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**Road reserves as conservation assets: exploring the  
species of conservation concern and the ecological  
condition of the N7 road reserve**

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- ABSTRACT -

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This thesis documents the ecological condition of the N7 road reserve, focusing on the vegetation condition and conservation value of the road reserve and adjacent farm land, and the plant species of conservation concern (i.e. Red List species) located within the road reserve. The aim was to assess the conservation value of the N7 road reserve and identify areas of particular interest and to communicate these findings to relevant conservation and management organisations.

The research was conducted using a number of innovative approaches. The initial fieldwork was completed by walking the entire transect in order to photograph and document the flora. The localities of each photo were recorded using 'geotagging' technology, a combination of camera and GPS devices. Vegetation condition was assessed relative to the adjacent farmland using a vehicle-based approach. The findings show great variation over the 684 kilometre transect.

The Fynbos biome is the only biome in which the condition of the road reserve vegetation is significantly better than the farmland vegetation condition. The Cape Lowlands are highly transformed and fragmented due to a significant history of land use and agriculture. The vegetation condition here is poor, although, the critical conservation status of the vegetation types means that any remaining vegetation has a high conservation value. The Oliphants River Valley has a more recent history of cultivation and the vegetation of this region is in relatively good condition and the conservation value is high, making this part on the N7 of high interest and conservation importance. The more arid parts of the transect, the Succulent Karoo and Desert biomes, have fewer disturbances in terms of intensive agriculture. The result is that the farmland is in significantly better condition than the road reserve. The conservation value is significantly lower in these biomes than in the Fynbos biome. Adjacent land use and road reserve management regime have a significant influence on the condition of road verge vegetation condition and threaten to reduce the potential conservation value that road reserves possess.

In total, ~ 670 plant species were identified in the N7 road reserve and of these, 62 are of conservation concern. These species are concentrated in the south of the transect with 44 occurring in the Fynbos biome. A number of endangered vegetation types in

the Cape Lowlands host a high concentration of species of conservation concern (25 sp/km<sup>2</sup>). This is comparable to the number of species of conservation concern in several nature reserves in the Cape Metropolitan Area. There are far fewer species of conservation concern in the Succulent Karoo (17) and Desert (1) biomes. While the density of species of conservation concern on the N7 is low relative to smaller and more tightly circumscribed nature reserves, the total number of Red List species is high.

The species of conservation concern in the N7 road reserve accrue some advantages compared to the populations in adjacent farmland. Overall, there were significantly more individuals in road reserve populations compared to farmland populations, although this was not the case for all species examined. The long-term persistence of these populations is unknown and is largely dependent on adjacent land use practices and appropriate road reserve management interventions. The findings of this research will inform future management in terms of the areas of conservation importance.

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## **CHAPTER 1 – GENERAL INTRODUCTION**

### **1.1 Background and Motivation for the research**

The broader aim of this research was to provide a detailed assessment of the ecological condition of the N7 road reserve. This was done by assessing the vegetation condition of the road reserve and adjacent farm land, and recording the plant species flowering in the road reserve, with a focus on species of conservation concern. The ultimate goal of the research was to identify areas of ecological importance and conservation potential, and to communicate these areas to road reserve managers and provide management recommendations.

There are a number of reasons why an in-depth look at the road reserves of this area is important. Firstly, the study area of this research lies in an area of unprecedented biological diversity. South Africa is among the most biologically diverse countries on the globe, consisting of eight different biomes and over 400 vegetation types (Mucina and Rutherford, 2006). It is one of the 17 mega-diverse countries which together contain over two – thirds of the world’s biodiversity (Mittermeier et al., 1997). While it occupies only 2% of the earth’s surface, South Africa contains over 20 000 plant species (which is 6% of the world’s known plants), 65% of which are endemic (von Staden et al., 2009), and 24% are of conservation concern (Raimondo and von Staden, 2009). Of the eight globally recognized biodiversity ‘Hotspots’ in Africa, three occur in South Africa (Le Roux, 2002), and two of these fall within the study area of this project: namely ‘The Cape Floristic Region’ and the ‘Succulent Karoo’. The N7 traverses a range of environmental gradients which pass through three biomes and 31 vegetation types on its way from Cape Town to the Namibia/South Africa border post at Vioolsdrif. Many rare species are known to occur in this area, particularly in the fragmented and transformed vegetation types close to Cape Town.

Secondly, these habitats and species will be placed under greater pressure in the future due to climate change. The ability of species to respond to human induced climate change is influenced by a number of factors, most importantly suitable available habitat (Brook et al., 2008; Keith et al., 2008). Complex interactions between disturbance regime, distribution pattern and population processes will determine whether climate change will expose species to increased risk of extinction (Keith et al., 2008). Species survival through migration is dependent on suitable intact

landscapes (Brook et al., 2008), effective connectivity between conservation areas (Rutherford et al., 1999) and the temporal scale of the migration keeping pace with that of the changing climate (Midgley et al., 2002). As Rutherford et al. (1999) point out, considering climate change, conserving species in fixed protected areas may be a fundamentally flawed approach. Road reserves have (albeit limited) potential to act as linear habitats that provide connectivity.

Already some South African species have been lost (Pimm et al., 1995) and it seems certain that under the current conditions, many more are to follow (Midgley et al., 2002; Midgley et al., 2003; Scholes and Biggs, 2005; Mucina and Rutherford, 2006). The evolutionary significance of such a reduction in genetic diversity remains uncertain (Charlesworth and Charlesworth, 1987). On theoretical grounds, genetic diversity and variation is considered vital for allowing both short-term adaptation to environmental fluctuations and long-term evolutionary change (Frankel and Soulé, 1981; Barrett and Kohn, 1991; Schaal et al., 1991). This highlights the importance of researching and conserving these areas.

Thirdly, there is no baseline data for the ecological condition of road reserves in South Africa. While South Africa has a considerable history of conservation action (Rouget et al., 2006), road and railway reserves do not form a traditional focus for conservation organisations (Cilliers and Bredenkamp, 2000). Although Dawson (1991) has completed roadside vegetation surveys there is no comprehensive analysis of the vegetation within South African roadsides (Cilliers and Bredenkamp, 2000). A large-scale inventory is required in order to determine what plant species occur and where (Esler and Milton, 2006). Bennett (1991) outlines a number of practical steps that can be undertaken to enhance and protect wildlife habitats on road sides. Most importantly, he calls urgently for inventories of the distribution, quality and conservation significance of existing road side vegetation. Through identifying and mapping of sites supporting rare plant species, uncommon plant communities and relatively intact natural vegetation, effective management of these areas from disturbance and destruction can be achieved (Bennett, 1991).

Lastly, there is an extensive road network in South Africa (366 872 kilometers of non-urban roads; 7200 kilometers of National Roads) ([http://www.nra.co.za/live/content.php?Item\\_ID=279&Revision=en/2&Start=0](http://www.nra.co.za/live/content.php?Item_ID=279&Revision=en/2&Start=0)) and the adjacent road reserves have the potential to play a role in conserving indigenous

flora. Road reserves have been thoroughly studied in many northern Hemisphere countries (Way, 1977; Kaule, 1986; Sykora et al., 1993; Zwaenepoel, 1993) and Australia (Lewis, 1991; Leigh and Briggs, 1992). These studies have highlighted the potential that they can play in hosting indigenous flora and conserving rare species. Protected from intensive cultivation and grazing that adjacent land is subject to, road reserves have the potential to retain indigenous flora and provide refuge for rare species.

Because of my personal interest in the vegetation of the N7 road reserve and considering the abovementioned need for baseline data relating to vegetation on road reserves in South Africa, it was decided to assess the N7 road reserve in the spring 2008.

## **1.2 General Approach**

Driving up the N7 during Spring 2006 and 2007 it was noted that an abundance of wildflowers were in bloom in the road reserve at this time. Stopping at roadside stops to explore the vegetation provided a small entry point from which to assess the vegetation, but was by no means enough to gain an overall picture of the vegetation in the road reserve. It was decided that exploring the road reserve on foot was the best way to explore all possible habitats. In order to make the study comprehensive, it was decided to walk from the South African Border with Namibia (Vioolsdrif) to Cape Town in the N7 road reserve to record the species flowering during spring. During subsequent research into such assessment methods I discovered that this approach to biodiversity inventory and monitoring had been popularized by J. Michael Fay in 1999. His 'mega-transect' through the Congo Basin lasted 455 days and took him 3,200 km across the breadth of Africa. His main purpose was to assess the ecological and environmental status of the region.

The approach for this study was to walk the mega-transect of the N7 photographing plant species to gain a list of spring flowering plants. The geographic location of each photograph was recorded using a geo-tagging technique of syncing the time stamp of each photograph with the GPS track recorded on the walk. Further fieldwork was conducted at different times of year to record species which were not flowering in the spring of 2008.

Such an approach to recording ecological and botanical data is a novel idea for South African road reserve research. It allows the researcher time to thoroughly assess and record data from a large linear area. Provided enough time is available this method allows the researcher to explore the entire transect rather than stopping to record data at predetermined plots. For practical reasons the overall vegetation condition in the road reserve was assessed on a separate fieldwork trip using a vehicle-based assessment approach.

Vehicle based surveys have been used for a number of road reserve studies in South Africa (Dawson, 1991; Milton and Dean, 1998). Rapid surveys of roadside vegetation using a qualitative approach focusing on vegetation structure can be conducted to an acceptable level of accuracy without the need for a detailed botanical survey and evaluation (Grievies and Lloyd, 1984). These studies rated the road reserve vegetation as high, medium or low (Grievies and Lloyd ,1984) or measured the percentage of road reserve that was well vegetated, moderately and sparsely vegetated (Palmer and Lewis, 1987). This study has followed a similar approach to the abovementioned studies, as well as recording the vegetation condition in the adjacent farmland to provide comparable data.

### **1.3 Objectives**

#### **1.3.1 Aims**

The project aims to present a comprehensive ecological assessment of the N7 road reserve. This includes recording the presence and distribution of Red Data Book (RDB) species in the N7 road reserve, as well as recording the vegetation condition and conservation value of the road reserve.

A secondary aim is to supply this data to road verge management agencies in order to inform future management and conservation of the road reserve.

A further aim is to test the method of using a mega-transect and ‘geo-tagged’ photographs as a means of assessing botanical data over large distances.

### **1.3.2 Key Questions**

1. What is the ecological condition and conservation value of the road reserve and adjacent farm land? How are they influenced by vegetation type, adjacent land use and road reserve management practices?
2. What patterns are associated with the distribution of Red Data Book (RDB) species along the N7 in relation to the vegetation type in which they are found, their growth form characteristics and their population status? Is there a conservation advantage accrued to RDB species in the road reserve when compared to adjacent populations?
3. What lessons/data arising from this study can be incorporated into future studies, management plans and land use practices?

### **1.4 Limitations**

There were several limitations encountered during the course of this research. Firstly, the appearance of vegetation is determined by the season and varies during the year. Dunnett et al. (1998) have shown, for example, the link between climate and vegetation cover in road reserves. The mega-transect walk was conducted in August – September 2008. This time of year is when most of the plants are in flower, and is a good time to conduct such research. However, many plants do not flower in springtime and these would have been missed. Most notably amongst the species which were likely missed were the autumn flowering geophytes within the Amaryllidaceae and the early winter flowering geophytes (e.g. Oxalis). Also many of the dwarf leaf succulent shrubs (Aizoaceae) from the Knersvlakte flower before August. Although further fieldwork was conducted at other times of the year, it was not logistically possible to observe the study area for a full year. In addition, the vehicle-based survey of the vegetation condition of the road reserve was conducted in December 2008 when most of the growth and flowering for the season was over. This would no doubt influence the qualitative observations of the road reserve condition. However, this probably renders the estimated values more conservative than would otherwise have been the case. The year in which the study took place would also influence the findings as the vegetation will differ from year to year depending on environmental and climatic variables.

Secondly, a number of difficulties are related to a rapid vehicle-based survey. Drive-by surveys are best completed by a trained observer who can identify plant species based on shape and colour, both of which are variable depending on the season and habitat (Milton and Dean, 1998). Vegetation quality is subjectively assessed in a vehicle based survey and lacks the rigor of a comprehensive analysis (Dawson, 1991). The visibility of certain species, particularly smaller species is limited and these are likely to be overlooked when assessing roadside vegetation (Milton and Dean, 1998).

Thirdly, identification of plant species was largely achieved through photography which is less reliable than collecting plant specimens. Plants species were photographed during the walk of the mega-transect and plant identification was made from these photographs. Precise identification of plant species is usually done from pressed herbarium specimens. However, it was not practical to collect so many plant specimens while walking the mega-transect. While many highly qualified experts (See Appendix 2) helped in the identification of these photos, it was not possible in some instances to be absolutely certain of species identification from the photographs. Several additional trips were therefore made along the N7, often in the company of specialists, to visit specific populations, particularly of the RDB species, and to confirm their identifications. Furthermore, the researcher's knowledge of the flora also limits the scope of plants recorded within the transect. Those families and genera which are well know to the researcher are likely to be well sampled, while those less well known are likely to be under sampled. These factors all influence the scope and accuracy of the final list of species documented in a study of this nature.

Finally, while walking within the N7 road reserve, the side of the road with the most abundant vegetation was chosen, except in cases where personal safety was of greater concern. Although observations were made across the road to the vegetation growing on the 'other' side, it was impossible to assess both sides of the road at the same time.

### **1.5 Thesis Structure**

Chapter 2 describes the study area in more detail, providing background information of the biomes and vegetation types present, as well as a history of human occupation and activities along the area now occupied by the N7.

Chapter 3 is a comprehensive literature review of academic publications relating to road reserves as potential conservation areas. The literature focuses on the positive

role that road reserves play in conserving indigenous vegetation and hosting rare and endangered species, as well as on their potential negative impacts as vectors for exotic and invasive species. The literature on fragmented habitats and the benefits of corridors in conservation is also reviewed. Management strategies and human impacts are also explored in this section.

Chapter 4 is an assessment of the ecological condition of the N7 road reserve. The chapter explores the road reserve condition as well as the condition of the adjacent land and examines the conservation value of the road reserve. The changes in the road reserve condition and the conservation value over different biomes and vegetation types are explored in relation to adjacent land use, management practices and environmental variables.

Chapter 5 looks at the Red Data Book (RDB) species occurring on the N7. The RDB species and their growth forms are listed. This is followed by a look at the distribution of the RDB species to assess whether they occur more frequently in relation to particular vegetation types, environmental variables and the condition of the road reserve vegetation. The population status of the RDB species is explored to assess whether they accrue any significant advantage over populations growing in the land adjacent to the road reserve.

Chapter 6 provides a synthesis and conclusion to the study. It provides an assessment of the use of a 'mega-transect' as a method for analysing roadside vegetation in South Africa. This is followed by a summary of the key findings made in the two data chapters of the thesis. Lastly, the chapter provides a number of recommendations for further research, road reserve management and land use practices in accordance with the aim of the study.

## **CHAPTER 2 – STUDY AREA**

### **2.1 Introduction**

The study area for this research spans the entire length of the N7, the national road between Cape Town (N1/N7 interchange) and the South Africa/Namibia border (Vioolsdrif). The focus of the study is the N7 road reserve, the strip of land on either side of the road, between the road and the fence line that demarcates privately owned land. Because the N1/N7 interchange has been explored previously and is known to host indigenous vegetation and species of conservation concern (McKenzie and Rebelo, 1997) it was not included in this study. The N7 passes through two provinces, three biomes and over 30 different vegetation types as well as varied climatic, geological and environmental gradients. This chapter will first describe the environmental conditions of each biome in the study area, and then explore the land use and road construction history which has impacted on the current vegetation condition of the N7.

### **2.2 Geology and soils**

#### **2.2.1 The Fynbos biome**

The many geological substrates that support the vegetation of the Fynbos biome are prerequisite for the evolution of the remarkable diversity of plant life and vegetation types that occur here. One of the most fascinating botanical destinations in the world, the Fynbos biome occurs on the following rock types: sandstone, quartzite, granite, gneiss, shale's and limestone (Rebelo et al., 2006). The variety of soils and vegetation types in the study area result in the N7 passing through many vegetation units, including Sandstone Fynbos, Sand Fynbos, Shale Renosterveld, Granite Renosterveld and Silcrete Renosterveld (Rebelo et al., 2006).

#### **2.2.2 The Succulent Karoo biome**

The Succulent Karoo biome covers a large area with a complex geological makeup (Mucina et al., 2006). The N7 passes through a number of physiographical (soil-landscape) regions of significance in this biome, including the Knersvlakte in the south, and the 'open and closed' mountains and hills of Namaqualand in the north (Mucina et al., 2006). The soils of the Knersvlakte are generally base-rich to calcareous, reddish in colour and shallow in character. The mountains and hills of

Namaqualand form part of the escarpment and have dominant rock types of granite and gneiss. The soils are generally base-rich to calcareous, reddish and shallow (Mucina et al., 2006).

### **2.2.3 The Desert biome**

The Desert region is comprised of two major belts; the Namaqua-Natal metamorphic belt and the Gariep metamorphic belt. The result is that a variety of rock and soil types are present in the study area, including alluvial deposits, shale, quartz and limestone (Jürgens, 2006).

## **2.3 Climate**

### **2.3.1 The Fynbos biome**

The south-western Cape experiences a Mediterranean type climate, characterised by cold, wet winters and hot, dry summers (Cowling and Holmes, 1992). The south-western Cape and the length of the west coast of South Africa and Namibia are characterised by extreme summer aridity. This occurs largely as a result of the stable South Atlantic anticyclone which prevents major vertical air movement (Fuggle, 1981) and which results in the relatively dry, summer conditions of the south-western Cape. In winter, the South Atlantic anticyclone shifts northwards allowing the influence of the westerlies and cyclonic frontal weather to influence the Cape. The associated winter rain is proportionately highest in the west of the Fynbos biome and decreases eastwards and northwards (Rebello et al., 2006).

Generally, areas within the higher mountainous regions receive more rain than the low lying areas (Cowling and Holmes, 1992). The mountainous regions also experience the coldest temperatures within the Fynbos biome, and the lowlands the warmest (Rebello et al., 2006). The west also receives greater seasonal temperature ranges and higher annual pan evaporation (Taylor, 1996). All of these factors result in significant variations in the local climates of the study area, with corresponding differences in vegetation.

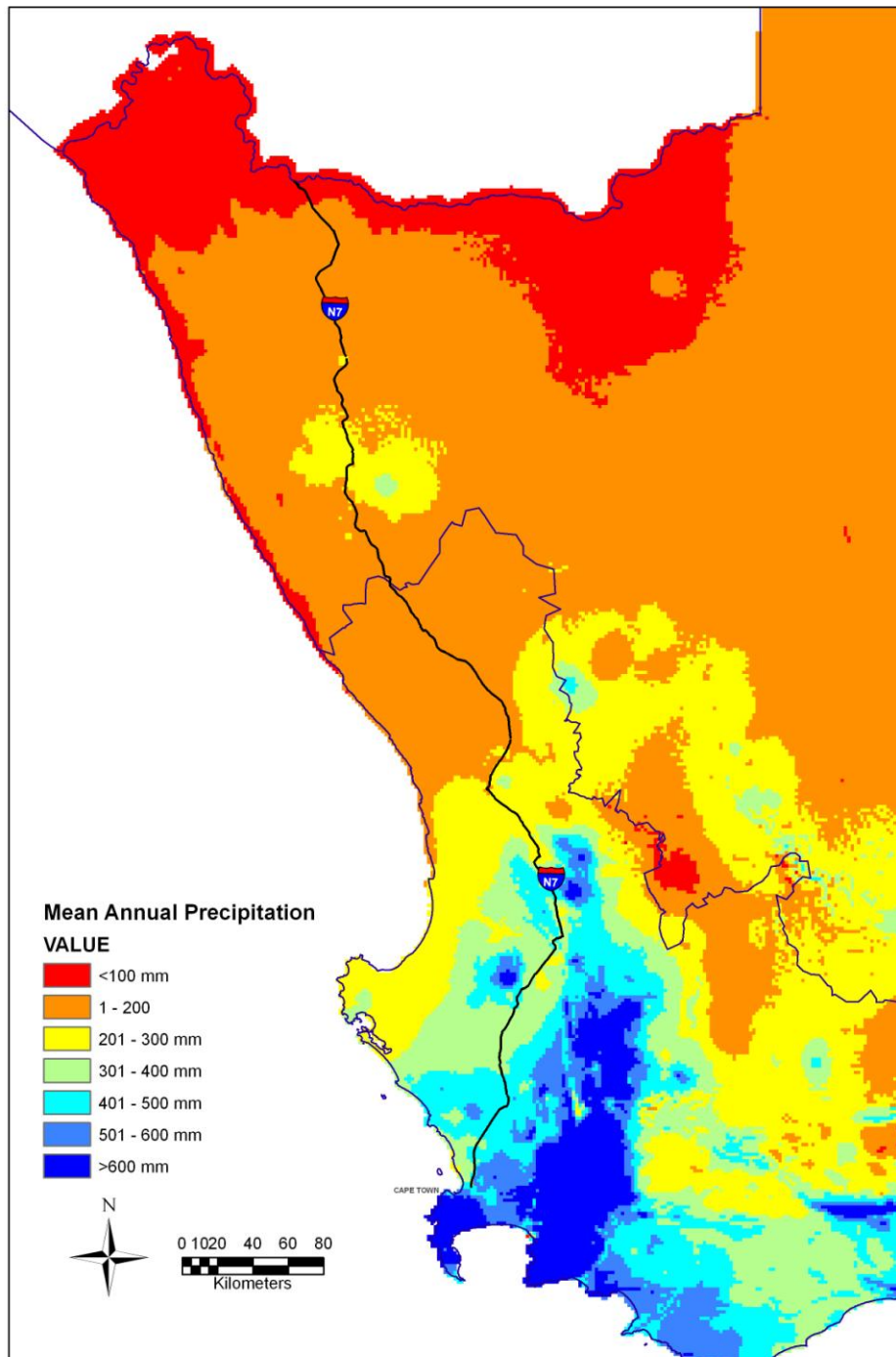


Figure 2.1: Map of the study area showing MAP (Mean Annual Precipitation) and the route of the N7 from Cape Town to Violsdrif on the Orange River.

### 2.3.2 The Succulent Karoo biome

The Succulent Karoo biome is a semi-desert region, largely influenced by the ocean, which has an even and mild climate (Mucina et al., 2006). The area of the Succulent Karoo biome that forms part of this research falls within a typical winter-rainfall

region, with a Mean Annual Precipitation (MAP) of 100 – 200 mm. This rainfall regime is distinctive in its relatively high predictability of rainfall and relatively rarity of prolonged droughts (Hoffman and Cowling, 1987; Desmet and Cowling, 1999). This element of high predictability is largely responsible for the high species diversity in this region, as it is with other winter-rainfall semi-deserts throughout the world (Cowling et al., 1999).

The Mean Annual Temperature (MAT) for the biome is 16.8 °C, with most vegetation units showing a range between 16 °C and 18 °C (Mucina et al., 2006). The warmest temperatures are associated with the low-lying coastal areas which experience catabatically warmed berg winds which descend from the higher altitudes of the interior (Rutherford and Westfall, 1986) particularly in the winter months. These conditions can persist for several days and have a significant effect on the vegetation (Cowling et al., 1999).

### **2.3.3 The Desert biome**

The Desert biome is by definition a place of extreme aridity. MAP is generally lower than 70 mm, while MAT is over 20 degrees Celsius for most vegetation units. The South Atlantic high-pressure cell has a strong influence on the general aridity of the coastal area during the summer months. In the eastern part of the Desert biome (Gariep Desert) a low pressure system, which frequently develops in the Orange River basin, is responsible for the late summer rains and high inter annual variability (Jürgens, 2006). The coastal regions of the Desert biome experience a more evenly-distributed rainfall pattern with a small peak in the winter months. This is due to the cyclonic winter rain and coastal fogs experienced in this region (Jürgens, 2006).

## **2.4 Vegetation**

### **2.4.1 Biomes**

Three biomes fall within the study area of this project. Each will be discussed in terms of their biodiversity and current threats. A selection of photographs depicting each of the biomes is shown on the CD in Appendix 1.

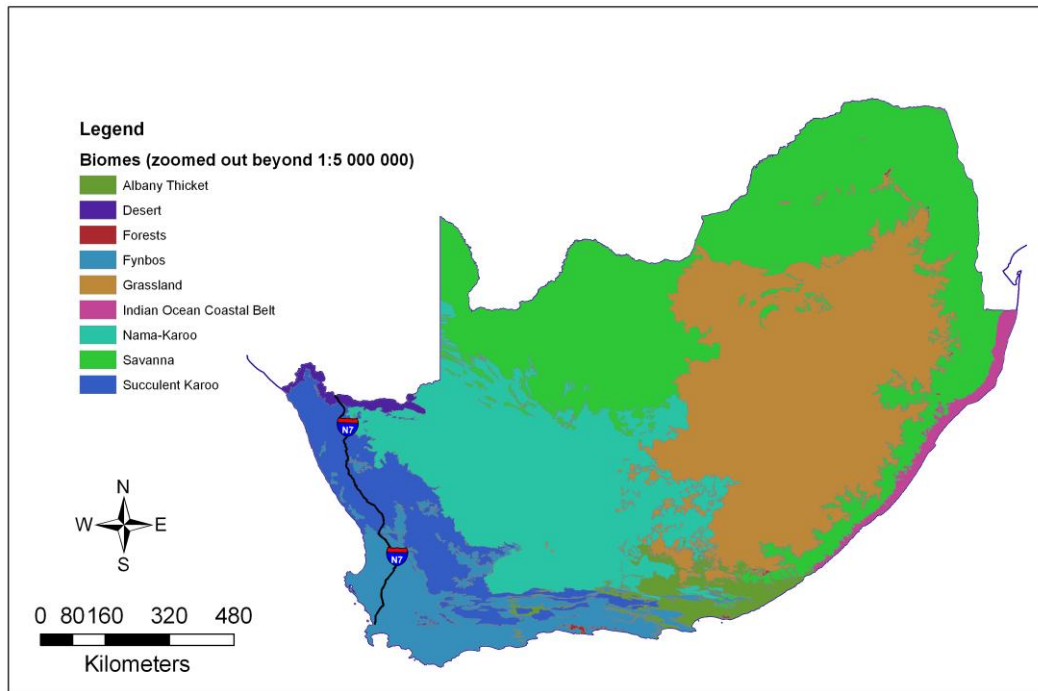


Figure 2.2: The Biomes of South Africa, showing the N7 on the western side of the country.

