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Long-term monitoring of vegetation dynamics in the Goegap Nature Reserve, Namaqualand, South Africa

by

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Submitted in partial fulfilment of the requirements for the degree

MAGISTER SCIENTIAE

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I declare that the thesis/dissertation, which I hereby submit for the degree Magister Scientiae at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

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ABSTRACT

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Namaqualand is a semi-desert area situated in the winter rainfall region of South Africa hosting the world's richest succulent flora, and is one of only two arid areas to classify as a global hotspot of biodiversity. The Goegap Nature Reserve, east of Springbok, lies in the Upland Succulent Karoo. After all the livestock were removed and the reserve fenced in 1969, a long-term monitoring project was initiated to record possible vegetation changes under the reduced grazing pressure. The first monitoring was done in 1974 when two line transects, of 1 km each, were surveyed. These surveys have been repeated annually covering a period of more than 30 years. When the reserve was enlarged in 1990, five additional line transects were set out in highly degraded areas. The main aim of this study was therefore to determine whether any changes in the vegetation in terms of species composition, species richness and life form richness in the monitored line transects could be detected. Rainfall as possible force driving these changes was also examined. It was found that changes did indeed take place in the vegetation. The species composition revealed notable changes over the entire monitored period, specifically in the two longest established line transects, whereas in the case of the species richness changes were also detected, but to a lesser extent and not notable in terms of an overall increase or decrease in the number of species. These changes are referred to as fluctuations. Rainfall can be regarded as a definite environmental driving force, with the time, intensity and duration of importance, specifically to the annual species composition. Overall, the veld condition improved and continuous monitoring of the line transects on a regular basis should take place to improve our understanding of the complex dynamics of this ecosystem. Because the changes in species composition are reflected in changes in grazing capacity the results are of direct importance to the management of the wildlife on the reserve.

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CHAPTER 1

INTRODUCTION

The Succulent Karoo is a global biodiversity hotspot located in southern Africa and is globally one of a few places to be so biologically distinct (Mucina & Rutherford 2006). A ‘hotspot’ refers to an area with a high concentration of endemic species and which is also threatened by habitat loss or alteration (Van Wyk & Smith 2001). Hotspots contain at least 1 500 endemic plant species and have already lost 75% or more of their original vegetation. Although these hotspots globally include less than 2% of the earth’s land surface-area, they contribute to 44% of all vascular plant species and 38% of birds, mammals, reptiles and amphibians (Hilton-Taylor 1996, Van Wyk & Smith 2001).

This biome hosts a high concentration of leaf-succulent shrubs. It is characterised by low winter rainfall, extreme summer aridity and lime-rich, weakly developed soils. Rainfall varies between 50 and 350 mm per annum, and the maximum summer temperatures vary between 30ºC and 40ºC. The species richness, mostly succulents, is much higher than for any other arid area of this size elsewhere in the world (Mucina & Rutherford 2006). Little information is available on the fauna of the Succulent Karoo (Low & Rebelo 1998, Le Roux & Van Rooyen 1999).

Although the plant species of the Succulent Karoo Biome are specialised to survive under harsh climatic conditions any human induced change in their surroundings could affect them adversely. One of the overriding problems in the region is land degradation due to inappropriate veld management practices such as overstocking. In a desert ecosystem, seedlings are sought-after forage. Severe grazing can reduce vegetation cover, resulting in the decrease and disappearance of shade and protection for the germination and survival of seedlings of various shrub species. Thus, some species may disappear due to overgrazing or grazing during an inappropriate time of the year such as the dry summer months and can result in diminishing a whole seedling crop. Trampling due to overgrazing can also destroy entire colonies of plants e.g. stone plants (family Aizoaceae) even if they are unpalatable. The result of overgrazing in arid areas leads to desertification, defined as the irreversible reduction of the biological potential of land (Cowling *et al*. 1999*b*, Le Roux & Van Rooyen 1999). An increase in abundance of certain indigenous plant species (such as *Galenia africana* and *Psilocaulon* spp.) indicates that the vegetation is overutilised and therefore grazing should be reduced to the minimum and effective management applied (Le Roux & Van Rooyen 1999). A study conducted by Steinschen *et al*. (1996) on whether the invasion of grasses threatens the annual species in Namaqualand, indicated that the greatest threat to these indigenous plant species was severe grazing.

Arable land, productive soils, indigenous vegetation, water resources and biodiversity are all decreasing due to human impact (South African Environmental Observatory Network 2004). Humans are furthermore, an important threat to the Succulent Karoo Biome, especially with regards to the collection of rare and endangered plant species. Many small succulents easily exceed ages of 50 years and recruitment occurs only once or twice during their entire lifetime. Effective resource management programmes are needed to address these problems (South African Environmental Observatory Network 2004). Fortunately, alien invasive plant species do not pose a large threat in the region. According to Le Roux and Van Rooyen (1999) there are only a few alien invasive plant species in the Succulent Karoo Biome (such as *Nerium oleander, Nicotiana glauca* and *Fumaria muralis*) that threaten the native vegetation of this biome.

Conservation in the Succulent Karoo Biome is challenging due to the high diversity of plant species and also the large variation in habitats. Lombard *et al*. (1999) stated that it is difficult to conserve all the plant species occurring in the Succulent Karoo Biome within a formal nature reserve system, due to its highly variable species richness together with high compositional species turnover. Ideally, conservation would include the design of a reserve network representing the enormous biodiversity of the Succulent Karoo vegetation (Cowling *et al*. 1999*a*).

Even though it is impossible to exactly predict the impacts of global warming, there is little doubt that climate change will add another layer of complexity to effective veld management and conservation. Both plant and animal species will react to climate change by migration, extinction and speciation. It is very important to ensure that a conservation area will persist in the face of predicted climate change (Cowling *et al*. 1999*a*, 1999*b*). However, conservation outside protected areas is also very important (Hendricks *et al*. 2005). Protected areas in the country will have to integrate parts of existing rangelands and will therefore be challenged to reduce numbers of livestock in the communal livestock production system (Hendricks *et al*. 2007).

Arid and semi-arid environments frequently display complex non-equilibrium dynamics involving non-linear and stochastic event-driven behaviour (Westoby *et al*. 1989*a*, 1989*b*). Vegetation changes occur unpredictably, in the short-term, in response to the inter-annual variation in rainfall, and episodically in the long-term (several decades) in response to rare events as well as grazing pressure, changes in climate, altered disturbance regimes, or a combination of these factors (Behnke & Schoones 1993, Illius & O'Connor 1998, Ward 2006). This complicates the complete understanding of long-term dynamics, because it is difficult to observe rare events.

Long-term ecological monitoring is required in order to increase the understanding of vegetation dynamics in arid areas (Wiegand & Jeltsch 2000, Ward 2006). The objectives of long-term ecological monitoring are to examine and document changes in essential assets of biological communities, while monitoring is also necessary for evaluating the progress of the management objectives of any project. In spite of the importance of long-term monitoring of the natural environment, 'monitoring' is often regarded as a low-grade science adding little to our understanding of the functioning of environmental systems (Burt 1994).

The Goegap Nature Reserve, approximately 15 000 ha in size, is situated in Namaqualand, in the Succulent Karoo Biome (Rösch 2001*b*). The Hester Malan Nature Reserve was established in 1966 (Le Roux 1984), and in 1969 the reserve was fenced and excluded the livestock that previously grazed freely in the reserve. In 1990, land from the neighbouring farm Goegap was added to the reserve and it was declared as the Goegap Nature Reserve. At that stage, this newly added section was much more heavily grazed than the Hester Malan section. It was only in 2002 that the fence dividing the Hester Malan section from the Goegap section was removed, after a survey showed that the vegetation on the Goegap part had recovered substantially (Rösch 2001*a*).

The fencing of the reserve and removal of livestock created an opportunity of investigating vegetation recovery after severe overgrazing. Firstly, it was of importance to investigate whether the veld condition improved since the removal of the livestock. Secondly, because wildlife were reintroduced into the reserve and started increasing in numbers it was important to prevent overgrazing, therefore degrading of the veld condition. To examine these issues, line transect surveys were established throughout the Goegap Nature Reserve to monitor the changes in vegetation, and some of these line transects have been monitored for more than 30 years already.

To improve our understanding of the vegetation dynamics of the Succulent Karoo it is vital to have knowledge of the way in which plant species respond to the climate and disturbance regimes as well as to have knowledge of the life history traits of the species that enable these responses. Therefore, the main aim of this study was to assess the changes in the vegetation, in terms of species composition, species richness and life form richness, in seven long-term monitoring transects in the Goegap Nature Reserve. Because the changes in species composition are reflected in changes in grazing capacity the results are of direct importance to the management of the wildlife on the reserve.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The objectives of this chapter are to give a broad overview of different concepts to be discussed further on throughout the study. The importance of long-term monitoring is firstly discussed because it forms the fundamentals for this long-term study. Thereafter the concepts of vegetation dynamics and the development of different models applicable to arid regions are considered because these models can help with interpretation of the vegetation composition changes. Since carrying capacity and the changes in carrying capacity were determined throughout the monitored years, a short description of veld management and the essentials of carrying capacity determination are also given. Lastly, an overview on adaptations of plant species occurring in the Succulent Karoo, with special reference to life forms is provided, because changes in life form composition throughout the monitored period was also investigated.

2.2 Long-term monitoring

2.2.1 *Introduction*

Environmental change is a persistent feature occurring all over the world. A few millennia ago, lush vegetation, as well as elephant and antelope dominated the North African region, now known as the Sahara Desert. Early explorers documented rivers in Botswana that have since disappeared. Preserved ice cores found in Antarctica and Greenland are evidence for extreme climatic changes that can take place within a short time. Frequently asked questions are: How will the changes affect precipitation? Will deserts spread or close up? How will our national parks and other protected areas be affected by such change? These questions can only be answered through the use of information obtained over a long period of time; therefore with long-term environmental research (Pickett 1989, South African Environmental Observatory Network 2004).

The value of long-term monitoring has only been recognised relatively recently. There are, however, a few monitoring experiments that have run for over a century and a well-known example is the Broadbalk Experiment in Rothamsted which has been in operation for over 150 years. Long-term experiments provide exceptionally valuable information by answering questions not even considered during the original set up of the experiment (Beard *et al*. 1999).

2.2.2 *Defining long-term ecological monitoring/research*

Long-term research can be practically defined as the persistence of studies of the environment beyond the usual limits of funding cycles, completion of a graduate degree, or the length of time ’interesting’ ideas remain trendy (Pickett 1989). Most modern research projects have a life-span of two to five years (masters or PhD) and therefore past environmental research has been limited mostly to this short time span. These studies yield important results, however, for the efficient conservation of our ecosystems another approach, long-term ecological research, is necessary. In some cases environmental monitoring has extended over longer periods, but rarely in such a way that cause-effect relationships could be established, thus proper experimental approaches that include adequate experimental controls were lacking. Research therefore has focused on small-scale questions, rather than big-scale issues that must be addressed for dynamic national and global management of the human environment (South African Environmental Observatory Network 2001, 2002, 2004, Krug *et al*. 2006).

2.2.3 *The importance of long-term studies in environmental science*

In spite of the importance of long-term monitoring of the natural environment, ‘monitoring’ is often regarded as a low-grade science adding little to our understanding of the functioning of environmental systems (Burt 1994). The objectives of long-term ecological monitoring are to examine and document changes in essential assets of biological communities. Monitoring is also necessary for evaluating the progress of management objectives of any project. Monitoring of the vegetation structure and dynamics has to be done in a scientifically accurate way, while being cost-effective and widely understandable. Monitoring methods can be limited by the expense, training requirements and poor repeatability. Therefore, it is essential to identify an appropriate group of rapid, repeatable and cost-effective methods that reflect various processes and functions (Havstad & Herrick 2003).

The past has an influence on the present and future course of an ecosystem. Long-term studies (LTS) document the effects of the past conditions on continuous processes (Figure 2.1). Therefore, the aim of LTS is to document the changing environmental influences and conditions before lost to the historical record (Pickett 1989, Burt 1994).

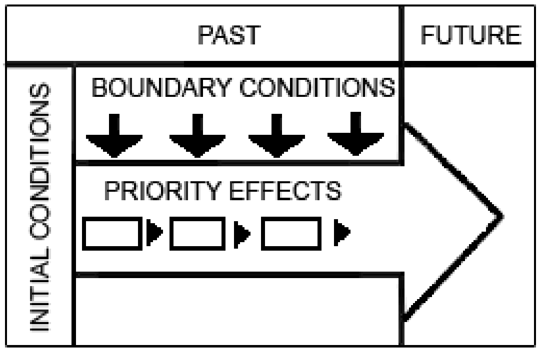


Figure 2.1 The various influences on an ecological process or system through time.

In Figure 2.1 the large horizontal arrow indicates the course of a system through time. The small boxes enclosed represent specific system states whose order can influence the outcome of the process. The vertical line separating the head from the body of the arrow represents the present, with the past on the left and the future on the right.

Methods used to gather information for management decisions on a seasonal or annual time frame are called short-term monitoring and provide data on vegetation status at specific sites. Methods used to gather information that create a 'trend-record' are called long-term monitoring. Short and long-term monitoring programmes can be integrated in order to achieve management objectives (Havstad & Herrick 2003). Short-term studies are often misleading and without long-term data there is a lack of interpretation. However, ecologists often appear insensitive to the vital role of LTS in formulating and testing basic ecological concepts. Thus, long-term data sets are fundamental for testing most theoretical constructs or concepts central to ecology, but most of these concepts are not tested because they require systematic, long-term observations. The organisms studied are usually selected either because they are suited for studies limited in time and space or they are likely to confirm the theoretical construct. There is consequently an unacknowledged excess of unanswered questions in ecology, and hypotheses of which the validity is not known. Most scientists are only interested in new and intriguing ideas and not in supporting long-term testing. The problem is that concepts are accepted and rejected with little experimental foundation. In addition, the need to examine spatial and temporal validity, or the application of a process, structure or mechanism, once recognized, has barely any support among ecologists. Most scientists have been working on long-term programmes of abiotic rather than biotic factors. This may be because numerous parameters address social needs (such as weather) and the greater ease in standardising methods (Franklin 1989). Just as LTS are vital to ecological sciences, they are also important to identify and resolve social issues, such as the sustained productivity of forests, agricultural lands and fisheries.

2.2.4 *Systematic approaches to long-term studies (LTS)*

An extensive and systematic approach to LTS is necessary. It is firstly important to note what are the vital issues that deserve the energy and cost associated with LTS. Experiments need to be included, where appropriate, to provide contrasting treatments, and need to be kept simple and straightforward (KISS principle: keep-it-simple-stupid). The design needs to foresee unpredicted modifications. Non-manipulative observations of processes in natural ecosystems are necessary in most cases and systematic examination of how processes and structures vary in time and space is crucial. Therefore, to develop proper designs for long-term research monitoring and programmes is complex (Franklin 1989). Furthermore LTS should include comparative studies of processes across and within biomes. Care should be taken not to view ecological mechanisms as being mutually exclusive (Franklin 1989).

It is important that more research includes different organisational levels, i.e. population, community, ecosystem and landscape. Most natural resource issues such as biodiversity conservation necessitate combined knowledge on all levels, from the genetic to the landscape. Detailed and specific information is required to make crucial decisions on biological resources as well as to formulate ecological hypotheses (Franklin 1989).

Procedural considerations include methodology and data management. A well-planned experimental design and exploitation of best current technology are important in monitoring programmes. The data documentation and management procedures need to be detailed although the documentation of initial conditions can be problematic. Nonetheless, data need to be available and easy accessible whenever required (Franklin 1989).

2.2.5 *Long-term study requirement*

According to Pace and Cole (1989) LTS are required when:

- Changes of an ‘unknown’ type are monitored. Although some changes may be expected, the nature of the change may be unclear.
- Studying the dynamics of certain ecological systems where no surrogate methods are available.

Many ecological phenomena fall under these two categories. Monitoring (Figure 2.2) plays an important role in LTS, and if carefully designed may reveal the scales of variability in an ecological system. It provides the vital data for evaluating indirect methods, such as models or remote sensing.

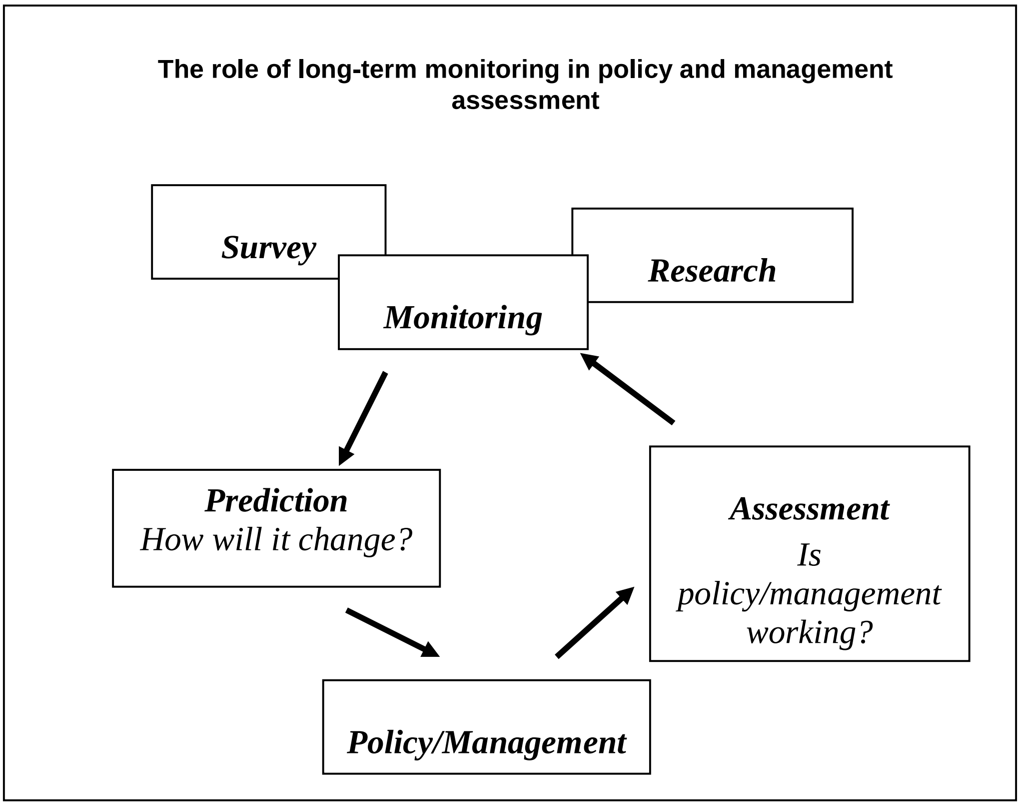


Figure 2.2 Monitoring, research and modelling are required to detect and manage environmental change, and are interconnected actions (Parr *et al*. 2003).

Pace and Cole (1989) suggested the following with regards to monitoring:

a) Monitoring is the most effective when combined with experimental manipulation;
b) Archiving is essential for future developments in analytical techniques, re-evaluation of existing ideas, as well as development of new questions and
c) A monitoring programme must be relatively inexpensive and comprise only a small percentage, about 10%, of the resources of a LTS.

Monitoring, however, requires substantial time allocation. It is suggested that technology and methods should be improved to reduce time and expenses of monitoring programmes. In any case it is important that the time used for monitoring should be acknowledged as valuable and vital even when the monitoring does not result in longer term studies (Pace & Cole 1989).

Ecological monitoring is based on collection, analysis and interpretation of data, designed to investigate biophysical phenomena outside project or programme cycles. The objective of ecological monitoring is to predict environmental trends to prevent disastrous consequences.

Indicators (or benchmarks) are used to help provide concise answers to the monitoring question (Abbot & Guijt 1998).

The following are examples of issues that have vital long-term components (Franklin 1989):

- Ecosystem changes associated with succession;
- Predator-prey interactions which tend to be complex with long-term cycles, specifically for large vertebrates;
- Productivity controls, for example, the effect of herbivory on short- and long-term productivity of terrestrial ecosystems;
- Geomorphic processes including weathering of parent materials and erosion;
- Ecosystem responses to atmospheric inputs, including pollutants and changes in key biogeochemical cycles;
- The effects of climatic change;
- Genetically engineered organisms and
- Biodiversity losses.

2.2.6 *Phenomena addressed by long-term studies (LTS)*

Slow phenomena

Many environmental processes happen over a much longer period of time than the time for a research degree. One such process for an example is succession. If one required reliable conclusions, long-term studies would be needed to examine succession. For long-lived species important life history events happen over long periods of time. In these cases LTS are fundamental to document population dynamics and their influence on ecosystems. LTS are also necessary to identify the factors controlling the recruitment or mortality of populations when these are intermittent (Pace & Cole 1989). Additional examples include soil development and wood decay (Franklin 1989, Pickett 1989, Burt 1994).

Transient occurrences are often misinterpreted by short-term studies. It was found that 70% of ecological experiments lasted less than one year (Pickett 1989, Burt 1994). The predicament with the short time frame of most ecological experiments is the variation in outcome due to the variability in the environment. Experiments done in different years often yield different results. Differences in initial conditions as well as changing boundary conditions may be of importance. Some differences may occur due to repeating studies at different times without a persistent priority system. Therefore, LTS are a reliable way to determine slow processes (Pickett 1989).

Episodic phenomena (rare events)

Rare events are the second main type of process amenable to LTS. This category includes any ecological event with a return time of more than a few years. The only way to learn the frequency and ecological significance of such phenomena is to observe them over long periods and only then will some be discovered. Rare events may, to some extent, be predictable (El Nino events in the eastern Pacific) or unpredictable (floods, fire, volcanic eruptions) or periodic. Rare events that are to some degree predictable can possibly be captured by short-term studies. Periodic recruitment, periodic mortality or small gap disturbance may also be open to short-term studies. An extreme type of rare event is unique, unprecedented and unrepeatable, such as the invasion of an exotic species or the outbreak of a disease and these are only accessible through LTS. Reproductive patterns for long-lived organisms are an example of this class of event. Many species are episodic reproducers as a consequence of environmental variables, seed production or disturbance patterns, and these are specifically evident in marginal or stressful environments. Rare events have an impact on ecosystems even if at intermediate frequencies (Franklin 1989, Pickett 1989, Burt 1994).

Rare events, such as a spatially extensive event (e.g. drought) or localised event (e.g. tornado) are better observed via long-term studies. However, even so, a LTS network will probably overlook local events too. If an event has extensive effects continued LTS will show this in records. Thus, without LTS these events’ importance in ecosystem development and life cycles of organisms go unnoticed (Franklin 1989, Burt 1994).

Subtle and complex phenomena

Subtle and complex phenomena require LTS in order to separate pattern (trend) from ‘noise’ (non-trend). Subtle processes change over time but the year-to-year variance is large compared to the magnitude of the trend. Complex phenomena include various interacting features. LTS are needed to investigate these events to sort out the relative contribution of multiple factors through acquiring an adequate statistical sample (Franklin 1989).

Subtle processes will not be noticed unless a long record is present because subtle processes are embedded in a variable matrix. Even if a clear outline does exist, high frequency variation will obscure this and short-term studies will fail to notice it. Systems or processes strongly influenced by climate are examples of this. LTS can reveal what the multiple factors contributing to, for example, climate change are, whereas without LTS it is difficult to attribute these fluctuations to certain processes (Pickett 1989, Burt 1994).

Complex processes have multiple causes. A system must be observed for long enough to include periods when different causes dominate its structure or function. For systems that are replicated sufficiently in space, a comparative method may be useful. Population regulation is the possible paradigm of a multivariate issue. Populations are controlled by various factors including predation and herbivory, competition and dispersal. Competitive interactions have been studied, almost exclusively, via short-term studies and it is vital to address the role of these interactions over long periods. It is clear that there can be noteworthy changes in consequences over time, for example relationships can shift from competitive to mutualistic. Interactions, initially regarded as unimportant may turn out to be vital, or interactions initially regarded as essential may turn out to be irrelevant (Franklin 1989, Pickett 1989).

Several ecological processes reveal high levels of year-to-year variability, for example productivity in deserts which is strongly linked to the level of precipitation. Thus, biological phenomena are strongly related to physical parameters (Franklin 1989). However, in moderate environments high annual variability also occurs, for example the litter-fall in mature deciduous hardwood forests (Gosz *et al*. 1972 in Franklin 1989). Ecologists should frequently assess and publish data on inter-annual high variability when conducting LTS and monitoring programmes (Pace & Cole 1989).

2.2.7 *Advantages of long-term studies (LTS)*

- Only LTS reveal the existence of trends, cycles and rare events and provide hypotheses for scientists to explain, whereas short-term experimentation may test the hypothesis, but only once it is formulated. It takes long to build up a dataset in ecology for the development of useful hypotheses, because the natural ecosystems are so complex (Burt 1994).
- Long-term datasets test hypotheses not formulated and thought of with the initial set-up. For example, the Rothamsted classical experiments began in 1843. The original aim was to determine which elements most limited plant growth. This aim was already achieved by the 1860s and with the continuation of these experiments even until today, many new questions have been investigated.
- Through LTS it becomes clear what significant changes have a negative impact on both the ecosystem and humans. It is important for long-term monitoring networks to carefully select indicator variables and species, to provide significant information on future changes, on local, regional and global scale, and to allow new vital questions to be formulated (Burt 1994).

Although LTS are essential, there still are limitations. Network sites may be subjectively selected and there may be an insufficient number of sampling sites. One problem area that has been identified is that successful projects need a dedicated leader, an opportunity (site and idea) and funding (often from various sources) (Franklin 1989). Above all there needs to be consistency and commitment in a LTS network (Burt 1994).

2.2.8 *Alternative approaches to long-term studies (LTS)*

Short-term experiments

LTS are more costly, time consuming and difficult than shorter term studies (Pace & Cole 1989). The most effective LTS are those interacting with short-term experimentation. Without LTS, short-term studies are often not interpretable, because of the complexity of natural ecosystems. The cause-and-effect relationships are, however, better understood via short-term studies and these are used to supplement LTS (Burt 1994).

Modelling

A simulation model forecasts future behaviour by using current knowledge. These models simulate the result of a combination of processes and thereby predict possible outcomes. LTS are logistically difficult and scientists need to be patient while collecting data. Therefore the idea of predicting changes is attractive, specifically for experimentalists who want to evaluate the consequences of land management changes, or potential climate change before it is too late to avoid negative consequences. However, no model is superior to the assumptions and data it depends on. LTS information provides the means for model calibration as well as verification. Thus, LTS and modelling complement each other (Burt 1994).

