ',_XDev;F=1;SKIP=0
:  Student's T Equivalent Deviate = 2.553
 @@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
```

BSGralienTots

```
 459  pointer[values=RTime1,RTime2,RTime3,RTime4]RTime
 460
arepmeasures[treatmentstructure=Sow;print=corr,epsilon;aprint=aov,means;fprob=yes;pse=differences]RTime[]
 *** Correlation matrix ***
       RTime1      1.0000
       RTime2      0.3687      1.0000
       RTime3      0.2575      0.4077      1.0000
       RTime4      0.3386      0.0353      0.8227      1.0000
                   RTime1      RTime2      RTime3      RTime4

 Common correlation 0.3412

 *** Greenhouse-Geisser epsilon  0.6503     ***

460.......................................................................
***** Analysis of variance *****
Variate: _['DATA']
Source of variation      d.f.       s.s.       m.s.    v.r.  F pr.
Subject stratum
Sow                         3    3357.28    1119.09   26.66  <.001
Residual                   16     671.53      41.97    3.07
Subject.Time stratum
d.f. correction factor 0.6503
Time                        3     168.09      56.03    4.10  0.027
Time.Sow                    9     167.95      18.66    1.37  0.260
Residual                   48     655.96      13.67
Total                      79    5020.81
(d.f. are multiplied by the correction factors before calculating F probabilities)

***** Tables of means *****
Variate: _['DATA']
Grand mean  6.83
     Time         1         2         3         4
               5.48      5.55      7.27      9.01
      Sow       CON       FYN       MIX       TER
               1.03      1.03     16.71      8.54
     Time       Sow       CON       FYN       MIX       TER
        1                0.94      0.71     14.64      5.63
        2                0.99      1.14     13.97      6.09
        3                0.71      0.71     19.10      8.55
        4                1.47      1.54     19.13     13.88

*** Standard errors of differences of means ***
Table                     Time         Sow        Time
                                                   Sow
rep.                        20          20           5
s.e.d.                   1.169       2.049       2.880
d.f.                     31.21          16       41.99
Except when comparing means with the same level(s) of
 Sow                                             2.338
 d.f.                                            31.21

Correction factors have been applied to residual d.f.
(see analysis-of-variance table for details)
 461  DELETE [REDEFINE=yes] _XDev
 462  CALC _XDev = 0 + 1*EDT(0.992;31)
 463  PRINT [IP=*] ':  Student''s T Equivalent Deviate = ',_XDev;F=1;SKIP=0
:  Student's T Equivalent Deviate = 2.548 Time
 464  DELETE [REDEFINE=yes] _XDev
 465  CALC _XDev = 0 + 1*EDT(0.992;16)
 466  PRINT [IP=*] ':  Student''s T Equivalent Deviate = ',_XDev;F=1;SKIP=0
:  Student's T Equivalent Deviate = 2.693  Sow
 @@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
```

FBGraleintots

```
 514  pointer[values=RTime1,RTime2,RTime3,RTime4]RTime
 515
arepmeasures[treatmentstructure=Sow;print=corr,epsilon;aprint=aov,means;fprob=yes;pse=differences]RTime[]
 *** Correlation matrix ***
       RTime1      1.0000
       RTime2     -0.3126      1.0000
       RTime3     -0.1768      0.6503      1.0000
       RTime4     -0.3274      0.6125      0.8324      1.0000
                   RTime1      RTime2      RTime3      RTime4

 Common correlation 0.3464

 *** Greenhouse-Geisser epsilon  0.6356     ***

515.......................................................................
***** Analysis of variance *****
Variate: _['DATA']
Source of variation      d.f.       s.s.       m.s.    v.r.  F pr.
Subject stratum
Sow                         3    1208.98     402.99   10.75  <.001
Residual                   16     599.63      37.48    3.12
Subject.Time stratum
d.f. correction factor 0.6356
Time                        3     154.33      51.44    4.28  0.024
Time.Sow                    9     103.71      11.52    0.96  0.466
Residual                   48     576.58      12.01
Total                      79    2643.23
(d.f. are multiplied by the correction factors before calculating F probabilities)

***** Tables of means *****
Grand mean  4.28
     Time         1         2         3         4
               2.48      4.04      4.23      6.38
      Sow       CON       FYN       MIX       TER
               0.74      1.33     10.53      4.54
     Time       Sow       CON       FYN       MIX       TER
        1                0.81      0.81      7.50      0.81
        2                0.71      0.71      9.63      5.11
        3                0.71      0.71     10.52      4.98
        4                0.71      3.07     14.49      7.27