#### 2.4.1.1 Fynbos

The Cape Floral Kingdom, one of the world's six floral kingdoms, occurs in the area which corresponds with the Fynbos Biome and can be considered synonymous. It is the world's smallest, richest and most threatened floral kingdom and the only one to fall entirely within one country. The Cape Floral Kingdom covers only 4% of the land area of southern Africa, yet holds over 40% (9,000) of the plant species for the region. Many of the families (5), genera (160) and species (6,192) are endemic and have significant horticultural and medicinal uses (Le Roux, 2002).

The Fynbos Biome is well known for its high levels of diversity and endemism. However, some three-quarters of all plants in the South African Red Data Book (RDB) occur in the Cape Floral Kingdom. Furthermore, as many as 1,700 plant species are threatened to some extent with extinction (Mucina et al., 2006). By 1995, 36 Fynbos species were considered extinct (Pimm et al., 1995). After the Grassland biome, the Fynbos biome has lost the most biodiversity in the southern Africa region (Scholes and Biggs, 2005).

The major threats to the Fynbos Biome are increasing urban expansion, habitat loss through agriculture, inappropriate fire regimes, encroaching alien vegetation and climate change (Mucina et al., 2006). Due to the high levels of endemism in Fynbos, any loss of habitat due to climate change is likely to result in extinctions. According to Thomas et al. (2004), 27% of all South African *Proteaceae* will become extinct between the years 2000 – 2050 due to land use and mid-range climate change scenarios. These figures are supported by the work of Midgley et al. (2002) who predict that the Fynbos Biome will lose between 51% - 65% of its area by 2050. Approximately 10% of the endemic *Proteaceae* have their ranges restricted to the lost areas, predominantly in the north of the Biome (Midgley et al., 2002; Midgley et al., 2003). These figures suggest an enormous threat to the genetic diversity of the remaining populations. Furthermore, the predicted rate of climate change is likely to exceed the rate at which populations might be able to respond to climate change through migration. This is due to the fact that regeneration and dispersal events are largely limited to periods immediately after a fire, which occurs every 12 – 25 years (Midgley et al., 2002).

Renosterveld, a distinct vegetation found within the Fynbos Biome, occurs predominantly on granite and shale-derived, relatively rich soils. It faces similar threats to Fynbos, but because it is usually restricted to lowland habitats, it is most often cleared for agricultural land and nearly 85% has already been transformed (Kemper et al., 1999). Lowland habitats in the Fynbos biome have been significantly transformed and very little undisturbed vegetation remains in protected areas. Only 5% of lowland Fynbos and 1.6% of Renosterveld are officially conserved (Low and Rebelo, 1996). Considering these figures, Renosterveld is a high priority conservation area in South Africa (Kemper et al., 1999).

#### **2.4.1.2 Succulent Karoo**

The Succulent Karoo biome hosts the world's richest succulent flora and a high number of endemic and RDB plant species. There are over 5,000 species in this Biome, nearly 2,000 of which are endemic. Over half of all plants are succulents, particularly in the families *Mesembryanthemaceae*, *Euphorbiaceae*, *Asphodelaceae* and *Crassulaceae* all of which have levels of endemism over 80% (Le Roux, 2002).

Even though the high species richness and unique global status of the biome require urgent conservation attention, less than 6% of the biome is officially conserved. According to Scholes and Biggs (2005), the greatest loss of biodiversity in the arid shrublands of South Africa is land degradation. This means that the land use practices do not alter the vegetation cover type but lead to a continual loss in ecosystem productivity through, for example, overgrazing. This degradation can change species populations by 40 – 60%, which is less impact per unit area than urbanisation and cultivation (Scholes and Biggs, 2005). Many of the rare plants in the Succulent Karoo Biome are threatened by cultivation and livestock farming (Hall, 1987). O’Farrell and Milton (2006) suggest that there is a growing need for additional conservation areas in the Karoo which could provide refugia to indigenous plant communities and species. Particular attention should be paid to species palatable to domestic livestock and areas that may facilitate recolonisation of the adjacent rangelands.

Climate change models predict that within 50-100 years, the area covered by the Succulent Karoo biome will be so arid that only the hardiest of plants will survive (Mucina et al., 2006). Another study which focuses on the Succulent Karoo biome suggests that under conditions of doubled atmospheric CO<sub>2</sub> concentrations, the biome would lose up to 80% of its range as it shifts south to the cooler and wetter areas of the Western Cape (Hannah et al., 2002; Midgley and Thuiller, 2007).

#### **2.4.1.3 Desert**

The third and final biome covered by the study area is the Desert Biome. This desert is of global interest because of its long history of aridity, high diversity of organisms (including many endemics), wide range of adaptations to aridity and inclusion of both summer and winter rainfall regions (Jürgens, 2006). This extremely arid biome has less than 20% of its area conserved and is threatened by mining, agriculture, overgrazing and climate change (Jürgens, 2006). It is also the smallest biome in South Africa, occupying the area 20 – 30 km south of the Orange River in the north-western corner of the country (Le Roux, 2002).

## 2.4.2 Vegetation types

The N7 passes through 31 different vegetation types between its starting point near Cape Town and its end at Vioolsdrif on the South Africa/Namibia border (See Figure 2.3)

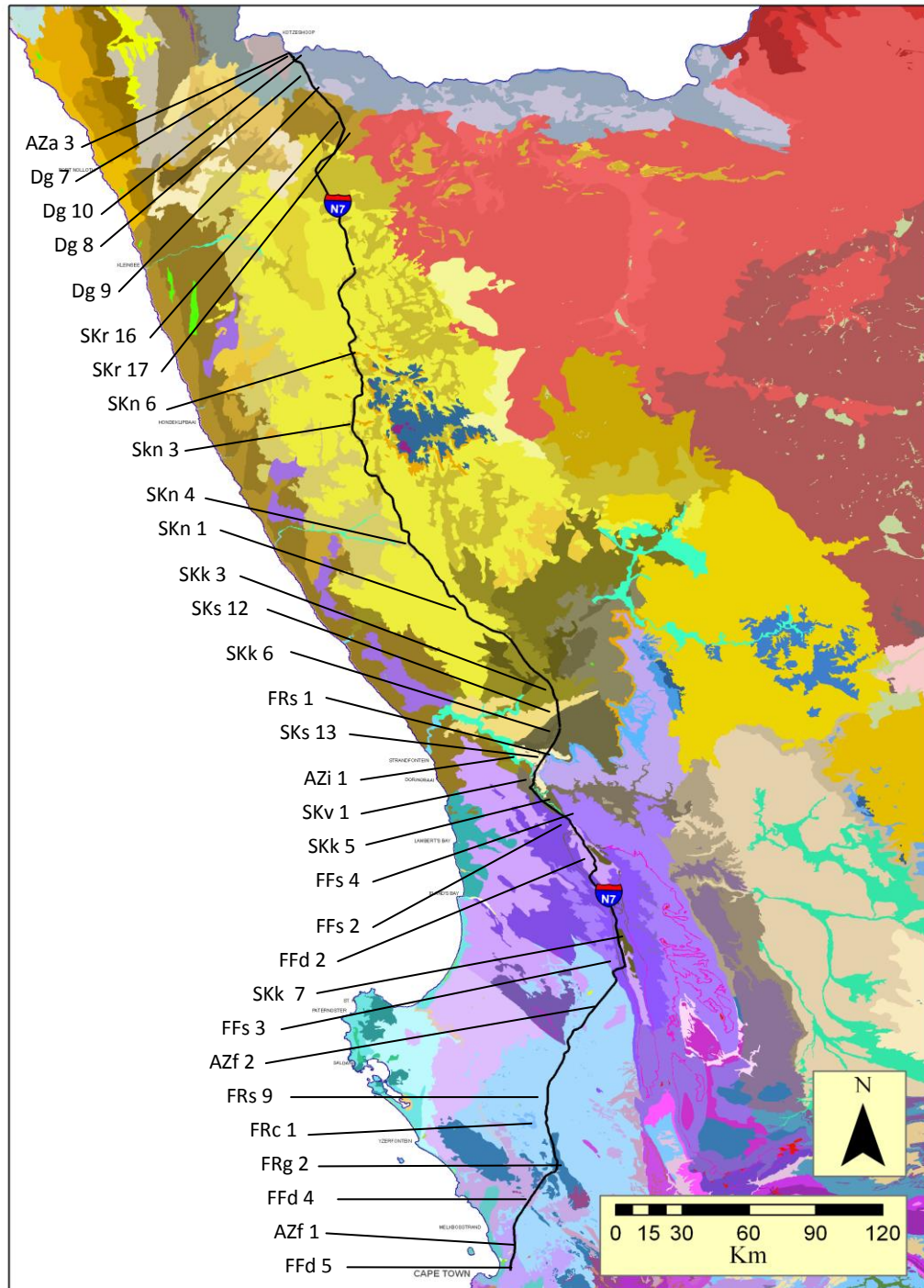


Figure 2.3: Map of the study area showing the 31 different vegetation types on the transect. The full names for the vegetation type codes are in Table 2.1 below.

Table 2.1: Vegetation types of the N7, ordered from south to north. The Table includes summarised environmental data and conservation information derived from Mucina and Rutherford (2006). (Certain information from the Desert biome is not available (n/a) while the conservation status of each vegetation type is included in Table 4.6 in chapter 4)

Vegetation Type	Code	Area (km <sup>2</sup> )	Altitudinal range (m)	MAP (mm)	MAT (°C)	Geology/Soils	% Conserved	% Intact
Cape Flats Sand Fynbos	FFd 5	546	20 - 200	576	16.2	Tertiary sands Lamotte form	0.3	19
Cape Lowland Freshwater Wetlands	Azf 1	72	0 - 400	566	16.5	Derived from Cape Supergroup shales and Cape granites	16	84.9
Swartland Shale Renosterveld	FRs 9	4946	50 - 350	430	17.2	Malmesbury Group shales	0.9	9.6
Swartland Silcrete Renosterveld	FRc 1	100	40 - 220	425	16.9	Silcrete layers over Malmesbury Group Shale	0.9	10.2
Atlantis Sand Fynbos	FFd 4	698	40 -250	438	16.6	Acid tertiary sands	6	60
Swartland Granite Renosterveld	FRg 2	947	50 - 350	520	16.3	Glenrosa and Mispah soils from Cape Granite	2.6	21.4
Cape Vernal Pools	Azf 2	< 1	50 -850	342	17.3	Malmesbury Group shales	0	11.9
Oliphants Sand Fynbos	FFs 3	1059	200 - 1200	449	16.1	Ordovician soils; Table Mountain Group	67	92
Leipoldtville Sand Fynbos	FFd 2	2756	50 - 350	263	17.6	Tertiary sands	0	44.9
Citrusdal Vygieveld	SKk 7	127	180 - 700	316	17.9	Shale and quartzite of the Cape Supergroup	4.2	66

Graafwater Sand Fynbos	FFs 2	1254	100 - 650	354	17.1	Ordovician soils; Table Mountain Group	0	71
Cederberg Sandstone Fynbos	FFs 4	2449	300 - 1800	393	15	Ordovician soils; Table Mountain Group	49	84.9
Vanrhynsdorp Gannabosveld	SKk 5	971	100 - 300	163	18.2	Gariiep Supergroup	0	79.5
Doringrivier Quartz Karoo	SKv 1	472	60 - 500	196	18	Table Mountain Group quartzites	0	85.2
Namaqua Riviere	Azi 1	855	0 - 800	147	18.1	Quaternary fluvial sediments	0.1	80
Klawer Sand Shrubland	SKs 13	126	40 - 320	192	18.4	Deep sands over Gariiep Supergroup schists and phylites	0	94.3
Vanrhynsdorp Shale Renosterveld	FRs 1	240	150 - 880	283	17	Knersvlakte Subgroup; Vanrhynsdorp group	3.8	97.9
Knersvlakte Dolomite Vygieveld	SKk 6	58	40 - 180	146	18.6	Namaibian Gariiep Supergroup	0	97.9
Namaqua Spinescent Grassland	SKs 12	522	60 - 340	151	18.1	Alluvium sediments over Gariiep Supergroup metapelites	4	96
Knersvlakte Quartz Vygieveld	SKk 3	1211	40 - 460	116	18.1	Vanrhynsdorp Group	5.1	97.7
Namaqua Klipkoppe Shrubland	SKn 1	10936	120 - 1260	161	16.6	Mokolian granites and gneisses	5.8	95
Namaqua Heuweltjieveld	SKn 4	2536	100 - 540	115	17.8	Mokolian granites and gneisses	10.5	96.5
Namaqua Blomveld	SKn 3	3809	460 - 1080	145	16.7	Mokolian granites and gneisses	1.5	94

Kamies Mountain Shrubland	SKn 6	425	800 - 1160	230	15.8	Bitterfontein quartzites; Bushmanland Group	1.6	98.4
Eenriet Plains Succulent Shrublands	SKr 17	260.8	650 - 950	122	17.3	Precambrian Namaqualand Metamorphic Complex	0	99.5
Umdaus Mountain Shrubland	SKr 16	432.9	500 - 1000	116	17.4	Mokolian granites, gneiss and schists	0	99.9
East Gariiep Plains Desert	Dg 9	1578.0	250 - 900	45 - 80	21.2-23.3	Quaternary sheet-wash alluvial deposits	0	
Southern Nababiepsberg Mountain Desert	Dg 8	343.2	250 - 984	50 - 100	n/a	Nama Group shale, quartzite and limestone	0	100
Eastern Gariiep Rocky Desert	Dg 10	2568.5	250 - 1205	45 - 80	n/a	Stalhoek complex; Bushmanland Group	0	99.7
Northern Nababiepsberg Mountain Desert	Dg 7	245.9	180 - 765	44	23.6	Schwarzrand Subgroup shale, quartzite and limestone	0	98.6
Lower Gariiep Alluvial Vegetation	Aza 3	571.5	0 - 1000	131	19.2	Dundee and Oakleaf soil forms	6	50

## **2.5 History**

The current condition of the vegetation within the N7 road reserve and in the adjacent farm land is determined to large degree by the historical use of this land. The history of the area occupied by the present route of the N7 will be discussed in two separate sections. The first relates to the occupation and use of land by the indigenous and colonial people in the study area. The second will outline the history of travel and road construction from Cape Town, into the Cape lowlands, over the mountains and past the Oliphants River into Namaqualand.

### **2.5.1 Land Use**

Before the arrival of European colonists and intensive agriculture the indigenous pastoralists of the Cape, the Khoikhoi, were using the veld for grazing their livestock. The group of Khoikhoi that occupied the Swartland were the Cochoqua's. Their centre of transhumance was in the area around modern day Mamre, on the fertile, well-watered shale soils that provided good year-round grazing (Penn, 2005).

The first permanent European settlement in the Cape was made by the Dutch East India Company (VOC) in an attempt to supply their passing ships with sufficient supplies of meat, vegetables, grain and water. The VOC had struggled to do this and towards the end of the seventeenth century had created a class of independent farmers – the free burghers – and had begun to grant them land on which to grow their crops (Penn, 2005). Thus began the expansion of agriculture in the Cape, including the area currently traversed by the N7. Initially the free burghers were prohibited from the livestock trade as the VOC obtained the bulk of their meat from the local Khoikhoi pastoralists in exchange for tobacco, alcohol and other gifts. These terms of trade favoured the VOC so much that they did not want the free burghers to encroach on their interests (Penn, 2005). The supply of meat became a problem and being largely dependent on the Khoikhoi the VOC decided to open the trade of livestock to the free burghers in July 1695. In order to strengthen the Cape and its capacity to produce food, the VOC began offering free transportation to the Cape and free land to the immigrants (Penn, 2005).

In 1705 colonial frontier farmers first moved their livestock north of the Berg River to the Piketberg area. The first official grazing permits for Piketberg were issued between 1707 – 1709 (Penn, 2005). The Khoikhoi were not completely excluded from

food production in the Cape and in 1688 Simon van der Stel wrote that the Khoikhoi were involved in helping the colonists with their agriculture during the 'harvest or ploughing season' (Penn, 2005).

Colonial stock farmers continued to expand north and in 1725 the first loan farms were allocated over the Piekenierskloof pass in the Oliphants River Valley. By 1732 there were farms along the entire length of the Oliphants River. There were loan farm all the way to the confluence of the Oliphants and the Doorn Rivers (Doring River), which is close to present day Trawal. There were also farms as far north as the Wiedouw River (Penn, 2005).

There was no cultivation of land in Namaqualand until European farmers arrived after the 1750's. The first areas to be cropped were the low lying areas with deeper soil. An early traveller to the area of Bitterfontien recorded a farmer ploughing his land in 1779 (Hoffman and Rohde, 2007). Indigenous pastoralists (Namaqua people) adopted the practice of cultivation early in the 19<sup>th</sup> century (Hoffman and Rohde, 2007).

Wheat was the most common crop in Namaqualand but smaller amount of barley, rye and oats were also cultivated. The area of land being cultivated in Namaqualand peaked in 1971 at just under 30,000 ha. By 1988 the area had declined by nearly two-thirds to just over 11,000 ha (Hoffman and Rohde, 2007). The success of these crops is highly dependent on rainfall and the areas farther from the high rainfall area of the Kamiesberg which have been abandoned are being colonized by indigenous shrubs (Hoffman and Rohde, 2007).

### **2.5.2 Travel and road construction**

The route that travellers used to get to Namaqualand and further north has changed many times over the years (Figures 2.4; 2.5 & 2.6). Olaf Bergh (1682) and Simon van der Stel (1685) both avoided crossing the Oliphants River Mountains by keeping to the coastal belt to the west of the mountains (Blue route in Figure 2.4). However, even before these early travellers, a number of expeditions to the Oliphants River Valley had been made by crossing the mountain range in the region of present day Piekenierskloofpas. Pieter van Meerhof was involved in a number of these expeditions, including the first one that saw colonists cross the mountains in 1660. They had been searching for a passage over the mountains for nine days when they

met a group of 20 Bushmen who showed them a suitable path by which to cross the mountains and descend into the valley. As they descended they saw a herd of 200 – 300 elephants on the opposite slopes and so named the river the ‘Oliphants River’. This approach to the Oliphants River is the same one that is used today, as is shown from information in the journals of the explorers of 1660. In an expedition in 1661 van Meerhof accompanied Pieter Everaert on another trip across the Piekenierskloofpas. On this trip, Everaert travelled further north from the Oliphants River and got as far as the Van Rhyne’s Dorp district (Mossop, 1927). They encountered a large encampment of Namaqua people (about 700) which included 4000 cattle and 3000 sheep (Hoffman and Rohde, 2007). Olaf Bergh travelled to Namaqualand in 1682 and camped near present day Garies and was visited by 200 inquisitive Namaqua people (Mossop, 1931). It wasn’t until Simon van der Stel’s 1685 journey that Springbok and the Koperberg were discovered (Mossop, 1927).

A number of developments in the 1800’s gave the ‘northern highway’ more permanence. Clanwilliam was founded in 1810, the Piekenierskloofpas was reconstructed as Grey’s Pass in 1848 and bridge was built over the Oliphants River at Citrusdal (Mossop, 1927). Initially the route along the Oliphants River was on the western side of the river, but then changed to the eastern side when the bridge was constructed (Mossop, 1927).

Grey’s pass was due to be reconstructed and work began in 1939, but was soon delayed due to the outbreak of World War Two. Work recommenced in the 1950’s and was completed in 1958. It was also at this stage that the road on the western bank of the Oliphants river was constructed, thus bypassing Citrusdal and Clanwilliam. The new pass was renamed the Piekenierskloofpas, reverting to the original name (Ross, 2002). The name Piekenierskloofpas (pass of the Pikemen) comes from the conflict between the Bushmen leader Gonnema and the frontier farmers. After a raid on some farms, Gonnema and his people were followed up a kloof by European soldiers, but the Bushmen escaped up Piekenierskloof into the mountains (Bulpin, 1980).

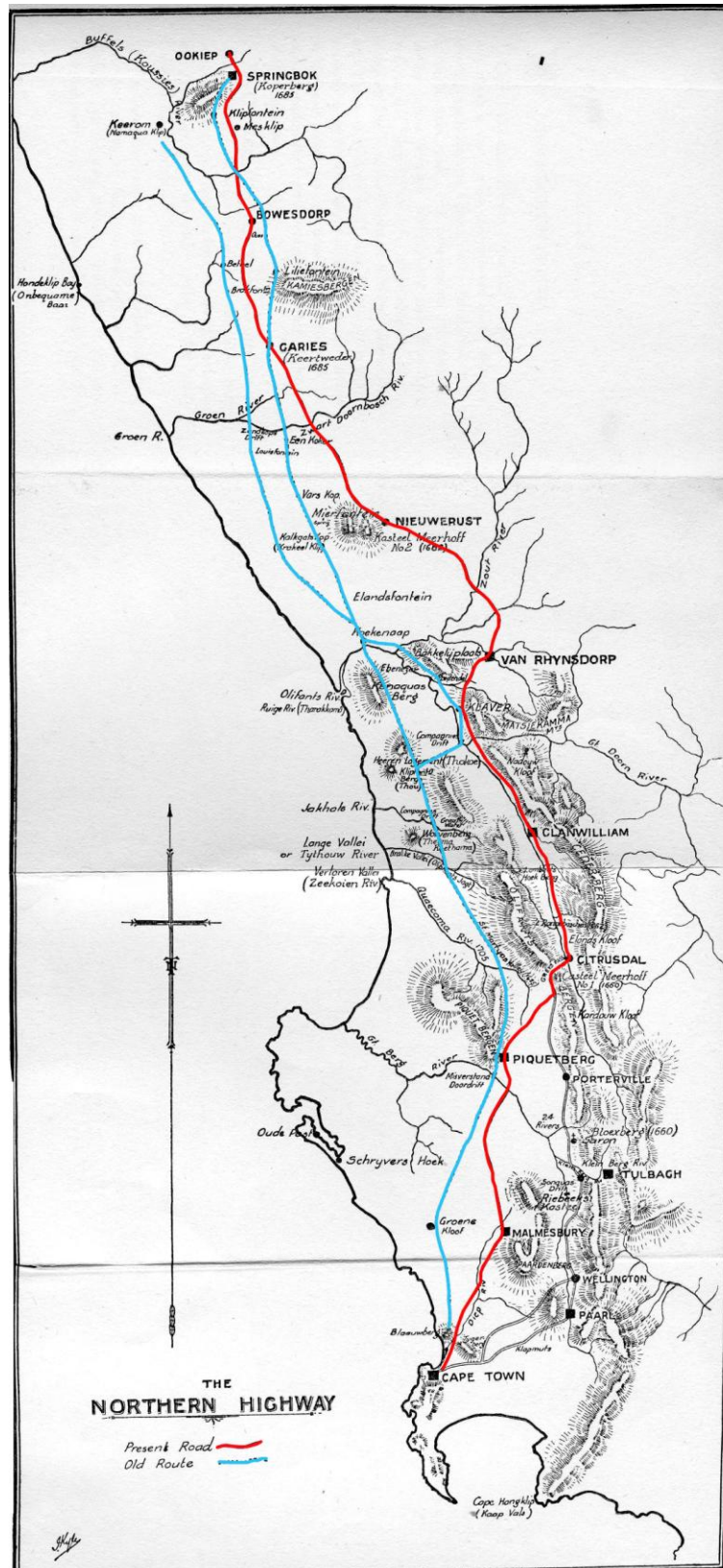


Figure 2.4: Route of 'The Northern Highway' in 1927 (in red). The 'old route' used by early travellers to Namaqualand and further north is indicated in blue. Note that the route at this time ends at Okiep (Mossop, 1927).



Figure 2.5: Topographic map of the Union of South Africa in 1936 showing the route of the N7 (in red) from Cape Town to Vioolsdrif (Lewis, 1936).

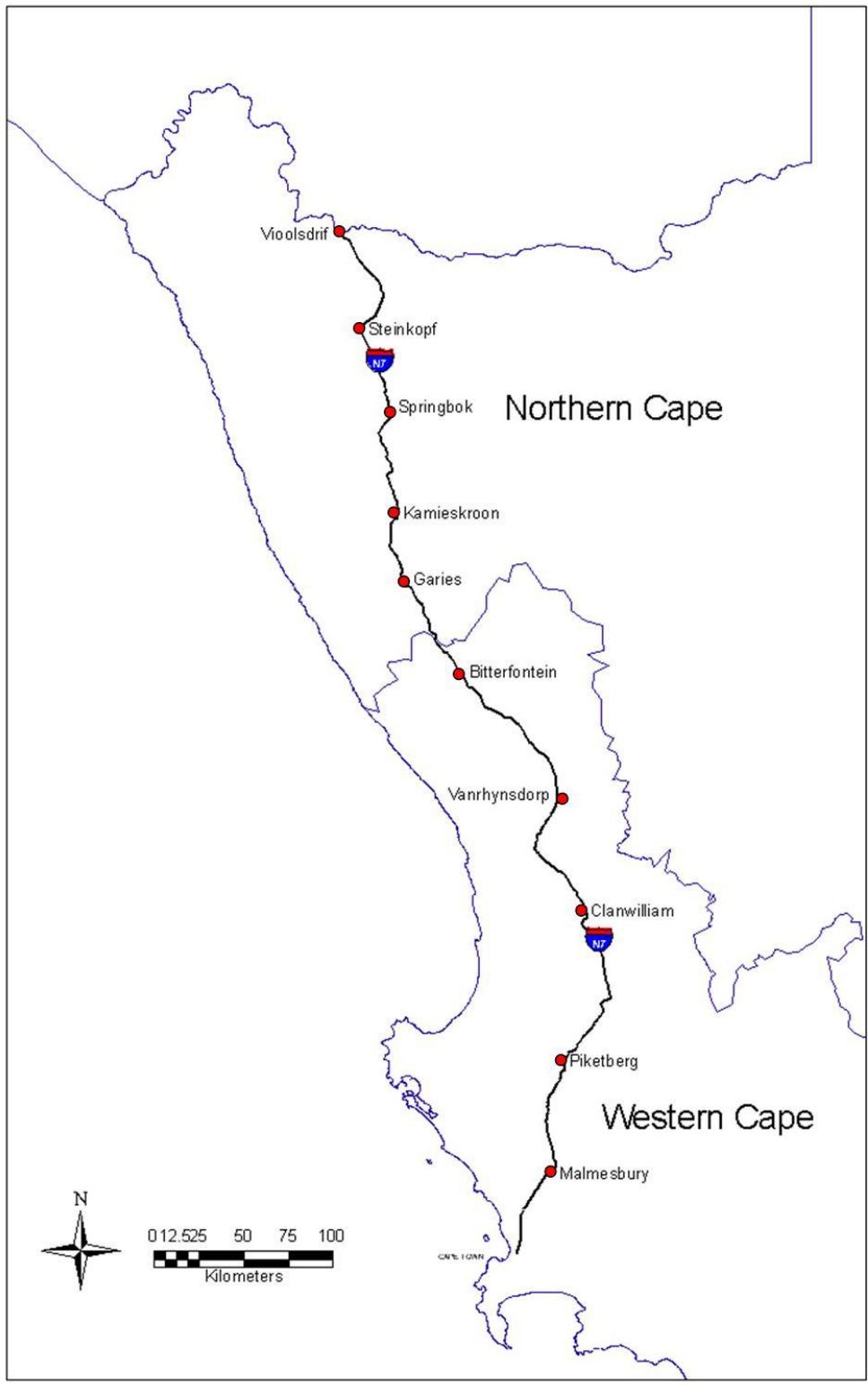


Figure 2.6: The present route of the N7 and the route traversed in this survey with main towns and provincial boundaries indicated (adapted from Mucina and Rutherford, 2006).