Space-time substitution (chronosequence)

Ecosystem change testing, with relation to succession, has been limited principally to chronosequence analysis. This is the most common approach for studying community and ecosystem succession but can often be misleading (Franklin 1989, Pickett 1989). The ergodic hypothesis implies that under certain conditions, sampling in space can be comparable to sampling through time, and that space-time transformations are possible. Thus, the assumption is made that the statistical properties of a time series are basically the same as thát of the observations of the same phenomenon taken in space. Spatial comparison may, however, not be matching like with like. Ergodic reasoning ignores process and spatial variation within and between sites (Burt 1994). LTS and space-time substitution may be regarded as complementary (Franklin 1989, Pickett 1989, Burt 1994).

The use of palaeo-environmental data

Analysis of palaeo-environmental data has lead to useful information on environmental change. Such studies provide information on slow processes (over centuries or millennia) and rare events can be identified. It may, however, be that they provide data too coarse-grained to be compared with LTS. Both approaches are needed (Burt 1994).

Mobile study teams

This includes the set up of a study group that is mobile and can rely on routine surveys, retrospective records or spatial comparisons to investigate changes caused by unique events. This may be difficult to maintain, but it is likely that at least some members on the team remain keen to record some extreme events (Burt 1994).

2.2.9 *Concluding remarks on long-term monitoring*

Some events are best addressed via LTS although this is an expensive route in terms of time, money and energy. It is therefore important to determine when LTS are necessary and when not for answering important ecological questions (Pace & Cole 1989). Long-term studies provide an invaluable basis for the development of environmental science (Burt 1994).

After the World Summit for Sustainable Development, it was seen that LTS and the related long-term ecological networks and programmes such as Environmental Observatories Network (EON) and Long-term Ecological Research (LTER) are crucial (Biggs *et al*. 1999, Henschel & Pauw, 2002, Henschel *et al*. 2003).

2.3 Vegetation dynamics

2.3.1 *Introduction*

The scientific study of succession began at the end of the nineteenth century and the concept of plant succession was initiated primarily in North America during the first two decades of the twentieth century (Glenn-Lewin *et al*. 1992). Succession can be defined as directional change over time in community composition. Succession begins when a disturbance is followed by colonisation of the disturbed site by plants (Mueller-Dombois & Ellenberg 1974, Connel & Slatyer 1977, Gurevitch *et al*. 2002). The study of succession aims at establishing the patterns and causes of succession.

2.3.2 *The traditional concept of succession*

Clements (1916 in Connell & Slatyer 1977) offered a rigid view of plant succession, and noted the following subcomponents in succession, referred to as relay floristics, in which one stage prepared the way for the next:

- Nudation by which novel surfaces are exposed;
- Migration is the arrival of disseminules;
- Ecesis includes germination, establishment, growth and reproduction;
- Competition which may result in replacement of species;
- Reaction whereby the species change the habitat and
- Final stabilisation as the climax.

Clements's views (1916 in Connell & Slatyer 1977) on the causes of succession dominated the literature on the topic for many years. In contrast to Clements, Gleason (1917 in Tainton 1999) suggested that succession was much less ordered. He believed that successional communities were incohesive groups and that the nature of any change was largely dependent on the availability of seed and a favourable environment.

According to Barbour *et al*. (1987) if there is some directional, cumulative, non-random change in a community over 1–500 years, the community is a successional (seral) community. However, if no significant changes occur over the given period, the community is said to be a mature or climax community. The climax community is said to be in a state of dynamic equilibrium. An apparent climax, is actually an earlier seral stage maintained by disturbance and is called a disclimax.

Succession, in the traditional sense, leads to a climax community. However, the climax is the most challenged concept in ecology (Niering 1987, Krohne 2001). Already in 1954 Egler suggested that the term vegetation change rather than succession should be used. Vegetation change refers to all kinds of temporal alterations within and between communities. The terms 'steady state' or 'relative stability' instead of climax, are more appropriate when looking at fairly stable conditions in any biotic system (Niering 1987). Such a view of community stability leads to the concept of dynamic equilibrium. Four stages of species equilibrium were defined by Mueller-Dombois and Ellenberg (1974):

- Non-interactive species equilibrium applies mainly to pioneer plant communities.
- Interactive species equilibrium is found when interactive species share the same niche and form ecological groups. Pioneer communities are replaced by communities consisting of non-interactive together with interactive species.
- Assertive species equilibrium is the consequence of interaction among species which leads to the formation of long-lived combinations.

- Evolutionary species equilibrium is the final stage of community development and the species are adapted genetically to each other and to the environment.

Connell and Slatyer (1977) proposed three other alternative models (the facilitation, tolerance and inhibition models) to elucidate the mechanisms of successional change after a perturbation. The models differ with regards to how new species arrive later in the succession sequence.

The early successional species in the **facilitation** model modify the physical environment in such a way as to facilitate colonisation by later-successional species. This continues until the occupier species no longer modify the site to facilitate invasion of other species (Connell & Slatyer 1977, Krohne 2001). Evidence for this model for autotrophs comes from primary succession on newly exposed surfaces (Connell & Slatyer 1977, Van Hulst 1992, Gurevitch *et al*. 2002).

In the **tolerance** model succession is also driven by changes in the physical environment caused by species. The early occupiers in this model, however, do not increase or reduce the later colonists' growth and invasion. The species' sequence of appearance is determined only by their life-history traits. The species appearing later have propagules dispersed more slowly and their progeny grows more slowly. They grow despite the presence of the early successors. In active tolerance the presence of one species lowers the growth rate of others by reducing the availability of resources, whereas in passive tolerance, the change is the result of individual resource requirement differences of the species involved (Connell & Slatyer 1977, Krohne 2001). The evidence for this model is that late successional plant species are often capable of establishing without any preparation of the area by earlier species. This model applies to most secondary succession. The view of this model suggests that succession leads to a community composed of the most efficient species in exploiting resources, each specialised on different kinds or quantities of resources (Connell & Slatyer 1977, Gurevitch *et al*. 2002).

The **inhibition** model, suggests that earlier colonists inhibit the invasion of succeeding colonists or suppress the growth of those already present and prevent any further succession. Thus, the main element determining the outcome of succession is the nature of the initial colonisation. In this model the species replacing a dying inhabitant need not have life-history traits different from the original inhabitant, and the tolerance of late-succession species is of importance, allowing late species to survive through long suppression periods. Evidence for this pathway is obtained from observations revealing that later species need no site preparation by earlier species in order to establish; early species suppress the establishment of later ones, inhibit their growth and reduce their survival. Even though this may be the case, the earlier species eventually die and are replaced. This model also applies to most secondary succession (Connell & Slatyer 1977, Gurevitch *et al*. 2002). In the inhibition model the early colonists are killed by disturbances caused by abiotic or biotic factors (natural enemies).

The models of Connell and Slatyer (1977) are conceptual models and do not effectively describe successional changes because they were never designed to do that. They explain only one aspect of succession and that is the net effect of an earlier species on a later one. Various other aspects such as seed viability, weather, floods, and herbivore abundance were not included in these models (Connell *et al.* 1987).

2.3.3 *Terminology*

A multitude of terms have been proposed to describe succession:

- ***Primary succession***. This is the establishment of vegetation on land *not* previously vegetated. The time-scale involved here may be centuries up to thousands of years. On such a long time-scale evolutionary changes are significant and cannot be ignored. The establishment on a wet substrate is termed hydrarch primary succession and on a dry surface xerarch primary succession (Mueller-Dombois & Ellenberg 1974, Burrows 1990, Barbour *et al*. 1987, Gurevitch *et al*. 2002).
- ***Secondary succession.*** This includes all the non-phenological vegetation changes occurring in established ecosystems. Secondary succession initiates after a partial disturbance by either man or nature. An example of an extreme case of secondary succession is old-field succession that initiates after agricultural cropland was abandoned. In general, the vegetation changes happen quite fast. However, in some cases it may take almost as long as primary succession. The extent of change that the disturbance causes depends on the intensity of the disturbance (Mueller-Dombois & Ellenberg 1974, Barbour *et al*. 1987, Burrows 1990, Tainton 1999, Gurevitch *et al*. 2002).
- ***Autogenic succession.*** Autogenic succession is driven by factors resulting from the community or its constituent organisms (biotic forces). Interactions include factors such as competition, shade generation and soil modification by plants (‘internal’ forces). “Third party” effects refer to a plant or animal species or microorganism that change the success of establishment of two species. In the presence of the third party the second species will be more successful in colonising (Glenn-Lewin *et al*. 1992).
- ***Allogenic succession:*** This refers to vegetation change due to environmental conditions (‘external’ forces). An example of this is long-term vegetation response to climate. Glenn-Lewin and Van der Maarel (1992) suggest that even though it might be possible to label individual processes as auto- or allogenic, it is misleading and not useful to label an entire successional pathway as either.

- ***Progressive succession:*** This refers to species enrichment related to increased structural complexity and biomass. This often leads to habitats that are progressively more mesic.
- ***Regressive (retrogressive) succession***: This is the loss of species and is related to decreased structural complexity. This kind of succession leads to a simpler community with fewer species which is either more hydric (wet) or xeric (dry).

It is important to distinguish between succession and non-directional vegetation change. Phenological changes as well as year-to-year or long-term environmental variations (fluctuations) are two other styles of vegetation change (Burrows 1990). Phenological changes (e.g. leaf emergence, flowering, fruiting, leaf-shedding) in plants are correlated with the seasons and do not generally result in changes in plant populations. Environmental variation such as those resulting from climatic variation cause changes in seed production, seedling establishment and survival, or in gross productivity or reproduction by mature plants. These changes are called fluctuations.

2.3.4 *Documenting succession*

Vegetation change can be investigated through various ways including studies on the same area and side-by-side comparisons. The first type of study is more reliable. Studies on the same area are based on permanent plots, containing marked individuals, exclosure studies, aerial photographs taken at different times, historical records and evidence of change in populations (Mueller-Dombois & Ellenberg 1974, Burrows 1990). However, few accurate, long-term records, in numerical data form, exist.

2.3.5 *Modelling and succession*

Modelling expresses vegetation dynamics by means of symbolic logic and mathematics. Models simplify the process, although current models can be relatively complex. The use and importance of modelling is increasing because of improved technology and are useful for ecological forecasting and conservation and management. Although models exhibit properties of generality, precision or reality they never exhibit all three simultaneously (Glenn-Lewin & Van der Maarel 1992). The main problem in modelling is the validation of the model. Models that include spatial variation and the nature of changes over time are needed for consistent prediction of vegetation dynamics. The following are examples of successional models:

- Analytical models are simple theoretical and explanatory expressions based on principles resulting from ecosystem observations;
- Statistical models are stochastic expressions where the parameters are probabilities of events and are useful for probabilistic predictions of vegetation dynamics and successional events;

- Lottery models are a form of statistical model and are used for prediction of succession;
- Simulation models are real and precise, but not general. They can be used for prediction and sensitivity analysis and attempt to duplicate the true behaviour of phenomena (Glenn-Lewin & Van der Maarel 1992).

2.3.6 *Vegetation dynamics and plant community management*

Vegetation dynamics and management are interconnected and understanding the processes involved in vegetation change, is vital for proper management. In wildlife management large areas of land are managed to maintain a diversity of vegetation types to favour a diversity of animal populations. Succession and climax are therefore two concepts often used by wildlife managers.

2.3.7 *Implications of vegetation change for range or veld management in arid and semi-arid rangelands*

Rangeland management is organised around models as to how ecosystems function. A brief discussion on some models for research and management on rangelands follows.

The range succession model

This model is also called the directional model (Milton & Hoffman 1994) and is derived from the Clementsian ideas of plant ecology and suggests that a given rangeland has a stable state (climax) in the absence of grazing. Succession towards the climax is a steady process with grazing pressure causing changes, retrogressive to the successional tendency. The grazing pressure therefore produces an equilibrium in the vegetation at a set stocking density. All possible vegetation states can be assorted on a single continuum which ranges from heavily grazed vegetation in an early successional, poor condition to ungrazed, climax, vegetation in an excellent condition. The aim of management is to choose the correct stocking density that establishes a long-term balance between the grazing pressure and the successional tendency. The model can incorporate rainfall by assuming that drought affects vegetation in a similar way to grazing. Management should therefore respond to drought by reducing grazing pressure because the joint pressure of drought and grazing should vary as little as possible (Westoby *et al*. 1989*a*).

However, evidence reveals that this model's assumptions are not appropriate in all cases. The following mechanisms have been identified in rangelands that conflict with model predictions (Westoby *et al*. 1989*a*, 1989*b*):

- Demographic inertia - some plant communities only establish after a rare event, but after this event the population may persist for long periods.

- Grazing catastrophe - plant abundance may change discontinuously and irreversibly in response to changes in stocking density.
- Priority in competition - mature plants have a competitive advantage above the seedlings of other species.
- Fire positive feedback - some vegetation types promote fire and are also promoted by fire.
- Soil change – a change in soil condition due to vegetation change may be irreversible.

In spite of all the criticism to the range succession model it is still in use in many rangelands. Some of the limitations of this approach are as follow (Friedel 1991):

- Climax is not always the most desirable condition;
- Pristine conditions for a site may not be the actual climax;
- No allowance for exotic species is made and
- It is not well studied in woodland and forests.

Because of the limitations of the range succession model various attempts have been made to broaden the theoretical basis of the model. In contrast with the Clementsian view, current ecological theories suggest alternative stable states, discontinuous and irreversible transitions, event-driven systems, non-equilibrium dynamics and stochastic effects in succession. Limitations of the range succession model are most obvious in arid and semi-arid rangelands, where rare events are important and where effects of grazing and intrinsic vegetation change operate irregularly. The state-and-transition model, discussed next, copes with these features (Westoby *et al*. 1989*b*, Ward 2006).

The state-and-transition model

A set of 'states' of vegetation and a set of 'transitions', triggered by natural events or management actions, between the states may in many cases describe rangeland dynamics (Westoby *et al.* 1989*a*, 1989*b*, Laycock 1991). Transitions may occur very quickly and the system does not come to rest halfway through a transition. Transitions are also often referred to by the concept of thresholds. The threshold is the boundary in space and time between two states (such as grassland and shrub-invaded grassland), and the initial shift across the boundary to a new domain is not reversible on a practical time scale without considerable involvement by the range manager (Friedel 1991).

To develop a state-and-transition model the information on rangelands should be stated in the following form (Westoby *et al*. 1989*a*, 1989*b*):

- A catalogue of potential alternative states of the system;
- A catalogue of potential transitions from one state to another. Information on the conditions inducing transitions (climatic conditions together with grazing or fire) for each entry;

- The above entries should be expressed as opportunities, i.e. climatic conditions under which management, fire and grazing can produce a favourable transition, or hazards, i.e. climatic conditions with heavy grazing which can produce unfavourable conditions.

The state-and-transition model is a stochastic model and in contrast to the range succession model, aims to foresee the opportunities and hazards and consequently to seize the opportunities and to evade the hazards as far as possible. This model emphasises the research on estimating the probabilities of the climatic conditions relevant to the particular transitions and thus the emphasis is on timing and flexibility. This model provides a practical way of organising information for management and incorporates cyclic and successional processes as well as stochastic reactions of vegetation to climatic or biotic disturbances.

In studies conducted in the Karoo where the state-and-transition model was applied the following conclusions were made (Milton & Hoffman 1994):

- There were five constraints on passive transitions between vegetative states – competition, seed availability, microsites, soil properties and keystone processes;
- Knowledge on the effects of the size of an area on its prediction for recovery is lacking;
- The model can be improved by adding a temporal dimension to passive and active transitions and
- The economics of actively managing various transitions needs to be examined.

The state-and-transition model therefore forecasts which vegetation states can be manipulated by livestock withdrawal and which can be changed by active management, and it can be used to guide management decisions for the conservation of biodiversity and wildlife management in arid and semi-arid environments (Milton & Hoffman 1994).

Non-equilibrium models of grazing systems

Equilibrium is reached between animal populations and forage resources under constant weather conditions. Disequilibrium is established when climatic variability disturbs the system. Non-equilibrium happens when the population dynamics are disconnected from the resources not associated with main factors (such as productive dry season grazing) that determine survival of the animal population over the season of plant dormancy (Richardson *et al*. 2005). Persistent non-equilibrium, as explained by Briske *et al.* 2003, is similar to this. The other two types of non-equilibrium are presented by threshold and state-and-transition models. Both these represent changes over time in vegetation composition. The state-and-transition model was designed for rangeland systems characterised by event-driven vegetation dynamics.

The standard successional models cannot be used to understand the patterns in vegetation changes in rangelands in disequilibrium. These models imply that plant and animal populations fluctuate in response to natural oscillations in abiotic factors (for example rainfall seasonality or quantity), or biotic factors such as facilitation and competition. Most of these models suggest that herbivory has less impact on the composition of the vegetation than climatic conditions or plant interactions (Milton & Hoffman 1994). In non-equilibrium grazing systems the physical conditions supporting plant growth fluctuate widely and the consumption by animals does not control plant biomass because the same physical factors controlling plant population growth control the animal population. Grazing systems in equilibrium, on the other hand, suggest that consumption by herbivores controls plant growth, the food availability regulates growth of herbivores and that the physical conditions are relatively unvarying. Given the climatic patterns in arid and semi-arid South Africa, non-equilibrium, event-driven grazing systems may occur. The productivity of arid rangelands may be unstable in the short-term but resilient in long term (Behnke & Schoones 1993, Illius & O’Connor 1998, Ward 2006).

The simplified model, as explained by Richardson *et al*. 2005, acts as an equilibrium model when soil moisture is consistent, however, when vegetation responds to differences in rainfall between years, the model imitates a system at disequilibrium. Arid rangeland systems exhibits complex dynamics and neither the equilibrium nor non-equilibrium theories can propose this, however, their standard model imitates such a system.

Cyclic models

In cyclic models species *a* is replaced with species *b,* and then later species *b* will again be replaced by species *a*. Shrub-dominated communities often display cyclic succession as indicated in a study done, on open areas within desert scrub in Texas, by Yeaton (1978 in Barbour *et al*. 1987). Cyclic succession also occurs in the Succulent Karoo bearing in mind the short turn-over rates (Yeaton & Esler 1990, Jürgens *et al.* 1999).

Competitive hierarchy model

In this model of Horn (1981 in Glenn-Lewin *et al*. 1992), plants occurring later in succession are increasingly dominant by virtue of their competitive success above early successional species. However, the late successional species may invade the earlier stages of succession. The outcome of competition among the species determines the replacement patterns. In a changing environment, the competitive relationships of species change and the result of succession by these specific mechanisms cannot be predicted. The competitive hierarchy model can be seen as the primary-secondary continuum with non-invasible initial floristics as one extreme and the other extreme is the initial composition with few species that are quickly replaced (Glenn-Lewin *et al*. 1992).

Vital attributes model

Succession requires understanding of life histories of species and therefore the vital attributes model is used to model succession. This model is based upon a small number of vital life traits, such as propagule persistence, dispersal, age at first reproduction and longevity or life span. Each life history trait is classified into a few elements. This results into a set of species with certain dynamic properties that come into action at specific times or conditions after a perturbation. This model is useful in natural area management (Glenn-Lewin *et al*. 1992).

2.3.8 *Sustainability and productivity modelling*

Within-year management decisions on the production of milk and meat are evaluated through a short-term mechanistic model (Richardson & Hahn 2007) and this model is also used to develop equation-sets and rules for long-term models. Long-term models are then used to investigate the effects of different strategies on the sustainability of the ecosystem over many years. Factors such as the amount and distribution of rainfall, range condition and time of birth and death of animals within the year are also recognised.

Therefore, the short-term model is used to study inter-relations between rainfall, stocking rate and productivity. It shows that the timing of rainfall also influences birth and death rates. The long-term model is used to study long-term effects of the stocking rate strategies. This model shows that when moderately degraded rangeland is stocked with a recommended upper limit level, the land is unable to recover to less degraded states over 100 years (Richardson *et al*. 2007).

2.3.9 *Concluding remarks on vegetation dynamics*

It is vital to understand vegetation dynamics and develop a predictive understanding of the structure and function of the Succulent Karoo ecosystem in order to apply proper vegetation management together with sustained animal production. Vegetation change may be a slow process in an arid ecosystem due to the high inter-annual rainfall variation and therefore the variation in plant abundance and presence (Wiegand & Milton 1996, Cowling *et al*. 1999*a*, Ward 2006). The means of analysing the vegetation dynamics data include descriptive methods, multivariate analysis, experimental studies and modelling. Models incorporating spatial and temporal variation (gradients of changes over time) are ultimately needed for reliable prediction of vegetation dynamics (Glenn-Lewin *et al*. 1992).

One needs to understand that arid and semi-arid environments frequently display complex non-equilibrium dynamics involving non-linear and stochastic event-driven behaviour in order to apply effective vegetation management. Vegetation changes occur unpredictably, in the short-term, in response to the inter-annual variation in rainfall, and episodically in the long-term (several decades) in response to rare events as well as grazing pressure, changes in climate, altered disturbance regimes, or a combination of these factors. This complicates the complete understanding of long-term dynamics, because it is difficult to observe rare events. Long-term ecological monitoring is required to study the interaction between the rainfall, geology and ecology in order to increase the understanding of long-term dynamics in arid areas (Wiegand & Jeltsch 2000, Ward 2006).

No technology can yet reverse the extreme damage of degradation in arid and semi-arid ecosystems, and therefore long-term ecological monitoring integrated with other fields such as socio-economics and social and ethical issues must be used to maintain options for future generations (Wiegand & Jeltsch 2000).

2.4. Veld management

2.4.1 *Introduction*

The key component of managing wildlife populations in dynamic systems is correct habitat management (Behnke & Scoones 1993, Bothma *et al*. 2004). Veld management is defined as the management of natural vegetation for specific objectives related to different forms of land use. A comprehensive assessment of the veld condition is an absolute necessity for a successful veld management program. A generally accepted principle is that as the area for wildlife decreases, management must become more intensive (Trollope 1990).

The term “veld condition” refers to the condition of the vegetation in relation to several functional characteristics. These characteristics include the production of sustained forage and the veld’s resistance to soil erosion. The concept of veld condition is valuable to evaluate the present condition of the rangeland and for devising veld management programmes such as the stocking density, rotational grazing, rotational resting and veld burning (Trollope *et al*. 1989).

2.4.2 *Carrying capacity and succession*

Rangeland management has adapted plant succession theory into grazing systems. In general, it is believed that grazing pushes the successional sequence back to a sub-climax stage. It is therefore important to balance the grazing pressures with the regenerative powers of plants. The carrying capacity concept aims to set the stocking density at the level where this balance is maintained. In practice, managers use indicator species which are sensitive to grazing, to observe the extent to which grazing has altered and is altering the climax vegetation. This approach therefore has the potential to act as a warning of range deterioration. The biggest shortcoming of the approach is that it does not incorporate non-equilibrium dynamics (see section 2.3.7 above).

The idea of carrying capacity was at first developed for domestic grazers and did not make provision for the broad range of diets found in wild African herbivores. However, methods have been developed that deal with plant resource variation and distinguishes between grazing and browsing. By separating these components in the wildlife diet for stocking density calculation, the diversity in the vegetation resources is optimally utilized (Bothma *et al*. 2004).

2.4.3 *Ecological carrying capacity versus economic carrying capacity*

Wildlife managers distinguish between ecological and economical carrying capacity (Figure 2.3). Where wildlife occurs at a high density animals are often not in a good condition and under these circumstances the vegetation will often also not be in a good state. An improved vegetation state and healthier animals will be obtained when fewer animals are maintained. This can be achieved by hunting (wild animals) or culling (domestic stock and wildlife). The point of maximum sustained yield lies half way to two thirds of the stocking density at ecological carrying capacity and is termed economic carrying capacity (Figure 2.3). As the population of animals grows beyond the economic carrying capacity, the off-take rate starts to fall and returns to zero.

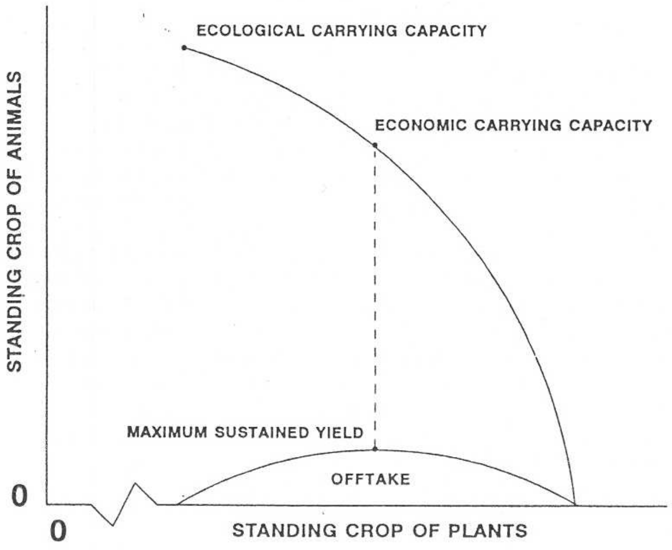


Figure 2.3 The relationship between plant and animal populations in a grazing system (Behnke & Scoones 1993).

2.4.4 *Veld condition assessment*

Veld condition assessments make comparisons between plant communities possible and provide a way to (a) quantify and (b) observe spatial and temporal changes within a specific vegetation type. The three main objectives for assessing veld condition are:

- Veld condition evaluation relative to its potential in that ecological zone;
- Evaluation of current management effects on veld condition and monitoring changes over time and
- Classifying and quantifying the different vegetation types (Tainton 1999).

Very little formalised research was conducted on methods of assessing veld condition before the early 1970s in southern Africa, but currently a range of techniques are available.

Southern African grasslands' range condition assessments are based on the estimation of proportional species composition. The wheel-point apparatus and the nearest plant method or modifications thereof are used for estimations of species composition. The species composition data are manipulated in various ways to fulfil the objectives of the grazing capacity determination and the monitoring of a range condition index (Hurt & Bosch 1991).

Thus, various plant survey methods can be used for the gathering of vegetation data. Vorster (1982) did a thousand point survey with the chain method, and recorded all basal, crown and canopy spread strikes in his study to develop the ecological index method. Mentis (1981) evaluated the wheel-point and step-point methods of veld condition assessment. He concluded that the step-point method is used in preference to the wheel-point method, although there may be exceptions, because it saves in equipment and manpower. However, the step-point method does not provide an estimate of basal cover and should rather not be used in bushy veld or uneven terrain. If an estimate of basal cover is required, a modified wheel-point apparatus may be used.

