THE RESTORATION POTENTIAL OF FYNBOS RIPARIAN SEED BANKS AFTER ALIEN CLEARING

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Thesis presented in partial fulfilment of the requirements for the degree of Master of Science, Department of Conservation Ecology and Entomology at the University of Stellenbosch

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December 2007

Declaration

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

Signature…………………………………… Date……………………………………….

SUMMARY

Riparian areas are highly complex systems with varying levels of disturbance that are highly susceptible to invasion by alien plants. Once invaded, riparian areas play a major role in the dispersal and spread of invasive alien plants (IAPs) through the river system and, in some cases, to neighbouring landscapes. Riparian areas have therefore been prioritized by many alien clearing initiatives in South Africa. Current practice for the restoration of cleared areas is minimal and relies mainly on the un-aided recovery of native species from residual individuals and soil stored seed banks. Little research, however, has been done on the effectiveness of this approach or the extent to which riparian seed banks contribute towards community restoration. This study is part of a national research initiative (*Targets for Ecosystem Repair in Riparian Ecosystems in Fynbos, Grassland and Savanna Biomes)* funded by Department of Water Affairs and Forestry, in collaboration with Working for Water, The Centre for Invasion Biology and the Universities of Cape Town, Stellenbosch, Rhodes and Witwatersrand. The initiative undertook to investigate different restoration techniques on various invaded sites for their cost-effectiveness, efficiency, practicality and conservation integrity.

This study has three aims. The first is to determine the composition of seed banks in un-invaded riparian areas within the fynbos biome to be used as a benchmark for future research, restoration grading and other management requirements. The second aim is to determine the composition of seed banks in heavily invaded riparian areas, and thus to assess the impact of invasion on the integrity of the seed banks. The third aim is to evaluate the restoration potential of riparian seed banks following the clearing of invasive alien plants (IAPs).

Study sites were selected within four river systems in the south-western part of the Western Cape Province in South Africa: the Berg, Eerste, Molenaars and Wit Rivers. Plots were selected in both invaded (>75% IAP canopy cover; considered “closed” alien stands) and un-invaded (also termed reference, with <25% IAP canopy cover) sections of the river. Replicate plots were established along varying gradients of elevation (mountain stream and foothill) and moisture regimes (dry, wet and transitional bank zones). Soil samples were collected together with above-ground vegetation surveys and comparisons were made. Results from this study confirm those of previous studies that seed banks offer little

reference to current aboveground vegetation, but rather offer insight into past vegetation history as well as future vegetation assemblages.

Worldwide, many of the species that characteristically form seed banks are early successional species. A community study was done for the seed bank based on the species that germinated and were identifiable at termination of the project (6 months after initiation). Three clusters of species could be identified. One group comprised 32 generalist species that occurred in both reference and invaded sections of the rivers. A second group comprised 39 species associated with invaded sites, and a third group of 40 species that was associated with reference sites. A few sub-community groups were found within both the “reference” and “invaded” community groups which were assumed to be habitat specific. Most species were “pioneer” or relatively-short lived, early-successional species which play a vital role in the initial post-disturbance vegetation cover, and facilitate establishment of later successional species.

Seed banks are notoriously variable over space and time, and floristic representation is often biased as a result of differences among species in seed production, dispersal and longevity in the soil. The general consensus is that seeds have an irregular, clustered spatial distribution that is dictated by both biological and environmental factors. Within river systems, the irregular clustering can be exceptionally skewed with the influence of pockets of high sediment deposition along the bank. Environmental factors that were found to significantly skew germination results were the presence of fire, as well as the extent and intensity of invasion (duration and cover). The high level of diversity and abundance in reference Berg River mountain stream seed banks was perceived to be a direct result of a moderate fire frequency (between 8-15 years) and the relatively natural state of the vegetation (i.e. very little invasion). Also, diversity and richness of indigenous species from the Wit and Molenaars Rivers were substantially higher in the invaded samples than the reference samples, probably because both river systems have a long history of invasion and other anthropogenic disturbances which would have an effect on the samples from “reference” sections (i.e. even a 25% presence of IAPs seems adequate enough to alter the composition of the seed bank). Correspondence analyses showed that species had clear affinities towards different levels of “key” riparian environmental variables (fire, invasion and anthropogenic disturbance). Most species were associated with moderate levels of fire frequency, invasion history, and anthropogenic disturbance.

Comparisons of seed bank species assemblages between the lateral and longitudinal variables of the rivers offered insights into the habitat requirements of certain fynbos and riparian species. Most significant were the results from bank zone comparisons which showed distinct species groupings along the different moisture bands. As could be expected, riparian species were best represented within the wet bank zones and fynbos species within the dry bank zone, while species characteristic of both zones occurred in the transitional zone, making this seed bank zone the richest in species. Mountain stream sections were richer and more diverse than foothill sections over both invaded and reference samples. This is hypothesised to be linked to lower levels of anthropogenic disturbance experienced in the mountain stream sections.

The impact of invasion on the riparian seed bank was most clearly shown through the correspondence analyses for the 20 most frequently occurring species. The seed bank assembly patterns were clearly defined by the state of the river (reference or invaded). Interestingly, this pattern was evident at all three spatial scales; landscape (rivers), reach (mountain stream and foothill sections) and habitat (dry, wet and transitional zones). The reference seed bank assemblage was more tightly grouped, implying that the species were more closely associated with each other and less variable than those of the invaded seed bank assemblages. The species groupings within the invaded seed banks were influenced by variables such as reach and zone, whereas the reference seed bank assemblages seem relatively unaffected by these variables. This implies that the presence of invasive alien plants creates additional variation within the seed bank which alters the natural groupings. At a broad scale, the invaded seed banks were less species rich. This means that not only will the resulting seedling community be harder to predict, but it will also have fewer species. However although generally lower in species richness, the seed banks from almost all invaded rivers interestingly showed a higher diversity of indigenous species than their reference counterparts. This is very promising in terms of rehabilitation of post-cleared riparian sites, but more information is needed to understand the seed bank composition and determine how sustainable the seed banks are for rehabilitation in the long-term. All invaded sections had fewer herbaceous perennial species but more herbaceous annual species. Graminoids made up 50% or more of the seed bank regardless of state (reference or invaded), while woody species (shrubs/shrublets) were generally more prevalent in the reference samples. These results imply that following the removal of invasive alien plants, the vegetation to regenerate from the seed bank is likely to comprise of short-lived, herbaceous species that are not necessarily an accurate reflection of the indigenous riparian community. It is however important to note that this study investigated only the species that were able to germinate over the study period (6 month germination period). Many riparian species may not have been represented because they are either late germinators or may not be present in the soil seed bank at all. In order to gain a holistic understanding of riparian community recruitment, it is recommended that seed bank studies such as this one be included in a more broad scale, long term investigation which takes into account various reproductive strategies used by riparian species.

Research of this nature is in its infancy worldwide and there are many challenges involved in measuring diversity and change in these systems. However, within the scope of this study, I suggest that these results shed light on previously unanswered and important questions regarding the ecology of seed banks in the riparian ecosystems of the Western Cape.

OPSOMMING

Oewerwal-areas is uiters komplekse stelsels met verskillende versteuringsvlakke wat baie maklik deur uitheemse plante binnegedring word (bekend as ‘invasive alien plants (IAP)). Wanneer dit gebeur, speel oewerwal-areas ’n hoofrol in die verspreiding en uitbreiding van die IAP’s deur middel van die rivierstelsel. In sommige gevalle word die IAP’s selfs na aangrensende landskappe versprei. As gevolg hiervan het heelwat inisiatiewe vir die uitroei van uitheemse plante in Suid-Afrika hulle fokus op oewerwal-areas geplaas. Tans word die minimum gedoen om die herstelproses in skoongemaakte areas aan te help. Die inheemse spesies moet hoofsaaklik sonder hulp herstel deur middel van saadbanke wat in die grond gestoor is. Baie min navorsing is egter tot dusver oor die doeltreffendheid van hierdie praktyk gedoen, of oor die mate waartoe oewerwal-saadbanke tot die herstel van die gemeenskap bydra. Hierdie studie vorm deel van ’n nasionale navorsingsinisiatief (*Targets for Ecosystem Repair in Riparian Ecosystems in Fynbos, Grassland and Savanna Biomes)* wat befonds word deur die Departement van Watersake en Bosbou, in samewerking met Werk vir Water, die Sentrum vir Indringerbiologie, die universiteite van Kaapstad, Stellenbosch, Witwatersrand en Rhodes. Hierdie nasionale navorsingsinisiatief het onderneem om verskillende hersteltegnieke op verskeie aangetaste terreine ten opsigte van die koste-effektiwiteit, doeltreffendheid, praktiese uitvoerbaarheid en bewaringsintegriteit te ondersoek.

Hierdie studie het drie doelwitte. Die eerste is om vas te stel wat die samestelling van saadbanke in onaangetaste oewerwal-areas binne die fynbosbioom is. Hierdie samestelling kan dan as ’n maatstaf vir verdere navorsing, gradering vir herstel en ander bestuursvereistes gebruik word. Die tweede doelwit is om vas te stel wat die samestelling van saadbanke in oewerwal-areas is wat swaar deur indringerplante aangetas is, en dus die impak van die indringing op die integriteit van die saadbank te evalueer. Die derde doelwit is om die herstelpotensiaal van oewerwal-areas ná die verwydering van die IAP’s te evalueer.

Studieterreine is in vier rivierstelsels in die suid-westelike deel van die Wes-Kaap in Suid-Afrika gekies, naamlik die Berg-, Eerste-, Molenaars- en Witrivierstelsel. Persele is gekies in sowel rivierseksies wat deur indringerplante aangetas is (>75% IAP-kroondekking) as rivierseksies wat nie aangetas is nie (<25% IAP-kroondekking). Soortgelyke persele is op verskillende hoogtes (bergstroom en voetheuwel) en vogregimes (droë, nat en oorgangs

oewersones) gevestig. Grondmonsters is geneem an die grond is vir ‘n tydperk van ses mande in ‘n plastaktonnel geplaas, klam gehou en die saailings wat gevestis is, is identifiseur en angetekend. Die resultate van hierdie studie bevestig die resultate van vorige studies dat saadbanke min verwysing na huidige bogrondse plantegroei bied, maar eerder insig kan gee in sowel die geskiedenis van die plantegroei as toekomstige plantegroeiversamelings.

Baie van die spesies wat oor die wêreld heen kenmerkend saadbanke vorm, is vroeë suksessionele spesies. ’n Plant gemeenskap studie is gedoen op die saadbank wat gebaseer is op die spesies wat ontkiem het en wat teen die beëindiging van die projek (ses maande ná die aanvang) identifiseerbaar was. Drie groepe spesies kon geïdentifiseer word. Een groep het uit 32 algemene spesies bestaan wat in sowel die verwysing- as aangetaste rivierseksies voorgekom het. ’n Tweede groep het uit 39 spesies bestaan wat met aangetaste terreine geassosieer word en ’n derde groep het uit 40 spesies bestaan wat met die verwysingterreine geassosieer is. ’n Paar subgemeenskapsgroepe is in sowel die verwysing- as die aangetaste gemeenskapsgroepe gevind en daar is aangeneem dat hulle habitatspesifiek is. Die meeste spesies was pionierspesies – vroeë suksessionele spesies met ’n redelike kort leeftydperk – wat ’n wesenlike rol in die aanvanklike plantebedekking ná die versteuring speel, en wat die vestiging van latere suksessionele spesies bemiddel.

Saadbanke wissel baie met verloop van tyd en die floristiese verteenwoordiging is dikwels nie akkuraat nie as gevolg van verskille tussen spesies ten opsigte van saadproduksie, -verspreiding en lewensduur in die grond. Die algemene konsensus is dat saad ’n onreëlmatige, gebondelde verspreiding vertoon wat deur sowel biologiese as omgewingsfaktore gereguleer word. Binne rivierstelsels kan hierdie onreëlmatige vorming van groepe vererger word deur die voorkoms van sedimentafsetsel met die oewer langs. Omgewingsfaktore wat die ontkiemingresultate beduidend skeefgetrek het, was die teenwoordigheid van vuur en die omvang en intensiteit van indringing (duur en bedekking). Die hoë vlak van diversiteit en volopheid in saadbanke in die Bergrivier-bergstroom wat as verwysing gedien het, was ’n direkte gevolg van ’n matige vuurfrekwensie (tussen agt en vyftien jaar) en die relatiewe natuurlike stand van die plantegroei (d.w.s. baie min indringing). Die diversiteit en rykheid van inheemse spesies van die Wit- en Molenaarsrivier was beduidend hoër in die aangetaste monsters as die verwysingmonsters. Die moontlike rede is dat albei rivierstelsels ’n lang geskiedenis van indringing en ander antropogeniese versteurings het wat ’n invloed op die monsters uit verwysingseksies sou hê (dit lyk of ’n teenwoordigheid van selfs 25% IAP’s voldoende kan wees om die samestelling van die saadbank te verander). Volgens ‘n ooreenkomsontleding toon spesies ’n duidelike verwantskap met verskillende vlakke van belangrike oewerwal-omgewingveranderlikes (vuur, indringing en antropogeniese versteuring). Die meeste spesies is met gemiddelde vlakke van vuurfrekwensie, geskiedenis van indringing en versteuring geassosieer.

Vergelykings van saadbankspesie-versamelings tussen die laterale en longitudinale veranderlikes van die riviere het insig gegee in die habitatvereistes van sekere fynbos- en oewerwal-spesies. Die belangrikste resultate is verkry van banksonevergelykings wat duidelike groeperings van spesies met die verskillende vogbande langs getoon het. Soos verwag sou kon word, is oewerwal-spesies die beste in natbanksones en fynbosspesies in droëbanksones verteenwoordig, terwyl spesies wat in albei sones aard in die oorgangsone voorgekom het. As gevolg hiervan is die meeste spesies in die oorgangsone aangetref. Bergstroomseksies is ryker en meer divers as voetheuwelseksies in sowel aangetaste as verwysingmonsters. Daar word veronderstel dat dit verbind kan word met laer vlakke van antropogeniese versteuring in die bergstroomseksies.

Die impak van indringing op die oewerwal-saadbank is die duidelikste uitgewys deur die ooreenkomsontleding van die twintig spesies wat die meeste voorgekom het. Die saadbank-samestellingspatrone is duidelik deur die toestand van die rivier (verwysing of aangetas) gedefinieer. Interessant genoeg was die patroon duidelik op al drie die ruimteskale: landskap (riviere), reikwydte (bergstroom- en voetheuwelseksies) en habitat (droë, nat en oorgangsones). Die saadbankversameling wat as verwysing gebruik is, was digter gegroepeer; dit impliseer dat die spesies nader verwant is en minder as die aangetaste saadbankversamelings varieer. Die spesiegroeperings binne die aangetaste saadbanke is deur veranderlikes soos reikwydte en sone beïnvloed, terwyl dit voorgekom het of die verwysing-saadbankversamelings relatief ongeaffekteer was deur hierdie veranderlikes. Dit impliseer dat die teenwoordigheid van indringer-uitheemseplante ’n bykomende variasie in die saadbank skep wat die natuurlike verwantskappe verander. Op ‘n breë skaal het dit gelyk of daar nie so baie spesies in die aangetaste saadbanke was nie. Dit beteken dat dit moeiliker sal wees om te voorspel hoe die saailinggemeenskap daar gaan uitsien en ook dat daar minder spesies in die saailinggemeenskap sal voorkom. Hoewel daar oor die algemeen minder spesies in voorkom, het die saadbanke in bykans al die aangetaste riviere ’n hoër diversiteit van inheemse spesies as die verwysingriviere getoon. Dit is baie belowend ten opsigte van die rehabilitasie van oewerwal-terreine waar uitheemse-indringerplante verwyder is, maar meer inligting word benodig om die saadbanksamestelling te begryp en te bepaal hoe volhoubaar die saadbanke vir rehabilitasie op lang termyn is. Al die aangetaste seksies het minder kruidagtige, meerjarige spesies, maar meer kruidagtige, eenjarige spesies. Grasspesies het 50% of meer van die saadbank gevorm, ongeag of dit ’n verwysing- of aangetaste monster was, terwyl houtagtige spesies (struike) oor die algemeen meer in die verwysingmonsters voorgekom het. Hierdie resultate impliseer dat die plantegroei wat ná die verwydering van indringer-uitheemseplante van ’n saadbank regenereer, waarskynlik uit kruidagtige spesies met ’n kort leeftyd sal bestaan wat nie noodwendig ’n akkurate weerspieëling van die inheemse oewerwal-gemeenskap is nie. Dit is egter belangrik om daarop te let dat hierdie studie slegs die spesies wat binne die studietydperk van twaalf maande (2 x ses maande) kon ontkiem, ondersoek het. Baie oewerwal-spesies is moontlik nie verteenwoordig nie omdat hulle óf later ontkiem het óf glad nie in die saadbank teenwoordig was nie. Ten einde ’n holistiese begrip van die vestiging in oewerwal-gemeenskappe te verkry, word aanbeveel dat saadbankstudies soos hierdie een in ’n langtermyn-ondersoek ingesluit word wat op ’n wyer skaal geskied en wat verskeie voortplantingstrategieë wat deur oewerwal-spesies gebruik word, in berekening bring.

Navorsing van hierdie aard is oor die wêreld heen nog in ’n vroeë stadium en daar is talle uitdagings ten opsigte van die meting van diversiteit en verandering in hierdie stelsels. Binne die omvang van hierdie studie stel ek egter voor dat hierdie resultate lig werp op voorheen onbeantwoorde en belangrike vrae oor die ekologie van saadbanke in die oewerwal-stelsels van die Wes-Kaap.

ACKNOWLEDGEMENTS

Financial support was provided by the DST-NSF Centre of Excellence for Invasion Biology (C.I.B) at Stellenbosch University. Additional funding under the national project: "Targets for Ecosystem Repair in Riparian Vegetation" was provided by the Department of Water Affairs and Forestry (DWAF) and the Working for Water (WfW) project. I thank all those from the Department of Botany and Zoology, the C.I.B, and the Department of Conservation Ecology at Stellenbosch University for their assistance and guidance. I am especially grateful to Prof Karen Esler, Dr Pat Holmes and Prof Dave Richardson for their endless support, as well as detailed and constructive suggestions which led to a much improved manuscript; and Dr Martin Kidd for his patience and assistance with the statistical analyses and interpretation. I would like to thank the Working for Water team for their assistance in site selection, all the private land owners, reserve managers and CapeNature for allowing access to conduct my research, and the Welgevallen Experimental Farm of Stellenbosch University, who allowed me to use their growing tunnels. Finally, I'd like to thank Marina Faber and Shayne Fuller for their excellent assistance in the field.

On a personal note, I am eternally grateful to my friends and family who supported me through this incredible learning journey. I am especially appreciative to my parents for their constant patience and encouragement throughout my life. I thank Kimmy, my sister, who was always there when I needed her, and was especially patient and giving of her time and guidance. And finally, Shayne Fuller, for having the faith in me when I didn't, and for always catching my tears of frustration and lifting me up again. I couldn't have done this without you.

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CHAPTER 1: THE ECOLOGY OF SOIL SEED BANKS IN RIPARIAN ZONES – A REVIEW

1.1 ABSTRACT

This chapter presents a review of the literature on the ecology of soil seed banks, with particular focus on riparian vegetation. Within terrestrial ecosystems, research shows soil seed banks to contribute significantly to the regeneration of plant cover following a disturbance in many vegetation types. Seed bank data can yield information on the species composition, relative abundance, and potential distribution of the species within a specific community. It can also offer insights into the longevity and persistence of rare and/ or problem species. Research has shown many invasive alien plants have long-lived seeds and are thus able to establish large seed banks. Additionally, riparian areas are highly susceptible to invasion by alien plants; and once invaded, these areas play a major role in the further spread of these species through the landscape. Worldwide, there is a shortage of knowledge on riparian seed banks. It is surprising, then, that relatively little research has focused on riparian zones considering the importance that effective management of river systems plays in a socio-economic and landscape context, and their susceptibility to invasion. This chapter highlights recent advances in seed bank research, globally, locally and within the context of invasion biology. It also suggests directions for future research in riparian systems.

Key words: riverine areas, soil-stored seeds, IAPs, invasion ecology

1.2 INTRODUCTION

The seed bank is defined as 'a reserve of viable seeds, fruits, propagules and other reproductive plant structures in the soil' (Goodson *et al.,* 2001). Seed banks reveal the history of lost vegetation; after destruction or disturbance of vegetation by fire, overgrazing, drought, flooding or alien vegetation invasion, seed banks are important for natural regeneration (van der Valk and Pederson, 1989). A study of seed bank composition assists in predicting the initial post recruitment vegetation composition. Seed bank data can yield information on three features of regenerating vegetation: (1) the species composition, (2) the relative abundance of recently recruited species, and (3) the potential distribution of each species (Welling *et al.,* 1988). Analyses of the compositional data of both the seed bank and above-ground vegetation can reveal which desirable species are lacking from the seed bank, and whether any undesirable species may become established. In disturbed or degraded sites, rehabilitation is intended to return the lost functions of ecosystems and a thorough understanding of the role of seed banks can be important for designing restoration projects (Richter and Stromberg, 2005).

This chapter reviews relevant literature on seed banks, both generally and within the riparian context, notes the gaps in research and offers recommendations for future seed bank investigations.

1.2.1 SEED BANK ECOLOGY

Seed bank studies are only recently developing into a body of theory as many studies in the past have yielded different classifications. The first published study by Chilcote in 1969 offered a fairly simple division of seed banks into four general categories (see Csontos and Tamás, 2003). By the early 1980's several studies had covered seed bank classification at much finer spatial scales (Thompson and Grime, 1979; Grime, 1981), each study refining the classification. By the mid '80's, Nakagoshi (1985) had refined 12 different categories. Grubb (1988) incorporated the aspect of disturbance in seed bank classification and differentiated three types according to the species' characteristic reaction to disturbance and the related soil seed bank recruitment:

1. '*Disturbance-broken'* types: have a soil seed bank that reacts to disturbances quickly. These species are natural pioneers, appearing first after a disturbance.
2. *'Risk-spreading'* types: retain a certain percentage of their soil seed bank even under favourable conditions. This is especially important for those species where there is a high, or even total, mortality of juvenile plants in certain years. It is thought that some kind of innate seed dormancy is involved in the lengthening of the germination period to several subsequent years, thereby reducing the risk of extinction (Harper, 1977).
3. '*Weather-dependent'* types: have seeds that 'read' a signal from the environment, indicating the occurrence of appropriate weather for germination. In the semi-arid areas, where this type is quite frequent, the signal is usually the wetting of the soil. In fire-dependent areas, the signal can be the raised temperatures, the chemicals in

the smoke or ash, or a combination of major and minor effects of a fire that may cause the seeds to germinate (Le Maitre and Midgley, 1992).

In addition to the paper by Grubb (1988), Leck (1989) compiled probably the first literature review focusing on seed banks in a variety of habitats. This was followed by Thompson's in depth look at the functional significance of seed banks (Thompson, 1992 and 1993). He came up with a three-category soil seed bank classification based on seed longevity. The types include:

1. Transient- the seeds are viable for a maximum of 1 year;
2. Short-term persistent- viability is longer than 1 year but less than 5 years;
3. Long-term persistent- viability is at least 5 years.

This terminology came under some scrutiny and as a result Thompson *et al.* (1998) proposed the longevity index (L) which arranges the species along a continuum of seed persistence:

$$L = (SP + LP) / (T + SP + LP),$$

where T, SP and LP represent the number of transient, short term persistent and long-term persistent records, respectively (Thompson *et al.,* 1998).

The majority of studies have investigated seed banks in soils of temperate terrestrial ecosystems, and mainly in Europe and North America. In recent years, with the increase in research on invasive alien species, several papers have been published which focus on the terrestrial components of seed banks within the fynbos region (Holmes 1990; Holmes, 2002; Holmes and Cowling, 1997a; Holmes and Newton, 2004) and likewise for other less-investigated habitats bordering the fynbos region (Jones and Esler, 2004; de Villiers, 2000). However, very little research has focused specifically on the riparian seed banks of the fynbos biome and the seed bank dynamics that exist in this region. Given what is known about riparian ecology, I would predict riparian seed banks in the fynbos biome to be comprised of mainly transient and short-term persistent species with patches of long-term persistence in areas of less intense disturbance. Although influenced by flood-related disturbances, fynbos riparian scrub (Closed Scrub Fynbos) is a fire-adapted vegetation type and includes many typical fynbos elements (restioids, proteiods, ericoids) that need fire for regeneration. Therefore, depending on the extent of fire frequency and representation of plant regeneration guilds in the vegetation (some thicket species resprout strongly after fire, while other species rely on seeds to regenerate) , the seed bank dynamics are expected to be a mixture of species with different life-history traits, each related to the disturbance regime of the particular sections of the river. Fire-related disturbances may affect patches of open riparian areas in the drier summer months when vegetation and surface soils are dry as a result of the lowered water table and wind velocities are high. Under such conditions, only the steep ravines and kloofs and boulder field areas would escape the natural fires that sweep through the neighbouring fynbos landscape (also see section 1.2.4).

1.2.2 LIFE-HISTORY STRATEGIES

Not much is known of how seeds are deposited into the soil. What is known is that the number of viable buried seeds of each species at any given time is largely dependent on the balance between "gains" and "losses". A gain in seed numbers by a species results largely from the amount of seed shed in the environment, which is in turn affected by the plants' abundance and seed production, and the proportion of seeds which become buried in the soil. The losses are due largely to germination, predation and death. Both gains and losses are affected by past and present environmental and management conditions, and how these interact with the species (Fenner and Thompson, 2005). Several studies have shown that many of the species that characteristically form seed banks are early-successional species (Goodson *et al*., 2001; Warr *et al.,* 1993; Thompson, 1993; Thompson, 1992). It is generally accepted that long-lived species have relatively short-lived seed banks whereas short-lived species have persistent seed banks. Kellman (1974) found that small quantities of seed from a forest regrowth stand could be dispersed into undisturbed forest and become incorporated into the seed bank. Beatty (1991) found that in a mosaic landscape, buried seed resulted largely from active seed dispersal within and between the communities studied. So no consensus has been reached on whether seed banks beneath climax communities are of earlier successional origin. This might be different, however, if we look specifically within highly disturbed systems, such as riparian habitats, and across different continents or biomes.

Various studies have explored spatial and temporal variation in soil seed banks, but much additional research is needed before a consensus can be reached. Thompson (1978) and Nakagoshi (1984 and 1985) showed there to be a general decrease in seed density down the soil profile and that seed bank density, as well as species richness, decreases with successional maturity of the vegetation. Late successional communities, such as climax forests, often have relatively few viable buried seeds (Whipple, 1978; Donelan and Thompson, 1980; Galatowitsch and Richardson, 2005) although new seed inputs may occur following opening of gaps in the canopy or undergrowth (Marquis, 1975) . It appears that in some floras, larger seeded species decay at faster rates than smaller ones (Toole and Brown, 1946; Thompson, 1987) and that seed bank size is affected by the proximity to disturbed areas (Young, 1985). Young's study looked at a 75-year-old secondary forest adjoining a young vegetation community in Costa Rica. The old forest was found to contain three times as many seeds in the seed bank compared to a forest of the same age 150 metres away from the disturbance. In other floras however, such as South African fynbos and in Australian kwongan shrubland, seed bank size does not appear to be correlated to seed persistence in the soil and the role of fire should be considered (also see section 1.2.4) (Holmes and Newton, 2004; Leishman and Westoby, 1998). The general consensus is that seeds have irregular, clustered spatial distributions, dictated by both biological and environmental factors (Thompson, 1978).

A lack of correspondence between the species present in the seed bank and in the current (above-ground) vegetation has been reported in grasslands (Thompson, 1987; Graham and Hutchings, 1988a and 1988b; Bakker, 1989), woodlands (Pratt *et al.,* 1984; Galatowistch and Richardson, 2005), and wetlands (van der Valk, 1981; Smith and Kadlec, 1983; Welling *et al.,* 1988). According to Goodson *et al.* (2001), this can be partly attributed to the reproductive strategies of the vegetation species concerned. Some species are known to produce many short-lived seeds, while others produce very few or no seeds at all and rely on vegetative propagation and asexual growth. Other plants, such as annuals, rely on the production of large numbers of seeds and, as a result, are often over-represented in the seed bank relative to the above-ground cover of the parent plant. Such contrasts can be attributed to the successional cycle of plant communities whereby the seed bank can be representative of species and vegetation types that are no longer observed in the current vegetation. In forest habitats, for example, seed bank species may represent early-successional species that can no longer survive in the shaded habitat of a dense forest, but are still present in the soil seed bank (Warr *et al*., 1993). In contrast, habitats with a high frequency of disturbance show similar species composition of the seed bank and the vegetation, for example in arable land (Wilson *et al.,* 1985) and some river systems (Goodson *et al.,* 2001, Leck, 1989). In undisturbed habitats there is generally less correspondence between the species present in the seed bank and the vegetation (Warr *et al.,* 1993). (Also see 'intermediate disturbance hypothesis' in relation to riparian areas in section 1.2.3.) Thompson (1992) found that seed banks beneath temperate woodlands were dominated by herbaceous species, with few trees and shrub species present; while seed banks of tropical forests consisted almost entirely of woody pioneer shrubs and trees. Several additional studies confirm a low representation of woody species in the persistent portion of the seed bank (Leck, 1989; Thompson *et al.,* 1998; Coa *et al.,* 2000), with those covering riparian areas confirming at general lack of correspondence despite variable disturbance patterns (Leck, 1989; Andersson *et al.,* 2000; Goodson *et al*., 2001).

1.2.3 SEED BANK DYNAMICS IN RIPARIAN SYSTEMS

Riparian ecosystems are fundamental for the delivery of key services such as the provision of food, dispersal of propagules, control of evapo-transpiration and water temperature, filtering of sediments, stabilisation of stream banks and support of faunal communities, and thereby form vital links between terrestrial and aquatic ecosystems (Galatowitsch and Richardson, 2005; Mackenzie *et al.,* 1999; Naiman *et al*., 1993). In this paper, the term "riparian" refers to the entire area of interaction between aquatic and terrestrial environments including the river channel, its banks and the contemporary flood plain (Gurnell, 1995).

The primary reproductive characteristics of riparian plants are selected trade-offs between sexual and asexual reproduction, timing of dormancy, timing of seed dispersal, seed dispersal mechanisms, seed size and longevity. Many riparian plants have specialised seed dispersal strategies that optimize propagule dispersal with the onset of the flooding season (Leck, 1989). Hydrochory (dispersal by water) is utilized by many riparian species. Some species additionally use vegetative reproduction, whereby segments of the roots or stems are broken off during flood or disturbance and may successfully re-root if they become lodged at a suitable site (Boedeltje *et al.,* 2003). Conducted on a low-order river in the Netherlands, this study found that throughout the riparian corridor, species distribution was more directly related to seed production per plant rather than morphological adaptations (for example, resprouting capability) (Boedeltje *et al*., 2003). In addition, it is important to note that not all species are represented in the seed bank. Some riparian tree species in the fynbos biome, for example, have short lived seeds that, with the use of hydrochory or avichory (dispersal by birds), are transported to a suitable site where their survival is highly dependant on their immediate germination. Such species include the Wild Almond *(Brabejum stellatifolium),* Yellowwood (*Podocarpus elongatus),* Wild Olive *(Olea europaeae* subsp. *africana),* Cape Holly *(Ilex mitis)* and the Wild Peach *(Kiggelaria africana)* which can have little or no presence in the soil seed bank although they are common riparian species.

Disturbance patterns within riparian zones are the major driving forces for the community's biodiversity and vegetation succession (Naiman and Décamps, 1997; Goodson *et al*., 2001). The quantity and quality of biotic material remaining to initiate succession depend on the type, intensity, frequency and duration of the disturbance (Decamps, 1996). Floods maintain heterogeneity within the riparian zone by creating pocket regeneration niches that facilitate the coexistence of co-generic species (Goodson *et al*., 2001), but are also responsible for preparing sites for invasion by additional species favoured by the new conditions. In general, riparian plant communities are composed of specialized and disturbance-adapted species within a matrix of less-specialized and less-frequently disturbed upland forest. Naiman and Décamps (1997) break the classification down further into four functional adaptation types.

1. INVADER: plants that produce large numbers of wind- and water-dispersed propagules that colonize available alluvial habitats.
2. ENDURER: plants that resprout after breakage or burial of either the stem or roots following floods or natural herbivory.
3. RESISTER: plants that withstand flooding for weeks during the growing season, moderate fires, or epidemics.
4. AVOIDER: plants that lack the adaptations to specific disturbance types causing individuals that germinate in an unfavourable habitat not to survive.

Some species are well suited as invaders, endurers or resisters depending on the local environmental conditions. Such species often prove to be optimal invaders (Richardson *et al*., 2000). Successful colonization, of native or non-native species, is dependent on the species' ability to successfully disperse, its ability to multiply and spread in the new habitat, and its ability to compete with established species. The species that are able to utilize the environmental conditions to their advantage and compete successfully will be more dominant in a given habitat or micro-habitat.

What makes riparian seed banks unique is that they reflect the hydrological, geomorphological and ecological interactions as a result of being subjected to constant fluvial processes that are extremely variable in space and time. Processes of erosion or deposition of sediment occurring on an intermittent, frequent or periodic scale as well as varying levels of inundation by river water, result in uniquely variable disturbance regimes for each river system. These complex natural processes undoubtedly affect the formation, establishment and persistence of riparian seed banks. In addition, there are many anthropogenic impacts such as land use, pollution, river channel engineering, and the regulation of river flow regimes that can affect seed banks along riparian systems (Naiman and Decamps, 1997; Goodson *et al*., 2001).

With such unique interactions taking place at multiple scales in each river system, it could therefore be expected that every sample within a single site will most likely demonstrate huge variation in species diversity and number of germinable seeds. Seed bank size, composition, and depth distribution are determined, in part, by seed longevity. Factors selecting for longevity are morphology (especially size, shape and seed coat thickness), and dispersibility (also a factor of morphology) (Leck, 1989). In the majority of cases, most seeds are found in the upper layers of the soil. For example, Nicholson and Keddy (1983) found that 81% of the seeds occurred within the top 2cm; and in a wetland study Leck (1989) found 80% of the seeds occurring within the top 4-5cm. However, this might not be the case in every riparian environment as disturbance cycles reveal unique erosion and deposition patterns of sediment, particularly after flooding.

In a study done by Harper (1977) on northern temperate wetland vegetation, it was found that more often than not, the seed bank was dominated by one species, and that species was usually a graminoid (Leck, 1989). This is thought to result of the variability of seed production, with one or a few species producing excessive seed numbers, while other common species may only contribute very few seeds, as was discussed earlier under general seed bank dynamics. In wetland communities, however, once established, some species have the ability to expand primarily by vegetative means which could add extensively to their local dominance (van der Valk, 1981). This phenomenon may explain regular disparities between above-ground floristic composition, and the seed bank composition (Leck, 1989). Annuals also form a high percentage of the seed bank composition, both within wetland areas (Leck, 1989), and within the fynbos seed bank composition (Cowling and Holmes, 1992) although generally herbaceous species dominate, with graminoids comprising >50%, while woody species are found predominantly on the edges of the riparian/wetland bank (Leck, 1989). Beismann *et al.* (1996) found in their study of the seed banks along the Upper Rhine River in Germany, that of the seed bank species recorded, only 25 and 20% (0-50cm and 50-250cm depths respectively) were present in the above-ground vegetation, and concluded that the dominant vegetation species were not well-reflected in the underlying seed bank. They hypothesized that large differences between the seed bank and above-ground vegetation were related to the transport cycles of the propagules, and could be expected in areas such as river systems that had medium to long transport cycles due to the utilization of water in seed dispersal. Goodson *et al.* (2001) confirm that the frequency and severity of soil disturbance within a given area has a direct influence on the above-ground vegetation and, ultimately, the underlying seed bank.

Colonization of river banks is tightly integrated with the high water or flooding season. New habitat patches become available through scour and erosion, allowing dispersal and deposition of fresh sediment, nutrients and seeds from the seed banks, and producing ideal sites for seedling germination through the creation of areas of moist sediment. Additionally, colonization and germination is highly dependant on connectivity to seed resources. In the majority of cases this occurs in a unilateral downstream direction (water dispersal) but can occur in a cross-community multidirectional manner with the assistance of animal dispersal mechanisms. In the absence of human or animal intervention, the downstream community relies almost entirely on the combination of upstream and adjacent terrestrial seed source for restoration success (Young, 1985; Nilsson *et al.*, 1991). When such seed resources are dominated by non-native plants, whether invasive or not, the integrity of the entire riparian community is threatened. This complex interaction further signifies the importance of timely clearance of alien invasive vegetation both upstream and adjacent to riparian zones so as to avoid further spread of the species through the system.

In addition to flood cycles, levels of inundation are thought to be highly influential to riparian seed bank species assemblages. Abernethy and Willby (1999) found that areas under permanent inundation generally had low species richness and low propagule germination. Moderately or intermediately disturbed sites (termed “damp mud”) had seed banks dominated by facultative aquatic species (ruderal hydrophytes), and greater disturbance led to greater similarity between composition of samples. The most intensely disturbed sites (termed "temporary backwaters") also had a large, species-rich propagule bank of mainly floodplain annuals, and it was in these sites that the above-ground vegetation most resembled the seed bank. In contrast, Brock and Rogers (1998) studied seed banks along the Nyl River in South Africa and found that the water regime history (permanent, season or occasional inundation) had little or no effect on the diversity or abundance of species present in the soil samples. These contrasting results illustrate once again the variability and uniqueness of riparian areas, making it almost impossible to compare studies between different rivers systems unless some form of heterogeneity is shared between the two communities.

Riparian areas and forests in particular, are valuable systems to study as they can provide insights into how plant species richness varies at regional scales with respect to natural disturbances (Naiman *et al*., 1993). Profiles along river courses are especially effective in evaluating the intermediate disturbance hypothesis for explaining biodiversity patterns (Nilsson *et al.,* 1989). This hypothesis proposes that biodiversity is highest when disturbance is neither too rare nor too frequent and is generally the most widely supported, especially in the riparian context. Nilsson *et al.* (1989, 1991) examined entire rivers in northern Sweden and found that riparian vegetation was most species rich in the middle reaches of free-flowing rivers. Décamps and Tabacchi (1994) found similar patterns in French rivers. Ultimately, each riparian system should be treated as an individual ecosystem and studied within its own biophysical parameters. Comparisons can only be made when spatial and temporal heterogeneities can be quantified.

1.2.4 THE ECOLOGY OF SOIL SEED BANKS IN THE FYNBOS BIOME

The combination of seeds that accumulate in the soil allows for the succession of the variety of species within the fynbos biome and is an attribute of the biodiversity of this region (Musil, 1991; van Wilgen *et al*., 1996). Regeneration from soil seed banks is generally led by annuals, forbs and short-lived shrubs which provide soil stabilization and nutrient recycling into the soil for other species which, although simultaneously germinating, take longer to reach maturity (i.e. are longer-lived) and provide vegetation at later successional stages. Unlike the fire-prone fynbos vegetation whose dependency on fire for regeneration has been well studied, the influence of fire on seed germination within riparian areas has had little research attention (Manders, 1990). River corridors, especially the higher reaches which are protected by deep ravines or rocky outcrops, may evade natural fires that run through the neighbouring fynbos vegetation because of their high moisture level, both in the ground and within the vegetation, together with their topographical postion (Sieben, 2002; van Wilgen *et al*., 1990). However, under hot summer conditions, fynbos fires are known to burn through riparian vegetation in more open topography (Holmes pers comm., 2006). Additionally, the presence of invasive tree species could allow summer fires to be more severe in riparian vegetation, owing to their increased biomass, threatening the persistence of riparian tree species (Manders, 1990).

Although fire regimes are relatively well researched in the fynbos biome (Bond, 1980; le Maitre and Midgley, 1992), and may be utilized to understand and help manage the fynbos elements of riparian vegetation, the influence of fire on certain riparian species is less understood (mostly Afrotemperate Forest tree species). Riparian areas are mosaics of habitat-specific (disturbance-related) species and form a network of micro-habitats which share similar disturbance (fire/flood) regime requirements. For example, the outer sections of the riparian zone (the drier areas) have notably dominant species groupings (*Berzelia lanuginosa - Cannamois virgata* community) (Prins, 2003), which are structurally adapted to promote and utilize fire. In contrast, the wetter, internal patches of the riparian zone (often dominated by the *Podocarpus latifolius – Brabejum stellatifolium* community) (Prins, 2003), have structural and/or morphological differences such as waxy leaves and thicker bark which prevents fires from spreading into those patches. The various community relationships form unique patterns of species assemblages within the riparian landscape which allows for a variation in fire disturbance, and results in high alpha and gamma diversity.

As previously discussed, seed bank formation can be broadly divided into two main groups, those species that form transient seed stores (remaining viable for one year), and those that form persistent seed banks (seeds remain viable for more than one year) (Thompson, 1993; Warr *et al*., 1993). The transience or persistence of seeds in the soil is part of the regeneration strategy adopted by the species (Murdoch and Ellis, 2000) and many of the fynbos species actually fall between these two groups offering both transient and persistent seed banks. These species have the potential to use both sprouter and seeder mechanisms of regeneration depending on environmental conditions (Parker and Kelly, 1989; Cowling *et al.,* 1997). In California's chaparral vegetation (climatically similar area to the fynbos biome), Parker and Kelly (1989) found that a number of species with transient seed banks appeared to lack any form of dormancy and tended to disperse seed just prior to germination. Still other species follow the within-year dormancy patterns which are based on stratification or after-ripening requirements. However, chaparral differs substantially from fynbos in its regeneration strategies. Fynbos is globally unusual for woody vegetation (with the exception of kwongan with which it is most similar) in having a high proportion (close to 50%) of obligate reseeder species in the vegetation. By far the most common strategy in woody vegetation is the resprouting mode, and this is the ancestral response for woody species (Holmes, pers comm., 2006). Furthermore, in both chaparral and fynbos communities, aerial seed banks in the form of seed retention in above-ground serotinous cones is a prominent regeneration strategy in the fynbos overstorey stratum. Many species in the *Proteaceae* family use this form of seed retention although variation may occur among and within species and between geographic locations (Cowling, 1987). Fire-dependant seed release is used by most serotinous fynbos species. The timing and quantity of seed release is directly related to the fire temperature and cool, wet, post-fire conditions, among other environmental conditions (Parker and Kelly, 1989; Bond and van Wilgen, 1996). Such variations in serotiny illustrate the role of fire in the selection for dormancy and long-term seed storage (Parker and Kelly, 1989).

Information on dormancy characteristics and seed longevity are highly relevant to seed bank research, yet relatively few studies have attempted to estimate how dormancy and the effect of fire influences seed bank dynamics. Pierce and Moll (1994) found that of the six shrubs selected and tested for their differing germination conditions, all showed surprisingly similar requirements. Additionally, the best results were found under a combination of requirements, specifically alternating diurnal temperatures (20° /10° C and 30° / 15° C for 10/14 h, Light/Dark over 60 days) together with the removal of insulating vegetation (by fire or vegetation clearing). Holmes has done more recent work (2002) investigating patterns of seed persistence and the impact of invasive species in fynbos communities. Her results show that seed bank composition and guild structure change following invasion and, particularly within the sand plain fynbos seed banks, resulting in the low presence of long-lived obligate seeders. She concluded that in those conditions, sand plain fynbos will be difficult to restore from the seed bank alone following alien clearance (Holmes, 2002). In a more fine-scale study on seed persistence of particular fynbos species and families, Holmes and Newton (2004) found many Fabaceae, *Pelargonium* and nut-fruited Proteaceae species to have long-term persistent seed banks as a result of their hard-seeded nature. Conversely, the serotinous species of Proteaceae generally formed transient seed banks and tended to lose viability after 6 months of burial

(*Protea* sp.) although a low proportion of serotinous *Leucadendron* species were able to persist and maintain viability after 3 years. Smaller seeded species like Ericaceae seemed to use light as a germination cue rather than smoke or heat, but it is suggested that more research needs to be done on the response to light by small-seeded species generally before conclusions can be made (Holmes and Newton, 2004).

Parker and Kelly (1989) found that in most fire-prone mediterranean communities, woody species continue to produce seed and add to the seed bank between fires. In the case of short-lived plants (such as annuals, fire ephemerals and short lived perennials) time between fires and seed longevity becomes vital to the populations' survival. Persistence in the seed bank as well as response to the next fire is dependent upon the seeds' longevity and death rates (Parker and Kelly, 1989). Bond (1980) found large declines in dicotyledon regeneration in older fynbos stands and a resulting shift in the seed bank composition towards monocotyledons. In his study, all Proteaceae plants were serotinous, and although prematurely opened seed cones should allow some seeds to enter the soil seed bank, results show that seeds reaching the soil before a fire will find conditions unsuitable for germination, thereby losing viability or suffering heavy predation losses. Additionally, within the fynbos, processes such as myrmecochory (active seed burial by ants) and movement of seeds by rodents is frequently found- particularly myrmecochory which was found within at least 29 families and 78 genera by Bond and Slingsby (1983) - and should therefore be a vital aspect to consider in future seed bank studies in within this region.

1.2.5 RIPARIAN VEGETATION IN THE FYNBOS BIOME

Riparian vegetation within the fynbos biome is fairly distinctive from the surrounding fynbos vegetation (Boucher, 1978). The composition of the riparian community varies according to the phytogeographic affinity towards either the fynbos or Afrotemperate Forest vegetation groups; which are, in turn, dependent on several environmental factors including stream size and position in landscape, local topography, and surrounding soils, vegetation or land use (Holmes, 1998). The most recent description defines three broad community groups termed Fynbos Riparian vegetation, Cape Lowland Alluvial vegetation, and Cape Lowland freshwater wetlands running from upper catchments, through the floodplains and into the wetlands respectively (Mucina *et al.,* 2006; Rebelo *et al.,* 2006). Riparian communities with a fynbos affinity have been described as Closed-Scrub Fynbos (Cowling and Holmes, 1992) or Broad Sclerophyllous Closed Scrub (Kruger, 1978). Such communities are usually found in the mountain stream or montane reaches of rivers where the extent of alluvium is limited as a result of the high levels of erosion.

In deep gorges or kloofs where protection from fire is afforded, Afrotemperate Forest communities usually form the dominant vegetation in riparian zones. Dominant species in these forests include *Rapanea melanophloeos, Halleria lucida, Maytenus acuminata, Cunonia capensis, Ilex mitis* and *Podocarpus* species (Boucher, 1978; McDonald, 1988; Manders, 1990). These forests usually have a fairly abrupt boundary with surrounding fynbos vegetation which is maintained by fire (Midgley *et al*., 1997). As the gradient and water velocity decrease, the ability of the river to deposit becomes greater, providing a suitable alluvium base for dense Closed Scrub communities to develop (Boucher, 1978). Dominant species in Closed Scrub Fynbos include *Metrosideros angustifolia, Brachylaena neriifolia, Salix macronata, Leucadendron salicifolium, Cunonia capensis, Rapanea melanophloeos* with dominant graminoids such as *Calopsis paniculatus, Cannomois virgata* and *Elegia capensis* (Boucher, 1978, van Wilgen and Kruger, 1985; McDonald, 1988; 1993). In slower-flowing permanent streams, the entire zone may be dominated by dense stands of swamp communities of *Prionium serratum* with additional low-growing species (Boucher,1978).

Recent studies done by Reinecke and King (2007), Prins (2003) and Sieben (2002) added significantly to defining the composition and community structure of riparian areas in the fynbos biome, particularly so in the upper reaches of the catchments (Sieben, 2002). Prins (2003) found five distinct communities with the riparian areas in her study while Sieben's (2002) study was more extensive and thus found 26 riverine and 11 mire communities. Mucina *et al*. (2006) and Rebelo *et al.* (2006) combined several relevant community studies to come up with a broad classification of fynbos riparian vegetation to be utilized at the landscape scale. (For summarised descriptions of Prins 2003, Sieben 2002, Rebelo *et al.* 2006 and Mucina *et al*. 2006 see Chapter 2; Appendix 2.1, Tables A1-A3).

1.2.6 THE IMPACT OF INVASIVE ALIEN SPECIES ON SEED BANKS

Riparian areas are highly susceptible to invasion by alien vegetation (Rowntree, 1991; Planty-Tabacchi *et al.,* 1996; Galatowitsch and Richardson, 2005). It is widely understood that the current state of rivers in South Africa and worldwide is very poor and becoming increasingly affected by invasive alien species. Such susceptibility to invasion within riparian areas is thought to be a result of the exposure of riparian vegetation to periodic natural and human related disturbances, dynamic nutrient levels and hydrology, water dispersal of propagules, and the role of stream banks as a seed reservoir for both indigenous and exotic species (Rowntree, 1991; Galatowitsch and Richardson, 2005). The result of such invasions is the inability of the river to provide many, if not most, of the ecosystem's hydrologically-related services (Galatowitsch and Richardson, 2005).

There is a significant reduction in indigenous seed-bank density and richness, as well as a change in both seed-bank composition and guild structure following the invasion by woody alien species in terrestrial fynbos habitats (MacDonald and Richardson, 1986; Holmes, 2002; Holmes, 2001). In older invasive alien stands, fynbos seed-banks are significantly smaller than the extensive seed banks of the alien species (Holmes, 2001). Rejmánek and Richardson (1996) found that the major characteristics of invasive species include a short juvenile period and short intervals between large seed crops, allowing for early, continuous and exponentially increasing reproduction, ultimately leading to rapid population growth. They related small seed mass with high seed production, successful dispersal, higher germinability following after ripening, and high seedling relative growth rates. The presence of a persistent seed bank is also a typical characteristic of successful non-native plant invaders, which allows rapid re-invasion after clearing. Furthermore, nitrogen-fixing invasive species alter the chemical balance in the soil making it incompatible for many fynbos species thereby selecting for invasive over native species.

Elton's (1958) classic hypothesis that diversity enhances community resistance to biological invasions has regularly been questioned in invasive biology. In their review, Naiman and Décamps (1997) state that there is a consistent trend of the richest communities exhibiting the greatest proportion of exotics. This was found along all the rivers they sampled as well as within specific sites. Stohlgren *et al*. (2003) found similar patterns (the "rich get richer") at varying spatial scales and in various habitats throughout the United States. This suggests that the richest communities in riparian corridors may be the most invasible because of the substantial environmental heterogeneity created by moderate floods, but little evidence is available to support or disprove this hypothesis.

Levine (2000) looked at susceptibility of diverse communities to invasion by bringing aspects of propagule pressure into context. His experiments showed that in a relatively unaltered riparian corridor, propagule supply makes the most diverse communities the most likely to be invaded. Additionally, he concluded that Elton's hypothesis may not reflect the intrinsic effects of diversity. For example, positive correlations may result from a similar response of native and exotic species to environmental conditions. One of his major findings was that as native species richness increased, the proportion of propagules that germinated and survived to the growing season significantly declined for two of three invaders studied. Therefore, even with the spatial variability of a natural system, diversity can significantly enhance resistance to biological invasions. However, factors co-varing with diversity such as disturbance, propagule pressure, and species composition may be important drivers of community-level patterns of diversity and invasion. Further investigation into these co-varying factors is fundamental, as they may be responsible for the relatively high frequency of invasions into naturally diverse communities and could offer insight into patterns both at community- and neighbourhood- scales.

Within the fynbos context, several invasive species have been noted for their reproductive characteristics, particularly seed bank dynamics, and their level of association with riparian systems. Such examples included studies done by Holmes and Cowling (1997b) on *Acacia saligna*, a hard seeded legume with soil-stored seed banks; Pieterse (1997) who investigated three woody leguminous invaders; and Richardson and co-workers who focused on the serotinous pines with canopy stored seed banks (Richardson and Bond, 1991; Richardson *et al.,* 1990; Richardson *et al.,* 1994). All agreed that invasion caused a decrease in species richness, cover and frequency of native plants within their natural ecosystems. Invasive characteristics are shared by many of the above-mentioned species, most notably the invasive *Acacia* species. Such characteristics include having a large persistent seed bank that accumulates rapidly as a result of the prolific quantities of seeds set per flowering season. The time taken for plants to reach reproductive maturity is usually short (in *A. mearnsii* as short as 20 months) which means that seeds begin accumulating over a far more extensive period than for most native plants. In addition, the seeds are long-lived unless stimulated to germinate by a disturbance, most especially fire (Holmes, 1989). Adult plants often coppice after burning or felling and some species, like *Acacia melanoxylon*, can also form profuse amounts of root-suckers once the roots have been exposed (Moll, 1978), all of which allows for additional regeneration. Although structurally (they have a higher water content) harder to ignite than fynbos vegetation, once ignited, the alien *Acacia* species burn with greater severity owning to their higher biomass (van Wilgen and Richardson, 1985). As a result of an increase in biomass, the fire is excessively fuelled causing temperatures to rise to the detriment of soil-stored seeds, micro-organisms and all fauna in and around the river system. Although not within the riparian context, Holmes (2002, 1989) has shown the damage that artificially hot fires can cause to the fynbos seed bank. The most common result following a high intensity fire are soil temperatures raised to such a degree that they damage the soil and cause seed mortality to a depth of 4cm or more (Holmes, 2002; 1989). This destroys mainly the sensitive indigenous seeds that are generally concentrated in the upper 3cm of soil and promotes the robust recruitment from the alien invasive seed bank. An additional pre-adaptation of invasive species is that many are serotinous (seeds protected inside cones) and the seeds are released in large quantities after a fire (Holmes, 2001). This adaptation is shared by many fynbos species, thereby causing severe competition in the critical germination period.

Management of such invasive species needs much foresight and long-term commitment. Currently, in South Africa, the clearance of invaded sites is seen to be such an enormous task (both financially and physically) that few resources are allocated for adequate follow-up treatments. In some cases, this results in an almost redundant clearing effort. Recently, Holmes *et al.* (2005) published a paper focusing specifically on invaded riparian areas within South Africa; reviewing the impact of invasion on riparian areas, current practices of alien-clearing in these areas, and suggested a useful decision-making framework for more effective restoration of riparian areas. The review indicated several present short-comings both in research and practical application. Firstly, successful restoration of riparian areas depends greatly on the effective and constant management of upland ecosystems and neighbouring landscapes. Practical and economically sustainable solutions need to be promoted and brought into current alien clearing programmes. An example of this is that collection and sowing of seeds should be part of alien clearing programmes to reintroduce the long-lived riparian species that may be lacking in the seed bank. Secondly, that the past and present socio-economic factors preventing natural stream flow and flood disturbances (that are responsible for maintaining natural biodiversity), must be limited as far as possible. And thirdly, that a long-term commitment is vital in terms of planning, implementing and monitoring, all of which should be based on up-to-date research that is practical and applicable.