## **2.6 Summary**

The documentation of land use in the study area describes a significant history of intensive agriculture and livestock grazing. Particularly in the well-watered, nutrient rich Cape Lowlands there has been a long history of livestock grazing that predates colonial settlement in the Cape. This was followed by crop cultivation which has transformed this area to highly productive agricultural lands but which has also occurred at the expense of the indigenous vegetation. Today, the remaining Sand Fynbos and Renosterveld habitats are largely disturbed and highly fragmented. There is a high concentration of threatened vegetation types and plant species of conservation importance in the Fynbos biome, and particularly in the Cape Lowlands. Although the history of land use and intensive agriculture is less intense in the more arid parts of the study area, there is still a long history of livestock grazing in the Namaqualand region. Crop cultivation has declined in this area in the past 50 years, although land transformation from agriculture has left its mark.

The N7 traverses two ‘biodiversity hotspots’, namely the Cape Floristic Region and the Succulent Karoo. Within this area there is a high number of endemic and RDB species. The N7 passes through some highly transformed areas within these biodiverse regions and has the potential to support some of the indigenous vegetation and RDB species that occur here. This highlights the need to research these roadside habitats and protect any remaining indigenous vegetation.

## CHAPTER 3 – LITERATURE REVIEW

*“Few forces have been more influential in modifying the earth than transportation.”*  
*Ullman, E.L. (1956), in his contribution to Man’s Role in Changing the Face of the Earth*

### 3.1 Introduction

Roads are the physical manifestations of the social connections and the economic and political decisions that lead to land use change. Research into the ecological effects that roads impose on natural habitats is a relatively new field (Coffin, 2007). The term describing this branch of science is “road ecology” which was coined by landscape ecologist Richard T.T. Forman in 1998 (Forman, 1998). It refers to the mounting evidence that roads are having dramatic effects on ecosystem components. The processes and structures that cause these effects are as much related to the engineering of roads as to land use planning and transportation policy (Coffin 2007).

This study focuses on road reserves: the strip of land on either side of the road. There is usually a clearly defined boundary (fence line) where the road reserve abuts the adjacent land. While this area is termed the road reserve, it is not a protected reserve in the way a nature reserve is protected. It is intended as a buffer between the road and the adjacent land, often hosting other services such as electric or telephone cables (Dawson, 1991).

While roads have a severe impact on the landscape through which they run, their associated road reserves can be seen as playing a positive role. Their biological value can be high as they play a role in conserving indigenous flora (Way, 1977; Lamont et al., 1994a; Forman and Alexander, 1998) in landscapes that are predominantly under cultivated land. In some cases road reserves can represent a large portion of all that remains of threatened habitats (Esler and Milton, 2006; Leigh and Briggs, 1992) and can be seen to offer a refuge for species (Hibberd and Soutberg, 1991). In Australia, public concern for the preservation of wildflowers and their habitat in road reserves led to the adoption of a new policy to increase the width of road reserves for wildflower conservation (Hussey, 1991).

It has been theoretically and empirically shown that where population size and geographic range has been largely reduced, the chance of extinction is increased (Brook et al., 2006). In this regard, they can be seen as a linear habitat and a wildlife corridor (Spellerberg, 1998) that can facilitate the recolonisation of habitat through connectivity and thereby reduce the effect of local extinctions (Hibberd and Soutberg, 1991; Beier and Noss, 1998; Kalwij et al., 2008). However, road reserves can also be seen as transformed areas due to road maintenance activities that promote the establishment of pioneer exotic species (Spellerberg, 1998; Gelbard and Belnap, 2003; Zwaenepoel et al., 2006).

This chapter will review the literature related to road reserves. The first section relates broadly to the ecological effects of roads and is pertinent to the first data chapter of the thesis (Chapter 4). The second section looks at studies on rare plants and the reproductive success of plants in road reserves (or fragmented habitats). This literature is related to the second data chapter of the thesis (Chapter 5). The final section of literature focuses on the management of road reserves and other fragmented remnants of native vegetation. It relates to Chapter 6 in the thesis which provides a set of recommendation for the future management of the N7 road reserve.

## **3.2 The effects of roads on natural habitats and fragmented landscapes**

### **3.2.1 Positive effects of a road reserve**

A number of studies have looked specifically at whether road reserves function as a refuge for plants and can be considered to have conservation value. In landscapes that are largely transformed due to human activities, road reserves contain more plant and animal species than the adjacent land (Adams and Geis, 1983; Adams, 1984; Pauwels and Gulinck, 2000), and contain threatened indigenous species and ecosystems (Spooner and Smallbone, 2009). Milberg and Lamont (1995) explain that road reserves are linear remnants that are important in the management and conservation of landscapes that are largely used for agriculture. Road reserves have limited development potential due to road safety regulations and are, therefore, unlikely to be completely transformed (Bennet, 1991).

Table 3.1: The number of higher plant species recorded in the road verges of countries where comprehensive inventories have been undertaken.

Country	No. of species in the total flora	No. recorded in road reserves	% of the total flora	Reference
Britain	2,000	870	44	Way (1977)
Germany	2,500	1,000	40	Kaule (1986)
Holland	1,418	709	50	Sykora et al. (1993)
Belgium	1,260	768	61	Zwaenepoel (1993)

In Australia these roadside habitats often host the only surviving native vegetation (Lewis, 1991; Leigh and Briggs, 1992) and represent the sole refuge for some rare plant species (Breckwolft, 1990). In their study, Leigh and Briggs (1992) found that 25% of rare plants in Australia were restricted to the native vegetation in road reserves. In southern Belgium, road reserves are considered to be of significant conservation value as their biological quality, species richness and species rarity is greater than that of the adjacent land (Tanghe and Godefroid, 2000). These discoveries of rare species and habitats being represented within road reserves form the basis for the support of road reserves as potential conservation assets. Even though these populations are highly fragmented and are often considered less worthy of conservation than more pristine areas, current studies suggest that they may retain links with neighbouring, non-verge populations via gene flow and thus retain considerable genetic variability (Hogbin et al., 1998; Van Rossum et al., 2004). This is a highly advantageous outcome for small remnant populations as it increases their effective population size by countering possible inbreeding depression and genetic drift associated with isolated populations (Ellstrand and Elam, 1993).

The plants in road verges are also a potential seed reserve and source of seeds after drought (Esler and Milton, 2006). In their study on the impact of age on roadside vegetation, Spooner and Smallbone (2009) conclude that roadsides are critically important in conserving native biota in agricultural landscapes. Road reserves are thus believed to play a major role in the conservation of indigenous flora in various areas throughout the world (Lamont et al., 1994a).

While the road reserves in the arid and semi-arid areas of South Africa are not protected from disturbance, they have value as protected areas for certain groups of plants and animals. Although they cannot replace properly-managed and formally-protected conservation areas, their uniqueness as linear features means that they can potentially protect a large diversity of biota (Tshiguvho et al., 1999).

Few studies of road reserves have attempted to assess their overall conservation value by considering large transects of the road (Dawson, 1991). Most studies have focused on small areas or particular species that are used as indicators. In his study on the road reserves of South Africa as potential valuable conservation areas, Dawson (1991) assessed over 8,000 km of road reserve. From this survey he calculated the percentage conservation value for each segment of road. Dawson (1991) concluded that the road reserves in certain parts of the Fynbos and Grassland biomes had conservation value. The Succulent Karoo Biome was deemed to have limited conservation value, but did provide refuge for highly palatable species. While Dawson's (1991) survey did not include the Desert biome it provided extremely useful information for the future maintenance and management of the road reserve. There is a lack of similar studies in South Africa, and certainly a need for more vegetation type, specific data to be collected for road reserve managers.

If managed correctly, road reserves also have the potential to be important sites for environmental education and tourism as they can provide good examples of surviving indigenous flora in largely transformed landscapes (Saunders and Hobbs, 1991; Tshiguvho et al., 1999; Esler and Milton, 2006). In the study area, road reserves are extremely important to the enjoyment of the spring flower gazing tourists that journey to Namaqualand and the West Coast every year. Road reserves are the first examples that people see as they drive into these areas and often host conserved untransformed examples of the vegetation type present. Esler and Milton (2006) argue that road verges have a significant tourism value as they are sometimes the only piece of natural vegetation visible and accessible to the general public.

### **3.2.2. The negative effects of roads on landscapes**

Roads also have negative effects on the terrestrial and aquatic ecosystems of a landscape (Trombulak and Frissel, 2000) by interrupting the horizontal ecological flows of these systems (Forman and Alexander, 1998). During road construction the

physical environment is altered on and adjacent to the road (Trombulak and Frissel, 2000) and environmental disturbance can be significant (Angold, 1997). The total surface area of a road represents the amount of vegetation that has been completely destroyed, which over a large road can amount to a significant area which once hosted plants and animals (Trombulak and Frissel, 2000). Following the construction of roads, the disturbed adjacent areas are revegetated. In South Africa this is usually done with indigenous species (Dawson and van der Breggen, 1991). Road construction also alters the soil structure underneath and adjacent to the road and it has been shown that compaction can be up to 200 times greater than in undisturbed land (Trombulak and Frissel, 2000). Imported construction materials can transform the naturally occurring vegetation (Angold, 1997) and excess material that is washed into rivers can negatively affect aquatic systems (Trombulak and Frissel, 2000).

Roads also have a significant impact on the chemical environment and major additions of heavy metals, salt, organic molecules, ozone, and nutrients have been reported (Trombulak and Frissel, 2000). Chemical spills along roads are an important source of pollution on roads (Coffin, 2007). Acting either as a fertilizer (nitrogen), growth stimulator (carbon dioxide) or pollutant (heavy metals), vehicular emissions play a significant role in transforming road verge plant populations creating so-called 'edge effects' (Angold, 1997) which decrease with distance from the road (Truscott et al., 2005). Angold (1997) concludes that the size of the road determines the distance of the 'edge effect', with larger, busier roads having a greater affect.

In a study on the effect of roads on British heathland vegetation it was found that the road influenced adjacent vegetation up to 200 m from the road, specifically through the impact of lead emissions from cars (Angold, 1997). Pollution and chemicals on roads can also be dispersed via storm water run-off into the surrounding environment and have far reaching consequences (Coffin, 2007).

### **3.2.3 Exotic species in the road reserve**

Another major negative impact of roads is their ability to spread exotic plant species through dispersal (Spellerberg, 1998; Trombulak and Frissel, 2000; Gelbard and Belnap, 2003; Zwaenepoel et al., 2006; Nishizawa et al., 2009) and thus compromise the conservation value of road reserves and adjacent land (Milton and Dean, 1998;

Kawlij et al., 2008). There are three major mechanisms which allow roads to spread exotic species: they provide habitat by altering natural conditions, they increase the likelihood of invasion by removing indigenous species, and they allow easier movement via natural or human vectors (Trombulak and Frissel, 2000). Historically, exotic species were introduced to road reserves as an erosion control mechanism, although indigenous species are now preferred for this task (Dawson and van der Breggen, 1991; Tyser et al., 1998; Trombulak and Frissel, 2000).

Road verges are often disturbed habitats due to management practices and are readily supplied with alien propagules (seeds) by passing vehicles (Garnier et al., 2006; Zwaenepoel et al., 2006; Kawlij et al., 2008). Another less well documented source of alien seeds in the road reserve is from crops in adjacent farmland (Garnier et al., 2006). Considering that they are bordered by road on one side and possibly cropland on the other, the edge:area ratio that characterises roadside vegetation greatly increases the opportunities for invasion by exotics (Milberg and Lamont, 1995). Precipitation runoff from roads further supports the establishment of weedy alien species which often colonise road verges and rapidly spread along this corridor, thus degrading the condition of the natural vegetation of the road verge (Milton and Dean, 1998; Kawlij et al., 2008).

In a study looking at road verges as invasion corridors in the Nama-Karoo, South Africa, it was found that distance from urban areas was not a significant predictor of alien richness and refuted the corridor hypothesis proposed in the same study (Kawlij et al., 2008). Gelbard and Belnap (2003) explain that the clearing of vegetation and soil movement associated with road construction creates areas of bare and deeper soil which are suitable habitat for invasive exotic species. The construction and management of large paved roads also increases the chance of alien vegetation establishment through increased road verge disturbance and high numbers of passing vehicles. Roads do not only allow for the spread of exotic species along their road verge corridors, but also act as conduits for spread into adjacent land (Gelbard and Belnap, 2003; Musil et al., 2005; Kawlij et al., 2008).

Studies from arid areas in the United States (Glacier National Park) have found that the presence of exotic species declines with distance from the road (Tyser and

Worley, 1992). In another study, Gelbard and Belnap (2003) compared the cover and richness of exotic and alien species in the road verge and adjacent land between roads of different development levels (e.g. paved, graded and four wheel drive tracks). The findings for the busier, improved and paved roads, was that there was greater cover and richness of exotic species and a lower richness of indigenous species in land adjacent to the road verge (up to 50 m into the land).

In a vehicle-based study of alien plant assemblages near roadsides in arid and semi-arid South Africa, Milton and Dean (1998) found that 98% of Fynbos and 81% of Succulent Karoo biome transects contained alien plants. The frequency and number of alien species were greatest in these two biomes of the five studied. Another significant finding from the research was that for the Succulent Karoo biome (and less so for the Fynbos biome) there was a significantly greater number of alien species in road verges adjacent to farmland compared to those adjacent to uncultivated rangelands (Milton and Dean, 1998).

#### **3.2.4 Animals in the road reserve**

While this study is not directly concerned with the presence of animals in the road reserves, it does focus on the ecological condition and conservation value of road reserves. Animals can be considered good indicators of the potential conservation value of road reserves and are therefore briefly considered in this literature review.

Animal behaviour has been shown to be both positively and negatively influenced by roads (Trombulak and Frissel, 2000). Roads have the potential to facilitate range extensions of animals, specifically small mammals (Adams and Geis, 1983). Larger animals (antelope) in the road reserve pose a risk to both passing vehicles and the animals themselves (Elof and van Niekerk, 2005). The clearing of indigenous vegetation from road reserves promotes new growth of pioneer species which attracts animals to the road reserve to feed (Esler and Milton, 2006) which further increases the potential for animal-vehicle collisions. Animal mortality from vehicle collisions has been well documented throughout the world. Affected animals include antelope, birds, reptiles, amphibians and insects (Trombulak and Frissel, 2000). This form of animal mortality can have a significant effect on a particular population and has been documented as an additional threat for some rare species (Trombulak and Frissel,

2000). Amphibians can be particularly severely affected as their seasonal movements require a migration from wetland to upland habitats. In areas where predominantly natural vegetation still exists, roads can be seen to fragment these habitats and inhibit species movement (Joly and Morand, 1997; Spellerberg, 1998; Esler and Mitlon, 2006). Generally speaking, mortality increases with traffic flow. However, some larger roads have a more extensive shoulder that is vegetation free, thus keeping animals further away and lowering the incidence of collisions (Trombulak and Frissel, 2000).

As with plants, road reserves have also been suggested as corridors that provide connectivity between fragmented habitats and refugia for insect species (Eversham and Telfer, 1994). In their study, Eversham and Telfer (1994) concluded that road reserves were used as a refugia by certain beetle species in the British heathlands and Mungira and Thomas (1992) found that road reserves contained a wide variety of common and rare butterflies in the Dorset region of England. In Finland, it was found that butterfly and moth species abundance in the road reserve decreased when adjacent to cultivated land but road reserves play a significant role in their conservation (Saarinen et al., 2005). In the Western Cape, a study looking at ant diversity as an indicator of the conservation value of road reserves, found relatively more diverse species and rare species in the road reserve. Ant diversity in the road reserve was correlated with abundance of food from road kill, lower pressure on plants from grazing and increased surface run-off (Tshiguvho et al., 1999). Ants are a useful bio-indicator, especially for plants, as their presence is related to plant cover, flowers (nectar), seeds, prey species and carrion (Tshiguvho et al., 1999).

### **3.2.5 The role of roads in landscape fragmentation, connectivity and corridors**

The ability of species to adapt to climate change and transforming landscapes is determined by the presence of suitable habitat (Brook et al., 2008) and connectivity between these areas (Gilbert et al., 1998; Rutherford et al., 1999). This section will examine the literature surrounding the effects of habitat fragmentation and the potential of corridors to provide connectivity.

Since the development of agriculture, natural vegetation cover has been extensively modified in many parts of the world. This ecosystem and habitat fragmentation has led to large changes in the physical and biogeographic environments (Saunders et al.,

1991). A direct outcome of this fragmentation is the reduction in population size of many plant and animal species (Hobbs and Yates, 2003). The resulting landscape can be described as a mosaic of remnant indigenous vegetation, agricultural land and other man-made features. The natural flows of water, nutrients and energy are disrupted in such a landscape which, in turn, affects the biota in the remnant patches, primarily through isolation (Saunders et al., 1991). Isolation and fragmentation of plant populations can be of concern in terms of genetic consequences. The effects of inbreeding, genetic drift and gene flow on genetic diversity and fitness in small populations and rare plants is of concern (Ellstrand and Elam, 1993; Van Rossum et al., 2004). Factors related to roads which influence these effects, are changes in population size, degree of isolation and fitness (Ellstrand and Elam, 1993). However, it is not only rare plants that are threatened by isolation and fragmented landscapes. Van Rossum et al. (2004) showed that common species can be more severely affected by fragmented habitats and warn that their commonness is not a guarantee of long-term survival.

Soons et al. (2005) showed that habitat fragmentation isolated populations of grassland remnants resulting in lack of connectivity even for species with long distance seed dispersal strategies. Losses of suitable habitat for species through the deterioration and fragmentation of natural landscapes increases the potential for species extinctions (Cousins, 2006). Using an annual herb as an indicator species, Groom (1998) showed that extinction was much greater in small isolated populations than in larger populations. Consequences of habitat fragmentation and isolation of fragments are expected to be greatest in species with poor dispersal abilities (Bennett, 2003), where recolonisation is unlikely to follow local extinction events (Cousins, 2006). In a study of Fynbos vegetation, Bond et al. (1988) found that small fragments had fewer species than areas of similar size within a large tract of vegetation. The loss of habitat and fragmentation not only decreases the area available to a species but also its connectivity to other areas (Soons et al., 2005).

While it is generally agreed by conservation biologists that landscape connectivity increases the viability of a particular species (Beier and Noss, 1998; Gilbert et al., 1998; Bennett, 2003), there has been much debate and some criticism of the idea that corridors provide connectivity and reduce extinctions. One of the main criticisms is

that there is a lack of experimental data to support the theory (Hobbs, 1992). The second major issue raised is that of a cost-benefit analysis. It is argued that corridors are much more expensive to create and maintain than traditional conservation areas and are therefore unjustifiable in the absence of clear evidence of their benefits (Simberloff and Cox, 1987; Simberloff et al., 1992). It has been further suggested that they may play a negative role in terms of conservation by allowing the spread of alien species, wild fires and contagious diseases (Simberloff and Cox, 1987).

Despite the criticisms and lack of experimental data to support conservation corridors they have remained a popular conservation tool. Gilbert et al. (1998) did show through experimentation using moss patches as micro ecosystems that connective corridors reduce the rate of loss of species. In this way species richness is preserved for longer periods of time. Rather than avoiding the use of corridors due to lack of evidence, those who wish to transform the landscape should bear the burden of showing that their activities will not harm natural species (Beier and Noss, 1998).

Road reserves can function as linear conservation habitats that require very little maintenance (Tshiguhvo et al., 1999) and can therefore be considered as corridors that provide connectivity in certain areas. However, it must be noted that road reserves are anthropogenic in origin and differ from corridors of natural origin (Bennett, 1991). Nevertheless, their function could be critical in the conservation of indigenous flora by improving connectivity between fragmented populations (Spooner and Smallbone, 2009).

### **3.3 Red Data Book (RDB) species in road reserves**

#### **3.3.1 Rare plants and their reproductive success in the road reserve**

A number of studies have looked at rare plants in road reserve habitats (Way, 1977; Lamont et al., 1993; Yates and Broadhurst, 2002; Yates and Ladd, 2005). Bennett (1991) concludes that road reserves frequently have intrinsic botanical value as they contain relictual, uncommon, rare and threatened species. The diversity of flora and number of RDB species in the study area of this research project is extremely high (see Chapters 2 and 5). Due to these circumstances, it is likely that even the relatively small road reserves contain RDB species. This section looks at research on rare plants, including their reproductive success, in road reserves and other remnant

patches of natural vegetation.

Reproductive success in many plant species depends on the plant producing sufficient inflorescences, pollinators visiting and successfully pollinating the flowers, seed being produced, and favourable conditions for the germination and survival of the new generation. Plant pollination, successful germination and selective advantages of road reserve populations will be discussed in the following section.

### **3.3.1.1 Pollination**

In fragmented landscapes, access to populations by pollinators may be reduced (Aizen and Feinsinger, 1994a, 1994b). However, many pollinators' (insects, birds and rodents) movements are not inhibited by fences and it has been questioned whether fragmentation will decrease pollinator-plant interaction (Cane, 2001). Plants that are most likely to suffer extinction in the case of fragmentation are those that are pollinated by a single pollinator (Bond, 1994). Pollination and reproductive success in fragmented habitats have been recorded as having a wide range of outcomes (Yates and Ladd, 2005). In a study on forest habitat fragments it was shown that pollination and seed set was significantly lower when compared to continuous habitat (Aizen and Feinsinger, 1994a). In a study from Australia on small and isolated road verge populations of *Banksia goodii*, it was found that this endangered shrub possessed drastically reduced seed-set within the road reserve populations possibly as a consequence of a reduction and/or change in pollinator activity (Lamont et al., 1993).

In their study on Renosterveld fragments Donaldson et al. (2002) found that the size of the fragment and the distance to large remnants of the vegetation had a significant effect on the seed or fruit set in a number of species that they studied. In another study in Nature Reserves of the Cape Floristic Region it was shown that a generalist pollinator, the oil collecting *Rediviva peringueyi*, was critical in maintaining the pollination-web. The bee was absent from small conservation areas in urban areas and this caused a failure in the seed-set of specialist oil-secreting plants adapted to be pollinated by only this bee (Pauw, 2007). This, however, does not mean that populations on small fragments always incur a pollination deficit (Donaldson et al., 2002). In their study, Yates and Ladd (2005) found that small populations on road verges of the endangered shrub *Verticordia fimbriilepis* ssp. *fimbriilepis* (*Myrtaceae*)

had equal or greater diversity of insect visitors to flowers, rates of pollination, and seed production compared with larger populations in conservation reserves. In a study of the rare Australian shrub *Grevillea barklyana* (*Proteaceae*) Hogbin et al. (1998) found that roadside populations had significantly more inflorescences and seed than non-verge populations. Elevated reproductive success has also been reported in small road verge populations of the Australian shrubs *Banksia hookeriana* and *B. menziesii* (Lamont et al., 1994a, 1994b). Assessment of the reproductive output of road verge vegetation should, therefore, occur on a case by-case basis (Hogbin et al., 1998).

### **3.3.1.2 Successful germination and seedling establishment**

It not only the abundance of pollinators and rates of pollination and seed production that determine the success of a species in a fragmented habitat. Habitat change and disturbance regime must also be considered in order to understand the success of seeds germinating and seedlings surviving (Yates and Ladd, 2005). These factors may be even more important than seed production in determining the success of small isolated populations (Yates and Broadhurst, 2002).

The changes in habitat caused by fragmentation can result in lower natural seedling establishment and survival (Hobbs and Yates, 2003). In a study on two critically endangered *Acacia* species in Australia, it was found that the remaining populations were almost entirely restricted to road verge populations. However, populations of both species were in decline. The reasons for the decline were the reduced frequency of fire in the now fragmented landscape (these *Acacia* species respond favourably to fire in terms of seed germination), and increased competition from annual weeds (Yates and Broadhurst, 2002). In another study on a rare shrub, Yates and Ladd (2005) showed that recruitment was greatly increased in the immediate post-fire environment. Seedling germination in years of no fire was dependent on above average rainfall and competition-free recruitment sites. These studies highlight the importance that road reserves can play in conserving rare species, but that careful management of such known rare species is required to prevent their complete extinction.

### **3.3.1.3 Advantages accrued to road reserve populations**

In an Australian study, Lamont et al. (1994a) found that *Banksia menziesii* individuals immediately adjacent to the road were two and a half times the size of those away from the road. These plants' success was attributed to greater access to water, increased nutrient availability and reduced root competition because the road apron is free of large plants and enables the plants to exploit resources that would not otherwise be available to them in a non-verge environment (Lamont et al., 1994a). Such additional water and nutrients leads to increased vegetative and reproductive growth (Hogbin et al., 1998).