Methods for veld condition assessment can either be based on agronomic principles or on ecological principles. Humphrey (1949, 1962) in Tainton (1999) stated that a veld condition assessment should not be restrained by ecological concepts, and that the maximum forage production for the livestock type being grazed should be the only criterion used to estimate the veld condition.

Methods based on ecological principles score veld condition according to the response of the vegetation to biotic and abiotic environmental impacts. The frequency and intensity of defoliation (such as grazing and fire) are major environmental variables and it is assumed that the defoliation regime can be designed to change the vegetation state to that most suited to the management objectives. It is also assumed that soil and climatic factors, specifically rainfall, influence the veld condition (Tainton 1999).

Weighted palatability composition method (WPCM)

The weighted palatability composition method (WPCM) is an example of a method based on agronomic principles and assigns palatable ratings to species. For classifying grassland species the following classes were described: Class I – Highly palatable, Class II – Intermediate, and Class III – Unpalatable (Tainton, 1999).

Ecological index method

The ecological index method (EIM) was developed by Vorster (1982) for veld condition assessment in the Karoo areas. It was a refinement of the method used in the Karoo region by Van den Berg and Roux (1974 in Vorster 1982). The technique is based on the principle that veld in a certain topographical unit, in a homogeneous area, is compared to a veld benchmark on a similar topographical unit in the same area. A veld benchmark for a topographical unit reflects the potential botanical composition and cover for that unit. It is, however, difficult to find benchmark sites in the Karoo, and the “best” site in respect of botanical composition and cover is often used to present the veld benchmark (Vorster 1982).

The ecological index method classifies plant species into different ecological groups *viz.* decreasers, increasers and invaders (Vorster 1982):

i. Decreasers: Species that are dominant in veld in excellent condition and that decrease in number as the veld is under- or overutilised. The climax grass species will be classified in this group.
ii. Increasers 1: Species that occur naturally in veld, but increase when veld is selectively utilised or underutilised.
iii. Increasers 2a: Species that are rare in veld in excellent condition but increase when veld is moderately overgrazed during the long-term. These species usually increase as the Decreaser species decrease. The Karoo bushes and taller shrubs will belong to this group, as well as sub-climax grass species.
iv. Increasers 2b: These species are rare in veld in excellent condition but increase when the veld is heavily overgrazed over the long-term. The species include moderately hardy, less palatable Karoo bushes and taller shrubs and perennial pioneer grasses.
v. Increasers 2c: These species are rare in veld in excellent condition and increase when veld is excessively overgrazed over the long-term. This group consists of the

rain-dependent annual grasses, ephemerals, hardy unpalatable Karoo bushes and taller shrubs and the poisonous plant species.

vi. Invaders: Plant species belonging to this group can be described as foreign to a plant community and also increase quickly in number when the veld is in an agro-ecologically deprived state (Vorster 1982).

To calculate a range condition score a grazing value is assigned to each of the ecological groups (Vorster 1982, Bothma et al. 2004) as follows:

i. Decreasers = 10
ii. Increasers 1 = 7
iii. Increasers 2a = 4
iv. Increasers 2b = 4
v. Increasers 2c = 1
vi. Invaders = 1

This weighting presents both an agro-ecological and an agronomic scale because of the close relation between the ecological status and agronomic value of the species (Taiton 1999).

The EIM differs from the other methods because the ecological group contribution is expressed in terms of actual cover and not relative cover or nearest plant data whereas most other veld condition assessment techniques use botanical composition and cover as two separate indicators. An advantage is that fewer calculations need to be done (Vorster 1982).

If grazing capacity norms are related to veld condition it may be advantageous to use canopy spread in the calculation rather than basal cover. If for example two identical sites were compared where the one has undergone severe grazing and the other not, the veld condition index value of the severely grazed site would be lower when using canopy spread. There may, however, be only a small difference between the relative botanical composition (Vorster 1982).

Problems can occur with the classification of a species into the correct ecological group in the absence of sufficient quantitative data. One of the important factors when classifying a plant species into a ecological group is the region of occurrence. Through the experience of specialists, such as pasture scientists, this problem may be overcome. The use of other quantitative techniques may also be of help. Furthermore, the benchmark is prone to dynamic changes, due to short-term seasonal rainfall fluctuations, which is a problem. It is therefore necessary to re-characterise such benchmarks every five to ten years. If the benchmark has progressed new values are taken. Veld that is not in an excellent condition is especially affected by this problem (Vorster 1982).

Key species method (KSM)

This method was developed by Mentis (1983 cited in Tainton 1999) because not all species in the grassland show the typical Decreaser/Increaser response to utilisation intensity. He stated that only species that respond sensitively to the grazing gradient should be used to determine the veld condition. Individual or groups of species that react similarly to a specific grazing management treatment represent key species (Tainton 1999). The previous grazing history of a certain sample site is reflected by the key species method (Hurt & Bosch 1991).

Weighted key species method (WKSM)

This method by Heard *et al*. (1986) in Hurt & Bosch (1991) and Tainton (1999) is a modified approach of the key species method. It is used to derive a condition index from weighted key species abundances. The final score gives an exact indication of the sample site position along the grazing gradient (Hurt & Bosch 1991, Tainton 1999). Thus, the method monitors temporal changes in species composition (Hurt & Bosch 1991).

Degradation gradient method (DGM)

This is another modification of the key species method (Hurt & Bosch 1991, Tainton 1999). It was developed in the climatic-climax grasslands using multivariate procedures. The vegetation condition is quantified along a degradation gradient, thus a model describing long-term vegetation and habitat changes from under-utilised to severely over-utilised rangeland. Establishment of a degradation gradient for each ecological zone is vital for interpretation of the condition assessment. Data on species composition are collected, from veld in various stages of degradation, in each ecological unit. These data are obtained from long-term grazing trials, obvious variations in the pastoral impact on vegetation, and species composition sampling at different distances from well established points of animal concentrations (example watering points) (Hurt & Bosch 1991, Tainton 1999).

The gradients are described in terms of (i) floristic composition and (ii) soil factors. The gradient is subdivided into five classes:

a) Under-utilised;
b) Under-grazed;
c) Moderately grazed;
d) Moderately to severely degraded and
e) Severely degraded (Tainton 1999).

This approach does not include a single benchmark for a given area against which a particular sample of veld can be rated. By applying the degradation model the sample site position can be quantified on the degradation gradient and thereby provides an index of its condition. Only the species acting as significant indicators of grazing conditions are used (Tainton 1999). These models are therefore used as basis for objective and quantitative condition assessments of new sites. This is done by integration of the new sites into the old ordinations (Hurt & Bosch 1991).

Grazing index method (GIM)

This method is based on the ecological index method (EIM) and was proposed by Du Toit (1996) for Karoo veld, and according to the author is a more direct evaluation of the veld grazing value than the EIM. For this method the descending point method is used and a 200-point survey is carried out to obtain the botanical species composition. Species abundance values are multiplied by their Grazing Index Value (GIV). A combined grazing index value for the studied community is then derived. The relationship between the grazing index method score and grazing capacity is determined by comparison with a benchmark.

The grazing index method is basically similar to ecological index method, with the exception that the Ecological Index Values (EIVs) of species are replaced by the Grazing Index Values (GIVs). The grazing index method is believed to result in more reliable range condition scores and therefore more accurate grazing capacity determinations than the ecological index method because the Grazing Index Values of species take more properties of the species into consideration (Du Toit 1995, 2000). The following factors were subjectively scored for the Grazing Index Values:

- The acceptable dry matter production;
- Forage value of this dry matter during the growing season;
- Forage value of this dry matter during the dormant season;
- How easy the plant material can be grazed (e.g. presence of thorns);
- The degree to which the species is perennial and
- The apability of a species to defend the soil against erosion.

The parameters were selected to avoid bias as far as possible (Du Toit 1995, 2003).

2.4.5 *Comparison of the ecological index method (EIM) and the degradation gradient method (DGM)*

The ecological index method and the degradation gradient method were developed with different objectives in mind. The ecological index method is primarily a method the establish veld condition and to use the veld condition index to estimate a grazing capacity. The degradation gradient method aims at describing and understanding vegetation dynamics within a theoretical framework.

An objective range condition assessment technique, which can be used to monitor veld condition must be sensitive to detect spatial and temporal changes. According to a study done by Hurt & Bosch (1991), both the EIM and the DGM appeared to be relatively sensitive techniques. However, the EIM uses all species to calculate a condition index, and includes a subjective allocation of species into the decreaser and increaser categories. These two categories are problematic especially in semi-arid areas where most species react strongly to other dynamic forces such as moisture stress. Thus, grazing-induced changes may be concealed (Hurt & Bosch 1991).

For the DGM selected species are used for interpretation. According to Hurt and Bosch (1991) The EIM does therefore not provide such a sensitive measure of change as the DGM and it is not recommended to use this method for monitoring range trend. If it is necessary to determine the grazing capacity it is important to include all the species with their different grazing values. Where grazing-induced changes in the composition of the species are of importance, then only species affected by grazing intensity should be included in the condition index calculations (Hurt & Bosch 1991).

The assessment of veld condition needs to be ecologically interpretable and needs to provide the basis for the description of management strategies. In order to obtain the wanted ecological interpretation, it is important to have information and knowledge on features such as species responses to grazing, community dynamics in the studied biome, and vegetation and habitat degradation relations. The DGM provides this knowledge whereas the EIM does not. The DGM provides information on whether the degradation trend is reversible via normal rangeland management practices, or if physical reclamation methods are needed to restore the land productivity. Thus, the DGM predicts the recovery potential of vegetation degraded to various extents. The EIM is not based on a gradient that can be associated with changes in habitat conditions, and does not identify multiple benchmarks. The DGM has the advantage of placing a sample site objectively along a degradation gradient. The DGM also tests the appropriateness of the degradation model for the condition assessment by using residual analysis. The objective selection of key species and the relatively homogenous vegetation areas on which the DGM is based, guarantees that ecotypical variation is reduced within species. The EIM principally uses subjective species classification; species are categorised as decreasers and increasers and thus are subjected to errors during the condition index calculations (Hurt & Bosch 1991).

To develop gradients, large numbers of vegetation samples are needed. The DGM could be criticised as being time consuming and cost-inefficient, but Hurt and Bosch (1991) do not see this as a problem. Throughout the grassland biome, many range assessments have been conducted and sufficient data for gradient construction should be available. The same arguments do however, not apply to the Succulent Karoo. Furthermore, “marker sites” must be included in the database for objective identification of a grazing gradient (Hurt & Bosch 1991).

2.4.6 *Concluding remarks on veld condition*

Veld condition data are important in veld management, and when the trends in veld condition are monitored over time these can be used to evaluate and modify veld management practices. It is vital to monitor the veld in a game ranch or conservation area on a regular basis because these form part of a dynamic ecosystem. Data from grass and shrub surveys will provide the basis for adjusting the browser and grazer stocking density, the rotational resting program and the veld-burning program (Trollope 1990).

The DGM provides a technique to test the degradation model’s appropriateness as the basis for assessment and does not focus on carrying capacity but rather on the dynamics and theory. The EIM and GIM, on the other hand, are not as sensitive in measuring changes as the DGM and are not based on a gradient associated with changes in habitat conditions. Conversely, they are more practical methods and focused to give you an answer regarding carrying capacity. Both the EIM and GIM use all species to calculate veld condition (Hurt & Bosch 1991).

2.5. Mechanisms of plant species survival

Plants growing in arid and unpredictable environments, such as the Succulent Karoo, face stress from drought and heat. Rainfall in arid areas is unpredictable in time, space and amount and is a strong selective force shaping the life-history patterns and affecting all the life cycle stages of annuals. The soil water availability is a principal factor of long-term dynamics in arid regions. Two main survival strategies of plants growing in such conditions are drought tolerance (succulence) and drought avoidance or evasion (ephemerals). Drought evasion is a strategy common among annual species (short-lived species). They complete their life cycle in one year and their root and shoot systems die after seed production. Annual plants are divided into growing plants and dormant seeds, where the dormant percentage is the far greater of the two. Succulence is mainly displayed by perennial species (Le Roux & Van Rooyen 1999, Van Rooyen 1999, Ward 2006).

2.5.1 *Life form classification*

The life form classification of Raunkiaer (1934 in Mueller-Dombois & Ellenberg 1974) was developed to show the relationship between plant form and climate. Raunkiaer believed that the relationship between plant form and climate could best be reflected by the position of the perennating bud. He classified plants into the following main groups:

- Phanerophytes (P)
- Chamaephytes (Ch)
- Hemicryptophytes (H)
- Lianes
- Annuals (Therophytes)
- Geophytes (Cryptophytes)

Raunkiaer's classification system was applied in this study to establish whether there were changes in the life form spectrum across the monitored years. Further detail and definitions of the life forms are provided in the Chapter 3.

2.5.2 *The annual species – evasion*

A high percentage of plant species in Namaqualand are drought evading and display a large degree of plasticity in their growth rate, size and phenology (Van Rooyen *et al*. 1990). The floristic composition of annual vegetation in Namaqualand is determined by the interaction between temperature, and the timing and intensity of rainfall. The duration of the rainfall is also important; since a soft rainfall shower is more effective than a cloudburst yielding the same amount of rain (Milton *et al*. 1997, Le Roux & Van Rooyen 1999, Van Rooyen 1999, Wiegand & Jeltsch 2000, Ward 2006). Annual species show a number of adaptations to accomplish their drought evading behaviour.

Dormancy

Delayed seed germination is an evolutionary stable strategy in short-lived but not in long-lived plants in environments that are variable, such as in the Succulent Karoo. The abundance of dormant seeds in the soil is inversely related to the dominant plant species' life expectancy. Dormancy prevents germination in unsuitable habitat conditions where establishment may not take place. Three types of seed dormancy are described namely (Fenner & Thompson 2005):

- Innate dormancy: Seeds that are innately (primary) dormant are incapable of germination directly after dispersal even if conditions are suitable for growth.
- Enforced dormancy: This happens when the seed is deprived of its requirements for germination (absence of sufficient moisture, light or temperature). Ecologically, it is useful to identify factors in the environment preventing germination *in situ* at any period (Murdoch & Ellis 2000).
- Induced dormancy: Innate dormancy does not occur in many species' newly dispersed seeds. If they fail to meet suitable conditions for germination however, they attain an induced (secondary) dormancy. It is an acquired condition of inability to germinate caused by some experience after ripening (Harper 1977).

Annual and pauciennial succulents show staggered seed germination whereas germination of perennial succulents seldom shows innate seed dormancy (Milton *et al*. 1997). Increased seed dormancy occurs in increasingly unpredictable environments (greater seed carryover from year to year takes place) (Van Rooyen 1999). Dormancy is an adaptation to prevent seeds from responding to unpredictable rainfall in the dry season that do not supply the seeds with enough moisture for establishment and growth (Baskin & Baskin 1989, Fenner & Thompson 2005).

The Succulent Karoo seed banks show a high degree of spatial heterogeneity. The seed bank size varies over an order of magnitude on a geographical scale. Most of the annual species in Namaqualand have persistent seed banks that are large when compared to the annual seed additions and losses. Seed banks are important for annual plants because they may produce an age structure in the adult population (Van Rooyen 1999). Large seed banks are expected in frequently disturbed or very arid sites where annuals or pauciennials predominate. This general pattern is confirmed by the seed-bank dynamics of Succulent Karoo plant assemblages. Large-seeded, non-succulent Karoo shrubs with long life spans do not maintain dormant seed banks (Milton *et al*. 1997).

Polymorphism

Polymorphism occurs when developmentally or morphologically different seeds differ in innate dormancy. These seeds are produced on the same or on different plants of a species (Murdoch & Ellis 2000). Seeds from the same plant can vary in size, seed coat anatomy, morphology or mechanism and timing of release. This influences the dispersal, and the germination behaviour *and* growth (Esler 1999). Polymorphism is an adaptation increasing the survival chances of plants in unpredictable environments (disturbed habitats and arid) environments, such as the Karoo (van Rooyen 1999). Polymorphic seeds occur in many Succulent Karoo species (Esler 1999). It enables adaptation to two strategies: an escape in space and an escape in time (van Rooyen 1999).

Polymorphism for germination requirements has been observed for several ephemerals in Namaqualand. Some seeds from the annual Mesembryanthemaceae species (vygies) germinate very quickly while others from the same seed capsule take a longer time to germinate. Thus, it is suggested that the seed populations consist out of fast-germinating seeds, making maximum use of the short growing period, and of slowly germinating seeds that avoid the drought risk (Esler 1999).

Flowering

Desert annuals are able to flower over a wide seasonal range in photoperiod and temperature if efficient moisture is available, due to the facultative nature of both photo-induction and thermo-induction of flowering. In an unpredictable growing season environment, this flexibility enhances the probability of successful reproduction. Thus, ephemerals are able to flower and reproduce irrespective of whether the rainfall season starts in the autumn or winter. During early autumn rains, plants germinate and flower initiation occurs only during the decreased temperatures during the winter, and if favourable conditions occur during the rest of the season, the plants become large and produce many flowers in the spring after the temperatures have increased. If rain starts in the mid-winter, however, the temperatures are low and the juvenile phase is shortened, resulting in early flowering. Water stress also affects the lifespan and flowering period of the ephemerals (Van Rooyen *et al*. 1991 & 1992, Steyn *et al*. 1996*a&b)*.

In summary, the annual plant species complete their life cycles in the short periods when climatic conditions are favourable. They germinate and grow during the wet winter and flower and set seed during the spring. They vanish and survive the dry season as seeds. The annual species in Namaqualand have adaptations to counteract the year-to-year variability in their environmental conditions, such as the production of seed banks. Most of these seeds are dormant and this prevents the instantaneous germination of all the seeds. Different species are favoured under different environmental conditions in different years, depending on the first rainfall (Le Roux & Van Rooyen 1999).

2.5.3 *The succulent species – tolerance*

Succulents utilise the water they stored in their leaves and stems during times of drought. They have evolved various strategies in order to maintain optimal moisture conditions. These include a thick cuticle and few stomata to prevent excess water loss. Some succulents use the CAM (Crassulacean Acid Metabolism) photosynthetic pathway where carbon dioxide is taken in during the cooler night time, therefore preventing water loss through open stomata (Le Roux & Van Rooyen 1999).

The vygies, a dominant succulent group, have a highly specialised dispersal device, associated with rain. Precipitation causes dispersal to take place and water is available for germination. The seeds are enclosed in capsules that open up in moist conditions, allowing the dispersal of the seeds by raindrops, and close in dry conditions. In more primitive species, the seeds are ejected by a splash-cup action; however, in the more evolved species the seeds do no not lie fully exposed and are covered by an elastic membrane at the top of the locule in the capsule. Only a few seeds are ejected at a time, but over a greater distance. Thus, this adaptation enhances dispersal in space, but inhibits it in time (Le Roux & Van Rooyen 1999).

Some plants do not grow higher than the soil level, with only one or a few leaves per individual (such as the *Lithops* species and other windowplants, family Mesembryanthemaceae). These plants withdraw the water from the exposed leaves into the subsequent year's leaves, sheltered underground, when drought conditions dominate. Old dry leaves protect the following year's leaves and also reflect the sun. Some plant species of Namaqualand maximise their solar energy balance during the cooler winter months (when the solar energy is low and the day length short) by orientating their leaves northwards. Windowplants, withdrawn underground, leave only a 'window' on the surface of the soil for the intake of sunlight. The leaf 'windows' are non-pigmented zones that allow deep penetration of the sunlight to chlorophyllous tissue. Another method of maximising radiation during the winter season is found on large leaves of geophytes lying on the ground (Cowling *et al*. 1999*a*, Le Roux & Van Rooyen 1999).

Succulent-dominated communities in Namaqualand are exceptional in the sense that most of the perennials are relatively short-lived shrubs. In Namaqualand, plants die and are replaced constantly, resulting in significant compositional change of the perennial component over decades, thus, the age structure of the succulents are uneven (Cowling *et al*. 1999*a*).

Non-succulent dwarf shrubs have small leaves to limit transpiration, or large leaves which are shed during the dry season. Some plant species have no leaves and rather green stems for photosynthesis and this reduces transpiration. Geophytes are both evasive and tolerant because they survive the dry period underneath the soil surface as bulbs, corms, rhizomes or tubers.

2.5.4 *Concluding remarks on plant life history strategies*

Knowledge of life history traits of plant species is essential to understanding plant responses to climate and disturbance regimes. Without this knowledge vegetation dynamics in arid environments cannot be fully understood.

It is therefore important to appreciate the significance of long-term studies and the role that long-term monitoring fulfils in ecological studies, especially in arid regions. Because the area of study is a conservation area, sound veld management practices are crucial. Therefore veld condition assessments are needed to assess the impact of possible overutilisation by mammalian herbivores on vegetation and to provide recommendations on the carrying capacity for the Goegap Nature Reserve.

CHAPTER 3

STUDY AREA

3.1 Introduction

Namaqualand is a semi-desert of unique plant wealth situated in the Succulent Karoo Biome in the northwestern corner of South Africa (Figure 3.1). Synonymous with impressive wild flower displays of annual plant species in the spring season, Namaqualand exhibits many features that are not shared by the rest of the semi-deserts of the world. It is one of only two entirely arid areas to classify as a global hotspot of biodiversity. This hotspot, together with the Horn of Africa (www.conservation.org), hosts the world’s richest semi-desert flora. Namaqualand contains about 3 500 plant species (Cowling *et al*. 1999*a*, Le Roux & Van Rooyen 1999, Desmet 2007).

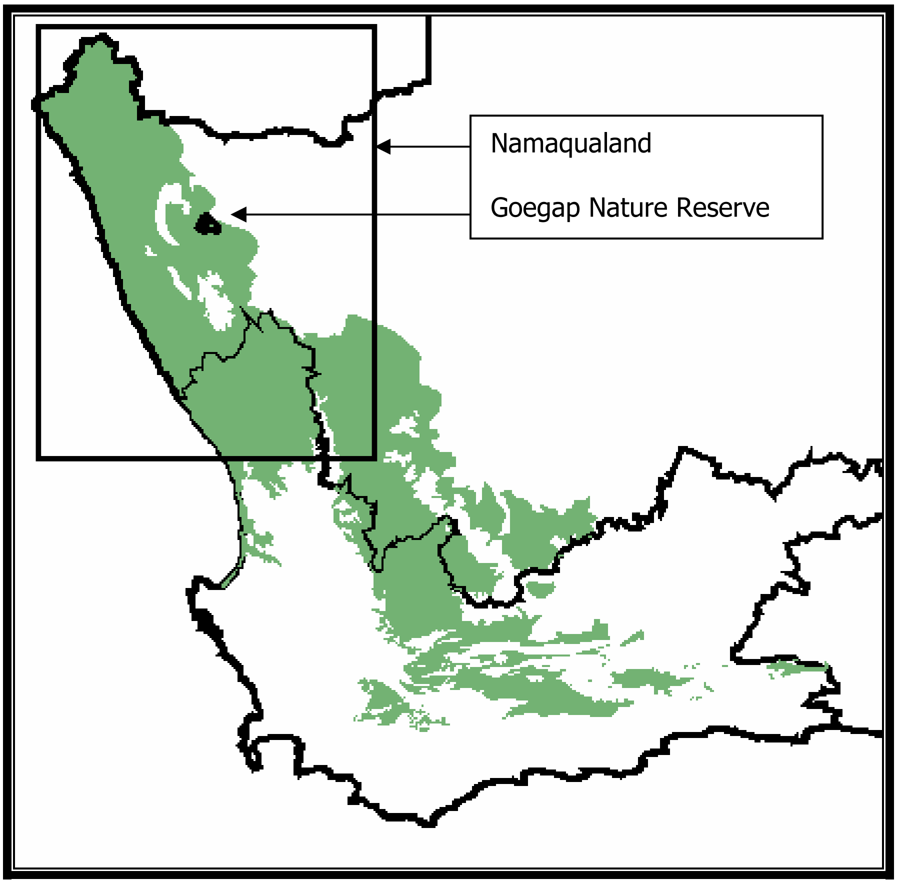


Figure 3.1 Map of the Succulent Karoo Biome (shaded in green) (Mucina & Rutherford 2006).

Human population growth, habitat degradation and other features of global climate change are threatening the existence of desert ecosystems. Namaqualand has been compared to numerous other deserts throughout the world because of its high plant diversity occurring in its desert climate. Many of these comparative studies, in e.g. Esler and Rundel (1999), Esler *et al*. (1999) and Whitford (1999), indicate that no other desert in the world has such high levels of endemism as Namaqualand (Cowling *et al*. 1999*a*). The species richness of the Namaqualand flora exceeds the number of species occurring in similar-sized areas of winter rainfall deserts in America, North Africa and the Middle East.

Namaqualand differs from other winter rainfall deserts mainly in two ways (Cowling *et al*. 1999*a*): (a) the higher predictability of rainfall between years and (b) the mild winter and early spring temperatures. These factors allow growth of perennials and annuals to continue throughout winter to reproductive maturity during late winter and early spring. Fog, usually occurring along the coast, is a vital source of moisture in the Strandveld where the annual rainfall is below 100 mm. Hot, desiccating bergwind conditions can occur throughout the year and may cause an abrupt end to flowering when they occur in spring (Hilton-Taylor 1996, Desmet & Cowling 1999).

According to Mucina and Rutherford (2006) the Succulent Karoo is divided into six bioregions namely the Richtersveld, Namaqualand Hardeveld, Namaqualand Sandveld, Namaqualand Knersvlakte, Trans-escarpment Succulent Karoo and the Rainshadow Valley Karoo. Namaqualand is divided into four geographical regions namely the Richtersveld, Sandveld, the hills and mountains of the Kamiesberg Range (Namaqualand Hardeveld) and the Knersvlakte. Three of the five centres of endemism in the Succulent Karoo Biome (Van Wyk & Smith 2001) also form part of the Namaqualand geographical region (Le Roux & Van Rooyen 1999). They are the Gariep Centre of Endemism, the Knersvlakte Centre of Endemism and the Hantam-Roggevled Centre of Endemism (Van Wyk & Smith 2001). A total of 135 plant families and 724 genera have been recorded in Namaqualand of which approximately 25% of this flora is endemic (Cowling *et al*. 1999*a&b*, Le Roux & Van Rooyen 1999, Desmet 2007). The diverse plant life occurring here is dominated mainly by low, often minute, leaf-succulent shrubs including the families Mesembryanthemaceae (vygies) Crassulaceae (stonecrops), Asteraceae and an enormous bulb flora (Low & Rebelo 1998, Cowling *et al*. 1999*a&b*).