1.3 CONCLUSION

What is known about fynbos seed banks:

1.) Persistent seed bank patterns and germination cued by fire are common owing to the fire disturbance patterns associated with the fynbos.

2.) There seems to be a general lack of correlation between seed size, shape and persistence in fynbos. This is probably the result of the prominence of myrmecochory and caching by rodents, both of which result in burial of larger seeds.

3.) Several insect (ants) and animal (rodents) species interact with seed bank dynamics and it is hypothesised that burial may induce secondary dormancy for certain species that would otherwise germinate prior to burial. These species will then have the added advantage of surviving underground and forming persistent seed banks. Such dynamics must be incorporated in future studies of this nature.

4.) Long-term persistent seed bank species are unlikely to become locally extinct unless the fire interval exceeds their life span

5.) Some longer-lived obligate seeder species have short-term persistent seed banks and may rely on annual seed inputs to maintain their soil seed banks.

6.) Some species rely on a combination of seeder and sprouter abilities to be utilised under suitable conditions which secures the population after an intense fire.

7.) Fynbos seed banks are greatly threatened by invasive alien plant species which are able to produce profuse seed from early life stages, and have highly competitive and plastic qualities.

8.) Only in the case of very long-invaded stands is there little to no indigenous seed germination from the seed bank.

What is known about riparian seed banks from fynbos-like biomes:

1.) Riparian seed banks are highly complex and the vegetation directly reflects the unique interactions within that region of the river.

2.) To date, there are few data offering fixed patterns of persistent or transient seeds in riparian seed banks, however rough guidelines can be drawn along inundation levels, with transient seeded species more likely to occur in habitats with high inundation and persistent seeded species on the upper reaches.

3.) Flooding is the major (and vital) source of disturbance and fire generally evades the topographically protected areas of the riparian corridor.

4.) The most common reproductive adaptation is a combination of vegetation and sexual reproduction with the utilization of hydrochory to spread the seeds and vegetative structures.

5.) Some dominant tree species are dispersed by animals and therefore not often present in the soil seed bank but still play a vital role in the community. In the restoration of post-cleared sites, supplementing (in the form of planting rather than seeding) of these species would be at an advantage to the integrity of the community.

6.) Diversity appears to be highest in areas of moderate disturbance, the main river system offering significantly higher diversity than the tributaries.

7.) Riparian areas are highly susceptible to invasion by alien species and timely control of invasion is fundamental to prevent species spread and further community integrity damage.

There is a clear divide between riparian vegetation and its neighbouring fynbos community in the field. On paper it seems even more so. Although several aspects are shared between riparian and fynbos communities, it is crucial to distinguish the differences and treat them accordingly. For example, both areas react positively to a relatively high level of disturbance. However, in fynbos communities fire is the driving force of disturbance whereas in riparian areas both fire and flooding are important drivers. The seed banks within each system should therefore be unique in composition and dynamics and it is unlikely that any close comparisons can be found. It is, however, an area that deserves immediate attention. With the ever increasing demand on natural water resources, any aspect that can assist in the restoration and rehabilitation of our transformed river systems is essential. Seed bank studies can provide a sound resource to be utilised in restoration ecology and much can be said from what has already been covered. However, there is a need for more research. Data on seed banks is often incongruent and makes comparisons across studies and communities difficult if not impossible. Some of the most common problems include heterogeneity of sampling methods, insufficient number of samples, failure to sample throughout the year and for more than one year, failure to consider dormancy breaking and germination requirements, lack of controls, inadequate provision of summary data, and failure to analyze the data statistically. What is necessary is good basic knowledge of the community that is “under-construction” as it were, most especially including life-history traits and the major controlling environmental variables for the system. That knowledge can make it possible to manipulate the structure and development of riparian plant communities, and to interfere at vulnerable stages of the growth or development of the target weeds in order to achieve alien control goals. This information is vital to enable managers and landowners to conserve, restore and equip their people with the necessary skills to protect the land from further destruction.

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1.5 PERSONAL COMMUNICATIONS

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CHAPTER 2: INTRODUCTION TO STUDY

2.1 THESIS OUTLINE

This thesis explores the riparian seed bank composition of invaded and reference (un-invaded) sections of four river systems in the south-western part of the Western Cape, South Africa, with the aim of providing insight into the potential restoration use of riparian seed banks after alien clearing in these areas. Chapter 1 is a review of the current seed bank and riparian ecosystem literature both globally and within the fynbos context. This review highlights the lack of investigation into riparian seed bank ecology, specifically within the fynbos biome. This chapter (Chapter 2) provides more details into the rationale of the research project, offering thesis outline, objectives, study area information and details on methods used. As most of the chapters are written in *South African Journal of Botany* format (Chapters 1, 3, 4 and 5), detail that was found to be excessive in those chapters is included here in Chapter 2. Chapter 3 introduces fynbos riparian seed banks within un-invaded (reference) state and investigates the seed bank composition in terms of species assemblages, diversity indices as well as briefly looking at the similarity of above-ground and seed bank species. The impact of invasion of riparian areas is investigated in Chapter 4 by comparing reference and invaded samples in terms of species assembly patterns, diversity and similarity indices at three different spatial scales; landscape (between rivers), reach (mountain stream and foothill) and zone (wet bank and dry bank). Chapter 5 takes a broad look at the seed bank assemblages of the entire data set (i.e. invaded and reference samples) in terms of possible community groupings, as well as investigating the similarity of species between above-ground and seed bank assemblages. Final conclusions are discussed in Chapter 6 bringing the research project as a whole together and offering practical restoration recommendations to be utilized by land-owners and managers as part of future alien-clearing programmes.

2.2 OBJECTIVES

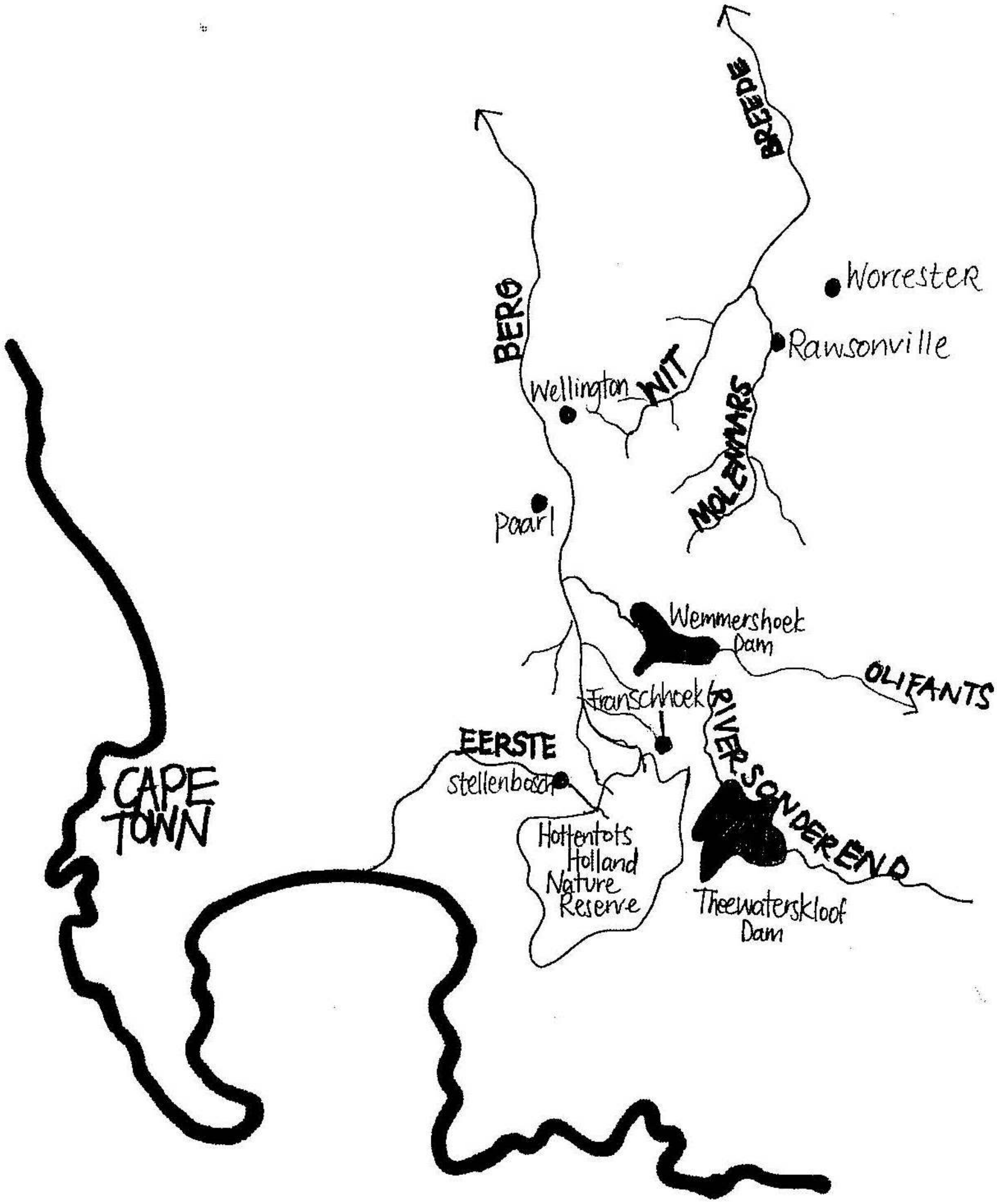
The main objective of this study was to investigate to what extent soil seed banks influence and limit the recovery of vegetation in riparian areas after clearing of alien invasive vegetation. Several variables and co-variables were taken into consideration. The major variables being the state of the above-ground vegetation (reference vs. invaded), the alien plant species, the density and history of alien species and the clearing methods and time since clearing. The co-variables incorporate the abiotic factors, the longitudinal reach type (mountain stream or foothill), the lateral bank zones (wet, transitional and dry) and the surrounding ecosystem conditions.

The aims of the project were:

- To record alien and indigenous soil seed bank composition over a range of riparian habitats through sampling and analysis;
- To relate seed banks to above-ground vegetation;
- To make recommendations as to whether seed banks may be relied upon to restore cleared riparian zones and/or when other interventions may be necessary;
- To offer achievable goals for riparian ecosystem repair based on desired characteristics for ecosystem in the future rather than being restricted to some historical ecosystem of the past (i.e. appropriate targets to be set based on degree of ecosystem degradation and in relation to other environmental variables).

2.3 STUDY AREA

The study area falls within the fynbos biome which is characterised by winter rainfall and summer drought, with more than 60% of the rain falling between April and September. Most mountains in the Western Cape receive between 1000 and 2000mm of rain per year, although in some areas (like the Jonkershoek mountains) it might exceed 3000mm (Sieben, 2002). Four river systems within this region were chosen for their variety of reach types, history of vegetation (both alien and natural), and for their relatively close proximity to the research facilities. Both reference and invaded plots were selected along the same four river systems; the reference plots were located within sections of the rivers that were relatively undisturbed riparian areas (< 25% alien plant canopy cover), and the invaded plots were selected in heavily invaded areas (> 75% alien plant cover). Two factors were taken into consideration when setting up the sampling plots, namely lateral (wet & dry bank) and longitudinal (mountain stream and foothill) zones. A summary of the localities of the sample sites is shown in Table 2.1.



<u>Figure 2.1</u>: Map of study area of four river systems (Berg, Eerste, Molenaars and Wit Rivers) within the Western Cape, South Africa. Map Scale 1: 825 000.

2.3.1 THE BERG AND RIVERSONDEREND RIVER SYSTEMS

With the exception of the Franschhoek Pass, which is drained by the Riversonderend River, also included in this study, nearly the whole of the northern section of the Hottentots Holland Nature Reserve is drained by the Berg River. The Minister of Water Affairs granted permission for the construction of a new dam in the Franschhoek Valley in 1997, and construction is currently underway. This dam will dramatically alter the flow of the Berg River. Reports show that the majority of foothill and flood plain zones between Franschhoek and Paarl and up to the La Motte plantation are highly disturbed by canalization and virtually all riparian vegetation has been replaced by exotic and invasive species (Burgers 1992, Sieben 2002). For this reason, reference study sites were limited with two sites falling within the Le Motte Plantation (Assegaaiboskloof, numbered 1 & 4 in Figure 2.2 a), and the remaining sites were located within the adjacent Riversonderend catchment. Alien clearance within the riparian areas has been conducted throughout the Le Motte plantation since 2001. A fire swept through the valley in 1999 and burnt almost all of the vegetation. A subsequent fire swept through the entire mountain catchment in January 2006 burning both invaded and natural riparian areas.

Shortcomings in locations for reference plots in the Berg River catchment resulted in additional reference plots being located in the Riversonderend River catchment. These samples were then added to (and referred to hereafter as part of) the Berg River system. The mountain stream sites in this area fall within the Mont Rochelle Private Nature Reserve (numbered 2 & 3 in Figure 2.2 c), which had relatively pristine fynbos and riparian vegetation with little evidence of disturbance. Minor invasive alien plant (IAP) infestations have been controlled by both CapeNature and the private owner for the past four years. In 1998 a large fire swept through the area and evidence of this natural disturbance event was found on a few sites. The remaining reference foothill sites were located in RusBos Nature Reserve (numbered 5 & 6 in Figure 2.2 c) which falls under the Theewaterskloof Nature Reserve. This area was previously impacted by invasive aliens but samples were taken from areas recorded to have < 25% invasion history and currently the vegetation (both riparian and fynbos) is well established and recovery appears positive. Alien clearance has been administered by CapeNature on a fairly intensive level since 1995. Two fires burnt through this area within approximately the last ten years, most recently in 2000. Sampling sites were chosen where vegetation was relatively uninvaded (<25%) and where vegetation recovery age could be estimated at between five and six years.

Three invaded mountain stream plots (numbered 101 – 103 in Figure 2.2 a) and one invaded foothill plot (numbered 104 in Figure 2.2 a) were established within the Assegaaiboskloof Nature Reserve and sampling was done after the major fire of January 2006. Sites were selected on the basis of a detailed riparian study by Reinecke and King (2007) together with information on invasion history acquired from the reserve manager. An additional mountain stream plot was established along the Dwars River (numbered 107 in Figure 2.3) in the neighbouring catchment, in order to supplement the lack of suitable sites on the Eerste River. This mountain catchment also burnt during the fire season of 2005/2006 and the site was chosen with the help of Working for Water (WfW) staff (for more details on the WfW project see section 2.4.1) and site history data records. The final two foothill sites fell in the farming area outside of Franschhoek town on the Rhodes Fruit farm (numbered 105 and 106 in Figure 2.2 b) where the WfW team has initiated a project. Sites were sampled prior to clearing.

Figure 2.2 a, b & c: Locations of plots along the Berg and Riversonderend River systems: a: within the Le Motte forestry area of Assagaibos Nature Reserve; b: along the lower Dwars and Berg Rivers; c: the Riversonderend catchment within the Theewaterskloof Nature Reserve. Plots numbered 1- 3 = reference mountain stream plots, 4-6 = reference foothill plots, 101-103 = invaded mountain stream plots, 104-106 = invaded foothill plots. Map Scale 1:100 000.

2.3.2 THE EERSTE RIVER SYSTEM

The source of the Eerste River is in the Dwarsberg Mountains, some 1320m above sea level. The mountain stream zone flows through the Hottentots Holland Nature Reserve and into Jonkershoek Nature Reserve, where the vegetation comprises predominately indigenous fynbos and riparian communities. Once it leaves the reserve, the river flows through the town of Stellenbosch where it becomes highly disturbed by canalization and the dominance of non-native trees, particularly oaks (*Quercus robur*), poplars (*Populus canescens*) and gum (*Eucalyptus* spp.) trees. Additionally, several anthropogenic features such as dams and canals become evident. The Jonkershoek Nature Reserve has near-pristine indigenous vegetation status, and all reference sites fall within this area (numbered 7-12 in Figure 2.3). Invaded plots were established along the main river channel from the Assegaaiboskloof CapeNature Scientific Services Office (numbered 10 in Figure 2.3) to the start of the Stellenbosch University sports fields (numbered 11 & 12 in Figure 2.3). Alien clearing within the nature reserve is maintained by the CapeNature, however alien clearing on private land has been minimal, if at all, as no alien clearing initiatives (like WfW) are currently working in this sub-catchment. A fire swept through most of the reserve during the fire season of 1999/2000 and much of the upper riparian areas were burnt. There are no records of fire outside the reserve. This may be a result of the intense and long-standing urban developments along the lower reaches, as well as the resulting encroachment of non-native invasive species that are not fire-prone. Additional mountain stream plots were established on the adjacent catchment on Simonsberg slopes (numbered 108 & 109 in Figure 2.3) where two perennial streams were densely invaded, as well as along the upper reaches of the Dwars River, a tributary to the Berg River (numbered 107 in Figure 2.3). Much of the Simonsberg drainage area was burnt both in 1992 and 2000, including both sample sites for this study. An additional fire in 2006 affected some sections of the catchment, but sample plots were not affected. A few farmers have successfully cleared their sections of the catchment (e.g. Thelema Mountain Vineyards) while others are only just beginning (Quin Rock Wine Estate) or continuing (Tokara Wine Estate) the initial clearing process. Although progressing, problems have arisen due to neighbours in some of the above catchments neglecting the clearing of their land and thereby causing re-invasion in the subsequent sections of the catchment.

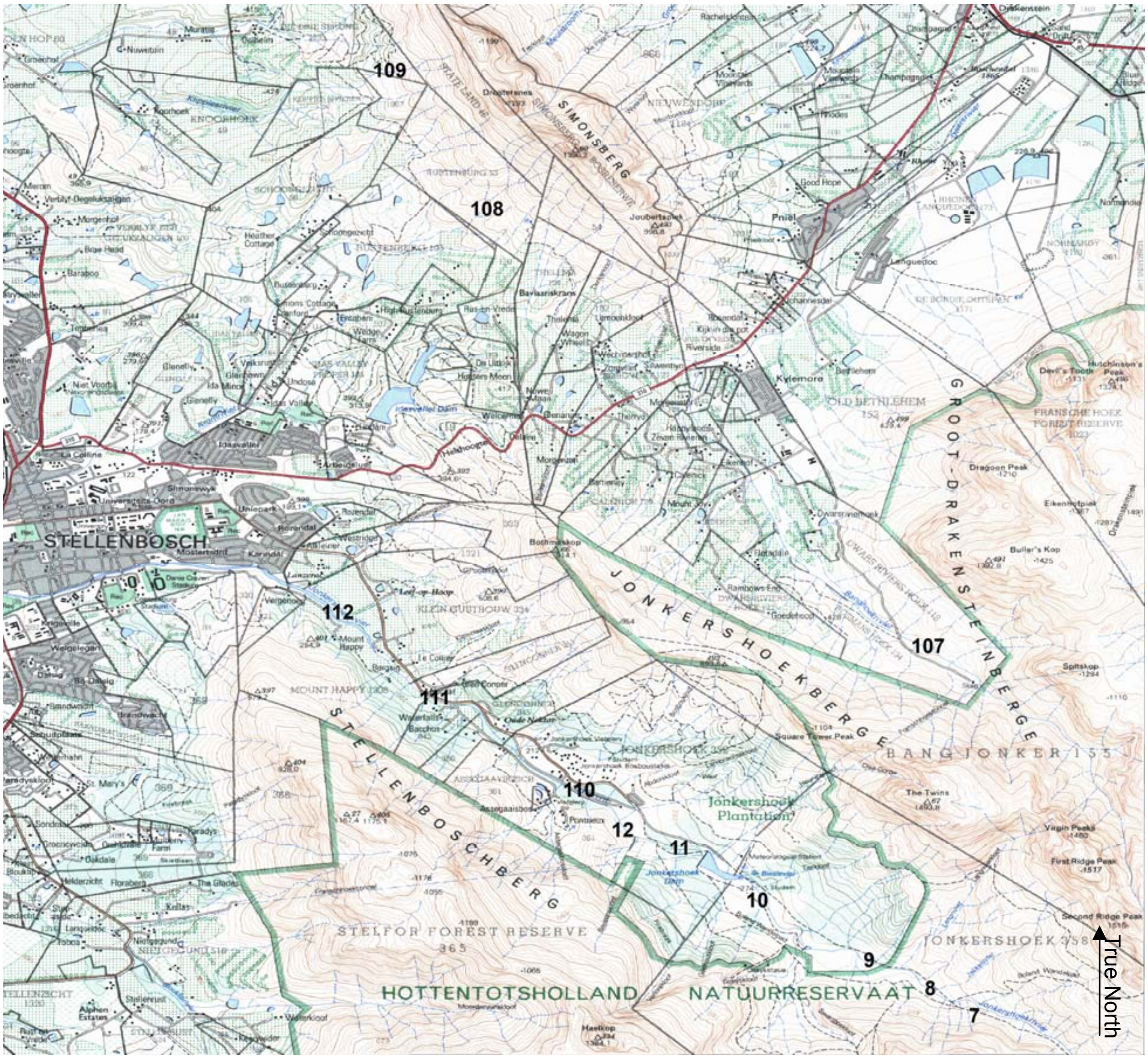


Figure 2.3: Locations of plots sampled within the Eerste River and neighbouring catchments. Plots numbered 7-9 = reference mountain stream plots, 11& 12 = reference foothill plots, 107-109 = invaded mountain stream plots, 110- 112 = invaded foothill plots. Map Scale 1:100 000.

2.3.3 THE MOLENAARS RIVER SYSTEM

The Molenaars has its source in the Du Toits Mountains and runs through the town of Rawsonville before joining the Breede River. Several tributaries start in the surrounding mountains and join the Molenaars, those included in the study are the Krom, Elands and Tygerstels Rivers. Alien clearance is evident throughout the river catchment and is ongoing. The main channel is fairly braided in sections with islands forming along much of its length. These islands are relatively close to either side of the river and become more apparent in the summer months with the decline of water levels, becoming partially submerged for much of winter. One of the reference foothill sites (numbered 17 in Figure 2.4 b) was located on such an “island” as the N1 highway runs along much of the adjacent river bank. The second reference foothill site (numbered 16 in Figure 2.4 a) is along the Elands River and is classified as an upper foothill zone and the third is at the junction of the Elands and Krom Rivers (numbered 18 in Figure 2.4 a). The reference mountain stream sites are on the Krom River (numbered 14 in Figure 2.4 a), on a small tributary that joins the Krom just upstream from the Huguenot Tunnel (numbered 15 in Figure 2.4 a), and on a small semi-perennial tributary to the Molenaars called Tygerstels River (numbered 13 in Figure 2.4 c). Invaded mountain stream sites were limited and one plot was established in the upper reaches of the Krom River (numbered 113 in Figure 2.4 a). Working for Water has been clearing along this river since 2002, which involved one major clean-up and two follow-up treatments commencing in December 2005. Inadequate follow-up clearance has allowed infestation to continue at a higher density than prior to initial clearance. Some riparian species have shown good recovery, although dense patches of *Acacia mearnsii* are still evident. No fire has swept through this section of the river in the last eight years. Supplementary invaded mountain stream sites were established in the Hawequas Scout Adventure farm in the Wellington area. Two plots were established in the tributaries to the greater Berg River system, the Spruit (numbered 114 in Figure 2.4 a) and the Dasbos (numbered 115 in Figure 2.4 a) Rivers. No clearance has occurred in the riparian areas and a fire swept through some of the upper catchments in 2004, although no evidence of fire was found in the sampled plots. The invaded foothill plots were located along the Molenaars River main channel within a private farm that is heavily invaded with black wattle (*Acacia mearnsii*) (number 116, 117 & 118 in Figure 2.4 b). Alien clearing was initiated a few years ago (with the assistance of CapeNature and the WfW team) along the lower reaches of the river and the riparian vegetation is recovering successfully. However, extensive dense stands still persist along the majority of the river banks, interspersed with a few indigenous riparian species. A long-term alien clearing management plan is in the process of being drawn up and the land-owner is fully committed to the project.

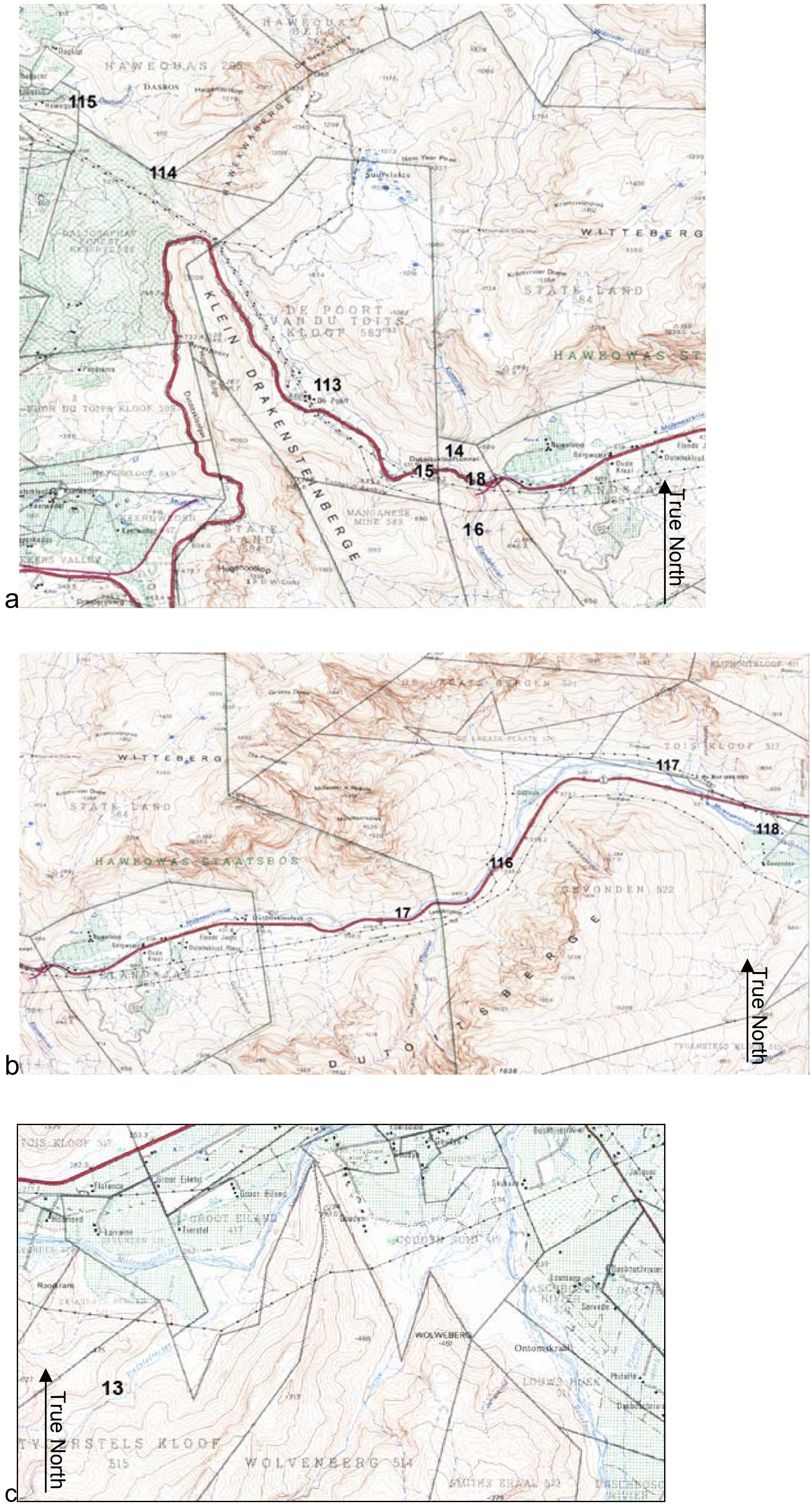


Figure 2.4 a, b & c: Location of plots sampled along the Molenaars River. Plots numbered 13-15 = reference mountain stream plots, 16-18 = reference foothill plots, 113-115 = invaded mountain stream plots, 116-118= invaded foothill plots. Map scale 1:100 000.

2.3.4 THE WIT RIVER SYSTEM

The Wit River runs along the Bainskloof Pass before joining the Breede River system. Alien clearance is still ongoing throughout the river, with the densest infestations found in the lower sections of the river. The area around Tweede Tol is known to offer the most characteristic riparian and fynbos communities, and all reference sampling sites fall within close proximity to this area. Reference mountain stream plots were located on the Wit main channel (numbered 19 & 20 in Figure 2.5 a) and along the Tweede Tol tributary (numbered 21 in Figure 2.5 a). Reference foothill sites were limited as a result of the dense infestations, one located on the Wit main stream just above a weir (numbered 22 in Figure 2.5 a), and the other on the Bastiaanskloof River which is a tributary to the Wit (numbered 23 in Figure 2.5 a). Heavy infestation is evident once the river leaves the Tweede Tol resort and enters into private land (Bastianskloof farm). Alien clearing has been initiated by the land owner, and with additional help from WfW and CapeNature (Limietberg), clearing is ongoing. Two invaded foothill sites were established along the Wit main channel within the private farm of Bastianskloof (numbered 123 & 124 in Figure 2.5 a). A fire swept through some section of the valley in January 2006 (affecting mainly the Tweede Tol area), but plots were established in unburnt areas. Invaded plots in the mountain stream sections were scarce and thus only one was established along the main Wit River system at Eerste Tol (numbered 119 in Figure 2.5 b) where most of the catchment has been cleared; however sampling occurred in a remaining dense patch of *Acacia mearnsii*. Supplementary invaded mountain stream (numbered 120 &121 in Figure 2.5 b) and foothill sites (numbered 122 in Figure 2.4 b) fell within the Limietrivier drainage network which shares its source with the Wit River in the Slanghoek mountains before it splits just above the Eerste Tol. Oaklands farm was used for the remaining foothill site (numbered 122 in Figure 2.5 b) under a dense stand of *Eucalyptus* sp. and *Acacia mearnsii*. A fire affected most of the terrestrial sections around the site, but certain sections of the riparian area were left un-burnt and a plot was established therein. Previous riparian research has been done on Oaklands farm (see Prins 2003).

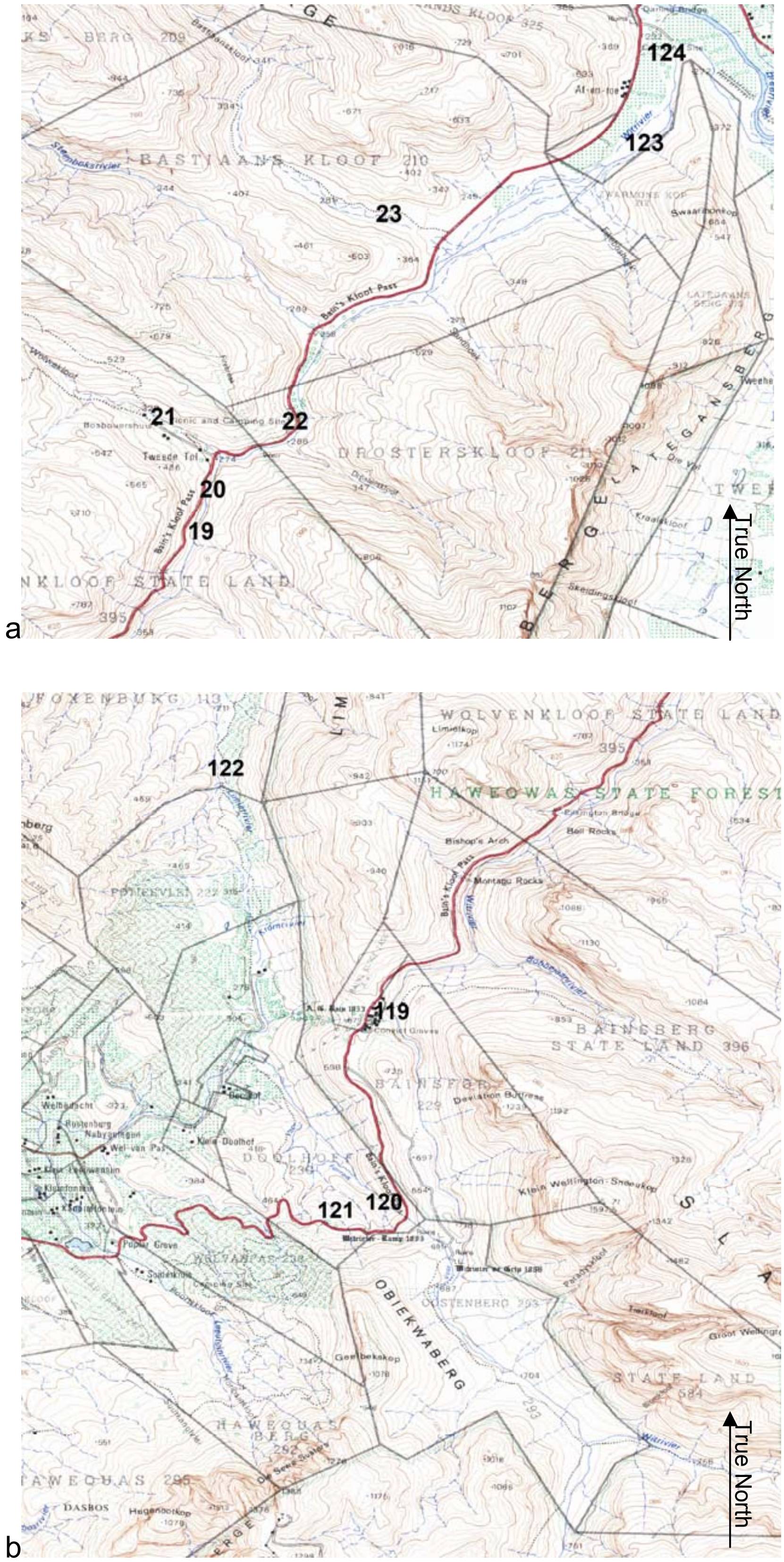


Figure 2.5 a & b: Locations of plots sampled along the Wit River system. Plots numbered 19-21 = reference mountain stream plots, 22 & 23 = reference foothill sites, 119-121 = invaded mountain stream plots, 122-124 = invaded foothill plots. Map Scale 1:100 000.

Table 2.1: Localities of riparian study sites along four rivers in the Western Cape, South Africa. (Site codes used for surveys and seed bank trays indicated in brackets)

	Eerste Reference	Eerste Invaded	Berg Reference	Berg Invaded	Molenaars Reference	Molenaars Invaded	Wit Reference	Wit Invaded
MOUNTAIN STREAM PLOTS	Eerste Witbrug (ErWbMS) S 33º 99’ 37” E 18º 97’ 61” Altitude 352m	Klippies River (ErKrMS) S 33º 52’ 36” E 18º 53’ 35” Altitude 713m	Ass’bos kloof (BgAssb MS) S 33º 59’ 07” E 19º 02’ 34” Altitude 353m	Frankryk River (BgAsb MS) S 33º 57’ 41” E 19º 03’ 30” Altitude 472m	Krom River (MolK1MS) S 33º 43’ 79” E 19º 06’ 53” Altitude 448m	Smaelblar River (MolDpMS) S 33º 43’ 06” E 19º 05’ 343” Altitude 563m	Wit main (Wit 1 MS) S 33º 34’ 27” E 19º 08’ 33” Altitude 276m	Wit Eerste Tol (Wit MS 1) S 33º 37’ 02” E 19º 06’ 05” Altitude 732m
	Eerste Main (Er2 MS) S 33º 98’ 49” E 18º 95’ 52” Altitude 325m	Tokara (ErTkMS) S 33º 53’ 52’ E 18º 54’ 54’ Altitude 419m	Du Toits River (Bg DT MS) S 33º 54’ 19” E 19º 09’ 77” Altitude 670m	Ass’bos trib (Bg Asb2 MS) S 33º 58’ 36” E 19º 04’ 57” Altitude 427m	Smaelblar River (MolK2 MS) S 33º 43’ 70” E 19º 06’ 61” Altitude 452m	Dasbos River (Mol Vk1 MS) S 33º 38’ 33” E 19º 04’ 44” Altitude 333m	Wit main 2 (Wit 2 MS) S 33º 34’ 20” E 19º 08’ 51” Altitude 279m	Bainskloof 1 (WitBK MS1) S 33º 40’ 46” E 19º 03’ 26” Altitude 713m
	Jakkals (Er J MS) S 33º 99’ 21” E 18º 97’ 33” Altitude 364	*Dwars River (BgDW MS) S 33º 56’ 54” E 18º 58’ 16” Altitude 398m * part of Berg River system	Perde Klip River (Bg 2 MR MS) S 33º 54’ 17” E 19º 09’ 83” Altitude 681m	Wolwekloof (BgWkMS) S 33º 56’ 24” E 19º 02’ 46” Altitude 257m	Tygerstels River (Mol MS 3) S 33º 43’ 23” E 19º 14’ 70” Altitude 311m	Spruit River (Mol Vk2 MS) S 33º 38’ 31” E 19º 04’ 41” Altitude 330m	Tweede Tol trib. (Wit Trib MS1) S 33º 34’ 06” E 19º 08’ 18” Altitude 300m	Bainskloof 2 (WitBk MS2) S 33º 41’ 07” E 19º 04’ 09” Altitude 713m
FOOTHILL PLOTS	Eerste 1 (Er 1 FH) S 33º 97’ 88” E 18º 94’ 99” Altitude 281m	Eerste S.bridge (ErSbFH) S 33º 56’ 27” E 18º 56’ 27” Altitude 138m	Ass’bos kloof (BgAsb FH) S 33º 58’ 02” E 19º 04’ 51” Altitude 310m	Dwars River (BgRfFH) S 33º 52’ 06” E 18º 59’ 52” Altitude 158m	Elands River (MolELFH) S 33º 44’ 43” E 19º 06’ 82” Altitude 468m	Molenaars 1 (MolDT FH) S 33º 42’ 30” E 19º 11’ 53” Altitude 345m	Wit wier (WitW FH) S 33º 34’ 13” E 19º 08’ 70” Altitude 261m	Wit main 1 (WitBk1 FH) S 33º 32’ 56” E 19º 09’ 47” Altitude 309m
	Eerste 2 (Er 2 FH) S 33º 58’ 45” E 18º 56’ 34” Altitude 234m	Eerste Asb. office (ErAbFH) S 33º 57’ 54” E 18º 55’ 27” Altitude 171m	Du Toits 1 (Bg1 TW FH) S 33º 56’ 92” E 19º 10’ 15” Altitude 345m	Berg main (BgRfFH2) S 33º 51’ 54” E 19º 00’ 02” Altitude 155m	Krom/Elands junction (MolK/E FH) S 33º 43’ 91” E 19º 06’ 86” Altitude 440m	Molenaars 2 (Mol1 FH) S 33º 41’ 48” E 19º 12’ 56” Altitude 284m	Bastiaanskloof trib (WitBk FH) S 33º 32’ 81” E 19º 09’ 07” Altitude 259m	Wit main 2 (WitBk2 FH) S 33º 32’ 24” E 19º 10’ 25” Altitude 246m
	Eerste 3 (Er 3 FH) S 33º 44’ 43” E 19º 06’ 81” Altitude 251m	Eerste Niel Ellis (ErNeFH) S 33º 57’ 20” E 18º 54’ 38” Altitude 192m	Du Toits 2 (Bg2 TW FH) S 33º 58’ 036” E 19º 09’ 365” Altitude 322m	Berg- Ass’bos (BgAsb FH) S 33º 57’ 43” E 19º 04’ 08” Altitude 280m	Molenaars main (MolM FH) S 33º 43’ 39” E 19º 10’ 73” Altitude 359m	Molenaars 3 (Mol CT FH) S 33º 41’ 48” E 19º 13’ 16” Altitude 303m		Limiet River (WitOkFH) S 33º 35’ 32” E 19º 05’ 01” Altitude 318m

2.4. TERMINOLOGY AND METHODS USED

2.4.1 THE WORKING FOR WATER PROGRAMME (WfW)

In an attempt to curb threats posed by invasive alien plants (IAPs), various alien clearing initiatives have been started in recent years, from private to government and from local to national. River corridors have been significantly targeted to avoid the spread of propagules along rivers and to increase the water availability (Richardson *et al.,* 1997). A prime example of such an initiative is The Working for Water (WfW) Programme which has been clearing invasive alien plants from disturbed landscapes throughout South Africa, but significantly within riparian corridors, since it's inception in 1995. The main aim of the project is to improve and increase both the quality and quantity of water production, and to conserve biodiversity (van Wilgen *et al*., 1998), which includes the full recovery of the fynbos vegetation cover following alien removal. However, limited budgets often result in unsatisfactory and inadequate results (Holmes, 1998; Holmes, 2001). Restoration that is found to be insufficient can result in soil erosion, loss of soil-stored propagules, poor water quality and the high risk of re-invasion by alien plant species (Holmes, 2001).

Through the programme, data gathered over the years shows that the dominant invasive species in mountain catchments areas are *Hakea* and *Pinus* species. *Hakea* species generally occur on the mountain slopes and not within the riparian area (pers obs. 2005-6). Occasional stands of mixed groupings occur, with resprouter species such as *Acacia mearnsii, Eucalyptus* species and *Leptospermum laevigatum* present (Holmes, 1998). In recent years populations of species such as *A. mearnsii* and *A. longifolia* have exploded in the many mountain catchment areas, although *A. longifolia* is now relatively well-controlled by an introduced bio-control agent, the bud-galling wasp (*Trichilogaster acaciaelongifoliae*) (McGeoch and Wossler, 2000). In such cases, it is vital to look for the best options for a specific catchment area and there are a variety of control options available for each invasive species (Macdonald, 2004; van Wilgen *et al*., 1992). In light infestations, the invasive species are slashed and material is stacked in piles which are then left on site to decay until the next fire. Any further regeneration of alien seedlings is removed prior to seed set. This approach has little impact on fire intensities, soils and surviving fynbos vegetation and has thus been found to be very successful if a systematic approach to clearing is maintained (Holmes, 1998). A more labour intensive approach is necessary for dense infestations whereby stands of the IAP are felled and left for 12 - 18 months to allow for seed release and germination. The site is burnt soon thereafter to kill off all alien seedlings. Follow-up visits at 1.5 - 2 year intervals to remove any invasive seedling recruitment will complete the programme for the site. Although successful in many areas, this technique has the potential to decrease indigenous recovery because of the increased risk of severe fires from the dry biomass left on site. Holmes (1998) recommends that felling be done outside the high risk fire period and that the dead biomass be burnt under cooler, wind-free conditions in situations where biomass levels are very high. This method decreases the possibility of damage to geophytes and soil-stored seeds, thereby improving vegetation recovery. In riparian zones within the Western Cape, the main problem species is the Black Wattle (*Acacia mearnsii*), which seems to be both drought and flood tolerant (pers. obs) and rapidly forms dense stands by means of resprouting *and* regeneration of soil-stored seed banks. With this species, the most common control is to remove if small enough (i.e. entire plant with roots) or cut to stump level and poison the stump to prevent resprouting. Follow-up treatments are very labour-intensive as seedlings germinate *en masse* almost immediately after fire.or when a nutrient and sunlight gap appears in the canopy (i.e after clearing). As hand pulling of such dense masses of seedlings is very labour intensive, most clearing projects chose to spray the emerging seedlings with poison. This choice has side-effects of damaging the indigenous seedlings as well as the potential of seepage into the soil which affects the indigenous seed bank. An alternative is to wait 1-2 years post clearing so germinants are man height (but have not set seed yet), thereby some of the alien seed bank may have already been lost to competition, and those that germinated are easier to remove entire plant. Additionally, at this stage it is easier to distinguish indigenous from alien species and those indigenous species that germinated can be left to assist in the establishment of the community. Experience has revealed that control is best achieved when numerous complementary control methods (including biological, mechanical and chemical) are carefully incorporated into a fire management programme (van Wilgen *et al*., 1992).

2.4.2 ADDITIONAL CLARIFICATION ON RIPARIAN TERMINOLOGY

All of the chapters within this thesis have a descriptive outline of riparian vegetation within the fynbos biome and it is therefore not necessary to repeat the information within this section. Appendix 2.1 of this chapter (Tables A1- A3) offers summarized descriptions of riparian vegetation covered in this study as described by various authors (Rebelo *et al.,* 2006; Mucina *et al.,* 2006; Sieben, 2002; Prins, 2003). Information below is additional descriptions of various aspects within riparian areas, most specifically on a lateral and longitudinal scale.

The major components of a riparian zone can be defined on a lateral scale as the aquatic zone, the wet bank zone and the dry bank zone; and on a longitudinal scale by mountain stream, foothill, transitional and lowland zones (Boucher and Tlale, 1999; Davies and Day, 1998). Mountain stream zones occur where erosion exceeds sediment accumulation; foothill zones where erosion and accumulation are more or less in balance; and lowland river zones, where accumulation exceeds erosion (Davies and Day, 1998). Many different microhabitats are found along the banks as well as in the aquatic environment of all lateral zones (Sieben, 2002). These microhabitats will change as the water level fluctuates (Davies and Day, 1998), particularly so in the foothill zone. Here, river size increases as the catchments' size increases, the slope becomes gentler and thus velocity decreases. This combination of an increase in suspended material and a decrease in flow velocity raises the level of deposition. In mountain stream sections, high levels of erosion are always present. However, with a decrease in flow volume, small areas of deposition may form in more protected areas such as side channels of slower-moving water. A cross-section through a riverbed (Figure 2.6) illustrates the different habitats, which are affected uniquely by different levels of flow.

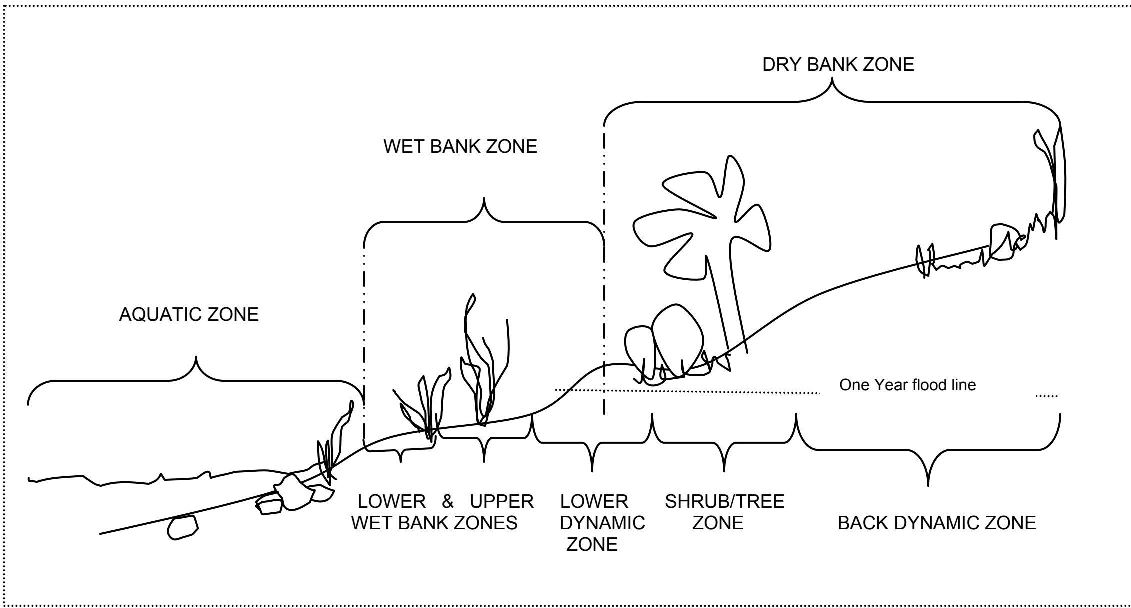


Figure 2.6: Zonation patterns of riparian areas within South Africa (after Boucher and Tlale, 1999)

The wet bank zones consist of substrata that are moist during most of the year. Flooding is seasonal with a Class 3 (wet season) flood maximum inundation level completely covering this zone. Within the wet bank, two subzones may occur; namely the moss or sedge subzone, which is wetted by 5-50% winter baseflows and by Class 1 (dry season) floods; and the upper wetbank shrub or *Prionium* subzone, which is maintained by Class 2 and 3 (mid- and wet season) floods (Boucher, 1999). Within the dry bank zone moisture is accessible only to plants with deeper root systems as flooding occurs only on a 1:20 year time frame. Three subzones are recognised in the dry bank zone; namely the lower dynamic subzone (the transition from wet bank to dry bank), the tree-shrub sub-zone (where vegetation is generally long-lived and is maintained by 1:2 to approximately 1:20 year maximum flood levels), and the back dynamic subzone (maintained by large floods recurring at 20-100 year intervals). The outer part of the zone is determined by the end of the riparian deposits or by a debris line where still present (Boucher, 1999). It is important to note that previous studies have found that a dry bank zone may be absent in small, fast-flowing mountain streams where high-speed erosion prevents efficient lateral alluvial deposits (Boucher, 1999).

Table 2.2: Diagnostic characteristics of longitudinal reach types of riparian zones within the south-western Cape, South Africa

REACH TYPE	DIAGNOSTIC CHARACTERISTICS
Mountain stream	Steep gradient stream dominated by bedrock and boulders with step-pool morphology or cascades and plunge pools. Intensive erosion as a result of high velocity of water. Approximate equal distribution of ‘vertical’ and ‘horizontal’ flow components. Locally cobble or coarse gravels in pools or plane beds. Plane bed reaches at lower gradients. Vegetation invasion a moderate threat.
Upper Foothills *(cobble bed)*	Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plane bed, pool-riffle or pool-rapid morphology. Narrow flood plain of sand, gravel or cobble often present. Velocity decreases and areas of deposition occur as well as erosion. Extensive vegetation cover (both natural and invasive). Accessibility leads to high potential for disturbance.
Lower Foothills *(gravel bed)*	Lower gradient mixed bed alluvial channel with sand and gravel dominating the bed, pool- riffle morphology, or pool-rapid with sand bars. Deposition over-riding erosion. Pools of significantly greater extent than rapids or riffles. Flood plain often present. High level of disturbance and intense plant invasion.

Adapted from tables and data in the following sources:
(Chutter, 1998; Rowntree and Ziervogel, 1999; Boucher, 1999)

Table 2.3: Diagnostic characteristics and sub-zone categories of lateral riparian zones within the south-western Cape, South Africa

RIPARIAN ZONE	DIAGNOSTIC CHARACTERISTICS	SUB-ZONE CATEGORIES
Wet Bank Zone	• Substrate moist during most of the year. • Flooding is seasonal with Class 3 Flood maximum inundation level completely covering this zone. • Plants adapted to periodic water logging, resist erosion and bind the soil - play a very important role in the local ecology.	**1) Moss or Sedge Subzone**, • wetted by 5-50% Winter Baseflows & by Class 1 (dry season) floods **2) Upper wetbank Shrub or *Prionium* subzone,** • maintained by Class 2&3 floods
Dry Bank Zone	• Moisture accessible only to plants with a deeper roots system • Flooding is only a 1:20 year time frame.	**1) Lower Dynamic Subzone** • the transition from wet bank to dry bank **2) Tree-shrub sub-zone** • vegetation generally long-lived • maintained by 1:2 – (approx.) 1:20 year maximum flood levels **3) Back Dynamic subzone** • maintained by large floods recurring on 20-100 year intervals.

Adapted from tables and data in the following sources:
(Chutter, 1998; Rowntree and Ziervogel, 1999; Boucher 1999)

2.4.3 SEED BANK SAMPLING

Soil samples were collected during late summer (March-April 2005 & 2006) from all sites to allow for environmental conditions (i.e. seasonal seed rain, temperature gradients and germination cues) to be uniform throughout all samples, and therefore allow for sound comparability. At each river reach (mountain stream or foothill section) a plot was established on the river bank, where the influence of riparian vegetation was evident. Each plot measured twenty metres in length (parallel to the river) and five metres in width (perpendicular to the river crossing both the wet bank and dry bank zones). Where the wet bank zone was distinctive, one 20 m-long transect was placed through the wet bank vegetation and a second transect through the dry bank vegetation (within the five meter width of the plot). Along each lateral zone transect, ten quadrats (1m x 1m) were placed using random numbers to determine their location. Ecological information was recorded for each quadrat, including species presence and percentage canopy cover, % rock cover and % bare ground, together with an estimate of total canopy cover for the quadrat. A small specimen herbarium was collected of seedlings or species that could not be identified on site. Various geomorphological features of the river and the sampling area were noted, including morphological unit (pool, rapid, riffle etc) geology, altitude, aspect, slope and GPS location.

A hand-held soil corer (measuring 5cm diameter and 10cm depth) was used to extract the soil. When impossible to use the corer due to rocks and/or roots, a hand-trowel was used that maintained the uniform 5cm diameter. Each sample comprised 5 cores collected from within the $1m^2$ quadrat then bulked together. Sampling was done across the whole plot to encompass spatial variability in the seed bank. This method was then repeated in the dry bank zone where it was present. Replicate sites were then sampled along each particular river reach. However, minimal availability of reference sites along the Berg River System prompted the inclusion of the Riversonderend System to compensate for shortcomings, as previously mentioned. These two river systems were then grouped together under the Berg system when analysing the data. Where possible, study sites encompassed both the wet and dry bank samples. However, many mountain stream sections only offered sites available within the lower dynamic subzone (also referred to as transitional or trans zone).

Samples were transported in thick plastic bags to the premises on Welgevallen Experimental Farm in Stellenbosch, where they were labelled according to the details of the area of collection (e.g. – Berg1, MS, #1). Samples were then air dried and passed through a 1mm sieve to remove any fibrous roots or large stones. The fine leaf litter contents that remained after sieving were incorporated into the sample trays as it was suspected that many of the smaller seeds were contained in the mass. All of the larger seeds that were noted were also incorporated into the sample, however seed counting was not done as many were hidden in the leaf litter, and as the experiment was testing seed viability rather than seed numbers, it was felt unnecessary. Seedling trays (20cm x 15cm) were lined with thin fibrous cloth to ensure that water drained without the loss of seeds. A suitable layer of washed river sand (depending on the amount of soil collected in the sample) was placed on top of the cloth to ensure a uniform depth was maintained throughout all trays. Control trays were kept of the river sand and monitored to note any emergent seedlings originating from the river sand or dispersal into the tunnel. The trays were labelled and placed in an open-sided plastic shade tunnel. Smoke treatment was equally distributed throughout all trays on the same day (11th May 2005, 1st May 1006) by means of a diluted liquid chemical concentrate (Kirstenbosch's Seed Primer Plus Liquid Concentrate Solution at a ratio of 1 part concentrate for every 9 parts water, totalling 20 litres of diluted smoke treatment). The trays were then left for 24 hours to absorb the treatment before irrigation commenced. Trays were kept moist with a fine spray irrigation system set on an automatic cycle with regular adjustments according to outdoor variations in moisture and temperature. The temperatures were maintained as close to the natural environment as possible, with the drop in temperature during autumn and winter monitored. These temperatures are vital in the seed germination process and a 2º C difference can result in unique germination results. The maximum and minimum temperatures recorded during the study period were 38ºC and 8 ºC (2005), and 39ºC and 5º C (2006), respectively.