## **3.4 The management of road reserves**

### **3.4.1 Fire**

While fire is a necessary component for the regeneration of both Fynbos and Renosterveld vegetation, it also has a potentially negative effect in road reserves already susceptible to alien plant invasions. In an Australian study, it was found that the number of exotic species, their frequency and cover increased after fire and the number of indigenous species decreased (Milberg and Lamont, 1995). The evidence of the fire was still evident seven years later with alien grasses dominating the vegetation. The increased cover by alien grass further increases the chance of future burning and, therefore, species composition change. This altered fire regime is also likely to affect the fauna in the road reserve. Therefore, the increase of exotic perennial grasses is likely to decrease the overall conservation value of road verges (Milberg and Lamont, 1995). In a number of subsequent Australian studies it was shown that fire was necessary for the recruitment and establishment of seedlings of rare, fire-adapted plants. In fragmented agricultural landscapes fire suppression is the primary management tool, which will adversely affect such fire-adapted species (Yates and Broadhurst, 2002; Yates and Ladd, 2005).

In the South African context both fire-adapted and non fire-adapted vegetation types could be significantly transformed by frequent fires in the potentially alien species rich road verges. Fynbos vegetation burns on average every 12 – 15 years (Cowling and Richardson, 1995) and Renosterveld vegetation is adapted to burn every 3 – 10

years in order to regenerate (Rebelo, 1992). Where fire suppression is practiced, fire-adapted vegetation will suffer as long-term population persistence depends on seedling production (Yates and Ladd, 2005), usually in the few years following a fire event. If the vegetation were to burn more frequently than the naturally occurring cycle, the vegetation would also be negatively affected as the slow-maturing plants are eliminated and replaced by a more grassy landscape (Cowling and Richardson, 1995).

The South African National Roads Agency Limited (SANRAL) recognizes the potential effects of burning both indigenous and alien vegetation and has not banned fires in the road reserve. Smoke is a potential safety hazard to passing vehicles and controlled burning in the road reserve is not common, although, previous fires may have already transformed the road reserve vegetation. In their study on a rare species in a fragmented landscape, Yates and Ladd (2005) suggest that suitable fire regimes should be an integral part of managing and maintaining viable populations. Bond et al. (1988) also suggest that manipulating the fire regime of Fynbos tracts could reduce the loss of diversity associated with vegetation fragments.

### **3.4.2 Direct human impacts**

The mowing of roadside verges is one of the most common management practices for road reserves throughout the world. Various studies have assessed the results of mowing on roadside vegetation. Where exotic plants in the road reserve are less sensitive to clipping than the indigenous vegetation, mowing of the road verge will favour the exotic plants (Forman and Alexander, 1998). In studies conducted in The Netherlands and Great Britain, it was shown that mowing roadside vegetation twice a year maintained the most species-rich vegetation (Parr and Way, 1988; Tikka et al., 2000). However, Jantunen et al. (2007) found that mowing once a year was a more suitable maintenance regime for the grassland road verges of southeastern Finland. Depending on the type of vegetation, the time of year at which mowing takes place will determine how significant an affect it has on indigenous vegetation. The frequency of mowing will also favour particular species and the species composition will change if the mowing regime is changed (Parr and Way, 1988). In Japan, a study by Kitazawa and Ohsawa (2002), found that areas that were mowed showed the greatest concentration of unique and rare species compared to other maintenance

methods. It was concluded that these mown sites should be maintained to preserve the unique biodiversity of the area (Kitazawa and Ohsawa, 2002). It had been suggested that the highest species diversity will be maintained with intermediate levels of disturbance (Jantunen et al., 2007).

Another method of controlling alien species in the road reserve is the use of herbicide treatments. While these can reduce the cover of some exotic species they may also favour other exotic species and negatively affect indigenous vegetation (Tyser et al., 1998). In a study on oilseed rape from Europe, it was found that feral population of the plant that had escaped into road reserve were either mown and/or sprayed with herbicide (45% in the UK and up to 80% in France). The study concludes that anthropogenic processes (management, cropping and seed transport) have a critical impact on the persistence of feral roadside populations of this plant (Garnier et al., 2006). In their study in the Potchefstroom area, in South Africa Cilliers and Bredenkamp (2000) found that the current roadside plant community composition was the result of direct management practices (mowing and herbicide spraying) and disturbances.

### **3.4.3 South African road reserve maintenance**

In the winter rainfall regions of South Africa the management of road reserve vegetation is minimal. The shoulder of major roads are either scraped or sprayed with a general herbicide to ensure the hardened surface is free of plants. Plants within 5 meters of the road are trimmed to ensure they do not obscure vehicles and traffic signs (Dawson, 1991). SANRAL specifies that grass alongside the road should be cut to at least 3 meters from the road shoulder, or 6 meters from the yellow line (SANRAL, 2008). In his study on the road reserve condition in South Africa, Dawson (1991) found that in many of the biomes assessed, road reserve maintenance had a negative impact on the conservation value of the vegetation. He concludes that inappropriate maintenance practices are reducing the potential of road reserves to act as conservation assets in a number of Veld Types (old vegetation types) of the Fynbos biome. While certain road reserves in South Africa do constitute valuable conservation areas, this is more fortuitous than planned, and it is imperative that a conservation policy for road reserves is formed (Dawson, 1991). Dawson (1991) also

suggests a ‘minimum-maintenance’ policy for South African road reserves where mowing non-grassland vegetation types is limited and frequent burning is reduced.

#### **3.4.4 Impact of management on road reserves**

The various road reserve management tools described above can either be destructive or, in some cases, beneficial to vegetation, depending on when and how they are implemented. Certain indigenous species can prosper under anthropogenic management regimes owing to the species’ mechanisms for reproduction, establishment and dispersal. In some cases, threatened species and ecosystems require anthropogenic disturbance for persistence and recruitment (Spooner et al., 2004; Jantunen et al., 2007). If exotic plant species in the road reserve are mowed or sprayed with herbicide during their vegetative or flowering phase, the population size is likely to decrease. However, if the maintenance is carried out prior to seedling emergence, the removal of other vegetation and therefore competition could favour the exotic species (Garnier et al., 2006). The effects of mowing and spraying should also be considered in terms of the locally-present, indigenous species and their growth cycle. For example, areas rich in geophytes, such as Renosterveld should be mowed when the plants have already set their seed, rather than during their vegetative growth phase. A study looking at the control of alien grasses in Renosterveld concluded that mowing was the most suitable and cost effective method, and that an increase in the density of indigenous forbs and geophytes was observed during one year of the study (Musil et al., 2005).

Where road reserve maintenance is high, disturbance tolerant species are likely to dominate (Bennett, 1991; Forman and Alexander, 1998). The multiplicity of factors influencing alien plant communities highlights the importance of understanding and considering local conditions (climatic gradients, landscape context and road-verge properties) when managing road verges (Spooner et al., 2004; Kawlij et al., 2008). Spooner et al. (2004) conclude that road maintenance has a stronger controlling influence on roadside vegetation populations than environmental determinants. In another South African study it was also found that while soil type and water availability may influence roadside plant communities, the main contributors were adjacent land use, management practices and disturbances (Cilliers and Bredenkamp, 2000).

The role of road verges could either be a habitat reserve for indigenous vegetation or an invasive species reservoir and conduit. The outcome is likely to be ecosystem and management dependent (Von Holle and Simberloff, 2005). The kind of impact (either positive or negative) of management on population persistence depends on the timing of its application (Garnier et al., 2006). Unfortunately, there is usually a conflict of interests between maintaining road reserves for safety reasons and for conservation value (Dawson and van der Breggen, 1991; Loney and Hobbs, 1991). This highlights the critical importance of understanding local conditions when designing road reserve management plans (Loney and Hobbs, 1991). An integrated management strategy is required to maintain the potential of road reserves as conservation assets. Such a strategy should also include monitoring and evaluation (Loney and Hobbs, 1991).

### **3.5 Conclusion**

Road reserves are anthropogenic corridors of remnant indigenous vegetation in otherwise completely transformed landscapes. In this way they can be seen as playing a vital role in the conservation of indigenous and rare species, as well as providing connectivity between habitat fragments that allow for species movement (fauna and flora). Unfortunately road reserves are often disturbed habitats due to road construction and maintenance and are therefore far from pristine. They often host alien vegetation and act as conduits for the further spread of these exotic species. Despite this, many rare species find refuge in road reserves and in certain circumstances accrue reproductive advantages over non-verge populations.

Road design, management, and restoration therefore need to be more carefully tailored to address the full range of ecological processes (terrestrial and aquatic) that affect species. Deliberate monitoring is necessary to ensure that projects have robust ecological benefits and minimal adverse effects and that they are cost-efficient relative to their actual benefits (Weaver et al., 1987).

## **CHAPTER 4 – VEGETATION CONDITION AND CONSERVATION VALUE OF THE ROAD RESERVE WITHIN DIFFERENT BIOMES AND VEGETATION TYPES ALONG THE N7**

### **4.1 Introduction**

Comprehensive inventories of plant species occurring in road reserves suggest that they can contain a significant number of indigenous species and are often critical repositories of a region's flora. For example in several countries in Europe, between 40-61% of the country's total number of plant species have been recorded in road reserves (Way, 1977; Kaule, 1986; Sykora et al., 1993; Zwaenepoel, 1993) (Table 3.1). These figures highlight the significant potential that road reserves have to host and protect indigenous plants. In areas that are largely transformed by agriculture, road reserves play an even more important role in providing habitat for indigenous plant species (Adams and Geis, 1983; Adams, 1984; Pauwels and Gulinck, 2000) and improving connectivity between fragmented populations (Spooner and Smallbone, 2009). However, this role is strongly influenced by the condition of the vegetation in the road reserve relative to the condition of the vegetation in the land immediately adjacent to it.

The condition of the vegetation in the road reserve is influenced by many factors. Initially, road construction may significantly alter the composition and ecosystem processes occurring within the road reserve (Angold, 1997). However, ongoing maintenance also has a significant impact on the condition of the vegetation in the road reserve. Disturbances which result from road maintenance can often facilitate the establishment of exotic and weedy species which thrive under these conditions (Garnier et al., 2006; Zwaenepoel et al., 2006; Kawlij et al., 2008). Precipitation runoff from roads further supports the establishment of weedy alien species which colonise road verges. This can facilitate their rapid spread along the road verge corridor, and degrade the condition of the natural vegetation occurring in this environment (Milton and Dean, 1998; Kawlij et al., 2008). The condition of vegetation in the road reserve is also influenced by the adjacent land use. For example, spillover effects from crop spraying in farmlands adjacent to roads are likely to negatively affect the vegetation in the road reserve. Although not well documented, alien plants also often disperse from adjacent croplands where they originate to the

road reserve environment (Garnier et al., 2006).

A number of studies have looked at the condition of road reserves relative to adjacent land. These studies are often focused on particular plant species, localised areas or alien vegetation (Hogbin et al., 1998; Milton and Dean, 1998; Tanghe and Godefroid, 2000). Few studies of road reserves have attempted to assess their overall conservation value by considering large transects of the road. One exception is the study of Dawson (1991) that assessed the potential conservation value of South African road reserves. Over 8,000 km of road reserve were assessed and the conservation value was calculated for each segment of road. Dawson (1991) concluded that it was only in parts of the Fynbos and Grassland biomes that road reserves possessed any significant conservation value. In the Succulent Karoo biome road reserves had limited conservation value.

This Chapter describes the vegetation condition and the related conservation value of the N7 road reserve and addresses three main questions:

- (1) What is the ecological condition of the vegetation of the 690 km long N7 road reserve and the adjacent farm land relative to the postulated original vegetation condition?
- (2) What is the conservation value of the N7 road reserve in terms of its condition relative to the adjacent farmland and in terms of the conservation status of the vegetation type as a whole?
- (3) How does vegetation condition and conservation value vary over different vegetation types and biomes in relation to adjacent land use, management practices and environmental variables?

## **4.2 Study area**

The study area incorporates the road reserve and the immediately visible adjacent farmland of the entire 684 km N7 national road from Cape Town in the south to Vioolsdrif on the Namibian border in the north. It includes the road reserve on either side of the national road. The study area traverses three biomes (Fynbos, Succulent Karoo and Desert) and over 30 different vegetation types (Mucina and Rutherford, 2006). The vegetation, elevation and topography vary greatly along the transect, providing an extensive and diverse area from which to assess the vegetation of the

road reserve as well as its conservation value (see Chapter 2).

### 4.3 Methods

The method used to calculate the condition of the vegetation within the N7 road reserve and adjacent farmland was similar to the method used by Dawson (1991). Vegetation condition was assessed from a moving vehicle traveling at an average speed of 80 km/h and scored using an index between 1 and 5 according to the degree of ‘intactness’ relative to that of the postulated original, undisturbed vegetation (Table 4.1). The vegetation condition index scores were subjectively-determined relative to a benchmark description of the vegetation type obtained from Mucina and Rutherford (2006).

Table 4.1: Description of the criteria used to assess vegetation condition according to the ‘intactness’ of the road reserve and adjacent vegetation condition (adapted from Dawson 1991).

Vegetation Condition Index Score	Description
1	Completely Transformed: <10% indigenous vegetation remaining
2	Largely Transformed: up to 40% indigenous vegetation remaining
3	Transformed: Approximately equal proportions of exotic and indigenous vegetation
4	Largely Intact: Mainly indigenous vegetation (60 – 90%), characteristic species of vegetation type present
5	Close to Benchmark: > 90% indigenous vegetation, low presence of exotic species, characteristic species of vegetation type present

Vegetation condition was measured in December 2008 by two observers for every kilometer of the road reserve and adjacent farmland, on both the East and the West sides of the N7. These scores from either side of the road were averaged to get an overall score for each kilometer. The dominant land use practice as well as the

presence of alien vegetation in the road reserve (RR) and farmland (FL) was also recorded every kilometer.

Adjacent land use was assigned to one of four main classes (settlement, cultivated, uncultivated and a mixture of cultivated and uncultivated land) while alien vegetation was assigned to one of three growth form classes (trees, shrubs and grasses). Agricultural crops were considered as alien vegetation for this study (while agricultural crops may not be listed alien invasive species, they are largely exotic species and have the propensity to escape from their farmland to adjacent road reserves or natural veld). The geographic co-ordinates were recorded at the start of each kilometer using a GPS. These waypoints were overlaid on the Vegetation Map of South Africa (Mucina and Rutherford, 2006) and the South African Atlas of Agrohydrology and Climatology (Schulze et al., 1997) to determine the vegetation type, annual average rainfall, average temperature and elevation above Mean Sea Level (MSL) for each kilometer segment. To reduce the variance and to highlight the general pattern across the mega-transect the 1 km segments were grouped into 69, 10 km segments and the vegetation condition within the RR and FL was averaged within these broader units.

A similar approach to that used by Dawson (1991) was adopted in deriving a conservation value index for each 1 km segment of the N7 road reserve. Firstly, the difference between the road reserve (RR) condition score and the farmland (FL) condition score (RR-FL) was calculated. This provided values between -2.5 and 2.5. Positive values reflected areas where the RR vegetation was in better condition than the FL vegetation while negative values reflected areas where the RR was in poorer ecological condition relative to the adjacent FL environment. Based on the results of the RR-FL calculation a dissimilarity index (D) was determined for each 1 km segment of the road reserve. Where the value for RR-FL was negative or zero, the RR area was deemed to have a conservation potential less than or equal to the adjacent FL and the dissimilarity index value (D) was set at zero. For positive RR-FL values the dissimilarity index value ranged between 1 and 5, increasing at 0.5 unit intervals (Table 4.2).

Table 4.2: Calculation of a Dissimilarity Index (D) based on the difference between the condition of the road reserve (RR) relative to the adjacent farmland (FL) environment (RR-FL).

RR - FL	D
$\leq 0$	0
0.5	1
1	2
1.5	3
2	4
$\geq 2.5$	5

Once the index of dissimilarity (D) had been calculated for each 1 km segment the score for the road reserve vegetation condition (RR) was added to this value (D+RR). Finally, the (D+RR) value of each kilometer segment was multiplied by a factor reflective of the conservation status (CS) of the vegetation type present for that kilometer as determined by Mucina and Rutherford (2006) (Table 4.3).

Table 4.3: The conservation status (CS) categories of South African vegetation types (Mucina and Rutherford, 2006) and the multiplication factor associated with each category.

Conservation Status (CS)	Abbreviation	Multiplication Factor
Critically Endangered	CR	4
Endangered	EN	3
Vulnerable	VU	2
Least Threatened	LT	1

Therefore, the Conservation Value index (CV) of any one km segment of the N7 was formulated as follows:

$$\text{Conservation Value (CV)} = (\text{D} + \text{RR}) * \text{CS}$$

Where:

CV = Conservation Value

D = Dissimilarity index

RR = Road Reserve condition

CS = Conservation Status of the vegetation type

## **Statistical Analysis**

Differences between vegetation condition in the road reserve (RR) and adjacent farmland (FL) along the transect and within biomes were determined by a non-parametric Wilcoxon Signed Rank Test (Zar, 1984). Differences between the three biomes (Fynbos, Succulent Karoo and Desert) in their road reserve (RR) and adjacent farmland (FL) vegetation condition scores and conservation values were determined by a non-parametric, Kruskal-Wallis One-Way ANOVA and Dunn's multiple comparison. The relationship between conservation values for each 1 km segment of the transect and altitude, rainfall and temperature were determined using a non-parametric Spearman rank correlation procedure. The effect of different adjacent land uses on the RR condition was determined using a non-parametric, Kruskal-Wallis One-Way ANOVA and Dunn's multiple comparison.

## **4.4 Results**

### **4.4.1 Vegetation condition**

#### **4.4.1.1 Road reserve and adjacent farm land vegetation condition**

Average vegetation condition scores ranged from 1.0 to 5.0 for both road reserve (RR) and farm land (FL) vegetation with an average value of  $2.64 \pm 1.06$  and  $2.68 \pm 1.28$  respectively (Table 4.4; Figure 4.1). There was no significant difference between RR and FL vegetation condition scores across the entire length of the 684 km N7 mega-transect from Cape Town to Vioolsdrif and they were positively correlated to each other ( $n=684$ ,  $R^2 = 0.63$ ,  $y=0.958x + 0.1502$ ). However, RR and FL vegetation

condition differed significantly within different biomes (i.e. the rows in Table 4.4). The Fynbos biome was the only biome in which the RR values were significantly higher than FL values (Figure 4.2). In both the Succulent Karoo and Desert biomes, at the drier end of the gradient, the FL vegetation condition was significantly better than the RR vegetation condition. RR and FL vegetation condition scores differed significantly between biomes (i.e. the columns in Table 4.4). RR vegetation condition scores were significantly lower in the Fynbos and Desert biomes when compared to the Succulent Karoo biome ( $\chi^2 = 122.3$ ;  $df = 2$ ;  $p < 0.001$ ). In contrast, FL vegetation condition scores were significantly higher in the Succulent Karoo and Desert biomes when compared to the Fynbos biome ( $\chi^2 = 213.4$ ;  $df = 2$ ;  $p < 0.0001$ ).

Table 4.4: Average road reserve (RR) and farm land (FL) vegetation condition scores ( $\pm$ std. dev) for all transects and for the three biomes present along the 684 km N7 mega-transect between Cape Town and Vioolsdrif. Significant differences within rows (i.e. within a biome) were tested using a Wilcoxon Signed Rank Test. The Z score and p value are shown for these comparisons. Significant differences within columns (i.e. between biomes) were tested using a Kruskal-Wallis One-Way ANOVA with Dunn's multiple comparison. Dissimilar superscripts denote significant differences ( $p < 0.001$ ) between biomes in RR and FL column scores. The  $\chi^2$  statistic and p values for these comparisons are provided in the text.

Biome	Number of 1 km transects	Road Reserve	Farm Land	Z score	p value
	N	(RR)	(FL)		
Fynbos	246	2.04 $\pm$ 1.16 <sup>a</sup>	1.70 $\pm$ 1.21 <sup>a</sup>	7.02	0.001
Succulent Karoo	412	3.02 $\pm$ 0.81 <sup>b</sup>	3.24 $\pm$ 0.97 <sup>b</sup>	5.86	0.001
Desert	26	2.29 $\pm$ 0.86 <sup>a</sup>	3.06 $\pm$ 0.73 <sup>b</sup>	3.62	0.001
All transects	684	2.64 $\pm$ 1.06	2.68 $\pm$ 1.28	1.40	0.161

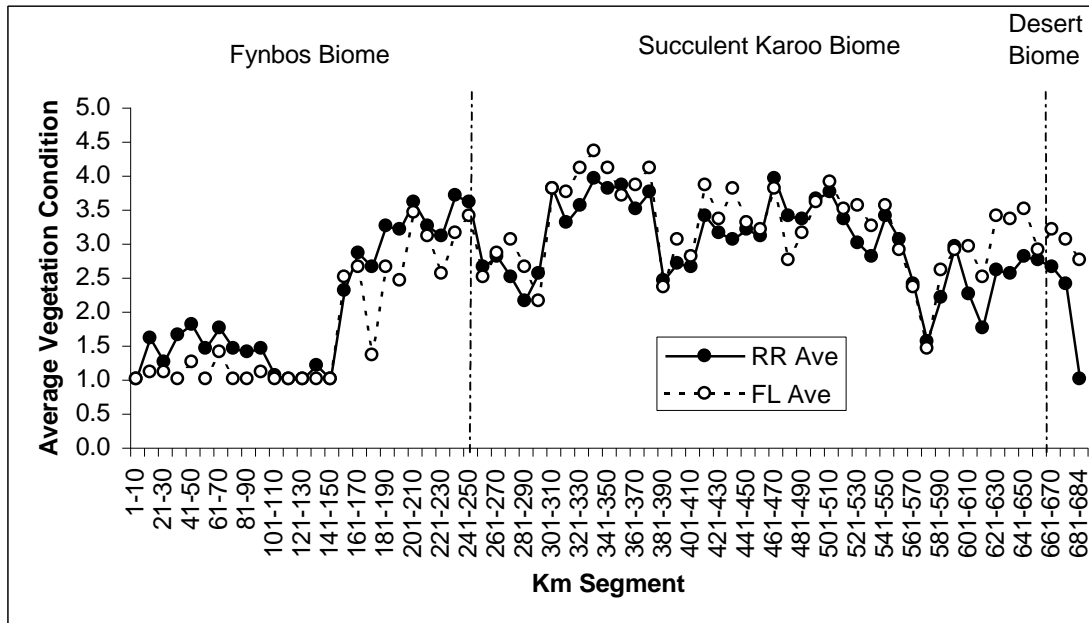


Figure 4.1: Road reserve (RR) and farm land (FL) vegetation condition scores averaged over 10 km segments, occurring on the N7 from Cape Town in the South (transect segment 1-10) to Violsdrif in the North (transect segment 681-684).

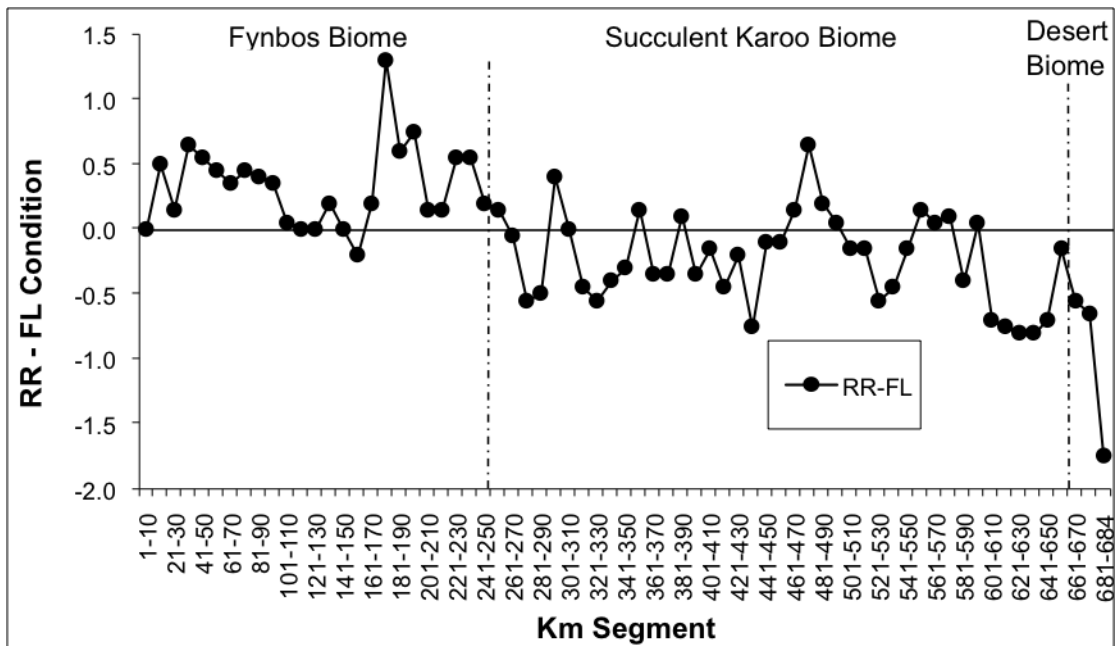


Figure 4.2: Road reserve (RR) vegetation condition minus farm land (FL) condition, averaged over 10 km segments, occurring on the N7 from South to North (Cape Town to Violsdrif). The horizontal line at zero represents scores for which no difference between the RR and FL exists.

#### 4.4.1.2 The effect of adjacent land use on road reserve condition

By far the greatest land use adjacent to the N7 was uncultivated land (55.1% of the transect). The other significant land uses on the N7 were (in order of declining importance): cultivated land (29.1%), a mixture of cultivated and uncultivated land (12.4%) and settlement (3.7%). Other land uses that occurred in only a few transect segments of the N7 were mining and open water such as is found along the Oliphants River.

The overall RR vegetation condition score was significantly higher than the FL vegetation condition score when the road reserve occurred adjacent to cultivated land ( $Z = 8.4$ ,  $n = 199$ ,  $p < 0.001$ ) and settlement ( $Z = 2.5$ ,  $n = 25$ ,  $p = 0.011$ ) land use types (Fig. 4.3). However, where the adjacent land use was uncultivated land, the FL vegetation condition score was significantly higher than the RR vegetation condition score ( $Z = 8.7$ ,  $n = 370$ ,  $p < 0.001$ ). There was no statistically significant difference between RR ( $3.1 \pm 0.9$ ) and FL ( $2.8 \pm 0.6$ ) vegetation condition scores when a mixture of cultivated and uncultivated land was the dominant land use practice on the land adjacent to the road reserve ( $Z = 1.1$ ,  $n = 85$ ,  $p = 0.280$ ).