The conserved areas in Namaqualand are divided into three main nature reserves or national parks. They are the (a) Richtersveld National Park (162 455 hectares), (b) Goegap Nature Reserve (14 865 hectares) and (c) the Namaqua National Park which incorporates the 930 hectare Skilpad Wildflower Reserve (more than 110 000 ha in total). Most people tend to take this desert area for granted and although Namaqualand's flower heritage has been abused for many years, nowadays it has acquired much wider botanical recognition (Cowling *et al*. 1999*b*, Le Roux & Van Rooyen 1999).

3.2 Goegap Nature Reserve

The Goegap Nature Reserve is situated between 29° 34’ 24” S and 29° 43’ 24” S and 17° 54’ 40” E and 18° 07’ 20 E” about 15 km east of Springbok, Northern Cape Province (Rösch 2001*b*) and covers an area of approximately 15 000 ha (Figure 3.2).

According to Acocks’s (1988) classification the reserve straddles the Namaqualand Broken Veld and the False Succulent Karoo whereas Low & Rebelo (1998) classify the reserve as being located partly in the Upland Succulent Karoo and partly in the Bushmanland vegetation types. According to Mucina *et al*. (2005) the reserve lies within the Namaqualand Blomveld and Namaqualand Klipkoppe Shrubland vegetation types (Namaqualand Hardeveld Bioregion), with a small part in the east lying in the Bushmanland Arid Grassland (Bushmanland Bioregion).

Figure 3.2 Map of Namaqualand indicating (by the blue arrow) the locality of the Goegap Nature Reserve (travel.iafrica.com).

3.3. Background

The Hester Malan Nature Reserve was established in 1966 (Le Roux 1984). In 1969 the reserve was fenced and thus excluded the livestock that previously grazed freely in the reserve. In 1990, bordering land was added to the reserve and it was declared as the Goegap Nature Reserve (Rösch 2001*b*). At that stage the Goegap Nature Reserve comprised of two parts: the western section, formerly known as the Hester Malan Nature Reserve which was approximately 7 000 hectares in size, and the eastern section, formerly known as the farm Goegap, about 8 000 hectares in size. Initially, the veld on the Goegap farm was in a much worse condition than the veld on the Hester Malan section of the reserve and it was decided not to remove all the fences dividing the two sections (Rösch 2003). The result of a field survey in 2000 (Rösch 2001*a*) showed that the vegetation on the Goegap part of the reserve had recovered substantially, and that sustainable grazing could be achieved. Therefore, in 2002 the fence dividing the two sections of the reserve was finally removed.

3.4 Climate

The climate of the Goegap Nature Reserve can be described as warm and dry, with large fluctuations in the daily and seasonal temperature (Table 3.1). The reserve occurs within a winter rainfall region and receives soft, erratic and uncertain, though effective rainfall (Table 3.2). Rainfall data were gained from the long-term climate and rainfall data of the reserve (Table 3.3) and the South African Weather Service (info1@weathersa.co.za). The annual rainfall is relatively low (varying between 100 and 350 mm) with the highest percentage of rainfall received mainly during winter from April to September. More summer rainfall is received in the eastern side of the reserve because it is situated in the transition zone between the winter and summer rainfall areas (Rösch 2003). Temperature extremes vary from about -10ºC in the winter, to 41ºC in the summer.

Table 3.1 The monthly maximum and minimum temperatures (in ℃) of Springbok, Namaqualand, from 1973 to 2007 (electronic data supplied by the South African Weather Bureau)

	MONTHLY MAX (℃)			**MONTHLY MIN (℃)**		
Month	**Mean**	**Range**		**Mean**	**Range**	
		Lowest	Highest		Lowest	Highest
JAN	29.7	26.9	32.0	16.1	13.5	18.4
FEB	30.0	28.3	32.2	17.0	14.6	20.6
MAR	28.8	26.2	31.5	16.5	13.3	19.0
APR	25.1	21.6	27.7	14.0	11.6	16.8
MAY	20.8	18.6	24.3	10.9	8.10	13.8
JUN	17.4	14.3	21.0	8.40	6.50	11.1
JUL	17.1	14.9	20.7	7.70	5.40	10.3
AUG	17.9	14.2	20.7	7.60	5.40	11.4
SEP	21.1	16.5	25.4	9.50	7.40	14.0
OCT	24.1	19.3	26.6	11.3	8.20	15.8
NOV	26.3	22.6	30.5	12.8	9.20	16.0
DEC	28.1	25.3	31.2	14.5	12.2	16.8

Table 3.2 The mean monthly rainfall (in mm) of Springbok, Namaqualand, from 1973 to 2007 (electronic data supplied by the South African Weather Bureau)

	MONTHLY RAINFALL (mm)		
Month	**Mean**	**Range**	
		Lowest	Highest
JAN	7.50	0.00	56.80
FEB	7.70	0.00	65.50
MAR	11.60	0.00	70.50
APR	18.60	0.00	78.90
MAY	27.40	0.00	95.50
JUN	33.30	0.00	111.20
JUL	30.10	0.20	100.10
AUG	28.70	0.00	102.80
SEP	14.60	0.00	70.60
OCT	13.50	0.00	39.70
NOV	8.900	0.00	52.00
DEC	6.500	0.00	50.70

Table 3.3 Coordinates (degrees, minutes and seconds) of six rain meters in the Goegap Nature Reserve (data supplied by the Northern Cape Department of Environment and Nature Conservation)

Number	**Line Transect**	**S**	**E**
1	Koperberg and T'ganagas Plains	29 39 53.7	17 59 53.5
3	Zebrawater Foothills	29 36 37.2	17 58 31.9
5	Bluemine Mountain	29 37 16.5	18 00 36.8
6	Jaleeg Plains	29 42 22.8	18 05 8.10
8	Bleshoek Plains	29 41 18.1	17 55 49.6
9	Goegap Plains	29 41 31.0	17 58 45.8

3.5 Wildlife

Although the Goegap Nature Reserve is situated in an arid region, it is home to 45 mammal species, 25 reptile species, three amphibian species and 94 bird species. The dominant wildlife includes the Hartmann's mountain zebra (*Equus zebra hartmannae*), gemsbok (*Oryx gazella*), springbok (*Antidorcas marsupialis*), klipspringer (*Oreotragus oreotragus*), duiker (*Sylvicapra grimmia*) and steenbok (*Raphicerus campestris*) (Northern Cape Nature Conservation Services undated).

3.6 Vegetation

Approximately 581 plant species have been recorded in the Goegap Nature Reserve (Northern Cape Nature Conservation Services undated). For only a few weeks each year the flowers (mainly the annual plant species) transform the veld into a flower paradise. Perennial plants are mainly summer deciduous or evergreen dwarf shrubs of which many have succulent leaves for the conservation of water during the drier periods.

According to Rösch (2001*b*) the vegetation of the Goegap Nature Reserve can be divided into two major phytosociological units:

A. The vegetation on the rocky hills and
B. The vegetation on the plains.

The vegetation occurring predominantly on the rocky hills includes the following plant communities:

1) *Helichrysum obtusum* dwarf open shrubland
2) *Searsia undulata* tall sparse shrubland
    a. *Nenax namaquensis – Searsia undulata* tall sparse shrubland
    b. *Diospyros ramulosa – Searsia undulata* tall sparse shrubland
3) *Leipoldtia schultzei* short open shrubland
    c. *Dyerophytum africanum – Hermbstaedtia glauca – Leipoldtia schultzei* short open shrubland
    d. *Pteronia divaricata – Tetragonia microptera – Leipoldtia schultzei* short open shrubland
    e. *Ruschia* species (HRSK 17) – *Leipoldtia schultzei* short open shrubland
    f. *Eriocephalus microphyllus – Leipoldtia schultzei* short open shrubland
    g. *Euphorbia decussata – Leipoldtia schultzei* short open shrubland
    h. *Ruschia robusta – Leipoldtia schultzei* short open shrubland

The vegetation dominating the plains of the reserve includes the following communities:

1) *Stipagrostis namaquensis* short closed grassland
2) *Ruschia brevibracteata* short sparse shrubland
3) *Stipagrostis obtusa* short closed grassland
4) *Stipagrostis brevifolia* short sparse shrubland
5) *Drosanthemum otzenianum* low closed shrubland
6) *Psilocaulon junceum – Drosanthemum hispidum* low sparse shrubland
7) *Mesembryanthemum guerichianum* dwarf sparse shrubland
    a. *Galenia sarcophylla – Mesembryanthemum guerichianum* dwarf sparse shrubland
    b. *Drosanthemum hispidum – Mesembryanthemum guerichianum* dwarf sparse shrubland
8) *Tripteris sinuata* short open shrubland
    a. *Galenia meziana – Tripteris sinuata* short sparse shrubland

  b. *Stipagrostis brevifolia –Tripteris sinuata* short open shrubland
  c. *Leipoldtia schultzei –Tripteris sinuata* short open shrubland
  d. *Aptosimum spinescens – Tripteris sinuata* short open shrubland

9) *Psilocaulon junceum – Zygophyllum retrofractum* low sparse shrubland

10) *Psilocaulon junceum* low sparse shrubland

3.7 Geology and soils

The reserve includes the distinctive koppies and sandy plains characteristic of Namaqualand (Northern Cape Nature Conservation Services undated). The reserve's geology consists mainly of gneisses and granite of the Namaqualand Metamorphic Complex (Figures 3.3 & 3.4) covered with early tertiary to more recent deposits of sands (Marais *et al*. 2001). The granite and gneiss are approximately 1 100 million years old. The soil of the reserve includes red, deep soil as well as land covered with exposed rock (Land Type Survey Staff 1987). The koppies generally consist of granite boulders on the crests and midslopes, whereas the footslopes and valleys comprise the Hutton soil type.

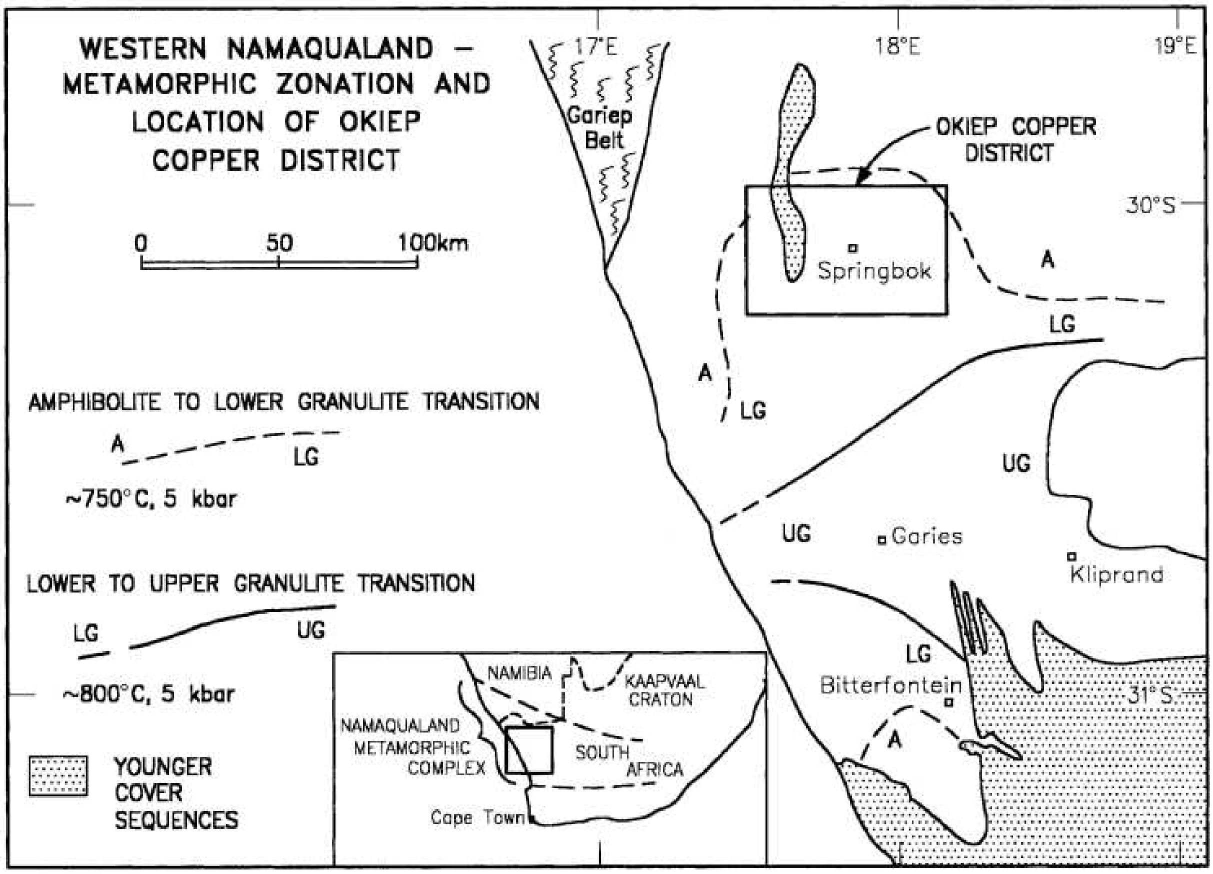


Figure 3.3 A simplified representation of the metamorphic zonation in western Namaqualand (Robb *et al*. 1999).

The Goegap Nature Reserve includes four land types (Land Type Survey Staff 1987): Ae80, Ae85, Ib127 and Ib129 (Figure 3.5). Map unit Ae indicates red, high base status soils deeper than 300 mm and dunes are absent. Map unit Ib refers to land covered 60 – 80% with rock, stones or boulders. The land types are described as follow (Land Type Survey Staff 1987):

1) Ae80: granites and gneisses of the Okiep Group of the Namaqualand Metamorphic Complex. The soil type dominating this land type is the Hutton soil type, and occurs specifically along the footslopes and valleys (80% of the land type);
2) Ae85: gneissic granite of the Namaqualand Metamorphic Complex covered with early tertiary to more recent deposits of sands. This land type includes the deep soil (more than 1 200 mm) of the Hutton soil form;
3) Ib127: gneissic granite of the Namaqualand Metamorphic Complex. This land type is covered 67% with rock. Granite boulders dominate on the crests and midslopes whereas the footslopes and valleys are dominated by Hutton soils;
4) Ib129: this land type (on the eastern side of the reserve) includes boulders of granite and gneisses of the Okiep Group of the Namaqualand Metamorphic Complex. The reserve boundary fence is situated at the base of these boulders.

Arid areas are usually characterised by shallow soils. The dominant soils are red and yellow reflecting weathering in a well-drained, oxidizing environment. The soils occurring on the plains of the reserve are generally deeper than the soils occurring on the ‘koppies’, which usually have a slightly darker colour. The soil formation is dependent on the environmental conditions of the arid area and includes factors such as climate, drainage, and age as well as biotic factors. The abiotic environmental factors (such as strong wind, low rainfall and long periods of drought) as well as the nature of the parent material are of more importance with regards to soil formation than the biotic factors (such as trampling and the burrowing of animals) (Le Roux 1984, Watkeys 1999).

The soil at the base of the solid rock domes is more humus-rich than on other parts of the reserve because water flows down the steep rocky sides and gathers at the base of the rocks. Thus, shrubs occur here in higher densities because of the higher moisture level in the soil (Le Roux 1984).

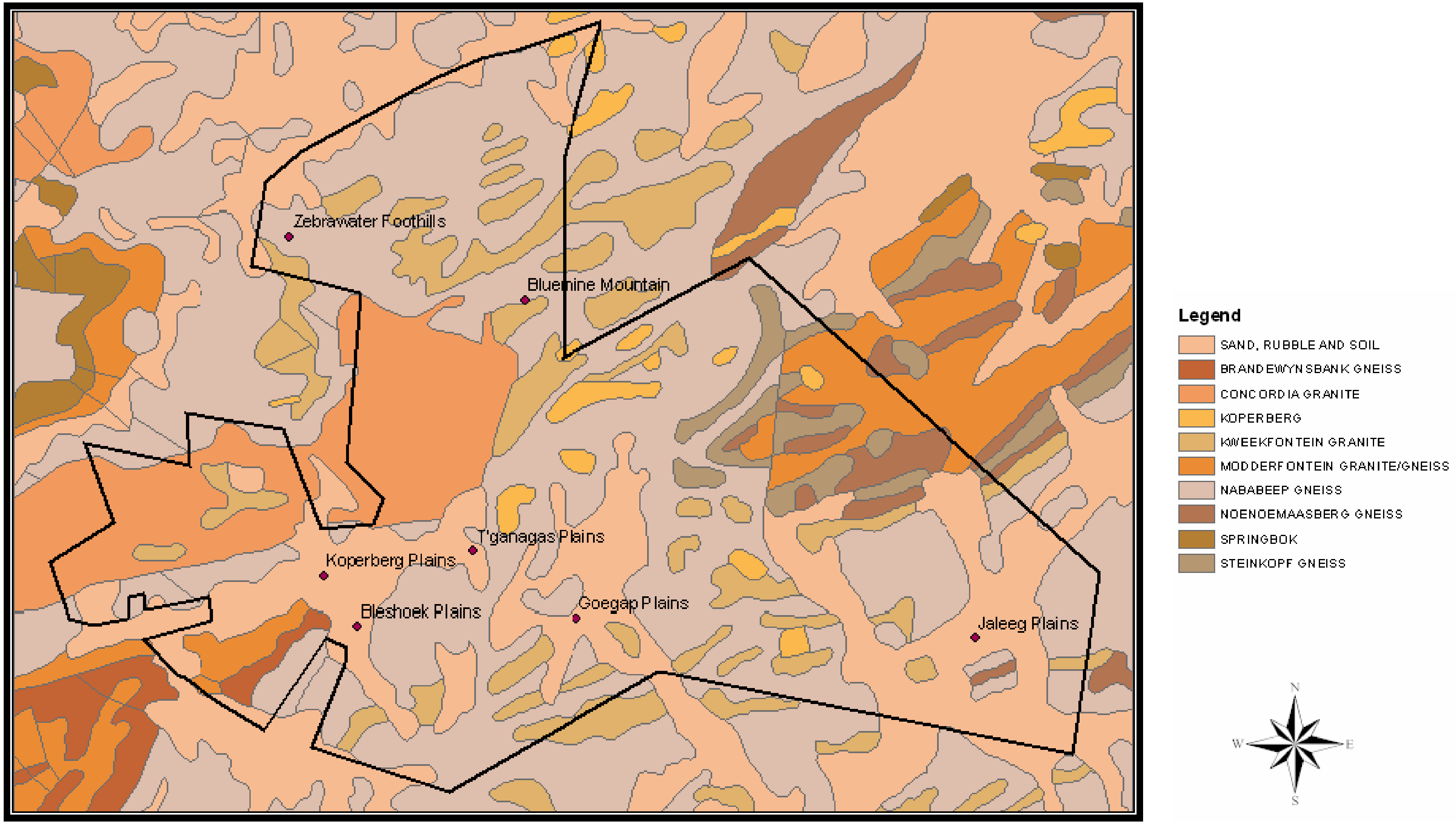


Figure 3.4 Map indicating the geology of the Goegap Nature Reserve (Geological vector data was supplied by the Council or Geoscience, Pretoria) together with the positions of the line transects.

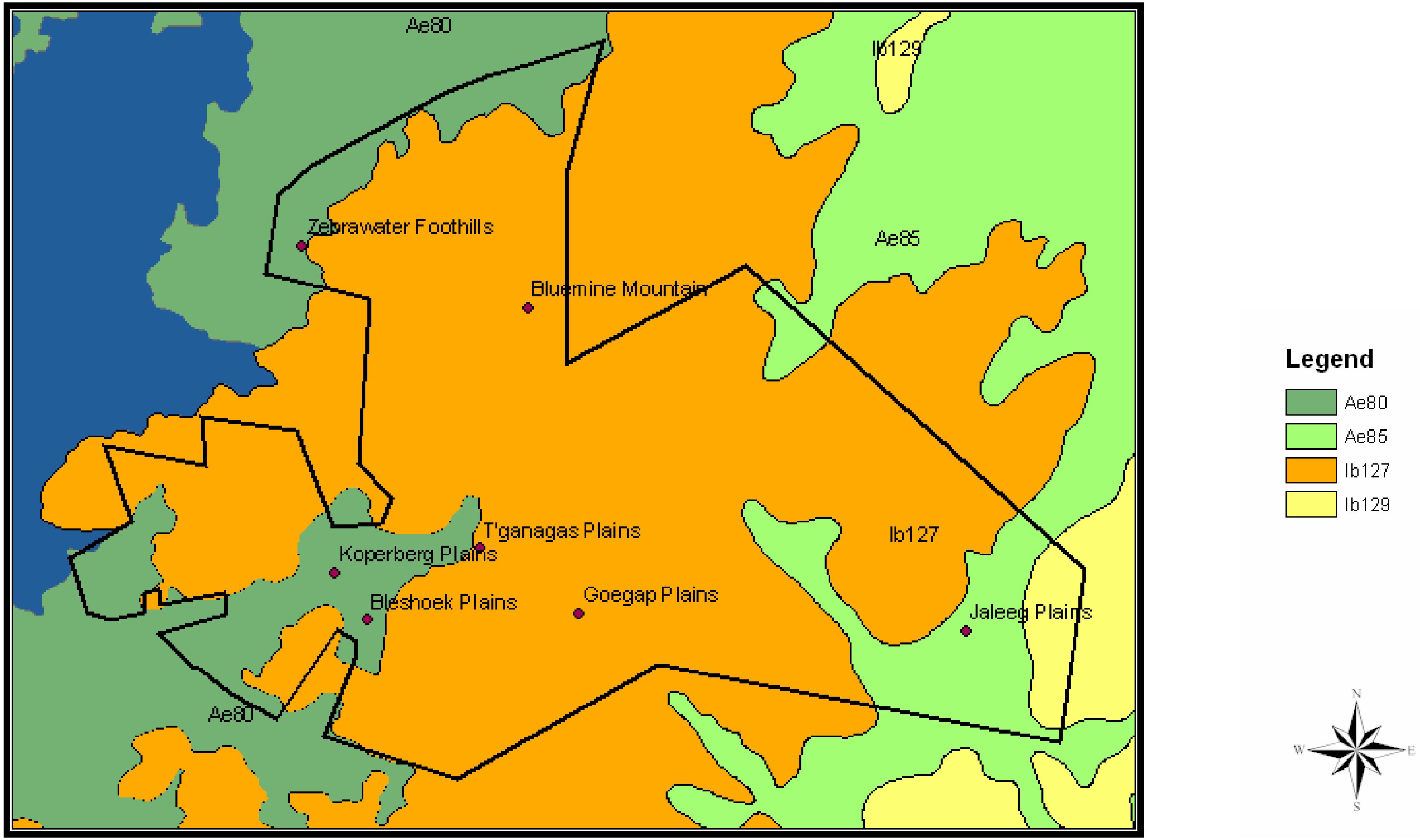


Figure 3.5 Map indicating the land types of the Goegap Nature Reserve and the positions of the line transects.

3.8 Management units

Rösch (2001*a*) stated that the effective management of the Goegap Nature Reserve is of extreme importance. Using various factors including plant communities and land types, management units were identified (Rösch 2001*b*). These ten management units (Figure 3.6) form the basis for the management and monitoring programs.

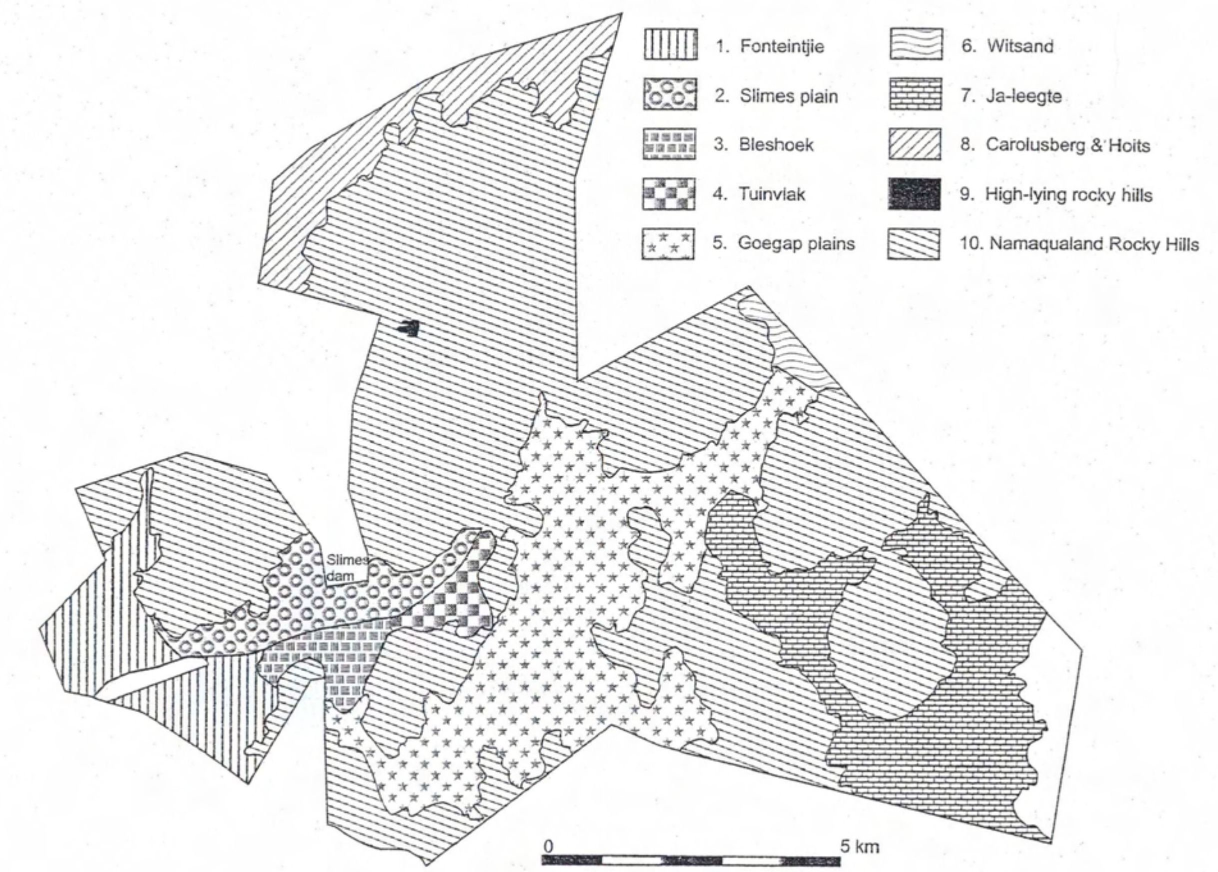


Figure 3.6 The management units identified on the Goegap Nature Reserve (Rösch 2001*b*).