*** Standard errors of differences of means ***
Table                     Time         Sow        Time
                                                   Sow
rep.                        20          20           5
s.e.d.                   1.096       1.936       2.711
d.f.                     30.51          16       41.46
Except when comparing means with the same level(s) of
 Sow                                             2.192
 d.f.                                            30.51
Correction factors have been applied to residual d.f.
(see analysis-of-variance table for details)
 516  DELETE [REDEFINE=yes] _XDev
 517  CALC _XDev = 0 + 1*EDT(0.992;31)
 518  PRINT [IP=*] ':  Student''s T Equivalent Deviate = ',_XDev;F=1;SKIP=0
:  Student's T Equivalent Deviate = 2.548 Time
 519  DELETE [REDEFINE=yes] _XDev
 520  CALC _XDev = 0 + 1*EDT(0.992;16)
 521  PRINT [IP=*] ':  Student''s T Equivalent Deviate = ',_XDev;F=1;SKIP=0
:  Student's T Equivalent Deviate = 2.693 Sow
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
```

```
BSForbalTots
 568  pointer[values=RTime1,RTime2,RTime3,RTime4]RTime
 569
arepmeasures[treatmentstructure=Sow;print=corr,epsilon;aprint=aov,means;fprob=yes;ps
e=differences]RTime[]
 *** Correlation matrix ***
       RTime1      1.0000
       RTime2      0.4448      1.0000
       RTime3      0.4282      0.5282      1.0000
       RTime4      0.2370      0.3518      0.5576      1.0000
                   RTime1      RTime2      RTime3      RTime4

 Common correlation 0.3723

 *** Greenhouse-Geisser epsilon  0.7071     ***

569.....................................................................
***** Analysis of variance *****
Variate: _['DATA']
Source of variation      d.f.       s.s.       m.s.    v.r.  F pr.
Subject stratum
Sow                         3     1.7138     0.5713    0.26  0.853
Residual                   16    35.1628     2.1977    3.37
Subject.Time stratum
d.f. correction factor 0.7071
Time                        3     2.7620     0.9207    1.41  0.258
Time.Sow                    9     8.1803     0.9089    1.39  0.243
Residual                   48    31.2780     0.6516
Total                      79    79.0969
(d.f. are multiplied by the correction factors before calculating F probabilitie
s)

***** Tables of means *****
Variate: _['DATA']
Grand mean  2.298
     Time         1         2         3         4
              2.079     2.253     2.265     2.593
      Sow       CON       FYN       MIX       TER
              2.497     2.286     2.322     2.085
     Time       Sow       CON       FYN       MIX       TER
        1                2.100     1.778     2.972     1.466
        2                2.506     2.292     2.162     2.052
        3                2.506     2.190     2.158     2.206
        4                2.876     2.884     1.996     2.616

*** Standard errors of differences of means ***
Table                    Time       Sow      Time
                                             Sow
rep.                       20        20         5
s.e.d.                 0.2553    0.4688    0.6444
d.f.                   33.94        16     41.60
Except when comparing means with the same level(s) of
 Sow                                      0.5105
 d.f.                                      33.94
Correction factors have been applied to residual d.f.
(see analysis-of-variance table for details)
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
```

```
FBForbalTots
 617  pointer[values=RTime1,RTime2,RTime3,RTime4]RTime
 618
arepmeasures[treatmentstructure=Sow;print=corr,epsilon;aprint=aov,means;fprob=yes;ps
e=differences]RTime[]
 *** Correlation matrix ***
       RTime1      1.0000
       RTime2      0.5357      1.0000
       RTime3      0.6697      0.3871      1.0000
       RTime4      0.3657      0.2707      0.3750      1.0000
                   RTime1      RTime2      RTime3      RTime4

 Common correlation 0.3454

 *** Greenhouse-Geisser epsilon  0.7083     ***

618.....................................................................
***** Analysis of variance *****
Variate: _['DATA']
Source of variation      d.f.       s.s.       m.s.    v.r.  F pr.
Subject stratum
Sow                         3     20.194      6.731    0.57  0.645
Residual                   16    190.082     11.880    3.11
Subject.Time stratum
d.f. correction factor 0.7083
Time                        3    210.853     70.284   18.40  <.001
Time.Sow                    9     31.562      3.507    0.92  0.498
Residual                   48    183.342      3.820
Total                      79    636.033
(d.f. are multiplied by the correction factors before calculating F probabilitie
s)