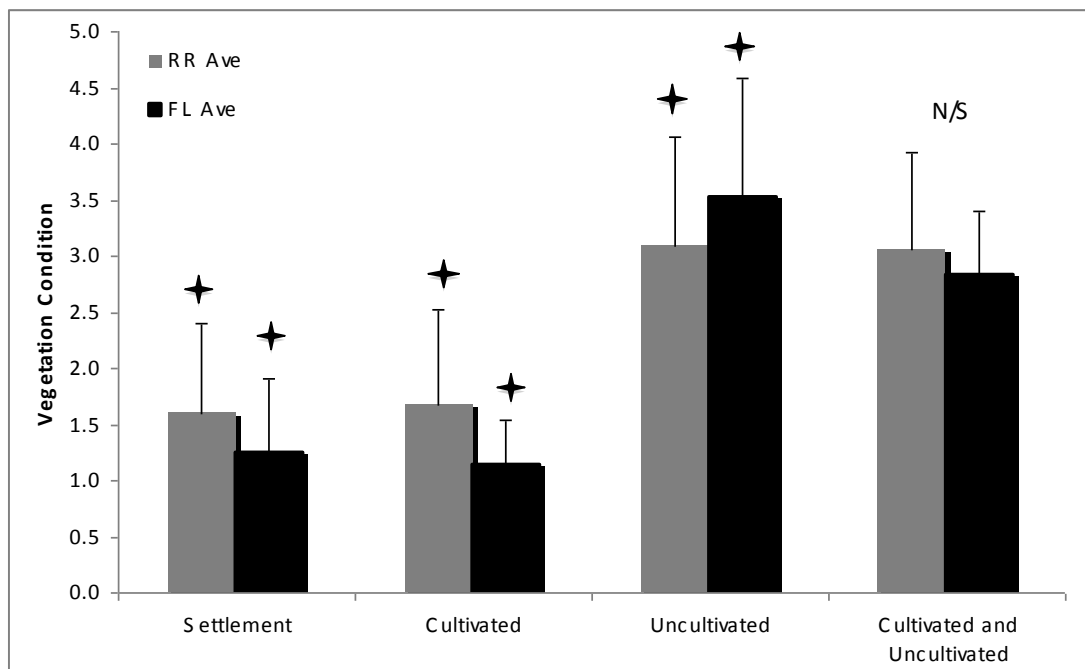


Figure 4.3: Average road reserve (RR) and farm land (FL) vegetation condition score ( $\pm$ std. dev.) as determined by adjacent land use practices.  $\star$  indicates where the RR and FL are significantly different.

#### 4.4.1.3 Alien vegetation in the road reserve

Alien vegetation was found in 43.3% of the RR and 52.9% of the FL 1 km transects on the N7. The Fynbos biome had the greatest proportion of alien vegetation with 82.5% of RR and 91.5% of FL transects hosting one or more alien plant (Table 4.5). Alien grasses (including cultivated cereal crop species) were present in the Fynbos consistently in both the RR (70.3%) and FL (68.7%). Alien shrubs were more common in the RR (24.4%) than the FL (9.9%) while alien trees were more common in the FL (50.4%) than the RR (28.5%). In the Succulent Karoo biome alien vegetation was less abundant in the RR (21.4%) and the FL (32.8%) than in the Fynbos biome. Alien grasses were more common in the RR (11.2%) than the FL (8.7%) while both alien shrubs and trees were more common in the FL (4.9% and 24.5%) than the RR (1.5% and 11.9%). In the Desert biome very little alien vegetation was encountered. However, there were more trees in the RR (15.4%) than in the FL (7.7%) (See Appendix 1 for a list of alien species identified in this study).

Table 4.5: The number and percentage of RR and FL 1 km transects along the N7 that had alien vegetation present. Alien vegetation was categorized as belonging to one of three growth forms: Grasses, Shrubs or Trees. The number of transects free of alien vegetation was also calculated. For this study, planted crops were considered as alien species.

Growth form	Fynbos (n = 246)		Succulent Karoo (n = 412)		Desert (n = 26)	
	RR	FL	RR	FL	RR	FL
Grasses	173 (70.3%)	169 (68.7%)	46 (11.2%)	36 (8.7%)	0	0
Shrubs	60 (24.4%)	24 (9.9%)	6 (1.5%)	20 (4.9%)	1 (3.8%)	0
Trees	70 (28.5%)	124 (50.4%)	49 (11.9%)	101 (24.5%)	4 (15.4)	2 (7.7%)
Aliens absent	43 (17.5%)	21 (8.5%)	324 (78.6%)	277 (67.2%)	21 (80.8%)	24 (92.3%)

## 4.4.2 Conservation value (CV)

### 4.4.2.1 Conservation value (CV) of vegetation types and biomes

There were significant differences between the average CV scores for the three biomes along the N7 (Table 4.6). Average CV scores for the Fynbos biome ( $8.0 \pm 5.8$ ) were significantly greater than those for the Succulent Karoo ( $3.6 \pm 1.5$ ) which were, in turn, significantly higher than those for the Desert biome ( $2.4 \pm 0.9$ ) ( $\chi^2 = 215.8$ ,  $df = 2$ ,  $p < 0.001$ ). There was considerable variability in CV scores between different vegetation types, particularly within the Fynbos and Succulent Karoo biomes, and this resulted in relatively high standard deviation values for the CV scores.

Table 4.6: Summary of the length (in km) of each vegetation type occurring on the N7 between Cape Town and Vioolsdrif as well as the average condition of the road reserve (RR) and adjacent farmland (FL), the conservation status (CS) and conservation value of each vegetation type and biome. Average ( $\pm$ stdev) values are provided for each biome. Vegetation Type Codes and the Conservation Status (CS) abbreviations are derived from Mucina and Rutherford (2006) and are explained in Table 4.3 above.

Biome	Vegetation Type Code	Total length (kms)	RR Condition (Average)	FL Condition (Average)	Conservation Status	Conservation Value
Fynbos	FFd 5	20	1.4	1.1	CR	8.1
Azonal	Azf 1	1	1.0	1.0	LT	1.0
Fynbos	FRs 9	97	1.2	1.0	CR	6.1
Fynbos	FRc 1	1	1.0	1.0	CR	4.0
Fynbos	FFd 4	12	1.8	1.2	VU	5.9
Fynbos	FRg 2	23	1.7	1.2	CR	11.1
Azonal	Azf 2	1	1.0	1.0	CR	4.0
Fynbos	FFs 3	31	3.2	2.8	LT	4.5
Fynbos	FFd 2	45	3.1	2.4	EN	14.0
Fynbos	FFs 2	10	3.7	4.2	VU	7.6
Fynbos	FFs 4	1	4.0	4.0	LT	4.0
Fynbos	FRs 1	1	2.0	3.0	LT	2.0
<b>Biome</b>	<b>Ave.</b>	<b>20.3</b>	<b>2.0</b>	<b>1.7</b>		<b>8.0</b>
	<b>Stdev.</b>	<b>28.0</b>	<b>1.2</b>	<b>1.2</b>		<b>5.8</b>

Table 4.6 (continued)

Biome	Vegetation Type Code	Total length (kms)	RR Condition (Average)	FL Condition (Average)	Conservation Status	Conservation Value
Suc Karoo	SKk 7	4	3.5	3.0	VU	9.0
Suc Karoo	SKk 5	35	2.7	2.6	VU	6.3
Suc Karoo	SKv 1	6	3.5	3.8	LT	3.5
Azonal	Azi 1	1	3.0	3.0	LT	3.0
Suc Karoo	SKs 13	14	2.3	2.8	LT	2.3
Suc Karoo	SKk 6	2	2.3	2.0	LT	3.3
Suc Karoo	SKs 12	6	4.5	4.4	LT	4.7
Suc Karoo	SKk 3	34	3.6	4.1	LT	3.7
Suc Karoo	SKn 1	184	3.1	3.3	LT	3.5
Suc Karoo	SKn 4	9	2.8	2.9	LT	3.3
Suc Karoo	SKn 3	88	2.8	3.0	LT	3.3
Suc Karoo	SKn 6	1	5.0	5.0	LT	5.0
Suc Karoo	SKr 17	22	2.7	3.2	LT	2.8
Suc Karoo	SKr 16	9	2.7	3.6	LT	2.8
<b>Biome</b>	<b>Ave.</b>	<b>29.6</b>	<b>3.0</b>	<b>3.2</b>		<b>3.6</b>
	<b>Stdev.</b>	<b>50.1</b>	<b>0.8</b>	<b>1.0</b>		<b>1.5</b>
Desert	Dg 8	10	2.4	3.3	LT	2.4
Desert	Dg 7	1	1.0	3.0	LT	1.0
Desert	Dg 9	12	2.6	3.2	LT	2.6
Desert	Dg 10	1	1.5	2.0	LT	1.5
Azonal	Aza 3	2	1.0	2.0	EN	3.0
<b>Biome</b>	<b>Ave.</b>	<b>5.2</b>	<b>2.3</b>	<b>3.1</b>		<b>2.4</b>
	<b>Stdev.</b>	<b>5.4</b>	<b>0.9</b>	<b>0.7</b>		<b>0.8</b>

Average conservation value (CV) scores for 10 km segments (Figure 4.4) provide a summary of the general pattern along the mega-transect. Three areas with high conservation value are apparent. The first is a 10 km segment 11-21 km north of Cape Town. This is strongly influenced by a small section of relatively pristine Cape Flats Sand Fynbos (FFd 5) and has a CV of  $8.1 \pm 8.3$  (Table 4.6). The second peak in CV possesses an average value of  $9.4 \pm 6.3$  and is located 40 – 100 km north from Cape Town. It is comprised predominantly of Cape Lowland vegetation types, most of

which are cultivated intensively. The main vegetation types occurring in this area are Swartland Shale Renosterveld (FRs 9) with a CV of  $6.1 \pm 4.3$  and Swartland Granite Renosterveld (FRg 2) with a CV of  $11.1 \pm 7.5$ . Smaller areas of Fynbos vegetation are also present. For example, Cape Flats Sand Fynbos (FFd 5) with a CV of  $8.1 \pm 8.3$  and Atlantis Sand Fynbos (FFd 4) with a CV of  $5.9 \pm 3.1$  also occur in this region.

The third peak in conservation value (CV) occurs 190-240 km north of Cape Town (Figure 4.6) and has an average CV score of  $12.2 \pm 5.4$ . It is located along the Oliphants River Valley, from the Algeria turn-off to 20 km north of Clanwilliam. The main vegetation types which occur here are Oliphants Sand Fynbos (FFs 3) with a CV of  $4.5 \pm 1.6$ , Leipoldville Sand Fynbos (FFd 2) with a CV of  $14.0 \pm 4.9$  (the highest value of any vegetation type) and Graafwater Sand Fynbos (FFs 2) with a CV of  $7.6 \pm 1.6$  (Table 4.6).

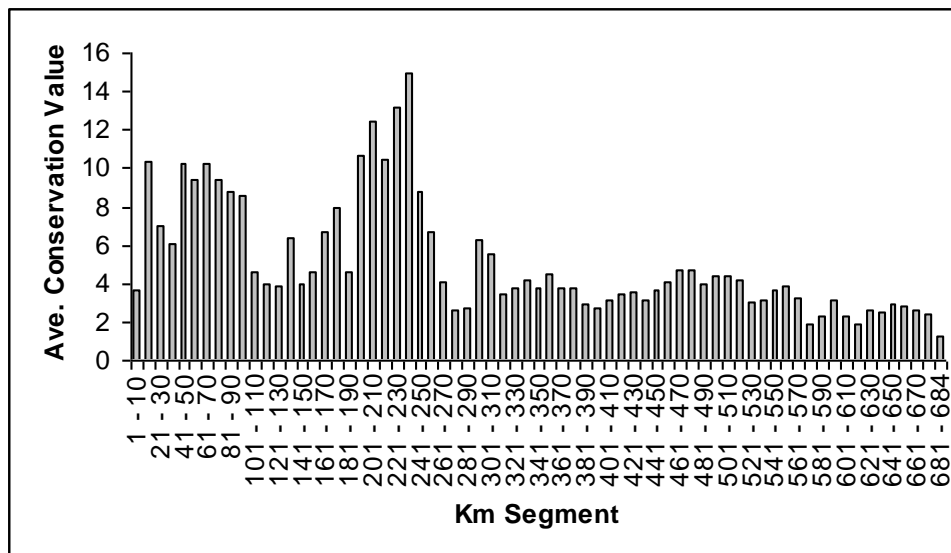


Figure 4.4: Conservation Value, averaged over 10 km segments, of the road Reserve along the N7 from Cape Town in the south (km segments 1-10) to Violsdrif in the north (681-684).

#### 4.4.2.2 Conservation value and environmental variables

For the 684, 1 km segments, conservation value (CV) is significantly correlated ( $p < 0.001$ ) with altitude, mean annual rainfall and temperature. CV was negatively correlated with altitude ( $r = -0.4523$ ) and temperature ( $r = -0.1820$ ), while it was positively correlated with rainfall ( $r = 0.5767$ ).

## **4.5 Discussion**

This chapter has explored the vegetation condition and the related conservation value of the 684 km long N7 road reserve stretching from Cape Town in the south to Vioolsdrif in the north. The discussion will explain how the vegetation condition and conservation value varies over the different biomes in relation to adjacent land use, management practices and environmental variables.

### **4.5.1 The ecological condition of the N7 road reserve and the adjacent farmland**

The road reserve (RR) and farm land (FL) vegetation condition differed significantly within and between the different biomes in the study area. As suggested in another study of South African road reserves by Cilliers and Bredenkamp (2000), these differences are determined primarily by adjacent land use practices, historical land use and road construction history, road verge management practices and the presence of alien vegetation. Since each biome has its own unique set of biophysical, historical and land use influences the condition of the road reserve is discussed separately for each biome.

#### **4.5.1.1 Fynbos biome**

The Fynbos biome was the only biome in which the RR values were significantly higher than the FL values within the same biome. However, when compared to the other two biomes along the transect, the Fynbos biome had significantly lower RR vegetation condition scores when compared to the Succulent Karoo biome, and had significantly lower FL vegetation scores when compared to the Succulent Karoo and Desert biome. This is largely due to the history and nature of land use in the biome.

In the Cape Lowlands, which extends from Cape Town to the bottom of the Piekenierskloof Pass, about 190 km north of Cape Town, both the RR and the FL are in very poor condition, although the RR is marginally better than the FL. This is due to the fact that small sections of the N7 road reserve are still vegetated by indigenous flora, whereas most of the FL has been transformed by a long history of land use.

Even before colonial farmers used the land for agriculture and grazing, the indigenous people of the Cape (the Khoikhoi) were grazing their sheep and cattle in this area (Penn, 2005). Colonial use of the land around Cape Town dates back to the late

1600's and by 1705 there were settler farms as far North as Piketberg (Penn, 2005). Today, from Cape Town to the base of the Piekenierskloof Pass, the FL is completely transformed (i.e. ploughed and planted with crops, mainly canola, wheat and vines) leaving almost no natural vegetation. In this study, where the adjacent land use was cultivated land, the RR vegetation condition was significantly better than FL condition (see section 4.3.1.2). However, the intensive landuse in the FL has also had a negative impact on the RR and explains why the average RR condition is only marginally higher than the FL in this area. The spillover effects from crop spraying in the FL has also contributed significantly to the current condition of the RR. However, with over 300 years of agricultural use in this area, both intensive crop cultivation and grazing, it is expected that the degree of transformation of the land is high.

In their study on the biodiversity of South Africa, Biggs et al. (2006) calculated a Biodiversity Intactness Index (BII) for various land use types. They defined the index as '...a richness-and-area weighted average population impact of a set of land-use activities on a group of organisms, in a given area'. The average BII for cultivated land in their study was given as 25.1% (Biggs et al., 2006). This is a relatively low BII and reflects the high transformation associated with cultivation. While the cultivated FL in the Cape Lowlands is completely transformed due to on-going cultivation activities, the road reserve is not likely to have been ploughed since the road was rehabilitated on its existing route in the early 1980s. However, because of the geographic and temporal extent of agriculture on the fertile soils of the Cape Lowlands, it is likely that the original construction of the N7 in this area would have been completed on land that was already largely transformed by agriculture. Furthermore, widening of the road, which occurred in the 1980s, would have further destroyed any RR vegetation which might have existed at the time. While some attempt at re-establishment of vegetation would have been carried out in terms of the road construction project this appears not to have significantly improved the condition of the RR relative to the putative benchmark vegetation. Furthermore, continued maintenance of the RR, such as bush clearing and mowing, prohibits the re-establishment of a diverse indigenous flora. Herbicide is also occasionally used in the RR as an alternative means of controlling alien vegetation in this area. This combination of herbicide spraying, bush clearing and mowing further decreases diversity in the RR by eliminating natural competitors to alien vegetation (Esler and

Milton, 2006). However, it has also been shown that mowing is the most effective strategy for controlling alien grasses in renosterveld vegetation which is a common vegetation type in the Cape Lowlands (Musil et al., 2005).

In the Oliphants River Valley, both the RR and the FL are in far better condition than the Cape Lowlands. However, as with the Cape Lowlands, the RR is in a significantly better condition than the adjacent FL primarily as a result of cultivation in the FL.

Although early settler farmers experienced difficulties in crossing the Piekenierskloof Pass, farms were established along the Oliphants River as early as 1732. This is a significant history of intensive cultivation which was restricted at first to areas immediately adjacent to the Olifants River. There has been a significant expansion of agriculture in the Oliphants River Valley in the past century (Banora, 2009), which today consists mainly of citrus, potato, grain and rooibos cultivation. Between 1946 and 1988 there was a 25% increase in the total area cultivated in the Cederberg Local Municipality. The expansion of the citrus and deciduous fruit industries in the Oliphants River Valley was the most significant (Banora, 2009).

The current route of the N7 in this area, on the west side of the Oliphants River, is an adjustment from the previous route which existed on the east side of the river until the late 1950's. At the time of construction it is likely that much of the road would have been built through uncultivated indigenous vegetation. Furthermore, some of the cultivated land adjacent to the N7 has been cleared relatively recently and certainly after the N7 was constructed.

Another reason for the relatively high vegetation condition score obtained for the road reserve in the Oliphants River Valley is that the road frequently traverses steep and rocky terrain which makes intensive management of the road reserve (e.g. mowing) more difficult. The RR vegetation is, therefore, largely intact and exemplifies the potential that road reserves can play in preserving vegetation in cultivated landscapes. It is in this area that the RR – FL values are at their highest in the whole transect.

Adjacent to the N7 the FL is largely under intensive cultivation, although many of the more rocky areas remain largely uncultivated. The effects of the cultivation also appear not to have had as negative an impact on the condition of the RR vegetation as in the Cape Lowlands. This is probably related to differences in the age, type and

extent of the cultivation in the two areas. The dominance of citrus orchards along the N7 in the Oliphants River Valley appears to have fewer harmful effects on the RR than other types of agriculture that have more intensive annual cycles of ploughing, planting and spraying (e.g. wheat and canola).

In summary, the following key factors appear to explain the relatively high RR scores in the Oliphants River Valley. Firstly, the N7 was built largely through uncultivated indigenous vegetation. Secondly, the clearing of agricultural land on either side of the road for agricultural purposes has happened within the recent past and has not had a significantly negative impact on the condition of the road reserve. Finally, the geology and relief of the area has discouraged intensive management of the road reserve and has contributed to its relatively high vegetation condition status.

Alien vegetation was observed in 82.5% of RR and 91.5% of FL transects in the Fynbos biome. This is slightly lower, although comparable to the values obtained by Milton and Dean (1998) who recorded alien vegetation in 98% of the Fynbos biome road reserve transects they assessed. Alien vegetation along the N7 was comprised mainly of trees (e.g. *Acacia saligna*, *Eucalyptus globulus*) and grasses (e.g. *Pennisetum setaceum*) (See Appendix 1 for a list of alien plants). Alien trees were far more common in the FL than the RR transects because trees are cleared in the RR for safety reasons by contractors. For much of the Fynbos biome, the N7 road reserve is bordered by road on one side and cropland on the other. This means that the edge:area ratio greatly increases the opportunities for invasion by exotics (Milberg and Lamont, 1995), both from vehicles on the road and from crops and weeds in the farmland. It has been shown that alien propagule pressure is the controlling factor determining habitat invasibility, when compared with the physical environment and already established resident species (Von Holle and Simberloff, 2005). Precipitation runoff from roads further supports the establishment of weedy alien species in road verges and their spread along this corridor, which adds to the degradation of the condition of the natural vegetation of the road verge (Milton and Dean, 1998; Kawlij et al., 2008). These processes have resulted in the remaining indigenous vegetation being largely transformed to a depauperate mix of annual grasses and hardy indigenous annuals, geophytes and shrubs at present.

While there are a number of factors that influence the condition of the vegetation in the RR, it is both the historical as well as the present adjacent land use that exerts the greatest influence. The same observation was made by Ullmann et al. (1995), in New Zealand, who suggested that the basic floristic composition of roadside vegetation is derived from the adjoining areas, and additional immigration of species is mainly initiated by human activities.

The long history of intensive crop cultivation in the lowlands and valleys of the Fynbos biome has resulted in the transformation of the vegetation in the FL to a very poor condition. It has been shown that road verges that have been adjacent to agricultural land for over 150 years have a significantly lower plant species richness than road verges in modern agricultural landscapes (Cousins, 2006). Spooner and Smallbone (2009) also showed that road age had an effect on the composition of the roadside flora. This supports the evidence that road reserve condition is in worse condition adjacent to areas where agriculture has been practiced for more than a century (e.g. Cape Lowlands) compared with areas where cultivation has been more recent (e.g. Oliphants River Valley).

Finally, the spillover effects of crop spraying in the Fynbos biome have had a negative effect on the RR, as has the continued maintenance of the RR. The disturbances in both the RR and FL have promoted the establishment of alien vegetation. The result is that the condition of the RR and FL is significantly lower than in other biomes along the N7.

#### **4.5.1.2 Succulent Karoo biome**

Within the Succulent Karoo biome, at the drier end of the gradient, the FL vegetation condition was significantly better than the RR vegetation condition over most of its range except perhaps in the foothills of the Kamiesberg where extensive cultivation has occurred. This suggests that agricultural activities on lands adjacent to the road reserve in this biome have generally not been as detrimental to the condition of the vegetation as have the combined impacts of road construction and maintenance of the road reserve itself. However, compared to the other two biomes examined in this study, the Succulent Karoo biome had significantly higher RR vegetation condition scores than both the Fynbos and Desert biomes and significantly higher FL vegetation

condition scores when compared with the Fynbos biome but not with the Desert biome.

Namaqualand, which forms a significant part of the Succulent Karoo biome, has a long history of land use. Webley (2007) suggests that it has one of the longest records of grazing by domesticated livestock in Southern Africa and pastoralists and their livestock are believed to have been in the area for over 2,000 years (Hoffman and Rohde, 2007). From 1750 onwards, however, colonial farmers appropriated a significant portion of the land in Namaqualand for commercial livestock farming and mining purposes (Hoffman and Rohde, 2007). They also cultivated the land for cereal production, particularly in the higher rainfall areas of this biome (e.g. along the foothills of the Kamiesberg). This practice continues today and probably explains why the average vegetation condition score for RR transects is greater than for FL transects in the Kamiesberg. However, cultivation has declined significantly in the second half of the 20<sup>th</sup> century in the drier parts of Namaqualand and the abandoned croplands have been recolonised by a wide range of indigenous shrubs, annuals and bulbs (Hoffman and Rohde, 2007; Kellerman and van Rooyen, 2009). Such successional processes are likely to continue into the future.

Where FL is not cultivated in the Succulent Karoo biome the vegetation is relatively intact in terms of species composition and cover. Under these conditions the vegetation condition of the FL is significantly greater than that of the RR although the condition of the RR is still high relative to the other two biomes assessed in this study. Not only is there less influence on the vegetation in the road reserve from the adjacent uncultivated land but in addition, landscapes associated with uncultivated land are often arid, rocky and associated with steep slopes which make intensive management of the road reserve, including mowing and scraping, more difficult.

Since fencing keeps livestock out of the RR, grazing has little impact on the vegetation. Palatable plants, in particular, often find refuge in such protected areas (Dawson, 1991). Indeed in this study, *Zygophyllum namaquanum* was found in the RR and is known to be highly palatable (van Zyl, 2000). In the absence of a significant grazing impact in the RR it is suggested that the most important reason why the condition of the RR vegetation was generally lower than that of the FL is road disturbances through construction and maintenance. The same conclusion was

reached by O' Farrell and Milton (2006) who suggested that construction and maintenance of the road are the most significant drivers influencing road reserve plant communities in the Succulent Karoo biome.

The presence of alien vegetation was also observed in the Succulent Karoo biome with species such as *Atriplex nummularia*, *Bromus tectorum* and *Prosopis glandulosus* being common in places along the N7. Alien vegetation was recorded in 21.4 % of RR and 32.8 % FL of transects which is substantially lower than the value of 81% recorded by Milton and Dean (1998) in their assessment of the transects they observed in the Succulent Karoo biome. There are a number of reasons for the differences between the two studies. Firstly, Milton and Dean (1998) investigated areas far beyond the N7. This expanded study area would have resulted in different results. Secondly, the time of year would also influence the outcome. Milton and Dean (1998) carried out their study over a number of years between the months of September and May, which provides the opportunity to observe more species, especially annuals. For this study the recording of alien vegetation took place in early December when much of the vegetation was dry and the annual flora was largely absent.

While there are certain areas within the Succulent Karoo biome that have higher RR vegetation condition scores when compared to the FL, the biome as a whole shows the opposite trend. The decline in intensive crop cultivation in the past half century and the resultant recolonisation of abandoned fields by indigenous flora is likely to have made a significant improvement on the FL vegetation condition. The continued maintenance of the RR is also likely to provide the disturbance to the vegetation that decreases its overall condition to below that of the FL. However, the fact that intensive agriculture is less common in this biome than the Fynbos biome and has decreased since 1970, results in the FL condition being significantly greater than in the Fynbos biome. Less disturbance in the FL results in the RR only being disturbed by road verge maintenance. This results in the significantly better RR vegetation condition in this biome when compared to the Fynbos biome.