3.9 The line transects

From 1974 two line transects (named the Zebrawater Foothills and Bluemine Mountain) were established by the Department of Agriculture. These line transects were monitored and field data recorded on a yearly basis, each time more or less at the end of August. In 1990 the number of line transects was increased to seven (Figure 3.7), three on the old part of the nature reserve (Hester Malan Nature Reserve part) and four on the new section (Goegap farm). Three of the five new line transects (named the Goegap, Bleshoek and Jaleeg Plains) have been monitored since 1991, whereas the Koperberg and T'ganagas Plains line transects have been monitored only since 1997. These five new line transects are currently also monitored on a yearly basis together with the two older ones (Rösch 1997).

The management units represented by the line transects and a summary of the environmental features of the seven line transects reported on in study are provided in Tables 3.4 and 3.5.

Table 3.4 The line transects in the different management units. The management units were identified by Rösch (2001*b*)

Line transect	**Management Unit**
Bleshoek Plains	3
Bluemine Mountain	10
Goegap Plains	5
Jaleeg Plains	7
Koperberg Plains	2
T'ganagas Plains	4
Zebrawater Foothills	8/10

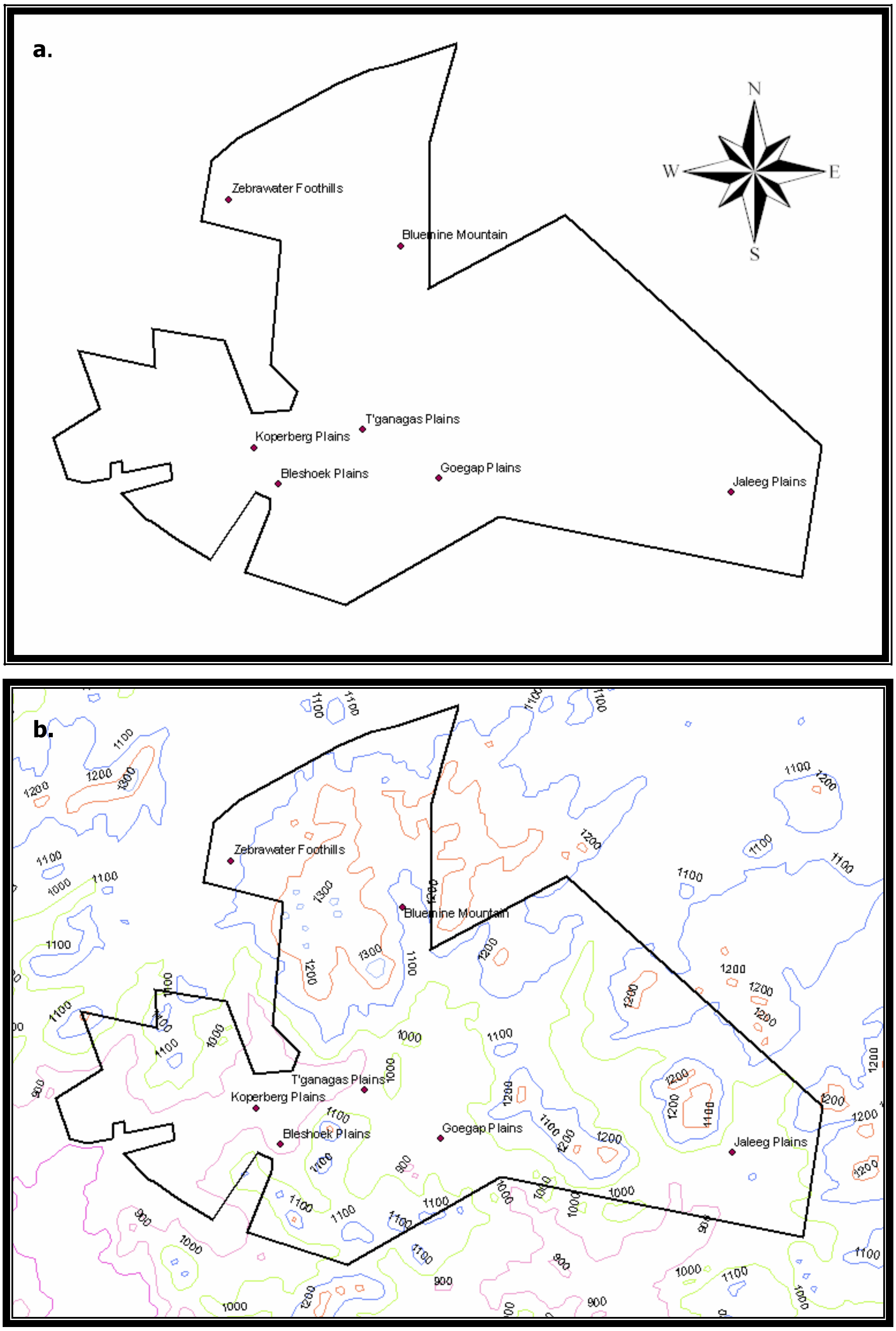


Figure 3.7 The Goegap Nature Reserve a) indicating the location of the long-term monitoring transects and b) the transects in relation to the topography of the reserve.

Table 3.5 The altitude, land type, geology and soil of the seven line transects

Line transect	**Altitude (m)**	**Land type**	**Geology**	**Soil**	**Main vegetation communities**
BLESHOEK PLAINS	903.5	Ae80	Nababeep gneisses Sand, rubble and soil	Hutton soil (coarse, sandy)	*Galenia sarcophylla – Mesembryanthemum guerichianum* dwarf sparse shrubland subcommunity and the *Psilocaulon junceum – Zygophyllum retrofractum* low sparse shrubland
BLUE MINE MOUNTAIN	1080.6	Ib127	Kweekfontein granite (granite boulders on the crest) Nababeep gneiss	Hutton soils	*Searsia undulata* tall sparse shrubland and *Leipoldtia schultzei* short open shrubland
GOEGAP PLAINS	941.0	Ib127	Nababeep gneiss (No rock cover) Sand, rubble and soil	Hutton soils (coarse, sandy)	*Tripteris sinuata* short open shrubland
JALEEG PLAINS	959.3	Ae85	Nababeep gneiss Sand, rubble and soil	Hutton soil (deep form, > 1 200 mm)	*Drosanthemum hispidum – Mesembryanthemum guerichianum* dwarf sparse shrubland subcommunity, *Psilocaulon junceum* low sparse shrubland and *Stipagrostis brevifolia* short sparse shrubland
KOPERBERG PLAINS	850.9	Ae80	Sand, rubble and soil	Hutton soil (sandy, high in salt concentration)	*Psilocaulon junceum – Drosanthemum hispidum* low sparse shrubland and *Galenia sarcophylla – Mesembryanthemum guerichianum* dwarf sparse shrubland subcommunity
T'GANAGAS PLAINS	950.9	Ae80	Nababeep gneiss Sand, rubble and soil	Hutton soil	*Drosanthemum hispidum – Mesembryanthemum guerichianum* dwarf sparse shrubland subcommunity
ZEBRAWATER FOOTHILLS	1075.8	Ae80/Ib127	Kweekfontein granite (granite boulders on crest) Nababeep gneiss	Hutton soils	*Drosanthemum hispidum – Mesembryanthemum guerichianum* dwarf sparse shrubland subcommunity, *Searsia undulata* tall sparse shrubland and *Leipoldtia schultzei* short open shrubland

CHAPTER 4

METHODS

4.1. Field methodology

The field methodology involved the annual monitoring of line transects on the Goegap Nature Reserve. Seven line transects (Table 4.1, Figures 4.1 – 4.7) were investigated in the reserve. The Zebrawater Foothills and Bluemine Mountain line transects have been monitored for the longest period. These line transects were established and have been monitored annually since 1974. Three line transects (Goegap Plains, Bleshoek Plains and Jaleeg Plains) were established and monitored since 1991 and two line transects (Koperberg Plains and T'ganagas Plains) monitored since 1997.

Table 4.1 Coordinates (degrees, minutes and seconds) of the starting and ending points of seven line transects in the Goegap Nature Reserve

Line transects	Starting point		End point	
	S	**E**	**S**	**E**
Bleshoek Plains	29 41 31.0	17 58 45.9	29 41 06.3	17 58 21.7
Zebrawater Foothills	29 37 12.0	17 57 48.9	29 37 39.7	17 57 47.7
Koperberg Plains	29 40 34.1	17 58 25.0	29 40 58.7	17 57 59.9
Bluemine Mountain	29 37 54.0	18 00 33.1	29 37 25.7	18 00 23.4
Goegap Plains	29 40 57.8	18 01 08.1	29 41 28.5	18 00 56.5
T'ganagas Plains	29 40 41.1	18 00 03.5	29 40 15.2	17 59 42.0
Jaleeg Plains	29 41 12.6	18 05 22.8	29 41 39.1	18 05 44.7

These seven line transects have been surveyed annually at the end of August or beginning of September. The vegetation surveys are conducted during this time of the year, the main flowering period, because the annual species are present during spring time and because the species are more easily identified then, than any other time of the year (Rösch 2003).

The descending point method (Roux 1963, Mentis 1981) with 1 000 points per survey was used to determine the species composition and vegetation cover (Rösch 2003). Each line transect was one kilometre (1 000 m) in length, and was marked at 100 m intervals with droppers. A 100 m rope, marked at 1 m intervals, was spread between each pair of droppers and straightened with both ends hooked to a dropper. The line was walked from the beginning to the second dropper and at each 1 m interval, a thin rod was released and the species recorded if it qualified as a strike. When arriving

Figure 4.1 The Bleshoek Plains line transect in the Goegap Nature Reserve in the spring of 2006.

Figure 4.2 The Bluemine Mountain line transect in the Goegap Nature Reserve in the spring of 2006.

Figure 4.3 The Goegap Plains line transect in the Goegap Nature Reserve in the spring of 2006.

Figure 4.4 The Jaleeg Plains line transect in the Goegap Nature Reserve in the spring of 2006

Figure 4.5 The Koperberg Plains line transect in the Goegap Nature Reserve in the spring of 2006.

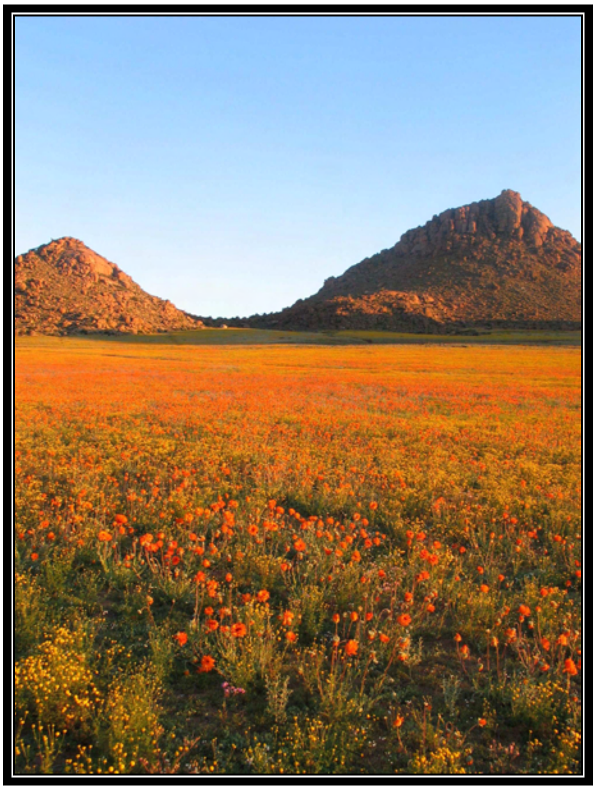


Figure 4.6 The T'ganagas Plains line transect in the Goegap Nature Reserve in the spring of 2006.

Figure 4.7 The Zebrawater Foothills line transect in the Goegap Nature Reserve in the spring of 2006.

at the second dropper the rope was detached and moved to the next two droppers. This procedure was repeated ten times at each line (Rösch 1997).

The descending point method included the following data recorded at each 1 m interval (Rösch 1997):

- first strike – plant species first touched by the rod;
- second strike – plant species growing beneath the first plant species and also touched by the rod;
- dead woody individuals – the rod touched dead woody plant material of a plant that was still anchored;
- seedlings – plant species still in seedling phase touched by the rod and
- rocks or stones were noted for the line transects at Zebrawater Foothills and Bluemine Mountain.

4.2. Data analysis

4.2.1 *Vegetation cover and diversity*

The following were calculated for each line transect:

- The species richness (S) or number of species recorded per transect was obtained with the PC-ORD computer package (PC-ORD version 4, MjM Software Design, Gleneden Beach, Oregon, USA).
- Species evenness (E) was computed by means of the PC-ORD computer package using the equation (McCune & Mefford 1999):

  $E = H/\ln(S)$

  Where H = Shannon's index of diversity.

  $\ln(S)$ = natural logarithm of the number of species per transect.
- Shannon's index of diversity (H) was computed by means of the PC-ORD computer package using the equation (McCune & Mefford 1999):

  $H = -\sum(Pi*\ln(Pi))$

  Where Pi = the importance probability of species i.

  $\ln(Pi)$ = the natural logarithm of the importance probability of species i.
- Simpson's diversity index for infinite populations (D) was computed by means of the PC-ORD computer package using the equation (McCune & Mefford 1999):

  $D = 1 - \text{sum}(Pi*Pi)$

  where Pi refers to the importance probability in the element i.

  This is the complement of the original Simpson's diversity index.
- The number of first strikes and seedlings was expressed as a percentage of the total number of possible strikes (1 000). This value represented the vegetation cover.
- The number of second strikes was likewise expressed as a percentage of the total number of possible strikes (1 000).
- The number of dead strikes was expressed as a percentage of the total number of possible strikes (1 000).

4.2.2 Life forms

To obtain a measure of the functional diversity of the vegetation each recorded species was assigned to a life form category according to the life form classification of Mueller-Dombois & Ellenberg (1974). Only the categories relevant to this study are mentioned in the outline below:

Phanerophytes (P) – autotrophic, kormophytes, woody or herbaceous evergreen perennial plants that grow taller than 50 cm, or whose shoots do not die back periodically to that height limit:

- Dwarf trees less than 2 m tall – Nanophanerophytes (N P scap).
- Normal-sized shrubs (< 2 m) – Nanophanerophytes (N P caesp).

Chamaephytes (Ch) – Autotrophic, kormophytes, woody or herbaceous evergreen perennial plants that remain perennially within 50 cm above ground surface or if they grow taller than 50 cm, their shoots die back periodically to that height limit:

- Woody (up to branch tips) dwarf shrubs, frutescent (Ch frut).
- Semi-woody (woodiness restricted to base of shoot system) dwarf shrubs, suffrutescent (Ch suff).
- All herbaceous perennial forbs, grasses and ferns that do not grow taller than 1 m or die back periodically to a shoot system that remains green at least 25 cm above ground surface (Ch herb).
- All succulents that grow up to 50 cm, except those that die back to a remnant portion at the soil surface (hemicryptophytes) or within the soil (geophytes) (Ch succ):
    - Stem succulents (Ch st succ) and
    - Leaf succulents (Ch l succ).

Hemicryptophytes (H) – Perennial herbaceous plants with periodic shoot reduction to a remnant shoot system that lies flat on the ground surface:

- Caespitose hemicryptophytes (H caesp).
- Reptant hemicryptophytes (creeping or matted) (H rept).
- Rosette hemicryptophytes (H ros).

Lianas – Plants growing by supporting themselves on other plants, but that still germinate on the ground and maintain contact with the soil.

Annuals (Therophytes) – Plants completing their whole life cycle in one year and whose shoot and root system dies after seed production.

Geophytes (Cryptophytes) – Perennial herbaceous plants with periodic shoot reduction of the entire shoot system to storage organs in the soil.

The total number of first strikes and seedlings of all the different life forms (i.e. perennials, annuals, geophytes and lianas) encountered were also calculated as a percentage of the total number of possible strikes. The frequency of the total number of these first strikes and seedlings was also expressed as the percentage contribution made to the vegetation cover. The frequency of strikes (%) of the annuals and all perennials combined was plotted versus the annual rainfall of the Springbok weather station and the rainfall data collected on the Goegap Nature Reserve.

The life form data were used to calculate the following diversity indices:

- Life form richness;
- Life form evenness;

- Shannon index of life form diversity and
- Simpson's index of life form diversity.

The indices were calculated in two different ways. In the first instance the number of species in a life form was used as a measure of its abundance and in the second instance the sum of all strikes of the species in a particular life form was used as a measure of its abundance.

4.2.3 Range condition and carrying capacity

Because the area of study is under protection, it is important to assess the impact of possible overutilisation by mammalian herbivores on vegetation; thus, to conduct a veld condition assessment and provide recommendations on the carrying capacity for the Goegap Nature Reserve. The veld condition was assessed with the use of GIV (grazing index values) of species (Du Toit 2003, Rösch 2003).

The first step in formulating a veld management program is to determine the veld condition in every homogenous vegetation unit in the given area. The seven line transects investigated in this study represent seven of the 10 management units of the Goegap Nature Reserve (see Chapter 3). One technique often used to determine the veld condition is the Ecological Index Method (EIM) (Bothma 2000). The technique has been shown to provide reliable results in the karoo environment (Vorster 1982). The grazing index method (GIM) is a refinement of the EIM and was proposed by Du Toit (1996, 1998) specifically for the karoo veld. Each species has a unique grazing index value allocated to them, and the cover of each species is then multiplied by its grazing index value. Thís product corresponds to the condition index of that species in the specific veld under survey. Therefore, when all the condition indices of the individual species are added together, the sum represents the veld condition index (or veld condition score) of that specific veld. The veld condition index is then compared with the veld condition index of the benchmark. The veld condition index of the benchmark is divided by the veld condition index of the veld sample (Du Toit 2003). The veld condition score (VCS) of 650 was taken as the highest possible score (Lloyd 1996). This answer is the grazing capacity of the sample in morgan per small stock unit (morgan/SSU). A correction factor of 7.14 is applied to convert the grazing capacity to large-stock unit (LSU) per hectare (Du Toit 2002). This value can be compared to the grazing capacity norm appropriate to the area under study (Du Toit 2003, Rösch 2003).

4.2.4 Ordination

According to Kent and Coker (2001) ordination means to "set in order", and here ordering means vegetation sample arrangement in relation to each other, in terms of their species composition and/or their associated environmental control similarity. Individual samples or species and their degree of similarity to each other, and the correlation of the individuals with underlying environmental factors, are determined. The techniques of ordination and gradient analysis are also methods for data reduction and exploration that lead to hypothesis formulation. Two types of gradient analysis are defined, namely direct, for example canonical correspondence analysis (CCA), and indirect ordination, for example correspondence analysis (CA).

s

The CANOCO computer software package (CANOCO version 4.5, Microcomputer Power. Ithaca, NY, USA) (Ter Braak & Smilauer 2003) was used to investigate the species composition changes. Firstly, detrended correspondence analysis (DCA) was used to find out if a linear or a unimodal context must be applied (Leps & Smilauer 2003). The unimodal method was used (and not the linear method of ordination) because the gradient value was long (>4 SD). Correspondence analysis (CA) was used to do an indirect gradient analysis and canonical correspondence analysis (CCA) was used to do a direct gradient analysis. The perennial species were analysed with regard to the progress throughout the monitored years separately from the annual species. Perennial species do not react notably to the rainfall whereas annual species do react to rainfall.

CANOCO can be applied to most methods of ordination and is designed for data analysis in community ecology. Ordination deals not primarily with classes, as in classification, but is an essential technique of gradient analysis. The plant species occurring in the line transects can be arranged in sequence by their positions along an environmental gradient or axis, and any change in these plant species are related to changes in the environment (Whittaker 1978*b*, Ter Braak & Smilauer 2003). To make use of this method, quantitative data are needed, though replications are unnecessary (qualitative data can be used but it is difficult to derive a gradient from this).

The rainfall data, obtained from different rain meters situated in the reserve, were analysed in six different ways:

- First quarter rainfall: the sum of rainfall in January, February and March (late summer rainfall);
- Second quarter rainfall: the sum of rainfall in April, May and June (early and partly mid-winter rainfall);
- Summer rainfall: the sum of rainfall in October, November and December of the previous year and the rainfall in January, February and March of the current year;
- Winter rainfall: the rainfall in April, May, June, July and August of the current year (the rainfall having an influence on the current year's flowering) (September rainfall is excluded because this is when field work is done);
- Previous winter rainfall: the sum of rainfall of April, May, June, July, August and September of the previous year and
- Annual rainfall: the rainfall throughout the year (from January up to December) of the current year.

Thus, the rainfall can be divided into different groups related mainly to the seasons (winter and summer) and by using CANOCO the annual species will be placed in relation to the different rainfall groups.

CHAPTER 5

RESULTS

5.1 Bleshoek Plains

5.1.1 *Rainfall*

Figure 5.1 shows the large fluctuations in the rainfall at the Bleshoek Plains line transect during the monitored years. The annual rainfall varied approximately threefold from 105.5 mm up to 303.8 mm rain. Such highly variable rainfall is typical for semi-arid and arid environments (Low & Rebelo 1998, Le Roux & Van Rooyen 1999, Mucina & Rutherford 2006). The winter rainfall received was much higher than the summer rainfall, indicating that the area was situated in a winter rainfall region.

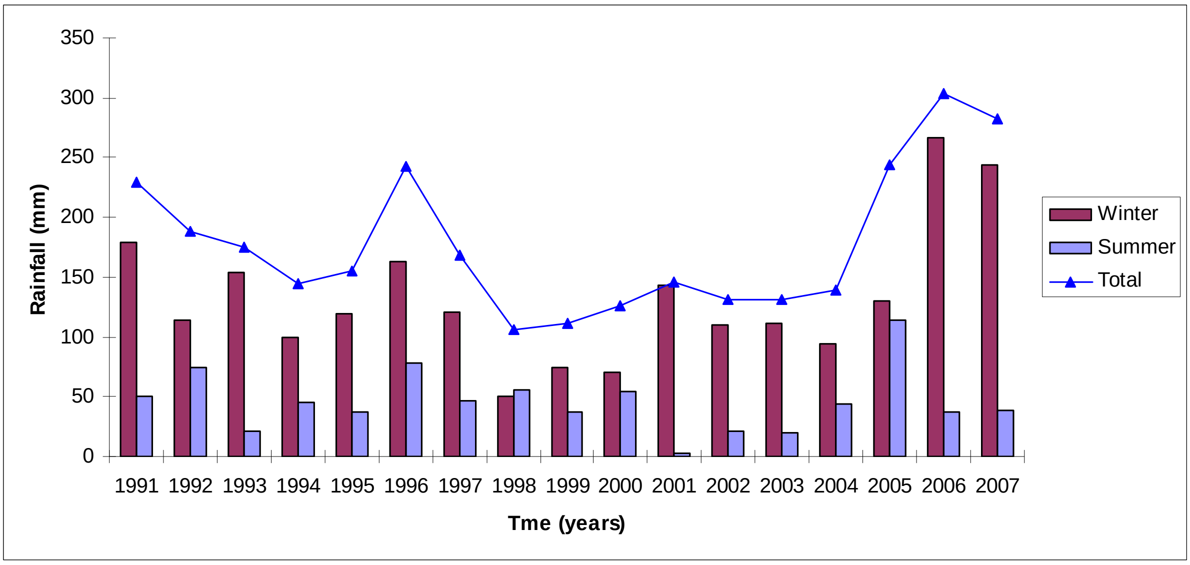


Figure 5.1 The rainfall during the monitored years at the Bleshoek Plains line transect. Summer = rainfall in the summer months (January to March and October to December of the current year), Winter = rainfall in the winter months (April to September), and Total = the total annual rainfall (January to December).

5.1.2 *Frequency of occurrence of annual and perennial species*

The frequency of occurrence of the perennial species did not reveal any changes in a specific direction at the Bleshoek Plains line transect over time (Figure 5.2). In contrast, the frequency of the annual species showed a clear relationship with the winter rainfall (Figure 5.3). It should be noted that in Figures 5.2 and 5.3 the summer rainfall refers to the rainfall from October to December of the previous year and January to March of the current year, therefore this value represents the summer period preceding the current winter growing season. The winter rainfall refers to the rainfall from April to August of the current year.

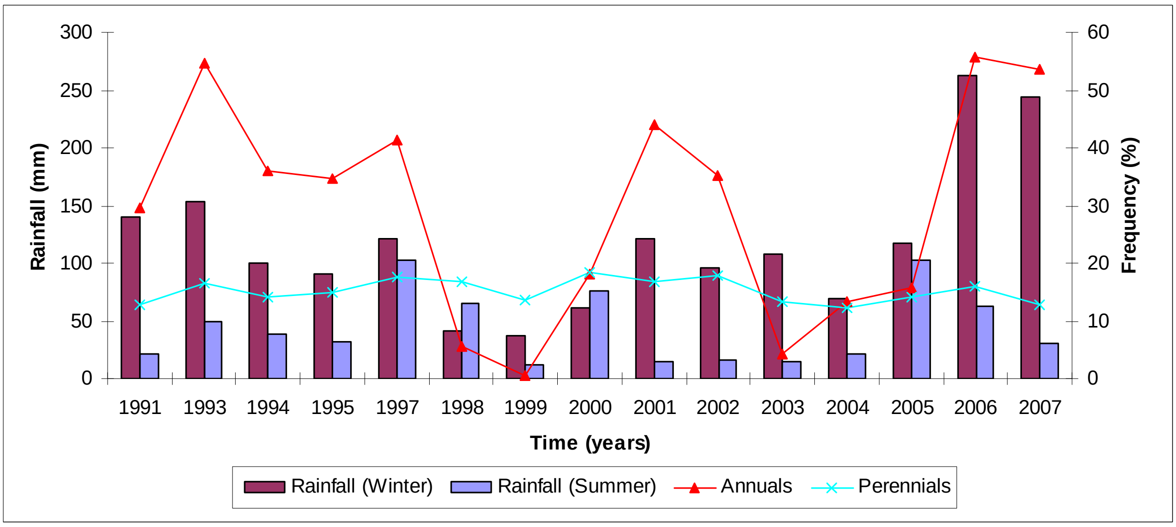


Figure 5.2 The frequency of strike of the annual and perennial species and the winter and summer rainfall during the monitored years for the Bleshoek Plains line transect. The blue line represents the percentage frequency of the perennial species, whereas the red line represents the annual species. The summer rainfall stretches from October to December of the previous year and January to March of the current year, whereas the winter rainfall includes the rainfall from April to August of the current year.