***** Tables of means *****
Variate: _['DATA']
Grand mean  8.16
     Time         1         2         3         4
             8.02      8.85      5.65     10.10
      Sow       CON       FYN       MIX       TER
             7.49      8.75      7.87      8.52
     Time       Sow       CON       FYN       MIX       TER
        1                6.89      9.47      8.21      7.52
        2                7.14      9.67      8.69      9.89
        3                5.28      6.01      5.38      5.95
        4               10.64      9.84      9.20     10.72

*** Standard errors of differences of means ***
Table                    Time       Sow      Time
                                             Sow
rep.                       20        20         5
s.e.d.                  0.618     1.090     1.528
d.f.                       34        16     42.95
Except when comparing means with the same level(s) of
 Sow                                      1.236
 d.f.                                        34
Correction factors have been applied to residual d.f.
(see analysis-of-variance table for details)
 619  DELETE [REDEFINE=yes] _XDev
 620  CALC _XDev = 0 + 1*EDT(0.992;34)
 621  PRINT [IP=*] ': Student''s T Equivalent Deviate = ',_XDev;F=1;SKIP=0
: Student's T Equivalent Deviate = 2.535
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
```

BSBrdlvTots

```
arepmeasures[treatmentstructure=Sow;print=corr,epsilon;aprint=aov,means;fprob=yes;ps
e=differences]RTime[]
 *** Correlation matrix ***
      RTime1      1.0000
      RTime2      0.9776      1.0000
      RTime3      0.4643      0.5388      1.0000
      RTime4     -0.1120     -0.0942      0.4154      1.0000
                  RTime1      RTime2      RTime3      RTime4

 Common correlation 0.3560

 *** Greenhouse-Geisser epsilon  0.6839     ***

669.....................................................................
***** Analysis of variance *****
Source of variation      d.f.       s.s.       m.s.    v.r.  F pr.
Subject stratum
Sow                         3     0.9887     0.3296    0.64  0.598
Residual                   16     8.1891     0.5118    3.21
Subject.Time stratum
d.f. correction factor 0.6839
Time                        3     1.7239     0.5746    3.61  0.037
Time.Sow                    9     1.4418     0.1602    1.01  0.440
Residual                   48     7.6496     0.1594
Total                      79    19.9932
(d.f. are multiplied by the correction factors before calculating F probabilitie
s)

***** Tables of means *****
Variate: _['DATA']
Grand mean  0.909
     Time        1        2        3        4
             0.854    0.780    1.159    0.844
      Sow      CON      FYN      MIX      TER
            0.911    0.950    0.735    1.042
     Time      Sow      CON      FYN      MIX      TER
        1                0.710    0.812    0.710    1.184
        2                0.710    0.710    0.710    0.992
        3                1.180    1.464    0.812    1.180
        4                1.044    0.812    0.710    0.812

*** Standard errors of differences of means ***
Table                   Time         Sow        Time
                                                  Sow
rep.                      20          20           5
s.e.d.                0.1262      0.2262      0.3146
d.f.                  32.83          16          42
Except when comparing means with the same level(s) of
 Sow                                          0.2525
 d.f.                                         32.83
Correction factors have been applied to residual d.f.
(see analysis-of-variance table for details)
 670  DELETE [REDEFINE=yes] _XDev
 671  CALC _XDev = 0 + 1*EDT(0.992;33)
 672  PRINT [IP=*] ':  Student''s T Equivalent Deviate = ',_XDev;F=1;SKIP=0
:  Student's T Equivalent Deviate = 2.539
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
```

FBBrdlvTots

```
 726  pointer[values=RTime1,RTime2,RTime3,RTime4]RTime
 727
arepmeasures[treatmentstructure=Sow;print=corr,epsilon;aprint=aov,means;fprob=yes;ps
e=differences]RTime[]
 *** Correlation matrix ***
      RTime1      1.0000
      RTime2      0.9237      1.0000
      RTime3      0.9605      0.9132      1.0000
      RTime4      0.9109      0.8971      0.9123      1.0000
                  RTime1      RTime2      RTime3      RTime4