Seedling emergence was monitored fortnightly for the first three months and thereafter on a monthly basis. Once basic identification was possible, duplicates of seedlings in the same tray were carefully removed after counting. Once large enough, specimens that required more space were transferred to small pots to encourage growth and flowering. To assist in future identification, a seedling herbarium was put together using various stages of the specimens' development. The current level of identification is to genus level, with most specimens to species level. Where possible species were grown until flowering stage to ensure correct identification to species level. Monitoring was terminated in December 2006 because of time constraints of the project, however most seedlings were identified to species level at time of termination.

2.4.4 DATA ANALYSIS

2.4.4.1 Diversity indices of indigenous species in seed banks of invaded and reference plots

Simpson's Index of diversity was used as it weights the most abundant species more heavily than the rare species. The formula measures the probability that two individuals randomly selected from a sample will be of different species. If n_i is the number of individuals i of species s which are counted, and *N* is the total number of all individuals counted, then the following formula is an estimator for Simpson's index (*D*) without replacement:

$$D = \sum_{i=1}^{s} \frac{n_i\left(n_i - 1\right)}{N\left(N-1\right)}$$

Note that **$0 \leq D \leq 1$** with values near zero corresponding to highly diverse or heterogeneous ecosystems and values near one corresponding to a more homogenous ecosystem. This is neither intuitive nor logical and therefore many biologists use the **1/*D*** version of the index which allows the higher index to equate to a higher diversity level and the lower diversity index to a lower diversity level. The programme used (*Species Diversity and Richness Version 2.65* (Seaby and Henderson, 2005)), gives the final index number in the **1/*D*** format and therefore the higher the index, the higher the diversity of indigenous species. The indices were then illustrated in a comparative format through the programme *Statistica 7.0*. (StatSoft Inc., 2004). Where necessary, further details were established for each plot by dividing the total composition (100%) into percentage growth forms. This was done using *Microsoft ® Office Excel 2003.*

2.4.4.2 Species Richness and Abundance

Species richness was calculated by counting the number of different species that occurred per sample or plot and abundance by the count of seedlings that germinated per species. Both were calculated in *Excel*. Comparisons between different sections of the rivers, as well as between reference and invaded sections of the rivers were done.

2.4.4.3 Sørensen's similarity index

Sørensen's similarity index (Kent and Coker, 1992) is based on the probability that two randomly chosen individuals belong to species shared by both samples. The higher the index, the higher the similarity of species between samples. The formula is:

$$S_s = 2C / (A + B)$$

Where S_s = Sørensen similarity coefficient
A = number of species in quadrat/sample 1
B = number of species in quadrat/sample 2
C = number of species common to both quadrats/samples

This index was used to compare the similarity within comparative plots/samples before and after invasion (i.e. to establish whether invasion increases or decreases the similarity of species within like plots/samples) by calculating the mean similarity index and mean shared species between all reference plots for each river; which was then compared against the mean index and mean shared species within the invaded plots of each river. Additionally, Sørensen's index was used at a broader scale to compare the probability of shared species occurring with reference and invaded sections of the same river. All similarity indices were computed using *Estimate S Program Version 7.5* (Cowell, 2005) and compared to the results from the correspondence analyses.

2.4.4.4 Correspondence Analyses for top twenty seed bank species

Correspondence analyses were computed for the twenty most frequently occurring species overall (indigenous and alien), as well as the twenty most frequently occurring indigenous species. Comparisons between reference and invaded plots were done at three different spatial scales:

- landscape scale – comparing rivers
- reach scale – comparing mountain stream and foothills
- habitat scale – comparing wet, dry and transitional bank zones.

2.4.4.5 Correspondence Analysis for External Factors

Correspondence analyses were also computed for the twenty most frequently occurring species overall, as well as the twenty most frequently occurring indigenous species in terms of their relation to certain levels of "key" environmental factors (see below):

- fire frequency
- invasion history
- level of human/man-made disturbance.

Ratings of these factors ran from 0 to 3, with the lower the rating, the lower the level of human influence. Ratings were based on information from the WfW database (for fire and invasion) and from visual inspection on site (disturbance). Disturbance was termed so if anthropogenic evidence, in terms of agricultural practises, road-work or developmental practices, or any other form of un-natural disturbance was found within and/or around the study site. See Chapter 4, Appendix 4.2 for full table. The programme *Statistica 7.0* (StatSoft Inc., 2004) was used for all of the correspondence analyses.

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2.6 APPENDIX 2.1

Riparian plant communities as described by Prins (2003), Sieben (2002), Rebelo *et al*. (2006) and Mucina *et al*. (2006)

Table A1: Riparian communities in the fynbos biome as described by Prins (2003)

1. ***Rhus angustifolia – Metrosideros angustifolia* community**

   Altitudes ranging from 50 - 480m, relatively moderate gradients (5-20º) and shallow , relatively acidic sandy soils (pH 4.45), and usually on south facing slopes.
   Characterised by: *Rhus angustifolia & Polygonum salicifolium*
   Dominant species: *Brabejum stellatifolium & Metrosideros angustifolia*

2. ***Podocarpus latifolius – Brabejum stellatifolium* community**

   Altitudes ranging from 240-550m, slopes moderate (5-30º), medium to course sandy soils with a pH of 4.64, found on both northern and southern aspects.
   Characterised by: *Kiggelaria africana, Olea europea subsp. Africana & Maytenus acuminata* Dominant species*: Brabejum stellatifolium, Diospyros glabra & Metrosideros angustifolia*

3. ***Prionium serratum – Diospyros glabra* community**

   Altitudes ranging from 40-500m with slightly steeper gradients (5-45 º) on shallow, medium to course sandy soils with pH 4.37; usually on the north slopes.
   Characterised by: *Prionium serratum, Driopterus* sp. *& Erica caffra*
   Dominant species: *M. angustifolia, D. glabra, Brachylaena neriifolia, Elegia capensis , Cannomois virgata & Pteridium aquilinium*

4. ***Berzelia lanuginosa- Cannamois virgata* community**

   Altitudes from 50-520m on relatively deep sandy and acidic soils (pH 3.67) and mostly on the gentle northern slopes (2-30º).
   Characterised by: *Berzelia lanuginose, Leucadendron salicifolium, Metalasia muricata, & Cullima ciliaris*
   Dominant species: *Cannamois virgata, M. angustifoliua & Pteridium aquilinium*

5. ***Erica inconstans – Brachylaena neriifolia* community**

   Altitudes range from 320- 560m on very sandy and acidic substrate and the most gentle slope (0-40 º) and mainly on the northern slopes
   Characterised by: *Erica inconstans*
   Dominant species: *Berzelia lanuginose, Metrosideros angustifolia, B. neriifolia & E. capensis*

Table A2: High Altitude Fens and Mire (a) and Riparian (b) communities as described by Sieben (2002).

(a)

Community Group S1: Fens
1.1 *Protea lacticolor-Hippia pilosa* Tall Shrubland
1.2 *Elegia thyrsifera-Centella laevis Closed Herbland*
1.3 *Anthochorto crinalis-Elegietum intermediae*
1.4 *Ficinio argyropae-Epischoenetum villosi*
1.5 *Restio bifurcus-Anthochortus crinalis* Short Restioland

Community Group S2: Restio marshlands
2.1 *Platycaulos depauperatus* Short Herbland
2.2 *Erica autumnalis-Restio purpurascens* Tall Restioland
2.3 *Grubbia rosmarinifolia-Restio aff. versatilis* Closed Shrubland
2.4 *Tetrario capilaceae-Restietum subtilis*

(b)

Community Group 1: Aquatic communities
1.1 *Fontinali antipyreticae-Isolepidetum digitatae*
1.2 *Pentaschistido pallidae-Isolepidetum digiatate*

Community Group 2: Pioneer Wet Banks
2.1 *Symphyogyna podophylla-Sematophyllum dregei* Moss Community
2.2 *Brachylaena neriifolia-Metrosideros angustifolia* Pioneer Community

Community Group 3: Erosion Wet Banks
3.1 *Symphyogno podophylla-Schizietum tenellae*
3.2 *Sphagno capensis-Disetum tripetaloidis*
3.3 *Pseudobaeckeo africanae-Prionietum serrati*

Community Group 4: Deposition Wet Banks
4.1 *Wimmerello bifidae-Juncetum lomatophylli*

Community Group 5: Ericaceous Fynbos
5.1 *Ischyrolepis triflora-Protea grandiceps* Closed Tall Shrubland
5.2 *Nebelia fragariodes-Staberoha cernua* Closed Short Shrubland
5.3 *Erica longifolia-Tetraria crassa* Closed Short Shrubland
5.4 *Cliffortia atrata-Restio purpurascens* Closed Tall Shrubland
    Subass. 5.4a: *Cliffortia atratae-Restionetum purpurascentis typicum* subass. nova hoc loco
    Subass. 5.4b: *Cliffortia atratae-Prestionetum purpurascentis centelletosum erianthae* subass. nova hoc loco
5.5. *Restio purpurascens-Cliffortia hirsuta* Closed Tall Shrubland

(b) continued.

Community Group 6: Transitional Fynbos

6.1. *Elegia capensis-Cliffortia hirsute* Closed Tall Shrubland
6.2. *Muraltia heisteria-Erica pinea* Closed Tall Shrubland
6.3. *Euryops abrotanifolius-Haplocarpha lanata* Closed Tall Shrubland

Community Group 7: Asteraceous Fynbos

7.1. *Wahlenbergia parvifolia-Pentameris thuarii* Closed Tall Grassland
7.2. *Helichrysum cymosum-Myrsine africana* Closed Short to Tall Shrubland
    Subass. 7.2a. *Helichryso cymosi-Myrsinietum africanae ficinietosum acuminatae* subass. nova hoc loco
    Subass. 7.2b. *Helichryso cymosi-Myrsinietum africanae inops* subass. nova hoc loco
    Subass. 7.2c. *Cliffortia polygonifolia-Cullumia setosa* Variant
7.3. *Pelargonium tomentosum-Chasmanthe aethiopica* Closed Tall Shrubland

Community Group 8: Cliffortia odorata Shrublands

8.1. *Pteridium aquilinum-Cliffortia odorata* Closed Tall Shrubland
8.2. *Rubus rigidus-Clifforta odorata* Closed Tall Shrubland

Community Group 9: Afromontane Forests

9.1. *Platylophus trifoliatus-Cunonia capensis* Forest
9.2. *Platylophus trifoliatus* Forest
9.3. *Curtisia dentate-Diospyros whyteana* Scree Forest
9.4. *Todea Barbara-Cunonia capensis* Forest
    Subass. 9.4a. *Todeo barbarae-Cunonietum capensis typicum* subass. nova hoc loco
    Subass. 9.4b. *Todeo barbarae-Cunonietum capensis hymenophylletosum peltatae* subass. nova hoc loco

Community Group 10: Riparian Scrub

10.1. Ischyrolepis subverticillata-Metrosideros angustifolia Low Thicket
    Subass. 10.1a. *Ischyrolepis subverticillatae-Metrosiderotetum angustifoliae podalyrietosum calyptratae* subass. nova hoc loco
    Subass. 10.1b. *Ischyrolepis subverticillatae-Metrosiderotetum angustifloliae typicum* subass. nova hoc loco

Table A3: Fynbos riparian vegetation (a) and Cape Lowland alluvial vegetation (b) as described by Rebelo *et al*. (2006) and Mucina *et al.* (2006) in Mucina and Rutherford (2006).

(a)

Fynbos Riparian Vegetation

Including *Brabejum–Rhus* Riverine Scrub (Boucher 1978). *Elegia capensis–Miscanthus capensis* Scrub & *Calopsis paniculata–Cliffortia strobilifera* Scrub (Cleaver et al. 2005).

Description: Vegetation of narrow belts of alluvial thickets and accompanying palmiet (*Prionium serratum*) vegetation along upper stretches of the rivers draining mountain fynbos.
Altitude: from near sea level to 1-300 m.

Vegetation & Landscape Features Narrow, flat or slightly sloping alluvial flats supporting a complex of reed beds dominated by tall palmiet (*Prionium serratum*) and restios (*Calopsis*, *Cannomois*, *Elegia*, *Ischyrolepis* and *Rhodocoma*), low shrublands with moisture-loving species of *Berzelia*, *Cliffortia*, *Helichrysum* etc.
With tall riparian thickets of *Metrosideros angustifolia* and *Brachylaena neriifolia* in places.

Important Taxa
Trees: *Brabejum stellatifolium*, *Brachylaena neriifolia*, *Cunonia capensis*, *Kiggelaria africana*, *Pseudoscolopia polyantha*, *Widdringtonia nodiflora*.
Tall Shrubs: *Berzelia lanuginosa*, *Cliffortia strobilifera*, *Metrosideros angustifolia*, *Psoralea pinnata*, *Berzelia squarrosa*, *Cassine schinoides, Cliffortia atrata*, *Diospyros glabra, Erica caffra*, *Freylinia lanceolata, Halleria elliptica*, *Maytenus oleoides, Podalyria calyptrata*, *Psoralea aphylla*.
Low Shrubs: *Helichrysum cymosum*, *H. helianthemifolium*, *Penaea cneorum*, *Pseudobaeckea africana*.
Semiparasitic Shrub: *Osyris compressa*.
Woody Climber: *Asparagus scandens*.
Megagraminoids: *Prionium serratum*, *Calopsis paniculata*, *Ischyrolepis subverticillata*, *Cannomois virgata*, *Ehrharta rehmannii, Elegia capensis*, *Merxmuellera cincta, Miscanthus capensis, Rhodocoma capensis*.
Graminoids: *Ficinia brevifolia*, *Isolepis digitata*, *Juncus capensis*, *Pentaschistis curvifolia*, *P. pallida*, *Tetraria cuspidata*.
Herbs: *Grammatotheca bergiana, Persicaria decipens*.
Geophytic Herbs: *Wachendorfia thyrsiflora*, *Blechnum punctulatum*, *Disa tripetaloides*, *Osmunda regalis*, *Pteridium aquilinum*, *Todea barbata*.
Carnivorous Herbs: *Drosera capensis*, *Utricularia bisquamata*.

Endemic Taxa
Tall Shrub: *Ixianthes retzioides*.
Low Shrub: *Metalasia riparia*.
Herb: *Pelargonium pseudoglutinosum*.
Graminoid: *Isolepis digitata* (aquatic).
Moss: *Wardia hygrometrica* (aquatic; representative of monotypic endemic family).

(b)

Cape Lowland Alluvial Vegetation

Riparian vegetation p.p. (Boucher 1978).

Distribution & Description Western Cape Province: Vegetation of broad alluvia of middle and lower stretches of rivers of the Western Cape such as the upper Olifants, Berg, Eerste, Lourens, Palmiet, Bot, Klein, Breede, Goekoe, Gouritz, Hartebeeskuil, Klein Brak, Groot Brak, Keurbooms and a number of small tributaries of the above-mentioned water courses. Altitude ranging from 20–300 m.

Vegetation & Landscape Features Flat landscape with slow-flowing (in place meandering) lowland rivers fringed on banks by extensive tall reeds dominated by *Phragmites australis* and *Typha capensis* as well as by flooded grasslands and herblands and tall riparian thickets (gallery forests) with *Salix mucronata* subsp. *capensis* on the river terraces.

Important Taxa
Riparian thickets:
Trees: *Salix mucronata* subsp. *mucronata*, *Virgilia divaricata*, *Podocarpus elongatus*.
Tall Shrubs: *Buddleja saligna, B. salviifolia*, *Cliffortia strobilifera*, *Freylinia lanceolata*, *Rhus angustifolia*.
Low Shrubs: *Cliffortia odorata*, *Senecio halimifolius*, *Cliffortia ferruginea*.

Flooded grasslands & herblands:
Tall Shrub: *Melianthus major*.
Megagraminoids: *Prionium serratum*, *Calopsis paniculata*, *Cyperus thunbergii*.
Graminoids: *Cynodon dactylon*, *Cyperus congestus, C. denudatus*, *C. textilis*, *Eragrostis sarmentosa*, *Ficinia distans*, *Fuirena hirsuta*, *Hemarthria altissima*, *Isolepis cernua*, *I. prolifera*, *Juncus capensis*, *J. lomatophyllus*, *Leersia hexandra*, *Merxmuellera cincta*, *Paspalum distichum*, *Pennisetum macrourum*.
Herbs: *Conyza scabrida*, *Helichrysum helianthemifolium*, *Laurembergia repens, Persicaria decipiens*.
Geophytic Herbs: *Wachendorfia thyrsiflora*, *Triglochin bulbosa*, *Watsonia galpinii*, *Zantedeschia aethiopica*.

Open water:
Aquatic Herb: *Myriophyllum spicatum*.

Endemic Taxon
Riparian thickets:
Tree: *Salix mucronata* subsp. *hirsuta* (only Olifants River and maybe Berg River catchments)

CHAPTER 3: A REFERENCE STUDY OF INDIGENOUS SEED BANK COMPOSITION ALONG FOUR RIVER SYSTEMS IN THE WESTERN CAPE, SOUTH AFRICA

3.1 ABSTRACT

Riparian areas contribute significantly to the spread of many invasive species, some of which can significantly impact ecosystem function and ecosystem services such as water supply. These areas have therefore been targeted by many alien clearing programmes. Little attention, however, has been paid to rehabilitating these areas after clearing and the role that soil seed banks play in this process. This study aimed to assess the composition and viability of reference seed banks, to be used as a bench mark for conservation managers and landowners, when assessing post disturbance recovery and rehabilitation techniques. The focus was on soil seed bank composition of the riparian vegetation in four river systems within the fynbos biome of the south-western part of the Western Cape. Both mountain and foothill sections of the Eerste, Molenaars, Berg and Wit Rivers were sampled. Plots were located in relatively undisturbed fynbos/riparian areas, with less than 25% canopy cover of alien invasives. Two factors were taken into consideration when setting up the sampling plots, namely lateral (wet and dry bank) and longitudinal (mountain stream and foothill) zones. Vegetation data were collected on site and contrasted with the seedling emergence data from soil seed bank samples to compare diversity and vegetation groupings. The seed bank composition was found to have little overlap with the current aboveground vegetation. The mountain stream slopes of all rivers were found to have a greater species diversity within the seed bank, particularly so under the influence of past intermittent fires. On a lateral scale, the transitional zone between wet and dry banks was found to have a higher seed bank diversity with representatives of both riparian and fynbos species.

Key words: stream bank vegetation, disturbance, species assemblages, soil-stored seeds

3.2 INTRODUCTION

The massive increase in the rate of movement of humans and their commodities between previously isolated parts of the world has been the primary cause of the rapid increase in biological invasions (Rejmánek, 1995). In southern Africa, most problematic invasive plants hail from parts of the world with similar environments to parts of South Africa (Richardson and Thuiller, 2007). The fynbos biome falls within a mediterranean climatic region with winter rainfall and summer drought and is world-renowned for its diverse flora. A combination of global warming, increased human population numbers, rapid development and the introduction of invasive alien plants (IAPs), has not only threatened biodiversity in the region but has left this area with a serious water shortage for the majority of the year (November- March).

Riparian areas are widely regarded as being particularly susceptible to invasion by alien plant species. This is thought to be a result of the exposure of riparian vegetation to periodic natural and human related disturbances, dynamic nutrient levels and hydrology, water dispersal of propagules, and the role of stream banks as a seed reservoir for both indigenous and exotic species (Rowntree, 1991; Galatowitsch and Richardson, 2005; Planty-Tabacchi *et al.,* 1996). Invasive alien plants (IAPs) impose greatly on the natural water table levels, removing large quantities from the water systems daily (Rowntree, 1991; Galatowitsch and Richardson, 2005). In an attempt to curb this threat, various alien clearing initiatives have targeted river corridors to reduce the spread of propagules through water systems and to increase water availability (Richardson *et al.,* 1997). Included in a range of initiatives is the Working for Water (WfW) programme which was initiated in 1995 with the aims of improving and increasing both the quality and quantity of water production, conserving biodiversity and providing employment (van Wilgen *et al*., 1998). The final aim of such clearance programmes includes the full recovery of the fynbos/riparian vegetation cover following alien removal, yet a limited budget often results in unsatisfactory and inadequate results (Holmes, 1998; 2001). Inadequate restoration can result in soil erosion, loss of soil-stored propagules, poor water quality and the high risk of re-invasion by alien plant species (Holmes, 2001).

In their study investigating riparian scrub recovery after alien clearing in the fynbos region, Galatowitsch and Richardson (2005) highlighted the need for research into the recruitment dynamics of disturbed riparian areas, in order to ascertain whether the main supply of new propagules for recolonisation comes from external sources, via water, wind or animal dispersal, or from *in situ* soil stored seed banks. The seed bank is defined as 'a reserve of viable seeds, fruits, propagules and other reproductive plant structures in the soil' (Goodson *et al.,* 2001). Seed bank data can yield information on three features of new vegetation: (1) the species composition, (2) the relative abundance of recently recruited species, and (3) the potential distribution of each species (Welling *et al.,* 1988). Additionally, analyses of the compositional data of both the seed bank and aboveground vegetation can reveal which desirable species are lacking from the seed bank and may need to be reintroduced by other means (e.g. replanting). It has been documented that soil seed banks contribute significantly to the regeneration of plant cover following a disturbance in many vegetation types (Musil and de Witt, 1990; Holmes and Marais, 2000) but relatively little research has focused on riparian zones. Rehabilitation is intended to return the lost functions of ecosystems following the clearing of invaded lands and a thorough understanding of the role of seed banks can be important for designing restoration projects (Richter and Stromberg, 2005).

The aim of this study was to investigate riparian seed bank composition within natural or reference sections of four rivers in the fynbos biome of the south-western Cape, South Africa. This knowledge is to be used as a benchmark for future research (see Chapter 4) and to be used as a reference guide in establishing the degradation level of a disturbed or invaded fynbos riparian area.

3.2.1 SEED BANK DYNAMICS WITHIN RIPARIAN SYSTEMS

The formation of a soil seed bank is initiated with the dispersal of the seeds (or propagules) by gravity, wind, water, animals, or mechanical means (Leck, 1989). Within terrestrial (Grubb, 1988; Thompson, 1992 and 1993; Warr 1993; Holmes, 2002; Holmes and Newton, 2004; Goodson, *et al.,* 2001) and wetland (Leck 1989, Smith and Kadlec, 1983, van der Valk, 1981; Welling *et al*., 1988) systems, much work has been done to explain the dynamics of seed banks. Little information can be found, however, for riparian seed bank dynamics. Riparian areas are highly variable by nature and highly species diverse as result of flood disturbance. They are influenced by varying gradients of environmental factors and ecological processes and the associated plant communities thus are mosaics of micro-habitats within the larger landscape (Gregory *et al.,* 1991). It is predicted that many processes serve to bury seeds in the soils of riparian ecosystems; the main being the flood water which disperses propagules vast distances and serves to bury them under sediment in the process (Richter and Stromberg, 2005). Additionally, animal activity and soil drying and cracking can also contribute to seed burial. Mechanical translocation of soil during the process of damming or canalization, may also play a role in movement of propagules through the soil. Bare patches of soil, created by any of the above-mentioned disturbances, are typically colonized by ruderals (Grime, 1981). Over time, longer-lived competitors (like many riparian tree invaders e.g. *Acacia mearnsii*) may replace these ruderals. When open patches re-occur, they may be colonized by residual species that have persisted in the seed bank, or by immigrants dispersed from nearby vegetation patches or off-site seed banks. This process is what makes riparian areas so diverse but also allows the system to become vulnerable to invasion by alien invasive trees and shrubs.

Holmes and Newton (2004) contest that terrestrial seed bank composition in alien invaded stands indicates the potential for some indigenous vegetation recovery, as well as the potential of alien recolonization. It is therefore vital to incorporate the knowledge of the local vegetation successional cycle when investigating the restoration potential of seed banks. Regeneration from soil seed banks is generally initiated by annuals and short-lived shrubs which provide soil stabilization and nutrient recycling into the soil. Within riparian areas however, large variation occurs as a result of the change in habitats between reaches (mountain stream to coastal plain) and moisture regimes (dry banks and wet banks). Additionally, seed bank composition varies according to the dominant above-ground vegetation type and in riparian areas is particularly variable as a result of the disturbance by seasonally changing water levels (Leck, 1989). It is therefore best to acknowledge that the successional cycle following a disturbance is unique to each habitat and is directly related to several environmental variables.

Riparian vegetation within the fynbos biome is fairly distinctive from the surrounding fynbos vegetation (Boucher, 1978). The composition of the riparian community varies according to the phytogeographic affinity towards either the fynbos or Afrotemperate Forest vegetation groups; which are, in-turn, dependent on several environmental factors including stream size and position in landscape, local topography, and surrounding soils, vegetation or land use (Holmes, 1998). Riparian communities with a fynbos affinity have been described as Closed-Scrub Fynbos (Cowling and Holmes, 1992) or Broad Sclerophyllous Closed Scrub (Kruger, 1974). Such communities are usually found in the mountain stream or montane reaches of the rivers where the extent of alluvium is limited as a result of the high levels of erosion.

Although several different versions are offered, this study uses Boucher and Tlale's (1999) divisions of the major components of a riparian zone. These can be defined as the aquatic zone, the wet bank zone and the dry bank zone on a lateral scale; and mountain stream, foothill zone, transitional and lowland zones on a longitudinal scale. Areas covered in this study include the:

- *mountain stream zone*- where the gradient is steep and erosion exceeds sediment accumulation;
- *foothill zone*- where the gradient is more moderate and sediment accumulation and erosion are more or less in equilibrium.
- *wet bank zone*- where the substrate is moist for most of the year and flooding is seasonal.
- *dry bank zone*- where moisture is available only to plant with a deeper root system and flooding occurs in a 1:20 year time frame
- *transitional zone* (also termed the lower dynamic subzone) – which forms the transition between the wet and dry bank zones and was frequently the only riparian zone available to sample in the mountain stream sections.
  (Chutter, 1998; Rowntree and Ziervogel, 1999; Boucher, 1999).

These areas form the link between the aquatic and terrestrial ecosystems (Mackenzie *et al*., 1999). Riparian ecosystems are highly important for the delivery of key services such as the provision of food, control of evapo-transpiration and water temperature, filtering of sediments, stabilisation of stream banks and support of faunal communities, as well as the conservation of biodiversity which encompasses all of the above (Naiman and Décamps, 1997; Galatowitsch and Richardson, 2005).

This study investigates soil seed bank composition at reference, un-invaded riparian sites between four river systems (landscape scale) and within four habitats at two scales (i.e. reach scale: mountain stream and foothill, habitat scale: wet bank and dry bank zones). Results were compared with those from similar studies on terrestrial seed bank composition in the fynbos biome to ascertain the extent that riparian seed banks may play in restoration.

This study investigated the following questions:

1. To what extent does the seed bank have potential to regenerate riparian vegetation that is structurally and compositionally similar to undisturbed riparian vegetation?
2. What differences are there in seed bank composition among different riparian zones (longitudinal and lateral), e.g. mountain stream versus foothill and wet bank versus dry bank zones?
3. Does riparian vegetation in the fynbos biome have significant soil-stored seed banks (relative to terrestrial vegetation)?

3.3 METHODS

3.3.1 STUDY SITES

Four river systems within the south-western part of the Western Cape were chosen for their variety of reach types, history of vegetation (both alien and natural), and for their relatively close proximity to the research facilities. Plots were located in relatively undisturbed fynbos/riparian areas, with less than 25% alien plant canopy cover. Two factors were taken into consideration when setting up the sampling plots, namely lateral (wet & dry bank) and longitudinal (mountain stream & foothill) zones. Within each plot, ten quadrats were randomly selected and soil samples and vegetation surveys were taken per quadrat. For more detailed description on study sites and sampling procedures see Chapter 2.

3.3.1.1 The Eerste River System

The source of the Eerste River is in the Dwarsberg Mountains, some 1320 m above sea level. The Mountain stream zone flows through the Hottentots Holland Nature Reserve and into Jonkershoek Nature Reserve, where the vegetation comprises predominately indigenous fynbos and riparian species. Once it leaves the reserve it becomes heavily invaded by several alien species, and therefore, all reference plots were established within the reserve.

3.3.1.2 The Berg and Riversonderend River Systems

With the exception of the Franschoek Pass (which is drained by the Riversonderend River, also included in this study), nearly the whole northern section of the Hottentots Holland Nature Reserve is drained by the Berg River. Reports show that the majority of foothill and flood plain zones between Franschhoek and Paarl and up to the La Motte plantation are highly disturbed by canalization and virtually all riparian vegetation has been replaced by exotic and invasive species (Burgers, 1992; Sieben, 2002). For this reason, study sites were limited and two sites fall within the Le Motte Plantation (Assegaaiboskloof), while the remaining sites fall within the Riversonderend Drainage Basin rather than directly into the Berg River Basin. These two river systems were then grouped together under the Berg system when analysing the data.

3.3.1.3 The Molenaars River System

The Molenaars has its source in the Du Toits Mountains and runs through the town of Rawsonville before joining the Breede River. Several tributaries start in the surrounding mountains and join the Molenaars, those included in the study are the Krom and Elands Rivers. Alien clearance is evident throughout the river and is on-going; however reference sites were established in suitable areas of <25% invasion.

3.3.1.4 The Wit River System

The Wit River is a tributary of the Breede River system and runs along Bainskloof pass. Alien clearance is still ongoing throughout the river, with the densest infestations found in the lower sections of the river. The area around Tweede Tol is known to offer the most characteristic riparian and fynbos species, and all sampling sites fall within close proximity to this area.

3.3.2 DATA COLLECTION

A total of 22 plots were established in the reference (un-invaded) sections of the four river systems. Within each plot, ten 1m² quadrats were randomly selected and sampled. Both the above-ground vegetation data (species presence and % canopy cover, % rock cover and % bare ground, and estimate of total canopy cover) and soil samples were collected per quadrat and, in total, 290 quadrats were surveyed and sampled over the four rivers. Soil samples were placed in labelled trays and treated with a uniform dosage of smoke treatment prior to irrigation commencement. Thereafter, seedlings that emerged from the soil seed bank were counted and identified as close to species level as possible. Monitoring took place bi-monthly for the first 3 months, and thereafter on a monthly basis for the last 3 months. Seedlings that were unidentifiable at termination of monitoring in December 2005, were planted into bags and identified at a later stage. Termination of the entire project was in December 2006 and most specimens had been identified to species level by this stage. All analyses within this chapter were computed for the seed bank germinants *only*, see Chapter 5 for above-ground and seed bank comparisons. Also see Chapter 2 for more details on seed bank sampling and data collection.

3.3.3 DATA ANALYSIS

A data set comprising a total of 290 soil seed bank samples and the relevant above-ground vegetation data was collected and analysed using various techniques. All analyses were done at plot level (i.e. all ten 1m² quadrat samples per plot were lumped together) and included both indigenous and alien seedlings that germinated. Replication plots (i.e. Berg River, mountain stream, wet zone 1 & 2; Berg River, mountain stream, dry zone 1 & 2; and Berg River, mountain stream, tranzitional zone 1) was combined and analysed as one plot (i.e. Berg, MS wet 1, Berg MS dry 1, and Berg MS trans 1), making the total plots in analyses 18. The overall seed bank composition was grouped into growth form, dominant families and the species origin (alien or indigenous). An above-ground and below-ground (seed bank) species comparison was made using the vegetation survey data collected and the seed bank germination data (see Chapter 5 for a more detailed comparison). To investigate species groupings according to the habitat variables (river, slope and zone), seedling emergence data were analysed using diversity indices and correspondence analysis. The programme *Species Diversity and Richness* (Seaby and Henderson, 2005), was used to calculate Simpson's Diversity Index and for the different variables (river,slope and zone), and *Statistica* was used on the twenty most frequently occurring species in the correspondence analyses. Correspondence analysis searches for the multivariate relationships between data in one or more data sets. It is a geometric technique for displaying the rows and columns of a two-way contingency table as points in a low dimensional space, which makes the data more useful for interpretation (Kent and Coker, 1992). Data analysis was impossible for all species as some species were so rare that their counts were not adequate to be used in the analysis. Mean species richness counts between the different rivers, slopes and zones were compared to evaluate if significant distinctions of species occurrence were found between the different habitats, and to determine the seed bank composition.

3.4 RESULTS

3.4.1 SEED BANK AND ABOVE-GROUND VEGETATION COMPARISONS

There is generally poor correspondence between the assemblage of species represented in the seed bank and that represented in the aboveground vegetation. The above-ground vegetation community within the reference sections of the rivers was generally comprised of "woody" shrub and tree species (such as *Erica caffra, Brachylaena neriifolia)* and restiods (such as *Ischyrolepis subverticillata* and *Calopsis paniculata)* with some other graminoids (Cyperaceae and Poaceae). The seed bank community was made up of a variety of growth forms from several different families. Although mainly comprising pioneer species, a large presence of "woody" shrub and restioid species was noted (such as *Metalasia spp, Euryops abrotanifolius* and *Ischyrolepis subverticillata*), which was very different from the community found within the invaded seed bank samples (See Appendix 5.2 in Chapter 5 for details of all vegetation comparisons).

Alien species presence was directly related to the state of the reference site, with an overall seed bank proportion of 15% alien. The herbaceous perennial growth form was most prevalent in the seed bank, followed closely by shrub/shrublets and annuals (Figure 3.1). The family Asteraceae was by far the most dominant (Figure 3.2). Overall, five families occurred in five or more plots (Asteraceae, Poaceae, Cyperaceae, Crassulaceae and Scrophulariaceae), nine in two or more plots (Asteraceae, Poaceae, Cyperaceae, Crassulaceae, Scrophulariaceae, Fabaceae, Aizoaceae, Campanulaceae and Rosaceae), and the remaining families occurred in two plots or fewer (Figure 3.2). A comparative analysis of the aboveground vegetation assemblage and seed bank composition offered interesting results and is summarized in Table 3.1. Very little overlap in above - vs below-ground species presence was found, with the dominating groups representing very different growth forms.

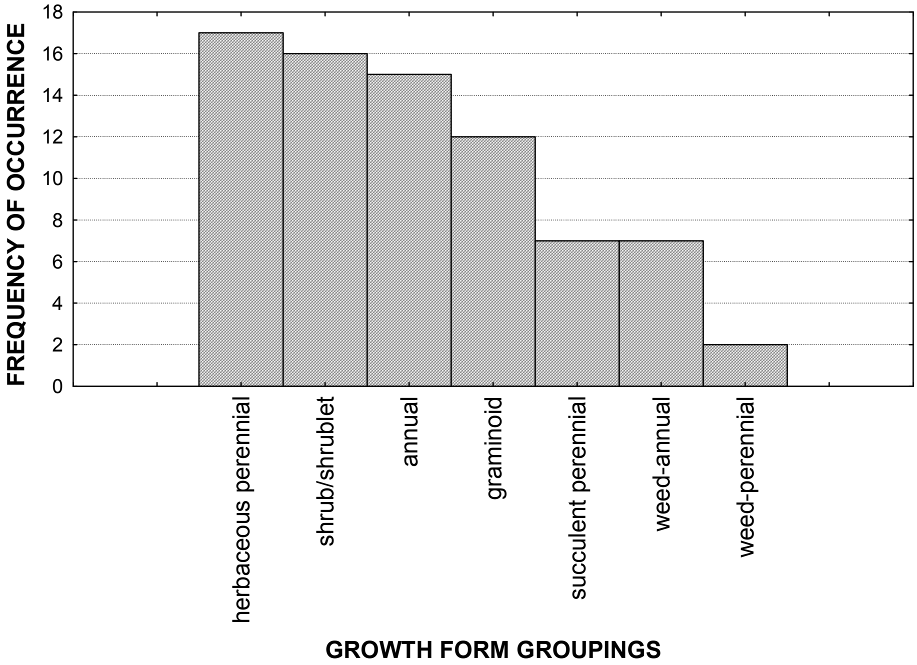

Figure 3.1: The distribution of plant growth forms in the riparian seed bank flora of the Western Cape, South Africa. Data are for all sample plots combined, n = 290 samples.

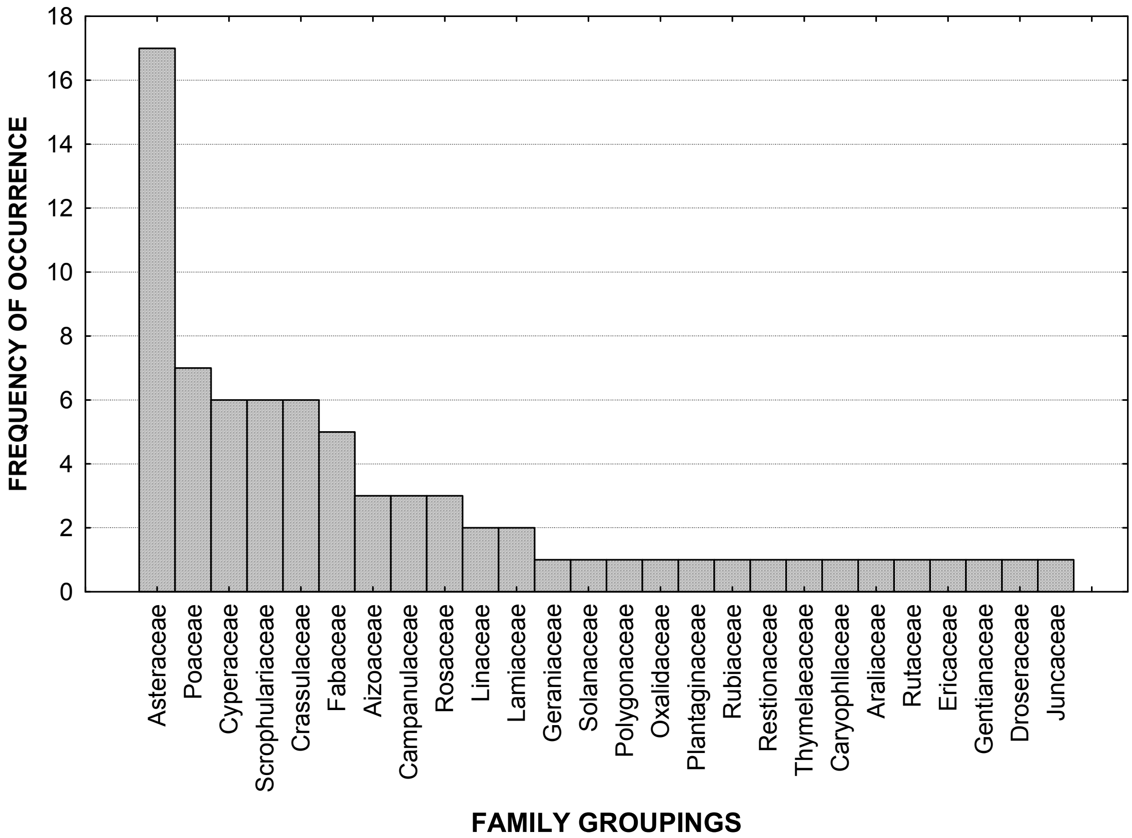

Figure 3.2: Frequency of plant families occurring in riparian seed banks of the Western Cape, South Africa. Data are for all sample plots combined, n = 290 samples.

Table 3.1: The twenty most frequently occurring species in riparian above-ground vegetation and in below ground soil seed banks (seedling emergents) in the Western Cape, South Africa. Data were compiled for all sample plots combined, n = 290 samples. * = Alien species.

Above-ground vegetation	**Growth form**	**Seed bank seedlings**	**Growth form**
**Acacia mearnsii*	tree-alien	*Cliffortia cuneata*	shrub/shrublet
Brabejum stellatifolium	tree	*Erica caffra*	shrub/shrublet
Salix capensis	tree	*Erepsia anceps* / *Carpobrotus* sp.	succulent perennial
Brachylaena neriifolia	shrub/small tree	*Disparago* sp.	herbaceous perennial
Metrosideros angustifolia	shrub/small tree	*Euryops abrotanifolius*	herbaceous perennial
Erica caffra	shrub/shrublet	*Metalasia* sp./ *Seriphium plumosa*	herbaceous perennial
Erica sp	shrub/shrublet	*Struthiola tomentosa* /*S. striata*	herbaceous perennial
Morella serrata	shrub/shrublet	*Pseudoselago serrata*	herbaceous perennial
Oftia africana	shrub/shrublet	*Solanum retroflexum*	perennial weed
Seriphium plumosum	shrub/shrublet	*Helichrysum helianthemifolium*	herbaceous annual
Helichrysum sp.	herbaceous perennial	*Pseudognaphalium luteo-album*	herbaceous annual
Calopsis paniculata	graminoid	** Hypochaeris radicata*	annual alien
Cannomois virgata	graminoid	*Wahlenbergia cernua* / *Oftia africana*	annual/ shrublet
Cyperus sp.	graminoid	*Ficinia anceps*	graminoid
Elegia capensis	graminoid	*Ischryrolepis subverticillata*	graminoid
Ischyrolepis sp	graminoid	*Isolepis prolifera*	graminoid
Pentameris thurii	graminoid	*Juncus capensis*	graminoid
Prionium serraturm	graminoid	*Panicum schinzii*	graminoid
Rhodocoma capensis	graminoid	*Pennisetum macrourum*	graminoid
Blechnum capense	fern	*Pentaschistus pallida*	graminoid

3.4.2 SEED BANK ASSEMBLY PATTERNS AT THREE SPATIAL SCALES

3.4.2.1 Comparisons at landscape scale (between rivers)

The Berg/Riversonderend River System has the highest below-ground species richness although the Molenaars River System had the highest density of seedlings (Table 3.2). Table 3.3 and 3.4 give more detailed accounts for species richness and seedling densities of each plot sampled. These results were confirmed when Simpson's Diversity Index was used. Figure 3.3 shows a significant difference in diversity levels between the Berg and the Wit Rivers.

Table 3.2: Riparian seed bank species richness of four rivers in the Western Cape, South Africa (data are presented as means ± SD and ranked in descending order of richness, Berg n =60 samples, Molenaars n = 60 samples, Eerste n = 50 samples, Wit n = 50 samples. Data includes both indigenous and alien species.)

BERG	**Richness**	**MOLENAARS**	**Richness**	**EERSTE**	**Richness**	**WIT**	**Richness**
Bg MS (trans)	56	Mol MS (trans)	56	Er MS (d)	40	Wit MS (d)	38
Bg FH (trans)	39	Mol FH (d)	36	Er MS (w)	37	Wit MS (trans)	22
Bg FH (d)	39	Mol FH (trans)	30	Er FH (d)	36	Wit MS (w)	21
Bg FH (w)	37	Mol FH (w)	19	Er FH (w)	33	Wit FH (trans)	21
				Er MS (trans)	28		
				Er FH (trans)	27		
Mean Index	**42.75**		**32.25**		**33.5**		**22.5**
SD	(± 8.88)		(±15.15)		(± 5.16)		(± 8.34)

(**NOTE**: Sample codes for all analyses: **Rivers**: Bg- Berg, Er- Eerste, Mol- Molenaars; **Slope**: MS- mountain stream, FH-foothill; **Zones**: (w)- wet bank, (d)- dry bank, (trans)- transitional zone. Species codes are detailed within tables of the analyses.)

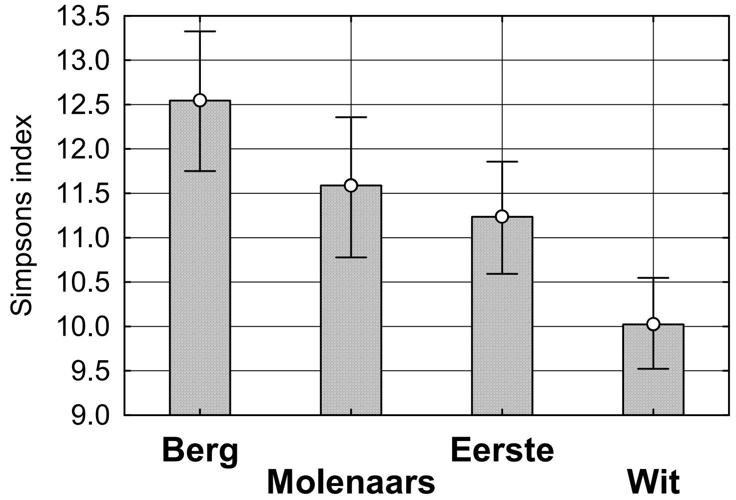

Figure 3.3: Simpson's Index of diversity for riparian seed banks in four rivers in the Western Cape, South Africa. Error bars represent 95% Confidence Interval.

Table 3.3: Riparian seed bank species richness for each plot sampled along four rivers in the Western Cape, South Africa (data are presented as mean and ranked in descending order of richness. Data includes both indigenous and alien species. Codes defined as in Table 3.2)

Sample	Species Richness
Bg MS (trans)	56
Mol MS (trans)	56
Er MS (d)	40
Bg FH (trans)	39
Bg FH (d)	39
Wit MS (d)	38
Bg FH (w)	37
Er MS (w)	37
Er FH (d)	36
Mol FH (d)	36
Er FH (w)	33
Mol FH (w)	30
Er MS (trans)	28
Er FH (trans)	27
Wit MS (trans)	22
Wit MS (w)	21
Wit FH (trans)	21
Mol FH (trans)	19

Table 3.4: Riparian seed bank seedling counts (abundance) for each plot sampled along four rivers in the Western Cape, South Africa (data are presented as mean and ranked in descending order of abundance. Data includes both indigenous and alien species. Codes defined as in Table 3.2)

Sample	Seedling counts
Mol MS (trans)	1606
Bg FH (w)	1591
Bg MS (trans)	1588
Bg FH (trans)	1312
Bg FH (d)	595
Wit MS (d)	572
Mol FH (w)	513
Er MS (w)	464
Er MS (d)	447
Er FH (d)	441
Wit FH (trans)	433
Er FH (trans)	383
Wit MS (trans)	362
Mol FH (trans)	335
Er FH (w)	326
Er MS (trans)	320
Mol FH (d)	292
Wit MS (w)	219

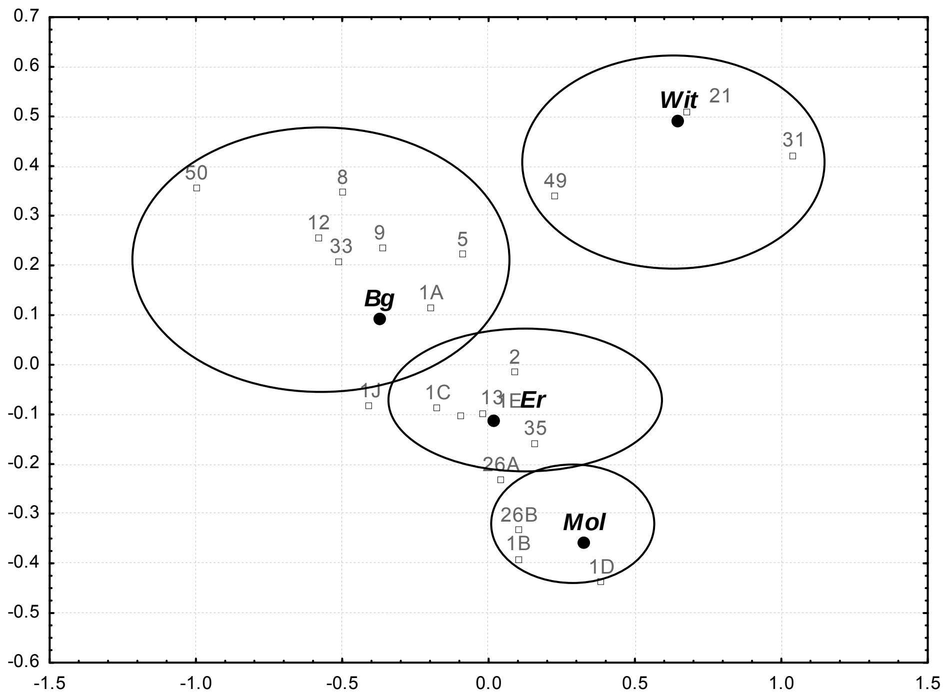

Figure 3.4: Correspondence analysis of seed bank species groupings between four rivers in the Western Cape, South Africa (Bg = Berg River, Wit = Wit River, Er = Eerste River, Mol = Molenaars River). Eigenvalue X: 0.14079 (54.59% of Inertia); Eigenvalue Y: 0.06729 (29.09% of Inertia). Species codes are as follows: 1A = *Panicum schinzii,* 1B = *Pennisetum macrourum,* 1C = *Juncus capensis,* 1D = *Ficinia anceps,* 1E = *Isolepis prolifera,* 1J = *Pentaschistus pallida,* 2 = *Euryops abrotanifolius,* 5 = *Erepsia/ Carpobrotus* sp., 8 = *Solanum retroflexum,* 9 = * *Hypochaeris radicata,* 12 = *Cliffortia cuneata,* 13 = *Metalasia* sp./ *Seriphium plumosa,* 21 = *Ischyrolepis subverticillata,* 26A = *Pseudognaphalium luteo-album,* 26B = *Helichrysum helianthemifolium,* 31 = *Struthiola tomentosa/ S. striata,* 33 = *Wahlenbergia cernua/ Oftia Africana* , 35 = *Disparago sp.,* 49a/b = *Erica caffra*, 50 = *Zaluzianskya capensis (* = alien weed).*

Correspondence analysis of emergent seedlings from the soil seed bank show fairly well-defined species groupings with species associated with certain habitats offered by the different river systems (Figure 3.4). The Berg and the Eerste Rivers showed a greater variety of species associated with the habitats offered within their riparian areas. The species that grouped together with the Wit River are noted to be generalist riparian species (*Ischyrolepis subverticillata, Struthiola tomentosa. S. striata, Erica caffra*), while those species associated with the Molenaars river were suspected to be associated with highly disturbed sites (*Pennisetum macrourum, Ficinia anceps, Helichrysum helianthemifolium).* However, it should not be assumed that these species occur exclusively in the river system groups. Rather, this analysis indicates that the abundance of selected species was greatest within specific river systems and it is suggested that the groupings are representative of the vegetation history of the site rather than any specific species assemblage associations.

3.4.2.2 Comparisons at reach scale

Species richness values (as per Table 3.2 and 3.3) were compiled in relation to the reach scale variable for all rivers sampled (i.e. mountain stream or foothill). The mean totals are shown in descending order of species richness level (Table 3.2). Mountain stream sections of all rivers were higher in species diversity than the foothill sections. Correspondence analysis (Figure 3.5) shows distinct species groupings between mountain stream and foothill slopes. Riparian species are better represented in the seed banks of foothill slopes, with Poaceae, Cyperaceae and herbaceous weedy species dominating. In contrast, mountain stream sites represent a diverse assemblage of fynbos species, with few riparian species present.

Table 3.5: Seed bank (emergent seedling) species richness of mountain stream and foothill sites in riparian zones of four rivers in the Western Cape, South Africa. Data are presented as total counts (species richness) and means ± SD. Data includes both indigenous and alien species. Site codes are presented in 3.2.

MOUNTAIN STREAM	**Index**	**FOOTHILL**	**Index**
Bg MS (trans)	56	Bg FH (d)	39
Mol MS (trans)	56	Bg FH (trans)	39
Er MS (d)	40	Bg FH (w)	37
Wit MS (d)	38	Er FH (d)	36
Er MS (w)	37	Mol FH (d)	36
Er MS (trans)	28	Er FH (w)	33
		Mol FH (w)	30
		Er FH (trans)	27
		Wit FH (trans)	21
		Mol FH (trans)	19
Mean Index	**36**	**Mean Index**	**31.7**
SD	± 11. 24	SD	± 7.53

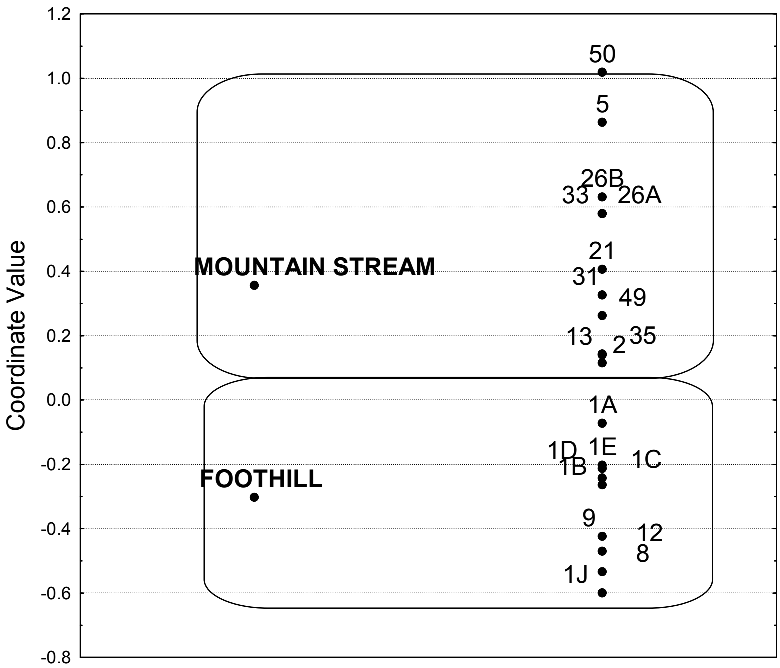

Figure 3.5: Correspondence analysis (2D) of species groupings between mountain stream and foothill slopes. Eigenvalue: 0.10774 (100.00% of Inertia). Contribution to Chi-Square: 1090.5. Species codes are as follows: 1A = *Panicum schinzii,* 1B = *Pennisetum macrourum,* 1C = *Juncus capensis,* 1D = *Ficinia anceps,* 1E = *Isolepis prolifera,* 1J = *Pentaschistus pallida,* 2 = *Euryops abrotanifolius,* 5 = *Erepsia/ Carpobrotus* sp., 8 = *Solanum retroflexum,* 9 = * *Hypochaeris radicata,* 12 = *Cliffortia cuneata,* 13 = *Metalasia* sp./ *Seriphium plumosa,* 21 = *Ischyrolepis subverticillata,* 26A = *Pseudognaphalium luteo-album,* 26B = *Helichrysum helianthemifolium,* 31 = *Struthiola tomentosa/ S. striata,* 33 = *Wahlenbergia cernua/ Oftia Africana* , 35 = *Disparago sp.,* 49a/b = *Erica caffra*, 50 = *Zaluzianskya capensis (* = alien weed).*

3.4.2.3 Comparisons at habitat scale (between bank zones)

Species richness and diversity was highest within the dry bank habitat of riparian zones (Table 3.6, Figure 3.6). Correspondence Analysis indicated very clear species groups associated with the different habitats and therefore the different moisture regimes (Figure 3.7 and Table 3.6). As could be expected, the riparian species such as Cyperaceae and Poaceae dominate the wet banks, while most of the fynbos species are represented in the dry bank. The transitional zone (or trans) has the greatest diversity of species representing both riparian and fynbos groups. It is important to note that the correspondence analysis results should not be compared with the species diversity figures as only the twenty most frequently occurring species were used in the correspondence analysis. Results between the two tests are opposing with the dry bank termed the least diverse bank in the correspondence analysis results. This can be explained by the fact that the dry banks are found to have the lowest species abundance levels (see Table 3.4) and this will skew the correspondence results in terms of diversity rankings.