#### **4.5.1.3 Desert biome**

In the Desert biome, as with the Succulent Karoo, the FL vegetation condition score was significantly higher than the RR. The RR condition score was relatively low and

declined significantly towards the end of the transect as one approaches the South African/Namibian borderpost where human disturbance from settlement and irrigated cultivation is high. The RR vegetation for this biome, however, is significantly lower than that of the Succulent Karoo biome. The adjacent land use is predominantly uncultivated land which explains why the FL condition is better than the condition of vegetation within the RR. The FL vegetation condition for this biome is also significantly better than in the Fynbos biome. The poor RR quality in this region is likely the result of road construction, road verge maintenance and extensive transportation activity closer to the border.

#### **4.5.2 The conservation value (CV) of the N7 road reserve**

There were significant differences between the average CV scores for the three biomes along the N7 (Table 4.6). Average CV scores for the Fynbos biome were significantly greater than those for the Succulent Karoo biome which were, in turn, significantly higher than those for the Desert biome. Three peaks in CV were observed along the transect, all of which were found in the Fynbos biome (Figure 4.4).

##### **4.5.2.1 Fynbos biome**

While the road reserve vegetation condition in the Fynbos biome is very low, the critical conservation statuses of the vegetation types present means that any remaining vegetation is likely to have a high conservation value. The first area of high CV is just north of Cape Town, and is a relatively pristine strip of Cape Flats Sand Fynbos, a vegetation type that is *Critically Endangered*. The second area of high CV is part of the Cape Lowlands that is largely under intensive crop cultivation, and is dominated by the Renosterveld vegetation units, Swartland Shale and Granite Renosterveld, as well as some other Fynbos vegetation types. These vegetation types have all been extensively transformed by agriculture and any remaining vegetation is, therefore, considered *Critically Endangered*, and results in the high CV for this area. These two areas are also host to many of the RDB species identified in this study (See Chapter 5). The high CV values associated with the low RR values indicates that each patch of remnant vegetation in the Cape Lowlands should be highly valued as a conservation asset and conserved as such. The Cape Lowlands contains four of the ten vegetation types most impacted by irreversible habitat transformation in South Africa (Rouget et

al., 2006). Kemper et al. (1999) also conclude that all renosterveld fragments, irrespective of their size, should be considered conservation worthy.

The final area of high CV is located adjacent to the Oliphants River Valley and contains a number of sand Fynbos units that are not *Critically Endangered*, but are *Vulnerable* and *Endangered*. The fact that the RR condition here is relatively high for the Fynbos biome results in the high CV of the area.

Dawson (1991) concluded that the Fynbos Veld Types that he studied (Coastal Renosterveld VT 46 and Coastal Fynbos VT 47) had low conservation values (22.3% and 16.5% respectively) due to poor management practices of mowing, weed spraying and burning. The disturbances caused by management combined with the pressures of alien seed propagules from the road and adjacent farmland increased the grass component in this area at the expense of shrubs. The reason that Dawson (1991) found the CV of these Fynbos units to be less worthy of conservation than in this study is likely to be a matter of differing methodology. While both studies calculated their CV values based on the condition of the RR vegetation, this study includes a relationship to the conservation status of the vegetation type present. This increases the CV of areas that have highly threatened vegetation types (usually due to transformation in the vegetation type), and provides a tool to identify areas (especially small areas) that are worthy of conservation attention by, for example, the responsible road management authorities.

The relationship between environmental variables and CV is best illustrated in the Fynbos Biome. CV is positively correlated with rainfall, while negatively correlated with altitude and temperature (See 4.4.2.2). High conservation values are therefore correlated with areas of low altitude and low temperature which experience high rainfall. This corresponds with the typical environmental and climatic conditions of the Fynbos biome, especially that of the Cape Lowlands.

#### **4.5.2.2 Succulent Karoo biome**

Due to the lack of intensive crop cultivation in the Succulent Karoo biome, the vegetation types present are mostly considered *Least Threatened*, except for Vanrhynsdorp Gannabosveld (SKk) 5 and Citrusdal Vygieveld (SKk 7), which are considered *Vulnerable* (Mucina and Rutherford, 2006). Because of the conservation

status of these vegetation types their CV scores are higher than the average for the Succulent Karoo biome. Even though the RR vegetation condition is higher in the Succulent Karoo biome than in much of the Fynbos biome, the lower conservation status of the vegetation types in the Succulent Karoo biome results in them having significantly lower CV scores than in the Fynbos biome. In their study, O'Farrell and Milton (2006) concluded that road reserves in the Succulent Karoo biome can be characterized largely as disturbed environments due to the impact of road construction and maintenance activities. It is suggested that they are unlikely to contribute significantly to the plant conservation needs of the biome (O'Farrell and Milton, 2006).

#### **4.5.2.3 Desert biome**

The CV for the Desert Biome is the lowest of all three Biomes in the transect. All the vegetation types in the Desert Biome are considered *Least Threatened* except for Lower Gariep Alluvial Vegetation (AZa 3) which is *Endangered*. However, only 25 km of the Desert Biome are encountered on the N7 and it is therefore difficult to draw conclusions about the condition of the RR and the CV of the Biome from this relatively small sample.

#### **4.6 Conclusion**

The vegetation condition and conservation value of the N7 road reserve varies significantly over the long and diverse transect. Vegetation type has a large influence on the condition of the road reserve condition. Many studies which promote the potential of road reserves as conservation assets locally (Cilliers and Bredenkamp, 2000) and abroad (Tikka et al., 2000; Tanghe and Godefroid, 2000) refer to grasslands which are naturally-adapted to grazing and therefore able to withstand the mowing associated with road reserve management. However, the species composition of the Fynbos biome is not adapted to such disturbance and will be degraded rather than preserved as grasslands might be under such management activity. Land use activities adjacent to the road reserve also play an important role in determining the quality of the road reserve vegetation which in turn affects the conservation value. It has been proposed that road reserves are linear habitats (Tshiguhvo et al., 1999) that improve connectivity between fragmented habitats (Spooner and Smallbone, 2009).

This idea has potential but can only be considered in areas where road reserve vegetation is continuous.

This outcome is unlikely in areas where the road reserve vegetation is as fragmented as its adjacent farm land, for example the Cape Lowlands. The transformation in this area is largely due to spillover effects from the cultivated land and a long history of cultivation. While the remnant road reserve vegetation in this area is not continuous and in relatively poor condition, the conservation value of this area is very high due to the threatened nature of the vegetation types present.

Beyond these lowlands, however, but still within the Fynbos Biome, the road reserve vegetation improves in condition and has some potential to provide connectivity between habitat fragments. This is related to the age of the road, topography and the type of adjacent land use. The relatively high values obtained for vegetation condition and the presence of several threatened vegetation types results in a region along the N7 of high conservation importance. Due to the high quality of the road reserve vegetation in this area, it has the highest conservation value in the entire transect.

In the more arid areas of the Succulent Karoo biome there is generally a decrease in amount of intensive agriculture and a related decrease in threatened vegetation types. Even though the road reserve condition in the Succulent Karoo biome is generally better than in the Fynbos biome the conservation value is relatively low because of the generally low conservation status associated with vegetation types in the Succulent Karoo biome. However, the relatively untransformed nature of the vegetation in this biome means it has some potential as a corridor. The very short part of the N7 that passes through true Desert does not allow for a sufficient analysis of road reserve condition and conservation value in this biome although the data that are available do not highlight any areas of particular importance with the Desert biome.

## **CHAPTER 5 – THE RED DATA BOOK (RDB) SPECIES OF THE N7 ROAD RESERVE**

### **5.1 Introduction**

Road reserves have the potential to be of great biological and conservation value as they can represent relatively undisturbed habitats in otherwise largely transformed landscapes (Way, 1977; Lamont et al., 1994a; Forman and Alexander, 1998). Even though they are not officially conserved in the same way that a nature reserve is, they often contain many indigenous plant species. Road reserves therefore have intrinsic value as botanical repositories (Bennett, 1991).

Even though road reserves are narrow strips of vegetation within a fragmented matrix of multiple land uses, they can still perform an important role. They retain links with neighbouring, non-verge populations via gene flow and therefore retain genetic variability. This is a very important outcome for these relatively small populations as it decreases the influence of the negative impacts associated with isolated populations (Ellstrand and Elam, 1993; Hogbin et al., 1998; Van Rossum et al., 2004).

More than just being repositories for indigenous plant species, road reserves can play an even more important role in conservation by hosting rare species (Bennett, 1991). Especially in largely transformed landscapes where the surrounding vegetation is used intensively, road reserves provide habitat for threatened vegetation types and plant species. In some cases, road reserves provide habitat for the only remaining native vegetation, and host the only remaining rare plant species (Breckwoldt, 1990; Lewis, 1991; Leigh and Briggs, 1992).

South Africa has a particularly rich flora, with exceptionally high levels of endemism (von Staden et al., 2009). Of the 20 456 known plant species, 13 % are in danger of regional or global extinction, and 24 % (one in four taxa) are of conservation concern (Raimondo and von Staden, 2009). Considering these figures, it is likely that any remaining natural habitat in road reserves in the study area will contain some plant species of conservation importance. It is also possible that some of these threatened species will be protected in this refuge.

One way to determine whether a plant species is benefitting from a particular habitat is to compare its reproductive success in that area with another area. The reproductive success of plants in road reserve and other fragmented habitats have shown a variety of outcomes (Yates and Ladd, 2005) determined by pollination patterns (Lamont et al., 1994a), reproductive strategies (sexual or asexual), habitat size (Donaldson et al., 2002) and disturbance regimes (Jantunen, 2007).

The pollination of plants in road reserves and other highly fragmented habitats may be reduced due to the reduction in access to these isolated populations (Aizen and Feinsinger, 1994a, 1994b). Although birds, insects and rodents are not inhibited by fences and fields and it is unclear whether plant-pollinator interactions are reduced in these habitats (Cane, 2001). Some studies, such as that of Lamont et al. (1993) showed significantly reduced seed set in isolated road side populations of *Banksia goodii*. Another study of an endangered Australian shrub, however, showed that there was a greater or equal number of insect visitors, rate of pollination and seed production in small road verge populations compared with larger populations in conserved areas (Yates and Ladd, 2005).

Pollinator activity and seed production are not the only factors affecting population success. Where fires are necessary for seedling germination, fragmented habitats that have reduced fire frequencies are likely to see a decrease in seedling germination and recruitment (Yates and Broadhurst, 2002). So, habitat change and management activities play a critical role in determining whether seeds germinate and survive (Yates and Ladd, 2005). The complex interaction of plant reproduction and anthropogenic influence on an ecosystem determine the continued existence of plants. This complex interaction is illustrated in a study on the pollination mutualism between *Brunsvigia orientalis* (Amaryllidaceae) and *Nectarina* sp (Sunbirds) in Cape Nature reserves. It was found that both habitat fragmentation in urban areas and fires indirectly caused a failure in this pollination system (Pauw, 2004).

While there are many negative impacts on plants related to habitat fragments and road reserves, there are also some positive elements associated with these anthropogenic changes. The disturbance (mowing and bush clearing) associated with road verge maintenance (often for safety reasons) results in certain plant species being favored

over others. The lack of root competition makes extra nutrients available for the plants that remain and leads to superfluous vegetative and reproductive growth (Hogbin et al., 1998; Lamont et al., 1994a). Considering the selective advantages and disadvantages accrued to rare plants in the road reserve, it is important to consider each population of RDB species individually and to properly assess their conservation importance on a site by site basis.

This chapter looks at the abovementioned issues by addressing the key questions:

- (1) Which RDB species and major growth forms occur in the N7 road reserve?
- (2) What is the distribution of the RDB species in relation to vegetation type, environmental variables and the condition of the road reserve vegetation?
- (3) Do RDB species accrue any reproductive advantage in the road reserve compared to adjacent populations?

All species considered to be of conservation concern according to the Red List of South Africa 2009 (Raimondo et al., 2009) are collectively referred to as RDB species or species of conservation concern. Those species referred to as being ‘threatened with extinction’ refer to the categories Critically Endangered, Endangered and Vulnerable (Raimondo et al., 2009).

## **5.2 Methods**

An inventory of all plant species seen flowering on the N7 was completed during fieldwork in the spring of 2008 and follow-up fieldwork at irregular intervals thereafter (Appendix 1). The final species list from the N7 road reserve was compared to the latest Red List of South African Plants 2009 (Raimondo et al., 2009) to identify which plants were listed and to determine their conservation status. The photos of these species were then processed through the geo-referencing software (Geosetter) to obtain their GPS co-ordinates. This information was entered into the GIS software (ArcMap) in order to plot their distribution on a map of the study area. Other data such as the distribution of vegetation types as well as environmental data was also incorporated into the database and used for analysis.

The list of RDB populations between Cape Town and the Knersvlakte was used to randomly select 32 populations to be revisited. At each site the number of individuals

was counted in the RR and the FL. The area surveyed varied between sites and was determined by the abundance of the species present. Area ranged from 75m<sup>2</sup> for the smallest population to 3000m<sup>2</sup> for the largest. The concentration of individuals per m<sup>2</sup> was then calculated for the RR and FL to determine whether the species favoured either side. Species were assigned to one of seven growth forms as follows: Aquatic, Geophyte, Herb, Non-succulent shrub, Leaf succulent shrub, Stem succulent shrub, and Tree.

### **5.2.1 Statistical Analysis**

The number of RDB species per km transect were correlated with RR condition and Conservation Value as well as with a range of environmental variables including latitude, altitude, rainfall and temperature using a Spearman Rank Correlation. The number of individuals in all populations of the 32 RDB species investigated were summed within and outside of the road reserve and the difference compared using a Wilcoxon Signed Rank Test. Differences within a growth form inside and outside the RR were also compared using the same approach.

## **5.3 Results**

### **5.3.1. RDB species and their growth forms**

In total, 670 species were recorded in the N7 road reserve during the fieldwork of this study (Appendix 1). Of these, 62 (9.3% of the total) are listed on the latest Red List of South Africa (Table 5.1). Of these 62, three are listed as Data Deficient – Taxonomically uncertain (DDT). While this category is not considered to be of conservation concern, as there is not enough information available about the range and distribution of the species to assess its risk of extinction, they are included in this list as they are of potential future conservation importance.

Non-succulent shrubs were the most common growth form on the N7 (39%). These were typical Fynbos shrubs, mainly in the family *Proteaceae* with a few in the families *Asteraceae*, *Fabaceae* and *Thymelaeaceae*. RDB listed geophytes were the second most common growth form on the N7 (34%). These consisted mainly of species within the families *Iridaceae* and *Hyacinthaceae*. Leaf succulent shrubs were the next most common growth form (14%), followed by stem succulent shrubs (6%), herbs (3%), aquatics and trees (1%) (Table 5.2).

Table 5.1: The Red Data Book Species on the N7. Table includes RDB status, growth form and biome. The conservation status codes are: CR – critically endangered; EN – endangered; VU – vulnerable; Thr – Threatened; NT – near threatened; Dec – declining; Rare – rare; DDD – Data deficient – Insufficiently Known; DDT - Data Deficient – Taxanonomically uncertain. Additional codes refer to the criteria and sub-criteria (e.g. population size) used to assess conservation status (see Appendix 3 for a full explanation of these IUCN codes and criteria).

FAMILY	GENUS	SPECIES	RDB STATUS	GROWTH FORM	BIOME
Aizoaceae	Antimima	aristulata	VU B1 ab(ii,iii,iv,v)	Leaf succulent shrub	Fynbos
Aizoaceae	Diplosoma	retroversum	EN B1 ab(ii,iii)	Leaf succulent shrub	Fynbos
Aizoaceae	Drosanthemum	hispifolium	VU B1 ab(ii,iii,iv,v)	Leaf succulent shrub	Fynbos
Aizoaceae	Jacobsenia	hallii	VU D2	Leaf succulent shrub	Succulent Karoo
Aizoaceae	Phyllobolus	viridiflorus	Rare	Leaf succulent shrub	Succulent Karoo
Aizoaceae	Ruschia	radicans	DDT	Leaf succulent shrub	Succulent Karoo
Amaryllidaceae	Brunsvigia	namaquana	DDT	Geophyte	Succulent Karoo
Amaryllidaceae	Gethyllis	ciliaris	NT A2ac; B1ab(I,iii,iv,v)	Geophyte	Fynbos
Apiaceae	Arctopus	dregei	VU B1ab(i,ii,iii,iv,v)	Herb	Fynbos
Apocynaceae	Hoodia	gordonii	DDD	Stem succulent shrub	Desert
Apocynaceae	Stapelia	glanduliflora	VU D2	Stem succulent shrub	Fynbos
Asphodelaceae	Aloe	dichotoma	VU A3ce	Tree	Succulent Karoo
Asphodelaceae	Aloe	framesii	NT B1ab(ii,iii,iv)	Leaf succulent shrub	Fynbos
Asphodelaceae	Bulbine	margaretae	VU D2	Geophyte	Succulent Karoo
Asphodelaceae	Bulbine	torsiva	DDT	Geophyte	Succulent Karoo
Asteraceae	Cadiscus	aquaticus	CR B2ab(i,ii,iii,iv,v)	Aquatic	Fynbos
Asteraceae	Marasmodes	sp nov	CR D	Non-succulent shrub	Fynbos
Colchicaceae	Androcymbium	vanjaarsveldii	Rare	Geophyte	Succulent Karoo

Crassulaceae	Adromischus	maximus	Rare	Leaf succulent shrub	Succulent Karoo
Crassulaceae	Crassula	exilis subsp exilis	Rare	Leaf succulent shrub	Succulent Karoo
Crassulaceae	Tylecodon	pygmaeus	Thr	Stem succulent shrub	Succulent Karoo
Eriospermaceae	Eriospermum	patentiflorum	VU B1ab(ii,iii,v)	Geophyte	Fynbos
Eriospermaceae	Eriospermum	viscosum	VU D2	Geophyte	Succulent Karoo
Euphorbiaceae	Euphorbia	fasciculata	VU B1ab(v) + 2 ab(v)	Stem succulent shrub	Succulent Karoo
Fabaceae	Aspalathus	horizontalis	CR B2ab(iii,v)	Non-succulent shrub	Fynbos
Fabaceae	Lotononsis	prostrata	NT A2c	Non-succulent shrub	Fynbos
Hyacinthaceae	Albuca	clanwilliamgloria	EN B1ab(ii,iii,v)	Geophyte	Fynbos
Hyacinthaceae	Lachenalia	bachmanii	EN B1ab(ii,iii,v)	Geophyte	Fynbos
Hyacinthaceae	Lachenalia	longibracteata	Dec	Geophyte	Fynbos
Hyacinthaceae	Lachenalia	pallida	Dec	Geophyte	Fynbos
Hyacinthaceae	Lachenalia	pustulata	NT B1ab(ii,iii,iv,v)	Geophyte	Fynbos
Iridaceae	Babiana	angustifolius	NT B1ab(iii)	Geophyte	Fynbos
Iridaceae	Babiana	leipoldtii	CR B2ab(i,ii,iii,iv,v)	Geophyte	Fynbos
Iridaceae	Babiana	lewisiana	VU D2	Geophyte	Succulent Karoo
Iridaceae	Babiana	odorta	EN B1ab(ii,iii,iv,v)	Geophyte	Fynbos
Iridaceae	Babiana	toximontana	EN B1ab(ii,iii,iv,v)	Geophyte	Succulent Karoo
Iridaceae	Gladiolus	meliusculus	VU B1ab(ii,iii,iv,v)	Geophyte	Fynbos
Iridaceae	Moraea	tricolor	EN B1ab(i,ii,iii,iv,v)	Geophyte	Fynbos
Iridaceae	Sparaxis	galeata	VU B1ab(ii,iii,iv,v)	Geophyte	Succulent Karoo
Oxalidaceae	Oxalis	pillansiana	DDD	Geophyte	Succulent Karoo
Proteaceae	Diastella	proteoides	CR A2c+3c+4c	Non-succulent shrub	Fynbos
Proteaceae	Leucadendron	cinereum	VU A2c+3c+4c	Non-succulent shrub	Fynbos
Proteaceae	Leucadendron	lanigerum var lanigerum	EN A2c	Non-succulent shrub	Fynbos

Proteaceae	Leucadendron	levisanus	CR A4c	Non-succulent shrub	Fynbos
Proteaceae	Leucadendron	loranthifolium	NT B1ab(iii,v)+2ab(iii,v)	Non-succulent shrub	Fynbos
Proteaceae	Leucadendron	procerum	VU A4c	Non-succulent shrub	Fynbos
Proteaceae	Leucadendron	thymifolium	CR A2c+3c+4c	Non-succulent shrub	Fynbos
Proteaceae	Leucospermum	hypophyllocarpodendron	VU A2c	Non-succulent shrub	Fynbos
Proteaceae	Leucospermum	parile	EN A2c+3c+4c	Non-succulent shrub	Fynbos
Proteaceae	Leucospermum	rodolentum	VU A2c	Non-succulent shrub	Fynbos
Proteaceae	Leucospermum	vestitum	NT A2c	Non-succulent shrub	Fynbos
Proteaceae	Protea	burchellii	VU A2c+3c+4c	Non-succulent shrub	Fynbos
Proteaceae	Protea	scolymocephala	VU A2c	Non-succulent shrub	Fynbos
Proteaceae	Serruria	decipiens	VU A2c+3c+4c	Non-succulent shrub	Fynbos
Proteaceae	Serruria	effusa	NT A3c	Non-succulent shrub	Fynbos
Proteaceae	Serruria	fasciflora	NT A2c+4c	Non-succulent shrub	Fynbos
Proteaceae	Serruria	millefolia	VU A4c	Non-succulent shrub	Fynbos
Proteaceae	Serruria	trilopha	CR A2c	Non-succulent shrub	Fynbos
Rhamnaceae	Phylica	plumosa	Dec	Non-succulent shrub	Fynbos
Scrophulariaceae	Manulea	paucibarbata	Rare	Herb	Fynbos
Sterculiaceae	Hermannia	rugosa	VU B1ab(ii,iii,iv,v)	Non-succulent shrub	Fynbos
Thymelaceae	Lachnaea	uniflora	VU B1ab(ii,iii,iv,v)	Non-succulent shrub	Fynbos

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Table 5.2: The number of RDB species in each growth form (rows) are shown divided into their conservation status (columns). The conservation status codes are as listed above in Table 5.1. DD – Data deficient (Includes DDD and DDT).

Growth Form	CR	EN	VU	Thr	NT	Rare	Dec	DD	Total
Aquatic	1	0	0	0	0	0	0	0	1
Geophyte	1	5	6	0	3	1	2	3	21
Herb	0	0	1	0	0	1	0	0	2
Shrub									
Non-succulent	6	2	10	0	5	0	1	0	24
Leaf succulent	0	1	3	0	1	3	0	1	9
Stem succulent	0	0	2	1	0	0	0	1	4
Tree	0	0	1	0	0	0	0	0	1
<b>Total</b>	<b>8</b>	<b>8</b>	<b>23</b>	<b>1</b>	<b>9</b>	<b>5</b>	<b>3</b>	<b>5</b>	<b>62</b>

### 5.3.2 The distribution of RDB species on the N7

Red Data Book species identified in this study of the N7 road reserve occur from 12 km to 668 km from Cape Town in 14 of the 31 vegetation types on the transect. A total of 91 populations of 62 different RDB species (39 genera in 19 families) were identified in the N7 road reserve. Although the RDB species are spread over much of the transect, they are not evenly distributed. Only 8 of the 62 RDB species are found within the Northern Cape province (0.03 species/km) while the remaining 54 fall within the Western Cape (0.13 species/km). There are 44 RDB species in the Fynbos biome while the Succulent Karoo biome hosts 17 species with only one occurring in the Desert biome (Table 5.1; Figure 5.1).

It is not only that there are more RDB species in the Fynbos biome and Western Cape province than in the more arid parts of the transect but this area also hosts a greater number of RDB species that are threatened with extinction. Of the *Critically Endangered*, *Endangered* and *Vulnerable* species on the N7, only eight (20%) are found in the Succulent Karoo biome, while the remaining 31 (80%) are found in the Fynbos biome. Of the *Rare* and *Data Deficient* species, only one (10%) is found in the Fynbos Biome and one (10%) in the Desert Biome with the remaining 8 (80%) occurring in the Succulent Karoo biome (Figure 5.1).

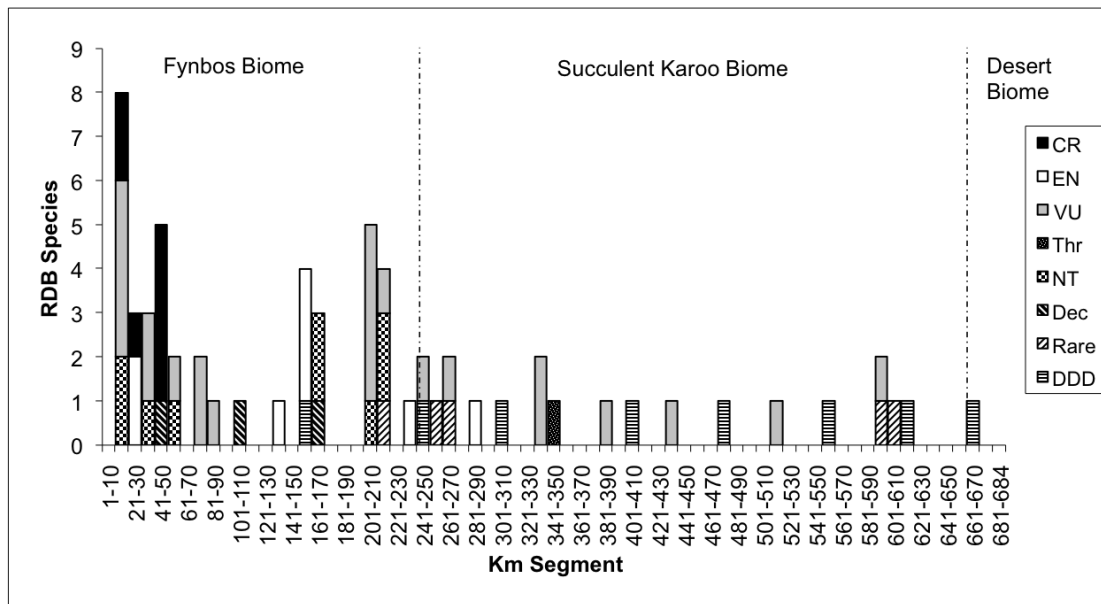


Figure 5.1: Graph showing the number and conservation status of RDB species per 10 km segment from Cape Town (segment 1-10) to Violsdrif (segment 681-684).