It is clear that except in the very dry years, the frequency of strikes of the annual species exceeded that of the perennial species. The vegetation at this line transect therefore comprised mostly annual vegetation.

5.1.3 *Species and life form diversity*

The following four measures of diversity were calculated for each year for the Bleshoek Plains line transect by means of the PC-ORD computer package (PC-ORD version 4, MjM Software Design, Gleneden Beach, Oregon USA) (McCune & Mefford 1999, Chapter 4):

- The species richness (S) or number of species
- Species evenness (E)
- Shannon’s index of diversity (H)
- Simpson’s diversity index

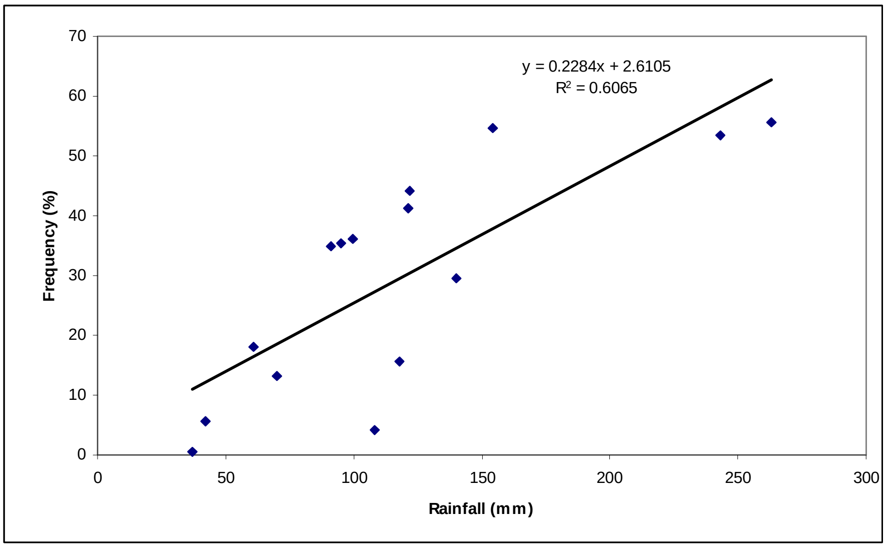


Figure 5.3 The regression of the winter rainfall against the frequency of annual species for the Bleshoek Plains line transect.

To obtain a measure of the functional diversity of the vegetation each recorded species was assigned to a life form category (Mueller-Dombois & Ellenberg 1974). The life form data were then used to calculate the same diversity indices as for the species data. The life form indices were calculated in two different ways. In the first instance the number of species in a life form was used as a measure of its abundance and in the second instance the sum of all strikes of the species in a particular life form was used as a measure of its abundance.

Richness

The species richness records the total number of species without reference to the distribution of individuals among the species (Krohne 2001). The species richness of the perennial species (Figure 5.4) did not reveal any definite changes in a specific direction, and therefore showed no specific increase or decrease during the past monitored years. The species richness of the annual species revealed large fluctuations. There was a significant positive correlation (r^2 = 0.20) between the species richness of the annual species and the rainfall but this relation was not found with the perennial species richness. There was a strong correlation between the frequency of occurrence of the annual species and annual species richness (Figure 5.5).

Table 5.1 shows that the most prevalent life forms for the Bleshoek Plains line transect were the therophytes and the chamaephytes.

Table 5.1 Number of species per life form occurring at the Bleshoek Plains line transect

	1991	**1993**	**1994**	**1995**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Phanerophytes (P)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
NP scap	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NP caesp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chamaephytes (Ch)	**8**	**8**	**8**	**7**	**8**	**10**	**7**	**8**	**7**	**7**	**6**	**7**	**8**	**8**	**7**
Ch frut	2	1	2	1	2	2	2	3	2	2	2	1	2	3	2
Ch suff	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Ch herb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ch succ	6	7	6	6	6	8	5	5	5	5	4	6	6	4	5
Ch l succ	4	5	4	4	4	6	4	3	3	3	3	5	5	3	4
Ch st succ	2	2	2	2	2	2	1	2	2	2	1	1	1	1	1
Hemicryptophytes (H)	**3**	**3**	**4**	**4**	**4**	**4**	**3**	**4**	**3**	**3**	**3**	**3**	**3**	**4**	**3**
H caesp	3	3	4	4	4	4	3	4	3	3	3	3	3	4	3
H rept	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H ros	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Liana (L)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Therophytes (T)	**22**	**31**	**28**	**23**	**23**	**13**	**3**	**13**	**20**	**21**	**2**	**12**	**9**	**25**	**22**
Geophytes (G)	**2**	**3**	**1**	**1**	**2**	**1**	**3**	**3**	**1**	**2**	**0**	**3**	**1**	**2**	**3**

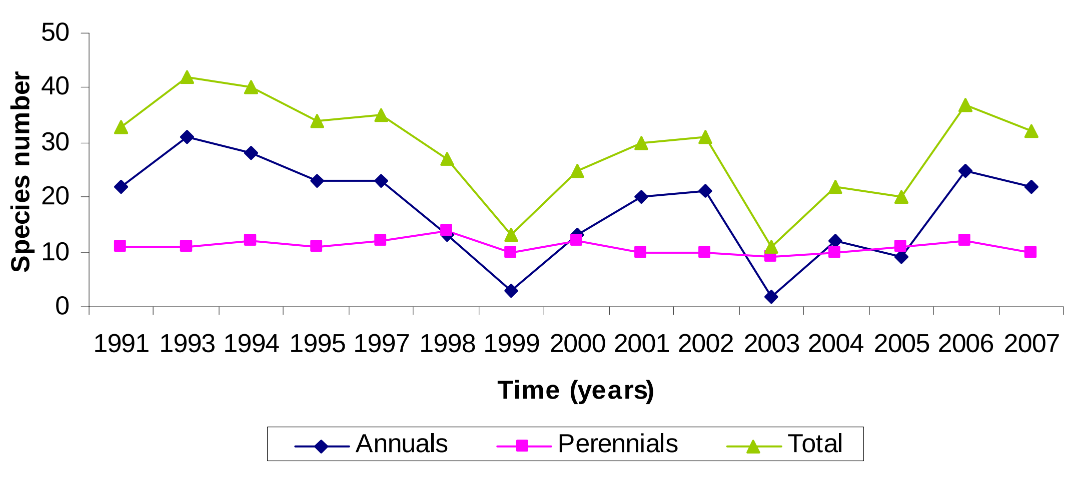


Figure 5.4 The species richness of annual and perennial species as well as total species richness during the past monitored years for the Bleshoek Plains line transect.

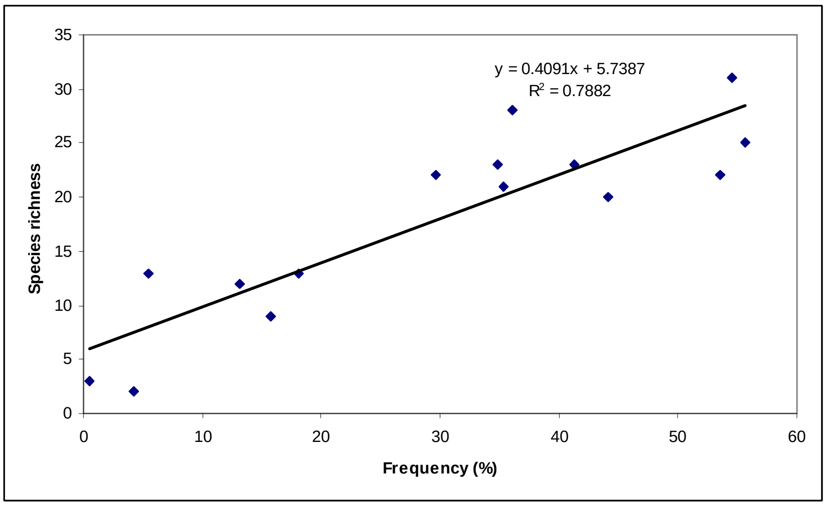


Figure 5.5 The regression of the frequency of strike for the annual species against the annual species richness for the Bleshoek Plains line transect.

Diversity measures

The evenness (E) and Simpson's index of diversity (D) remained almost unchanged over the monitoring period whereas the Shannon index (H) mirrored the total species richness trends (Figure 5.6a). Where the number of species was used as a measure of the abundance of growth forms (Figure 5.6b) the diversity increased in the years with a low winter rainfall. The opposite trend was observed where the number of strikes was used as a measure of the abundance of the growth forms (Figure 5.6c). In all three graphs (Figure 5.6a-c) the changes were not directional but depended primarily on the amount of winter rainfall.

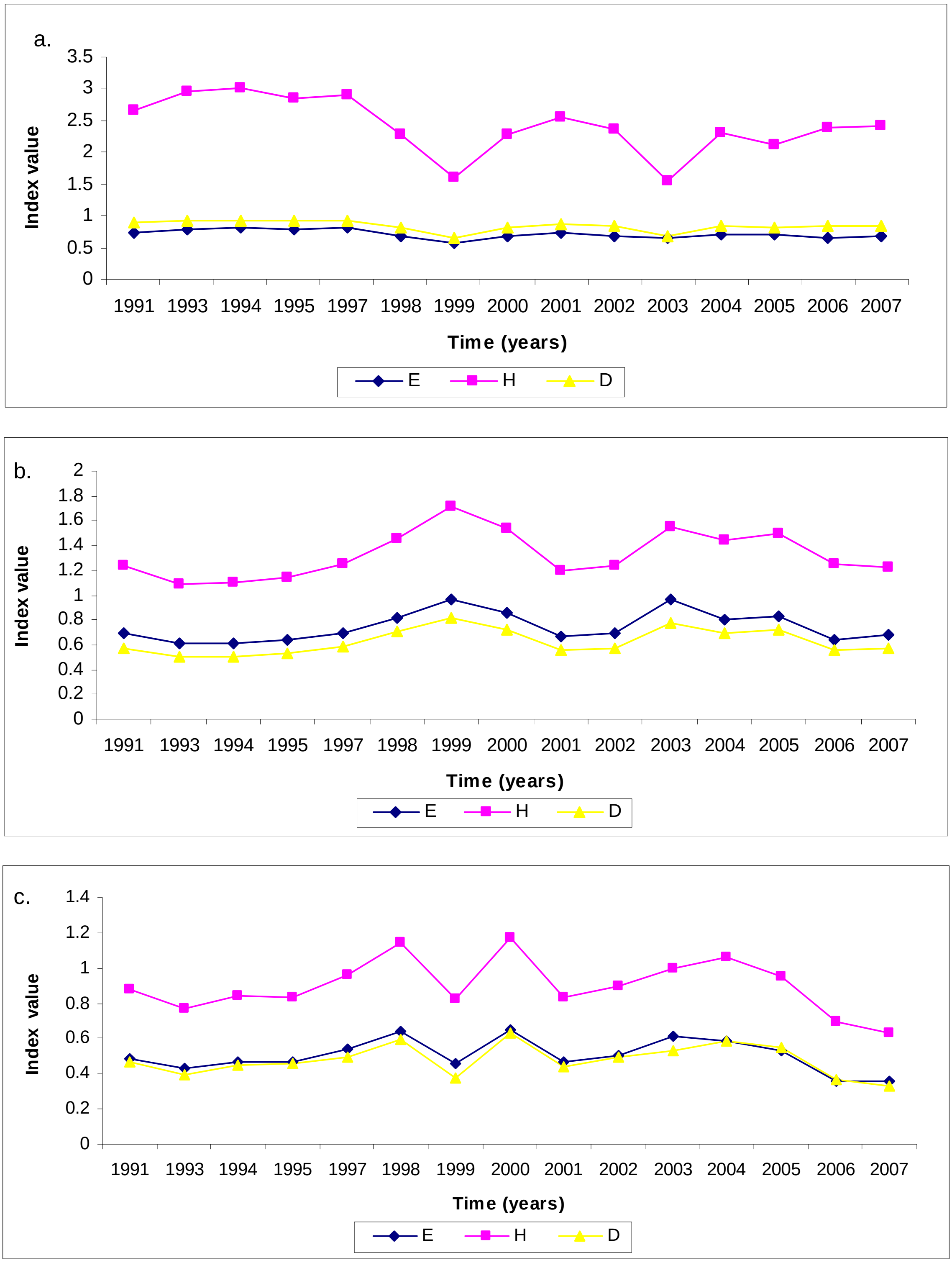


Figure 5.6 The diversity measures in the Bleshoek Plains line transect, using (a) the first strikes of all species, (b) the number of species in the different life forms and (c) the number of strikes in the different life forms. E = species/life form evenness, H = Shannon's diversity index and D = Simpson's diversity index.

5.1.4 *Species composition*

Individual species

The most abundant perennial species at Bleshoek Plains line transect was *Leipoldtia schultzei* (Appendix 8.1). This succulent species showed a slight increase in frequency of occurrence over the monitored years (r^2 = 0.38; Figure 5.7a). In contrast, *Ruschia robusta*, another succulent species showed a marked decline (r^2 = 0.25) in the last few years. The two palatable grass species, *Stipagrostis obtusa* and *S. brevifolia*, also showed a marked decline (r^2 = 0.60; r^2 = 0.44) over the monitored years (Figure 5.7b).

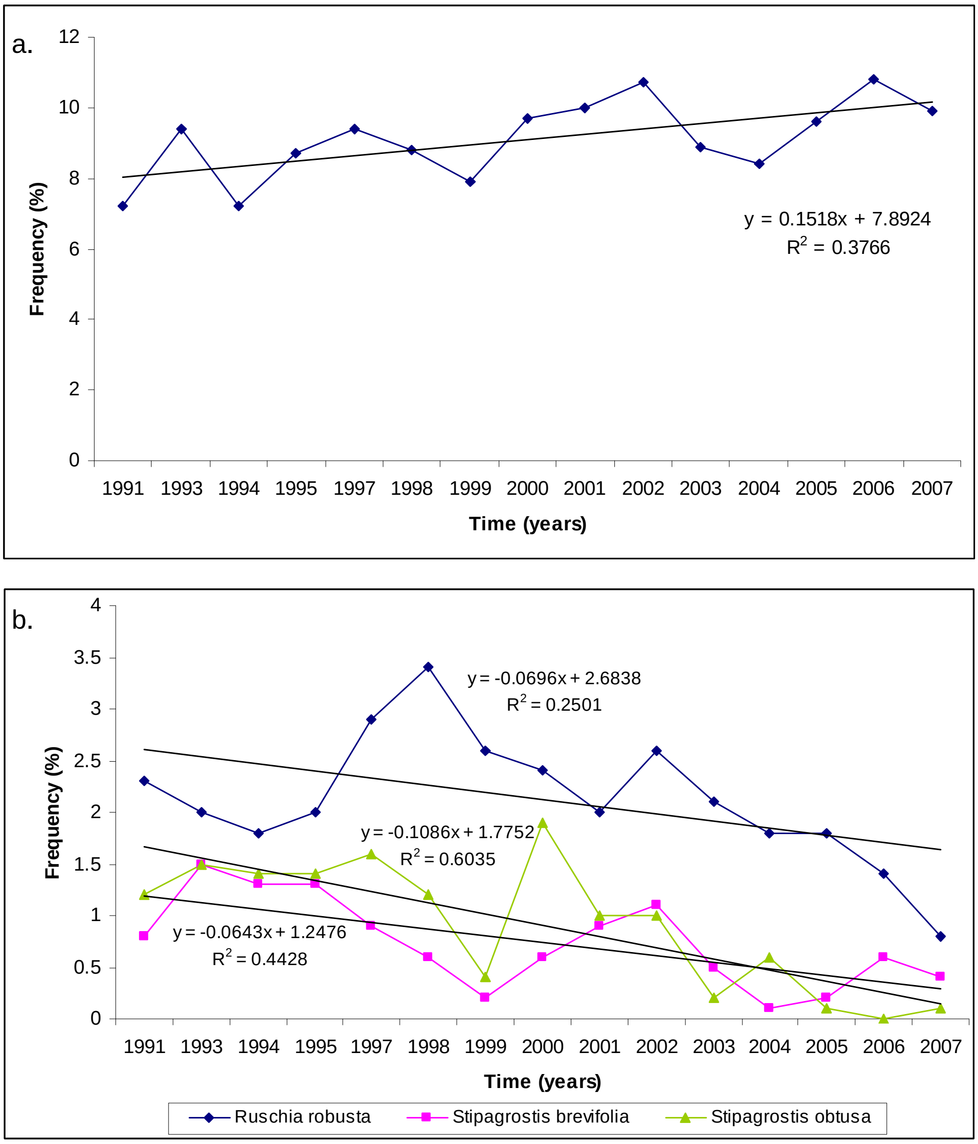


Figure 5.7 Changes in frequency of selected perennial species at Bleshoek Plains line transect; (a) *Leipoldtia schultzei*; and (b) *Ruschia robusta, Stipagrostis obtusa* and *S. brevifolia*.

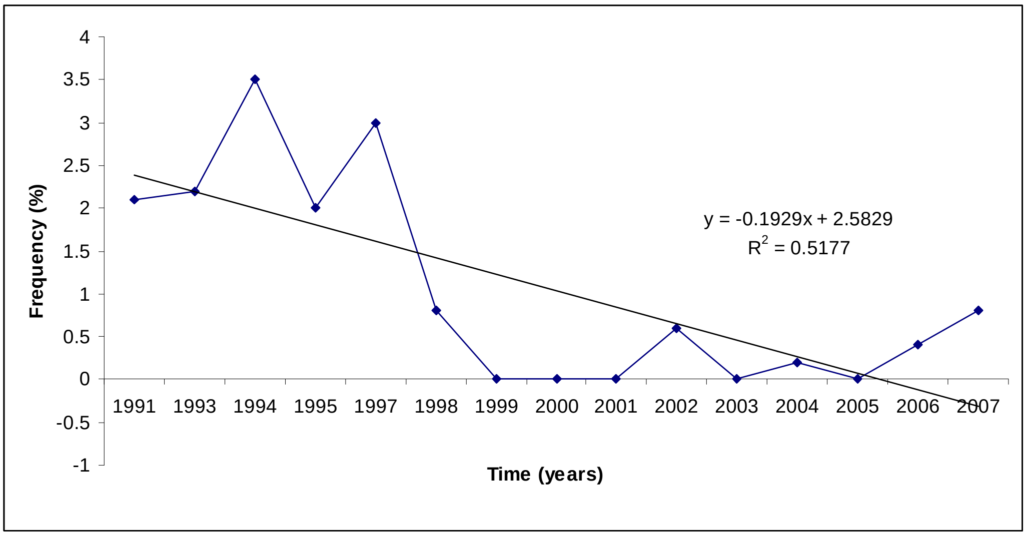


Figure 5.8 Changes during the past 15 years in an unpalatable annual species, *Leysera tenella,* occurring in the Bleshoek Plains line transect.

In general, the annual species showed large fluctuations in abundance. *Leysera tenella* showed a decreasing trend (r^2 = 0.52) in the Bleshoek Plains line transect (Figure 5.8). This change is an indication of veld recovery. However, the decrease of the perennial grass species showed the opposite trend.

Community composition

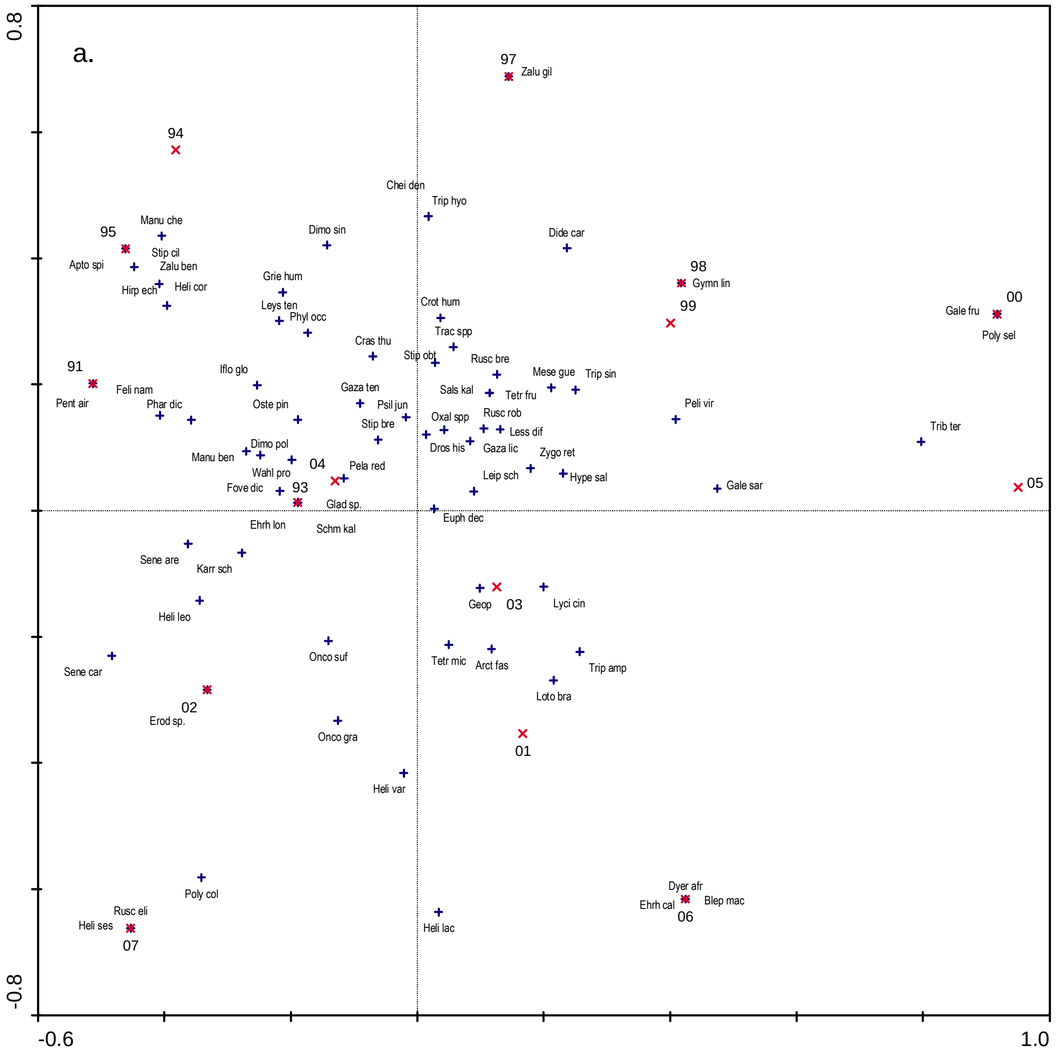
The changes in the species composition were illustrated by the use of Correspondence Analysis (CA) in the computer programme CANOCO. The scatter diagram of data of all species in the Bleshoek Plains line transect reveals that changes did occur (Figure 5.9a). There is no clear directional trend, although the progression seems to go from the top of the ordination space to the bottom.

Perennial species composition

When only the perennial species were used in the CA ordination (Figure 5.10) there is a clear progression in the years from the left to the right on the scatter diagram as indicated by the arrow in Figure 5.11.

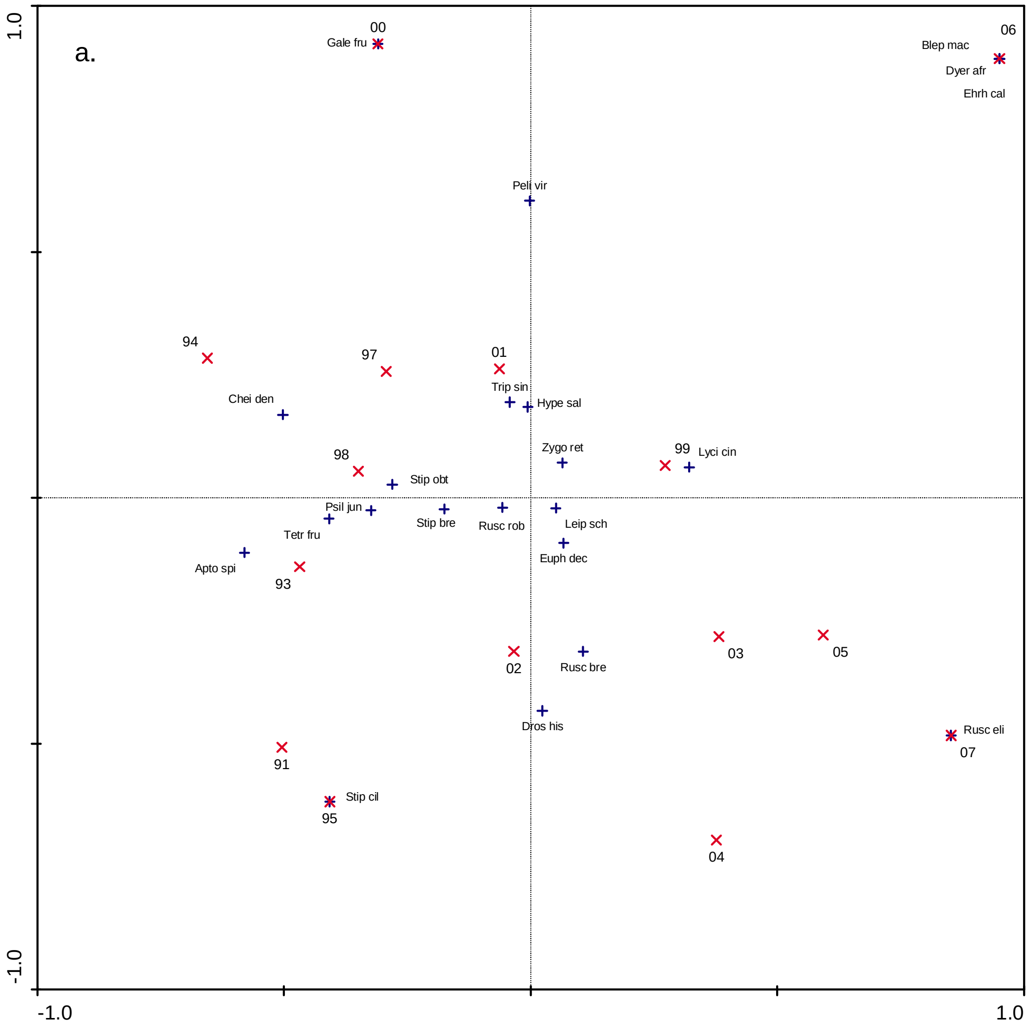
Annual species composition

The change in the annual species composition was analysed by Canonical Correspondence Analysis with regards to the rainfall because rain gives rise to changes in short-lived vegetation. Rainfall was expressed in different ways: the first quarter rainfall (1Q), second quarter rainfall (2Q), summer rainfall (Summer), winter rainfall (Winter), rainfall of the previous winter (Prev winter), and annual rainfall (Annual).



b.	Axes :	1	2	3	4	Total inertia
	Eigenvalues :	0.272	0.216	0.158	0.127	1.150
	Cumulative percentage					
	Variance of species data :	23.6	42.5	56.2	67.2	
	Sum of all eigenvalues :					1.150

Figure 5.9 (a) Scatter diagram produced by a Correspondence Analysis (CA) ordination showing the position of all species (75 species) relative to the monitored years for the Bleshoek Plains line transect. The red x-marks represent the years and the blue crosses the species. (b) Details of the CA ordination.



b.	Axes :	1	2	3	4	Total inertia
	Eigenvalues :	0.051	0.029	0.022	0.014	0.162
	Cumulative percentage					
	Variance of species data :	31.3	49.1	62.6	71.0	
	Sum of all eigenvalues :					0.162

Figure 5.10 (a) Scatter diagram produced by a Correspondence Analysis (CA) ordination showing the position of perennial species (22 species) relative to the monitored years for the Bleshoek Plains line transect where the red x-marks represent the years and the blue crosses the species. (b) Details of the CA ordination.