Table 3.6: Riparian seed bank species richness within the different banks of four rivers sampled in the Western Cape, South Africa. Data are presented as mean indices and totals as mean ± SD. Wet bank n = 40 samples, Dry bank n = 40 samples, Transitional zone n = 60 samples.

WET BANK	Species Richness	DRYBANK	Species Richness	TRANSITIONAL ZONE(trans)	Species Richness
Bg FH	37	Er MS	40	Bg MS	56
Er MS	37	Bg FH	39	Mol MS	39
Er FH	33	Wit MS	38	Bg FH	39
Mol FH	30	Mol FH	36	Wit MS	22
				Wit FH	21
				Mol FH	19
Mean Index	**= 34.25**	**Mean Index**	**= 38.25**	**Mean Index**	**= 32.66**
SD	± 3.40	SD	± 1.71	SD	±14.56

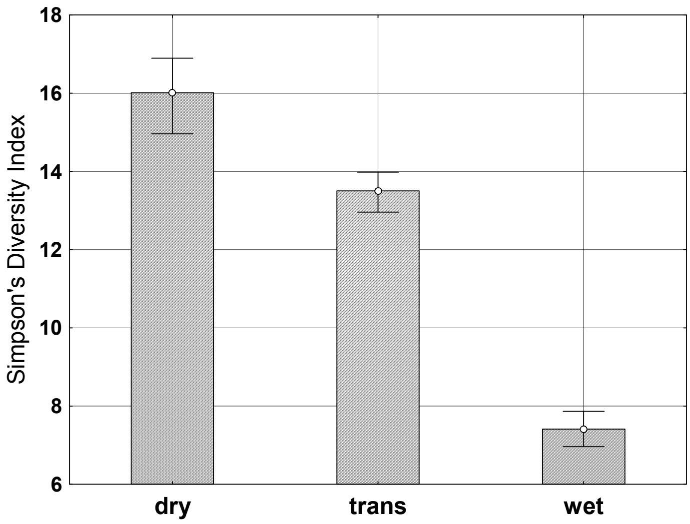

Figure 3.6: Simpson's Diversity Index for riparian seed bank species compared between banks of four rivers sampled in the Western Cape, South Africa. Error bars indicate 95% Confidence Interval.

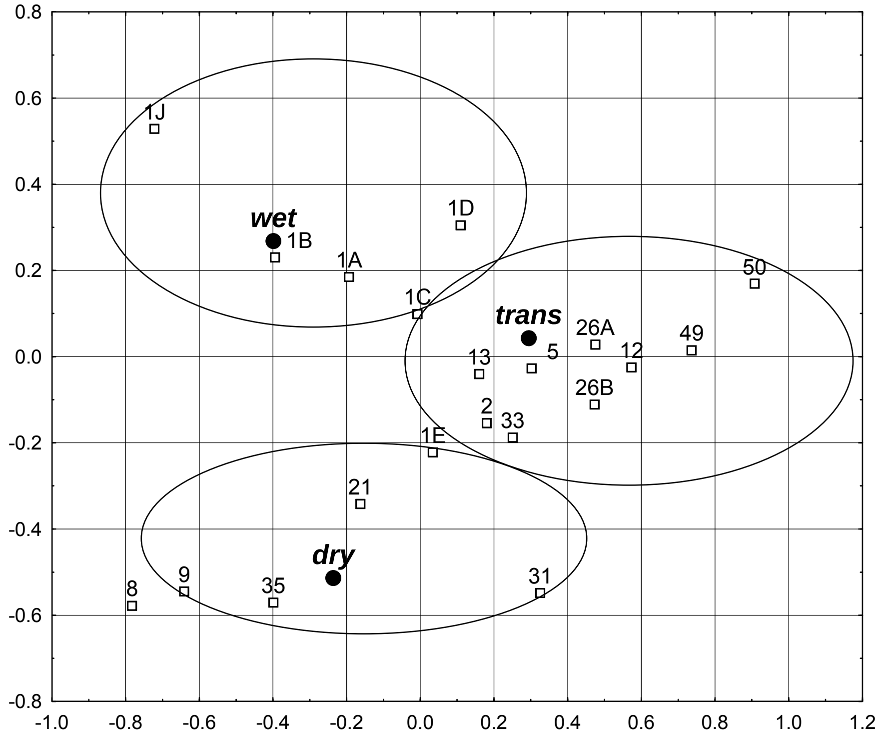

Figure 3.7: Correspondence analysis indicating distinct species groups in three habitat types (wet bank, dry bank and transitional zone) of riparian zones. Data for all four rivers (Berg, Eerste, Molenaars and Wit Rivers) in Western Cape, South Africa were combined. Eigenvalue X: 0.10093 (58.60% of Inertia); Eigenvalue Y: 0.07130 (41.40% of Inertia). Species codes are as follows: 1A = *Panicum schinzii,* 1B = *Pennisetum macrourum,* 1C = *Juncus capensis,* 1D = *Ficinia anceps,* 1E = *Isolepis prolifera,* 1J = *Pentaschistus pallida,* 2 = *Euryops abrotanifolius,* 5 = *Erepsia/ Carpobrotus* sp., 8 = *Solanum retroflexum,* 9 = * *Hypochaeris radicata,* 12 = *Cliffortia cuneata,* 13 = *Metalasia* sp./ *Seriphium plumosa,* 21 = *Ischyrolepis subverticillata,* 26A = *Pseudognaphalium luteo-album,* 26B = *Helichrysum helianthemifolium,* 31 = *Struthiola tomentosa/ S. striata,* 33 = *Wahlenbergia cernua/ Oftia Africana* , 35 = *Disparago sp.,* 49a/b = *Erica caffra*, 50 = *Zaluzianskya capensis (* = alien weed).*

3.5 DISCUSSION

This study offers insight into the habitat requirements of certain fynbos and riparian species by illustrating the species groupings on a lateral and longitudinal gradient within four rivers in the south-western Cape of South Africa. Above-ground riparian vegetation studies are fairly abundant, both globally (Hupp, 1992; Stromberg, 1997; Naiman and Décamps, 1997; Andersson *et al.,* 2000; Gomi *et al*., 2002; Nilsson and Svedmark, 2002) and within the fynbos biome (Boucher, 1978; McDonald, 1988, Burgers 1992, McDowell, 1996; Boucher, 1999; Sieben, 2002; Boucher and Tlale 1999, Galatowitsch and Richardson, 2005; Prins *et al.* 2005, Reinecke and King, 2007), and all show similar habitat-specific vegetation groupings. The few studies that have been done on the seed banks of wetlands (van der Valk, 1981; Leck, 1989; Welling *et al.,* 1988) and riparian areas (Abernethy and Willby, 1999; Nilsson *et al*., 1991; Goodson *et al*., 2001) state that as a result of the varying levels of site-specific disturbances (both natural and anthropogenic), inter-river (between different river systems) vegetation comparisons (both above-ground and from the seed bank) are rarely possible. This was indeed the case within this study as diversity level and species grouping comparisons between river systems showed no patterns and were suspected to be related to site history. Although within a terrestrial medditeranean landscape, a recent study by Buisson *et al.* (2006) found that site specific variables contributed to 23% of the vegetation patterns when investigating the seed bank patterns in relation to plant succession at the edges of abandoned fields. They found each site to be characterised by a unique historical path which had a direct influence on the particular set of species found. Such variation in historical land-use, together with the extreme variability of both riparian areas and seed banks, makes evaluating the restoration potential of riparian seed banks on a broad scale almost impossible. However, this study showed that when investigated at a habitat-specific scale, a definite diversity gradient exsists with distinct species groupings. Additionally, the species that were represented by the seed bank germinants, were of adequate diversity to kick-start community restoration, but were not an accurate reflection of all riparian species and would therefore require intervention to complete the restoration process. The value of maintaining a seed source for the woody, animal-dispersed riparian species cannot be over-looked (Wassie and Teketay, 2006). It is suggested that in areas where such seed sources are lacking or destroyed, re-introductions in the form of planting adult specimens should become part of the post-disturbance restoration process. Without this vital step, restoration is expected to be incomplete and may result in the re-establishment of IAPs.

Species assemblages at reach scale imply that the mountain stream sections are more suitable for riparian species while the foothill sections are favoured more by fynbos species. It is suggested that this is related to the frequency of fires through the reach areas. Many upper reaches (mountain streams) may be protected from neighbouring fynbos fires because of their topography and vegetation structure, and are thereby more likely to be dominated by riparian tree and scrub species rather fire-dependant fynbos species. In contrast, the foothill sections of the riparian areas are more open in topography (and thereby more accessible for human-related disturbances, including fire) and therefore have a higher frequency of fire sweeping through the riparian sections. Therefore, foothill sections of the rivers can be expected to be dominated by fire-dependant fynbos, fire-tolerant fynbos riparian scrub and some invasive alien tree species, as was found in this study.

The results from bank zone comparisons showed distinct species groupings along the different moisture bands. As could be expected, riparian species were best represented within the wet bank zones and fynbos species similarly so within the dry bank zone. Species from both zones were present within the transitional zone, resulting in this zone offering the highest species diversity. High disturbance levels exsist both within the wet banks, in the form of constant water movement; and dry banks, in the form of fire, herbivory, alien plant invasion and anthropogenic disturbances like footpaths and motorways. The intermediate disturbance hypothesis (Connell, 1978) proposes that biodiversity is highest when disturbance is neither too rare nor too frequent and is generally the most widely supported, especially in the riparian context. It suggests that in areas with low disturbance, competitive exclusion by the dominant species arises, while in areas with high disturbance only species tolerant of frequent upheaval can persist. Nilsson *et al.* (1989, 1991) examined entire rivers in northern Sweden and found that riparian vegetation was most species rich in the middle reaches of free-flowing rivers. Décamps and Tabacchi (1994) found similar patterns in French rivers. This study found that the seed banks within the mountain stream sites offered higher species diversity than the seed banks from the foothill sites. This result implies that mountain stream sites offer a more "favourable" level of disturbance, perhaps because of their topography and resulting inaccessibility to anthropogenic causes of disturbance. Foothill sites, other the other hand, generally have a long history of anthropogenic disturbance and have therefore may have exceeded the optimal level of disturbance in terms of maintaining community diversity. As a result, the above-ground community becomes less diverse (although often still species-rich) and more homogenous with pioneer species (such as *Psoralea* and *Helichrysum* species) and weedy agricultural species (*Solanum retroflexum, Conyza albida, Hypochaeris radicata*) dominating, as was found within this study. Additionally, the above-ground vegetation of the foothill slopes within this study was found to be largely dominated by graminoids and herbaceous perennials from both fynbos and riparian vegetation types. In contrast, the extant vegetation found along mountain stream slopes studied tended to be dominated by more long-lived woody fynbos shrubs, with some Afrotemperate Forest elements well represented and few riparian species present.

Most large-seeded fynbos species (approximately 30% of the flora) are limited by their short dispersal distances. Some species rely on ants for dispersal into the soil profile (Johnson, 1992, Bond and Slingsby, 1983) while others may rely on small mammals and rodents to assist in dispersal. In contrast, riparian species can achieve greater seed dispersal distances with the aid of moving water within the river channel (Barrat-Segretain, 1996; Nilsson *et al*., 1991; Boedeltje *et al.,* 2003; Vogt *et al*. 2006). This dispersal mode often requires seeds to have certain morphological and physiological adaptations. The majority of riparian species within the study area were noted to have some adaptation for dispersal by water. Large-seeded fruits (like that of *Brabejum stellatifolium*) have a better chance of travelling to a bare patch of ground along the river's edge than other small-seeded species, while Poaceae species have seeds with small wings which allow them float or fly. Seed longevity must be taken into consideration as several riparian species, like *B. stellatifolium* for example, have short-lived seeds and are therefore not always represented in the soil seed bank. Additionally, many species of Cyperaceae form new plants at the end of their long spikes, weighting them down toward the ground where they form roots and an entirely new plant. Alternatively, these vegetative young plants can be broken off and can travel in the river channel to establish in a new area. Although some predictions are offered within this study and others (Galatowitsch and Richardson, 2005), it is clear that more research is needed in order to properly understand the life-history strategies and inter-relationships that underpin fynbos riparian areas.

Many of the species that characteristically form seed banks are early succession species (Warr *et al*., 1993). Within this study, most of the species that were identified in the first three months were noted to be pioneer species. Succession within terrestrial fynbos communities is said to be fairly constant after the initial post-fire flush of annuals and geophytes. Species are then successively eliminated according to life spans, thus differences in life histories, rather than competitive abilities, is thought to drive succession in fynbos communities (Bond and van Wilgen, 1996). Riparian communities, however, may have higher levels of competition as a result of less frequent fires enabling more stable environments for longer-lived plant life forms such as trees and tall shrubs. The latter are absent from the soil seed bank. Seedling germinants of riparian species in this study tended to belong to either Poaceae or Cyperaceae with a few belonging to Restionaceae or Asteraceae. Fewer annuals were present within the wet zones when compared to the fynbos germinants represented in the dry or transitional zones. Initial germination and establishment by Poaceae and Cyperaceae representatives was rapid throughout all samples, with a swift decline following the first month. Thereafter, a slower phase of germination was reflected by Ericaeae and Restionaceae species. Although this study generally reflects the emergence pattern that has been found in similar fynbos seed bank studies, it has until now, not yet been illustrated within riparian areas of this region.

Results from this study reiterate previous findings that seed banks offer little reference to current aboveground vegetation, but rather offer insight into past vegetation groupings as well as future vegetation assemblages (Warr *et al*. 1993). Evidence is shown that in relatively natural environments (<25% invasion), the potential for the seed bank to recruit a vegetation community similar to that of previous years is possible only if the cleared area is maintained free of IAPs and the re-introduction of certain key riparian woody species (like *Brabejum stellatifolium* and *Metrosideros angustfolia*) is added into the restoration process. However, the success rate of riparian seed banks as conservation tools of disturbed areas will depend on the history of the site. If, for example, the area is so greatly disturbed by flooding, erosion or mining that a large percentage of the topsoil has been lost, then relying on the soil-stored seed bank would be non-viable. It is vital, therefore, for conservationists to educate interested and affected parties and implement regulations with regards to development or alteration of natural environments, in order to successfully rehabilitate these areas post-disturbance. Seed banks can hold remnants of past species assemblages that have since been removed above-ground and can greatly assist in the restoration of alien-cleared areas if properly investigated and understood. The fynbos biome is under increasing stress due to development, agriculture and global warming. It is suggested that with the right knowledge, and dedication in applying this knowledge, seed bank restoration can play a vital role in both restoring and conserving the diversity within this fragile system.

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CHAPTER 4: THE IMPACT OF INVASIVE ALIEN PLANTS ON RIPARIAN SEED BANKS IN THE FYNBOS BIOME, SOUTH AFRICA

4.1 ABSTRACT

Riparian areas contribute significantly to the spread of many invasive alien species which alter the ecosystem and, in the case of alien trees, bring about significant water loss to the river system. In South Africa, these areas have therefore been targeted by many alien clearing programmes. Little attention, however, has been paid to rehabilitating these areas after alien clearing and the role that soil seed banks play in this process. This study aimed to assess the composition and viability of riparian seed banks before and after invasion, to be used as a key informant, by conservation managers and landowners, of post disturbance rehabilitation requirements.

The focus was on soil seed bank composition of the riparian vegetation in four river systems within the fynbos biome of the Western part of the Western Cape Province. Both mountain and foothill sections of the Eerste, Molenaars, Berg and Wit Rivers were sampled. Equal numbers of plots were located in both relatively undisturbed fynbos riparian areas, with less than 25% invasive alien plant cover, and in heavily invaded (>75% invasive cover) sections of the rivers. Two factors were taken into consideration when setting up the sampling plots, namely lateral (wet and dry bank) and longitudinal (mountain stream and foothill) zones. The seedlings that emerged from the soil samples were compared between undisturbed and invaded sites in terms of diversity, species richness, similarity and assembly groupings. Site history, most especially fire history and extent of invasion, was found to influence the diversity levels of indigenous species in the seed banks of all rivers. In general, samples taken from invaded sections of rivers offered a higher diversity of indigenous species than those taken from reference sections, although the invaded samples had lower abundance of indigenous species than the reference samples. At all three spatial scales investigated, species assemblages were strongly influenced by the state of the river (reference or invaded) and tight, closely related grouping patterns were found within reference samples whereas the invaded samples showed a more diffuse, highly variable pattern.

Key words: riverine areas, non-native plants, assembly patterns, site history

4.2 INTRODUCTION

Seed bank studies offer insights into the initial post-disturbance vegetation community and can be highly valuable in evaluating effective restoration techniques for disturbed landscapes at community and site specific scales. Despite many terrestrial (Holmes 1990; Thompson, 1992; Holmes, 2002; Holmes and Newton, 2004; Thompson *et al,* 2003) and wetland (Leck, 1989, Keddy and Constabel, 1986; Leck and Brock, 2000) seed bank studies, research on riparian seed bank dynamics is in its infancy. All plant communities are subjected to many forms of disturbance, most of which have a direct impact on the seed bank dynamics. Within river systems, the most prominent form of disturbance is water flow which is highly variable both in space (erosion and deposition depending on river reach type) and time (seasonality of floods). This, in turn, has resulted in riparian areas being notoriously variable and particularly sensitive to human impacts that alter the natural disturbance cycle (Rowntree, 1991; Wohl, 2005). The relatively recent increase of invasive alien plants (IAPs) in riparian zones, together with the sequential destructive changes to the structure and functioning of the ecosystem, has caused IAPs to generally be thought of as a form of disturbance in riparian zones. Because of their linear and uni-directional nature, river corridors play a major role in the dispersal and spread of IAPs throughout the system and laterally into surrounding areas. As a result, several alien clearing initiatives have been initially targeting river corridors before moving on to clear the neighbouring landscapes. In South Africa, the Working for Water (WfW) project is a prime example of such an initiative, whose main aim is to improve and increase both the quality and quantity of water production, and to conserve biodiversity (van Wilgen *et al*., 1998), which includes the full recovery of the fynbos vegetation cover following alien removal. However, limited budgets often result in unsatisfactory and inadequate results (Holmes, 1998; Holmes, 2001). Poorly planned or executed restoration projects can result in soil erosion, loss of soil-stored propagules, poor water quality and the high risk of re-invasion by alien plant species (Holmes, 2001).

Little is known of riparian seed banks and the role they play in community restoration after disturbance. Less still is known of the impact of invasion on the riparian seed bank dynamics. Seed banks are notoriously variable in terms of the diversity, abundance and richness of species that make up the composition (Grubb, 1988; Bertiller, 1998; Brock and Rogers, 1998; Abernethy and Willby, 1999). Previous research has offered the explanation that in areas of high levels of disturbance, a high diversity of herbaceous and short-lived species will dominate the initial recruitment phase (i.e. form the seed bank), while in areas of little or no disturbance, the species diversity within the seed bank will be low and the species present will be of dissimilar nature to the above-ground vegetation (Grubb, 1988; Leck, 1989; Nilsson *et al*., 1989).

As a result of the frequency and intensity of disturbance within river systems and the required resilience to disturbance of the species that persist under these circumstances, riparian vegetation is distinctive from the surrounding terrestrial vegetation and forms a vital link between aquatic and terrestrial ecosystems (Boucher, 1978; Sieben, 2002; Naiman and Décamps, 1997). The plant assemblages that are found in the above-ground vegetation are those that are able to utilize the natural resources (nutrient deposition, exposed sites, transportation of seeds vast distances) to their advantage in order to persist in the community. Because of the highly variable nature of river systems, riparian communities rarely have species assemblages that are uniform in nature, but are more often specific to a certain section of the river where unique interactions take place which are utilized by some species and not by others (Barrat-Segretain, 1996; Sieben, 2002; Naiman and Décamps, 1997; Galatowitsch and Richardson, 2005; Richter and Stromberg, 2005; Naiman *et al.,* 1993; Tabacchi *et al.,* 2000). Despite the high variability, we suspect at some level certain community patterns may be evident. This paper aims to explore the seed bank assembly patterns found within four rivers in the south western cape of South Africa with the aim of providing insight into more effective restoration techniques following alien clearing in riparian areas.

The main objectives of this chapter are as follows:

1. To establish the impact that alien plant invasion has on the riparian seed banks within the study area. This will be done comparatively with the use of:
    - correspondence analysis on three scales : river, reach and zone
    - diversity indices on three scales : river, reach and zone
    - similarity indices on three scales : river, reach and zone

2. To establish the impact of certain “key” environmental variables on the most frequently occurring species in terms of their associations and relate that to the results from the above-mentioned analyses.

4.3 RESEARCH DESIGN AND METHODS

4.3.1 STUDY SITES

Four river systems within the south-western fynbos region were chosen for their variety of reach types, history of vegetation (both alien and natural), and for their relatively close proximity to the research facilities. The above-ground vegetation was sampled in plots that were selected in both relatively undisturbed fynbos/riparian areas (<25% alien plant canopy cover) and heavily invaded (>75% alien cover) riparian sections of the rivers. Two factors were taken into consideration when setting up the sampling plots, namely lateral (wet & dry bank) and longitudinal (mountain stream & foothill) zones. For more detailed descriptions of study sites and sampling procedures see Chapter 2.

4.3.2 DATA COLLECTION

Plots were established, measuring 20 meters in length (parallel to the river) and 5 meters in width (running perpendicular to the river) in both reference and invaded sections of the four river systems. Within each plot, ten quadrats ($1m^2$) were selected using random numbers and both the above-ground vegetation data (species presence and % canopy cover, % rock cover and % bare ground, and estimate of total canopy cover) and soil samples were collected per quadrat. Soil samples were collected using a hand-held soil corer (10cm deep and 5cm diameter) and 5 cores were taken per quadrat and lumped together to form one sample. This was to allow for seed bank variability. In total, 23 plots (310 quadrats) were sampled within the invaded plots and 22 plots (290 quadrats) within the reference plots giving a total of 600 samples once combined. Soil samples were placed in labelled trays and treated with a uniform dosage of smoke treatment prior to commencement of irrigation. Thereafter, seedlings that emerged from the soil seed bank were counted and identified as close to species level as possible. Monitoring took place bi-monthly for the first 3 months, and monthly for the last three months. Termination of the entire project was in December 2006 and most specimens had been identified to species level by this stage. All analyses within this chapter were computed for the seed bank germinants *only*, see Chapter 5 for above-ground and seed bank comparisons. Also see Chapter 2 for more details on seed bank sampling and data collection.

4.3.3 DATA ANALYSIS

The impact of invasion on indigenous seed bank composition

4.3.3.1 Diversity indices of indigenous species in seed banks of invaded and reference plots

Simpson's Index of diversity was used as it weights the most abundant species more heavily than the rare species. The formula measures the probability that two individuals randomly selected from a sample will be of different species. If n_i is the number of individuals i of species s which are counted, and *N* is the total number of all individuals counted, then the following formula is an estimator for Simpson's index (*D*) without replacement:

$$D = \sum_{i=1}^{s} \frac{n_i\left(n_i - 1\right)}{N\left(N - 1\right)}$$

Note that $\mathbf{0 \leq D \leq 1}$ with values near zero corresponding to highly diverse or heterogeneous ecosystems and values near one corresponding to a more homogenous ecosystem. This is neither intuitive nor logical and therefore many biologists use the **1/*D*** version of the index which allows the higher index to equate to a higher diversity level and the lower diversity index to a lower diversity level. The programme used (*Species Diversity and Richness Version 2.65* (Seaby and Henderson, 2005)), gives the final index number in the **1/*D*** format and therefore the higher the index, the higher the diversity of <u>indigenous</u> species. The indices were then illustrated in a comparative format through the programme *Statistica 7.0*. (StatSoft Inc., 2004). Where necessary, further details were established for each plot by dividing the total composition (100%) into percentage growth forms. This was done using *Microsoft ® Office Excel 2003.*

4.3.3.2 Species Richness and Abundance

Species richness was calculated by counting the number of different species that occurred per sample or plot and abundance by the count of seedlings that germinated per species. Both were calculated in *Excel*. Comparisons between different sections of the rivers, as well as between reference and invaded sections of the rivers were done.

4.3.3.3 Sørensen's similarity index

Sørensen's similarity index (Kent and Coker, 1992) is based on the probability that two randomly chosen individuals belong to species shared by both samples. The higher the index, the higher the similarity of species between samples. The formula is:

$$S_S = 2C / (A + B)$$

Where S_S = Sørensen similarity coefficient
A = number of species in quadrat/sample 1
B = number of species in quadrat/sample 2
C = number of species common to both quadrats/samples

This index was used to compare the similarity within comparative plots/samples before and after invasion (i.e. to establish whether invasion increases or decreases the similarity of species within like plots/samples) by calculating the mean similarity index and mean shared species between all reference plots for each river; which was then compared against the mean index and mean shared species within the invaded plots of each river. Additionally, Sørensen's index was used at a broader scale to compare the probability of shared species occurring with reference and invaded sections of the same river. All similarity indices were computed using *Estimate S Program Version 7.5* (Cowell, 2005) and compared to the results from the correspondence analyses.

4.3.3.4 Correspondence Analyses for top twenty seed bank species

Correspondence analyses were computed for the twenty most frequently occurring species overall (indigenous and alien), as well as the twenty most frequently occurring indigenous species. Comparisons between reference and invaded plots were done at three different spatial scales:

- landscape scale – comparing rivers
- reach scale – comparing mountain stream and foothills
- habitat scale – comparing wet, dry and transitional bank zones.

Correspondence analyses were also computed for the twenty most frequently occurring species overall, as well as the twenty most frequently occurring indigenous species in terms of their relation to certain levels of "key" environmental factors:

- fire frequency
- invasion history
- level of human/man-made disturbance.

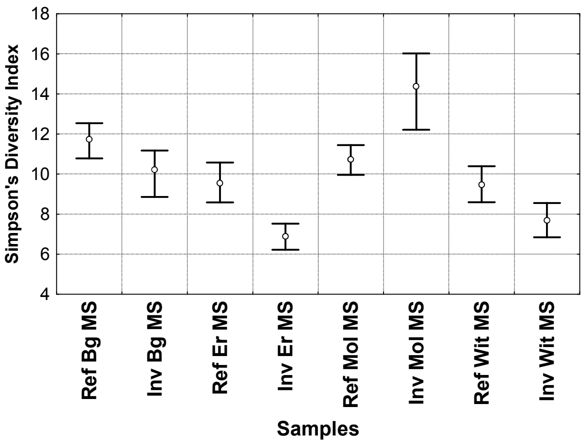
Ratings of these factors ran from 0 to 3, with the lower the rating, the lower the level of human influence. Ratings were based on information from the WfW database (for fire and invasion) and from visual inspection on site (disturbance). Disturbance was termed so if anthropogenic evidence, in terms of agricultural practises, road-work or developmental practices, or any other form of un-natural disturbance was found within and/or around the study site. See Appendix 4.2 for full table. The programme *Statistica 7.0* (StatSoft Inc., 2004) was used for all of the correspondence analyses.

4.4 RESULTS

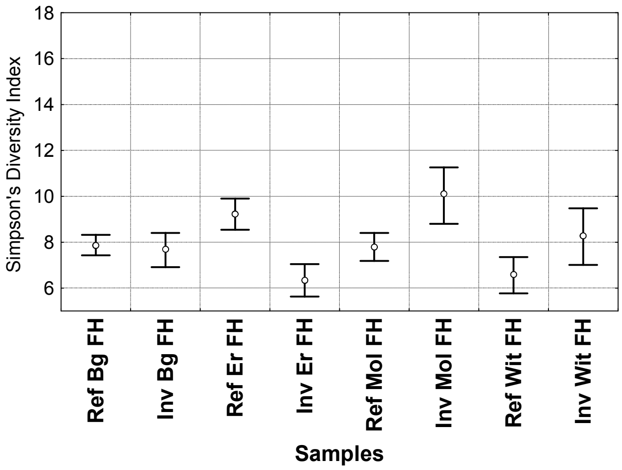
4.4.1 DIVERSITY INDICES FOR INDIGENOUS SPECIES IN SEED BANK

Site history influenced the diversity levels of indigenous species in the seed banks of all rivers. Comparisons among diversity indices from the four rivers at reach scale showed no clear pattern (Appendix 4.1, Tables B1.1- B1.4). There was a general decrease in diversity levels of indigenous species in moving from reference to invaded mountain stream plots of all rivers, with the exception of the invaded Molenaars mountain stream plot whose diversity was higher than most other plots (Figure 4.1, Figure 4.3). This pattern is less clear within the foothill plots (Figure 4.2). However, when investigated at a broader scale (Figure 4.4), a pattern began to emerge. Interestingly, invaded sections of most rivers had a higher diversity of indigenous species in their seed banks than did the reference sections (Figure 4.4).

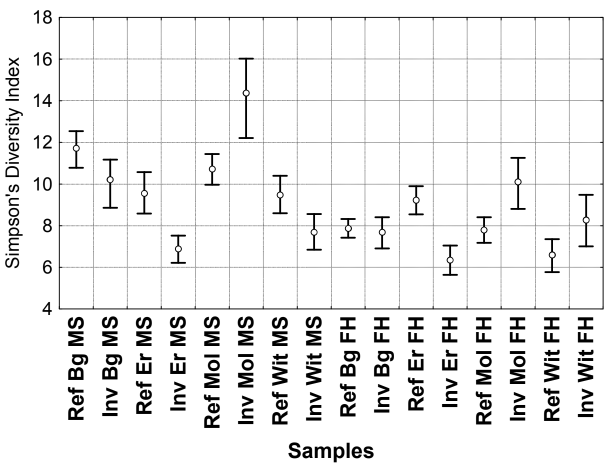
The combined seed bank species for each river were then grouped into growth forms (Figure 4.5 and Table 4.1) in order to establish whether a pattern in vegetation structure emerged at that scale. Graminoid species consistently made up 50% or more of the seed bank regardless of invasion status. There was an increase in herbaceous annual species and a decrease in herbaceous perennial species once a plot become invaded. Generally, shrub/shrublet species were more abundant in the reference seed banks, with the exception of the invaded Molenaars plots which showed a higher abundance of this growth form. Tree species were only evident in a few plots within the un-invaded sections of the Eerste River. An additional correspondence analysis was computed for all of the species in terms of their growth forms to establish whether different growth forms showed an affinity towards certain rivers or sections of rivers (Appendix 4.1, Figure B 2). The seed banks within both the Wit and Eerste rivers had a high percentage of succulent and herbaceous annual species. Succulent species were only found in the seed banks of these two rivers while herbaceous annual species were also present in invaded and reference sections of the Berg, Molenaars and Wit rivers. Herbaceous perennial species occurred mostly in the reference sections of the Wit and Molenaars rivers while graminoid species occurred particularly within the reference sections of the Berg and Eerste rivers as well as the invaded sections of the Molenaars.



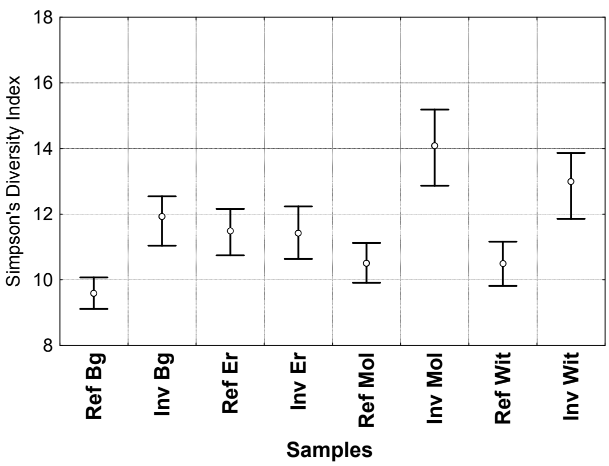
<u>Figure 4.1:</u> Diversity indices for all combined mountain stream plots sampled



<u>Figure 4.2:</u> Diversity indices for all combined foothill plots sampled



<u>Figure 4.3</u> Diversity indices of all combined mountain stream and foothill plots together



<u>Figure 4.4:</u> Diversity indices for all rivers on a landscape scale

<u>All abbreviations for figures, tables and maps follow the format</u>: Ref= Reference ; Inv= Invaded; Er= Eerste River; Mol= Molenaars River; Bg= Berg River; MS= Mountain stream; FH= Foothill; Trans= Transitional bank zone. Data excludes alien species.

4.4.2 SEED BANK SPECIES RICHNESS AND ABUNDANCE

Results from species richness indices (Table 4.2) show no clear pattern but appeared to be more site-specific. Generally, mountain stream sections were more species rich than the foothill sections throughout both reference and invaded samples. When seedling abundance data alone is considered, a more consistent pattern is evident with the reference plots having a greater abundance of seedlings than the invaded plots (Table 4.2).

4.4.2.1 Sørensen's Similarity Index

As in the diversity indices and species richness results, Sørensen's Similarity Index showed very little pattern (Appendix 4.3, Tables D 1.1 & D1.2) and seemed to be based on site specific history. At a broad scale, comparing similarity of species between reference and invaded samples, (Table D 1.1) results showed the Molenaars River to have the highest similarity of species and the Berg River the lowest. The mountain stream samples showed a high similarity between reference and invaded sections, while the foothill comparisons showed a low level of similarity. At the habitat scale, the transitional bank offered the highest similarity between reference and invaded samples. Table D 1.2 shows the similarity indices compared at a finer scale, comparing similarity of species among plots of reference versus similarity of species among invaded plots. Here similarity indices were higher in most of the reference samples, with the exception of the invaded Molenaars samples which were the highest overall. The reference samples from the foothill sections showed a slightly higher similarity index than their invaded counterparts. At a habitat scale, both dry and transitional reference samples offered higher similarity than the invaded section; however the wet invaded samples were more similar than the wet reference samples of all the rivers. Dry bank reference samples had the highest level of similarity and invaded transitional bank the lowest level of similarity.

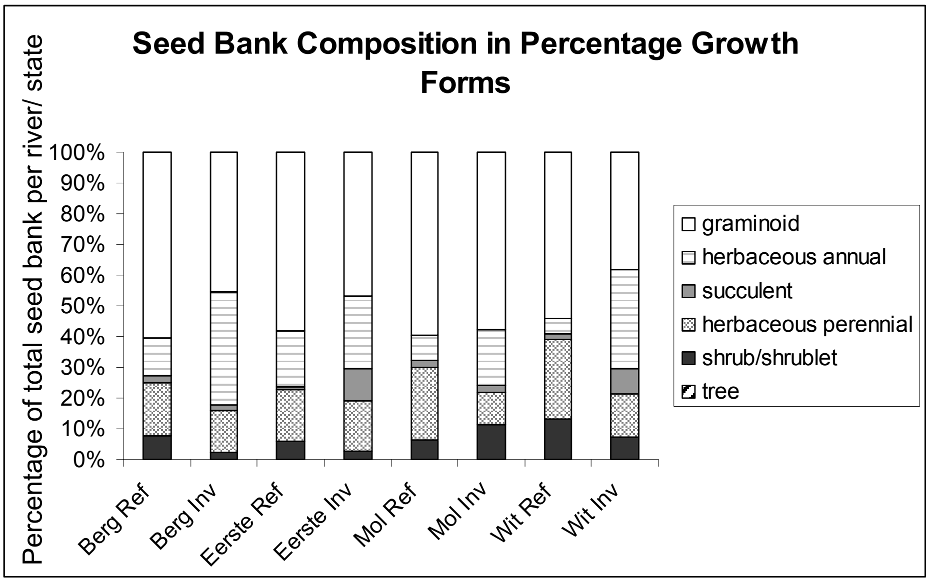


Figure 4.5: Relative percentage abundance of growth forms for reference (Ref) and invaded (Inv) sections of the four rivers, Berg, Eerste, Molenaars and Wit.

Table 4.1: Seedling abundance for reference (Ref) and invaded (Inv) sections of four rivers divided into growth forms. Data includes indigenous species only.

RIVER	**Berg**	**Berg**	**Eerste**	**Eerste**	**Mol**	**Mol**	**Wit**	**Wit**
State	**Ref**	**Inv**	**Ref**	**Inv**	**Ref**	**Inv**	**Ref**	**Inv**
Tree	0	0	11	0	0	0	0	0
shrub/shrublet	338	13	137	48	174	164	198	100
herbaceous perennial	768	76	370	274	623	150	386	191
Succulent	109	9	30	176	57	35	33	107
herbaceous annual	540	206	406	396	218	251	76	443
Graminoid	2672	521	1308	788	1578	818	816	519
TOTALS:	**4427**	**825**	**2262**	**1682**	**2650**	**1418**	**1509**	**1360**

Table 4.2: Total species richness and seedling abundance for reference and invaded stream segments. Data includes indigenous species only. MS = mountain stream, FH = foothill, Ref = reference, Inv = invaded.

River	**Section**	**Richness**	**Abundance**
BERG	MS Ref	53	1501
	MS Inv	34	346
	FH Ref	52	2926
	FH Inv	30	479
EERSTE	MS Ref	46	1219
	MS Inv	37	734
	FH Ref	42	1043
	FH Inv	37	948
MOLENAARS	MS Ref	47	1533
	MS Inv	46	556
	FH Ref	40	1117
	FH Inv	51	862
WIT	MS Ref	37	1062
	MS Inv	44	805
	FH Ref	21	447
	FH Inv	35	555

4.4.2.2 Seed bank species assembly patterns

Species assembly patterns were clearly defined by the state of the river (reference or invaded) and this pattern was evident at all three spatial scales. The reference seed bank species group together more tightly while the invaded seed bank species are more spread out (Figure 4.6: A1, B1 and C1). Additionally, correspondence analyses were computed for the top twenty indigenous species after removing the alien elements (Figure 4.6: A2, B2 and C2) and a similar pattern emerged at all scales except the landscape scale. Reference seed bank species assemblages seem to be relatively un-affected by variables such as reach (Figure 4.6: B1 & B2) or zone (Figure 4.6: C1 & C2) while within the invaded seed banks, the species show distinct associations with these variables.

4.4.2.3 Impact of environmental factors on seed bank species assemblages

Species assemblages showed a clear affinity towards certain environmental factors for all species (Figures 4.7: D1, E1 & F1) and indigenous species only analyses (Figure 4.7: D2, E2 & F2). Fire frequency (Figure 4.7: D1 & D2) showed most species grouping together under moderate frequency of fire (rating 1), with fewer species being associated with too frequent or too recent fires (ratings 0, 2, 3) (see Chapter 2 for more details of fire environmental variable indices). A history of long invasion (rating 3 in Figure 4.7: E1 & E2) seemed to select different species to those associated with less intense levels of invasion. The lower and less intense levels of invasion also had specific species closely associated with them (ratings 0, & 2 in Figure 4.7: E1 & E2). The varying levels of disturbance show distinct groupings of species, with the majority associating with low and moderate levels of human disturbance (Figure 4.7: F1 & F2). Results from CART (Classification and Regression Trees) analyses confirm the general pattern shown in the correspondence analyses summarised in Table 4.3 (Also see Appendix 4.2, Figure C1 for more details).

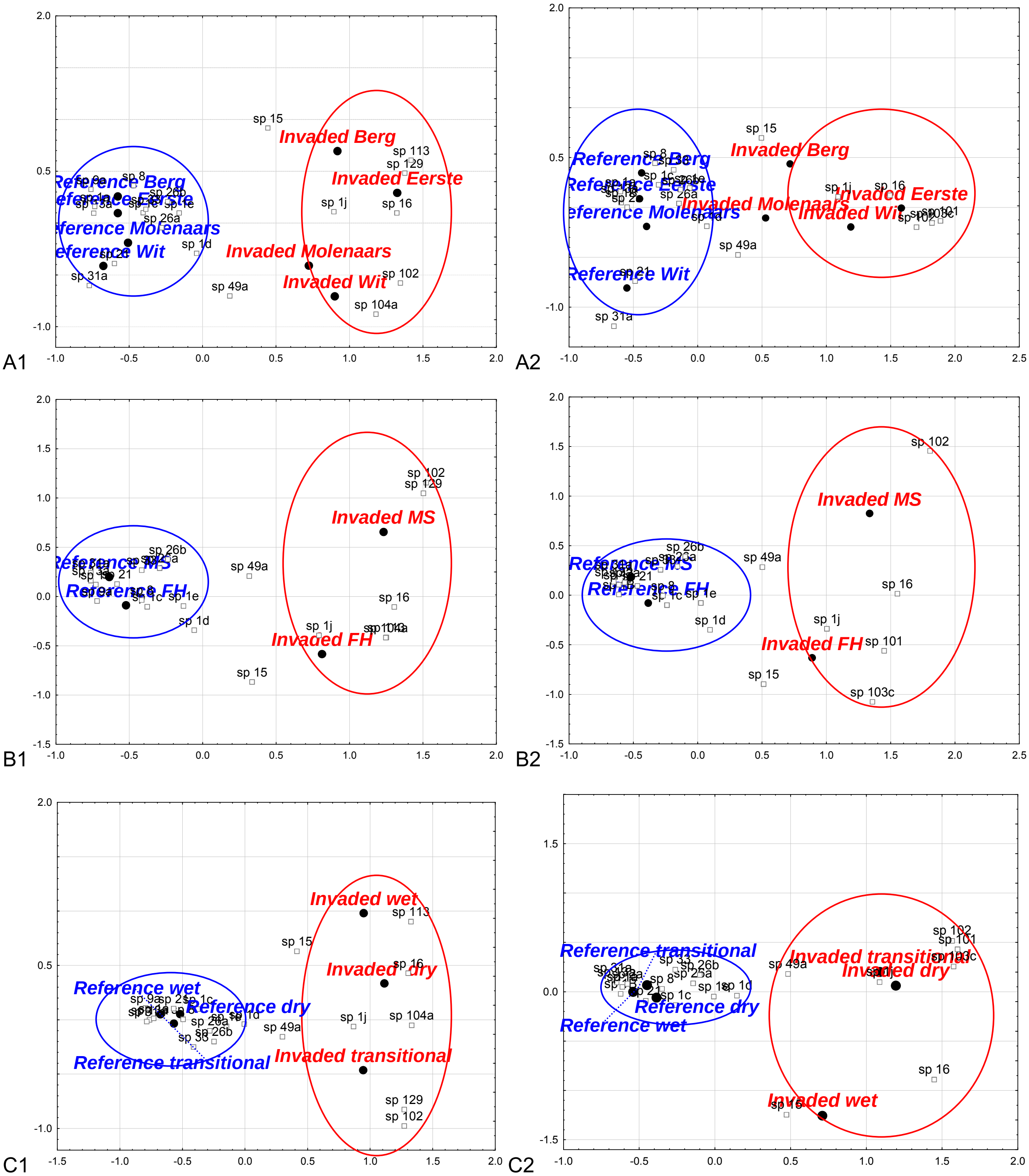
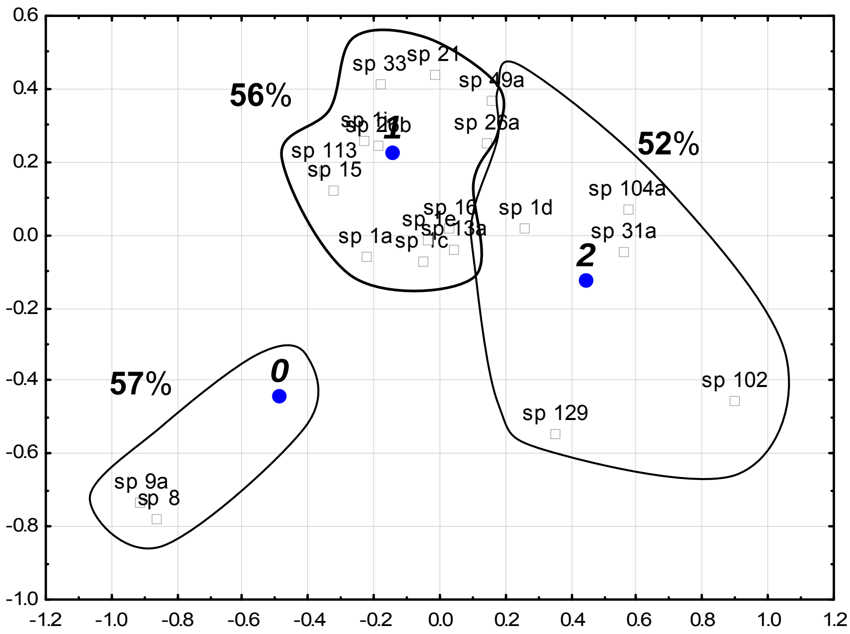
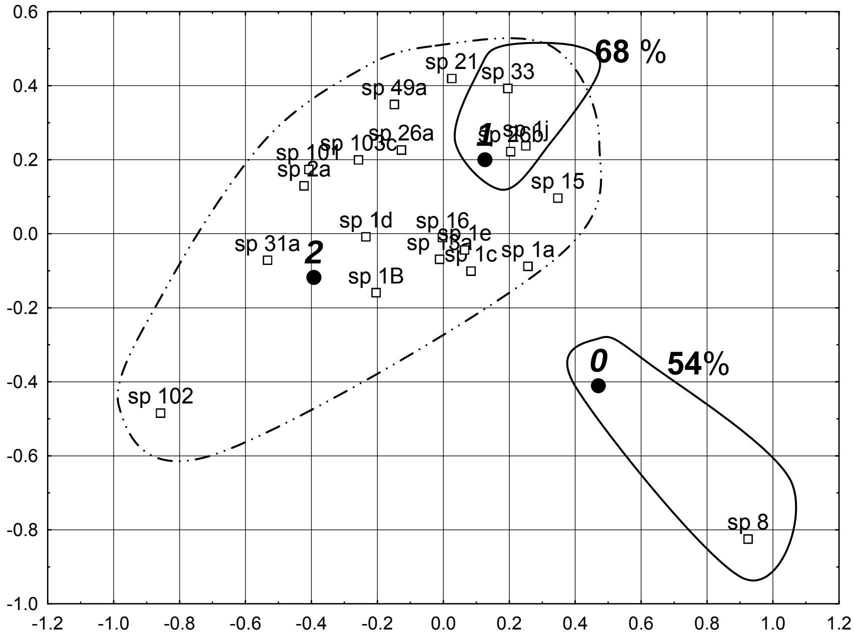


Figure 4.6: **A1- C2 Correspondence Analysis (CA) of seed bank species at three different spatial scales.**

A1:Analysis of top twenty overall species at *landscape* scale (Eigenvalue 1 = 0.58985 ; Eigenvalue 2 = 0.14093)
A2:Analysis of top twenty indigenous species at *landscape* scale (Eigenvalue 1 = 0.52548 ; Eigenvalue 2 = 0.11914)
B1:Analysis of top twenty overall species at at *reach* scale (Eigenvalue 1 = 0.58340 ; Eigenvalue 2 = 0.11914)
B2:Analysis of top twenty indigenous species at *reach* scale (Eigenvalue 1 = 0.48983 ; Eigenvalue 2 = 0.16243)
C1:Analysis of top twenty overall species at *habitat* scale (Eigenvalue 1 = 0.57271 ; Eigenvalue 2 = 0.11743)
C2:Analysis of top twenty indigenous species at *habitat* scale (Eigenvalue 1 = 0.48410 ; Eigenvalue 2 = 0.07817)
Refer to Appendix 4.4, Table E2 for species codes



D1



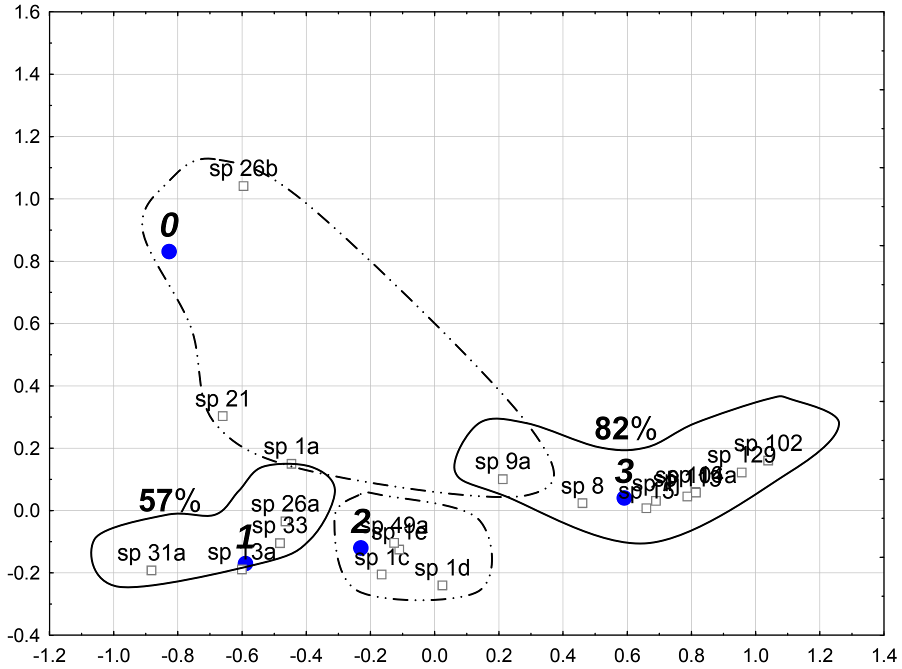
D2

Figure 4.7: **D1-F3 Correspondence Analysis (CA) of seed bank species in relation to environmental conditions (Fire history= D1 & D2, Extent of Invasion = E1 & E2, Human disturbance level= F1 & F2).**

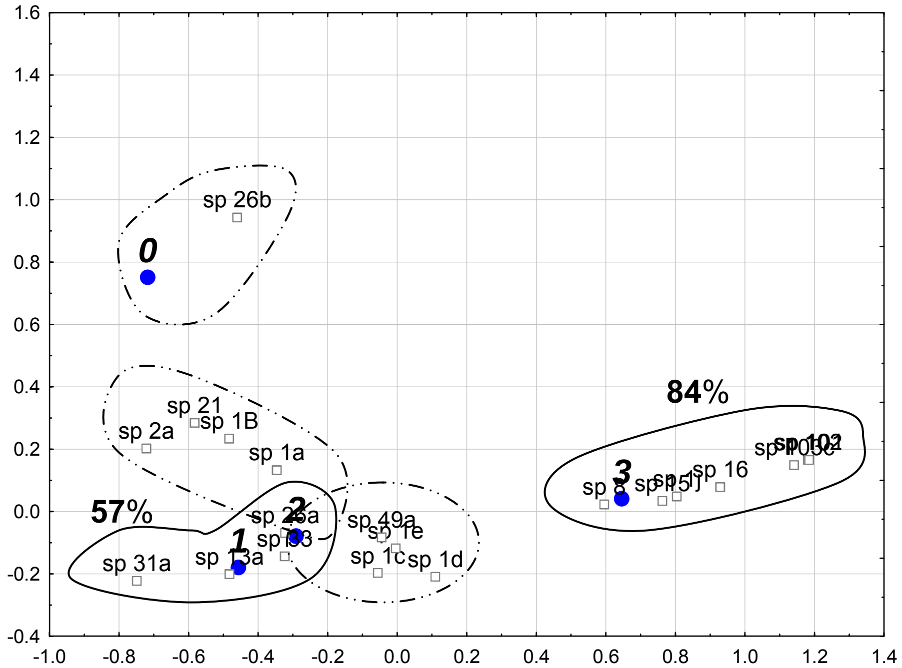
D1:Analysis of top twenty overall species in relation to fire history
(Eigenvalue 1 = 0.11588 ; Eigenvalue 2 = 0.6351)

D2:Analysis of top twenty indigenous species in relation to fire history
(Eigenvalue 1 = 0.09355 ; Eigenvalue 2 = 0.05014)

NOTE: Solid line indicates species assemblage; dotted line indicates highly variable group of species; percentage indicates chance that grouped species will associate with specific environmental conditions (only given for solid group). Refer to Table 4.3 for species codes.