### 5.3.3 The RDB species and vegetation types

The RDB species on the N7 are not distributed evenly among the vegetation types occurring along the transect. RDB species occur in 14 of the 31 vegetation types (45%) investigated. However, these 14 vegetation types encompass 609 kms or 89% of the N7 transect.

In vegetation types that have one or more RDB species, the average number of species per square kilometer for the N7 road reserve is 11.6 ( $\pm 13.0$ ). In these vegetation types, using an average width of 10 m of vegetation on each side of the N7, the 62 RDB species occur within 12.2 km<sup>2</sup> with a total of 5.1 RDB species/km<sup>2</sup>. The total area of road reserve for the entire N7 is 13.68 km<sup>2</sup>. This results in an overall value for the RDB species on the N7 of 4.5 species/km<sup>2</sup>.

An investigation of a particular vegetation type highlights how important some of them are in hosting RDB species. While AZf 2 has the highest number of RDB species per square kilometer, this cannot be considered a good indicator for the entire vegetation type as there is only a single, 1 km segment on the N7. Both Atlantis Sand Fynbos (FFd 4) and Cape Flats Sand Fynbos (FFd 5) have 25 RDB species/km<sup>2</sup>. Graafwater Sand Fynbos (FFs 2) has 15 RDB species/km<sup>2</sup> while Leipoldtville Sand Fynbos (FFd 2) has 8.7 RDB species/km<sup>2</sup>. Interestingly, these vegetation types all belong to the Sand Fynbos Group within the Fynbos Biome. The Renosterveld units have slightly fewer RDB species with Swartland Shale

Renosterveld (FRs 9) supporting 5.1 RDB species/km<sup>2</sup> and Swartland Granite Renosterveld (FRg 2) containing 6.5 RDB species/km<sup>2</sup>. Vegetation types in the Succulent Karoo biome are on average lower with the highest being Vanrhynsdorp Gannabosveld (SKk 5) with 5.5 RDB species/km<sup>2</sup> (Table 5.3).

Table 5.3: For each vegetation type containing RDB species a summary is given of the number of RDB species, the number of RDB species per 1 km segment on the N7 and the hypothetical number of RDB species per square kilometer. Summary statistics for each biome and the overall total are in bold.

Veg Type Code	# of kms	Area (km <sup>2</sup> )	# RDB sp	RDB/km	RDB/km <sup>2</sup>
Azf 2	1.0	0.0	1.0	1.0	50.0
FFd 2	46.0	0.9	8.0	0.2	8.7
FFd 4	12.0	0.2	6.0	0.5	25.0
FFd 5	20.0	0.4	10.0	0.5	25.0
FFs 2	10.0	0.2	3.0	0.3	15.0
FFs 3	31.0	0.6	3.0	0.1	4.8
FRg 2	23.0	0.5	3.0	0.1	6.5
FRs 9	99.0	2.0	10.0	0.1	5.1
<b>Ave</b>	<b>30.3</b>	<b>0.6</b>	<b>5.5</b>	<b>0.4</b>	<b>17.5</b>
<b>Std. Dev.</b>	<b>31.0</b>	<b>0.6</b>	<b>3.5</b>	<b>0.3</b>	<b>15.5</b>
SKk 3	34.0	0.7	3.0	0.1	4.4
SKk 5	35.0	0.7	4.0	0.1	5.7
SKn 1	184.0	3.7	5.0	0.0	1.4
SKn 3	88.0	1.8	4.0	0.1	2.8
SKs 13	14.0	0.3	1.0	0.1	3.6
<b>Ave</b>	<b>71.0</b>	<b>1.4</b>	<b>3.2</b>	<b>0.1</b>	<b>3.6</b>
<b>Std. Dev.</b>	<b>68.9</b>	<b>1.4</b>	<b>1.5</b>	<b>0.1</b>	<b>1.6</b>
Dg 9	12.0	0.2	1.0	0.1	4.2
<b>Total</b>	<b>609.0</b>	<b>12.2</b>	<b>62.0</b>	<b>0.1</b>	<b>5.1</b>
<b>Total Ave</b>	<b>43.5</b>	<b>0.1</b>	<b>4.4</b>	<b>0.2</b>	<b>11.6</b>
<b>Total Std. Dev.</b>	<b>48.7</b>	<b>1.0</b>	<b>3.1</b>	<b>0.3</b>	<b>13.0</b>

Comparing these figures with the density of RDB species found in the Nature Reserves in and around the Cape Metropolitan area one gets a contextualised idea of the importance of the N7 road reserve in hosting RDB species. Considering that the N7 is not an officially conserved area it ranks high in number of RDB species per unit area, and very high in terms

of total RDB species (Table 5.4). Although it may seem incongruous to compare discrete vegetation types with nature reserves, it is likely that these conservation areas are comprised of only one vegetation type each, mainly Sand Fynbos or Renosterveld units. The vegetation types with the highest number of RDB species/km<sup>2</sup> (FFd 4 and FFd 5 = 25.0) would be the fifth highest density of RDB species if it was considered as a conservation area. Many of the vegetation types with RDB species on the N7 have a high density of RDB species in relation to the nature reserves of the Cape Metropolitan area (Table 5.4).

Table 5.4: Nature Reserves in and around the Cape Town Metropolitan area, showing the number of RDB species per square kilometer (Rebelo, 2010, Unpublished Data).

Nature Reserve	No. RDB Species	Area (km <sup>2</sup> )	RDB sp / km <sup>2</sup>
Cape Flats Nature Reserve	15	0.3	50
Rondebosch Common	19	0.4	48
Kenilworth Racecourse	24	0.5	46
Uitkamp Wetlands	12	0.3	41
Plattekloof NHS	19	0.9	20
Rondevlei Nature Reserve	21	2.3	9
Tokai Forest	15	1.8	8
<b>N7 Road Reserve</b>	<b>62</b>	<b>13.7</b>	<b>4.5</b>
Macassar Dunes	17	7.4	2
Koeberg Nature Reserve	24	28.5	1

Comparing the total number of species threatened with extinction (CR, EN and VU) per vegetation type throughout the entire Fynbos biome we see that a few of the vegetation types on the N7 are among those containing most species threatened with extinction. Of the ten vegetation types containing the most endangered species in the Fynbos Biome there are four which occur on the N7. These include the most endangered and the third most endangered vegetation types, namely Swartland Shale Renosterveld (FRs 2) with 154 species threatened with extinction and Swartland Granite Resnosterveld (FRg 9) with 132 species threatened with extinction. The other vegetation types from the N7 occurring in the ‘most endangered’ category are the Sand Fynbos units - Cape Flats Sand Fynbos (FFd 5) with 98 species and Atlantis Sand Fynbos (FFd 4) which has 83 species threatened with extinction (Rebelo, 2010, Unpublished Data).

### 5.3.4 Correlates of RDB species distribution on the N7

The number of RDB species per km was significantly correlated with all variables except for the condition of the road reserve (Table 5.5). The distribution of RDB species was positively correlated with latitude and rainfall, and negatively correlated with temperature and altitude (Table 5.5). High numbers of RDB species are, therefore, correlated with areas of low altitude and relatively low temperatures but high rainfall. These are the characteristics of the Fynbos biome, especially the Cape Lowlands. The low correlation coefficient values, however, suggest that relatively weak relationships exist between the number of RDB species and the variables investigated.

Table 5.5: Spearman Rank Correlation coefficients between the number of RDB species and all other variables measured on the N7.

Variable	# RDB's	
	Corr	Prob
Latitude	0.1624	0.0000
Altitude	-0.1151	0.0013
Rainfall	0.1421	0.0001
Temperature	-0.1423	0.0001
RR Condition	0.0266	0.2439
Conservation Value	0.1403	0.0001

While there is not a strong correlation between the calculated conservation value and the number of RDB species on the N7, there is a relationship between the conservation status of the vegetation types and the number of RDB species present. Only 19 of the 62 RDB species on the N7 occur in vegetation types that are considered *Least Threatened* while 24 of the RDB species occur in *Critically Endangered* vegetation types. Of the 11 vegetation types occurring on the N7 that are of conservation concern only three of them contain no RDB species. A clear relationship exists, therefore, between RDB species and endangered vegetation types.

### 5.3.5 Population status of RDB species in the N7 road reserve

Comparing the number of RDB individuals within growth forms inside and outside the RR provides a different result from looking at all species together. When the number of

individuals counted for all species were summed, there was a significantly greater number ( $p=0.025$ ). However, there were a number of exceptions to this overall trend (e.g. *Lachenalia pallida\_2*, *Marasmodes* sp. Nov.). Because of the relatively low number of species in each of the growth forms there was no significant difference between the number of individuals in the RR as opposed to the FL for any of the growth forms investigated (geophytes ( $n=8$ ,  $Z=1.89$ ,  $p=0.054$ ), shrubs ( $n=20$ ,  $Z=1.79$ ,  $p=0.071$ ) and succulents ( $n=3$ ,  $Z=0.00$ ,  $p=1.000$ )).

When the population counts for *Lachenalia pallida\_2* were removed from the analysis for geophytes there was a significant difference between the RR and FL population counts, with more individuals occurring in the RR ( $n=7$ ,  $z=2.11$ ,  $p=0.031$ ). Similarly, *Marasmodes* sp. nov had a strong influence on the statistics for the shrubs. Removing this species from the data also changed the outcome and resulted in a significant difference in the number of individuals in the RR as opposed to the FL, again with more individuals in the RR ( $n=19$ ,  $Z=2.35$ ,  $p=0.015$ ).

Table 5.6: The population status of RDB species in the N7 road reserve and adjacent farmland. RDB species were counted in equivalent sized plots on either side of the road reserve fence. RDB species per  $m^2$  was then calculated for either side to compare concentration of RDB species between RR and FL and between growth forms.

No	Species	RR No. ind.	FL No. ind.	Area ( $m^2$ )	RR ind/ $m^2$	FL ind/ $m^2$
<i>Geophytes</i>						
1	<i>Albuca clanwilliamgloria</i>	100	35	3000	0.03	0
2	<i>Babiana angustifolia</i>	900	8	250	3.6	0.05
3	<i>Babiana leipoldtii</i>	81	0	500	0.16	0
4	<i>Babiana odorata</i>	76	92	75	1.01	1.23
5	<i>Eriospermum patentiflorum</i>	267	150	500	0.53	0.3
6	<i>Lachenalia bachmanii</i>	13140	400	500	26.28	0.8
7	<i>Lachenalia longibracteata</i>	49	7	500	0.1	0.01
8	<i>Lachenalia pallida_2</i>	190	250	n/a	n/a	n/a
	<b>Ave.</b>				<b>4.53</b>	<b>0.3414</b>
	<b>Std. Dev.</b>				<b>9.672</b>	<b>0.4881</b>
<i>Herbs</i>						
9	<i>Arctopus dregei</i>	1	4	300	0	0.01

Table 5.6 continued on next page

No	Species	RR	FL No. ind.	Area (m2)	RR ind/m2	FL ind/m2
<i>Non-succulent shrubs</i>						
10	<i>Aspalathus horizontalis</i>	49	46	300	0.16	0.15
11	<i>Diastella proteiodes</i>	1	0	n/a	n/a	n/a
12	<i>Hermannia micromammosa</i>	21	2	350	0.06	0.01
13	<i>Lachnea unifolia</i>	8	7	250	0.03	0.03
14	<i>Leucadendron cinereum</i>	3	0	500	0.01	0
15	<i>Leucadendron lanigerum</i>	19	13	250	0.08	0.05
16	<i>Leucadendron levisanus</i>	10	2	400	0.03	0.01
17	<i>Leucadendron loranthifolium</i>	5	4	500	0.01	0.01
18	<i>Leucadendron loranthifolium_2</i>	4	8	500	0.01	0.02
19	<i>Leucadendron procerum</i>	3	7	500	0.01	0.01
20	<i>Leucadendron thymifolium</i>	19	0	500	0.04	0
21	<i>Leucospermum</i>	10	10	500	0.02	0.02
22	<i>Leucospermum parile</i>	3	0	n/a	n/a	n/a
23	<i>Leucospermum rodolentum</i>	9	0	1000	0.01	0
24	<i>Marasmodes sp nov</i>	50	112	500	0.1	0.22
25	<i>Phyllica plumosa</i>	6	0	250	0.02	0
26	<i>Protea burchellii</i>	20	41	500	0.04	0.08
27	<i>Protea scolymocephala</i>	55	13	500	0.11	0.03
28	<i>Serruria decipiens</i>	71	13	500	0.14	0.03
29	<i>Serruria fascicularis</i>	18	11	400	0.05	0.03
	<b>Ave.</b>				<b>0.052</b>	<b>0.0389</b>
	<b>Std. Dev.</b>				<b>0.047</b>	<b>0.0581</b>
<i>Stem succulent shrubs</i>						
30	<i>Adromischus maximus</i>	97	130	600	0.16	0.22
31	<i>Euphorbia fasciculata</i>	24	2	700	0.03	0
32	<i>Stapelia glanduliflora</i>	6	6	500	0.01	0.01
	<b>Ave.</b>				<b>0.067</b>	<b>0.0767</b>
	<b>Std. Dev.</b>				<b>0.081</b>	<b>0.1242</b>

## 5.4 Discussion

This chapter has explored the Red Data Book (RDB) species occurring on the N7, paying particular attention to their distribution within vegetation types and growth forms and their population status. This discussion will explain the patterns that have emerged and compare them to similar studies (where available) both locally and abroad, to determine their significance.

### 5.4.1. The N7 road reserve as a refuge for RDB species

During this research, 670 plant species were recorded in the N7 road reserve. However, this is not a thorough inventory of the plants occurring here (See Section 1.4). While this is a small fraction (3.2%) of the total plant species occurring in South Africa, it is interesting to compare these figures to international studies on road reserve flora (Table 3.1). In four studies from countries in the northern hemisphere, over 40% of their total native flora was found in their road verges, far more than in this study. However, the total number of species in these countries was only marginally higher than the number identified along the N7, only one road in the entire country. This attests to the high diversity of South Africa's flora, and helps to explain why road reserves may play an important role in conserving species when compared with other countries.

In this study, 62 different RDB species, or 9.3% of the total species recorded were identified in the N7 road reserve. Among these, there were 91 different populations comprised of 39 genera in 19 families. While these numbers are impressive, it is important to compare them to the national and regional averages to see if they are indeed significant. Nationally, 13% of South African taxa are in danger of regional or global extinction (this represents the categories CR, EN and VU only). In total, 24% or one in four, of South Africa's plant species are of conservation concern. This is more than double the percentage of plants in the N7 road reserve that are of conservation concern.

In the N7 road reserve, the greatest concentration of RDB species was in the Fynbos biome (71% of the RDB species; 0.18 RDB sp/km). This is an expected outcome as the Fynbos biome hosts the highest concentration of RDB species for the country (Raimondo and von Staden, 2009). The concentration of RDB species in the Succulent Karoo biome is much lower than in the Fynbos biome (27% of the RDB species; 0.04 RDB sp/km). This is somewhat surprising as the Succulent Karoo biome has the second highest concentration of RDB species of all biomes in the country (Raimondo and von Staden, 2009). The Desert biome hosted only one RDB species on the N7 (2% of the RDB species; 0.03 RDB sp/km).

While this study has not covered a high percentage of the roads in the country, it has traversed some of the most threatened biomes and vegetation types and can be considered as a general indicator for the proportion of RDB species occurring in South African road reserves. Comparing this to other countries is difficult as only one figure has been obtained regarding the proportion of RDB flora hosted in a country's road reserves. Approximately 25% of Australia's endangered plant species are confined to remnant vegetation in road

verges (Leigh and Briggs 1992). This is far more than occurs on the N7 and is likely to be more than the proportion for the country as a whole.

The number of RDB species per square kilometer was calculated for each vegetation type and the N7 as a whole and was compared to the concentration of RDB species in nature reserves in the Cape Metropolitan Area (Table 5.4). For a number of the vegetation types in the Cape Lowlands the concentration was very high (25 RDB sp/km<sup>2</sup>) and comparable with some of the nature reserves. These vegetation types are highly transformed and therefore more likely to contain RDB species. Although the N7 as a whole has a relatively low concentration of RDB species compared to these nature reserves, the total number of RDB species in the N7 is comparatively high. One of the reasons for the discrepancies is the degree to which these areas have been evaluated. The number of RDB species recorded during a once-off transect is likely to be limited by the time spent in the study site and the time of year at which the study was conducted. Officially conserved areas are also likely to have been more thoroughly studied during a range of different seasons and in different years, and therefore are likely to have more comprehensive species inventories.

The N7 road reserve is an important refuge for RDB flora hosting over 60 species. This is an impressive total number of species and ranks high when compared with nature reserves in the Cape Metropolitan area. However, the proportion of plants in the N7 road reserve that are listed as RDB is far lower than for the country as a whole and they cannot be considered as an irreplaceable refuge for RDB species. This is due to the fact that they are generally disturbed, fragmented and isolated habitats often surrounded by transformed landscapes.

#### **5.4.2 Growth form and taxonomy of the RDB species**

The RDB species found in the N7 road reserve are fairly similar in degree of threat, growth form and taxonomy when compared with the country as a whole. The proportion of species in each IUCN category (e.g. CR, EN, VU, etc.) is relatively similar when the N7 road reserve is compared with South Africa as a whole. There are proportionately more species in the categories Near Threatened and Declining in the N7 while there are proportionately more Rare species for the country as a whole, otherwise the categories are closely aligned.

The RDB species were divided into seven different growth forms. The most common growth forms were non-succulent shrubs (39%), geophytes (34%) and leaf succulents (14%). The geophytes were evenly spread between the Fynbos and Succulent Karoo biomes which is an

expected outcome as both biomes are known to be rich in geophytes. The RDB listed succulents (leaf and stem) are concentrated in the Succulent Karoo biome, which is again a likely outcome based on the high proportion of succulent species which occur in this biome. The RDB non-succulent shrubs, however, are found predominantly in the Fynbos biome with 96% of them occurring here. These are mostly typical Fynbos shrubs, with 72% belonging to the family *Proteaceae*.

The families represented by the RDB species in the N7 road reserve are among the most threatened in the country. Six of the families are in the top 20 most threatened in the entire country. Of the geophytes, the families *Iridaceae*, *Amaryllidaceae*, *Asphodelaceae* and *Eriospermaceae* are in this list. The succulent plants are represented by the family *Asphodelaceae*, while the non-succulent shrubs are represented primarily by *Fabaceae* and *Proteaceae* (Raimondo and von Staden, 2009). Of the 10 most threatened genera in the country, four are represented in the N7. Three of these are from the *Proteaceae* (including *Serruria*, *Leucospermum* and *Leucadendron*) while *Babiana* in the *Iridaceae* was also recorded along the N7 (Raimondo and von Staden, 2009).

The profile of RDB species in the N7 road reserve is comparable with the RDB species in South Africa. The proportion of species that are threatened with extinction (CR, EN and VU) and those that are of conservation concern are fairly similar. There are also a number of overlaps between the most threatened families and genera that occur in South Africa and the N7 road reserve. This similarity in profile means that the N7 road reserve is worthy of conservation attention as it hosts species of conservation importance, and could prove to host even more if studied more thoroughly. This provides further motivation for additional studies to be undertaken in other road reserves throughout the country. It also raises the profile of road reserves as conservation assets and encourages road reserve managers to take this into account when implementing road reserve management strategies.

#### **5.4.3 The distribution of the RDB species**

The distribution of RDB species on the N7 has been correlated with climatic and environmental variables as well as with vegetation type. Interestingly, road reserve vegetation condition was not correlated with the distribution of RDB species. This is important as it means that a section of intact vegetation does not necessarily contain RDB species, and that a disturbed section of road reserve may contain RDB species. However, the distribution of RDB species was positively correlated with conservation value of the road reserve. This

suggests that intact sections of road reserve vegetation within threatened vegetation types are likely to contain RDB species. Therefore, the calculation of a conservation value for road reserve vegetation can be considered a useful tool for identifying areas of special concern.

An inspection of the distribution of the RDB species on the N7 per 10 km segment shows that they are concentrated close to Cape Town and decrease in numbers further north (Figure 5.1). As with conservation value (Chapter 4), there are three peaks in the distribution of RDB species, all of which occur within the Fynbos biome.

The first two peaks are located within the Cape Lowlands and are comprised of Sand Fynbos and Renosterveld vegetation types. These vegetation types are most transformed within the biome due to urbanisation and agriculture and are mostly restricted to small fragmented habitats (Raimondo and von Staden, 2009). All vegetation types on the N7 in the Cape Lowlands are listed as of conservation concern (Mucina and Rutherford, 2006), except for Cape Lowland Freshwater Wetlands which is only traversed for one kilometer. These vegetation types are among the most threatened in the whole biome. In fact, four of the 10 most endangered vegetation types in the Fynbos biome are located in the Cape Lowlands (Rebelo, Unpublished Data). The vegetation types on the Cape Lowlands are also host to the most RDB species of all the vegetation types on the transect. Cape Flats, Atlantis and Leipoldtville Sand Fynbos and Swartland Shale Renosterveld all occur on the Cape Lowlands and these are the four vegetation types that contain the most RDB species on the entire transect.

The last peak of high numbers of RDB species occurs just south of Clanwilliam and falls within the third peak of conservation value. Again these RDB species fall with the Sand Fynbos units FFd2 (endangered) and FFs2 (vulnerable). These vegetation types have been recently transformed due to the expansion of the Rooibos tea industry and as a result many of their endemic species are now threatened (Raimondo and von Staden, 2009).

While the positive statistical correlation between conservation value and number of RDB species is weak, there is an overlap between the geographic areas where conservation value is high and there are high numbers of RDB species. Most notable is the section of Cape Flats Sand Fynbos (FFd 5) located 11 – 21 kilometers north of the N1/N7 interchange. This critically endangered vegetation type is in good condition in this area as it is cleared of alien vegetation (*Acacia saligna*) which is present in the adjacent farm land. The conservation value is matched by a high number of species of conservation concern.

The number of RDB species is statistically correlated with a number of environmental and climatic variables. There is a positive correlation between the number of RDB species and latitude and rainfall while there is a negative correlation with altitude and temperature. These correlations are fairly weak, however, and reflect primarily the environmental conditions within the Cape Lowlands which has the highest latitude and rainfall with the lowest altitude and temperatures of all regions along the transect.

Species of conservation concern in the N7 road reserve are concentrated in the south of the transect, mainly between Cape Town and the base of the Piekensklou Pass. This area is known as the Cape Lowlands, and is highly fragmented and irreversibly transformed, largely due to agriculture and urbanisation. The result of this transformation is that the vegetation types occurring here are of conservation concern, and among the most threatened in the Fynbos biome. Furthermore, the species found in this remnant vegetation are more likely to be of conservation importance than in other areas on the transect and it is for this reason that most RDB species are found in this area.

#### **5.4.4 Population status**

The fact that there are RDB species in the N7 road reserve is an important finding. However, further information is needed to determine how significant and important these populations are to conservation. A first step in this process is to compare the size of RDB populations within the RR with the adjacent populations in the FL. This provides some much-needed baseline data for road reserve vegetation in South Africa. However, these numbers have limited importance on their own, and would be best compared with follow-up research on the same populations in years to come to add a temporal scale to the research. Monitoring population dynamics over time is important when trying to understand the conservation status of a population. The IUCN definitions for RDB species (see Appendix 3) make reference to these changes by recording ‘...reduction, continuing decline and extreme fluctuations’ in species over time.

Data from this study shows, when analysing all RDB populations together, that there are significantly more individuals in RR populations than in FL populations for most of the species investigated. This indicates that the RR acts as an important refuge for RDB species. However, when analysing RDB populations by different growth forms, this pattern was not as consistent. In all growth forms there were species that clearly derived much benefit from occurring in the road reserve, but there were also species that derived no benefit from being

in the road reserve. The reasons for a species benefitting from the road reserve or not are largely related to management regime and adjacent land use as well as to the specific life history traits of the species concerned.

Due to their annual growth cycle and summer dormancy, many geophytes are spared from disturbance during the summer months. Some geophytes are also stimulated by some disturbance (Gardiner and Vaughan, 2009; Gómez-García et al., 2009) and benefit from the clearance of grasses and shrubs associated with roadside maintenance. On the N7, in a number of cases, geophytes in the road reserve are protected from destruction in the adjacent farm land. For example, there is a healthy population of *Babiana angustifolius* in the road reserve just north of the N1/N7 interchange, while the adjacent land is so densely covered with alien vegetation (*Acacia saligna*) that only a few individuals survive. Due to agricultural activities, few *Lachenalia bachmanii* remain in the farm land, however, a healthy population survives on the other side of the fence in the road reserve.

Due to their size, shrubs are removed from the road edge for safety reasons where necessary (Dawson, 1991). This means that where they do remain, it is likely more fortuitous than a planned intervention. However, this also means that they are likely to be safe from disturbance unless the management regime is altered. In a number of cases, the only remaining RDB shrubs (mainly *Proteaceae*) were found in the road reserve. For example, *Diastella proteiodes* was found in the road reserve with no plants in the adjacent farmland and this species is noted as declining due to mowing in road reserves (Raimondo et al., 2009). Also, most subpopulations of *Leucadendron thymifolium* are restricted to road reserves (Raimondo et al., 2009) and this shrub was found in the N7 with no plants in the adjacent farmland.

While these findings are important and indicate that the N7 road reserve acts as a refuge for RDB species, it is still important to determine whether these populations have long term viability. This can be determined by assessing the genetic variability of the species and looking at their method of reproduction (sexual or asexual). The value of RDB species in road verges and fragmented habitats has been questioned as their small size and isolation is expected to reduce their reproductive success and genetic diversity (Hogbin et al., 1998; Lamont et al., 2003). Species extinctions are also expected to increase in small isolated habitats (Bond et al., 1988). In the Cape Lowlands, it was shown that size of habitat had a significant effect on seed set and reproductive failure in a number of geophytes (Pauw, 2004).