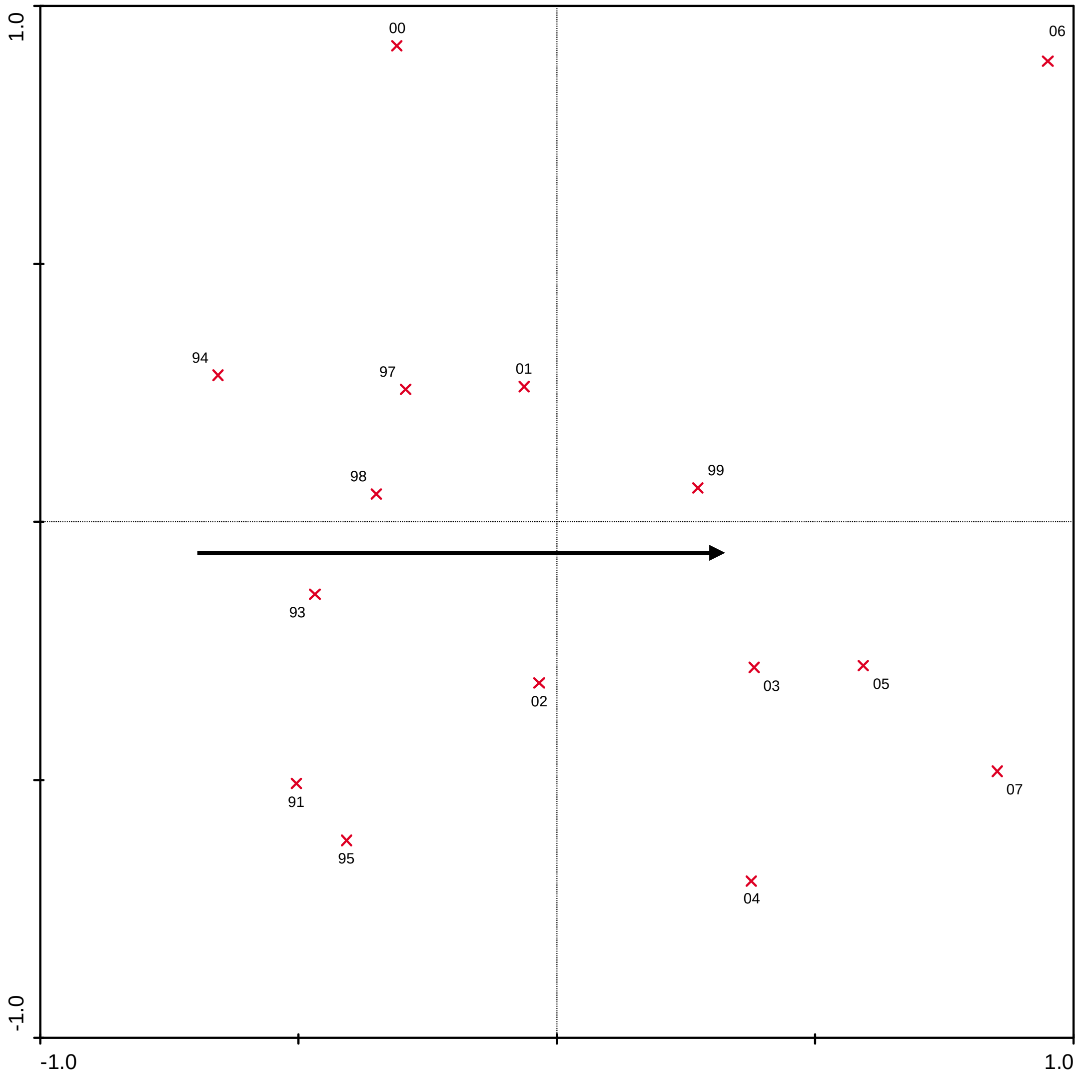
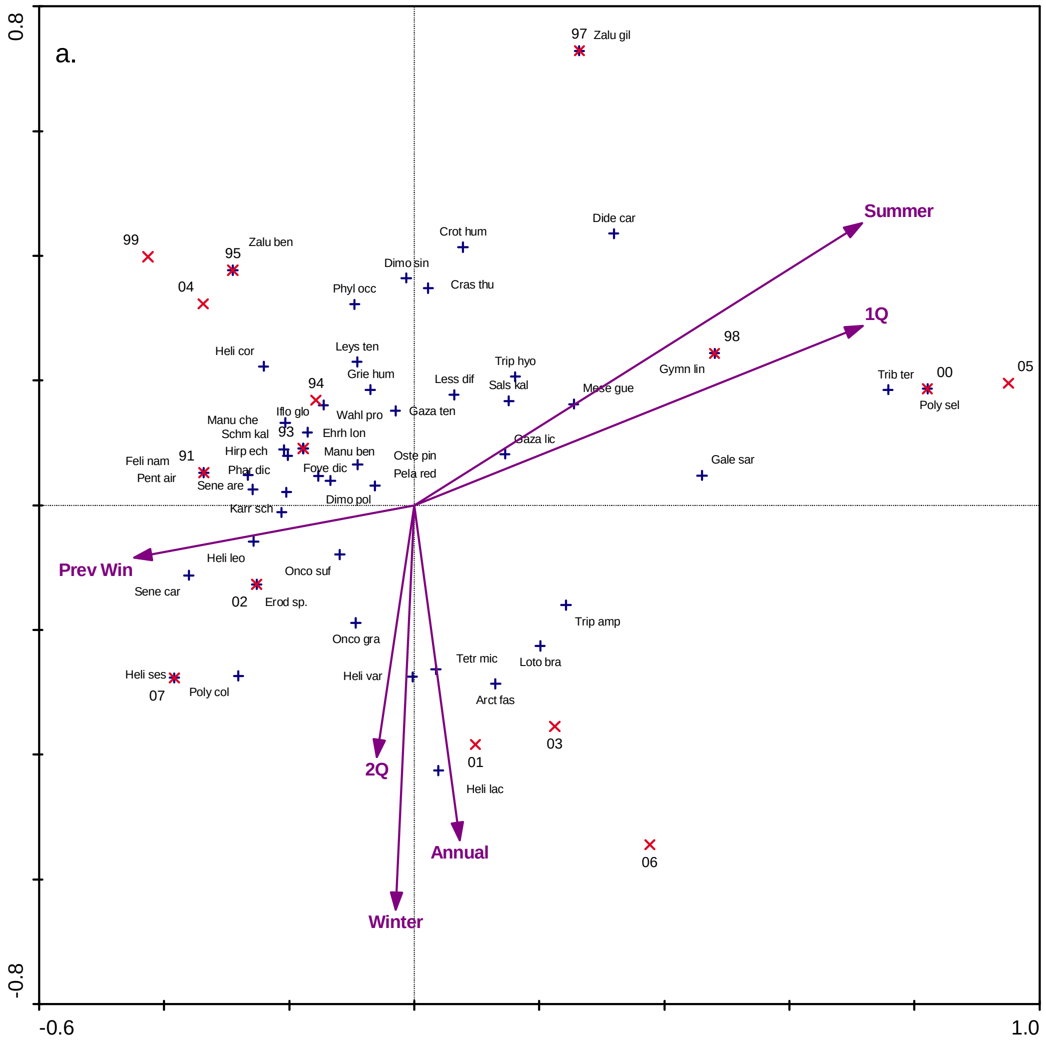


Figure 5.11 Scatter diagram produced by a Correspondence Analysis (CA) ordination showing the position of the monitored years for the Bleshoek Plains line transect with the arrow indicating the direction of vegetation change.

The annual species showed no directional trend in species composition over the monitored years (Figure 5.12). However, there were fluctuations in the annual species composition because these species react towards the rainfall. A few species, such as *Tribulus terrestris, Galenia sarcophylla, Gymnodiscus linearifolia* and *Polycarena selaginoides* were associated with high values for summer and first quarter rainfall. In contrast, most annual species were associated with the winter rainfall and second quarter rainfall axes. *Heliophila lactea* and *H. variabilis* were prominent in years with high winter rainfall values and species such as *Dimorphotheca sinuata* and *Lessertia diffusa* were more often encountered in years with less winter rainfall. There was a low (near to zero) correlation of summer rainfall with the winter and second quarter rainfall.



b. Axes :	1	2	3	4	Total inertia
Eigenvalues :	0.395	0.253	0.136	0.108	1.576
Species-environment correlations :	0.973	0.966	0.929	0.852	
Cumulative percentage variance					
of species data :	25.1	41.1	49.8	56.6	
of species-environment relation :	40.8	66.8	80.9	92.1	
Sum of all eigenvalues :					1.576
Sum of all canonical eigenvalues :					0.970

Figure 5.12 (a) Scatter diagram produced by a Canonical Correspondence Analysis (CCA) ordination showing the position of the annual species (49 species) relative to the years and rainfall in the Bleshoek Plains line transect. The red x-marks represent the years and the blue crosses the species. 1Q = rainfall from January to March of the current year, 2Q = rainfall from April to June of the current year, Summer = rainfall from October to December of the previous year and January to March of the current year, Winter = rainfall from April to August of the current year, Prev Win = rainfall from April to September of the previous year and Annual = the annual rainfall of the current year. (b) Details of the CCA ordination.

5.1.5 *Grazing capacity*

The grazing index method (GIM) as proposed by Du Toit (1996) for the Karoo veld was applied to calculate the grazing capacity of the vegetation on the Bleshoek Plains line transect. The method involves calculating the veld condition score and by comparing this value with a benchmark with a known grazing capacity, the grazing capacity of the range under consideration can be calculated.

In general, the grazing capacity was lowest in the years with a low winter and total annual rainfall and highest in years with a high winter as well as annual rainfall. The fluctuations in grazing capacity did not show directional trends (r^2 = 0.10; Figure 5.13).

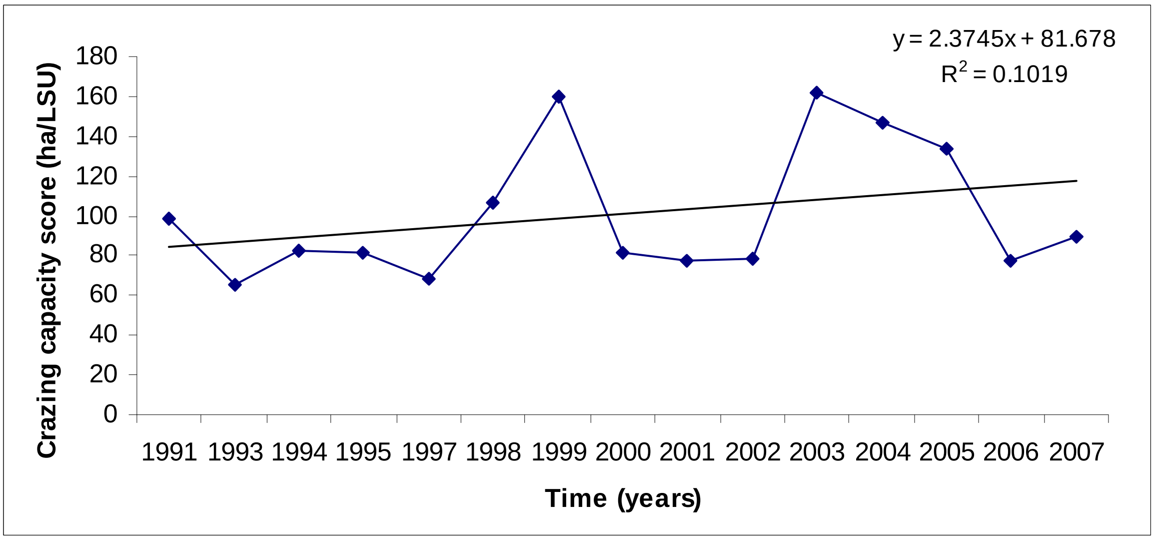


Figure 5.13 The grazing capacity (ha/LSU) throughout the monitored years for the the Bleshoek Plains line transect.

5.2 Bluemine Mountain

5.2.1 *Rainfall*

Figure 5.14 shows the fluctuation in the rainfall at the Bluemine Mountain line transect with an increase in total annual rainfall during the last three monitored years. The annual rainfall varied approximately fivefold from 65.30 mm up to 334.90 mm rain. The fluctuations in rainfall agree with the rainfall trends for semi-arid and arid environments (Le Roux & Van Rooyen 1999, Van Rooyen 1999, Ward 2006). The winter rainfall was much higher than the summer rainfall, indicating that the area was situated in a winter rainfall region.

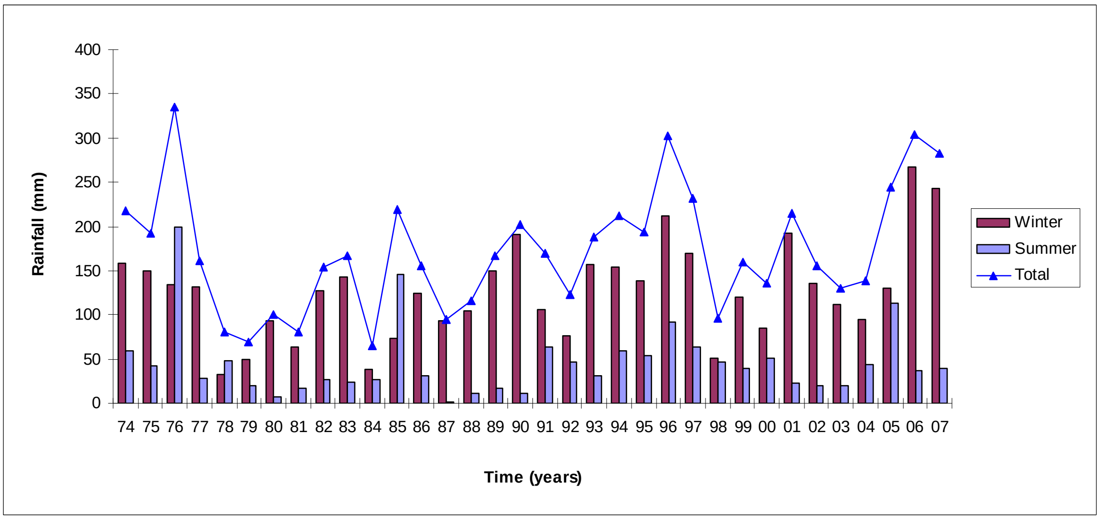


Figure 5.14 The rainfall during the monitored years at the Bluemine Mountain line transect. Summer = rainfall in the summer months (January to March and October to December of the current year), winter = rainfall in the winter months (April to September) and Total = the total annual rainfall (January to December).

5.2.2 *Frequency of occurrence of annual and perennial species*

The frequency of occurrence of the perennial species revealed a slight increase at the Bluemine Mountain line transect over time (Figure 5.15). In contrast, the frequency of the annual species showed some relationship ($r^2 = 0.43$) with the winter rainfall (Figure 5.16). In Figure 5.15 the summer rainfall refers to the rainfall from October to December of the previous year and January to March of the current year. The winter rainfall refers to the rainfall from April to August of the current year.

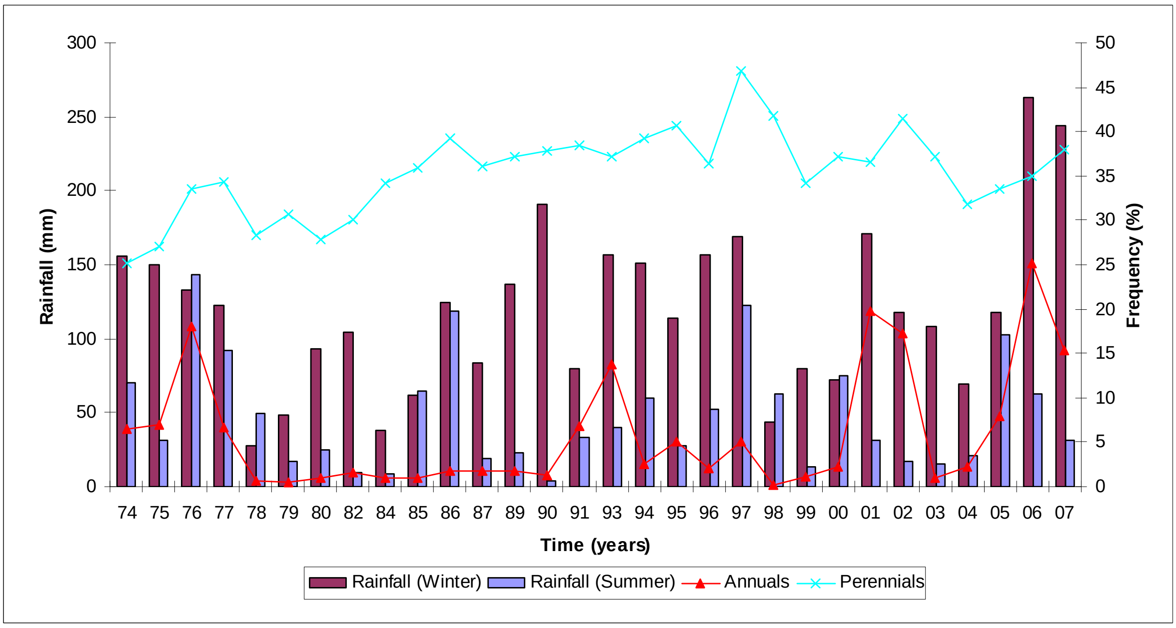


Figure 5.15 The frequency of strike of the annual and perennial species and the winter and summer rainfall during the monitored years for the Bluemine Mountain line transect. The blue line represents the perennial species, whereas the red line represents the annual species. The summer rainfall stretches from October to December of the previous year and January to March of the current year, whereas the winter rainfall includes the rainfall from April to August of the current year.

It is clear that the frequency of strikes of the perennial species exceeded that of the annual species. The vegetation at this line transect therefore comprised mostly perennial vegetation.

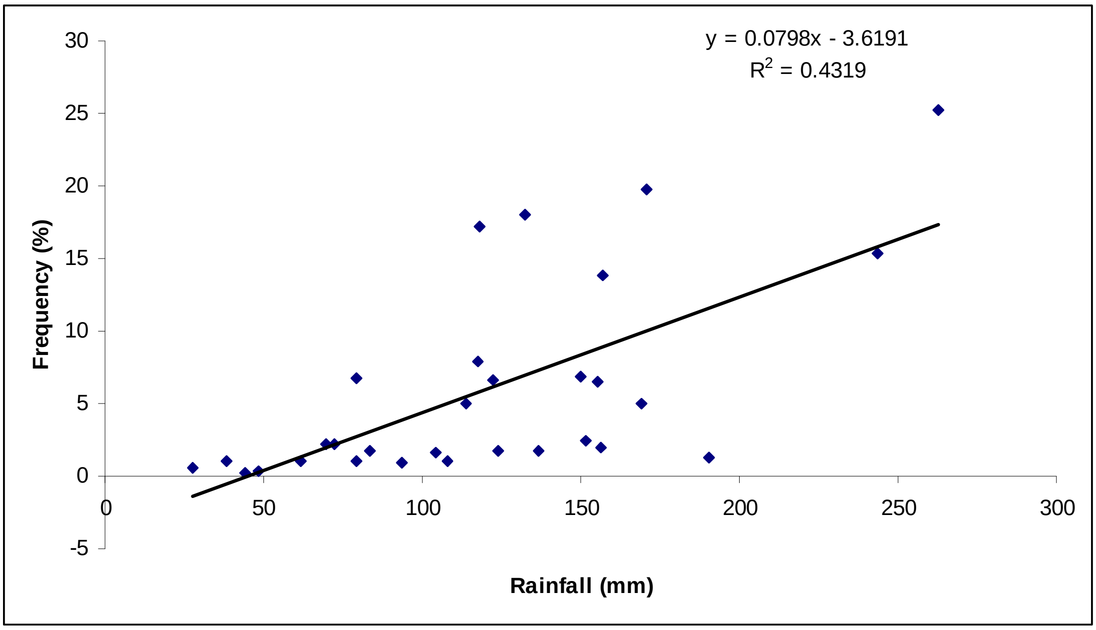


Figure 5.16 The regression of the winter rainfall against the frequency of annual species for the Bluemine Mountain line transect.

5.2.3 *Species and life form diversity*

Richness

The species richness of the perennial species (Figure 5.17) did not reveal any definite changes in a specific direction, and therefore showed no specific increase or decrease during the monitored years. The species richness of the annual species revealed large fluctuations. In general, the correlation between the species richness of the annual species and the total annual rainfall was more positive (r^2 = 0.3709) than that of perennial species richness and total annual rainfall (r^2 = 0.2824). There was a strong correlation (r^2 = 0.73) between the frequency of occurrence of the annual species and annual species richness (Figure 5.18).

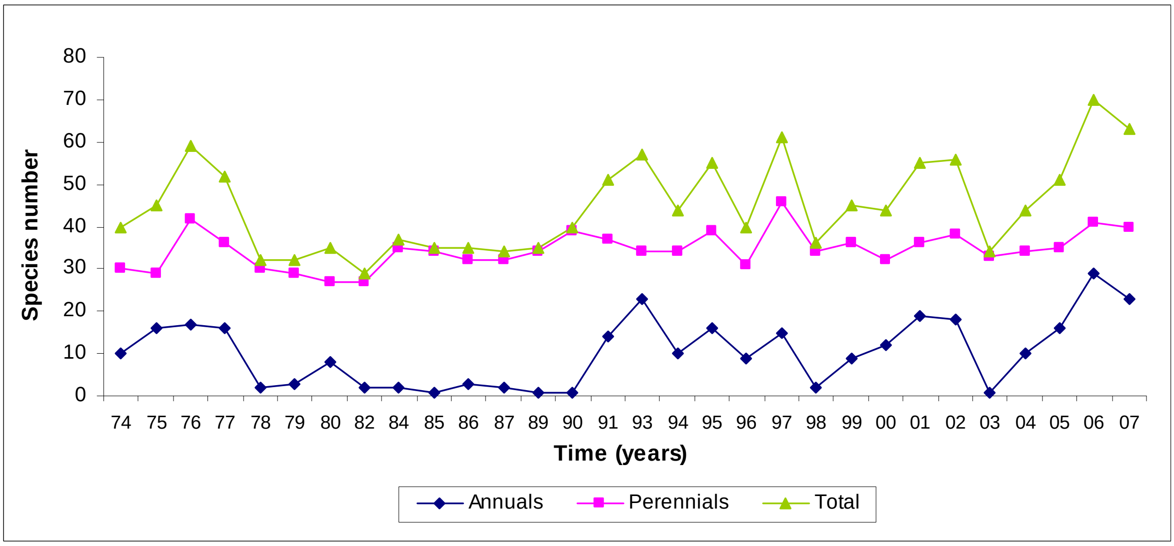


Figure 5.17 The species richness of annual and perennial species as well as total species richness during the past monitored years for the Bluemine Mountain line transect.

Table 5.2 shows that the most prevalent life forms for the Bluemine Mountain Line Transect were the therophytes and the chamaephytes.

Diversity measures

The evenness and Simpson's index of diversity remained almost unchanged over the monitoring period whereas the Shannon index mirrored the total species richness trends (Figure 5.19a). Where the number of species was used as a measure of the abundance of growth forms (Figure 5.19b) the diversity measures showed a decrease in the years with a low rainfall. A different trend was observed when the number of strikes was used as a measure of the abundance of the growth forms (Figure 5.19c) in which case there seems to be a gradual decline in diversity. In Figure 5.19a and 5.19b the changes were not directional but depended primarily on the amount of winter rainfall.