E1



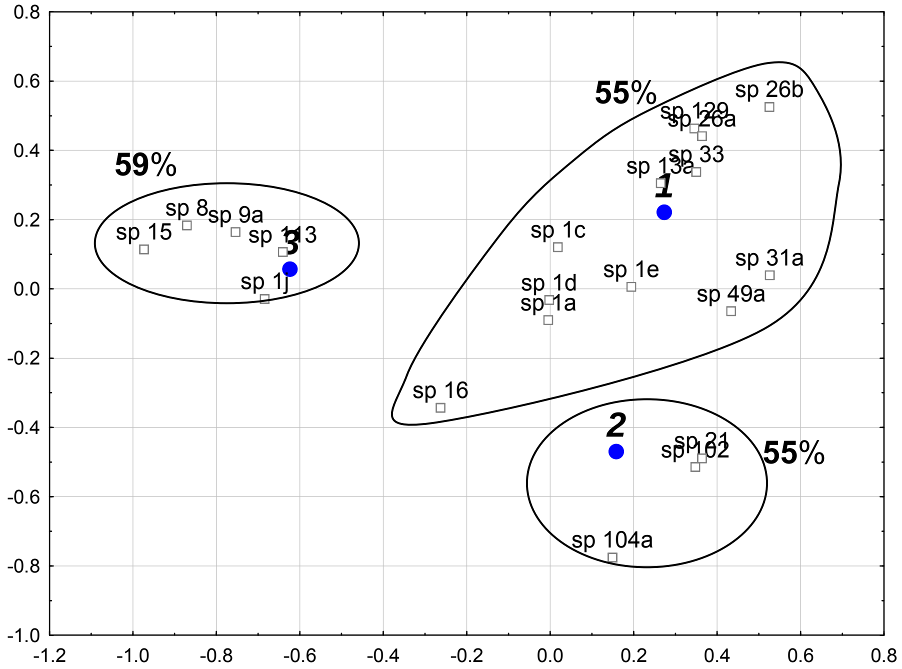
E2

Figure 4.7 continued: **D1-F3 Correspondence Analysis (CA) of seed bank species in relation to environmental conditions..**

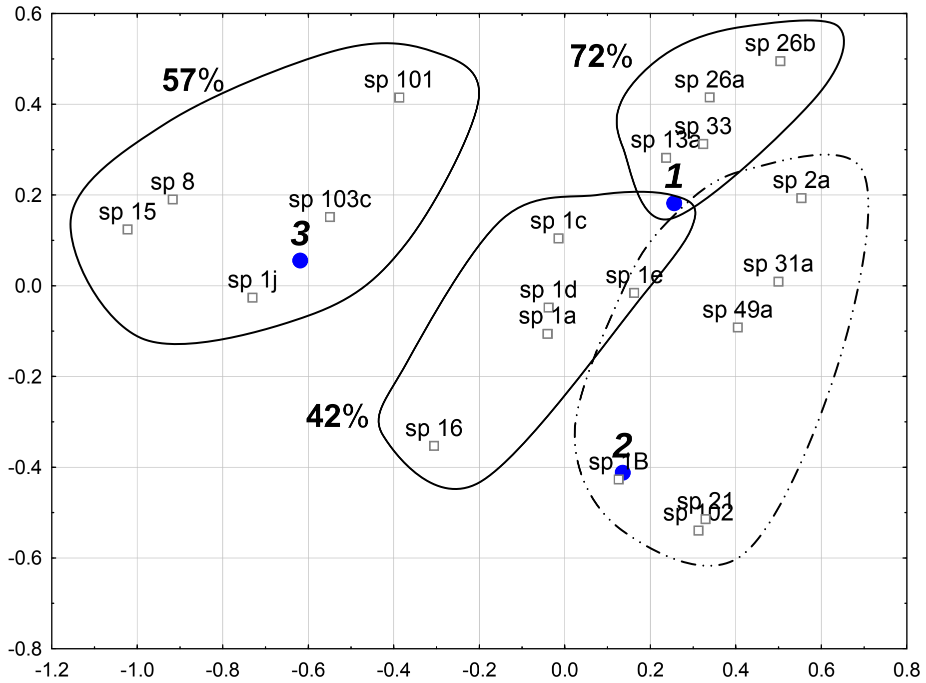
E1:Analysis of top twenty overall species in relation to extent of invasion
(Eigenvalue 1 = 0.31332 ; Eigenvalue 2 = 0.05703)

E2:Analysis of top twenty indigenous species in relation to extent of invasion
(Eigenvalue 1 = 0.29018 ; Eigenvalue 2 = 0.05524)

NOTE: Solid line indicates species assemblage; dotted line indicates highly variable group of species; percentage indicates chance that grouped species will associate with specific environmental conditions (only given for solid group). Refer to Table 4.3 for species codes.



F1



F2

Figure 4.7continued: **D1-F3 Correspondence Analysis (CA) of seed bank species in relation to environmental conditions**

F1: Analysis of top twenty overall species in relation to human disturbance level
(Eigenvalue 1 = 0.14771 ; Eigenvalue 2 = 0.08027)

F2: Analysis of top twenty indigenous species in relation to human disturbance level
(Eigenvalue 1 = 0.13548 ; Eigenvalue 2 = 0.05975)

NOTE: Solid line indicates species assemblage; dotted line indicates highly variable group of species; percentage indicates chance that grouped species will associate with specific environmental conditions (only given for solid group). Refer to Table 4.3 for species codes.

<u>Table 4.3:</u> Seed bank species used in correspondence analyses and their association with variables: State (Invaded/Reference), Reach (MS/FH), Zone (wet/trans/dry), Fire history, Extent of Invasion & Level of anthropogenic disturbance (Distb.): increasing from 0-3. Data was collected from soil samples taken along four rivers (Berg, Eerste, Molenaars and Wit) in the Western Cape (see text). Species were termed Generalists (G) when they showed no clear association to the variable and are found in a variety of habitats. Association categories are shown in descending order in brackets. (Data summarised from Figures A1- F2 & CART analyses. See Appendix 4.2).

Species code	Botanical name	State/ Reach	State/ Zone	Fire frequency	Invasion history	Distb.
Sp 1a	*Panicum schinizii*	Ref/ MS	Ref/ G	1	G (1,2,3)	1
Sp 1B	*Pennisetum macrourum*	Ref/ G	Ref/ G	G (1,2)	G (1,2,3)	1, 2
Sp 1c	*Juncus capensis*	Ref/ FH	Ref/ wet	1, 2	G (3,1,2)	1
Sp 1d	*Ficinia anceps*	Ref/ FH	Ref/ trans/wet	2, 1	G (3,1,2)	1
Sp 1e	*Pentaschistus pallida*	Ref/ FH	Ref/ trans/dry	1, 2	G	1
Sp 1j	*Isolepis prolifera*	Inv/ FH	Inv dry/trans	1	3	3
Sp 2a	*Euryops abrotanifolius*	Ref/ G	Ref/ G	1, 2	G (1,2,3)	1
Sp 8	*Solanum retroflexum*	Ref/ G	Ref/ G	0, 1	3	3
Sp 9a	* *Hypochaeris radicata*	Ref/ G	Ref/ G	0,1	G (1,2,3,0)	3
Sp 13a	*Metalasia* sp.	Ref/ MS	Ref/ G	1, 2	1	1
Sp 15	*Digitaria debilis*	G / FH	G/ wet/dry	1	3	3
Sp 16	* *Oxalis corniculata*	Inv/ G	Inv/ dry	1, 2	3	1
Sp 21	*Ischryolepis subverticillata*	Ref/ G	Ref/ G	1, 2	G (1,2,3)	2, 1
Sp 26a	*Pseudognaphalium luteo-album*	Ref/ MS	Ref/ wet/trans	2, 1	1	1
Sp 26b	*Helichrysum helianthemifolium*	Ref/ MS	Ref/ trans	1	G	1
Sp 31a	*Struthiola tomentosa*	Ref/ MS	Ref/ G	2, 1	1	1
Sp 33	*Wahlenbergia cernua*	Ref/ MS	Ref/ trans	1	1	1
Sp 49a	*Erica caffra*	G	G/ trans/dry	2, 1	G (3,1,2)	1
Sp 101	*Senecio polyanthemoides*	Inv/ FH	Inv/ trans/dry	1, 2	3	3
Sp 102	*Wahlenbergia obovata*	Inv/ MS	Inv/ trans	2, 1	3	2, 1
Sp 103c	*Ehrharta longiflora*	Inv/ FH	Inv/ trans/dry	1, 2	3	3
Sp 104a	* *Acacia mearnsii*	Inv/ G	Inv/ dry/trans	2, 1	3	2
Sp 113	* *Euphorbia prostrata*	Inv/ G	Inv/ wet	1	3	3
Sp 129	* *Conyza albida*	Inv/ MS	Inv/ trans	2	3	1

* = invasive alien plant G= generalist Indices in ( ) ranked in descending order

4.5 DISCUSSION AND CONCLUSION

Impact of invasion on riparian seed bank composition

Species that are generalists are termed so as they are able to survive in a variety of different types of habitats between or within specific communities. In riparian systems, each river forms a unique combination of varying levels of disturbance, hydrological regime, sediment accumulation and deposition which will ultimately determine the selection of species that will become the plant community of that specific stretch of river. Seed banks are notoriously variable but can offer valuable insight into the plant community of both the past and present. It makes sense then, to predict that the seed banks of riparian areas will be exceptionally variable as a result of the combined variability of riparian systems, with that of seed bank dynamics. Our results further confirmed the non-uniform nature of riparian plant communities (Sieben, 2003; Naiman and Décamps, 1997; Naiman *et al.,* 1993; Tabacchi *et al*., 2000).

At plot or sample level, very little pattern was evident throughout the investigation. A pattern only begins to develop at broader scales. Within the mountain stream sections, seed bank diversity levels of indigenous species generally declined once invasive alien plants became part of the system (Figures 4.1 and 4.3). Analyses for foothill seed bank samples showed no clear pattern of diversity levels between reference and invaded samples (Figure 4.2). This could be due to a longer history with anthropogenic disturbances in both invaded and reference areas. Causes for disturbance include construction of dams, weirs and canals which alter the natural flow of the river, as well as abstraction for irrigation, the resulting nutrient pollution from fields, and the introduction of invasive alien plants, which alter the integrity of the community (Davies and Day, 1998). More often than not, the upper catchments fall within nature reserves of some kind (governmental or private) and are therefore less affected by some of these anthropogenic factors (Sieben, 2002). However, water abstraction and dam building affects many upper catchments in the Western Cape, with dams like the Wemmershoek (draining the Wemmershoek, Olifants, Haevlei and Tierkloof Rivers of the Wemmershoek mountains), Slanghoek (draining the Breede River and it’s tributaries of the Slanghoek mountains), Theewaterskloof (draining the Riviersonderend, Palmiet Rivers and several smaller tributaries of the Riviersonderend mountains) and the recent Berg River Dam (draining the greater Berg River catchment of the Franschhoek mountains) altering water flows from the source, as well as assisting in the spread of invasive alien plants into many upper catchments. Diversity and species richness indices were skewed within the invaded samples from Wit and Molenaars

Rivers, possibly due to the fact that both river systems have a long history of invasion and other anthropogenic disturbances which would have an effect on the samples from "reference" sections (i.e. a 25% presence of IAPs may be adequate to disrupt the seed bank composition) while reference samples taken from the Berg and Eerste Rivers fell within nature reserves and had little if any history of invasion and/ or anthropogenic disturbances.

The impact of invasion on the riparian seed bank was most clearly shown through the correspondence analyses. The seed bank assembly patterns were clearly defined by the state of the river (reference or invaded) and this pattern was evident at all three spatial scales (Figure 4.5). The reference seed bank assemblage was more tightly grouped and implied that the species were more closely related and less variable than the invaded seed bank assemblages. The species groupings within the invaded seed banks were influenced by variables such as reach and zone, whereas the reference seed bank assemblages were relatively unaffected. This shows that the presence of invasive alien plants can create additional variation within the seed bank and alter the natural species associations.

Interestingly, *Digitaria debilis* (sp 15) and *Erica caffra* (sp 49a) were the only two species to show no affinity towards the state of the river. It is suggested that these species be further investigated as potential restoration species to be utilized in terms of community recovery. All species, however, showed affinities towards levels of "key" riparian environmental variables. Most species were associated with moderate levels of fire frequency, invasion history and disturbance (Figure 4.6). Species to notably group at the extremes included many IAPs (*Acacia mearnsii*, *Conyza albida, Hypochaeris radicata*), common indigenous "weedy" species (*Senecio polyanthemoides, Solanum retroflexum*) as well as a few indigenous species (*Wahlenbergia obovata, Digitaria debilis, Isolepis prolifera)*. Invasion history presented the clearest pattern of separation with certain species associated only with extreme levels of invasion. Such indigenous species included *Isolepis prolifera, Digitaria debilis, Erica caffra, Ehrharta longiflora* and *Wahlenbergia obovata; Solanum retroflexum* and *Senecio polyanthemoides* of the indigenous "weedy" group; and *Acacia mearnsii, Euphorbia prostrata, Conyza albida* and *Oxalis corniculata* of the alien plant group. Most of the above-mentioned group were also closely associated with high levels of disturbance as invasion and disturbance go hand-in-hand. Interestingly, alien and weedy species *Hypochaeris radicata* and *Solanum retroflexum* were associated with low fire frequency but high levels of invasion and disturbance. Overall, most species that were analysed were generalist and pioneer species and were thus a good representation of the initial post-recruitment vegetation.

An interesting result from this study is that when rivers were investigated at a landscape scale, seed banks from almost all invaded rivers showed a higher diversity of indigenous species than their reference counterparts (Figure 4.4). Previous research on terrestrial seed banks has generally shown the opposite (Holmes, 2001; Macdonald and Richardson, 1986) although a recent study within riparian systems generally concurs with this finding (Bagstad *et al.,* 2006). Species richness comparisons (Table 4.5) did not correspond with the diversity patterns, and were found to be site specific. Interestingly, abundance results (Table 4.5) showed reference sites having substantially higher levels of indigenous species than the invaded sites. Although this is very promising in terms of restoration of post-cleared riparian sites, more detail is needed to understand the seed bank composition and establish how sustainable it is for long-term restoration.

All seed bank seedling counts were grouped into growth forms (on a percentage –, Figure 4.5, and abundance –, Table 4.4, basis) in order to establish the quality of community representation within the seed bank of both reference and invaded sections of the rivers. All invaded sections showed a decrease in herbaceous perennial species with an increase in herbaceous annual species. Graminoids made up 50% or more of the seed bank regardless of state (reference or invaded), while the more woody species (shrub/shrublet) were generally more prevalent in the reference samples (with the exception of the invaded sections for the Molenaars River). These results imply that after alien clearing, the seed bank regeneration community would comprise mainly of short-lived, herbaceous species and would potentially not be an accurate reflection of the indigenous riparian community. However, this may be a time scale issue. It is important to remember that this study investigated only the species that were able to germinate within the given time frame. Many riparian species may not have been represented in the study because they are either late germinators which form part of the later succession phase, or they may not be present in the soil seed bank at all. In order to get a holistic understanding of riparian community recruitment, it is recommended that seed bank studies such as this one be included in a more broad scale, long term investigation which takes into account various reproductive strategies known to be utilized by riparian species within the chosen study habitat. However, the aims of this project were to assess the impact of invasion of the seed bank, and ultimately address the initial post-clearing community in terms of its restoration potential; within the time-frame of most alien clearing projects which currently are relatively short-term (5-10 years). Under such conditions, I feel the project sheds light on previously unanswered questions within the riparian seed bank ecology of the Western Cape.

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4.7 APPENDIX 4.1

ADDITIONAL ANALYSES COMPUTED ON RIPARIAN SEED BANK DATA COLLECTED ALONG FOUR RIVERS IN THE WESTERN CAPE, SOUTH AFRICA.

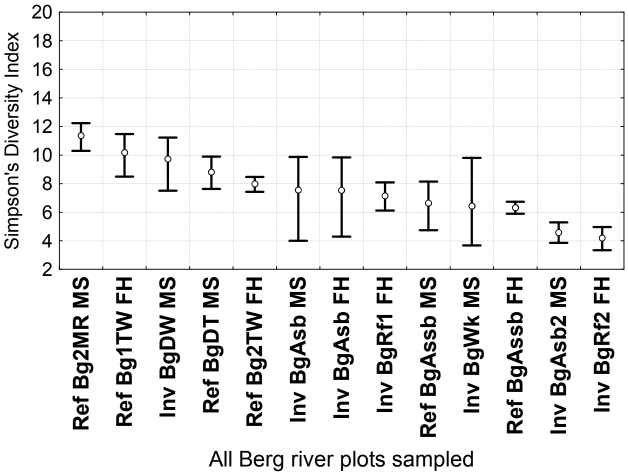

Figure B1.1

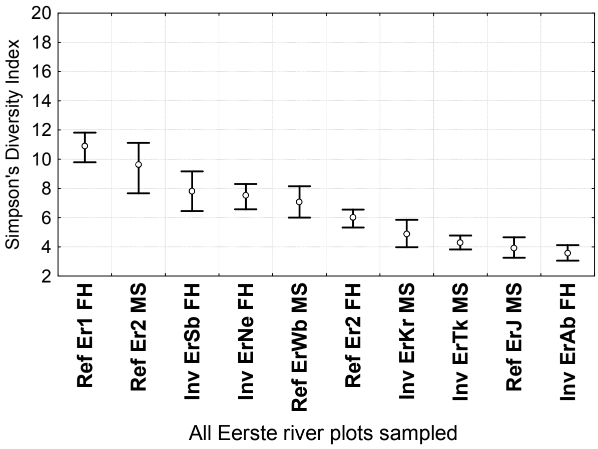

Figure B1.2

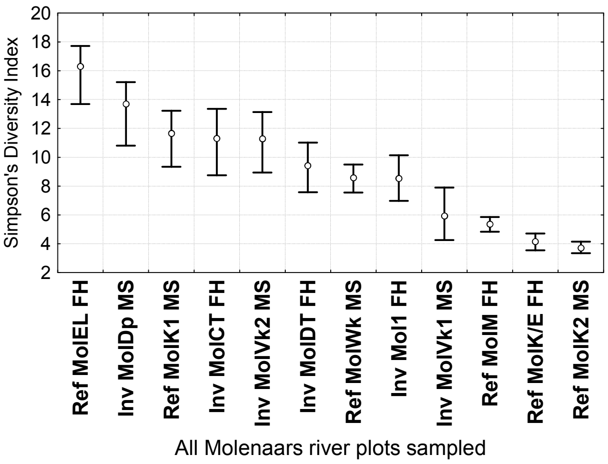

Figure B1.3

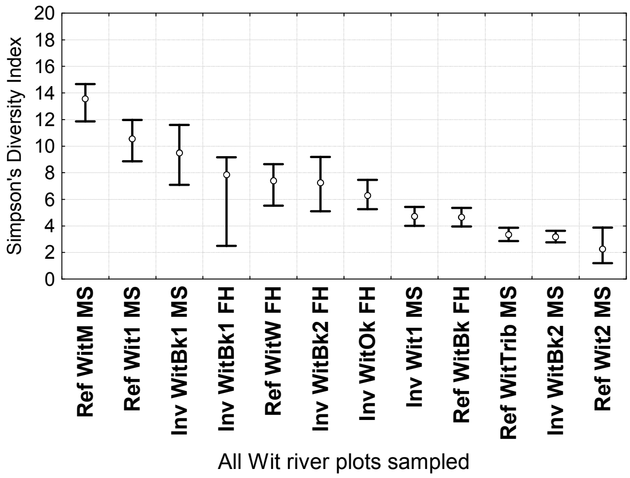

Figure B1.4

<u>Figures B1.1- 1.4:</u> Diversity Indices for Berg (Fig B1.1), Eerste (Fig B1.2), Molenaars (Fig B1.3) and Wit (Fig B1.4) river plots ranked in descending order of diversity. Data were collected from soil samples taken from invaded (Inv) and reference (Ref) sections of the four rivers in the Western Cape, South Africa.

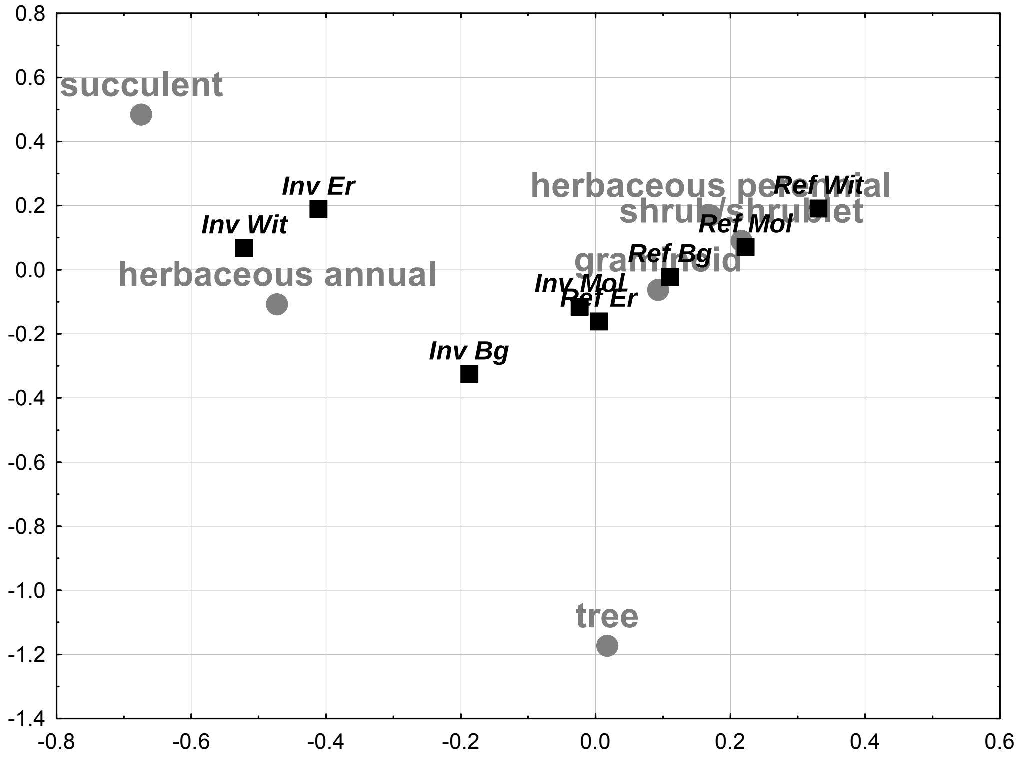

Figure B2: Correspondence analysis of growth forms and their association with invaded (Inv) and reference (Ref) sections of the four rivers sampled (Bg= Berg, Er= Eerste, Mol= Molenaars and Wit) in the Western Cape, South Africa. (Eigenvalue 1: 0.06417 ; Eigenvalue 2 0.01870)

4.8 APPENDIX 4.2

Table C1: Environmental indices for all plots sampled along four rivers in the Western Cape. Fire and invasion indices based on data from WfW data base, disturbance index based on visual assessment on site.

BERG	**Invaded**							**Reference**					
	BgDW MS	BgWk MS	BgAsb MS	BgAsb2 MS	BgRf1 FH	BgRf2 FH	BgAsb FH	BgAsb MS	Bg2MR MS	BgDT MS	BgAsb FH	Bg1TW FH	Bg2TW FH
Fire history	0	0	0	0	1	1	0	2	1	1	1	2	2
Extent of invasion	2	3	3	3	3	3	3	1	1	1	1	2	2
Influence of disturbance	1	2	1	1	3	3	3	1	1	1	2	1	1

EERSTE	**Invaded**					**Reference**				
	ErTk MS	ErKr MS	ErNe FH	ErSb FH	ErAb FH	ErJ MS	ErWb MS	Er2 MS	Er2 FH	Er1FH
Fire history	2	2	1	1	1	1	1	1	1	1
Extent of invasion	3	3	3	3	3	0	0	0	1	1
Influence of disturbance	1	1	3	3	3	1	2	1	2	1

MOLENAARS	**Invaded**						**Reference**					
	MolVk1 MS	MolVk2 MS	MolDp MS	MolDT FH	Mol1 FH	MolCT FH	MolK1 MS	MolK2 MS	MolWk MS	MolK/E FH	MolM FH	MolEL FH
Fire history	2	2	1	2	2	1	1	1	2	2	2	1
Extent of invasion	3	3	3	3	3	3	1	1	1	2	2	1
Influence of disturbance	1	1	1	1	2	1	1	1	1	3	2	1

WIT	**Invaded**						**Reference**				
	Wit1 MS	WitBk1 MS	WitBk2 MS	WitBk1 FH	WitBk2 FH	WitOk FH	Wit1 MS	Wit2 MS	WitTrib MS	WitW FH	WitBk FH
Fire history	2	2	2	2	2	2	1	1	1	1	2
Extent of invasion	2	3	3	3	3	3	2	2	1	2	1
Influence of disturbance	2	2	2	2	2	1	2	3	2	2	1

Fire history-
1: fires at interval of 8-20years years (optimal)
2: last fire between 4-8 years ago
3: last fire between 3-1 years ago, recent fire within a year
Extent of invasion
0: no invasion history
1: low density invasion, cleared 10 years ago, maintained clean
2: moderate density (25-75%) cleared 5-10 years ago, still occurring in patches
3: high density invasion (>75%), clearance started < 5 years ago, on-going, still dense in patches
Influence of disturbance
1: only natural disturbance and minimal human traffic
2: moderate human traffic, fairly accessible with paths and rough roads
3: heavy human traffic, easy access, roads regularly used

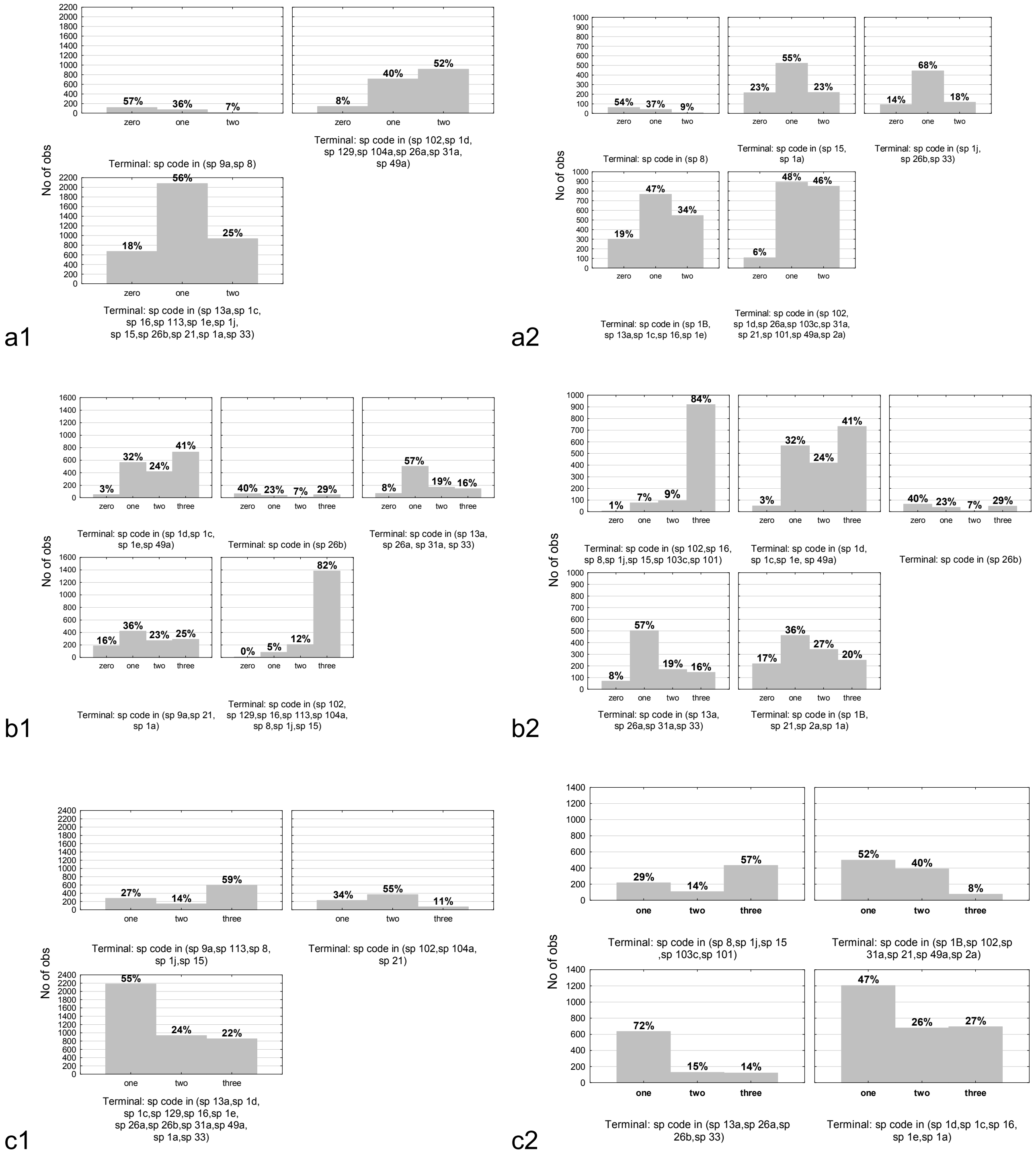

Figure C1: **a1- c2. Results from CART analyses on seed bank species and their association with certain environmental variables.** Analyses for **a1, b1 & c1** were done on the twenty most frequently occurring species overall. Analyses for **a2, b2 & c2** were done on the twenty most frequently occurring indigenous species only. Environmental variables are: **a1, a2 – Fire frequency; b1, b2 – Invasion history ; c1, c2 – Man-made disturbance levels**. “Terminal” is the group of species that, after many random selections, the analyses found to have strong associations with each other (in %) in terms of the specific variable. For a list of species codes see Appendix 4.4, Table E2.

4.9 APPENDIX 4.3

Table D1.1: Similarity data between overall species (indigenous and alien) in reference and invaded samples taken from four river systems in the Western Cape, South Africa.

RIVER SCALE			REACH SCALE			HABITAT SCALE		
Berg River	Reference	Invaded	***Mountain Stream***	Reference	Invaded	***Wet bank***	Reference	Invaded
Number of samples	7	9	Number of samples	17	14	Number of samples	8	7
Species observed	75	59	Species observed	76	93	Species observed	62	59
Shared species	29		Shared species	51		Shared species	27	
Sørensen Classic	**0.43**		Sørensen Classic	**0.60**		Sørensen Classic	**0.45**	
Eerste River	Reference	Invaded	***Foothill***	Reference	Invaded	***Transitional bank***	Reference	Invaded
Number of samples	8	7	Number of samples	14	17	Number of samples	17	17
Species observed	65	75	Species observed	75	87	Species observed	78	101
Shared species	32		Shared species	41		Shared species	52	
Sørensen Classic	**0.46**		Sørensen Classic	**0.51**		Sørensen Classic	**0.58**	
Molenaars River	Reference	Invaded				***Dry bank***	Reference	Invaded
Number of samples	8	9				Number of samples	8	7
Species observed	59	77				Species observed	65	67
Shared species	32					Shared species	30	
Sørensen Classic	**0.47**					Sørensen Classic	**0.46**	
Wit River	Reference	Invaded						
Number of samples	8	6						
Species observed	48	74						
Shared species	28							
Sørensen Classic	**0.46**							

Table D1.2: Similarity data among plots of overall species (indigenous and alien) in reference and invaded samples taken from four river systems in the Western Cape, South Africa.

RIVER SCALE			**REACH SCALE**			**HABITAT SCALE**		
Berg River	Reference	Invaded	***Mountain Stream***	Reference	Invaded	***Wet bank***	Reference	Invaded
Number of samples	7	9	Number of samples	17	14	Number of samples	8	7
Species observed	75	59	Species observed	76	93	Species observed	62	59
Mean shared species	22	11	Mean shared species	15	16	Mean shared species	13	13
Mean Sørensen	**0.59**	**0.52**	Mean Sørensen	**0.52**	**0.52**	Mean Sørensen	**0.51**	**0.55**
Eerste River	Reference	Invaded	***Foothill***	Reference	Invaded	***Transitional bank***	Reference	Invaded
Number of samples	8	7	Number of samples	14	17	Number of samples	17	17
Species observed	65	75	Species observed	75	87	Species observed	78	101
Mean shared species	18	18	Mean shared species	15	14	Mean shared species	14	15
Mean Sørensen	**0.60**	**0.56**	Mean Sørensen	**0.53**	**0.51**	Mean Sørensen	**0.50**	**0.49**
Molenaars River	Reference	Invaded				***Dry bank***	Reference	Invaded
Number of samples	8	9				Number of samples	8	7
Species observed	59	77				Species observed	65	67
Mean shared species	14	20				Mean shared species	18	17
Mean Sørensen	**0.53**	**0.62**				Mean Sørensen	**0.58**	**0.55**
Wit River	Reference	Invaded						
Number of samples	8	6						
Species observed	48	74						
Mean shared species	9	14						
Mean Sørensen	**0.47**	**0.45**						

4.10 APPENDIX 4.4

Table E.1 List of all above-ground species recorded in invaded and reference plots along four rivers in the Western Cape, South Africa

* indicates alien species

FAMILY	BOTANICAL NAME AND AUTHOR
ACHARIACEAE	*Kiggelaria africana* L.
AIZOACEAE	* *Amaranthus deflexus* L.
ANACARDIACEAE	*Rhus angustifolia* L.
ANACARDIACEAE	*Rhus crenata* Thunb.
AQUIFOLIACEAE	*Ilex mitis* (L.) Radlk. var. *mitis*
ARACEAE	*Zantedeschia aethiopica* (L.) Spreng.
ASPARAGACEAE	*Asparagus* sp. L.
ASTERACEAE	* *Hypochaeris radicata* L.
ASTERACEAE	* *Sonchus asper* (L.) Hill subsp. *Asper*
ASTERACEAE	*Brachylaena neriifolia* (L.) R.Br.
ASTERACEAE	*Cineraria* sp. L.
ASTERACEAE	*Euryops abrotanifolius* (L.) DC.
ASTERACEAE	*Helichrysum cymosum* (L.) D.Don subsp. *cymosum*
ASTERACEAE	*Helichrysum* sp. Mill.
ASTERACEAE	*Helichrysum* sp. 2 Mill.
ASTERACEAE	*Dicerothamnus rhinocerotis* (L.f.) Koekemoer *(= Elytropappus rhinocerotis)*
ASTERACEAE	*Metelasia muricata* (L.) D.Don
ASTERACEAE	*Oesteospermum* sp. L.
ASTERACEAE	*Seriphium plumosa* L.
ASTERACEAE	*Ursinia paleaceae* (L.) Moench
ASTERACEAE	* *Xanthium strumarium* L.
BLECHNACEAE	*Blechnum capense* Burm.f.
BRUNIACEAE	*Berzelia lanuginosa* (L.) Brongn.
CELASTRACEAE	*Maytenus acuminata* (L.f) Loes. var. *acuminata*
CELASTRACEAE	*Maytenus oleoides* (Lam.) Loes.
COMMELINACEAE	*Commelina benghalensis* L.
CUNONIACEAE	*Cunonia capensis* L.
CUNONIACEAE	*Platylophus trifoliatus (L.f.) D.Don*
CYPERACEAE	Cyperacea sp1
CYPERACEAE	Cyperaceae sp.2
CYPERACEAE	*Cyperus denudatus* L.f. var. *denudatus*
CYPERACEAE	*Ficina trichoides* (Schrad.) Benth. & Hook.f.
CYPERACEAE	*Ficinia anceps* Nees
CYPERACEAE	*Ficinia* sp. Schrad.
CYPERACEAE	*Isolepis digitata* Schrad.
CYPERACEAE	*Isolepis prolifera* (Rottb.) R.Br.
DENNSTAEDTIACEAE	*Pteridium aquilinum* (L.) Kuhn subsp. aquilinum
DROSERACEAE	*Drosera* sp. L.
DRYOPTERIDACEAE	*Rumohra adiantiformis* (G.Forst.) Ching
EBENACEAE	*Diospryos glabra* (L.) De Winter
EBENACEAE	*Diospryos whyteana* (Hiern) F.White
ERICACEAE	*Erica abietina* L. subsp. *aurantiaca* E.G.H.Oliv.& I.M.Oliv.
ERICACEAE	*Erica bergiana* L. var. *bergiana*
ERICACEAE	*Erica caffra* L. var. *caffra*

Table E1 continued

FAMILY	BOTANICAL NAME AND AUTHOR
ERICACEAE	*Erica curvirostris* Salisb. var. *curvirostris*
ERICACEAE	*Erica* sp. Fine
ERICACEAE	*Erica* sp. L.
ERICACEAE	*Erica* sp. 2
EUPHORBIACEAE	*Euphorbia* sp. L. (seedlings)
FABACEAE	* *Acacia longifolia* (Andrews) Willd.
FABACEAE	* *Acacia mearnsii* De Wild.
FABACEAE	* *Acacia melanoxylon* R.Br.
FABACEAE	*Aspalathus excelsa* R.Dahlgren
FABACEAE	*Aspalathus* sp. (grey)
FABACEAE	*Podalyria calyptrata* (Retz.) Willd.
FABACEAE	*Polygala myrtifolia*
FABACEAE	*Psoralea aphylla* L.
FABACEAE	*Psoralea pinnata* L. var. *pinnata*
FABACEAE	*Psoralea* sp.
FABACEAE	* *Sesbania punicea* (Cav.) Benth.
FABACEAE	*Virgilia oroboides* (P.J.Bergius) T.M.Salter subsp. *oroboides*
FAGACEAE	* *Quercus sp.*
GENTIANACEAE	*Chironia* sp.
IRIDACEAE	*Aristea capitata* (L.) Ker Gawl.
IRIDACEAE	*Irideaceae* sp.
JUNCACEAE	* *Juncus bufonius* L.
JUNCACEAE	*Juncus capensis* Thunb.
JUNCACEAE	*Juncus kraussii* Hochst subsp. *Kraussii*
JUNCACEAE	*Juncus* sp.
JUNCACEAE	*Juncus* sp. 1
JUNCACEAE	*Juncus* sp. Tall
LAURACEAE	*Cassytha ciliolata* Nees
LAURACEAE	*Cinnamomum campheora*
LOMARIOPSIDACEAE	*Elaphoglossum acrostichoides* (Hook. & Grev.) Schelpe
MYRICACEAE	*Morella integra* (A.Chev.) Killick
MYRICACEAE	*Morella quercifolia* (L.) Killick
MYRICACEAE	*Morella serrata* (Lam.) Killick
MYRSINACEAE	*Myrsine africana* L.
MYRSINACEAE	*Rapanea melanophloeos* (L.) Mez
MYRTACEAE	* *Eucalyptus camaldulensis* Dehnh.
MYRTACEAE	* *Leptospermum laevigatum* (Gaertn.) F.Muell.
MYRTACEAE	*Metrosideros angustifolia* (L.) J.E.Sm.
OLINIACEAE	*Olinia ventosa* (L.) Cufod.
OSMUNDACEAE	*Todea babara* (L.) T.Moore
PINACEAE	* *Pinus pinaster* Aiton
PITTOSPORACEAE	* *Pittosporum crassifolium* A.Cunn.
POACEAE	* *Paspalum urvillei* Steud.
POACEAE	*Aristida junciformis* Trin. & Rupr. subsp. *junciformis*
POACEAE	* *Briza maxima* L.
POACEAE	*Cynodon dactylon* (L.) Pers.
POACEAE	*Digitaria* sp.
POACEAE	*Ehrharta erecta* Lam. var. *erecta*
POACEAE	*Ehrharta longiflora* Sm.
POACEAE	*Ehrharta ramosa* (Thunb.) Thunb. subsp. *ramosa*
POACEAE	*Ehrharta* sp.
POACEAE	*Merxmuellera stricta* (Schrad.) Conert
POACEAE	*Pennisetum macrourum* Trin.

Table E1 continued

FAMILY	BOTANICAL NAME AND AUTHOR
POACEAE	*Pentameris thuarii* P.Beauv.
POACEAE	*Pentaschistis pallida* (Thunb.) H.P.Linder
POACEAE	*Pentaschistis* sp.
SCHIZAEACEAE	*Schizaea pectinata* (L.) Sw.
PLANTAGINACEAE	*Plantago lanceolata* L.
PODOCARPACEAE	*Podocarpus elongatus* (Aiton) L'Hér. ex Pers
PRIMULACEAE	* *Anagallis arvensis* L. subsp. *Arvensis*
PRIONIACEAE	*Prionium serratum* (L.f.) Drège *ex E.Mey.*
PROTEACEAE	*Brabejum stellatifolium* L.
PROTEACEAE	*Leucadendon* sp. (seedlings)
PROTEACEAE	*Protea nitida* Mill.
RESTIONACEAE	*Calopsis paniculata* (Rottb.) Desv.
RESTIONACEAE	*Cannomois virgata* (Rottb.) Steud.
RESTIONACEAE	*Elegia capensis* (Burm.f.) Schelpe
RESTIONACEAE	*Ischyrolepis subverticillata* Steud.
RESTIONACEAE	*Restio dispar* Mast.
RESTIONACEAE	*Restio perplexus* Kunth.
RESTIONACEAE	*Restio* sp.
RESTIONACEAE	*Restio tetragonus* Thunb.
RESTIONACEAE	*Rhodocoma capensis* Steud.
RHAMNACEAE	*Phylica buxifolia* L.
RHAMNACEAE	*Phylica pubescens* Aiton. var. *pubescens*
ROSACEAE	*Cliffortia cuneata* Aiton
ROSACEAE	*Cliffortia ruscifolia* L. var. *ruscifolia*
ROSACEAE	*Cliffortia strobilifera* L.
ROSACEAE	*Rubus* sp. L.
RUTACEAE	*Agathosma crenulata* (L.) Pillans
SALICACEAE	* *Populus alba* L.
SALICACEAE	*Salix mucronata* Thunb. subsp*. mucronata (= S. capensis)*
SAPOTACEAE	*Sideroxlyon inerme* L. subsp. *Inerme*
SCHIZAEACEAE	*Schizaea tenella* Kaulf.
SCROPHULARIACEAE	*Halleria elliptica* Thunb.
SOLANACEAE	*Solanum retroflexum* Dunal
SCROPHULARIACEAE	*Freylinia lanceolata* (L.f.) G.Don

Table E 2 Species recorded and identified in seed bank at termination of project. Data were collected from soil samples taken from reference and invaded sections all four rivers (Berg, Eerste, Molenaars and Wit) in the Western Cape, South Africa. (Abbreviation herb= herbaceous)

FAMILY	GROWTH FORM	BOTANICAL NAME AND AUTHOR	Sp CODE
POACEAE	annual graminoid	*Panicum maximum* Jacq.	sp 1A
POACEAE	graminoid	*Pennisetum macrourum* Trin	sp 1B
JUNCACEAE	graminoid	*Juncus capensis* Thunb.	sp 1C
JUNCACEAE	graminoid	*Juncus* sp.1 (L.)	sp 1Ci
CYPERACEA	graminoid	*Ficinia anceps* Nees	sp 1D
POACEAE	graminoid	*Pentaschistus pallida* (Thunb.) H.P. Linder	sp 1E
POACEAE	annual graminoid	* *Poa annua* L.	sp 1ei
CYPERACEA	graminoid	*Schoenoplectus* sp. (Rchb.) Palla	sp 1e²
POACEAE	annual graminoid	*Agrostis lachnantha* Nees var. *lachnantha*	sp 1F
CYPERACEA	annual graminoid	*Scirpus* sp. L.	sp 1G
POACEAE	graminoid	*Pentameris* sp. P.Beauv.	sp 1H
POACEAE	annual alien	* *Aira cupaniana* Guss.	sp 1i
CYPERACEA	graminoid	*Isolepis prolifera* (Rottb.) R.Br.	sp 1J
ASTERACEAE	herb. perennial	*Euryops abrotanifolius* (L.) DC.	sp 2a
ASTERACEAE	herb. perennial	*Ursinia paleaceae* (l.) Moench	sp 2b
ASTERACEAE	herb. perennial	*Senecio cordifolius* L.f	sp 3
MESEMBRYANTHEMACEAE	succulent perennial	*Erepsia anceps* (Haw.) Schwantes	sp 5
MESEMBRYANTHEMACEAE	succulent perennial	*Carpobrotus* sp. N.E.Br.	sp 5b
GERANIACEAE	herb. perennial	*Pelargonium cucculatum* (L.) L'Hér. subsp. *cucculatum*	sp 6a
GERANIACEAE	herb. perennial	*Pelargonium elongatum* (Cav.) Salisb.	sp 6b
PHYTOLACCACEAE	herb. perennial	* *Phytolacca octandra* L.	sp 7
SOLANACEAE	herb. annual	*Solanum retroflexum* Dunal	sp 8
ASTERACEAE	herb. annual	* *Hypochaeris radicata* L.	sp 9
ASTERACEAE	herb. annual	* *Sonchus asper* (L.) Hill subsp. *asper*	sp 9B
FABACEAE	perennial alien	* *Acacia longifolia* (Andrews) Willd.	sp 10
FABACEAE	perennial alien	* *Acacia melanoxylon* R.Br.	sp 10b
FABACEAE	perennial alien	* *Sesbania punicea* (Cav.) Benth.	sp 10c
ASTERACEAE	shrub/shrublet	*Chyrsanthemoides monilifera* (L.) Norl. subsp. *monilifera*	sp 11
ROSACEAE	shrub/shrublet	*Cliffortia cuneata* Aiton	sp 12
ASTERACEAE	herb. perennial	*Metalasia* sp. R.Br.	sp 13
ASTERACEAE	shrub/shrublet	*Seriphium plumosum* L. (=Stoebe plumosa)	sp 13b
POLYGONACEAE	herb. annual	* *Persicaria lapathifolia* (L.) Gray	sp 14
POACEAE	annual graminoid	*Digitaria debilis* (Desf.) Willd.	sp 15
OXALIDACEAE	geophyte	* *Oxalis corniculata* L.	sp 16
FABACEAE	sprawling shrublet	*Argyrolobium lunare* (L.) Druce	sp 16b
PLANTAGINACEAE	herb. perennial	*Plantago lanceolata* L.	sp 18
PRIMULACEAE	herb. annual	* *Anagallis arvensis* L. susp. *arvensis*	sp 19
RUBIACEAE	shrub/shrublet	*Anthospermum galiodes* Rchb.f. subsp. *Galiodes*	sp 20
RESTIONACEAE	graminoid	*Ischyrolepis subverticillata* Steud.	sp 21
RESTIONACEAE	graminoid	*Restio* sp. Rottb.	sp 21b
FABACEAE	shrub/shrublet	*Psoralea* sp. L.	sp 22
SCROPHULARIACEAE	herb. perennial	*Pseudoselago serrata* (P.J. Bergius) Hilliard (= *Selago serrata*)	sp 24
ASTERACEAE	shrub/shrublet	*Senecio pubigerus* L.	sp 25

Table E2 continued

FAMILY	GROWTH FORM	BOTANICAL NAME AND AUTHOR	Sp CODE
ASTERACEAE	Herb. annual	*Pseudognaphalium luteo-album* (L.) Hilliard & B.L.Burtt	sp 26a
ASTERACEAE	Herb. annual	*Helichrysum helianthemifolium*(L.) D.Don	sp 26b
ASTERACEAE	succulent perennial	*Othonna quinquedentata* Thunb.	sp 27
GRUBBIACEAE	shrub/shrublet	*Grubbia tomentosa* (Thunb.) Harms	sp 28
MYRICACEAE	shrub/shrublet	*Morella serrata* (Lam.) Killick	sp 28b
ASTERACEAE	perennial herb	* *Lactuca serriola* L.	sp 29
FABACEAE	shrub/shrublet	*Podalyria calyptrata* (Retz.) Willd.	sp 30
THYMELAEACEAE	Herb. perennial	*Struthiola tomentosa* Andrews.	sp 31a
THYMELAEACEAE	Herb. perennial	*Struthiola myrsinites* Lam. / *S. striata* Lam.	sp 31b
CARYOPHLLACEAE	Herb. annual	* *Spergula arvensis* L.	sp 32
CAMPANULACEAE	Herb. annual	*Wahlenbergia cernua* (Thunb.) A.DC.	sp 33
SCROPHULARIACEAE	shrub/shrublet	*Oftia africana* (L.) Bocq.	sp 33b
CRASSULACEAE	succulent perennial	*Crassula pellucida* L. subsp. *pellucida*	sp 34a
CARYOPHYLLACEAE	Herb. annual	* *Polycarpon tetraphyllum* (L.) L.	sp 34b
ASTERACEAE	shrub/shrublet	*Disparago* sp. Gaertn.	sp 35
SCROPHULARIACEAE	annual	*Pseudoselago quadrangularis* (Choisy) Hilliard (= Selago quadrangularis)	sp 37
APIACEAE	Herb. perennial	*Centella* sp. L.	sp 38
VERBENACEAE	Herb. annual	* *Verbena bonariensis* L.	sp 39
MYRTACEAE	shrub/shrublet	* *Leptospermum laevigatum* (Gaertn.) F.Muell.	sp 39C
ASTERACEAE	Herb. annual	*Cotula australis* (Spreng.) Hook.f.	sp 41
SCROPHULARIACEAE	Herb. perennial	*Dischisma ciliatum* (P.J.Bergius) Choisy subsp. *Ciliatum*	sp 43
CAMPANULACEAE	Herb. perennial	*Siphocodon debilis* Schltr.	sp 43b
AQUIFOLIACEAE	Tree	*Ilex mitis* (L.) Radlk. var. *mitis*	sp 44
CUNONIACEAE	Tree	*Cunonia capensis* L.	sp 44b
RUTACEAE	shrub/shrublet	*Agathosma crenulata* (L.) Pillans	sp 45
ROSACEAE	shrub/shrublet	*Cliffortia grandifolia* Eckl. & Zeyh.	sp 45B
RUTACEAE	shrub/shrublet	*Emplerurm unicapsulare* (L.f.) Skeels	sp 45c
ROSACEAE	shrub/shrublet	*Cliffortia ruscifolia* L. var. *ruscifolia*	sp 46
CRASSULACEAE	succulent annual	*Crassula thunbergiana* Schult. subsp. *Thunbergiana*	sp 47
ERICACEAE	shrub/shrublet	*Erica* sp.1 L.	sp 49a
BRUNIACEAE	shrub/shrublet	*Berzelia lanuginosa* (L.) Brongn.	sp 49b
CAMPANULACEAE	shrub/shrublet	*Roella* sp. L.	sp 49c
SCROPHULARIACEAE	Herb. annual	*Zaluzianskya capensis* (L.) Walp.	sp 50
ROSACEAE	shrub/shrublet	*Cliffortia strobilifera* L.	sp 51
GENTIANACEAE	Herb. annual	*Chironia* sp. L.	sp 52
LOBELIACEAE	Herb. perennial	*Monopsis lutea* (L.) Urb.	sp 52B
SCROPHULARIACEAE	Herb. perennial	*Wahlenburgia parvifolia* (P.J. Gergius) Lammers	sp 52C
FABACEAE	Herb. scrambler	*Rhynchosia capensis* (Burm.f.) Schinz	sp 53
CRASSULACEAE	succulent perennial	*Crassula coccinea* L.	sp 54
CRASSULACEAE	succulent perennial	*Crassula fascicularis* Lam.	sp 54b
CRASSULACEAE	succulent perennial	*Crassula tetragona* L. subsp. *tetragona*	sp 55
ROSACEAE	shrub/shrublet	*Rubus* sp. L.	sp 56

Table E2 continued

FAMILY	GROWTH FORM	BOTANICAL NAME AND AUTHOR	Sp CODE
DROSERACEAE	herb. perennial	*Drosera hilaris* Cham. & Schltdl.	sp 57
ASTERACEAE	herb. perennial	*Senecio polyanthemoides* Sch.Bip.	sp 101
SCROPHULARIACEAE	herb. annual	*Wahlenbergia obovata* Brehmer	sp 102
POACEAE	annual graminoid	* *Briza maxima* L. / *B.minor* L.	sp 103a
POACEAE	graminoid	*Pentaschistus* sp.	sp 103b
POACEAE	annual graminoid	*Ehrharta longiflora* Sm.	sp 103c
POACEAE	graminoid	*Cynodon dactylon* (L.) Pers.	sp 103d
JUNCACEAE	graminoid	Juncaceae sp. 1	sp 103g
FABACEAE	tree	* *Acacia mearnsii* De Wild.	sp 104a
FABACEAE	tree	* *Acacia longifolia* (Andrews) Willd.	sp 104b
FABACEAE	tree/shrub	* *Paraserianthes lopantha* (Willd.) I.C.Nielsen subsp. *Lopantha*	sp 104c
ASTERACEAE	herb. perennial	*Senecio* sp. L.	sp 105
GERANIACEAE	herb. perennial	*Pelargonium iocastum* (Eckl. & Zeyh.) Steud.	sp 106a
GERANIACEAE	herb. perennial	*Pelargonium papilionaceum* (L.) L'Hér.	sp 106bi
GERANIACEAE	herb. annual	* *Geranium molle* L.	sp 106c
OXALIDACEAE	geophyte	*Oxalis pes-caprae* L. var. *pes-caprae*	sp 107b
FABACEAE	herb. annual	* *Melilotus indica* (L.) All.	sp 107c
OXALIDACEAE	perennial geophyte	*Oxalis obtusa* Jacq.	sp 107d
MALVACEAE	herb. annual	*Hibiscus trionum* L.	sp 109
MESEMBRYANTHEMACEAE	annual succulent	*Dorotheanthus bellidformis* (Burm.f.) N.E.Br. subsp. *bellidiformis*	sp 110
CRASSULACEAE	succulent	*Crassula* sp.1 L.	sp 110b
MESEMBRYANTHEMACEAE	succulent	Mesemb. sp. 1	sp 110c
APIACEAE	herb. perennial	* *Apium inundatum* (L.) Rchb.f.	sp 111
COMMELINACEAE	herb. annual	*Commelina benghalensis* L.	sp 112
EUPHORBIACEAE	herb. annual	* *Euphorbia prostrata* Aiton	sp 113
ASTERACEAE	herb. perennial	*Senecio* sp.2 .L	sp 115
ASTERACEAE	herb. annual	*Arcotheca calendula* (L.) Levyns	sp 115c
MESEMBRYANTHEMACEAE	succulent	Mesemb. sp. 2	sp 116c
POLYGONACEAE	herb. annual	* *Persicaria lapathifolia* (L.) Gray	sp 117b
AIZOACEAE	herb. perennial	* *Amaranthus deflexus* L.	sp 117c
SCROPHULARIACEAE	herb. annual	Scroph sp.1	sp 118a
CAMPANULACEAE	herb. perennial	*Prismatocarpus fruticosus* L' Hér.	sp 118b
BRASSICACEAE	herb. perennial	* *Nasturtium officinale* R.Br.	sp 121
FUMARIACEAE	herb. perennial	* *Fumaria muralis* Sond. ex W.D.J Koch subsp. *Muralis*	sp 123
ASTERACEAE	shrub/shrublet	*Polyarrhena reflexa* (L.) Cass. subsp. *reflexa*	sp 125
ARECACEAE	herb. perennial	*Asparagus* sp. L.	sp 128
ASTERACEAE	herb. annual	* *Conyza albida* Spreng.	sp 129
CRASSULACEAE	succulent annual	*Crassula natans* Thunb. var. *natans*	sp 130
CRASSULACEAE	succulent	*Crassula*sp.	sp 133a
SCROPHULARIACEAE	herb. annual	*Nemesia versicolor* E.Mey. ex. Benth. var. *versicolor*	sp 135
FABACEAE	herb. annual	* *Vicia benghalensis* L.	sp 141

CHAPTER 5: A CLASSIFICATION OF RIPARIAN SEED BANK ASSEMBLAGES AND A COMPARISON OF SEED BANK AND ABOVE-GROUND VEGETATION ASSEMBLAGES IN REFERENCE AND INVADED SITES ALONG FOUR RIVERS IN THE WESTERN CAPE, SOUTH AFRICA

5.1 ABSTRACT

This study aimed to classify species in post-disturbance riparian communities based on data collected from the soil seed bank. Soil samples and above-ground vegetation samples were taken from invaded (> 75% alien plant cover) and reference (< 25% alien plant canopy cover) sections of four rivers in the Western Cape: the Berg, Eerste, Molenaars and Wit Rivers. Two factors were considered when selecting the sampling plots, namely lateral (wet and dry bank) and longitudinal (mountain stream and foothill) zones; and both were sampled. The seedling germination method was used and soil samples were monitored for a period of 6 months under natural germination conditions. Identification was made as close to species level as possible. The combined data set (reference and invaded) was entered into the *TurboVeg* database. Community classification was conducted on the data with *Twinspan* located within the programme *Megatab*. Groupings showed clear separation in relation to disturbance state of the river (reference and invaded). A few sub-community groups were found within each main community group. A large portion of the seed bank was made up of generalist species which were associated with both reference and invaded sections of the rivers. Above-ground vegetation surveys were investigated in order to establish similarity of present (above-ground) and future (seed bank) communities. Overall, very little similarity was found between above-ground and seed bank communities as they were represented by different growth forms. No general trend was found regarding the similarity of above-ground to seed bank vegetation and it is suggested that this is a result of varying site histories. However, over all plots (reference and invaded), the foothill sections showed a higher similarity of species than the mountain stream sections.