 Common correlation 0.8812

 *** Greenhouse-Geisser epsilon  0.9643     ***

727.....................................................................
***** Analysis of variance *****
Variate: _['DATA']
Source of variation      d.f.       s.s.       m.s.    v.r.  F pr.
Subject stratum
Sow                         3    147.107     49.036    1.10  0.376
Residual                   16    710.758     44.422   30.67
Subject.Time stratum
d.f. correction factor 0.9643
Time                        3     28.547      9.516    6.57  <.001
Time.Sow                    9     12.999      1.444    1.00  0.454
Residual                   48     69.531      1.449
Total                      79    968.942
(d.f. are multiplied by the correction factors before calculating F probabilitie
s)

***** Tables of means *****
Variate: _['DATA']
Grand mean  4.22
     Time        1        2        3        4
             3.42     4.35     5.07     4.02
      Sow      CON      FYN      MIX      TER
            4.21     2.07     4.82     5.76
     Time      Sow      CON      FYN      MIX      TER
        1                3.59     1.75     4.31     4.01
        2                4.03     2.56     4.64     6.16
        3                5.05     2.34     6.05     6.85
        4                4.16     1.63     4.28     6.02

*** Standard errors of differences of means ***
Table                   Time         Sow        Time
                                                  Sow
rep.                      20          20           5
s.e.d.                0.381       2.108       2.208
d.f.                  46.28          16       19.22
Except when comparing means with the same level(s) of
 Sow                                          0.761
 d.f.                                         46.28
Correction factors have been applied to residual d.f.
(see analysis-of-variance table for details)
 728  DELETE [REDEFINE=yes] _XDev
 729  CALC _XDev = 0 + 1*EDT(0.992;46)
 730  PRINT [IP=*] ':  Student''s T Equivalent Deviate = ',_XDev;F=1;SKIP=0
:  Student's T Equivalent Deviate = 2.501
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
```

Appendix 5: Herbicide assessment by WfW Teams at Oaklands.

Assessment of herbicide spraying by WFW teams on plots ($50m^2$) & subplots ($1m^2$) at Oaklands										
PLOT NO	**$50m^2$**		**$1m^2$**			**Done on 8/04/99**				
		A	**B**	**C**	**D**	**Comments**				
21	2%	0	0	0	0	very little dye present				
22	2%	0	<1%	0	0	very little dye present				
23	4%	0	0	<1%	0	some dying back outside plots				
24	6%	0	0	0	5%	some dying back outside plots				
25	8%	0	10%	10%	0%	*Hermanii* dying back				
26	4%	0	0	2%	0	*Rhus laevigata*, dying back				
27	2%	0	0	0	0	no impact				
28	0%	0	0	0	0	no impact				
29	2%	0	0	0	0	*Rhus laevigata*, dying back				
30	8%	0	0	0	0	*Bolus afra* dying back				
31	6%	0	<1%	5%	0	*Hermanii* dying back				
32	5%	0	0	0	2%	no impact				