However, in several Australian studies it has been shown that small and isolated populations of rare plants in road reserves have high genetic diversity, successful pollination and increased vegetative growth when compared with non-verge populations (Hogbin et al., 1998; Lamont et al., 1994a, 1994b).

The population status of RDB species in the N7 road reserve varied considerably according to growth forms, adjacent land use and presence of alien vegetation. Growth forms and vegetation types respond differently to the range of management practices (Jantunen et al., 2007; Esler and Milton, 2006), as do the frequency of insect visitations and pollination success (Noordijk et al., 2009). Therefore, generality when describing the most appropriate conditions to conserve RDB species in road reserves is problematic. Road reserve managers should be well informed about RDB populations in the road reserve and advised about the most appropriate management strategies for each vegetation type and even each population under their responsibility. This highlights the need for further fine scale research into RDB populations in road reserves.

## **5.5 Conclusion**

The N7 road reserve hosts over 60 RDB species and can therefore be considered a refuge for plants of conservation concern in South Africa. The species found here are comparable with the RDB species in South Africa in terms of their degree of threat and taxonomy. However, their concentration is much lower than the national and regional average and the benefit of these habitats to RDB species conservation is limited.

The population status of RDB species in the road reserve is ambiguous when compared with adjacent populations in the farm land. The success of these populations is dependent on a number of factors including the management regime of the road reserve, the adjacent land use and the presence of alien vegetation. It is therefore problematic to provide a general method of road reserve maintenance which will be universally beneficial for all RDB species. Fine-scale research is needed to expand on the findings of this research and should be provided to road reserve managers with site-specific recommendations. For example, a small population of the Critically Endangered geophyte *Babiana leipoldtii* remains in the road reserve while no individuals are present in the adjacent farm land which is heavily infested with alien vegetation (*Acacia saligna*). This plant is only known from four small fragments of habitat and is declining due to alien vegetation. Other site specific interventions are possible in areas of particular importance. The patch of Cape Flats Sand Fynbos 11 – 21 kilometers north of Cape

Town contains a number of RDB species, especially *Proteaceae*. Another example is a small section of vegetation at the base of the Piekenierskloof Pass that contains a number of RDB species. These include the Critically Endangered shrub, yet to be described (*Marasmodes sp nov.*) and the Endangered bulb *Moraea tricolor* whose presence here represents a range extension for this species. These populations could be monitored relatively easily and appropriately managed if they were clearly marked out and the relevant authorities were informed. Success in communicating such information to relevant road reserve managers has been achieved in Darling in the Western Cape (Esler and Milton, 2006) and these positive outcomes could form the basis for future interventions.

The findings of this research are limited by the lack of comparable literature on RDB species in road reserves of South Africa and abroad. No studies were found which documented the distribution and health of RDB species in South African road reserves. While a number of international studies examined rare and threatened species in road reserves and fragmented habitats, these investigations generally focused on only one species rather than an area or entire road (Hogbin et al., 1998; Lamont et al., 1994a, 1994b). This highlights the unique approach adopted in this research and because of its success it provides the motivation for further studies of this nature in other South African road reserves.

## **CHAPTER 6 – CONCLUSIONS AND SYNTHESIS**

### **6.1 Introduction**

The overall objective of this study was to complete an ecological assessment of the N7 road reserve. This included recording vegetation condition and conservation value of the road reserve as well as recording the presence and distribution of Red Data Book (RDB) species in the N7 road reserve. This was achieved by using a number of unique and innovative methods for recording roadside vegetation, including a vehicle-based survey and a mega-transect walk coupled with geo-tagging photographs. A further aim of the project was to assess these survey methods, their success and appropriateness for the context of South African road reserves. The last aim was to supply the ecological data to the relevant authorities in order to promote conservation in the N7 road reserve.

This concluding chapter will bring together the methodological, ecological and management aims of the project by evaluating the abovementioned research methods, summarising the ecological information and providing recommendations on how this data can be used in order to promote conservation in the road reserve.

### **6.2 Evaluation of methods**

There are inherent limitations in a once-off study of any site and these have been broadly discussed in the introductory chapter (See section 1.4). Assessing vegetation condition using a vehicle-based method is recognised as a useful and practical method of recording data for a large area in a short time (Grievess and Lloyd, 1984; Palmer and Lewis, 1987; Dawson, 1991; Milton and Dean, 1998) but it has certain limitations (See Section 1.4). This section will discuss the benefits and limitations of the more innovative method employed in this study, namely the walking of a mega-transect and identifying geo-tagged photographs.

There are a number of advantages associated with completing a road reserve assessment on foot. The major benefit lies in viewing the transect as a continuous sampling area as opposed to a fragmented one associated if one used a plot-based approach. It is also more thorough and detailed than a vehicle-based survey. A wide variety of vegetation types and habitats can be explored, including the zones of transition between them. The use of an accurate GPS device and a sound understanding of the technology involved in geo-tagging photographs allows for the recording of precise locality information for many plant species. This is useful as it allows for any species to be revisited with ease. It negates the need for extensive note-

taking on locality information in the field. Photographing unknown plant species instead of collecting specimens also allows the researcher to collect more information in a shorter time. In summary, this approach provides a useful tool for collecting large amounts of information from a large area in a relatively repeatable manner. This data can also be collected by a researcher with a moderate knowledge of the local flora.

However, there are several limitations associated with this approach. Firstly, it requires a large amount of time to cover distance. The 684 kilometers of the N7 was covered on foot in 24 days of walking at an average of 28.45 km/day. Average walking speed was 4.4 km/hour and travelling distance was 3.6 km/hour including stops for rest and photography. Secondly, the time of year and year of study will influence which species are in flower and the general condition of the vegetation. Thirdly, the identification of plant species from photographs is time consuming, and is not as accurate when compared, for example, to identifying pressed specimens. Lastly, the knowledge of the researcher will limit the species observed with a natural tendency to under sample families and genera unknown to the individual (see Section 1.4).

Walking a mega-transect is an innovative and interesting way to assess the vegetation of a transect or corridor. It provides a large amount of continuous data that would be impossible to collect using any other approach. The benefits of precise locality information for many unidentified plants species is slightly offset by the inaccuracies associated with identifying plants from photographs. Overall, this method has many strengths that in combination with other data collection methods can provide a comprehensive assessment of flora in road reserves and can be used in other applications as well.

### **6.3 Summary of findings of data chapters**

#### **6.3.1 Vegetation condition and conservation value of the N7 road reserve**

The condition of the road reserve vegetation and conservation value varied significantly over the transect and was largely influenced by the vegetation types present, the adjacent land use and the history of land use and road construction. In the Fynbos biome, there is a long history of intensive agriculture which has resulted in a highly transformed landscape and fragmented populations of indigenous vegetation. The resulting condition of the road reserve vegetation is very low, although, considering that the vegetation types within the Fynbos biome are highly threatened, any remaining vegetation in the road reserve has a high conservation

value. The Succulent Karoo has been transformed far less by intensive agriculture than has been the case in the Fynbos biome. The result is that the vegetation types are less threatened and the road reserve vegetation was generally in better condition here. For these reasons, the conservation value in this biome was less than that of the Fynbos biome. The part of the N7 that passes through the Desert biome is very short and does not allow for an in-depth analysis of the road reserve in this biome. However, the road reserve vegetation in the Desert biome was broadly similar to the condition of the vegetation in the arid Succulent Karoo biome.

### **6.3.2 The RDB species on the N7 road reserve**

The N7 road reserve contains over 60 RDB species and is undoubtedly a refuge for these species. The RDB species are concentrated in the south of the transect, usually coinciding with areas of high conservation value in the Fynbos biome. There are many RDB species that derive a benefit from being in the road reserve when compared to the populations in the adjacent farmland. However, there are several species which derive no benefit from growing in the road reserve. Whether the RDB populations derive a benefit from the road reserve is largely determined by their response to the management of the road reserve, the adjacent land use and the presence of alien vegetation. For these reasons the role of road reserves in conserving RDB species has limited potential only.

## **6.4 Recommendations**

The data recorded in this research is of potential practical use if it is provided to the relevant individuals, groups and organisations. The data will be made available to all interested parties through the South African Environmental Observation Network (SAEON) – Fynbos Biome node. The findings of this research will be supplied to the Custodians of Rare and Endangered Wildflowers (CREW) a branch of the Threatened Species Programme (TSP) housed within the South African National Biodiversity Institute (SANBI). This will maintain the Red List of South African Plants 2009 as a dynamic tool as it has been proposed (von Staden et al., 2009). It will also be supplied to the South African National Roads Agency Limited (SANRAL) who have had an interest in the research since it was initially proposed (SANRAL also co-funded the initial fieldwork). Furthermore, the information will be available to landowners adjacent to the N7, citizen science interest groups and educational programmes where required.

### **6.4.1 Management authorities**

The varied vegetation types and RDB species occurring in the N7 road reserve mean that a generalised road reserve management regime is going to favour certain species at the expense of others. It would be far more beneficial if vegetation type specific management regimes could be implemented (Esler and Milton, 2006). It would also be beneficial if road reserve management teams were aware of populations of RDB species and informed about the most appropriate way to deal with these. Considering these priorities, it is recommended that SANRAL commission a consultant to advise on the most appropriate management strategy for each vegetation type (or bioregion if these can be generalised) on the N7. Road maintenance staff need to be educated and trained about the conservation value/potential of the road reserves and how they can enhance this with minor changes to their operations (Dawson, 1991).

The mowing of road reserves is common practice for clearing alien vegetation and improving visibility. It is important to determine which mowing regime (i.e. frequency and timing of mowing) is most appropriate for each area. Identifying and minimizing seed production of keystone alien vegetation and replacing it with a native seed mix to rehabilitate the road reserve is recommended (Tyser and Worley, 1992). These findings need to be clearly communicated to the contractors who carry out maintenance activities within the road reserve. Areas of critical importance (high conservation value or high numbers of RDB species) can be physically marked out on the fence-line with each one will having specific management requirements.

#### **6.4.2 Adjacent land owners**

It has been shown in this research that the adjacent land use and vegetation condition impact on both the road reserve vegetation condition and the presence of RDB species. In areas where land adjacent to the road reserve is in poor condition due to alien vegetation, and the vegetation type is of conservation importance, it is recommended that the land owner be contacted and steps taken to remove the alien vegetation. This will improve the long-term viability of the road reserve vegetation and the overall conservation status of the vegetation type. Where RDB species occur in the road reserve and adjacent farm land, the land owners should be informed of these populations and recommendations made to ensure they are not inadvertently destroyed through crop or herbicide spraying, mowing or ploughing. The creation of a 'buffer zone' between agricultural land (grazed or cultivated) and the road

reserve where vegetation is particularly sensitive to land use activities, is advised. This could be incorporated within CapeNature's Stewardship Programme.

#### **6.4.3 Follow-up monitoring on areas of conservation value**

Areas deemed to have a high conservation value due to the condition and conservation status of the vegetation type or the number of RDB species present (or both) should be prioritised for future research. This will provide a temporal dimension to this study and the dynamics of these areas and populations can be better understood. CREW are already involved in identifying and monitoring populations of RDB species and could incorporate this into their fieldwork programme. Other institutions or even local groups of enthusiasts wanting to get involved in conservation activities could champion the monitoring and alien clearing of particular areas.

#### **6.5 Conclusion**

The findings of this research have provided a unique insight into the ecological condition of the N7 road reserve. The relatively large number of species recorded, especially RDB species has highlighted the potential for the road reserve to provide habitat and refuge to some of South Africa's most endangered vegetation types and species. However, the potential of road reserves to be of conservation value is limited by the impact of adjacent land use, the management regime of the road reserve and by the presence of alien vegetation. However, the critical conservation status of the vegetation types, in particular on the Cape Lowlands, means that the N7 road reserve is worthy of attention and that any remaining indigenous vegetation should be monitored and conserved. These finding also highlight the need for more studies in the road reserves of other parts of the Cape Lowlands, Fynbos biome and the entire country. The use of a mega-transect walk in conjunction with a vehicle-based assessment is recommended as methodology for this type of research.

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**APPENDIX 1: CD containing the list of plant species identified on the N7. Photos of plants species are included. Open the Excel file and click on the hyperlink to view photos. Photographs depicting the three Biomes in the study area are also included on the CD in the folder “Biome photos”.**

## APPENDIX 2: List of Experts who helped with plant photograph identification

Name	Plant Group	Affiliation
Terry Trinder-Smith	General	University of Cape Town
Prof. Leanne Dreyer	Oxalidaceae	University of Stellenbosch
Kenneth Oberlander	Oxalidaceae	University of Stellenbosch
Gerhard Marx	Euphorbiaceae	Expert on group
Matt Buys	Lobostemon/Aizoaceae	SANBI
Prof. Dirk Bellstedt	Zygophyllaceae	University of Stellenbosch
Rob Nagel	Stapelia	Expert on group
Steve Hammer	Conophytum/Bulbine/other Aizoaceae	Expert on group
Annelise le Roux	General	CapeNature
John Manning	General	SANBI
Ernst van Jaarsveld	Succulents	SANBI
Dr. Dee Snijman	Amaryllidaceae	SANBI
Dr. Tony Rebelo	Proteaceae	City of Cape Town/SANBI
Prof. Timm Hoffman	General	Plant Conservation Unit/UCT
David Gwynne-Evans	Hermannia	University of Cape Town
Prof. Charles Stirton	Fabaceae	University of Cape Town
Bruce Bayer	Haworthia	Expert on group
Dr. Ted Oliver	Ericaceae	Expert on group
Tessa Oliver	Orchidaceae	BIOTA
Graham Duncan	Lachenalia	SANBI
Adam Harrower	General	SANBI
Dr Cornelia Klak	Aizoaceae	University of Cape Town
Rupert Koopman	General	CapeNature/SANBI

### **APPENDIX 3: Explanation of IUCN categories, criteria and sub criteria for assessing species of conservation importance (from IUCN Red List Categories and Criteria Version 3.1)**

#### **IV. THE CATEGORIES**

##### **EXTINCT (EX)**

A taxon is Extinct when there is no reasonable doubt that the last individual has died. A taxon is presumed Extinct when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.

##### **EXTINCT IN THE WILD (EW)**

A taxon is Extinct in the Wild when it is known only to survive in cultivation, in captivity or as a naturalized population (or populations) well outside the past range. A taxon is presumed Extinct in the Wild when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.

##### **CRITICALLY ENDANGERED (CR)**

A taxon is Critically Endangered when the best available evidence indicates that it meets any of the criteria A to E for Critically Endangered (see Section V), and it is therefore considered to be facing an extremely high risk of extinction in the wild.

##### **ENDANGERED (EN)**

A taxon is Endangered when the best available evidence indicates that it meets any of the criteria A to E for Endangered (see Section V), and it is therefore considered to be facing a very high risk of extinction in the wild.

##### **VULNERABLE (VU)**

A taxon is Vulnerable when the best available evidence indicates that it meets any of the criteria A to E for Vulnerable (see Section V), and it is therefore considered to be facing a high risk of extinction in the wild.

##### **NEAR THREATENED (NT)**

A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.

##### **LEAST CONCERN (LC)**

A taxon is Least Concern when it has been evaluated against the criteria and does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and

abundant taxa are included in this category.

#### **DATA DEFICIENT (DD)**

A taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. A taxon in this category may be well studied, and its biology well known, but appropriate data on abundance and/or distribution are lacking. Data Deficient is therefore not a category of threat. Listing of taxa in this category indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate. It is important to make positive use of whatever data are available. In many cases great care should be exercised in choosing between DD and a threatened status. If the range of a taxon is suspected to be relatively circumscribed, and a considerable period of time has elapsed since the last record of the taxon, threatened status may well be justified.

#### **NOT EVALUATED (NE)**

A taxon is Not Evaluated when it has not yet been evaluated against the criteria.

### **V. THE CRITERIA FOR CRITICALLY ENDANGERED, ENDANGERED AND VULNERABLE CRITICALLY ENDANGERED (CR)**

A taxon is Critically Endangered when the best available evidence indicates that it meets any of the following criteria (A to E), and it is therefore considered to be facing an extremely high risk of extinction in the wild:

A. Reduction in population size based on any of the following:

1. An observed, estimated, inferred or suspected population size reduction of 390% over the last 10 years or three generations, whichever is the longer, where the causes of the reduction are clearly reversible AND understood AND ceased, based on (and specifying) any of the following:

- (a) direct observation
- (b) an index of abundance appropriate to the taxon
- (c) a decline in area of occupancy, extent of occurrence and/or quality of habitat
- (d) actual or potential levels of exploitation
- (e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.

2. An observed, estimated, inferred or suspected population size reduction of 380% over the last 10 years or three generations, whichever is the longer, where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.

3. A population size reduction of 380%, projected or suspected to be met within the next 10 years or three generations, whichever is the longer (up to a maximum of 100 years), based on

(and specifying) any of (b) to (e) under A1.

4. An observed, estimated, inferred, projected or suspected population size reduction of 380% over any 10 year or three generation period, whichever is longer (up to a maximum of 100 years in the future), where the time period must include both the past and the future, and where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.

B. Geographic range in the form of either B1 (extent of occurrence) OR B2 (area of occupancy) OR both:

1. Extent of occurrence estimated to be less than 100 km<sup>2</sup>, and estimates indicating at least two of a–c:

a. Severely fragmented or known to exist at only a single location.

b. Continuing decline, observed, inferred or projected, in any of the following:

(i) extent of occurrence

(ii) area of occupancy

(iii) area, extent and/or quality of habitat

(iv) number of locations or subpopulations

(v) number of mature individuals.

c. Extreme fluctuations in any of the following:

(i) extent of occurrence

(ii) area of occupancy

(iii) number of locations or subpopulations

(iv) number of mature individuals.

2. Area of occupancy estimated to be less than 10 km<sup>2</sup>, and estimates indicating at least two of a–c:

a. Severely fragmented or known to exist at only a single location.

b. Continuing decline, observed, inferred or projected, in any of the following:

(i) extent of occurrence

(ii) area of occupancy

(iii) area, extent and/or quality of habitat

(iv) number of locations or subpopulations

(v) number of mature individuals.

c. Extreme fluctuations in any of the following:

(i) extent of occurrence

(ii) area of occupancy

(iii) number of locations or subpopulations

(iv) number of mature individuals.

C. Population size estimated to number fewer than 250 mature individuals and either:

1. An estimated continuing decline of at least 25% within three years or one generation, whichever is longer, (up to a maximum of 100 years in the future) OR
2. A continuing decline, observed, projected, or inferred, in numbers of mature individuals AND at least one of the following (a–b):
  - a. Population structure in the form of one of the following:
    - (i) no subpopulation estimated to contain more than 50 mature individuals, OR
    - (ii) at least 90% of mature individuals in one subpopulation.
  - b. Extreme fluctuations in number of mature individuals.
- D. Population size estimated to number fewer than 50 mature individuals.
- E. Quantitative analysis showing the probability of extinction in the wild is at least 50% within 10 years or three generations, whichever is the longer (up to a maximum of 100 years).

**ENDANGERED (EN)**

A taxon is Endangered when the best available evidence indicates that it meets any of the following criteria (A to E), and it is therefore considered to be facing a very high risk of extinction in the wild:

A. Reduction in population size based on any of the following:

1. An observed, estimated, inferred or suspected population size reduction of 370% over the last 10 years or three generations, whichever is the longer, where the causes of the reduction are clearly reversible AND understood AND ceased, based on (and specifying) any of the following:
  - (a) direct observation
  - (b) an index of abundance appropriate to the taxon
  - (c) a decline in area of occupancy, extent of occurrence and/or quality of habitat
  - (d) actual or potential levels of exploitation
  - (e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.
2. An observed, estimated, inferred or suspected population size reduction of 350% over the last 10 years or three generations, whichever is the longer, where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.
3. A population size reduction of 350%, projected or suspected to be met within the next 10 years or three generations, whichever is the longer (up to a maximum of 100 years), based on (and specifying) any of (b) to (e) under A1.
4. An observed, estimated, inferred, projected or suspected population size reduction of 350%

over any 10 year or three generation period, whichever is longer (up to a maximum of 100 years in the future), where the time period must include both the past and the future, and where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.

B. Geographic range in the form of either B1 (extent of occurrence) OR B2 (area of occupancy) OR both:

1. Extent of occurrence estimated to be less than 5000 km<sup>2</sup>, and estimates indicating at least two of a–c:

- a. Severely fragmented or known to exist at no more than five locations.
- b. Continuing decline, observed, inferred or projected, in any of the following:
  - (i) extent of occurrence
  - (ii) area of occupancy
  - (iii) area, extent and/or quality of habitat
  - (iv) number of locations or subpopulations
  - (v) number of mature individuals.
- c. Extreme fluctuations in any of the following:
  - (i) extent of occurrence
  - (ii) area of occupancy
  - (iii) number of locations or subpopulations
  - (iv) number of mature individuals.

2. Area of occupancy estimated to be less than 500 km<sup>2</sup>, and estimates indicating at least two of a–c:

- a. Severely fragmented or known to exist at no more than five locations.
- b. Continuing decline, observed, inferred or projected, in any of the following:
  - (i) extent of occurrence
  - (ii) area of occupancy
  - (iii) area, extent and/or quality of habitat
  - (iv) number of locations or subpopulations
  - (v) number of mature individuals.
- c. Extreme fluctuations in any of the following:
  - (i) extent of occurrence
  - (ii) area of occupancy
  - (iii) number of locations or subpopulations
  - (iv) number of mature individuals.

C. Population size estimated to number fewer than 2500 mature individuals and either:

- 1. An estimated continuing decline of at least 20% within five years or two generations, whichever is longer, (up to a maximum of 100 years in the future) OR

2. A continuing decline, observed, projected, or inferred, in numbers of mature individuals AND at least one of the following (a–b):

a. Population structure in the form of one of the following:

(i) no subpopulation estimated to contain more than 250 mature individuals, OR

(ii) at least 95% of mature individuals in one subpopulation.

b. Extreme fluctuations in number of mature individuals.

D. Population size estimated to number fewer than 250 mature individuals.

E. Quantitative analysis showing the probability of extinction in the wild is at least 20% within 20 years or five generations, whichever is the longer (up to a maximum of 100 years).

### **VULNERABLE (VU)**

A taxon is Vulnerable when the best available evidence indicates that it meets any of the following criteria (A to E), and it is therefore considered to be facing a high risk of extinction in the wild:

A. Reduction in population size based on any of the following:

1. An observed, estimated, inferred or suspected population size reduction of 350% over the last 10 years or three generations, whichever is the longer, where the causes of the reduction are: clearly reversible AND understood AND ceased, based on (and specifying) any of the following:

(a) direct observation

(b) an index of abundance appropriate to the taxon

(c) a decline in area of occupancy, extent of occurrence and/or quality of habitat

(d) actual or potential levels of exploitation

(e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.

2. An observed, estimated, inferred or suspected population size reduction of 330% over the last 10 years or three generations, whichever is the longer, where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.

3. A population size reduction of 330%, projected or suspected to be met within the next 10 years or three generations, whichever is the longer (up to a maximum of 100 years), based on (and specifying) any of (b) to (e) under A1.

4. An observed, estimated, inferred, projected or suspected population size reduction of 330% over any 10 year or three generation period, whichever is longer (up to a maximum of 100 years in the future), where the time period must include both the past and the future, and where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.

B. Geographic range in the form of either B1 (extent of occurrence) OR B2 (area of occupancy) OR both:

1. Extent of occurrence estimated to be less than 20,000 km<sup>2</sup>, and estimates indicating at least two of a–c:

- a. Severely fragmented or known to exist at no more than 10 locations.
- b. Continuing decline, observed, inferred or projected, in any of the following:
  - (i) extent of occurrence
  - (ii) area of occupancy
  - (iii) area, extent and/or quality of habitat
  - (iv) number of locations or subpopulations
  - (v) number of mature individuals.
- c. Extreme fluctuations in any of the following:
  - (i) extent of occurrence
  - (ii) area of occupancy
  - (iii) number of locations or subpopulations
  - (iv) number of mature individuals.

2. Area of occupancy estimated to be less than 2000 km<sup>2</sup>, and estimates indicating at least two of a–c:

- a. Severely fragmented or known to exist at no more than 10 locations.
- b. Continuing decline, observed, inferred or projected, in any of the following:
  - (i) extent of occurrence
  - (ii) area of occupancy
  - (iii) area, extent and/or quality of habitat
  - (iv) number of locations or subpopulations
  - (v) number of mature individuals.
- c. Extreme fluctuations in any of the following:
  - (i) extent of occurrence
  - (ii) area of occupancy
  - (iii) number of locations or subpopulations
  - (iv) number of mature individuals.

C. Population size estimated to number fewer than 10,000 mature individuals and either:

1. An estimated continuing decline of at least 10% within 10 years or three generations, whichever is longer, (up to a maximum of 100 years in the future) OR

2. A continuing decline, observed, projected, or inferred, in numbers of mature individuals AND at least one of the following (a–b):

- a. Population structure in the form of one of the following:
  - (i) no subpopulation estimated to contain more than 1000 mature individuals, OR
  - (ii) all mature individuals are in one subpopulation.

b. Extreme fluctuations in number of mature individuals.

D. Population very small or restricted in the form of either of the following:

1. Population size estimated to number fewer than 1000 mature individuals.

2. Population with a very restricted area of occupancy (typically less than 20 km<sup>2</sup>) or number of locations (typically five or fewer) such that it is prone to the effects of human activities or stochastic events within a very short time period in an uncertain future, and is thus capable of becoming Critically Endangered or even Extinct in a very short time period.

E. Quantitative analysis showing the probability of extinction in the wild is at least 10% within 100 years.

**APPENDIX 4: Explanation of conservation status categories for vegetation types (from Mucina and Rutherford, 2006).**

The vegetation types of South Africa are divided into four categories depending on their conservation status. These categories draw on the IUCN Red List classification scheme and use the same terminology. The four categories are: Critically Endangered (CR), Endangered (EN), Vulnerable (VU) and Least Threatened (LT). These categories are determined by assessing plant species diversity and turnover, habitat transformation and levels of protection. The biodiversity target (BT) for each vegetation type and the percentage of remaining untransformed area are also considered in determining the ecosystem status.

<b>Natural Habitat Remaining (%)</b>	<b>Ecosystem Status</b>	<b>Code</b>
0 - BT	Critically Endangered	CR
BT – 60	Endangered	EN
60 – 80	Vulnerable	VU
80 – 100	Least Threatened	LT