Key words: Classification, river systems, invasive alien plants (IAPs), extant vegetation, soil-stored seed bank

5.2 INTRODUCTION

Riparian zones form the interface between terrestrial and aquatic ecosystems (Gregory *et al*., 1991) and thus possess an unusually diverse array of species and environmental processes (Naiman and Décamps, 1997). Disturbance events such as flooding, cause varying levels of erosion, sediment accumulation and deposition, as well as damage to the existing vegetation. The vegetation that is able to survive under such variable conditions must be resilient to fluctuating water levels, abrasion by passing debris and sediment, and must have life-history strategies suitable to such variable conditions. Riparian vegetation is thus highly distinctive from surrounding terrestrial vegetation and within the fynbos biome, varies in phytogeographic affinity towards either the fynbos or Afromontane Forest (recently renamed Afrotemperate Forest, Mucina *et al*., 2006) vegetation groups (Boucher, 1978). In the mountain stream catchments, the Afrotemperate elements are common with species such as *Rapanea melanophloeos, Halleria lucida, Maytenus acuminata, Cunonia capensis, Ilex mitis* and *Podocarpus* species frequently occurring (Boucher, 1978; McDonald, 1988; Manders, 1990). Often these riparian communities occur as narrow bands in steep gorges and kloofs that are protected from the natural fires that occur in the neighbouring fynbos vegetation. These forests usually have a fairly abrupt boundary with surrounding fynbos vegetation, which is maintained by fire (Midgley *et al*., 1997). As the gradient and velocity decrease, the ability of the river to deposit becomes greater, providing a suitable alluvium base for dense Closed Scrub communities to develop (Boucher, 1978). Dominant species in Closed Scrub Fynbos include *Metrosideros angustifolia, Brachylaena neriifolia, Salix mucronata, Leucadendron salicifolium, Cunonia capensis, Rapanea melanophloeos* with dominant graminoids such as *Calopsis paniculatus, Cannomois virgata* and *Elegia capensis* (Boucher, 1978; McDonald, 1988; McDonald, 1993). In slower flowing perennial streams, the entire zone may be dominated by dense stands of swamp communities of *Prionium serratum* with additional low-growing species (Boucher, 1978).

The most recent description by Mucina and Rutherford (2006) defined three broad community groups, termed: Fynbos Riparian vegetation, Cape Lowland Alluvial vegetation and Cape Lowland freshwater wetlands running from upper catchments, through the floodplains and into the wetlands respectively (Mucina *et al.,* 2006; Rebelo *et al*., 2006). Riparian communities with a fynbos affinity have been described as Closed-Scrub Fynbos (Cowling and Holmes, 1992) or Broad Sclerophyllous Closed Scrub (Kruger, 1978). Such communities are usually found in the mountain stream or montane reaches of the rivers where the extent of alluvium is limited as a result of the high levels of erosion.

Recent studies done by Prins (2003) and Sieben (2002) added significantly to defining the composition and community structure of riparian areas in the fynbos biome, particularly so in the upper reaches of the catchments (Sieben, 2002). Prins (2003) found five distinct communities within the riparian areas of her study while Sieben's study (2002) was more extensive and thus found 26 riverine and 11 mire communities. Mucina *et al.* (2006) and Rebelo *et al.* (2006) combined several relevant community studies to come up with a broad classification of fynbos riparian vegetation to be utilized at a landscape mapping scale. (For summarised descriptions of Prins, 2003; Sieben, 2002; Rebelo *et al.,* 2006 and Mucina *et al*., 2006 see Chapter 2, Appendix 2.1, Tables A1-A3).

The major components of a riparian zone can be defined on a lateral scale as the aquatic zone, the wet bank zone and the dry bank zone; and on a longitudinal scale by mountain stream, foothill, transitional and lowland zones (Davies and Day, 1998; Boucher and Tlale, 1999). Mountain stream zones occur where erosion exceeds sediment accumulation; foothill zones where erosion and accumulation are more or less in balance; and lowland river zones, where accumulation exceeds erosion (Davies and Day, 1998). Many different microhabitats are found along the banks as well as in the aquatic environment of all lateral zones (Sieben, 2002). These microhabitats will change as the water level fluctuates (Davies and Day, 1998), particularly so in the foothill zone. Here, river size increases as the catchment's size increases, the slope becomes gentler and thus velocity decreases. This combination of an increase in suspended material and a decrease in flow velocity raises the level of deposition. In mountain stream sections a high level of erosion is always present. However, with a decrease in flow volume, small areas of deposition may form in more protected areas such as side channels of slower-moving water. These microhabitats allow for pockets of different communities to establish within the larger community group.

Riparian vegetation composition studies within the fynbos biome have been extensive, both in content and over time (Boucher, 1999;; Sieben, 2002; Prins, 2003; Reinecke and King, 2007; Boucher and Tlale, 1999; Mucina and Rutherford, 2006). Little research, however, has looked at composition of the seed bank of these communities. Riparian seed banks play a major role in the initial post-disturbance community and knowledge of this community structure would assist in evaluating its rehabilitation potential. Worldwide, river systems are notoriously susceptible to invasion by invasive alien plant species (IAPs) as a result of their high intensity and frequency of disturbance events, and their ability to rapidly spread propagules through the system. In the Mediterranean climate of the Western Cape, IAPs cause major problems by impacting the availability and quality of water, and altering the natural stream flow of the rivers they invaded (Rowntree, 1991). Most alien clearing initiatives do not have resources available to implement additional restoration after clearing riparian areas and it is left to the under-ground soil seed bank to restore the community structure. Little is known about the viability and effectiveness of this approach.

This study aimed to gain insight into the transition from seed bank to present community structure and composition by doing an above-ground and seed bank community comparison.

5.3 METHODS

5.3.1 STUDY SITES

Four river systems within the Western Cape fynbos region were chosen for their variety of reach types, history of vegetation (both alien and natural), and for their relatively close proximity to the research facilities. The sampling method combined subjective selection of plots within identified lateral plant assemblages (as pioneered by the Braun-Blanquet School of Phytosociology (Kent and Coker, 1992)) and objective, random placement of sampling quadrats within these plots. Two assemblages were sampled at each site, namely the lateral wet bank and dry bank zones. In addition, two longitudinal riparian zones (mountain stream & foothill) were sampled. Plots were selected in both relatively undisturbed fynbos/riparian areas (<25% alien plant canopy cover) and heavily invaded (>75%) riparian sections of the rivers. For more detailed description on study sites and sampling procedures see Chapter 2.

5.3.2 DATA COLLECTION

Equal numbers of plots were established in both reference and invaded sections of the four river systems. Both the above-ground vegetation data and soil samples were collected per quadrat within each plot. In total, 290 quadrats were sampled within the reference plots and 310 quadrats within the invaded plots, giving a total of 600 samples once combined. Soil samples were then placed in labelled trays and treated with a uniform dosage of smoke treatment prior to irrigation commencement. Thereafter, seedlings that emerged from the soil seed bank were counted and identified as close to species level as possible. Monitoring took place bi-monthly for the first 3 months, and monthly for the last three months (See Chapter 2 for more details on data collection and seed bank sampling procedures). Abundance of seedlings per sample was then converted into a scale based on the seedling counts in order to run a TWINSPAN analysis (Table 5.1).

Table 5.1: Indices for seed bank abundance data used in analyses for all four rivers sampled (Berg, Eerste, Molenaars and Wit). Data was collected from seed bank germinants (see text).

INDEX	ABUNDANCE VALUE (counts)
0	0
1	1-19
2	20-39
3	40-59
4	60-79
5	80 +

5.3.3 DATA ANALYSIS

5.3.3.1 Seed bank community classification

The combined seed bank data set (reference and invaded) was entered into the TurboVeg (Hennekens, 1996) database. Community classification was conducted on the data with TWINSPAN (Hill, 1979), located within the programme Megatab (Hennekens, 1996). TWINSPAN (Two-way Indicator Species Analysis) is a polythetic division method of classification (Kent and Coker, 1992). Species data were arranged in a table with species in rows and samples in columns. This raw data table was then rearranged to group together species that are similar in their distribution and the re-arrangement is repeated until a differentiated table is produced. The final table has species arranged in groups (associations) characterised by diagnostic species. The association can be described as a plant community type, found by grouping together sample plots that have species in common (Kent and Coker, 1992). Diagnostic species distinguish between these associations (communities) by their presence in some communities and their absence in others (Whittaker, 1975). This classification was stopped at the 2nd level of division so as not to end up with communities that are meaningless. Results were interpreted in terms of community groups and sub-community groups.

5.3.3.2 Above-ground and seed bank comparisons

Above-ground vegetation sampling was done per quadrat and compared with the relevant seed bank sample collected. To simplify the comparison, data was compared at a plot level (i.e. all quadrats were pooled together) as the influence of each species would be apparent at plot scale and would avoid over-repetition. Above-ground and seed bank comparison tables from Appendix E were used. Additionally, species were grouped according to growth form and formulated in a table according to where the species was found (above-ground or seed bank, or both). Sørensen's Community Coefficient was used to investigate the degree of similarity between the above-ground vegetation and it's seed bank: $S_s = 2C/(A + B)$, where *C* is the number of species common to both samples, and *A* and *B* are the number of species in sample *A* and *B* respectively (Kent and Coker, 1992). In this study *A* refers to the species that germinated from the seed bank samples, and *B* refers to the above-ground vegetation sampled. Sample size was at plot level and comparisons were made of the degree of similarity between reference and invaded plots.

5.4 RESULTS

5.4.1 SEED BANK COMMUNITY CLASSIFICATION

The TWINSPAN classification discerned 2 main community groups and 3 sub-community groups. Most species are identified as being pioneer species, with a mixture of fynbos and riparian elements. The results of the analysis are shown in Appendix 5.1 (Table F) and summarized below.

- **Community Group A**- Diagnostic community to reference sites

The community structure in this group was dominated by graminoids, herbaceous perennials and a longer-lived woody shrubs and trees. The few alien species that were present were annuals that are usually associated with agricultural and disturbed landscapes (e.g. *Aira cupaniana, Hypochaeris radicata, Lactuca serriola, Anagallis arvensis*). It was initially hypothesised that most of these species occurred within the foothill sections where anthropogenic disturbance levels are higher. However, upon inspection of plots, it was found that most of these above-mentioned agricultural weedy species were occurring more often in the mountain stream sections and less so in the foothill sections. Of the 32 species present within this community group, *Eragrostis curvula, Struthiola tomentosa, Euryops abrotanifolius, Wahlenbergia cernua* and *Pseudoselago quadrangularis* were most abundant.

<u>Sub-community group A1</u>*: Argyrolobium lunare – Zalusianskya capensis pioneer subshrub*

This sub-community group occurred across all rivers, within both the mountain stream and foothill sections. *Argyrolobium lunare* occurred throughout most plots in this sub-community, as did *Othonna quinquedentata* and *Chironia* species. *Zaluzianskya capensis* had a very high abundance in plot 37 (Berg reference, Mont Rochelle, mountain stream) and occurred exclusively within the Berg River catchment while *Empleurum unicapsulare* occurred exclusively within plots 32 (Berg reference, Theewaters, foothill) and 35 (Berg reference, Assagaiboschkloof, foothill).

- **Community Group B**- Diagnostic community to invaded sites

The majority of species within this community group were either alien (invasive and non-invasive) or indigenous "weedy" species. The indigenous species that were grouped within this community are species that are often associated with disturbed areas such *Senecio polyanthemoides, Pelargonium* spp., and several graminoid species*.*

<u>Sub-community group B1</u>*: Paraserianthes lophantha - Leptospermum laevigatum weedy shrubland*

Species grouped here occurred within the foothill sites, although some species were present in a few mountain stream sites. Species within this group appeared to be associated with high levels of disturbance over an extended period of time as the two major IAPs in this group are trees, large herbaceous shrubs rather than annuals (*Paraserianthes lophantha* and *Amaranthus deflexus*). The indigenous species within this group are few and of a short-lived nature (mostly graminoids and herbaceous annuals).

<u>Sub-community group B2</u>*: Fumaria muralis- Dorotheanthus bellidiformis herbaceous undergrowth*

Species within this group were associated with the mountain stream sections of the Molenaars and Eerste River catchments. All plots were in highly disturbed, narrow bands (transitional zone) of vegetation along perennial rivers. None of the seed bank species were noted to be present in the above-ground vegetation and a common above-ground species was *Eucalyptus camaldulensis*.

5.4.2 ABOVE-GROUND AND SEED BANK COMPARISONS

Overall, the seed bank communities were more species rich than the above-ground vegetation communities, regardless of state (reference or invaded). There was generally a low correspondence of species between above-ground and seed bank communities. Sorensen's Community Coefficient for comparisons between above-ground vegetation and seed bank communities showed that within the foothill sections of both the Eerste and Witte Rivers, as well as the mountain stream section of the Molenaars River, the similarity increased after invasion (Table 5.2). This was to be expected as trends within terrestrial landscapes show a more homogenous community persisting after invasion, particularly after long-term invasion (Holmes, 2002). However, what is interesting is that the community similarity index decreased after invasion through all other plots sampled (13 out of 16 plots). Upon closer inspection (Appendix 5.2, Tables G1.1- 1.26 and G 2.1-2.29) it seems that the community shift is evident throughout most post-invaded plots, whereby the above-ground vegetation was predominantly alien invasive tree species, while the seed bank was composed of graminoids, herbaceous annuals and agricultural weedy species, with few species overlapping. Comparisons between reference plots showed that community structure was more similar in terms of a stronger shrub/shrublet presence in both the above-ground and seed bank communities and several herbaceous perennials overlapped. If we consider the comparisons between reference and invaded seed bank communities exclusively (results in Chapter 4), the results show that invaded seed bank species groupings seemed more variable and dependent on sections of the river (mountain stream or foothill) and moisture levels (bank zones). Therefore, the community structure of reference seed banks was found to be more consistent and less variable than that of the seed bank within invaded sections, the above-ground and seed bank communities would be more similar before invasion; and once the additional variability is added to the seed bank (in the form of all aspects relating to invasion), the community structure would shift and a divergence between above-ground and below-ground community composition would result. This can be seen in results of Table 5.2.

The species that were shared between above-ground and seed bank communities of invaded sections comprised mainly of agricultural weedy species or invasive shrub species (*Acacia mearnsii, Acacia longifolia, Amaranthus deflexus, Solanum retroflexum, Plantago lanceolata*) and a few indigenous graminoids (*Digitaria debilis and Cynodon dactylon*). In contrast, the overlapping species within the reference samples were all indigenous species, mainly comprising of shrub/shrublets (*Erica caffra, Euryops abrotanifolius,* *Psoralea* sp., *Struthiola tomentosa, Metalasia* sp.) with few graminoids (*Ischyrolepis subverticillata, Juncus capensis*). Interestingly, the seed bank community in reference samples contained some alien annual species that were not present in the above-ground vegetation. For example, *Solanum retroflexum* was fairly abundant in the reference seed bank community but was noted only once as being present in the above-ground vegetation. Species in high abundance within the reference and invaded samples showed some overlap in species. Those species abundant in the invaded samples included; *Euphorbia prostrata, Isolepis prolifera, Acacia mearnsii, Ficinia anceps, Oxalis corniculata* and *Juncus capensis*; the latter three also abundant within the reference samples. Other abundant species within the reference seed bank samples included; *Digitaria debilis, Panicum maximum, Erica caffra, Struthiola striata, Metalasia sp., Pentaschistis pallida,* and *Solanum retroflexum.* (see Appendix 5.2 of this chapter for full above-ground and seed bank species list).

Table 5.2 Number of species, by growth form, in different categories within different sections of the rivers sampled. Data collected for all samples (invaded = 310 quadrats, reference = 290 quadrats – see text.) Codes for river system are: River/ reach (MS= mountain stream, FH= foothill) / state (ref= reference, inv=invaded). Codes for growth forms are: Annual herb = annual herbaceous, Herb Annual (A) = annual herbaceous alien, Perennial herb = perennial indigenous herbaceous, Tree (A)= alien tree.

Growth form	Detected in the seed bank only	Detected in both seed bank and above-ground vegetation	Detected in vegetation only	Total
BERG RIVER / MS / ref				
Graminoids	9	3	9	21
Annual herb	3	0	1	3
Herb Annual (A)	9	0	0	9
Perennial herb	7	2	0	9
Shrub/shrublet	13	5	5	23
Tree	0	0	4	4
Tree (A)	0	0	1	1
Geophytes	1	0	1	2
Succulents	7	0	0	7
TOTAL	49	10	21	80
BERG RIVER / MS / inv				
Graminoids	12	1	2	15
Annual herb	5	0	0	5
Herb Annual (A)	16	2	0	18
Perennial herb	4	0	2	6
Shrub/shrublet	5	1	2	8
Tree	0	0	1	1
Tree (A)	0	2	2	4
Geophytes	2	0	0	2
Succulents	2	0	0	2
TOTAL	46	6	9	61
BERG RIVER / FH / ref				
Graminoids	9	6	16	31
Annual herb	5	0	0	5
Herb Annual (A)	9	1	0	10
Perennial herb	8	0	6	14
Shrub/shrublet	14	5	6	25
Tree	0	0	9	9
Tree (A)	0	1	1	2
Geophytes	1	0	0	1
Succulents	1	0	0	1
TOTAL	47	13	38	98

Table 5.2 continued

Growth form	Detected in the seed bank only	Detected in both seed bank and above-ground vegetation	Detected in vegetation only	Total
BERG RIVER / FH / inv				
Graminoids	12	5	1	18
Annual herb	2	0	0	2
Herb Annual (A)	13	2	1	16
Perennial herb	4	0	0	4
Shrub/shrublet	6	0	1	7
Tree	0	0	0	0
Tree (A)	2	2	2	6
Geophytes	2	0	0	2
Succulents	2	0	0	2
TOTAL	43	9	5	57
EERSTE RIVER / MS / ref				
Graminoids	13	1	7	21
Annual herb	3	0	0	3
Herb Annual (A)	11	0	0	11
Perennial herb	8	1	4	13
Shrub/shrublet	15	4	13	32
Tree	1	0	3	4
Tree (A)	1	0	0	1
Geophytes	1	0	1	2
Succulents	5	0	0	5
TOTAL	58	6	28	92
EERSTE RIVER / MS / inv				
Graminoids	8	0	0	8
Annual herb	1	0	0	1
Herb Annual (A)	14	0	0	14
Perennial herb	5	0	2	7
Shrub/shrublet	7	0	2	9
Tree	0	0	2	2
Tree (A)	3	1	1	5
Geophytes	2	0	0	2
Succulents	2	0	0	2
TOTAL	42	1	7	50
EERSTE RIVER / FH / ref				
Graminoids	13	0	1	14
Annual herb	3	0	0	3
Herb Annual (A)	10	0	0	10
Perennial herb	9	0	5	14
Shrub/shrublet	13	0	3	16
Tree	0	2	8	10
Tree (A)	1	0	1	2
Geophytes	1	0	0	1
Succulents	3	0	0	3
TOTAL	53	2	18	73

Table 5.2 continued

Growth form	Detected in the seed bank only	Detected in both seed bank and above-ground vegetation	Detected in vegetation only	Total
EERSTE RIVER / FH / inv				
Graminoids	11	4	4	19
Annual herb	4	0	0	4
Herb Annual (A)	17	3	3	23
Perennial herb	3	0	3	6
Shrub/shrublet	13	1	1	15
Tree	0	0	7	7
Tree (A)	1	2	6	9
Geophytes	2	0	1	3
Succulents	3	0	0	3
TOTAL	54	10	25	89
MOLENAARS RIVER / MS / ref				
Graminoids	12	2	4	18
Annual herb	1	0	0	1
Herb Annual (A)	10	0	0	10
Perennial herb	12	0	2	14
Shrub/shrublet	17	1	2	20
Tree	0	0	5	5
Tree (A)	0	1	0	1
Geophytes	1	0	0	1
Succulents	5	0	0	5
TOTAL	58	4	13	75
MOLENAARS RIVER / MS / inv				
Graminoids	13	1	0	14
Annual herb	4	0	0	4
Herb Annual (A)	8	0	0	8
Perennial herb	5	0	1	6
Shrub/shrublet	10	3	3	16
Tree	0	0	7	7
Tree (A)	0	2	0	2
Geophytes	2	0	0	2
Succulents	1	0	0	1
TOTAL	43	6	11	60
MOLENAARS RIVER / FH / ref				
Graminoids	9	4	9	22
Annual herb	6	0	0	6
Herb Annual (A)	8	0	0	8
Perennial herb	4	0	8	12
Shrub/shrublet	11	1	10	22
Tree	0	0	6	6
Tree (A)	0	0	3	3
Geophytes	0	0	1	1
Succulents	3	0	0	3
TOTAL	41	5	37	83

Table 5.2 continued

Growth form	Detected in the seed bank only	Detected in both seed bank and above-ground vegetation	Detected in vegetation only	Total
MOLENAARS RIVER / FH / inv				
Graminoids	13	1	1	15
Annual herb	5	0	0	5
Herb Annual (A)	10	0	0	10
Perennial herb	3	0	0	3
Shrub/shrublet	13	1	2	16
Tree	0	0	2	2
Tree (A)	1	2	0	3
Geophytes	1	0	0	1
Succulents	3	0	0	3
TOTAL	49	4	5	58
WITTE RIVER / MS / ref				
Graminoids	6	5	8	19
Annual herb	2	0	0	2
Herb Annual (A)	7	0	0	7
Perennial herb	4	0	0	4
Shrub/shrublet	8	2	5	15
Tree	0	0	3	3
Tree (A)	1	0	1	2
Geophytes	0	0	2	2
Succulents	3	0	0	3
TOTAL	31	7	19	57
WITTE RIVER / MS / inv				
Graminoids	9	0	1	10
Annual herb	8	0	0	8
Herb Annual (A)	22	0	1	23
Perennial herb	6	0	0	6
Shrub/shrublet	12	1	0	13
Tree	0	0	1	1
Tree (A)	0	0	3	3
Geophytes	1	0	0	1
Succulents	6	0	0	6
TOTAL	64	1	6	71
WITTE RIVER / FH / ref				
Graminoids	5	0	7	12
Annual herb	2	0	0	2
Herb Annual (A)	3	0	0	3
Perennial herb	2	0	0	2
Shrub/shrublet	9	1	6	16
Tree	0	0	3	3
Tree (A)	0	0	0	0
Geophytes	0	0	0	0
Succulents	1	0	0	1
TOTAL	22	1	16	39

Table 5.2 continued

Growth form	Detected in the seed bank only	Detected in both seed bank and above-ground vegetation	Detected in vegetation only	Total
WITTE RIVER / FH / inv				
Graminoids	8	1	2	11
Annual herb	5	0	0	5
Herb Annual (A)	15	0	0	15
Perennial herb	6	1	1	8
Shrub/shrublet	12	0	3	15
Tree	0	0	2	2
Tree (A)	1	1	0	2
Geophytes	1	0	0	1
Succulents	4	0	0	4
TOTAL	52	3	8	63

Table 5.3: Sørensen's Community Coefficient (S_S) for comparison between vegetation and seed banks in fynbos riparian plots sampled along four rivers in the Western Cape, South Africa. Comparisons included all plot samples (invaded = 310 quadrats, reference = 290 quadrats – see text) and comparisons were done at plot level. Code for river system is River (Berg, Eerste. Molenaars, Wit) / reach (MS= mountain stream, FH= foothill) / state (ref= reference, inv=invaded).

River/ reach/ state	Sorensens Index
BERG / MS / ref	0.28
BERG / MS / inv	0.21
EERSTE / MS / ref	0.14
EERSTE / MS / inv	0.41
MOLENAARS / MS / ref	0.11
MOLENAARS / MS / inv	0.22
WITTE / MS / ref	0.28
WITTE / MS / inv	0.28
BERG / FH / ref	0.31
BERG / FH / inv	0.38
EERSTE / FH / ref	0.56
EERSTE / FH / inv	0.25
MOLENAARS / FH / ref	0.13
MOLENAARS / FH / inv	0.15
WITTE / FH / ref	0.53
WITTE / FH / inv	0.10

5.5 DISCUSSION

Past work done by Sieben (2002), Prins (2003), and most recently by Mucina *et al.* (2006) and Rebelo *et al.* (2006), and Reinecke and King (2007), effectively described most above-ground riparian communities within this study area. This study begins to describe the associated seed bank community and confirms little correspondence occurring between above-ground and seed bank communities, as could be expected for ecosystems subject to varying levels of disturbance. The seed bank communities did, however, distinctly group under the different conditions of the river (reference and invaded states of the rivers) in the classification. This confirms what was found in the study investigating the impact of invasion on riparian seed banks (Chapter 4) which concluded that invasion impacts on the assembly patterns of species found within the seed bank community. Although conclusive, this is the first of such studies within riparian areas of the fynbos biome and more research is needed in order to get a more holistic view of the impact of invasion on the seed banks within these areas.

An interesting result from this study was that the seed banks of invaded sites were equally rich, if not richer, in indigenous species than the reference seed banks. Additionally, the seed bank composition was more diverse and species-rich than the above-ground vegetation, as was found by others (Leck, 1989; Thompson, 1992; Richter and Stromberg, 2005); particularly so within the reference sites, but even within the invaded sites. This finding is particularly important for evaluating the restoration potential of riparian seed banks. It seems that even after heavy and extensive invasion, the riparian seed banks in this study showed an adequate species composition to kick-start community restoration. It is strongly suggested, however, that additional planting of key riparian species be added into the restoration management programme in order to increase the integrity of the community (by introducing species that do not recruit from soil-stored seeds) and speed up the restoration process so as to lessen the chances of re-invasion. The entirety of the cleared area need not be replanted, however. The important factor to re-establish is a <u>seed source</u> from which the recovery of those key riparian species that do not recruit from the seed bank can begin and spread further through the riparian system (Sedell and Reeves, 1990; Wassie and Teketay, 2006).

Additionally, it is important to consider the time frame in which this study was completed. Previous research has shown the majority of seeds germinating within the first 3 months of a seed bank study (Leck, 1989). Therefore a germination period of 6 months was assumed adequate to deduce most germination results, especially considering riparian scrub is a fynbos community type and therefore many species are adapted to germinate within the first year after fire (this study used smoke treatment to induce germination). In this study, there was indeed a rapid decline in germination rate after the first 12 weeks. Very little germination was recorded in the last 4 weeks of the experiment. However, a longer term riparian seed bank study would add valuable insight into the later successional phase of species and is therefore recommended for a holistic approach to riparian seed bank composition. Within the context of the regional research project that this study is associated with (*Targets for Ecosystem Repair in Riparian Ecosystems in Fynbos, Grassland and Savannah Biomes*) it was vital to investigate the seed bank composition within the time-frame that is practical for most alien clearing initiatives and private-land clearing programmes. This is also usually a relatively short- time frame, in terms of restoration (mostly 2- 3 years, sometimes up to 10 years depending on how extensive the alien seed bank is) as in reality there is little time and few resources for long-term monitoring of the cleared sites.

Future research needs to be done investigating certain key riparian species (such as *Metrosideros angustifolia, Brabejum stellatifolium, Brachylaena neriifolia* and *Morella serrata)* in terms of their life history traits. This knowledge could assist managers and land owners by possibly offering cost-effective way to restore riparian areas with the usage of replanted refugia or seed sources after these areas have been cleared of invasive alien plant species. Once these refugia pockets become established (most of the species that are not present in the soil seed bank are taller woody shrub and tree species), birds may return and assist in the restoration process. Additionally, and linked to the above-mentioned points, it would be interesting to look more in depth at other aspects of seed bank dynamics and recruitment such as dispersal, seed longevity, germination cues and the varying levels of succession within riparian communities.

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5.7 APPENDIX 5.1

Table F: *Vegetation community table of seed bank plant communities among the four rivers (Berg, Eerste, Molenaars and Wit) sampled in the Western Cape, South Africa. Species that were identified at the completion of the 6-month monitoring programme were analysed and interpreted in terms of Community Groups and Sub-community Groups*.

Table F:

5.8 **APPENDIX 5.2**

Above-ground and seed bank species comparision tables. Data was collected from field-work surveys and species that germinated from the relevant soil seed bank samples along four rivers (Berg, Eerste, Molenaars and Wit) in the Western Cape, South Africa.

Tables G1.1- 1.26**:INVADED PLOTS**

Tables G2.1- 2.29**: REFERENCE PLOTS**

Table G 1.1: Eerste River invaded mountain stream plot 1

EERSTE RIVER INVADED * = alien plant species

MOUNTAIN STREAM TRANS

ErKrMSt

ABOVE-GROUND VEGETATION

Family	**Species**
ANACARDIACEAE	*Rhus angustifolia*
BLECHNACEAE	*Blechnum capense*
DRYOPTERIDACEAE	*Rumohra adiantiformis*
FABACEAE	* *Acacia mearnsii*
FABACEAE	*Virgilia oroboides*

SEED BANK COMMUNITY

Family	**Species**
AMARANTHACEAE	* *Amaranthus deflexus*
ASTERACEAE	*Senecio* sp
ASTERACEAE	*Senecio polyanthemoides*
ASTERACEAE	* *Conyza albida*
ASTERACEAE	* *Hypochaeris radicata*
ASTERACEAE	*Pseudognaphalium luteo-album*
ASTERACEAE	*Helichrysum helianthemifolium*
ASTERACEAE	* *Sonchus asper*
ASTERACEAE	*Metalasia sp*
ASTERACEAE	*Othonna quinquedentata*
BRASSICACEAE	* *Nasturtium officinale*
CAROPHYLLACEAE	* *Polycarpon tetraphyllum*
COMMELINACEAE	*Commelina benghalensis*
CRASSULACEAE	*Crassula thunbergiana* subsp *thunbergiana*
CYPERACEAE	*Isolepis prolifera*
CYPERACEAE	*Ficinia anceps*
CYPERACEAE	*Schoenoplectus sp.*
ERICACEAE	*Erica* sp
EUPHORBIACEAE	* *Euphorbia prostrata*
FABACEAE	* *Acacia mearnsii*
FABACEAE	* *Melilotus indica*
GERANIACEAE	*Pelargonium elongatum*
GERANIACEAE	*Pelargonium iocastum*
JUNCACEAE	*Juncus capensis*
OXALIDACEAE	*Oxalis corniculata*
OXALIDACEAE	*Oxalis pes-caprae subsp pes-caprae*
PHYTOLACCACEAE	* *Phytolacca octandra*
POACEAE	* *Briza maxima/ B. minor*
POACEAE	*Ehrharta longiflora*
POACEAE	*Pentaschistis pallida*
POACEAE	*Pentaschistis sp.*
POLYGONACEAE	* *Persicaria lapathifolia*
ROSACEAE	*Rubus* sp.
SCROPHULARIACEAE	*Wahlenbergia cernua*
SCROPHULARIACEAE	Scroph sp. 1(serrated leaves)
SCROPHULARIACEAE	*Wahlenbergia obovata*
SOLANACEAE	*Solanum retroflexum*
VERBENACEAE	* *Verbena bonariensis*

<u>Table G 1.2:</u> Eerste River invaded mountain stream plot 2

MOUNTAIN STREAM TRANS		* = alien plant species	
ErTkMSt			
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
BLECHNACEAE	*Blechnum capense*	AMARANTHACEAE	*Amaranthus deflexus*
DRYOPTERIDACEAE	*Rumohra adiantiformis*	ASTERACEAE	*Senecio polyanthemoides*
FABACEAE	* *Acacia mearnsii*	ASTERACEAE	*Metalasia* sp
FABACEAE	*Psoralea pinnata*	ASTERACEAE	* *Conyza albida*
MYRTACEAE	*Podalyria calyptrata*	ASTERACEAE	*Pseudognaphalium luteo-album*
		ASTERACEAE	*Ursinia* sp
		ASTERACEAE	*Senecio* sp.
		CAMPANULACEAE	*Prismatocarpus fruiticosus*
		CAMPANULACEAE	*Wahlenbergia obovata*
		CAROPHYLLACEAE	* *Polycarpon tetraphyllum*
		CRASSULACEAE	*Crassula* sp.
		CRASSULACEAE	*Crassula thunbergiana* subsp *thunbergiana*
		CYPERACEAE	*Ficinia anceps*
		CYPERACEAE	*Isolepis prolifera*
		ERICACEAE	*Erica* sp 2
		EUPHORBIACEAE	* *Euphorbia prostrata*
		FABACEAE	* *Acacia mearnsii*
		FABACEAE	* *Acacia longifolia*
		JUNCACEAE	*Juncus capensis*
		JUNCACEAE	*Juncus capensis*
		MYRICACEAE	*Morella* sp.
		OXALIDACEAE	*Oxalis corniculata*
		PHYTOLACCACEAE	*Phytolacca octandra*
		POACEAE	*Pentaschistus pallida*
		POACEAE	* *Briza maxima/ B. minor*
		POLYGALACEAE	* *Persicaria sp.* (annual)
		POLYGONACEAE	* *Persicaria lapathifolia*
		ROSACEAE	*Rubus* sp.
		SCROPHULARIACEAE	*Nemesia versicolor*
		SOLANACEAE	*Solanum retroflexum*
		VERBENACEAE	* *Verbena bonariensis*

Table G 1.3: Eerste River invaded foothill plot 1

FOOTHILL TRANS — * = alien plant species

ErSbFHt

ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
ACHARIACEAE	*Kiggelaria africana*	AIRIACEAE	* *Aira cupaniana*
ANACARDIACEAE	*Rhus angustifolia*	ASTERACEAE	* *Conyza albida*
ARACEAE	*Zandetischia aethiopica*	ASTERACEAE	*Senecio* sp
ASTERACEAE	* *Sonchus asper* var *asper*	ASTERACEAE	*Arctotheca calendula*
COMMELINACEAE	* *Commelina benghalensis*	ASTERACEAE	*Othonna quinquedentata*
FABACEAE	* *Acacia mearnsii*	ASTERACEAE	*Helichrysum helianthemifolium*
MYRTACEAE	*Metrosideros angustifolia*	ASTERACEAE	*Metalasia* sp
MYRTACEAE	*Eucalyptus camaldulensis*	ASTERACEAE	*Senecio polyanthemoides*
POACEAE	* *Paspalum urvillei*	ASTERACEAE	*Chyrsanthemoides monilifera* subsp. *monilifera*
POACEAE	*Pentameris thurii*	ASTERACEAE	*Pseudognaphalium luteo-album*
PROTEACEAE	*Brabejum stellatifolium*	ASTERACEAE	* *Hypochaeris radicata*
SOLANACEAE	*Solanum retroflexum*	ASTERACEAE	*Seriphium plumosa*
		BRASSICACEAE	* *Nasturtium officinale*
		CAMPANULACEAE	*Wahlenbergia sp*
		CAMPANULACEAE	*Wahlenbergia obovata*
		CAMPANULACEAE	*Prismatocarpus fruticosus*
		CRASSULACEAE	*Crassula* sp.
		CYPERACEAE	*Ficina anceps*
		CYPERACEAE	*Scirpus* sp
		EUPHORBIACEAE	* *Euphorbia prostrata*
		FABACEAE	* *Melilotus indica*
		FABACEAE	* *Acacia mearnsii*
		FABACEAE	*Psoralea* sp.
		FUMARIACEAE	* *Fumaria muralis*
		GENTIANACEAE	* *Geranium molle*
		GERANIACEAE	*Pelargonium iocastum*
		JUNCACEAE	*Juncus* sp
		JUNCACEAE	*Juncus capensis*
		MESEMBRYANTHEMACEAE	*Dorotheanthus bellidformis*
		OXALIDACEAE	*Oxalis corniculata*
		PHYTOLACCACEAE	* *Phytolacca octandra*
		POACEAE	*Panicum maximum*
		SOLANACEAE	*Solanum retroflexum*
		VERBENACEAE	* *Verbena bonariensis*

Table G 1.4: Eerste River invaded foothill plot 2 (wet)

FOOTHILL WET			* = alien plant species
ErAbFHw			
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
MYRICACEAE	*Morella integra*	APIACEAE	*Apium inundatum*
ERICACEAE	*Erica caffra*	ASTERACEAE	* *Conyza albida*
FABACEAE	* *Acacia longifolia*	ASTERACEAE	* *Hypochaeris radicata*
FABACEAE	* *Acacia/ Sesbania* seedlings	ASTERACEAE	*Pseudognaphalium luteo-album*
PROTEACEAE	*Brabejum stellatifolium*	ASTERACEAE	*Senecio* sp.
MYRTACEAE	* *Eucalyptus camaldulensis*	ASTERACEAE	* *Lactuca serriola*
FABACEAE	*Virgillia oroboides*	ASTERACEAE	*Arcotheca calendula*
FABACEAE	* *Sesbania punicea*	ASTERACEAE	* *Lactuca serriola*
LAURACEAE	* *Cinnamomum camphora*	ASTERACEAE	*Metalasia sp.*
FABACEAE	* *Acacia melanoxylon*	ASTERACEAE	*Senecio polyanthemoides*
		BRASSICACEAE	* *Nasturtium officinale*
		CAMPANULACEAE	*Wahlenbergia cernua*
		CAMPANULACEAE	*Wahlenbergia obovata*
		CAMPANULACEAE	*Wahlenbergia* sp
		CRASSULACEAE	*Crassula* sp.
		CYPERACEAE	*Ficinia anceps*
		CYPERACEAE	*Scirpus* sp.
		CYPERACEAE	*Isolepis prolifera*
		CYPERACEAE	*Schoenoplectus* sp.
		FABACEAE	* *Acacia mearnsii.*
		FABACEAE	*Podalyria calyptrata*
		FABACEAE	*Vicia benhalensis*
		GERANIACEAE	*Pelargonium iocastum*
		GERANIACEAE	*Pelargonium cucullatum*
		GERANIACEAE	*Pelargonium elongatum*
		JUNCACEAE	*Juncus capensis*
		JUNCACEAE	*Juncus capensis*
		OXALIDACEAE	*Oxalis corniculata*
		POACEAE	*Ehrharta longiflora*
		POACEAE	*Pentaschistus pallida*
		RESTIONACEAE	*Ischyrolepis subverticillata*
		ROSACEAE	*Rubus sp.*
		SCROPHULARIACEAE	*Nemesia versicolor*
		SOLANACEAE	*Solanum retroflexum*
		VERBENACEAE	* *Verbena bonariensis*

Table G 1.5: Eerste River invaded foothill plot 2 (dry)

FOOTHILL DRY			* = alien plant species
ErAbFHd			
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
AQUIFOLIACEAE	*Ilex mitis*	ANACARDIACEAE	*Rhus* sp.
ASPARAGACEAE	*Asparagus sp.*	ASTERACEAE	* *Conyza albida*
ASTERACEAE	*Brachylaena neriifolia*	ASTERACEAE	* *Hypochaeris radicata*
FABACEAE	* *Acacia longifolia*	ASTERACEAE	* *Lactuca serriola*
FABACEAE	* *Sesbania punicea*	ASTERACEAE	*Pseudognaphalium luteo-album*
LAURACEAE	* *Cinnamomum camphora*	ASTERACEAE	*Senecio* sp
MYRTACEAE	*Metrosideros angustifolia*	ASTERACEAE	*Senecio polyanthemoides*
POACEAE	*Paspalum urvillei*	ASTERACEAE	* *Sonchus asper*
PRIMULACEAE	* *Anagallis arvensis*	BRASSICACEAE	* *Nasturtium officinale*
PRIONIACEAE	*Prionium serratum*	CAMPANULACEAE	*Wahlenbergia obovata*
PROTEACEAE	*Brabejum stellatifolium*	CAROPHYLLACEAE	* *Polycarpon tetraphyllum*
RESTIONACEAE	*Elegia capensis*	CRASSULACEAE	*Crassula natan* var *natans*
		CYPERACEAE	*Isolepis prolifera*
		CYPERACEAE	*Schoenoplectus* sp.
		EUPHORBIACEAE	* *Euphorbia prostrata*
		FABACEAE	* *Acacia mearnsii.*
		FABACEAE	* *Melilotus indica*
		FABACEAE	*Vicia benghalensis*
		GERANIACEAE	*Pelargonium elongatum*
		GERANIACEAE	*Pelargonium cucullatum*
		GERANIACEAE	*Pelargonium iocastum*
		OXALIDACEAE	*Oxalis corniculata*
		OXALIDACEAE	*Oxalis per-caprae* var *pes-caprae*
		PHYTOLACCACEAE	* *Phytolacca octandra*
		POACEAE	*Pentaschistus pallida*
		POACEAE	*Ehrharta longiflora*
		POLYGONACEAE	* *Persicaria lapathifolia*
		SCROPHULARIACEAE	*Nemesia versicolor*
		SOLANACEAE	*Solanum retroflexum*
		VERBENACEAE	* *Verbena bonariensis*

Table G 1.6: Eerste River invaded foothill plot 3 (wet)

FOOTHILL WET			* = alien plant species
ErNeFHw			
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
COMMELINACEAE	*Commelina benghalensis*	AMARANTHACEAE	* *Amaranthus deflexus*
EUPHORBIACEAE	*Euphorbia* seedlings	ASTERACEAE	* *Conyza albida*
FAGACEAE	* *Quercus* seedlings	ASTERACEAE	* *Hypochaeris radicata*
FAGACEAE	* *Quercus sp.*	ASTERACEAE	* *Sonchus asper*
LAURACEAE	* *Cinnamomum camphora*	ASTERACEAE	*Metalasia* sp
MYRTACEAE	* *Eucalyptus camaldulensis*	ASTERACEAE	*Pseudognaphalium luteo-album*
MYRTACEAE	*Metrosideros angustifolia*	ASTERACEAE	*Senecio polyanthemoides*
MYRTACEAE	* *Leptospermum laevigatum*	BRASSICACEAE	* *Nasturtium officinale*
POACEAE	*Cynodon dactylon*	CAMPANULACEAE	*Wahlenbergia* sp.
POACEAE	*Ehrharta erecta*	CAROPHYLLACEAE	* *Polycarpon tetraphyllum*
POACEAE	*Brabejum stellatifolium*	COMMELINACEAE	*Commelina benghalensis*
PROTEACEAE	*Solanum retroflexum.*	CRASSULACEAE	*Crassula natans var natans*
SOLANACEAE	*Commelina benghalensis*	CYPERACEAE	*Isolepis prolifera*
		CYPERACEAE	*Ficinia anceps*
		CYPERACEAE	*Schoenoplectus* sp.
		EUPHORBIACEAE	* *Euphorbia prostrata*
		FABACEAE	* *Melilotus indica*
		FABACEAE	* *Acacia mearnsii*
		FABACEAE	* *Acacia longifolia*
		OXALIDACEAE	*Oxalis corniculata*
		PHYTOLACCACEAE	*Phytolacca octandra*
		POACEAE	*Ehrharta longiflora*
		POACEAE	*Briza maxima/ B. minor*
		POACEAE	*Pentaschistus pallida*
		POLYGONACEAE	* *Persicaria lapathifolia*
		ROSACEAE	*Rubus* sp.
		SCROPHULARIACEAE	*Diasica* sp
		THYMELAECEAE	*Struthiola tomentosa*
		VERBENACEAE	* *Verbena bonariensis*

Table G 1.7: Eerste River invaded foothill plot 3 (dry)

FOOTHILL DRY			* = alien plant species
ErNeFHd			
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
COMMELINACEAE	*Commelina benghalensis*	ASTERACEAE	* *Hypochaeris radicata*
FABACEAE	* *Acacia mearnsii*	ASTERACEAE	*Senecio polyanthemoides*
FABACEAE	* *Acacia longifolia*	ASTERACEAE	* *Conyza albida*
FAGACEAE	* *Quercus sp.*	ASTERACEAE	*Pseudognaphalium luteo-album*
PLANTAGINACEAE	*Plantago lanceolata*	ASTERACEAE	*Metalasia* sp
POACEAE	* *Briza maxima*	ASTERACEAE	*Senecio* sp
POACEAE	*Ehrharta longiflora*	BRASSICACEAE	* *Nasturtium officinale*
PRIONIACEAE	*Prionium serratum*	CAMPANULACEAE	*Wahlenbergia obovata*
PROTEACEAE	*Brabejum stellatifolium*	CAROPHYLLACEAE	* *Polycarpon tetraphyllum*
		COMMELINACEAE	*Commelina benghalensis*
		CRASSULACEAE	*Crassula natans* var *natans*
		CYPERACEAE	*Isolepis prolifera*
		CYPERACEAE	*Ficinia anceps*
		CYPERACEAE	*Schoenoplectus* sp.
		ERICACEAE	*Erica* sp.
		EUPHORBIACEAE	* *Euphorbia prostrata*
		FABACEAE	* *Melilotus indica*
		FABACEAE	* *Acacia mearnsii*
		GERANIACEAE	*Pelargonium iocastum*
		MYRTACEAE	*Leptospermum laevigatum*
		OXALIDACEAE	*Oxalis corniculata*
		PHYTOLACCACEAE	* *Phytolacca octandra*
		PLANTAGINACEAE	*Plantago lanceolata*
		POACEAE	*Cynodon dactylon*
		POACEAE	* *Briza maxima/ minor*
		POACEAE	*Pentaschistis curvifolia*
		POACEAE	*Pentaschistis sp.*
		POACEAE	*Ehrharta longiflora*
		POLYGONACEAE	* *Persicaria lapathifolia*
		RESTIONACEAE	*Ischyrolepis subverticillata*
		SCROPHULARIACEAE	Scroph sp 1.
		SOLANACEAE	*Solanum retroflexum*
		VERBENACEAE	* *Verbena bonariensis*

Table G 1.8: Berg River invaded mountain stream plot 1 (dry)

BERG RIVER INVADED * = alien plant species
MOUNTAIN STREAM DRY

BgDWMSd

ABOVE-GROUND VEGETATION		SEED BANK COMMUNITY	
Family	**Species**	**Family**	**Species**
FABACEAE	* *Acacia longifolia*	ASTERACEAE	* *Conyza albida*
FABACEAE	* *Acacia mearnsii*	ASTERACEAE	*Pseudognaphalium luteo-album*
DENNSTAEDTIACEAE	*Pteridium aquilinum*	ASTERACEAE	*Metalasia* sp
SCROPHULARIACEAE	*Halleria elliptica*	ASTERACEAE	*Senecio polyanthemoides*
		ASTERACEAE	* *Sonchus asper*
		ASTERACEAE	*Ursinia palaceae*
		BRASSICACEAE	* *Nasturtium officinale*
		CYPERACEAE	*Ficinia anceps*
		CYPERACEAE	*Isolepis prolifera*
		EUPHORBIACEAE	* *Euphorbia prostrata*
		EUPHORBIACEAE	* *Euphorbia prostrata*
		FABACEAE	* *Acacia longifolia*
		FABACEAE	* *Melilotus indica*
		FABACEAE	* *Acacia mearnsii*
		JUNCACEAE	*Juncus capensis*
		OXALIDACEAE	*Oxalis corniculata*
		PHYTOLACCACEAE	* *Phytolacca octandra*
		POACEAE	*Pentaschistus pallida*
		POACEAE	*Ehrharta longiflora*
		POACEAE	* *Briza maxima/ B. minor*
		POLYGONACEAE	* *Persicaria lapathifolia*
		VERBENACEAE	* *Verbena bonariensis*

Table G 1.9: Berg River invaded mountain stream plot 1 (wet)

MOUNTAIN STREAM WET * = alien plant species

BgDWMSw

ABOVE-GROUND VEGETATION		SEED BANK COMMUNITY	
Family	**Species**	**Family**	**Species**
BLECHNACEAE	*Blechnum capense*	ASPARAGACEAE	*Asparagus* sp.
FABACEAE	* *Acacia longifolia*	ASTERACEAE	* *Conyza albida*
PROTEACEAE	*Brabejum stellatifolium* resprouting	ASTERACEAE	* *Hypochaeris radicata*
		ASTERACEAE	*Senecio* sp
		BRASSICACEAE	* *Nasturtium officinale*
		CAROPHYLLACEAE	* *Polycarpon tetraphyllum*
		CRASSULACEAE	*Crassula thunbergiana* subsp *thunbergiana*
		CYPERACEAE	*Ficinia anceps*
		CYPERACEAE	*Isolepis prolifera*
		CYPERACEAE	*Schoenoplectus sp.*
		EUPHORBIACEAE	* *Euphorbia prostrata*
		FABACEAE	* *Acacia longifolia*
		GERANIACEAE	*Pelargonium elongatum*
		JUNCACEAE	*Juncus capensis*
		OXALIDACEAE	*Oxalis corniculata*
		POACEAE	*Pentaschistis sp.*
		POACEAE	*Pentaschistus pallida*
		POACEAE	*Cynodon dactylon*
		POACEAE	*Digitaria debilis*
		POACEAE	* *Briza maxima/ B. minor*
		POLYGONACEAE	* *Persicaria lapathifolia*
		POLYGONACEAE	* *Persicaria lapathifolia*
		ROSACEAE	*Rubus* sp.
		SOLANACEAE	*Solanum retroflexum*
		VERBENACEAE	* *Verbena bonariensis*

Table G 1.10: Berg River invaded mountain stream plot 2

MOUNTAIN STREAM TRANS — * = alien plant species

BgAsbMSt- burnt

ABOVE-GROUND VEGETATION		SEED BANK COMMUNITY	
Family	**Species**	**Family**	**Species**
ANACARDIACEAE	Rhus crenata	ANACARDIACEAE	Rhus crenata.
FABACEAE	* Acacia longifolia	ASTERACEAE	* Conyza albida
FABACEAE	* A.longifolia resprouting	ASTERACEAE	* Sonchus asper
PINACEAE	* Pinus pinnaster (burnt)	ASTERACEAE	Metalasia sp.
RESTIONACEAE	Elegia capensis	BRASSICACEAE	* Nasturtium officinale
		CAMPANULACEAE	Wahlenbergia obovata
		CAROPHYLLACEAE	* Polycarpon tetraphyllum
		CYPERACEAE	Ficinia anceps
		CYPERACEAE	Isolepis prolifera
		CYPERACEAE	Scirpus sp.
		CYPERACEAE	Schoenoplectus sp.
		CYPERACEAE	Ficinia anceps
		ERICACEAE	Erica sp
		EUPHORBIACEAE	* Euphorbia prostrata
		FABACEAE	* Acacia longifolia
		FABACEAE	* Acacia mearnsii
		GERANIACEAE	Pelargonium elongatum
		JUNCACEAE	Juncus capensis
		OXALIDACEAE	Oxalis corniculata
		OXALIDACEAE	Oxalis pes-carpae sub pes-carpae
		PHYTOLACCACEAE	* Phytolacca octandra
		POACEAE	Ehrharta longifolia
		POACEAE	Pentaschistus pallida
		RESTIONACEAE	Ischyrolepis subverticillata
		ROSACEAE	Rubus sp.
		VERBENACEAE	* Verbena bonariensis

Table G 1.11: Berg River invaded mountain stream plot 3

MOUNTAIN STREAM TRANS — * = alien plant species

BgAsb2MSt

ABOVE-GROUND VEGETATION		SEED BANK COMMUNITY	
Family	**Species**	**Family**	**Species**
AMARANTHACEAE	* Amaranthus deflexus	AMARANTHACEAE	* Amaranthus deflexus
ASTERACEAE	Seriphium plumosa	ASTERACEAE	* Conyza albida
DENNSTAEDTIACEAE	Pteridium aquilinum	ASTERACEAE	Pseudognaphalium luteo-album
FABACEAE	* Acacia longifolia	ASTERACEAE	Helichrysum helianthemifolium
FABACEAE	* Acacia mearnsii	ASTERACEAE	Seriphium plumosa
POACEAE	Ehrharta longiflora	ASTERACEAE	* Lactuca serriola
		BRASSICACEAE	* Nasturtium officinale
		CAMPANULACEAE	Prismatocarpus fruiticosus
		CAROPHYLLACEAE	* Spergula arvensis
		CRASSULACEAE	Crassula natans var natans
		CYPERACEAE	Scirpus sp.
		EUPHORBIACEAE	* Euphorbia prostrata
		OXALIDACEAE	Oxalis corniculata
		POACEAE	Pentaschistis curvifolia
		POACEAE	Pentaschistus pallida
		POACEAE	Ehrharta longiflora
		SCROPHULARIACEAE	Wahlenbergia obovata
		SCROPHULARIACEAE	Scroph sp.
		SCROPHULARIACEAE	Wahlenbergia cernua
		SOLANACEAE	Solanum retroflexum