33	6%	10%	0	0	5%	no impact				
34	6%	0	0	0	2%	*Bolus afra* dying back				
35	4%	10%	0	0	0%	*Bolus afra* dying back				
36	2%	0	0	0	5%	very little dye present				
37	0%	0	0	0	0	no impact				
38	0%	0	0	0	0	no impact				
39	1%	0	0	0	1%	no impact				
40	0%	0	0	0	0%	no impact				

Appendix 6: Floristic data measured during riparian vegetation survey.

Table of floristic data measured during the riparian vegetation survey.

COMMUNITY NO.	Rhus angustifolia-Metrosideros angustifolia community														2														3																													4										5								
PLOT NO.	2	6	7	2	2	3	3	3	3	3	3	4	4	7	6	6	6	5	5	5	6	1	5	6	2	5	5	5	1	6							1	1	1	1	2	5		1	2	2	2	2	3	4	4	4	4	7	3	3	7	5	6	6	7	4	4	4	5	7	4	1	1	1	2			6	7	7
	4	9	6	7	8	1	2	8	9	5	7	0	1	2	1	2	3	4	5	6	5	0	2	0	6	7	8	9	8	7	1	2	3	4	5	9	1	3	7	9	2	3	6	4	1	3	5	9	6	2	3	4	6	0	0	3	7	1	6	8	4	5	7	8	0	5	9	2	5	6	0	7	8	4	1	3
ALTITUDE (M)	3	4		4	4	4	4	4	4	4	4	4	4	3	2	2	2	3	2	3	2	5	2	2	4	3	2	2	3	5	2	2	2	3	3	5	5	5	3	3	2	3	3	4	2	3	4	4	4	4				4	4	4			5	4				1				5	3	3	3	5	5	2	3	
	6	0	5	8	8	4	2	0	4	2	4	4	2	4	8	4	4	8	7	0	7	5	8	8	4	0	9	8	4	0	6	8	8	0	0	6	0	0	2	9	8	8	3	6	6	6	4	8	3	4	4	7	8	4	8	3	4	8	2	2	5	8	8	0	8	5	8	2	6	2	8	6	7	7	4	4
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ASPECT	S	S	N	E	S	S	S	S	E	N	S	E	E	N	S	S	N	N	N	S	N	E	N	S	S	S	S	N	E	N	N	N	N	N	W	E	N	E	N	S	S	S	E	W	N	E	S	W	N	N	E	E	S	N	W	N	N	N	S	N	N	S	S	S	N	N	W	N	N	W	N	N	W	S	S	E
					E										W					W	E		E	E				E		E		W	W	W						E													E						W	E				W	E						W			W	E	
SLOPE (DEGREES)	2	2		1	1	1			1		1	1			1		1	2		2	1		1		3	1			4	1				1		1		2	2			1	4		1	2	1	1		1	2		1	1	1	1			3					1		1	3	1		4			2	4	4	2
	0	0	5	5	5	0	2	5	0	2	0	0	5	5	0	5	0	5	5	0	5	2	0	5	0	5	5	5	5	0	5	8	3	0	3	0	5	0	0	5	5	0	5	7	0	0	0	0	5	0	0	0	0	0	5	5	5	3	0	5	2	5	0	0	0	0	0	0	0	0	0	0	0	5	0	5
FINE SAND (%)	2	2	2	2	1			1	1	1					1		1			1			1		2	1	2	1	1			1		1					1																																		2	2	2	5
	3	0	8	7	8	5	6	5	1	4	6	1	3	7	8	7	9	3	6	0	4	1	2	6	4	7	1	2	2	5	9	5	4	7	3	1	3	6	1	1	2	5	4	4	4	5	5	5	5	5	5	5	5	4	5	4	5	4	5	4	4	4	3	3	4	3	4	4	4	4	0	5	5	0	2	0
MEDIUM SAND (%)	5	4	3	5	6	4	5	6	2	5	5				1		1			1			1		2	1	2	1	1			1		1					1							1	2			1	3		3	1	1	1		2	2				3	3	2	3	1	2		2			5	4	4	2
	0	8	0	0	2	7	5	0	1	2	7	1	3	7	8	7	9	3	6	0	4	1	2	6	4	7	1	2	2	5	9	5	4	7	3	1	3	6	1	1	2	9	9	4	9	1	2	0	1	0	4	4	1	7	2	9	0	6	3	7	9	9	1	5	8	8	8	0	3	7	0	9	2	4	4	1
COARSE SAND (%)	1	1		1		4	2	1	5	1	3	9	6	4		4	1	5	2	4	5	8	1	1	1			1	3	5	1	1	5	2	4	8	6	5	5	2	5	5	3	5	6	2	5			3	2	3	4	4	4	5		4	4	2	4	3	4	3	4	3	2	4	3	5		5	1	2	2	4
	3	5	7	2	8	1	1	7	0	9	1	5	4	1	9	6	1	9	4	0	6	2	9	7	7	8	4	8	7	5	9	7	5	5	2	0	0	3	1	1	3	4	7	6	8	9	7	0	8	7	5	0	8	0	6	0	0	2	2	0	5	4	4	0	0	0	3	8	2	1	0	3	5	1	7	6
SOIL pH	4	4	4	3	4	5	4	4	5	4	4	4	4	3	4	5	4	4	4	5	4	3	4	4	4	4	4	4	3	4	3	3	3	4	4	3	4	4	4	4	4	4	4	3	4	5	4	4	4	4	4	5	4	4	4	4	4	3	4	4	3	3	3	3	3	3	3	3	4	3		5	4	4	4	7