Table G 1.12: Berg River invaded foothill plot 1

FOOTHILL TRANS		* = alien plant species	
BgRfFH1t			
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
COMMELINACEAE	*Commelina benghalensis*	ASTERACEAE	*Pseudognaphalium luteo-album*
CYPERACEAE	Cyperaceae sp	ASTERACEAE	* *Conyza albida*
FABACEAE	* *Acacia mearnsii*	BRASSICACEAE	* *Nasturtium officinale*
FABACEAE	* *Acacia longifolia (dead)*	CAMPANULACEAE	*Wahlenbergia obovata*
MYRTACEAE	* *Eucalyptus camaldulensis*	COMMELINACEAE	* *Commelina benghalensis*
POACEAE	*Cynodon dactylon*	CRASSULACEAE	*Crassula thunbergiana* subsp *thunbergiana*
		CRASSULACEAE	*Crassula* sp.
		CYPERACEAE	*Isolepis prolifera*
		CYPERACEAE	*Ficinia anceps*
		ERICACEAE	*Erica* sp 1
		EUPHORBIACEAE	* *Euphorbia prostrata*
		FABACEAE	* *Acacia longifolia*
		FABACEAE	* *Acacia mearnsii*
		FABACEAE	* *Melilotus indica*
		JUNCACEAE	*Juncus capensis*
		OXALIDACEAE	*Oxalis corniculata*
		POACEAE	*Pentaschistis sp.*
		POACEAE	*Pentaschistus pallida*
		POACEAE	*Ehrharta longiflora*
		POACEAE	*Cynodon dactylon*
		POACEAE	* *Briza maxima/ B. minor*
		POLYGONACEAE	* *Persicaria lapathifolia*
		SOLANACEAE	*Solanum retroflexum*
		VERBENACEAE	* *Verbena bonariensis*

Table G 1.13: Berg River invaded foothill plot 2 (wet)

FOOTHILL WET — * = alien plant species

BgRfFH2w

ABOVE-GROUND VEGETATION

Family	Species
ASTERACEAE	* *Xanthium strumarium*
COMMELINACEAE	*Commelina benghalensis*
CYPERACEAE	*Cyperus* sp.
EBENACEAE	*Diospryos glabra*
FABACEAE	* *Sesbania punicea*
POACEAE	*Pennisetum macroaurum*

SEED BANK COMMUNITY

Family	Species
ASTERACEAE	*Pseudognaphalium luteo-album*
ASTERACEAE	*Ursinia palaceae*
ASTERACEAE	* *Lactuca serriola*
ASTERACEAE	* *Conyza albida*
BRASSICACEAE	* *Nasturtium officinale*
CAMPANULACEAE	*Wahlenbergia obovata*
CAMPANULACEAE	*Prismatocarpus fruiticosus*
CAROPHYLLACEAE	* *Spergula arvensis*
CAROPHYLLACEAE	* *Polycarpon tetraphyllum*
CYPERACEAE	*Isolepis prolifera*
CYPERACEAE	*Ficinia anceps*
CYPERACEAE	*Scirpus* sp.
ERICACEAE	*Erica* sp
EUPHORBIACEAE	* *Euphorbia prostrata*
FABACEAE	* *Acacia longifolia*
FABACEAE	**Melilotus indica*
JUNCACEAE	*Juncus capensis*
OXALIDACEAE	*Oxalis corniculata*
PHYTOLACCACEAE	* *Phytolacca octandra*
POACEAE	*Pentaschistus pallida*
POACEAE	*Digitaria debilis*
POACEAE	* *Briza maxima/ B. minor*
POACEAE	*Ehrharta longiflora*
ROSACEAE	*Rubus* sp.
SCROPHULARIACEAE	*Nemesia versicolor*
SOLANACEAE	*Solanum retroflexum*
THYMELACEAE	*Struthiola striata*
THYMELACEAE	*Struthiola myrsinites*
VERBENACEAE	* *Verbena bonariensis*

Table G 1.14: Berg River invaded foothill plot 2 (dry)

FOOTHILL DRY — * = alien plant species

BgRfFH2d

ABOVE-GROUND VEGETATION		SEED BANK COMMUNITY	
Family	**Species**	**Family**	**Species**
POACEAE	*Merxmuellera cincta*	AMARANTHACEAE	* *Amaranthus deflexus*
ASTERACEAE	* *Xanthium strumarium*	ASTERACEAE	* *Conyza albida*
POACEAE	*Digitaria* sp.	ASTERACEAE	*Pseudognaphalium luteo-album*
POACEAE	*Pennisetum macroaurum*	ASTERACEAE	*Senecio polyanthemoides*
		CAROPHYLLACEAE	* *Spergula arvensis*
		COMMELINACEAE	* *Commelina benghalensis*
		CRASSULACEAE	*Crassula thunbergiana* subsp *thunbergiana*
		CYPERACEAE	*Ficinia anceps*
		CYPERACEAE	*Isolepis prolifera*
		CYPERACEAE	*Scirpus* sp.
		CYPERACEAE	*Schoenoplectus* sp.
		EUPHORBIACEAE	* *Euphorbia prostrata*
		FABACEAE	* *Acacia mearnsii*
		FABACEAE	* *Acacia longifolia*
		JUNCACEAE	*Juncus capensis*
		OXALIDACEAE	*Oxalis pes-carpae*
		OXALIDACEAE	*Oxalis corniculata*
		PHYTOLACCACEAE	* *Phytolacca octandra*
		POACEAE	*Pentaschistis sp.*
		POACEAE	*Digitaria* sp.
		POACEAE	*Pennisetum macroaurum*
		POLYGONACEAE	* *Persicaria lapathifolia*
		RESTIONACEAE	*Ischyrolepis subverticillata*
		SOLANACEAE	*Solanum retroflexum*
		VERBENACEAE	* *Verbena bonariensis*

Table G 1.15: Berg River invaded foothill plot

FOOTHILL TRANS — * = alien plant species

BgAsbFHt

ABOVE-GROUND VEGETATION		SEED BANK COMMUNITY	
Family	**Species**	**Family**	**Species**
AMARANTHACEAE	* *Amaranthus deflexus*	ASTERACEAE	* *Lactuca serriola*
FABACEAE	* *Acacia mearnsii*	ASTERACEAE	* *Conyza albida*
FABACEAE	* *A.mearnsii & A. longifolia* seedlings	ASTERACEAE	*Senecio* sp.
MYRTACEAE	* *Eucalyptus camaldulensis*	ASTERACEAE	*Metalasia* sp.
POACEAE	*Pennisetum macroaurum*	ASTERACEAE	*Pseudognaphalium luteo-album*
RESTIONACEAE	*Restionaceae (burnt)*	ASTERACEAE	*Chrysanthemoides monilifera*
		ASTERACEAE	*Senecio polyanthemoides*
		BRASSICACEAE	* *Nasturtium officinale*
		CAMPANULACEAE	*Wahlenbergia obovata*
		CAROPHYLLACEAE	* *Spergula arvensis*
		CYPERACEAE	*Ficinia anceps*
		CYPERACEAE	*Isolepis prolifera*
		EUPHORBIACEAE	* *Euphorbia prostrata*
		FABACEAE	* *Acacia longifolia*
		JUNCACEAE	*Juncus capensis*
		OXALIDACEAE	*Oxalis corniculata*
		PHYTOLACCACEAE	*Phytolacca octandra*
		POACEAE	*Pentaschistus pallida*
		POACEAE	*Ehrharta longiflora*
		POACEAE	*Pentaschistis curvifolia*
		POACEAE	*Agrostis lachnantha*
		RESTIONACEAE	*Ischyrolepis subverticillata*
		RESTIONACEAE	*Restio* sp.
		SCROPHULARIACEAE	Scroph sp. 1
		VERBENACEAE	* *Verbena bonariensis*

Table G 1.16: Molenaars River invaded mountain stream plot 1 (wet)

MOLENAARS RIVER INVADED — * = alien plant species

MOUNTAIN STREAM WET

MolDpMSw

ABOVE-GROUND VEGETATION

Family	**Species**
AQUIFOLIACEAE	*Ilex mitis*
ASTERACEAE	*Brachylaena neriifolia*
CUNONIACEAE	*Platylophus trifoliatus*
FABACEAE	* *Acacia mearnsii* (dead)
MYRTACEAE	*Metrosideros angustifolia*

SEED BANK COMMUNITY

Family	**Species**
ASTERACEAE	*Metalasia sp*
ASTERACEAE	* *Conyza albida*
ASTERACEAE	*Senecio polyanthemoides*
ASTERACEAE	*Pseudognaphalium luteo-album*
BRASSICACEAE	* *Nasturtium officinale*
CAMPANULACEAE	*Wahlenbergia obovata*
CAROPHYLLACEAE	* *Spergula arvensis*
CYPERACEAE	*Ficinia anceps*
CYPERACEAE	*Isolepis prolifera*
ERICACEAE	*Erica* sp
ERICACEAE	*Erica* sp 2
EUPHORBIACEAE	* *Euphorbia prostrata*
FABACEAE	* *Acacia mearnsii.*
FABACEAE	*Podalyria calyptrata*
GERANIACEAE	*Pelargonium versicolor*
JUNCACEAE	*Juncus capensis*
MOLLUGINACEAE	*Adenogramma lichtensteiniana*
OXALIDACEAE	*Oxalis corniculata*
POACEAE	*Pentaschistus pallida*
POACEAE	*Panicum maximum*
POLYGONACEAE	* *Perscaria lapatholifolia*
RESTIONACEAE	*Ischyrolepis subverticillata*
VERBENACEAE	* *Verbena bonariensis*

Table G 1.17: Molenaars River invaded mountain stream plot 1 (dry)

MOUNTAIN STREAM DRY — * = alien plant species

MolDpMSd

ABOVE-GROUND VEGETATION

Family	**Species**
FABACEAE	* *Acacia mearnsii*
PROTEACEAE	*Brabejum stellatifolium*

SEED BANK COMMUNITY

Family	**Species**
ASTERACEAE	*Metalasia* sp
ASTERACEAE	*Pseudognaphalium luteo-album*
ASTERACEAE	*Helichrysum helianthemifolium*
ASTERACEAE	* *Conyza albida*
ASTERACEAE	*Euryops abrotanifolius*
BRASSICACEAE	* *Nasturtium officinale*
CAMPANULACEAE	*Wahlenbergia obovata*
CYPERACEAE	*Ficinia anceps*
CYPERACEAE	*Isolepis prolifera*
CYPERACEAE	*Schoenoplectus sp.*
CYPERACEAE	*Scirpus* sp.
ERICACEAE	*Erica* sp
EUPHORBIACEAE	* *Euphorbia prostrata*
FABACEAE	* *Acacia mearnsii.*
FABACEAE	* *Paraserianthes lophantha*
JUNCACEAE	*Juncus capensis*
JUNCACEAE	*Juncus* sp.
OXALIDACEAE	*Oxalis corniculata*
POACEAE	*Pentaschistus pallida*
POACEAE	*Ehrharta longiflora*
POLYGONACEAE	* *Persicaria lapathifolia*
RESTIONACEAE	*Ischyrolepis subverticillata*
SCROPHULARIACEAE	*Oftia africana*
SCROPHULARIACEAE	Scroph sp. 1
SCROPHULARIACEAE	*Nemesia versicolor*
THYMELAECEAE	*Stuthiola striata*
VERBENACEAE	* *Verbena bonariensis*

<u>Table G 1.18:</u> Molenaars River invaded mountain stream plot 2

MOUNTAIN STREAM TRANS		* = alien plant species	
MolVk2MSt			
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
ACHARIACEAE	*Kiggelaria africana*	ANACARDIACEAE	*Rhus crenata*
ANACARDIACEAE	*Rhus crenata*	ASTERACEAE	*Metalasia* sp
ASPARAGACEAE	*Asparagus sp.*	ASTERACEAE	*Pseudognaphalium luteo-album*
ASTERACEAE	*Brachylaena neriifolia*	ASTERACEAE	** Conyza albida*
ERICACEAE	*Erica caffra*	BRASSICACEAE	** Nasturtium officinale*
FABACEAE	** Acacia mearnsii*	CAMPANULACEAE	*Prismatocarpus fruiticosus*
FABACEAE	** Sesbania punicea*	CRASSULACEAE	*Crassula* sp.
MYRTACEAE	*Metrosideros angustifolia*	CYPERACEAE	*Ficinia anceps*
POACEAE	*Ehrharta longiflora*	CYPERACEAE	*Schoenoplectus sp.*
PROTEACEAE	*Brabejum stellatifolium*	CYPERACEAE	*Scirpus* sp.
RHAMNACEAE	*Phylica buxifolia*	EUPHORBIACEAE	** Euphorbia prostrata*
ROSACEAE	*Cliffortia ruscifolia*	FABACEAE	** Acacia mearnsii*
SCROPHULARIACEAE	*Halleria elliptica*	JUNCACEAE	*Juncus capensis*
		OXALIDACEAE	*Oxalis corniculata*
		POACEAE	*Pentaschistis sp.*
		POACEAE	** Briza maxima/ B. minor*
		POACEAE	*Pentaschistis curvifolia*
		POACEAE	*Pentaschistus pallida*
		RESTIONACEAE	*Ischyrolepis subverticillata*
		SCROPHULARIACEAE	*Oftia africana*

<u>Table G 1.19:</u> Molenaars River invaded foothill plot 2 (wet)

FOOTHILL WET		* = alien plant species	
MolDTFHw			
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
ASTERACEAE	*Brachylanea neriifolia*	ASTERACEAE	** Conyza albida*
FABACEAE	** Acacia mearnsii*	ASTERACEAE	*Pseudognaphalium luteo-album*
MYRICACEAE	*Morella serrata*	ASTERACEAE	*Metalasia* sp
MYRTACEAE	*Metrosideros angustifolia*	ASTERACEAE	*Senecio* sp
PRIONIACEAE	*Prionium serratum*	ASTERACEAE	*Seriphium plumosa*
RESTIONACEAE	*Ischyrolepis sp.*	ASTERACEAE	*Othonna quinquedentata*
RHAMNACEAE	*Phylica buxifolia*	ASTERACEAE	*Senecio polyathemoides*
		ASTERACEAE	** Sonchus asper*
		BRASSICACEAE	** Nasturtium officinale*
		CRASSULACEAE	*Crassula* sp.
		CYPERACEAE	*Isolepis prolifera*
		CYPERACEAE	*Ficinia anceps*
		ERICACEAE	*Erica* sp
		EUPHORBIACEAE	** Euphorbia prostrata*
		FABACEAE	** Acacia mearnsii*
		FABACEAE	** Paraserianthes lophantha*
		JUNCACEAE	*Juncus capensis*
		OXALIDACEAE	*Oxalis corniculata*
		PHYTOLACCACEAE	** Phytolacca octandra*
		POACEAE	** Briza maxima/ B. minor*
		POACEAE	*Panicum maximum*
		POACEAE	*Agrostis lachnantha*
		POACEAE	*Ehrharta longiflora*
		POACEAE	*Cynodon dactylon*
		POACEAE	*Pentaschistus pallida*
		SCROPHULARIACEAE	Scroph sp. 1
		SCROPHULARIACEAE	*Wahlenbergia cernua*
		SCROPHULARIACEAE	*Wahlenbergia obovata*
		SCROPHULARIACEAE	*Nemesia versicolor*
		SOLANACEAE	*Solanum retroflexum*
		VERBENACEAE	** Verbena bonariensis*

Table G 1.20: Molenaars River invaded foothill plot 2 (dry)

FOOTHILL DRY			* = alien plant species
MolDTFHd			
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
FABACEAE	* *Acacia mearnsii*	ASTERACEAE	* *Conyza albida*
ASTERACEAE	*Brachylaena neriifolia*	ASTERACEAE	*Pseudognaphalium luteo-album*
PROTEACEAE	*Brabejum stellatifolium*	ASTERACEAE	*Ursinia palaceae*
MYRTACEAE	*Metrosideros angustifolia*	ASTERACEAE	*Senecio* sp
MYRICACEAE	*Morella integra*	ASTERACEAE	*Chyrsanthemoides monilifera*
		BRASSICACEAE	* *Nasturtium officinale*
		CAMPANULACEAE	*Wahlenbergia obovata*
		CAMPANULACEAE	*Prismatocarpus fruiticosus*
		CRASSULACEAE	*Crassula* sp
		CYPERACEAE	*Ficinia anceps*
		CYPERACEAE	*Isolepis prolifera*
		CYPERACEAE	*Schoenoplectus sp.*
		ERICACEAE	*Erica* sp
		EUPHORBIACEAE	* *Euphorbia prostrata*
		FABACEAE	* *Acacia mearnsii*
		JUNCACEAE	*Juncus capensis*
		OXALIDACEAE	*Oxalis corniculata*
		PHYTOLACCACEAE	* *Phytolacca octandra*
		POACEAE	*Pentaschistus pallida*
		POACEAE	*Cynodon dactylon*
		POACEAE	*Pentaschistis curvifolia*
		POACEAE	* *Briza maxima/ B. minor*
		POLYGONACEAE	* *Persicaria lapathifolia*
		RESTIONACEAE	*Ischyrolepis subverticillata*
		SCROPHULARIACEAE	*Nemesia versicolor*

Table G 1.21: Molenaars River invaded foothill plot 3

FOOTHILL TRANS		* = alien plant species	
MolCTFHt			
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
FABACEAE	* *Acacia mearnsii*	ASTERACEAE	*Metalasia* sp
MYRTACEAE	*Metrosideros angustifolia*	ASTERACEAE	*Pseudognaphalium luteo-album*
PROTEACEAE	*Brabejum stellatifolium*	ASTERACEAE	* *Conyza albida*
		ASTERACEAE	*Senecio polyanthemoides*
		ASTERACEAE	*Othonna quinquedentata*
		BRASSICACEAE	* *Nasturtium officinale*
		CAMPANULACEAE	*Wahlenbergia obovata*
		CAMPANULACEAE	*Wahlenbergia capensis*
		CRASSULACEAE	*Crassula sp.*
		CYPERACEAE	*Isolepis prolifera*
		CYPERACEAE	*Ficinia anceps*
		CYPERACEAE	*Scirpus* sp.
		ERICACEAE	*Erica* sp mix
		ERICACEAE	*Erica* sp
		ERICACEAE	*Erica* sp2
		ERICACEAE	*Erica* sp3
		ERICACEAE	*Erica* sp 1
		ERICACEAE	*Erica* sp 2
		EUPHORBIACEAE	* *Euphorbia prostrata*
		FABACEAE	* *Acacia mearnsii.*
		FABACEAE	*Podalyria calyptrata*
		JUNCACEAE	*Juncus capensis*
		OXALIDACEAE	*Oxalis corniculata*
		POACEAE	*Pentaschistus pallida*
		POACEAE	* *Briza maxima/ B. minor*
		POACEAE	*Ehrharta longiflora*
		RESTIONACEAE	*Ischyrolepis subverticillata*
		SCROPHULARIACEAE	Scroph sp. 1
		SCROPHULARIACEAE	*Nemesia versicolor*
		SOLANACEAE	*Solanum retroflexum*
		VERBENACEAE	* *Verbena bonariensis*

Table G 1.22: Wit River invaded mountain stream plot 1

WIT RIVER INVADED			* = alien plant species
MOUNTAIN STREAM TRANS			
WitMS1t			
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
ASTERACEAE	*Seriphium plumosa* dead	APIACEAE	*Centella* sp.
FABACEAE	** Acacia mearnsii*	ASTERACEAE	*Senecio polyanthemoides*
FABACEAE	** Acacia mearnsii seedlings*	ASTERACEAE	*Arcotheca calendula*
MYRICACEAE	*Morella seedling*	ASTERACEAE	*Senecio* sp
OLEACEAE	*Olea capensis*	ASTERACEAE	*Helichrysum helianthemifolium*
RESTIONACEAE	*Ischyrolepis subverticillata*	ASTERACEAE	*Metalasia* sp
		ASTERACEAE	*Euryops* sp.
		ASTERACEAE	*Pseudognaphalium luteo-album*
		ASTERACEAE	*Polyarrhena reflexa*
		BRASSICACEAE	** Nasturtium officinale*
		CAMPANULACEAE	*Prismatocarpus fruticosus*
		CAMPANULACEAE	*Wahlenbergia parvifolia*
		CAMPANULACEAE	*Wahlenbergia obovata*
		CAMPANULACEAE	*Diascia elongata*
		CAMPANULACEAE	*Wahlenbergia cernua*
		CYPERACEAE	*Ficinia anceps*
		CYPERACEAE	*Scirpus* sp.
		DROSERACEAE	*Drosera hiliaris*
		ERICACEAE	*Erica* sp
		ERICACEAE	*Erica* sp. 2
		FABACEAE	** Acacia mearnsii*
		GENTIANACEAE	** Geranium molle*
		JUNCACEAE	*Juncus capensis*
		OXALIDACEAE	*Oxalis corniculata*
		PHYTOLACCACEAE	** Phytolacca octandra*
		POACEAE	*Ehrharta longiflora*
		POACEAE	** Briza maxima/minor*
		ROSACEAE	*Cliffortia* sp
		SCROPHULARIACEAE	*Diascia* sp
		SCROPHULARIACEAE	*Scroph* sp
		VERBENACEAE	** Verbena bonariensis*

Table G 1.23: Wit River invaded mountain stream plot 2

MOUNTAIN STREAM TRANS			* = alien plant species
WitBkMS1t			
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
FABACEAE	* *Acacia mearnsii*	APIACEAE	* *Apium inundatum*
FABACEAE	* *Acacia mearnsii seedlings*	ASTERACEAE	* *Conyza albida*
SALICACEAE	* *Populus alba*	ASTERACEAE	*Helichrysum helianthemifolium*
SALICACEAE	* *Populus seedling*	ASTERACEAE	*Pseudognaphalium luteo-album*
SOLANACEAE	* *Solanum mauritianum*	ASTERACEAE	* *Sonchus asper*
		ASTERACEAE	*Metalasia* sp
		ASTERACEAE	*Senecio polyanthemoides*
		ASTERACEAE	* *Hypochaeris radicata*
		ASTERACEAE	*Seriphuim plumosa*
		ASTERACEAE	* *Sonchus asper*
		ASTERACEAE	* *Lactuca serriola*
		ASTERACEAE	*Arcotheca calendula*
		ASTERACEAE	*Senecio* sp
		BRASSICACEAE	* *Nasturtium officinale*
		CAMPANULACEAE	*Wahlenbergia cernua*
		CAMPANULACEAE	*Wahlenbergia obovata*
		CAMPANULACEAE	*Prismatocarpus fruticosus*
		CAMPANULACEAE	*Wahlenbergia* sp
		CAROPHYLLACEAE	* *Polycarpon tetraphyllum*
		CAROPHYLLACEAE	* *Spergula arvensis*
		CRASSULACEAE	*Crassula* sp.
		CRASSULACEAE	*Crassula nutans* var *nutans*
		CYPERACEAE	*Ficinia anceps*
		CYPERACEAE	*Schoenoplectus* sp
		CYPERACEAE	*Scirpus* sp.
		EUPHORBIACEAE	* *Euphorbia prostrata*
		FABACEAE	* *Melilotus indica*
		FABACEAE	* *Acacia mearnsii*
		FUMARIACEAE	* *Fumaria muralis*
		GERANIACEAE	*Pelargonium iocastum*
		GERANIACEAE	*Pelargonium elongatum*
		MALVACEAE	* *Hibiscus trionum*
		MESEMBRYANTHEMACEAE	*Dorotheanthus bellidformis*
		OXALIDACEAE	*Oxalis corniculata*
		POACEAE	*Ehrharta longifolia*
		POACEAE	*Cynodon dactylon*
		POACEAE	* *Briza maxima/ B. minor*
		PRIMULACEAE	* *Anagallis arvensis*
		ROSACEAE	*Rubus* sp.
		SCROPHULARIACEAE	Scroph sp 1
		SCROPHULARIACEAE	*Diascia elongata*
		SOLANACEAE	*Solanum retroflexum*
		THYMELAECEAE	*Struthiola tomentosa*
		VERBENACEAE	* *Verbena bonariensis*

Table G 1.24: Wit River invaded foothill plot 1

FOOTHILL TRANS — * = alien plant species

WitOkFHt

ABOVE-GROUND VEGETATION		SEED BANK COMMUNITY	
Family	**Species**	**Family**	**Species**
ASTERACEAE	*Senecio* seedling	APIACEAE	*Centella* sp.
FABACEAE	* *Acacia mearnsii*	ASTERACEAE	*Senecio polyanthemoides*
FABACEAE	* *Acacia mearnsii seedlings*	ASTERACEAE	*Senecio* sp
MYRICACEAE	*Morella serrata* seedlings	ASTERACEAE	*Helichrysum helianthemifolium*
POACEAE	*Poaceae* seedlings	ASTERACEAE	*Pseudognaphalium luteo-album*
PROTEACEAE	*Brabejum stellatifolium* (burnt)	ASTERACEAE	*Metalasia* sp
SCROPHULARIACEAE	*Halleria elliptica seedlings*	ASTERACEAE	* *Conyza albida*
		ASTERACEAE	*Euryops abrotanifolius*
		ASTERACEAE	*Polyarrhena reflexa*
		BRASSICACEAE	* *Nasturtium officinale*
		CAMPANULACEAE	*Wahlenbergia obovata*
		CAMPANULACEAE	*Prismatocarpus fruticosus*
		CRASSULACEAE	*Crassula thunbergiana* subsp *thunbergiana*
		CYPERACEAE	*Ficinia anceps*
		CYPERACEAE	*Isolepis prolifera*
		DROSERACEAE	*Drosera* sp
		ERICACEAE	*Erica caffra*
		ERICACEAE	*Erica* sp 2
		FABACEAE	* *Acacia mearnsii*
		FABACEAE	* *Paraserianthes lophantha*
		GENTIANACEAE	* *Geranium molle*
		GERANIACEAE	*Pelargonium papilionaceum*
		JUNCACEAE	*Juncus capensis*
		OXALIDACEAE	*Oxalis corniculata*
		PHYTOLACCACEAE	* *Phytolacca octandra*
		POACEAE	*Ehrharta longiflora*
		POACEAE	*Pentaschistus pallida*
		POACEAE	* *Briza maxima/ B. minor*
		ROSACEAE	*Cliffortia sp*
		SCROPHULARIACEAE	*Nemesia versicolor*
		SCROPHULARIACEAE	Scroph sp 1
		SCROPHULARIACEAE	*Diascia elongata*
		VERBENACEAE	* *Verbena bonariensis*

Table G 1.25: Wit River invaded foothill plot 2

FOOTHILL TRANS			* = alien plant species
WitBk2FHt			
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
FABACEAE	** Acacia mearnsii*	ASTERACEAE	** Conyza albida*
POACEAE	*Pennisetum macrourum*	ASTERACEAE	*Metalasia* sp
		ASTERACEAE	*Helichrysum helianthemifolium*
		ASTERACEAE	*Pseudognaphalium luteo-album*
		ASTERACEAE	*Arcotheca calendula*
		BRASSICACEAE	** Nasturtium officinale*
		CAMPANULACEAE	*Wahlenbergia obovata*
		CAMPANULACEAE	*Prismatocarpus fruiticosus*
		CAMPANULACEAE	*Wahlenbergia cernua*
		CAROPHYLLACEAE	** Polycarpon tetraphyllum*
		CAROPHYLLACEAE	** Spergula arvensis*
		CRASSULACEAE	*Crassula nutans subsp nutans*
		CYPERACEAE	*Isolepis prolifera*
		CYPERACEAE	*Schoenoplectus* sp
		CYPERACEAE	*Ficinia anceps*
		ERICACEAE	*Erica* sp. 1
		EUPHORBIACEAE	** Euphorbia prostrata*
		FABACEAE	** Melilotus indica*
		FABACEAE	** Acacia mearnsii*
		FUMARIACEAE	** Fumaria muralis*
		GERANIACEAE	*Pelargonium iocastum*
		GERANIACEAE	*Pelargonium versicolor*
		JUNCACEAE	*Juncus capensis*
		MESEMBRYANTHEMACEAE	*Dorotheanthus bellidformis*
		MESEMBRYANTHEMACEAE	*Carpobrotus edulis*
		OXALIDACEAE	*Oxalis corniculata*
		POACEAE	*Ehrharta longiflora*
		POACEAE	** Briza maxima/ B. minor*
		POACEAE	*Pentaschistus pallida*
		PRIMULACEAE	** Anagallis arvensis*
		ROSACEAE	*Rubus* sp.
		SCROPHULARIACEAE	*Oftia africana*
		SCROPHULARIACEAE	*Nemesia versicolor*
		SOLANACEAE	*Solanum retroflexum*
		THYMELACEAE	*Struthiola striata*
		VERBENACEAE	** Verbena bonariensis*

Table G 1.26: Wit River invaded foothill plot 3

FOOTHILL TRANS			* = alien plant species
WitBk1FHt			
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
FABACEAE	* *Acacia mearnsii*	ASTERACEAE	*Metalasia* sp
MYRTACEAE	*Metrosideros angustifolia*	ASTERACEAE	* *Conyza albida*
POACEAE	*Pennisetum macroaurum*	ASTERACEAE	*Senecio* sp.
PRIONIACEAE	*Prionium serratum*	ASTERACEAE	* *Sonchus asper*
PROTEACEAE	*Brabejum stellatifolium*	BRASSICACEAE	* *Nasturtium officinale*
RESTIONACEAE	*Calopsis paniculata*	CAMPANULACEAE	*Wahlenbergia obovata*
RHAMNACEAE	*Phylica buxifolia*	CYPERACEAE	*Isolepis prolifera*
		CYPERACEAE	*Ficinia anceps*
		CYPERACEAE	*Schoenoplectus* sp.
		ERICACEAE	*Erica* sp
		EUPHORBIACEAE	* *Euphorbia prostrata*
		FABACEAE	* *Melilotus indica*
		FABACEAE	* *Acacia mearnsii*
		JUNCACEAE	*Juncus capensis*
		MESEMBRYANTHEMACEAE	*Dorotheanthus bellidformis*
		OXALIDACEAE	*Oxalis corniculata*
		POACEAE	*Pentaschistus pallida*
		POACEAE	*Ehrharta longiflora*
		POACEAE	*Pennisetum macroaurum*
		RESTIONACEAE	*Ischyrolepis subverticillata*
		ROSACEAE	* *Rubus* sp.
		SOLANACEAE	*Solanum retroflexum*
		VERBENACEAE	* *Verbena bonariensis*

Table G 2.1: Berg River reference mountain stream plot 1

BERG RIVER REFERENCE * = alien plant species

MOUNTAIN STREAM TRANS

BgAssb MS (trans)

ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
ASTERACEAE	*Brachylanea nerifolia*	AIZOACEAE	*Erepsia anceps*
ASTERACEAE	*Helichrysum cymosum*	ASTERACEAE	*Metalasia* sp.
CYPERACEAE	*Cyperaceae* sp.2	ASTERACEAE	*Euryops abrotanifolius*
CYPERACEAE	*Cyperaceae* sp.	ASTERACEAE	*Senecio hastifolius/S.cordifolius*
DROSERACEAE	*Drosera* sp.	ASTERACEAE	*Helichrysum helianthemifolium*
EBENACEAE	*Diospryos glabra*	ASTERACEAE	*Pseudognaphalium luteo-album*
ERICACEAE	*Erica seedling*	CYPERACEA	*Pentaschistus pallida*
ERICACEAE	*Erica* sp.	CYPERACEA	*Juncus capensis*
FABACEAE	*Psoralea pinnata*	ERICACEAE	*Erica* sp.1
MYRTACEAE	*Metrosideros angustifolia*	FABACEAE	*Psoralea* sp.
MYRTACEAE	*Metrosideros angustifolia* seedling	GRUBBIACEAE	*Grubbia tomentosa/G.rosmariniformis*
PINACEAE	* *Pinus pinaster*	LINACEAE	*Cliffortia cuneata*
POACEAE	*Ehrharta* sp.	POACEAE	*Panicum maximum*
POACEAE	*Grass seedling*	POACEAE	*Pennisetum macrourum*
PROTEACEAE	*Brabejum stellatifolium* seedling	PRIMULACEAE	* *Anagallis arvensis*
RESTIONACEAE	*Calopsis paniculata*	RESTIONACEAE	*Ischyrolepis subverticillata*
ROSACEAE	*Cliffortia rhuscifolia*	SCROPHULARIACEAE	*Pseudoselago serrata (=Selago serrata)*
		SOLANACEAE	*Solanum retroflexum (=S.nigurm)*

Table G 2.2: Berg River reference mountain stream plot 2

MOUNTAIN STREAM TRANS **Bg DT MS (trans)**		* = alien plant species	
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
ASTERACEAE	*Brachylaena neriifolia*	AIZOACEAE	*Erepsia anceps*
ASTERACEAE	*Euryops abrotinifolis*	AIZOACEAE	*Carpobrotus* sp.
ASTERACEAE	*Ursinia palaceae*	APIACEAE	*Centella* sp.
ERICACEAE	*Erica caffra*	ASTERACEAE	*Metalasia* sp.
ERICACEAE	*Erica* sp.	ASTERACEAE	*Pseudognaphalium luteo-album*
FABACEAE	*Psoralea* sp.	ASTERACEAE	*Senecio hastifolius/S.cordifolius*
FABACEAE	*Aspalathus sp (grey)*	ASTERACEAE	** Cotula australis*
IRIDACEAE	*Aristea major*	ASTERACEAE	** Hypochaeris radicata*
POACEAE	*Digitaria* sp.	ASTERACEAE	*Helichrysum helianthemifolium*
POACEAE	*Pentameris thurii*	ASTERACEAE	*Euryops abrotanifolius*
POACEAE	*Ehrharta erecta*	ASTERACEAE	*Ursinia paleaceae*
RESTIONACEAE	*Cannomois virgata*	ASTERACEAE	*Senecio sp.*
RESTIONACEAE	*Restio tetragonus*	ASTERACEAE	*Disparago* sp.
RESTIONACEAE	*Ischyrolepis subverticellata*	CRASSULACEAE	*Crassula pellucida* subsp. *pellucida*
		CRASSULACEAE	*Crassula pellucida* subsp. *pellucida*
		CRASSULACEAE	*Crassula coccinea*
		CRASSULACEAE	*Crassula thunbergiana* subsp. *thunbergiana*
		CYPERACEA	*Juncus capensis*
		CYPERACEA	*Pentaschistus pallida*
		CYPERACEA	*Scirpus sp.*
		CYPERACEA	*Juncus sp*
		CYPERACEA	*Isolepis prolifera*
		CYPERACEA	*Ficinia anceps*
		ERICACEAE	*Erica* sp.
		FABACEAE	*Rhynchosia capensis*
		FABACEAE	*Psoralea* sp.
		GERANIACEAE	*Pelargonium cucculatum*
		GRUBBIACEAE	*Grubbia tormentosa/rosmariniformis*
		LINACEAE	*Cliffortia cuneata*
		PLANTAGINACEAE	*Plantago lanceolata*
		POACEAE	*Panicum maximum*
		POACEAE	*Pennisetum macrourum*
		POACEAE	*Digitaria debillis*
		RESTIONACEAE	*Ischyrolepis subverticillata*
		ROSACEAE	*Cliffortia* sp.
		RUTACEAE	*Agathosma crenulata*
		SCROPHULARIACEAE	*Zaluzianskya capensis*
		SCROPHULARIACEAE	*Wahlenbergia obovata/W.cernua*
		SCROPHULARIACEAE	*Pseudoselago serrata (=Selago serrata)*
		SELAGINACEAE	*Selago quadrangularis*
		SOLANACEAE	*Solanum retroflexum (=S.nigurm)*
		THYMELAECEAE	*Struthiola tomentosa*

Table G 2.3: Berg River reference mountain stream plot 3

MOUNTAIN STREAM TRANS   * = alien plant species

Bg2 MR MS (trans)

ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
ASTERACEAE	*Brachylaena neriifolia*	AIZOACEAE	*Erepsia anceps*
ASTERACEAE	*Helichrysum* sp.	AIZOACEAE	*Carpobrotus edulis*
ERICACEAE	*Erica caffra*	ASTERACEAE	*Metalasia sp.*
FABACEAE	*Polygala myrtifolia*	ASTERACEAE	*Senecio hastifolius/cordifolius*
FABACEAE	*Podalyria calyptrata*	ASTERACEAE	*Senecio* sp.
FABACEAE	*Psoralea pinnata*	ASTERACEAE	*Euryops abrotanifolius*
MYRSINACEAE	*Rapanea melanophloeos*	ASTERACEAE	*Seriphium plumosa*
POACEAE	*Pennisetum macroaurum*	ASTERACEAE	*Othonna quinquedentata*
RESTIONACEA	*Cannomois virgata*	ASTERACEAE	*Lactuca serriola* *
		ASTERACEAE	*Disparago* sp.
		ASTERACEAE	* *Cotula australis* *
		BRUNIACEAE	*Berzelia lanuginosa*
		CAMPANULACEAE	*Roella* sp.
		CAMPANULACEAE	*Prismatocarpus fruticosus*
		CARYOPHLLACEAE	* *Polycarpon tetraphyllum*
		CARYOPHLLACEAE	* *Spergula arvensis*
		CRASSULACEAE	*Crassula thunbergiana* subsp *thunbergiana*
		CRASSULACEAE	*Crassula pellucida* subsp *pellucida*
		CRASSULACEAE	*Crassula coccinea*
		CRASSULACEAE	*Crassula fascicularis*
		CRASSULACEAE	*Crassula tetragona*
		CRASSULACEAE	*Crassula pellucida* subsp *pellucida*
		CYPERACEA	*Juncus capensis*
		CYPERACEA	*Pentaschistus pallida*
		CYPERACEA	*Scirpus sp.*
		CYPERACEA	*Isolepis prolifera*
		ERICACEAE	*Erica* sp.
		FABACEAE	*Podalyria calyptrata*
		FABACEAE	*Argyrolobium lunare*
		FABACEAE	*Rhynochosia capensis*
		FABACEAE	*Psoralea* sp.
		GENTIANACEAE	*Chironia* sp.
		OXALIDACEAE	*Helichrysum helianthemifolium*
		OXALIDACEAE	*Oxalis corniculata*
		PLANTAGINACEAE	*Plantago lanceolata*
		POACEAE	*Panicum maximum*
		POACEAE	*Pseudognaphalium luteo-album*
		POACEAE	*Pennisetum macrourum*
		POACEAE	*Agrostis lachnantha*
		POACEAE	*Pentameris sp.*
		PRIMULACEAE	* *Anagallis arvensis*
		RESTIONEAE	*Ischyrolepis subverticellata*
		RUBIACEAE	*Anthospermum galiodes* subsp *galiodes.*
		SCROPHULARIACEAE	*Wahlenbergia obovata/cernua*
		SCROPHULARIACEAE	*Zaluzianskya capensis*
		SCROPHULARIACEAE	*Pseudoselago serrata (=Selago serrata)*
		SELAGINACEAE	*Selago quadrangularis*
		SOLANACEAE	*Solanum retroflexum (=nigrum)*
		THYMELAECEAE	*Struthiolia tomentosa*

Table G 2.4: Berg River reference foothill plot 1 (wet)

FOOTHILL WET **BgAssb FH (w)**		* = alien plant species	
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
AQUIFOLIACEAE	*Ilex mitis*	ASTERACEAE	*Metalasia* sp.
ASTERACEAE	* *Hypochaeris radicata*	ASTERACEAE	* *Hypochaeris radicata*
ASTERACEAE	*Brachylaena neriifolia*	ASTERACEAE	*Helichrysum helianthemifolium*
ASTERACEAE	*Seriphium plumosa*	ASTERACEAE	*Seriphuim plumosa*
ASTERACEAE	*Helichrysum cymosum*	ASTERACEAE	*Senecio* sp.
BLECHNACEAE	*Blechnum capense*	ASTERACEAE	*Pseudognaphalium luteo-album*
BLECHNACEAE	*Blechnum capense*	ASTERACEAE	* *Lactuca serriola* *
CELASTRACEAE	*Mayteneus accumulata*	ASTERACEAE	*Disparago* sp.
CUNONIACEAE	*Cunonia capensis*	ASTERACEAE	*Senecio hastifolius/cordifolius*
CYPERACEAE	Cyperacea sp1	ASTERACEAE	*Othonna quinquedentata*
CYPERACEAE	Cyperaceae sp.2	ASTERACEAE	*Oftia africana*
FABACEAE	* *Acacia longifolia*	CAMPANULACEAE	*Siphocodon* sp.
JUNCACEAE	*Juncus capensis*	CARYOPHLLACEAE	* *Spergula arvensis*
JUNCACEAE	*Juncus sp*	CUNONIACEAE	*Cunonia capensis*
JUNCACEAE	*Juncus crausii*	CYPERACEA	*Ficinia anceps*
JUNCACEAE	*Juncus* sp. 1	CYPERACEA	*Isolepis prolifera*
JUNCACEAE	*Juncus buformus*	CYPERACEA	*Pentaschistus pallida*
JUNCACEAE	*Juncus* sp. tall	CYPERACEA	*Scirpus sp.*
JUNCACEAE	*Juncus crausii*	ERICAEAE	*Erica* sp.
MYRTACEAE	*Metrosideros angustifolia*	FABACEAE	* *Acacia longifolia*
MYRTACEAE	*Metrosideros angustifolia*	FABACEAE	*Podalyria calyptrata*
MYRTACEAE	*Metrosideros angustifolia*	GERANIACEAE	*Pelargonium cucculatum*
MYRTACEAE	*Metrosideros angustifolia*	PERENNIAL	*Solanum retroflexum*
OSMUNDACEAE	*Todea babarta*	POACEAE	*Panicum maximum*
PINACEAE	* *Pinus pinnaster*	POACEAE	*Juncus capensis*
POACEAE	*Digitaria* sp.	POACEAE	*Digitaria debilis*
POACEAE	*Pentaschistus* sp.	POACEAE	*Pennisetum macrourum*
PROTEACEAE	*Brabejum stellatifolium*	POACEAE	*Agrostis lachnantha*
RESTIONACEAE	*Callopsis paniculata*	PRIMULACEAE	* *Anagallis arvensis**
RESTIONACEAE	*Isolepis prolifera*	RESTIONACEAE	*Ischyrolepis subverticillata*
RESTIONACEAE	*Calopsis paniculata*	RUBIACEAE	*Anthospermum galiodes subsp galiodes.*
SCROPHULARIACEAE	*Halleria elliptica*	RUTACEAE	*Empleurum unicapsulare*
		RUTACEAE	*Agathosma crenulata*
		SCROPHULARIACEAE	*Wahlenbergia cernua*
		SCROPHULARIACEAE	*Pseudoselago serrata (=Selago serrata)*
		SCROPHULARIACEAE	*Zaluzianskya capensis*
		VERBENACEAE	* *Verbena bonariensis*

Table G 2.5: Berg River reference foothill plot 1(dry)

FOOTHILL DRY **BgAssb FH (d)**		* = alien plant species	
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
AQUIFOLIACEAE	*Ilex mitis*	APIACEAE	*Centella* sp.
ASPARAGACEAE	*Asparagus* sp.	ASTERACEAE	** Hypochaeris radicata **
BLECHNACEAE	*Blechnum capense*	ASTERACEAE	*Metalasia* sp.
CELASTRACEAE	*Mayteneus sp.*	ASTERACEAE	*Seriphium plumosa*
CUNONIACEAE	*Cunonia capensis*	ASTERACEAE	*Pseudognaphalium luteo-album **
FABACEAE	** Acacia longifolia*	ASTERACEAE	*Senecio sp.*
FABACEAE	*Virgilia oroboides*	ASTERACEAE	*Euryops abrotanifolius*
JUNCACEAE	*Juncus capensis*	ASTERACEAE	*Chrysanthemoides monilifera*
LAURACEAE	*Cassytha ciliolata*	ASTERACEAE	*Helichrysum helianthemifolium*
MYRSINACEAE	*Rapanea melanophloeos*	ASTERACEAE	*Senecio hastifolius/cordifolius*
MYRTACEAE	*Metrosideros angustifolia*	ASTERACEAE	** Lactuca serriola **
POACEAE	*Erhahta erecta*	CARYOPHLLACEAE	*Spergula arvensis **
PROTEACEAE	*Brabejum stellatifolium*	CRASSULACEAE	*Crassula pellucida* subsp *pellucida*
RESTIONACEAE	*Calopsis paniculata*	CYPERACEA	*Pentaschistus pallida*
RESTIONACEAE	*Calopsis cucculatis*	CYPERACEA	*Ficinia anceps*
SCROPHULARIACEAE	*Halleria elliptica*	CYPERACEA	*Scirpus sp.*
THYMELACEAE	*Stuthiola* sp. */Gnidia* sp.	CYPERACEA	*Isolepis prolifera*
		CYPERACEA	*Juncus sp*
		ERICACEAE	*Erica* sp.
		FABACEAE	** Acacia longifolia*
		FABACEAE	*Argyrolobium lunare*
		FABACEAE	*Podalyria calyptrata*
		FABACEAE	*Psoralea* sp.
		GERANIACEAE	*Pelargonium cucculatum*
		OXALIDACEAE	*Oxalis corniculata*
		PERENNIAL	*Cliffortia cuneata*
		PHYTOLACCACEAE	*Phytolacca octandra **
		PLANTAGINACEAE	*Plantago lanceolata*
		POACEAE	*Panicum maximum*
		POACEAE	*Juncus capensis*
		POACEAE	*Digitaria debilis*
		POACEAE	** Aira cupaniana**
		POACEAE	*Argrostis lachnanthna*
		PRIMULACEAE	*Anagallis arvensis*
		RESTIONACEAE	*Ischyrolepis subverticillata*
		RUTACEAE	*Empleuerum unicapsulare*
		SCROPHULARIACEAE	*Wahlenbergia cernua*
		SCROPHULARIACEAE	*Pseudoselago serrata (=Selago serrata)*
		SELAGINACEAE	*Selago quadrangularis*
		SOLANACEAE	*Solanum retroflexum (=Solanum nigrum)*
		THYMELAEACEAE	*Struthiolia tomentosa*
		VERBENACEAE	** Verbena bonariensis*

Table G 2.6: Berg River reference foothill plot 2

FOOTHILL TRANS **Bg1 TW FH (trans)**		* = alien plant species	
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
ASTERACEAE	*Metelasia muricata*	ASTERACEAE	*Metalasia* sp.
ASTERACEAE	*Seriphium plumosa*	ASTERACEAE	*Euryops abrotanifolius*
ASTERACEAE	*Brachylaena neriifolia*	ASTERACEAE	*Senecio sp.*
ASTERACEAE	*Euryops abrotanifolius*	ASTERACEAE	*Helichrysum helianthemifolium*
BRUNIACEAE	*Berzelia lanuginosa*	ASTERACEAE	*Chrysanthemoides monilifera*
CYPERACEAE	*Ficinia anceps*	ASTERACEAE	*Senecio hastifolius/cordifolius*
ERICACEAE	*Erica caffra*	ASTERACEAE	*Pseudognaphalium luteo-album* *
JUNCACEAE	*Juncus capensis*	ASTERACEAE	*Seriphium plumosa*
MYRTACEAE	*Metrosideros angustifolia* seedling	ASTERACEAE	*Othonna quinquedentata*
POACEAE	*Pennisetum macroaurum*	BRUNIACEAE	*Berzelia lanuginosa*
PROTEACEAE	*Brabejum stellatifolium* seedling	CAMPANULACEAE	*Siphocodon debilis*
PROTEACEAE	*Brabejum stellatifolium*	CAMPANULACEAE	*Siphocodon debilis*
RESTIONACEAE	*Calopsis paniculata*	CRASSULACEAE	*Crassula fasicularis*
RESTIONACEAE	*Restio* sp.	CYPERACEA	*Juncus capensis*
RESTIONACEAE	*Cannomois virgata*	CYPERACEA	*Ficinia anceps*
RESTIONACEAE	*Ischryolepis subverticulata*	CYPERACEA	*Juncus* sp
		CYPERACEA	*Isolepis prolifera*
		DROSERACEAE	*Drosera hiliaris*
		ERICACEAE	*Erica* sp. 1
		GRUBBIACEAE	*Grubbia rosmariniformis*
		POACEAE	*Panicum maximum*
		POACEAE	*Digitaria debilis*
		POACEAE	*Pentaschistus pallida*
		POACEAE	*Pennisetum macrourum*
		POACEAE	*Pentameris* sp.
		POLYGONACEAE	* *Persicaria lapathifolia*
		PRIMULACEAE	* *Anagallis arvensis*
		RESTIONACEAE	*Ischryrolepis* sp.
		SCROPHULARIACEAE	*Wahlenbergia cernua*
		SELAGINACEAE	*Selago quadrangularis*
		SOLANACEAE	*Solanum retroflexum * (=Solanum nigrum)*
		THYMELAEACEAE	*Struthiolia tomentosa*
		VERBENACEAE	* *Verbena bonariensis*

Table G 2.7: Berg River reference foothill plot 3

FOOTHILL TRANS **Bg2 TW FH (trans)**		* = alien plant species	
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
ASTERACEAE	*Brachylaena neriifolia*	ASTERACEAE	*Metalasia* sp.
ASTERACEAE	Asteracea seedling	ASTERACEAE	*Euryops abrotanifolius*
CYPERACEAE	*Ficinia trichodes*	ASTERACEAE	*Pseudognaphalium luteo-album* *
FABACEAE	*Aspalathus excelsa*	ASTERACEAE	*Othonna quinquedentata*
FABACEAE	* *Acacia longifolia*	ASTERACEAE	*Seriphium plumosa*
FABACEAE	*Polygala myrtifolia*	ASTERACEAE	* *Hypochaeris radicata* *
MYRTACEAE	*Metrosideros angustifolia*	ASTERACEAE	*Senecio hastifolius/cordifolius*
POACEAE	*Pennisetum macroaurum*	ASTERACEAE	*Senecio sp.*
POACEAE	*Pentaschistus* sp.	ASTERACEAE	*Helichrysum helianthemifolium*
PROTEACEAE	*Brabejum stellatifolium* seedling	ASTERACEAE	* *Cotula australis* *
RESTIONACEAE	*Restio tetragonus*	ASTERACEAE	* *Lactuca serriola* *
RESTIONACEAE	*Restio tetragonus*	BRUNIACEAE	*Berzelia lanuginosa*
RESTIONACEAE	*Ischyrolepis subverticillata*	CRASSULACEAE	*Crassula pellucida* subsp *pellucida*
ROSACEAE	*Cliffortia stroberlifera*	CYPERACEA	*Juncus capensis*
THYMELACEAE	*Freylinia lanceolata*	CYPERACEA	*Ficinia anceps*
		CYPERACEA	*Juncus* sp
		CYPERACEA	*Isolepis prolifera*
		ERICACEAE	*Erica* sp. 1
		FABACEAE	*Psoralea* sp.
		LOBELIACEAE	*Monopsis lutea*
		POACEAE	*Panicum maximum*
		POACEAE	*Pentaschistus pallida*
		POACEAE	*Pennisetum macrourum*
		POACEAE	*Digitaria debilis*
		POACEAE	*Argrostis lachnanthna*
		POACEAE	*Pentameris* sp.
		RESTIONACEAE	*Ischyrolepis subverticillata*
		ROSACEAE	*Cliffortia cuneata*
		ROSACEAE	*Cliffortia ruscifolia*
		RUBIACEAE	*Anthospermum galiodes* subsp *galiodes.*
		SCROPHULARIACEAE	*Wahlenbergia cernua*
		SCROPHULARIACEAE	*Zaluzianskya capensis*
		THYMELAEACEAE	*Struthiolia tomentosa*

Table G 2.8: Eerste River reference mountain stream plot 1 (wet)

EERSTE RIVER REFERENCE

MOUNTAIN STREAM WET

* = alien plant species

ErWb MS (w)

ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
BLECHNACEAE	*Blechnum capense*	AIZOACEAE	*Erepsia anceps*
ERICACEAE	*Erica caffra* seedlings	ASTERACEAE	*Metalasia* sp.
FABACEAE	*Psoralea* seedlings	ASTERACEAE	*Euryops abrotanifolius*
MYRICACEAE	*Morella serrata*	ASTERACEAE	*Senecio sp.*
MYRTACEAE	*Metrosideros angustifolia* seedlings	ASTERACEAE	** Cotula australis **
POACEAE	*Pennisetum macroaurum*	ASTERACEAE	*Senecio hastifolius/cordifolius*
PROTEACEAE	*Brabejum stellatifolium* seedling	ASTERACEAE	** Hypochaeris radicata **
RESTIONACEAE	*Elegia capensis*	ASTERACEAE	*Disparago* sp.
RESTIONACEAE	*Restio* sp.	BRUNIACEAE	*Berzelia lanuginosa*
RESTIONACEAE	*Calopsis paniculata*	CAMPANULACEAE	*Prismatocarpus fruticosus*
		CRASSULACEAE	*Crassula pellucida* subsp *pellucida*
		CYPERACEA	*Juncus capensis*
		CYPERACEA	*Scirpus* sp.
		CYPERACEA	*Ficinia anceps*
		CYPERACEA	*Pentaschistus pallida*
		CYPERACEA	*Isolepis prolifera*
		ERICACEAE	*Erica* sp.
		FABACEAE	*Psoralea* sp.
		FABACEAE	** Acacia longifolia **
		LOBELIACEAE	*Monopsis lutea*
		POACEAE	*Panicum maximum*
		POACEAE	*Pennisetum macrourum*
		POACEAE	*Aira cupaniana*
		POACEAE	*Argrostis lachnanthna*
		POACEAE	*Pentameris* sp.
		RESTIONACEAE	*Ischryrolepis* sp.
		RESTIONACEAE	*Restio* sp.
		ROSACEAE	*Cliffortia cuneata*
		RUTACEAE	*Agathosma crenulata*
		RUTACEAE	*Empleurum unicapsulare*
		SCROPHULARIACEAE	*Zaluzianskya capensis*
		SCROPHULARIACEAE	*Wahlenbergia cernua*
		SELAGINACEAE	*Selago quadrangularis*
		SELAGINACEAE	*Pseudoselago serrata (=Selago serrata)*
		SOLANACEAE	*Solanum retroflexum **

Table G 2.9: Eerste River reference mountain stream plot 1 (dry)

MOUNTAIN STREAM DRY **ErWb MS 1 (d)**		* = alien plant species	
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
ASTERACEAE	*Metalasia* sp.	AIZOACEAE	*Erepsia anceps*.
ASTERACEAE	*Seriphium plumosa*	ASTERACEAE	*Metalasia sp.*
BLECHNACEAE	*Blechnum capense*	ASTERACEAE	*Euryops abrotanifolius/ Ursinia paleaceae*
ERICACEAE	*Erica* sp	ASTERACEAE	*Seriphium plumosa*
ERICACEAE	*Erica* sp 2	ASTERACEAE	*Senecio hastifolius/cordifolius*
FABACEAE	*Psoralea pinnata*	ASTERACEAE	*Pseudognaphalium luteo-album* *
FABACEAE	*Podalyria calyptrata*	ASTERACEAE	*Chrysanthemoides monilifera*
IRIDACEAE	*Irideaceae* sp.	ASTERACEAE	* *Hypochaeris radicata*
LAURACEAE	*Cassytha ciliolata*	ASTERACEAE	*Helichrysum helianthemifolium*
POACEAE	*Pennisetum macroaurum*	ASTERACEAE	* *Lactuca serriola* *
PROTEACEAE	*Brabejum stellatifolium*	CRASSULACEAE	*Crassula pellucida subsp pellucida*
RESTIONACEAE	*Cannonmois virgata*	CYPERACEA	*Juncus capensis*
RESTIONACEAE	*Restio perplexus*	CYPERACEA	*Pentaschistus pallida*
RESTIONACEAE	*Elegia capensis*	CYPERACEA	*Scirpus sp.*
ROSACEAE	*Cliffortia cuneata*	CYPERACEA	*Isolepis prolifera*
		ERICACEAE	*Erica* sp
		FABACEAE	*Psoralea* sp.
		GENTIANACEAE	*Chironia* sp.
		PERENNIAL	*Cliffortia cuneata*
		PLANTAGINACEAE	*Plantago lanceolata* *
		POACEAE	*Panicum maximum*
		POACEAE	*Pennisetum macrourum*
		RESTIONACEAE	*Ischryrolepis* sp.
		RUBIACEAE	*Anthospermum galiodes subsp galiodes.*
		RUTACEAE	*Emplerurm unicapsulare*
		RUTACEAE	*Agathosma crenulata*
		SCROPHULARIACEAE	*Wahlenbergia cernua*
		SCROPHULARIACEAE	*Pseudoselago serrata (=Selago serrata)*
		SELAGINACEAE	*Selago quadrangularis*
		THYMELAEACEAE	*Struthiolia striata*

Table G 2.10: Eerste River reference mountain stream plot 2

MOUNTAIN STREAM TRANS **ErJ MS (trans)**		* = alien plant species	
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
ASTERACEAE	*Helichrysum* sp.	ASTERACEAE	*Helichrysum* sp.
ASTERACEAE	*Brachyleaena neriifolia*	ASTERACEAE	** Pseudognaphalium luteo-album*
ASTERACEAE	*Helichrysum* sp. 2	ASTERACEAE	*Senecio hastifolius/cordifolius*
ASTERACEAE	*Brachylaena neriifolia*	ASTERACEAE	** Hypochaeris radicata*
BLECHNACEAE	*Blechnum capense*	ASTERACEAE	*Euryops abrotanifolius*
ERICACEAE	*Erica* sp. seedlings	ASTERACEAE	*Metalasia* sp.
FABACEAE	*Podalyria calyptrata*	ASTERACEAE	*Senecio sp.*
LOMARIOPSIDACEAE	*Elaephoglossum acrostichoides*	ASTERACEAE	*Chrysanthemoides monilifera*
MYRTACEAE	*Metrosideros angustifolia*	ASTERACEAE	** Sonchus asper*
POACEAE	*Briza maxima*	ASTERACEAE	*Othonna quinquedentata*
PROTEACEAE	*Brabejum stellatifolium*	CAMPANULACEAE	*Microcodon* sp.
RESTIONACEAE	*Elegia capensis*	CARYOPHLLACEAE	** Spergula arvensis **
ROSACEAE	*Cliffortia ruscifolia*	CRASSULACEAE	*Crassula coccinea*
ROSACEAE	*Cliffortia cuneata*	CYPERACEA	*Juncus capensis*
		CYPERACEA	*Pentaschistus pallida*
		CYPERACEA	*Ficinia anceps*
		CYPERACEA	*Isolepis prolifera*
		ERICACEAE	*Erica caffra*
		GENTIANACEAE	*Chironia sp.*
		LINACEAE	*Argyrolobium lunare*
		MYRICACEAE	*Morella serrata*
		POACEAE	*Panicum maximum*
		POACEAE	*Pennisetum macrourum*
		POACEAE	*Pentameris sp.*
		POLYGONACEAE	*Persicaria lapathifolia **
		RUBIACEAE	*Anthospermum galiodes* subsp *galiodes.*
		SCROPHULARIACEAE	*Selago quadrangularis*
		SOLANACEAE	*Solanum retroflexum (=S.nigrum)*
		THYMELAEACEAE	*Struthiolia striata*

Table G 2.11: Eerste River reference mountain stream plot 3 (wet)

MOUNTAIN STREAM WET **Er1 FH (w)**		* = alien plant species	
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
AQUIFOLIACEAE	*Ilex mitis*	AQUIFOLIACEAE	*Ilex mitis*
MYRTACEAE	*Metrosideros angustifolia*	ASTERACEAE	*Metalasia* sp.
OSMUNDACEAE	*Todea barbara*	ASTERACEAE	*Pseudognaphalium luteo-album* *
PITTOSPORACEAE	* *Pittosporum crassifolium*.	ASTERACEAE	* *Hypochaeris radicata* *
PRIONIACEAE	*Prionium serratum*	ASTERACEAE	*Euryops abrotanifolius*
PROTEACEAE	*Brabejum stellatifolium*	ASTERACEAE	*Senecio hastifolius/cordifolius*
SALICACEAE	*Salix capensis*	ASTERACEAE	*Senecio sp.*
\		ASTERACEAE	*Helichrysum* sp.
		ASTERACEAE	* *Cotula australis* *
		ASTERACEAE	*Othonna quinquedentata*
		CRASSULACEAE	*Crassula thunbergiana* subsp *thunbergiana*
		CYPERACEA	*Juncus capensis*
		CYPERACEA	*Ficinia anceps*
		CYPERACEA	*Isolepis prolifera*
		CYPERACEA	*Pentaschistus pallida*
		FABACEAE	*Psoralea sp.*
		FABACEAE	*Rhynchosia capensis*
		OXALIDACEAE	*Oxalis corniculata*
		PERENNIAL	*Solanum retroflexum* *
		PLANTAGINACEAE	*Plantago lanceolata* *
		POACEAE	*Panicum maximum*
		POACEAE	*Digitaria debilis*
		POLYGONACEAE	* *Persicaria lapathifolia* *
		PRIMULACEAE	* *Anagallis arvensis*
		RESTIONACEAE	*Ischryrolepis* sp.
		RUTACEAE	*Agathosma crenulata*
		RUTACEAE	*Empleurum unicapsulare*
		SCROPHULARIACEAE	*Wahlenbergia cernua*
		SCROPHULARIACEAE	*Zaluzianskya capensis*
		SCROPHULARIACEAE	*Pseudoselago serrata (=Selago serrata)*
		THYMELAEACEAE	*Struthiolia striata*
		VERBENACEAE	* *Verbena bonariensis*

Table G 2.12: Eerste River reference mountain stream plot 3 (dry)

MOUNTAIN STREAM DRY **Er2 MS (d)**		* = alien plant species	
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
ANACARDIACEAE	*Rhus angustifolia*	ASTERACEAE	*Metalasia* sp.
BLECHNACEAE	*Blechnum capense*	ASTERACEAE	* *Hypochaeris radicata* *
BRUNIACEAE	*Berzelia lanuginosa*	ASTERACEAE	*Senecio sp.*
CELASTRACEAE	*Maytenus oleoides*	ASTERACEAE	*Senecio hastifolius/cordifolius*
ERICACEAE	*Erica abieetina* ssp *aurantiaca*	CARYOPHLLACEAE	* *Spergula arvensis* *
FABACEAE	*Podalyria calyptrata*	CRASSULACEAE	*Crassula coccinea*
FABACEAE	*Psoralea aphylla*	CYPERACEA	*Pentaschistus pallida*
IRIDACEAE	*Irideacea*	CYPERACEA	*Juncus capensis*
PROTEACEAE	*Brabejum stellatifolium*	CYPERACEAE	*Ficinia anceps*
RESTIONACEAE	*Ischryolepis subverticellata*	ERICACEAE	*Erica* sp.
RESTIONACEAE	*Elegia capense*	FABACEAE	*Psoralea* sp.
RESTIONACEAE	*Restio perplexus*	GENTIANACEAE	*Chironia sp.*
RHAMNACEAE	*Phylica pubescens*	LINACEAE	*Argyrolobium lunare*
ROSACEAE	*Cliffortia ruscifolia*	OXALIDACEAE	*Oxalis corniculata*
SCROPHULARIACEAE	*Halleria elliptica*	PERENNIAL	*Solanum retroflexum* *
		POACEAE	*Panicum maximum*
		POACEAE	*Pennisetum macrourum*
		POACEAE	*Agrostis lachnantha*
		PRIMULACEAE	* *Anagallis arvensis*
		RESTIONACEAE	*Ischryrolepis* sp.
		RUBIACEAE	*Anthospermum galiodes* subsp *galiodes.*
		SCROPHULARIACEAE	*Wahlenbergia cernua*
		SCROPHULARIACEAE	*Pseudoselago serrata (=Selago serrata)*
		THYMELAEACEAE	*Struthiola tomentosa*

Table G 2.13: Eerste River reference mountain stream plot 3 (wet)

MOUNTAIN STREAM WET **Er2 MS (w)**		* = alien plant species	
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
ASTERACEAE	*Brachylaena neriifolia*	ASTERACEAE	*Metalasia* sp.
ERICACEAE	*Erica caffra*	ASTERACEAE	*Pseudognaphalium luteo-album* *
MYRTACEAE	*Metrosideros angustifolia*	ASTERACEAE	*Senecio hastifolius/cordifolius*
PROTEACEAE	*Brabejum stellatifolium*	ASTERACEAE	*Helichrysum helianthemifolium*
		CAMPANULACEAE	*Microcodon* sp.
		CARYOPHLLACEAE	* *Spergula arvensis*
		CRASSULACEAE	*Crassula thunbergiana* subsp *thunbergiana*
		CUNONIACEAE	*Cunonia capensis*
		CYPERACEA	*Juncus capensis*
		CYPERACEA	*Pentaschistus pallida*
		CYPERACEA	*Isolepis prolifera*
		ERICACEAE	*Erica* sp.2
		ERICACEAE	*Erica* sp.1
		FABACEAE	*Psoralea* sp.
		PLANTAGINACEAE	*Plantago lanceolata*
		POACEAE	*Panicum maximum*
		POACEAE	*Pennisetum macrourum*
		POACEAE	* *Aira cupaniana*
		POACEAE	*Digitaria debilis*
		PRIMULACEAE	* *Anagallis arvensis*
		RESTIONACEAE	*Ischryrolepis* sp.
		RUBIACEAE	*Anthospermum galiodes* subsp *galiodes.*
		RUTACEAE	*Agathosma crenulata*
		SCROPHULARIACEAE	*Pseudoselago serrata (=Selago serrata)*
		THYMELAEACEAE	*Struthiolia striata*

Table G 2.14: Eerste River reference foothill plot 1 (wet)

FOOTHILL WET **Er1 FH (w)**		* = alien plant species	
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
AQUIFOLIACEAE	*Ilex mitis*	AQUIFOLIACEAE	*Ilex mitis*
MYRTACEAE	*Metrosideros angustifolia*	ASTERACEAE	*Metalasia* sp.
OSMUNDACEAE	*Todea barbara*	ASTERACEAE	*Pseudognaphalium luteo-album*
PITTOSPORACEAE	*Pittosporum* sp.	ASTERACEAE	** Hypochaeris radicata*
PRIONIACEAE	*Prionium serratum*	ASTERACEAE	*Euryops abrotanifolius*
PROTEACEAE	*Brabejum stellatifolium*	ASTERACEAE	*Senecio hastifolius/cordifolius*
SALICACEAE	*Salix capensis*	ASTERACEAE	*Senecio sp.*
		ASTERACEAE	*Helichrysum* sp.
		ASTERACEAE	** Cotula australis*
		ASTERACEAE	*Othonna quinquedentata*
		CRASSULACEAE	*Crassula thunbergiana ssp thunbergiana*
		CYPERACEA	*Juncus capensis*
		CYPERACEA	*Ficinia anceps*
		CYPERACEA	*Isolepis prolifera*
		CYPERACEA	*Pentaschistus pallida*
		FABACEAE	*Psoralea sp.*
		FABACEAE	*Rhynchosia capensis*
		OXALIDACEAE	*Oxalis corniculata*
		PLANTAGINACEAE	*Plantago lanceolata*
		POACEAE	*Panicum maximum*
		POACEAE	*Digitaria debilis*
		POLYGONACEAE	** Persicaria lapathifolia*
		PRIMULACEAE	** Anagallis arvensis*
		RESTIONACEAE	*Ischryrolepis* sp.
		RUTACEAE	*Agathosma crenulata*
		RUTACEAE	*Empleurum unicapsulare*
		SCROPHULARIACEAE	*Wahlenbergia cernua*
		SCROPHULARIACEAE	*Zaluzianskya capensis*
		SCROPHULARIACEAE	*Pseudoselago serrata (=Selago serrata)*
		SOLANACEAE	*Solanum retroflexum*
		THYMELAEACEAE	*Struthiolia striata*
		VERBENACEAE	** Verbena bonariensis*

Table G 2.15: Eerste River reference foothill plot 1 (dry)

FOOTHILL DRY **Er1 FH (d)**		* = alien plant species	
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
ACHARIACEAE	*Kiggelaria africana*	ASTERACEAE	*Metalasia* sp.
ANACARDIACEAE	*Rhus* sp. seedling	ASTERACEAE	*Helichrysum helianthemifolium*
ASPARAGACEAE	*Asparagus* sp. seedling	ASTERACEAE	* *Hypochaeris radicata*
ASTERACEAE	*Brachylaena neriifolia*	ASTERACEAE	*Pseudognaphalium luteo-album*
CUNONIACEAE	*Cunonia capensis*	ASTERACEAE	*Senecio hastifolius/cordifolius*
MYRTACEAE	*Metrosideros angustifolia*	ASTERACEAE	*Euryops abrotanifolius*
OLINIACEAE	*Olinia ventosa*	ASTERACEAE	*Senecio sp.*
PITTOSPORACEAE	* *Pittosporum* sp.	ASTERACEAE	*Chrysanthemoides monilifera*
PODOCARPACEAE	*Podocarpus elongatus*	ASTERACEAE	*Othonna quinquedentata*
PROTEACEAE	*Brabejum stelllatifolium*	ASTERACEAE	* *Lactuca serriola*
SCROPHULARIACEAE	*Halleria elliptica*	CARYOPHLLACEAE	* *Spergula arvensis*
		CRASSULACEAE	*Crassula pellucida* subsp *pellucida*
		CRASSULACEAE	*Crassula coccinea*
		CYPERACEA	*Pentaschistus pallida*
		CYPERACEA	*Juncus capensis*
		CYPERACEA	*Ficinia anceps*
		CYPERACEA	*Scirpus* sp.
		CYPERACEA	*Isolepis prolifera*
		FABACEAE	*Psoralea a sp*
		FABACEAE	*Argyrolobium lunare*
		FABACEAE	*Podalyria calyptrata*
		GENTIANACEAE	*Chironia* sp
		OXALIDACEAE	*Oxalis corniculata*
		PLANTAGINACEAE	*Plantago lanceolata*
		POACEAE	*Panicum maximum*
		POACEAE	*Pennisetum macrourum*
		POACEAE	*Digitaria debilis*
		PRIMULACEAE	* *Anagallis arvensis*
		RESTIONACEAE	*Ischyrolepis subverticillata*
		ROSACEAE	*Cliffortia cuneata*
		ROSACEAE	*Cliffortia* sp.
		RUBIACEAE	*Anthospermum galiodes* subsp *galiodes*
		SCROPHULARIACEAE	*Wahlenbergia cernua*
		SCROPHULARIACEAE	*Pseudoselago serrata (=Selago serrata)*
		SELAGINACEAE	*Selago quadrangularis*
		SOLANACEAE	*Solanum retroflexum*

Table G 2.16: Eerste River reference footill plot 2

FOOTHILL TRANS **Er2 FH (trans)**		* = alien plant species	
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
ASTERACEAE	*Brachylaena neriifolia*	ASTERACEAE	*Metalasia* sp.
CYPERACEAE	*Cyperus* sp.	ASTERACEAE	*Pseudognaphalium luteo-album*
LOMARIOPSIDACEAE	*Elaphoglossum acrostichoides*	ASTERACEAE	** Hypochaeris radicata*
MYRICACEAE	*Morella quercifolia*	ASTERACEAE	*Lactuca serriola **
OLINIACEAE	*Olinia ventosa*	ASTERACEAE	*Senecio hastifolius/cordifolius*
OSMUNDACEAE	*Todea barbara*	ASTERACEAE	*Chrysanthemoides monilifera*
PITTOSPORACEAE	*Pittosporum* sp.	ASTERACEAE	*Helichrysum* sp.
PODOCARPACEAE	*Podocarpus elongatus*	CUNONIACEAE	*Cunonia capensis*
PRIONIACEAE	*Prionium serratum*	CYPERACEA	*Juncus capensis*
PROTEACEAE	*Brabejum stellatifolium*	CYPERACEA	*Ficinia anceps*
SALICACEAE	*Salix capensis*	CYPERACEA	*Pentaschistus pallida*
SCHIZAEACEAE	*Schizeae tenella*	CYPERACEA	*Isolepis prolifera*
		CYPERACEA	*Scirpus sp.*
		CYPERACEA	*Juncus* sp
		ERICACEAE	*Erica* sp.
		ERICACEAE	*Erica* sp.
		FABACEAE	** Acacia mearnsii*
		FABACEAE	*Podalyria calyptrata*
		GENTIANACEAE	*Chironia sp.*
		OXALIDACEAE	*Oxalis corniculata*
		POACEAE	*Panicum maximum*
		POACEAE	*Pennisetum macrourum*
		POACEAE	*Agrostis lachnantha*
		POACEAE	*Pentameris* sp.
		POLYGONACEAE	** Persicaria lapathifolia*
		PRIMULACEAE	** Anagallis arvensis*
		RUBIACEAE	*Anthospermum galiodes* subsp *galiodes.*
		RUTACEAE	*Agathosma crenulata*
		SCROPHULARIACEAE	*Wahlenbergia cernua*
		THYMELAEACEAE	*Struthiolia striata*

Table G 2.17: Molenaars River reference mountain stream plot 1

MOLENAARS RIVER REFERENCE * = alien plant species

MOUNTAIN STREAM TRANS

Mol K1 MS (trans)

ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
ASTERACEAE	*Brachylaena neriifolia*	AIZOACEAE	*Erepsia anceps*
BLECHNACEAE	*Blechnum capense*	APIACEAE	*Centella* sp.
CYPERACEAE	*Ficinia anceps*	ASTERACEAE	*Metalasia* sp.
ERICACEAE	*Erica caffra*	ASTERACEAE	*Euryops abrotanifolius*
MYRICACEAE	*Morella serrata*	ASTERACEAE	*Senecio hastifolius/cordifolius*
POACEAE	*Erhartya* sp.	ASTERACEAE	*Pseudognaphalium luteo-album*
RESTIONACEAE	*Cannomois virgata*	ASTERACEAE	*Ursinia paleaceae*
RESTIONACEAE	*Ischyrolepis subverticillata*	CRASSULACEAE	*Crassula pellucida* subsp *pellucida*
		CRASSULACEAE	*Crassula coccinea*
		CYPERACEA	*Juncus capensis*
		CYPERACEA	*Pentaschistus pallida*
		CYPERACEA	*Ficinia anceps*
		ERICACEAE	*Erica* sp.
		FABACEAE	* *Acacia longifolia*
		FABACEAE	*Psoralea* sp.
		FABACEAE	*Rhynchosia capensis*
		GRUBBIACEAE	*Grubbia tormentosa/rosmariniformis*
		LINACEAE	*Cliffortia cuneata*
		POACEAE	*Panicum maximum*
		POACEAE	*Pennisetum macrourum*
		POACEAE	*Schoenoplectus/Scirpus sp.*
		POACEAE	*Pentameris* sp.
		POACEAE	*Digitaria debilis*
		PRIMULACEAE	* *Anagallis arvensis*
		RESTIONACEAE	*Ischyrolepis subverticillata*
		ROSACEAE	*Cliffortia* sp.
		RUTACEAE	*Emleurum unicapsulare*
		SELAGINACEAE	*Selago quadrangularis*
		THYMELAEACEAE	*Struthiolia tomentosa*

Table G 2.18: Molenaars River reference mountain stream plot 2

MOUNTAIN STREAM TRANS **Mol K2 MS (trans)**		* = alien plant species	
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
ASTERACEAE	*Brachylaena neriifolia*	ASTERACEAE	*Metalasia* sp.
CYPERACEAE	*Cyperus* sp	ASTERACEAE	*Pseudognaphalium luteo-album*
ERICACEAE	*Erica caffra*	ASTERACEAE	*Helichrysum helianthemifolium*
FABACEAE	* *Acacia longifolia*	ASTERACEAE	* *Hypochaeris radicata*
FABACEAE	* *Acacia longifolia* seedling	ASTERACEAE	*Senecio hastifolius/cordifolius*
MYRTACEAE	*Metrosideros angustifolia*	ASTERACEAE	*Chrysanthemoides monilifera*
PROTEACEAE	*Brabejum stellatifolium*	ASTERACEAE	*Senecio sp.**
RESTIONACEAE	*Calopsis paniculata*	CARYOPHLLACEAE	* *Spergula arvensis*
SALICACEAE	*Salix capensis*	CARYOPHLLACEAE	* *Polycarpon tetraphyllum*
		CRASSULACEAE	*Crassula pellucida* subsp *pellucida*
		CYPERACEA	*Ficinia anceps*
		CYPERACEA	*Juncus capensis*
		CYPERACEA	*Pentaschistus pallida*
		CYPERACEA	*Scirpus* sp.
		CYPERACEA	*Isolepis prolifera*
		OXALIDACEAE	*Oxalis corniculata*
		POACEAE	*Panicum maximum*
		POACEAE	*Pentameris* sp.
		POACEAE	*Pennisetum macrourum*
		POACEAE	* *Aira cupaniana*
		POACEAE	*Digitaria debilis*
		PRIMULACEAE	* *Anagallis arvensis*
		RUBIACEAE	*Anthospermum galiodes subsp galiodes*
		SCROPHULARIACEAE	*Wahlenbergia obovata/W.cernua*
		SCROPHULARIACEAE	*Pseudoselago serrata (=Selago serrata)*
		SOLANACEAE	*Solanum retroflexum (=S.nigrum)*
		VERBENACEAE	* *Verbena bonariensis*

Table G 2.19: Molenaars River reference mountain stream plot 3 (trans)

MOUNTAIN STREAM TRANS **Mol MS 3t**		* = alien plant species	
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
ASTERACEAE	*Brachylaena neriifolia*	AIZOACEAE	*Erepsia anceps*
ERICACEAE	*Erica caffra*	AIZOACEAE	*Carpobrotus* sp.
MYRICACEAE	*Morella serrata*	ASTERACEAE	*Euryops abrotanifolius*
MYRTACEAE	*Metrosideros angustifolia*	ASTERACEAE	*Senecio cordifolius*
OLINIACEAE	*Olinia ventosa*	ASTERACEAE	* *Hypochaeris radicata*
PRIONIACEAE	*Prionium serratum*	ASTERACEAE	*Metalasia* sp.
		ASTERACEAE	*Seriphium plumosa*
		ASTERACEAE	*Senecio* sp.
		ASTERACEAE	*Pseudognaphalium luteo-album*
		ASTERACEAE	*Helichrysum helianthemifolium*
		ASTERACEAE	*Othonna quinquedentata*
		ASTERACEAE	* *Lactuca serriola*
		ASTERACEAE	*Disparago* sp.
		CARYOPHLLACEAE	* *Spergula arvensis*
		CARYOPHLLACEAE	* *Polycarpon tetraphyllum*
		CRASSULACEAE	*Crassula pellucida*
		CRASSULACEAE	*Crassula coccinea*
		CRASSULACEAE	*Crassula fascicularis*
		CYPERACEA	*Juncus capensis*
		CYPERACEA	*Juncus* sp
		CYPERACEA	*Ficinia anceps*
		CYPERACEA	*Scirpus* sp.
		CYPERACEA	*Isolepis prolifera*
		ERICACEAE	*Erica* sp.1
		FABACEAE	*Argyrolobium lunare*
		GENTIANACEAE	*Chironia* sp.
		GRUBBIACEAE	*Cliffortia grandifolia*
		LAMIACEAE	* *Verbena bonariensis*
		LINACEAE	*Cliffortia cuneata*
		LOBELIACEAE	*Monopsis lutea*
		OXALIDACEAE	*Oxalis corniculata*
		PLANTAGINACEAE	*Plantago lanceolata*
		POACEAE	*Panicum maximum*
		POACEAE	*Pennisetum macrourum*
		POACEAE	*Pentaschistus pallida*
		POACEAE	*Agrostis lachnantha*
		POACEAE	*Pentameris* sp.
		POACEAE	* *Aira cupaniana*
		PRIMULACEAE	* *Anagallis arvensis*
		RESTIONACEAE	*Ischryrolepis subverticillata*
		ROSACEAE	*Cliffortia ruscifolia*
		RUBIACEAE	*Anthospermum* sp.
		SCROPHULARIACEAE	*Pseudoselago serrata*
		SCROPHULARIACEAE	*Wahlenbergia cernua*
		SCROPHULARIACEAE	*Dischisma ciliatum*
		SELAGINACEAE	*Pseudoselago quadrangularis*
		SOLANACEAE	*Solanum retroflexum*
		THYMELAEACEAE	*Struthiola tomentosa*

Table G 2.20: Molenaars River reference foothill plot 1 (dry)

FOOTHILL DRY **Mol EL FH (d)**		* = alien plant species	
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
AQUIFOLIACEAE	*Ilex mitis*	AIZOACEAE	*Erepsia anceps*
ASTERACEAE	*Ursinia palacea*	AIZOACEAE	*Carpobrotus edulis*
ASTERACEAE	*Seriphium plumosa*	APIACEAE	*Centella sp.*
ASTERACEAE	*Oesteospermum* sp.	ASTERACEAE	*Metalasia* sp.
ASTERACEAE	*Cineraria* sp.	ASTERACEAE	*Disparago sp.*
ASTERACEAE	*Brachylaena neriifolia*	ASTERACEAE	*Struthiola tomentosa*
BLECHNACEAE	*Blechnum capense*	ASTERACEAE	*Struthiola myrsinites*
CYPERACEAE	*Ficinia* sp.	ASTERACEAE	** Hypochaeris radicata*
ERICACEAE	*Erica* sp.	ASTERACEAE	*Othonna quinquedentata*
FABACEAE	*Podalyria calyptrata*	ASTERACEAE	*Ursinia palaceae*
FABACEAE	*Psorelea pinnata*	ASTERACEAE	*Senecio hastifolius/S.cordifolius*
FABACEAE	*Psoralea centata*	ASTERACEAE	*Euryops abrotanifolius*
GENTIANACEAE	*Chironia* sp.	ASTERACEAE	*Senecio* sp.
IRIDACEAE	*Aristea major*	ASTERACEAE	*Chrysanthemoides monilifera*
LAURACEAE	*Cassytha ciliolata*	ASTERACEAE	*Plecostachys parvifolia*
MYRICACEAE	*Myrsine africana*	ASTERACEAE	** Spergula arvensis*
MYRTACEAE	*Metrosideros angustifolia*	CAMPANULACEAE	*Selago quadrangularis*
POACEAE	*Merxmuellera stricta*	CYPERACEA	*Juncus capensis*
POACEAE	*Pennisetum macrorum*	CYPERACEA	*Pentaschistus pallida*
POACEAE	*Ehrharta* sp.	CYPERACEA	*Ficinia anceps*
POACEAE	*Pentaschistus* sp.	CYPERACEA	*Scirpus* sp.
POACEAE	*Schzaea pectinata*	FABACEAE	*Psoralea* sp.
POACEAE	*Pentameris thuarii*	FABACEAE	*Argyrolobium lunare*
PROTEACEAE	*Brabejum stellatifolium*	FABACEAE	*Pseudognaphalium luteo-album*
RESTIONACEAE	*Elegia capensis*	GRUBBIACEAE	*Grubbia tormentosa/G.rosmariniformis*
RESTIONACEAE	*Calopsis paniculata*	LAMIACEAE	*Crassula pellucida subsp pellucida*
RESTIONACEAE	*Elegia capensis*	POACEAE	*Panicum maximum*
RUTACEAE	*Agathosma crenulata*	POACEAE	*Pennisetum macrourum*
		PRIMULACEAE	** Anagallis arvensis**
		RESTIONACEAE	*Ischyrolepis subverticillata*
		RUBIACEAE	*Anthospermum galiodes* subsp *galiodes.*
		SOLANACEAE	*Solanum retroflexum*
		THYMELAEACEAE	*Wahlenbergia obovata/ cernua*
		VERBENACEAE	** Verbena bonariensis*

Table G 2.21: Molenaars River reference foothill plot 1 (wet)

FOOTHILL WET **Mol EL FH (w)**		* = alien plant species	
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
AQUIFOLIACEAE	*Ilex mitis*	AIZOACEAE	*Ishryolepis subverticellata*
ASTERACEAE	*Brachylaena neriifolia*	AIZOACEAE	*Erepsia anceps*
CUNONIACEAE	*Platylophus trifoliatus*	APIACEAE	*Centella* sp.
CYPERACEAE	*Ficinia* sp.	ASTERACEAE	*Euryops abrotanifolius*
ERICACEAE	*Erica caffra*	ASTERACEAE	*Metalasia sp.*
LAURACEAE	*Cassytha ciliolata*	ASTERACEAE	*Helichrysum helianthemifolium*
MYRTACEAE	*Metrosideros angustifolia*	ASTERACEAE	*Pseudognaphalium luteo-album*
OSMUNDACEAE	*Todea barbata*	ASTERACEAE	** Cotula australis*
POACEAE	*Pennisetum macrorum*	CRASSULACEAE	*Crassula pellucida* subsp *pellucida*
PROTEACEAE	*Brabejum stellatifolium*	CYPERACEA	*Pentaschistus pallida*
RESTIONACEAE	*Elegia capensis*	CYPERACEA	*Juncus capensis*
RESTIONACEAE	*Calopsis paniculata*	CYPERACEA	*Ficinia anceps*
		CYPERACEA	*Isolepis prolifera*
		CYPERACEA	*Scirpus* sp.
		FABACEAE	*Psoralea* sp.
		LINACEAE	*Argyrolobium lunare*
		LINACEAE	*Cliffortia cuneata*
		POACEAE	*Panicum maximum*
		POACEAE	*Pennisetum macrourum*
		POACEAE	*Pentameris* sp.
		POACEAE	*Agrostis lachnantha*
		POLYGONACEAE	** Persicaria lapathifolia*
		RUBIACEAE	*Anthospermum galiodes* subsp *galiodes.*
		SCROPHULARIACEAE	*Pseudoselago serrata (=Selago serrata)*
		SELAGINACEAE	*Selago quadrangularis*

Table G 2.22: Molenaars River reference foothill plot 2 (dry)

FOOTHILL DRY **Mol M FH (d)**		* = alien plant species	
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
ASTERACEAE	*Seriphium plumosa*	ASTERACEAE	*Metalasia* sp.
BLECHNACEAE	*Blechnum capense*	ASTERACEAE	*Helichrysum helianthemifolium*
ERICACEAE	*Erica caffra*	ASTERACEAE	*Othonna quinquedentata*
FABACEAE	** Acacia melanoxylon*	ASTERACEAE	*Pseudognaphalium luteo-album*
POACEAE	*Ehrhartya ramosa*	CARYOPHLLACEAE	** Spergula arvensis*
RESTIONACEAE	*Ischyrolepis subverticillata*	CYPERACEA	*Ficinia anceps*
SCROPHULARIACEAE	*Halleria elliptica*	CYPERACEA	*Pentaschistus pallida*
		CYPERACEA	*Juncus capensis*
		CYPERACEA	*Isolepis prolifera*
		FABACAEAE	*Psoralea* sp.
		POACEAE	*Panicum maximum*
		POACEAE	*Pennisetum macrourum*
		POACEAE	*Digitaria debilis*
		POLYGONACEAE	** Persicaria lapathifolia*
		PRIMULACEAE	** Anagallis arvensis*
		RESTIONACEAE	*Ischyrolepis subverticellata*
		RUBIACEAE	*Anthospermum galiodes* subsp *galiodes.*
		VERBENACEAE	** Verbena bonariensis*

Table G 2.23: Molenaars River reference foothill plot 2 (wet)

FOOTHILL WET **Mol M FH (w)**		* = alien plant species	
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
FABACEAE	** Acacia longifolia*	ASTERACEAE	*Metalasia* sp.
FABACEAE	** Acacia mearnsii*	ASTERACEAE	*Helichrysum helianthemifolium*
JUNCACEAE	*Juncus capensis*	ASTERACEAE	*Othonna quinquedentata*
MYRICACEAE	*Morella serrata*	ASTERACEAE	*Pseudognaphalium luteo-album*
MYRTACEAE	*Metrosideros angustifolia*	CARYOPHLLACEAE	** Spergula arvensis*
POACEAE	*Pentameris thuarii*	CYPERACEA	*Ficinia anceps*
PROTEACEAE	*Brabejum stellatifolium* sapling	CYPERACEA	*Pentaschistus pallida*
		CYPERACEA	*Juncus capensis*
		CYPERACEA	*Isolepis prolifera*
		FABACEAE	*Psoralea* sp.
		POACEAE	*Panicum maximum*
		POACEAE	*Pennisetum macrourum*
		POACEAE	*Digitaria debilis*
		POLYGONACEAE	** Persicaria lapathifolia*
		PRIMULACEAE	** Anagallis arvensis*
		RESTIONACEAE	*Ischyrolepis subverticillata*
		RUBIACEAE	*Anthospermum galiodes* subsp *galiodes.*
		VERBENACEAE	** Verbena bonariensis*

Table G 2.24: Wit River reference mountain stream plot 1 (wet)

WIT RIVER REFERENCE		* = alien plant species	
MOUNTAIN STREAM WET			
Wit1 MS (w)			
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
MYRTACEAE	*Metrosideros angustifolia*	ASTERACEAE	*Senecio hastifolius/S.cordifolius*
PINACEAE	*Pinus pinnaster* seedling	ASTERACEAE	** Hypochaeris radicata*
POACEAE	*Pennisetum macrourum*	ASTERACEAE	*Metalasia* sp.
PRIONIACEAE	*Prionium serratum*	CYPERACEA	*Juncus capensis*
PROTEACEAE	*Brabejum stellatifolium* seedling	CYPERACEA	*Ficinia anceps*
RESTIONACEAE	*Restio* sp.	CYPERACEA	*Pentaschistus pallida*
RESTIONACEAE	*Calopsis paniculata*	FABACEAE	*Hypocalyptus coluteoides*
RESTIONACEAE	*Rhodocoma capensis*	POACEAE	*Panicum maximum*
		RESTIONACEAE	*Ischryrolepis* sp.
		SOLANACEAE	*Solanum retroflexum*

Table G 2.25: Wit River reference mountain stream plot 1 (dry)

MOUNTAIN STREAM DRY		* = alien plant species	
Wit1 MS (d)			
ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
ASTERACEAE	*Brachylaena neriifolia*	AIZOACEAE	*Erepsia anceps*
CYPERACEAE	*Ficina trichoides*	APIACEAE	*Centella* sp.
ERICACEAE	*Erica bergianea*	ASTERACEAE	*Metalasia* sp.
ERICACEAE	*Erica curvirostris*	ASTERACEAE	*Euryops abrotanifolius*
ERICACEAE	*Erica* sp. seedling	ASTERACEAE	** Hypochoeris radicata*
IRIDACEAE	*Aristea/Watsonia*	ASTERACEAE	*Disparago* sp.
RESTIONACEAE	*Rhodocoma capensis*	ASTERACEAE	*Senecio hastifolius/S.cordifolius*
RESTIONACEAE	*Ischyrolepis subverticillata*	ASTERACEAE	*Senecio sp.*
RESTIONACEAE	*Restio dispar*	ASTERACEAE	** Lactuca serriola*
ROSACEAE	*Cliffortia ruscifolia*	ASTERACEAE	*Cotula australis*
THYMELACEAE	*Dicerothamnus rhinocerotis*	CAMPANULACEAE	*Prismatocarpus fruticosus*
		CARYOPHLLACEAE	** Spergula arvensis*
		CRASSULACEAE	*Crassula coccinea*
		CYPERACEA	*Ficinia anceps*
		CYPERACEA	*Juncus capensis*
		CYPERACEA	*Pentaschistus pallida*
		CYPERACEA	*Scirpus sp.*
		ERICACEAE	*Erica* sp.
		FABACEAE	*Hypocalyptus coluteoides*
		FABACEAE	** Acacia melanoxylon*
		POACEAE	*Panicum maximum*
		POACEAE	*Pennisetum macrourum*
		POACEAE	*Digitaria debilis*
		POACEAE	*Agrostis lachnantha*
		POACEAE	*Pentameris* sp.
		RESTIONACEAE	*Ischryrolepis* sp.
		ROSACEAE	*Cliffortia cuneata*
		ROSACEAE	*Cliffortia ruscifolia*
		RUBIACEAE	*Anthospermum galiodes* subsp *galiodes.*
		SCROPHULARIACEAE	*Wahlenbergia cernua*
		SOLANACEAE	*Solanum retroflexum (=nigrum)*
		THYMELAEACEAE	*Struthiolia striata*

Table G 2.26: Wit River reference mountain stream plot 2

MOUNTAIN STREAM TRANS

WitTrib MS 1 (trans)

* = alien plant species

ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
ASTERACEAE	*Brachylaena neriifolia*	ASTERACEAE	*Metalasia* sp.
ERICACEAE	*Erica caffra* seedlings	ASTERACEAE	* *Hypochoeris radicata*
JUNCACEAE	*Juncus capensis*	ASTERACEAE	*Senecio hastifolius/S.cordifolius*
MYRTACEAE	*Metrosideros angustifolia*	ASTERACEAE	*Pseudognaphalium luteo-album*
POACEAE	*Ehrharta racemosa*	ASTERACEAE	*Senecio sp.*
POACEAE	*Aristida junciformis*	CARYOPHLLACEAE	* *Spergula arvensis*
POACEAE	*Pentaschistis pallida*	CRASSULACEAE	*Crassula thunbergiana* subsp *thunbergiana*
PRIONIACEAE	*Prionium serratum*	CYPERACEA	*Ficinia anceps*
PROTEACEAE	*Brabejum stellatifolium*	CYPERACEA	*Juncus capensis*
RESTIONACEAE	*Rhodocoma capensis*	CYPERACEA	*Pentaschistus pallida*
		CYPERACEA	*Scirpus sp.*
		CYPERACEA	*Isolepis prolifera*
		FABACEAE	*Psoralea* sp,
		FABACEAE	*Podalyria calyptrata*
		POACEAE	*Panicum maximum*
		POACEAE	*Pennisetum macrourum*
		PRIMULACEAE	* *Anagallis arvensis*
		RESTIONACEAE	*Ischryrolepis* sp.
		ROSACEAE	*Cliffortia ruscifolia*
		ROSACEAE	*Cliffortia cuneata*
		SOLANACEAE	*Solanum retroflexum (=nigrum)*
		THYMELAEACEAE	*Struthiolia striata*

Table G 2.27: Wit River reference mountain stream plot 3

MOUNTAIN STREAM TRANS

Wit2 MS 1 (trans)

* = alien plant species

ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
CYPERACEAE	*Cyperus denudalus*	ASTERACEAE	*Metalasia* sp.
ERICACEAE	*Erica caffra*	CARYOPHLLACEAE	* *Spergula arvensis*
JUNCACEAE	*Juncus capensis*	CRASSULACEAE	*Crassula thunbergiana* subsp *thunbergiana*
MYRICACEAE	*Morella serrata*	POACEAE	*Panicum maximum*
MYRTACEAE	*Metrosideros angustifolia*		
POACEAE	*Pennisetum macroaurum*		
POACEAE	*Aristida junciformis*		
PRIONIACEAE	*Prionium serratum*		
RESTIONACEAE	*Isolepis digitata*		

Table G 2.28: Wit River reference foothill plot 1

FOOTHILL TRANS — * = alien plant species

WitW FH (trans)

ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
ASTERACEAE	*Brachylaena neriifolia*	ASTERACEAE	*Metalasia* sp.
CYPERACEAE	*Cyperus sp.* seedlings	ASTERACEAE	*Pseudognaphalium luteo-album*
ERICACEAE	*Erica caffra*	ASTERACEAE	*Helichrysum helianthemifolium*
MYRICACEAE	*Morella serrata*	CRASSULACEAE	*Crassula thunbergiana* subsp *thunbergiana*
PRIONIACEAE	*Prionium serratum*	CYPERACEA	*Pentaschistus pallida*
PROTEACEAE	*Brabejum stellatifolium*	CYPERACEA	*Ficinia anceps*
RESTIONACEAE	*Rhodocoma capensis*	CYPERACEA	*Juncus capensis*
	NOTE: Acacia close by !	ERICACEAE	*Erica caffra*
	NOTE: Berzelia close-by!	FABACEAE	*Psoralea* sp.
		POACEAE	*Panicum maximum*
		RUBIACEAE	*Anthospermum galiodes* subsp *galiodes.*
		SCROPHULARIACEAE	*Wahlenbergia cernua*
		SELAGINACEAE	*Selago quadrangularis*

Table G 2.29: Wit River reference foothill plot 2

FOOTHILL TRANS — * = alien plant species

WitBk FH (trans)

ABOVE-GROUND VEGETATION		**SEED BANK COMMUNITY**	
Family	**Species**	**Family**	**Species**
ASTERACEAE	*Seriphium plumosa*	ASTERACEAE	*Metalasia* sp.
ASTERACEAE	*Dicerothamnus rhinocerotis* (= Elytropappus rhinocerotis)	ASTERACEAE	*Euryops abrotanifolius*
BRUNIACEAE	*Brunia* sp. /*Berzelia* sp. seedling	ASTERACEAE	*Ursinia paleaceae*
CYPERACEAE	*Cyperus denudalus*	ASTERACEAE	*Disparago*sp.
ERICACEAE	*Erica caffra*	CAMPANULACEAE	*Roella* sp.
MYRICACEAE	*Morella serrata*	CARYOPHLLACEAE	* *Spergula arvensis*
MYRTACEAE	*Metrosideros angustifolia* seedling	CYPERACEA	*Juncus capensis*
POACEAE	*Pennisetum macroaurum*	CYPERACEA	*Ficinia anceps*
PRIONIACEAE	*Prionium serratum*	CYPERACEA	*Pentaschistus pallida*
PROTEACEAE	*Protea nitida*	ERICACEAE	*Erica caffra*
PROTEACEAE	*Leucadendon* sp. seedlings	FABACEAE	*Psoralea* sp.
RESTIONACEAE	*Rhodocoma capensis*	LINACEAE	*Cliffortia cuneata*
RESTIONACEAE	*Restio tetragonus*	LOBELIACEAE	*Monopsis lutea*
RESTIONACEAE	*Restio sp.* seedlings	POACEAE	*Panicum maximum*
RESTIONACEAE	*Calopsis paniculata*	PRIMULACEAE	* *Anagallis arvensis*
		RESTIONACEAE	*Ischryrolepis* sp.
		THYMELAEACEAE	*Struthiola tomentosa*

CHAPTER 6: FINAL CONCLUSIONS AND RECOMMENDATIONS

6.1 HUMAN-MEDIATED CHANGE AND THE ROLE OF RESTORATION

Riparian areas worldwide have a long historical association with humans. With the escalation of international transport, organisms are being moved around the world at an unprecedented rate. Alien (or non-native) plants that land in suitable habitats, which are usually free of their species-specific pathogens or biological control agents, can thrive and may take over large areas of natural vegetation. Globally, vast terrestrial and aquatic areas are now facing devastating problems resulting from invasive alien plants. River systems are just one type of habitat affected by plant invasions, but they are particularly sensitive to invasion; they are among the most disturbed and invaded habitats in the world (Planty-Tabbachi *et al.,* 1996).

Restoration is aimed at returning lost or compromised ecosystem functioning to an area that has been disturbed in some way, usually through human-mediated changes. However, restoration strategies for complex riparian areas need to be properly researched, and may need to be site-specific. On a landscape scale, these conservation/restoration techniques should directly preserve the natural configuration of the river systems and thereby, the structural integrity of the community (Planty-Tabacchi *et al.,* 1996). Frequently, restoration projects are undertaken with goals that are unrealistic, because of a short-term commitment, which results in “quick fixes” being implemented that are badly designed and result in failed community restoration. However, in reality, complete restoration is generally impossible at a landscape scale because of economic and functional (land-use) restrictions (Holmes *et al*., 2005). Long-term commitment, practicality and viability should be the prerequisites in forming the outcomes for all restoration projects. Currently, in South Africa, most alien clearing initiatives have limited funds, human resources and knowledge to implement extensive restoration activities for post-cleared sites. Relying on the seed bank is a technique that has shown effective restoration results within fynbos plant communities, with additional restoration intervention only required after extensive invasion (Holmes, 2002). Certain riparian plant species are also known to rely on seed banks for community regeneration, although, it is not known to what extent this technique can be utilized after heavy invasion. This research project investigated several different aspects of riparian vegetation within the fynbos biome, with the aim of initiating the understanding of these systems, guiding future research in this area, and adding to the evaluation of restoration techniques currently used in post-cleared riparian areas within South Africa.

6.2 RESEARCH NEEDS

This is the first study on the restoration potential of riparian seed banks within the fynbos biome, and it has identified many issues that require further research. Prioritizing more long-term studies on seed longevity within riparian zones and the germination requirements for “key” riparian species (such as those identified in this study as being absent in the seed bank yet characteristic, dominant riparian species e.g. *Brabejum stellatifolium, Brachylaena neriifolia* and *Metrosideros angustifolia*) would greatly improve the current knowledge-based restoration recommendations for these areas. In addition, investigating the tolerance of these key riparian species to various disturbances, such as floods, fires and invasion, would be highly valuable in assisting to obtain a better understanding of the problem we face in terms of finding the most effective yet economically viable long-term solution to restoring post-cleared riparian areas. Additionally, a very large data base was collected for this study, but because of time constraints, not all aspects were investigated. It is suggested that a follow-up study looking at the relationship between bare-ground, rock-cover and seed bank density and various other geomorphological aspects (such as a measure of velocity, slope gradient etc.) would be interesting in terms of riparian seed bank dynamics within those areas, and could be linked to broad restoration trajectories for certain sections of the rivers.

Additionally, further long-term investigation is needed into the seed bank dynamics of invaded sections of riparian areas. This study has shed light on the initial post-recruitment potential community, and a definite community shift is evident which needs to be further explored. For example, several agricultural weedy species were identified in the seed bank with no presence in the above-ground vegetation. This suggests that the post-cleared community, although potentially “free” of invasive alien tree species, may have the potential to infest the indigenous community with other herbaceous alien species. These species are mostly identified as weeds of disturbed areas and are not currently classified as invasive. However they may disrupt the regeneration niche for indigenous species and may thus retard the restoration process. This area of the seed bank successional community structure needs to be investigated further in order to evaluate the best way of promoting indigenous community recovery.

6.3 USING "REFERENCE" DATA IN RESTORATION

Thirdly, I would like to briefly review the utilization of "reference" data. We chose to investigate the reference state of both the above-ground and seed bank communities of four rivers within this region, in order to evaluate the "before and after" restoration potential of fynbos riparian seed banks in relation to invasion. It is important that when using reference data, the restoration criteria not be misrepresentative of a realistic goal. Some authors are strongly against the use of reference data (Wohl, 2005; Hughes *et al.,* 2005), their reasons being that reference data's starting point is fairly subjective: Where is the most natural point in history on which to base your reference data? Additionally, often catchment parameters have changed since the times chosen as historical reference points. Such parameters might include water quality, flow volume, land-use and runoff parameters, and river management practices (Hughes *et al.* 2005). We chose our "reference" sites to be within areas of least anthropogenic disturbance (e.g. dams, canals, agricultural by-products etc.) and with less that 25% alien plant cover. This choice was partly based on availability of adequate reference sites, and partly because we felt it necessary to base our comparisons on a realistic form of a "natural" riparian system. In today's environment, we cannot exclude certain anthropogenic elements when evaluating the integrity of a riparian area. It is only realistic to accept that because of past choices (for lack of a better word), many invasive alien plants species will be part of our river systems for many years, if not become integrated forever.

As a result of the human population crisis worldwide, together with the effects of climate change, effective usage of natural water will become a higher priority than maintaining a naturally functioning riparian ecosystem. The latter are not necessarily mutually exclusive, however, as non-invaded riparian systems yield higher water delivery than those invaded by alien trees (Dye and Jermain, 2004) but it is suggested that climate change is potentially exacerbating the invasive alien species problem worldwide. It is stressed that a realistic approach be used when dealing with most restoration trajectories, particularly so within riparian areas. Such a realistic approach, however, needs to incorporate relevant science-based conservation methods to achieve long-term success.

6.4 STRUCTURAL SHIFT IN SPECIES COMPOSITION

Much of this thesis deals with the impacts of invasive alien plants (IAPs) on riparian areas, specifically the impacts relating to seed bank dynamics within the fynbos region in the Western Cape of South Africa. Although unique in terms of the plant species and environmental variables (such as fire, geomorphology, and rainfall etc.), it is expected that the impact of these IAPs will produce similar results elsewhere in terms of altering the natural cycles to their own advantage. Within this study, the reference sections of the rivers showed a more diverse structural composition (of both the above-ground and seed bank communities) and it is suggested that if a disturbance came through the area, the community would be able to bounce back. However, once invaded, growth form structure in above-ground and seed bank communities changed and the security of indigenous regeneration was threatened. There are many facets to this broad finding of this study.

The value of a seed source

Firstly, the value of a seed source in the system is of high importance in terms of the restoration potential of the community (Sedell and Reeves, 1990; Wassie and Teketay, 2006). In most areas that have a natural cycle of disturbance with low levels of invasion, patches of Afrotemperate Forest species exist (most of which are re-sprouters or do not have a presence in the seed bank), that are able to recolonize areas of disturbance with the use of animal, bird or water dispersal. Within this study, it was noted that even in areas of closed canopy invasion, some fragments of indigenous riparian community persisted, although this was not the case in all the invaded sites. It is therefore suggested that within invaded riparian sites where refugia of indigenous species do still exist, restoration intervention after clearing can be minimal and community recovery is generally predicted to be successful assuming follow-up treatments are frequent enough to keep re-invasion under control and damage to persisting and regenerating indigenous species is avoided. However, in invaded riparian areas with extensive invasion history and few or no refugia remaining to regenerate the community, restoration intervention in the form of re-establishing nodes of key riparian species, is highly recommended to facilitate the restoration process after alien clearing.

Within this study area and for the duration of the project, all four rivers offered adequate refugia upstream and as a result, this intervention may not be a requirement of the restoration process as long as the stream flow does not become interrupted (by further damming or canalization) and these refugia remain intact. It is suggested, therefore, that this intervention be adequately researched in terms of the specifics of each site, as it offers the potential to be both cost effective and highly beneficial to the long-term restoration of the riparian community of properly researched, implemented and managed. A small-scale off-site nursery which propagates the selected key riparian species (such as *Brabejum* *stellatifolium, Brachylaena neriifolia, Morella serrata* and *Metrosideros angustifolia* grown under natural conditions) for re-introduction into cleared riparian areas could be one such intervention. This suggested intervention may require an initial outlay of costs to set up the nursery, train the staff etc., but subsequent costs could be kept fairly low by using on-site seed and vegetative cuttings where possible to avoid plant purchasing costs. On-site collections also alleviate any introductions of new genetic material into the community, however, in practice it is not always possible if species have been eliminated from the catchment area.

6.5 THE ROLE OF ALIEN CLEARING INITIATIVES

Closely linked and part of the suggested recommendations is a substantial upgrade on level of training of the alien clearing team and ground staff responsible for managing the team. A horticulturalist could be employed to manage the nursery as well as basic riparian plant identification training for the ground team in charge of clearing the sites. Such training would greatly improve the restoration success as destruction of indigenous species during clearing would decrease, thereby reducing the need for further restoration interventions which means a reduction in project costs overall. The practice that is currently used is a "slash-all" and "poison-all" approach which is highly destructive to both the above-ground and seed bank community that may be co-existing with the identified alien plant species being cleared. If large slash piles are left on site they become major fire hazards that may burn at extremely high temperatures, thereby destroying most of the indigenous seed bank (Holmes, 1989; Holmes, 2002). It is suggested that the slash be removed from the area, where possible; and where not feasible, burning should be done during moderate weather conditions to reduce the risk of run-away fires and to limit seed bank damage. Additionally, on-site (or at least within the catchment) seed collection could be sown after slash is removed (or fire passes through) as a pioneer step in restoring the riparian scrub. Most of the key riparian species identified as being dominant throughout the study area (both in mountain stream and foothill sections, as well as on the wet bank/ dry bank transition), but absent from the seed bank are bird dispersed species. The establishment of a few patches of these species (where such refugial populations no longer exist) would greatly increase the success and possibly even the rate at which the riparian community recovers as once taller shrubs become established, birds could then assist in spreading these species throughout the catchment.

6.6 MANTAINING NATURAL RIPARIAN PROCESS IN RESTORATION

Finally, attaining an ecologically functioning riparian ecosystem after alien clearing is dependent on various pre-, during-, and post- clearing objectives. It is vital that the situation be assessed prior to clearing, taking into account the suggested post-cleared land-use, realistic ability of returning ecosystem functioning to an accepted state, and the necessary clearing and restoration requirements needed to attain this standard. Disturbance patterns within riparian zones are the major driving forces for the community's biodiversity and vegetation succession (Naiman and Décamps, 1997; Goodson *et al*., 2001). It must, therefore, be a primary objective to re-instate and then maintain natural disturbance regimes after alien clearing in order to secure long-term restoration. Whether this requires engineering interventions such as gabions to secure the geomorphological and thereby biological functioning will depend on site- specific requirements and objectives (Richardson *et al*. 2007). It is clear that if an adaptive and holistic approach to riparian restoration is used, success becomes more attainable.

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