(maximum two decimals)	0	4	5	8	7	0	9	0	3	4	3	5	6	3	7	0	7	7	8	3	4	7	4	7	1	7	5	8	7	2	9	1	9	1	2	9	5	2	2	4	4	6	3	8	4	2	7	6	7	6	6	1	5	3	6	2	6	5	5	4	2	4	8	5	1	8	5	8	1	4		0	2	1	2	5
	6	9	1	8	5	2	1	6	4	4	8	0	3	5	0	9	9	2	0	0	4	5	1	5	5	4	5	1	4	7	1	8	3	8	8	5	3	4	8	3	8	9	6	7	1	2	7	1	0	3	7	2	4	3	1	5	8	2	2	4	7	0	1	4	8	2	8	8	8	7		5	2	5	8	1
SOIL DEPTH (CM)			1																																																1		1								1					1										
	7	6	6	1	2	1	2	8	2	3	2			3	8	2	8	1	1	1	6	1	6	1	3	1	2	3		3					4		1	1	1	2	2	3	1		8		5	1	2		2	1	4	2	3	1	6	2	3	5	3	4	3	2	2	6	1	1	1	1	1			6	6	4
	3	8	0	2	2	3	4	6	3	8	7		1	8	5	5	4	4	8	7	4	0	7	6	0	1	3	5	7	2	3	1	3	1	4	4	2	8	4	5	1	0	4	9	4	7	0	7	9	4	8	4	2	7	7	9	3	7	0	7	7	5	4	0	7	0	5	0	7	2	6		8	7	8	4
	8	8	0	5	2	0	9	0	8	0	0	2	9	2	9	5	9	7	7	6	1	3	5	8	0	8	0	9	2	1	0	9	5	4	7	7	1	1	9	0	4	3	3	7	3	1	2	0	0	5	8	2	4	3	0	8	1	9	2	4	3	7	9	3	0	0	0	5	8	1	1	9	1	5	2	8
BEDROCK COVER (%)																																																		1																									
				5	4		1		9	1	3	9	9			2			4	3				4	2		1		5				1			2	4		4	2	2	5	5	5		1	1	2	5	0		6		1	5				2				1	2	1			1		3	2		4			
		5		0	0	5	0		0	0	0	0	0	5	5	5			0	0				0	0	5	0	5	0	2			0	8		0	0		0	0	0	0	0	0		0	0	5	0	0		5		0	0	5			5	5			0	0	5		5	5		0	0		0		5	5
TOTAL COVER (%)	1	1	1		1	1		1									1		1			1											1																	1		1		1				1	1					1			1			1							
	0	0	0	8	0	0	7	0	9	8	9	7	6	9	9	9	0	7	0	9	8	0	8	9	9	8	8	9	7	9	9	9	0	8	9	8	7	9	7	9	7	8	6	5	8	8	9	9	0	9	0	7	0	9	7	8	0	0	8	9	9	9	0	8	9	0	9	9	0	8	8	7	9	9	9	9
	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	5	0	5	0	5	0	0	5	5	5	5	5	0	0	5	8	5	0	0	0	0	0	5	0	5	0	5	0	0	0	0	0	5	0	5	0	0	0	5	0	5	0	0	0	0	5	5	0	0	0	0	0	0	0	5	0	0	0	0	0	5

d) Wit River and Steenbok Rivers:

The Wit River (Figures 2.7 & 2.8) branches off from the Breede River system, and runs along the Bainskloof Pass (between the towns of Wellington and Wolseley). The river dries out in the Slanghoek Mountains. The invasive alien vegetation of this river has also been cleared in sections, however, the riparian vegetation is relatively characteristic between Eerste and Tweede Tol (area sampled). From Tweede Tol towards Ceres, vast sections of the river are infested, mainly with *Acacia mearnsii*. Clearing operations are currently underway on these rivers. The steepness of the slope (accessibility) and the age of the infestation make alien clearing very difficult in this area. The plots sampled occur between co-ordinates: 33°34'15"S/19°08'60"E & 33°37'10"S/19°06'20"E.

The Steenbok River is a perennial tributary of the Wit River, and runs through the Steenbok Park Nature Reserve. Although invasive alien trees have been cleared from this river in the past, sections of the river still have a distinctive band of riverine vegetation, which includes species like *Metrosideros angustifolia*, *Brabejum stellatifolium* and *Leucadendron salicifolium*. The plots sampled occur between co-ordinates: 33°32'60"S/19°08'35"E & 33°32'50"S/19°07'10"E.