Table 5.2 Number of species per life form occurring at the Bluemine Mountain line transect

	1974	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**	**1982**	**1984**	**1985**	**1986**	**1987**	**1989**	**1990**	**1991**
Phanerophytes (P)	**4**	**2**	**2**	**3**	**2**	**3**	**3**	**2**	**3**	**3**	**3**	**3**	**3**	**3**	**3**
NP scap	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NP caesp	3	2	2	3	2	3	3	2	3	3	3	3	3	3	3
Chamaephytes (Ch)	**25**	**26**	**38**	**30**	**26**	**25**	**24**	**24**	**31**	**30**	**27**	**28**	**30**	**35**	**30**
Ch frut	12	14	18	15	13	12	12	10	15	16	11	11	15	16	15
Ch suff	0	0	2	0	0	0	0	0	0	0	0	0	1	2	1
Ch herb	1	1	1	0	1	0	0	0	0	0	0	0	1	1	0
Ch succ	12	11	17	15	12	13	12	14	16	14	16	17	13	16	14
Ch l succ	10	9	14	12	11	12	10	11	13	11	13	14	11	14	13
Ch st succ	2	2	3	3	1	1	2	3	3	3	3	3	2	2	1
Hemicryptophytes (H)	**1**	**1**	**2**	**3**	**2**	**1**	**0**	**1**	**1**	**1**	**2**	**1**	**1**	**1**	**4**
H caesp	1	1	1	2	1	1	0	1	1	1	1	1	1	1	2
H rept	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1
H ros	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1
Liana (L)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Therophytes (T)	**10**	**16**	**17**	**16**	**2**	**3**	**8**	**2**	**2**	**1**	**3**	**2**	**1**	**1**	**14**
Geophytes (G)	**1**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**
	1993	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Phanerophytes (P)	**3**	**3**	**3**	**3**	**4**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**4**	**4**
NP scap	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NP caesp	3	3	3	3	4	3	3	3	3	3	3	3	3	4	4
Chamaephytes (Ch)	**30**	**30**	**34**	**26**	**37**	**31**	**31**	**26**	**30**	**32**	**30**	**28**	**29**	**32**	**31**
Ch frut	15	12	18	15	19	16	17	16	18	18	18	13	16	16	19
Ch suff	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1
Ch herb	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0
Ch succ	14	17	16	11	17	14	14	10	12	13	12	15	13	15	11
Ch l succ	12	14	14	10	16	13	13	9	11	12	11	13	12	14	10
Ch st succ	2	3	2	1	1	1	1	1	1	1	1	2	1	1	1
Hemicryptophytes (H)	**1**	**1**	**2**	**2**	**4**	**0**	**2**	**3**	**3**	**3**	**0**	**3**	**3**	**4**	**5**
H caesp	1	1	1	1	2	0	2	1	1	2	0	1	2	2	3
H rept	0	0	0	0	1	0	0	1	1	1	0	1	0	1	1
H ros	0	0	1	1	1	0	0	1	1	0	0	1	1	1	1
Liana (L)	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**
Therophytes (T)	**23**	**10**	**16**	**9**	**15**	**2**	**9**	**12**	**19**	**18**	**1**	**10**	**16**	**29**	**23**
Geophytes (G)	**1**	**1**	**1**	**1**	**1**	**0**	**0**	**1**	**1**	**1**	**0**	**2**	**2**	**3**	**1**

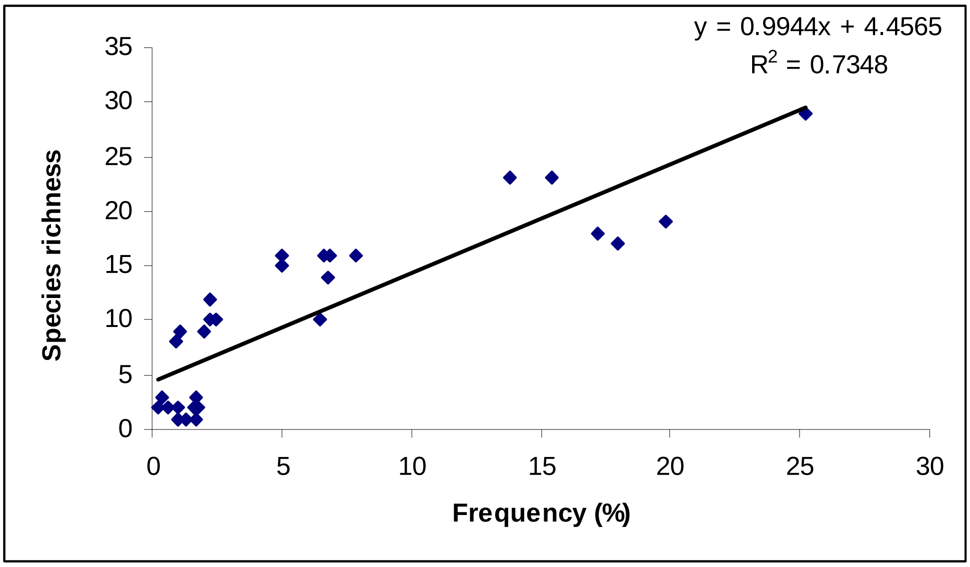


Figure 5.18 The regression of the frequency of strike for the annual species against the annual species richness for the Bluemine Mountain line transect.

5.2.4 *Species composition*

Individual species

The most abundant perennial species at Blue Mine Mountain were *Eriocephalus microphyllus* and *Tripteris sinuata* (Appendix 8.2) and *Ruschia elineata*. The former two species are both palatable species and revealed an increase (r^2 = 0.29; r^2 = 0.76) over the monitored years (Figure 5.20a), whereas *Ruschia elineata*, an unpalatable species, showed a decrease (r^2 = 0.56) over the monitored years (Figure 5.20b). In general, the annual species showed large fluctuations in abundance. The most abundant annual species at this line transect was *Galenia sarcophylla* (Appendix 8.2), a species with a low grazing index value (Du Toit 2003), which showed a decreasing trend (r^2 = 0.39) over the monitored years (Figure 5.20c).

Community composition

The changes in the species composition were detected by the use of Correspondence Analysis (CA) in the computer programme CANOCO. The scatter diagram of data at the Bluemine Mountain line transect indicated most of the early years towards the centre and slightly towards the left of the ordination space and the later years progressively more towards the right of the ordination space. Therefore in the ordination of the total floristic data of this line transect a weak gradient in direction could be observed (Figure 5.21a).

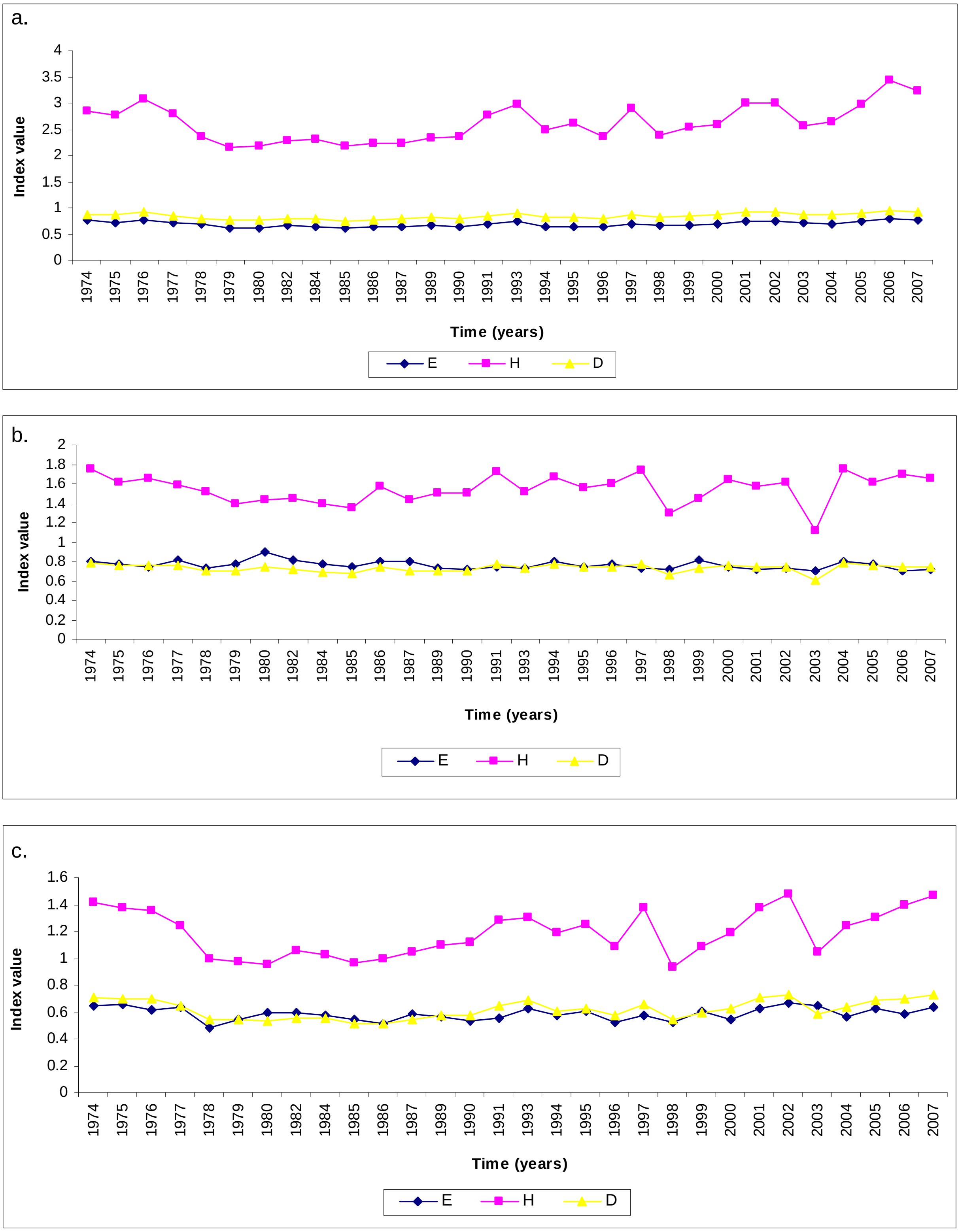


Figure 5.19. The diversity measures at the Bluemine Mountain line transect, using (a) the first strikes of all species, (b) the number of species in the different life forms and (c) the number of strikes in the different life forms. E = species evenness, H = Shannon's diversity index and D = Simpson's diversity index.

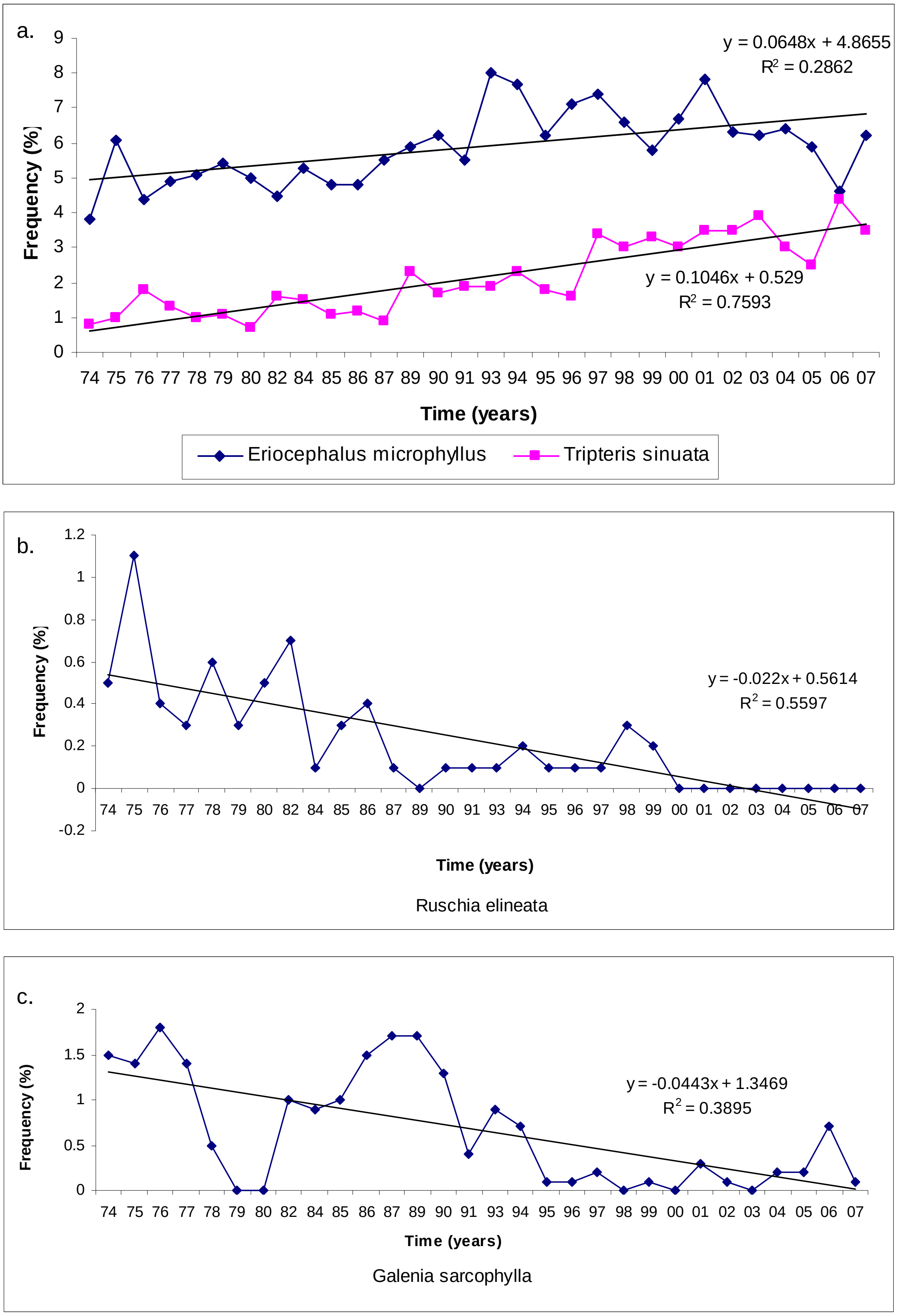
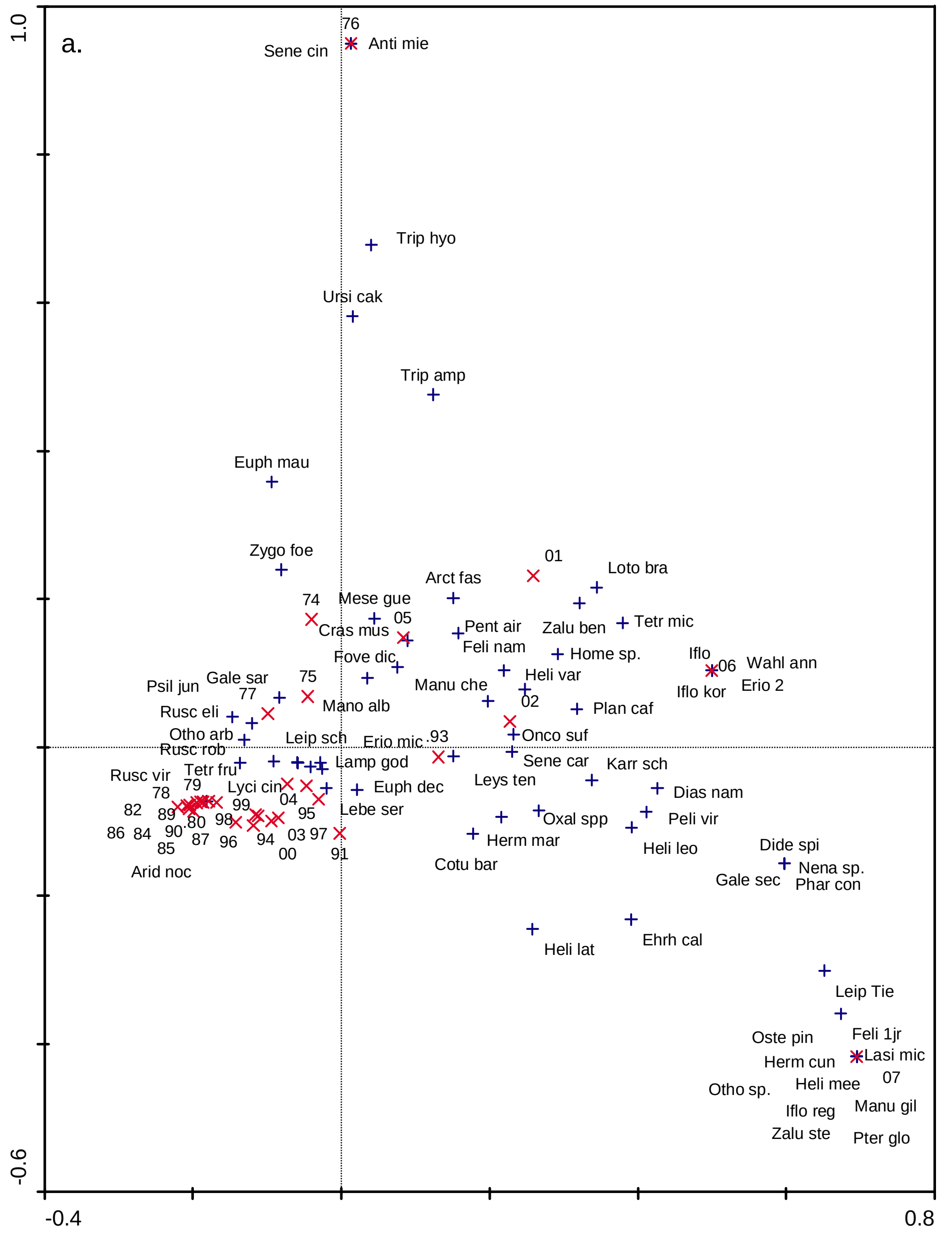


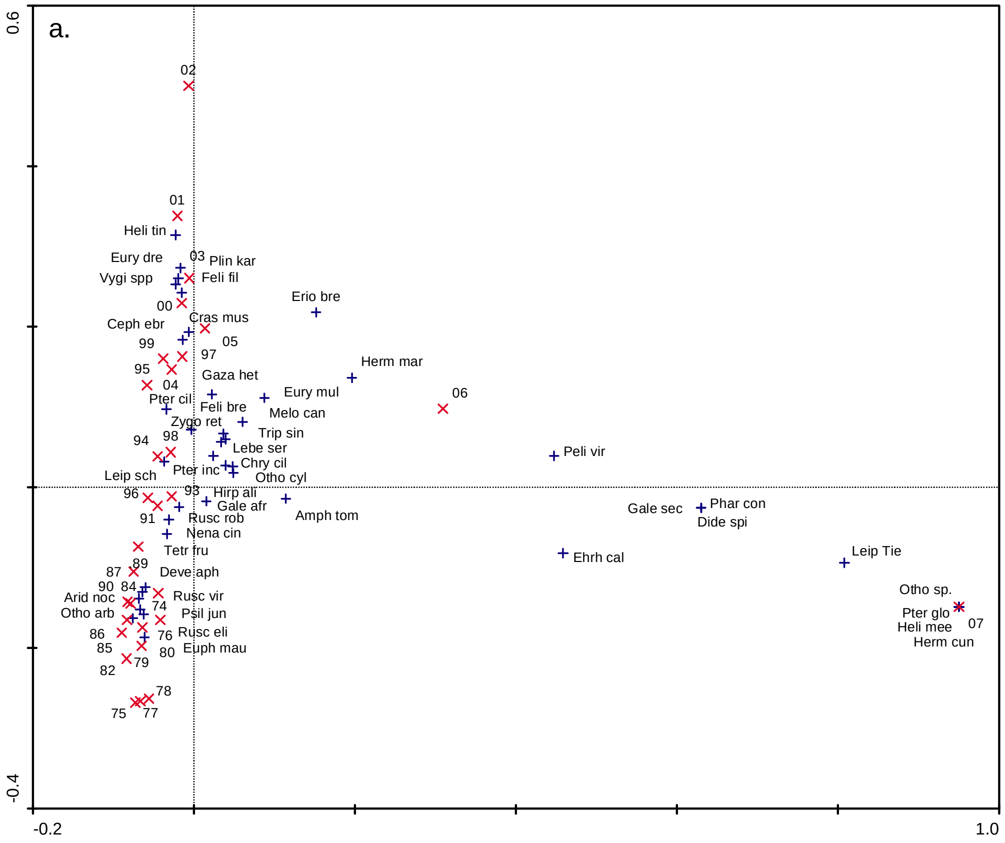
Figure 5.20 Changes in frequency of selected (a) palatable and (b) unpalatable perennial species and (c) an annual species at Bluemine Mountain.



b.

Axes :	1	2	3	4	Total inertia
Eigenvalues :	0.238	0.160	0.121	0.059	1.019
Cumulative percentage					
variance of species data :	23.3	39.1	50.9	56.8	
Sum of all eigenvalues :					1.019

Figure 5.21 (a) Scatter diagram produced by a Correspondence Analysis (CA) ordination showing the position of all species (the most important 66 species of the total 154 species) relative to the monitored years for the Bluemine Mountain line transect. The red x-marks represent the years and the blue crosses the species. (b) Details of the CA ordination.



b.					
Axes :	1	2	3	4	Total inertia
Eigenvalues :	0.162	0.066	0.030	0.027	0.518
Cumulative percentage					
variance of species data :	31.2	44.1	49.9	55.1	
Sum of all eigenvalues :					0.518

Figure 5.22 (a) Scatter diagram produced by a Correspondence Analysis (CA) ordination showing the position of the perennial species (the 44 most important species of the 91 species) relative to the monitored years for the Bluemine Mountain line transect. The red x-marks represent the years and the blue crosses the species. (b) Details of the CA ordination.

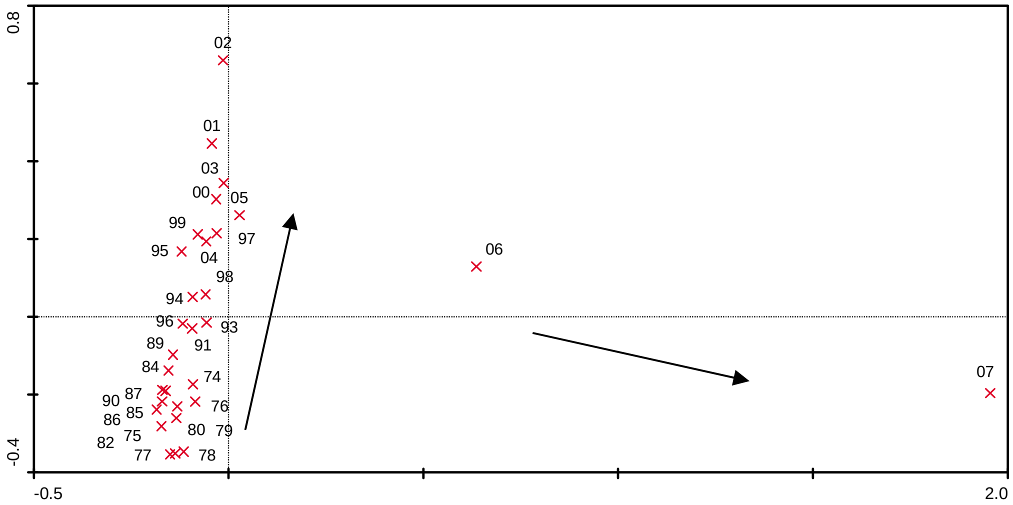


Figure 5.23 Scatter diagram produced by a Correspondence Analysis ordination of the floristic data of the perennial species indicating the change occurring over the monitoring period, where the arrows indicates the progress in years, in the Bluemine Mountain line transect.

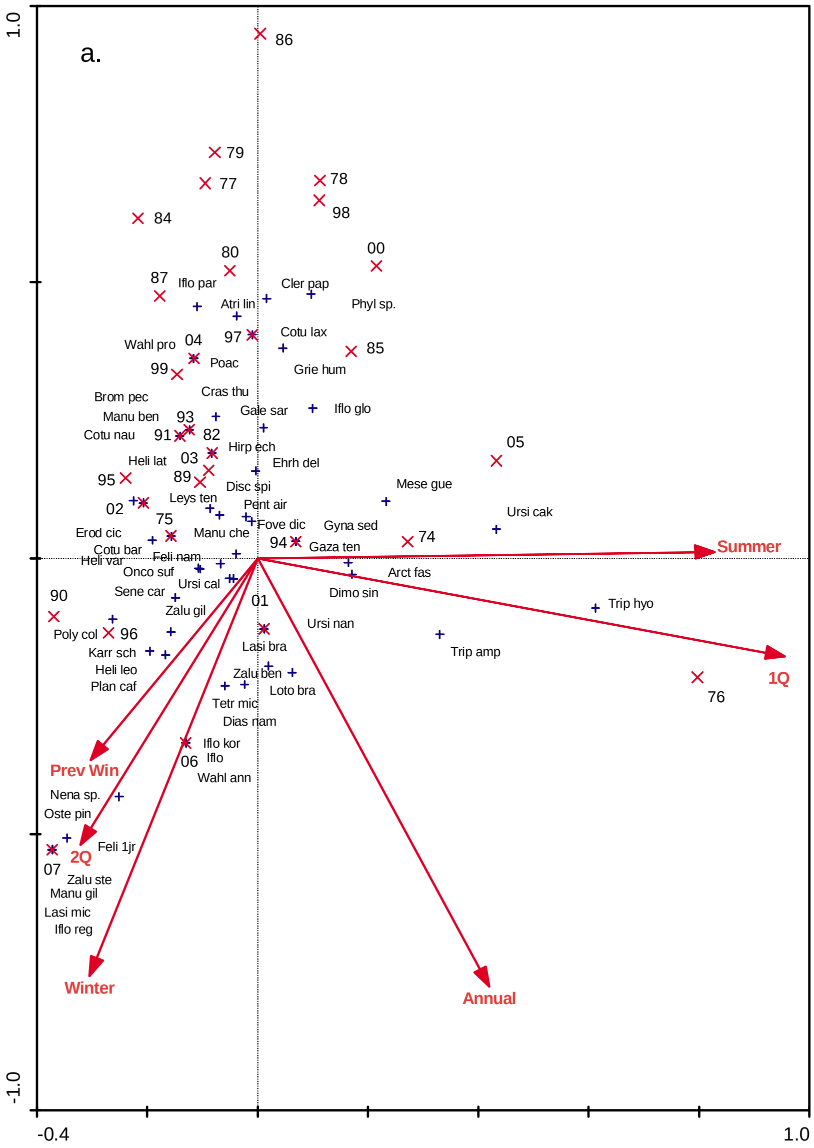
Perennial species composition

When the floristic data of only the perennial species (Figures 5.22) was used in the ordination the direction of the vegetation change was more apparent than when all species were used in the ordination. The direction of the change from the earlier years to the more recent years has been indicated by arrows in Figure 5.23. Many species were associated with the earlier years whereas the more recent years were associated with only a few species such as *Pteronia glomerata* and *Hermannia cuneifolia* (Figure 5.22). The vegetation occurring during the earlier years contained a larger component of unpalatable species left after the heavy grazing by livestock until 1969, than the more recent years.

Annual species composition

The change in the annual species composition was analysed by Canonical Correspondence Analysis with regards to the rainfall because of the relationship between rainfall and short-lived vegetation. Rainfall was expressed in different ways: the first quarter rainfall (1Q), second quarter rainfall (2Q), summer rainfall, winter rainfall, rainfall of the previous winter, and annual rainfall.

Most of the annual species occurring on the Bluemine Mountain line transect did not show a strong association with a high winter rainfall (Figure 5.24). The annual species also showed no directional trend in species composition over the monitored years. However, there were fluctuations in the annual species composition because these species react towards the timing and quantity of the rainfall and consequently years with similar rainfall patterns were grouped together. There was a low (near to zero) correlation between summer rainfall and the winter and second quarter rainfall.



b. Axes :	1	2	3	4	Total inertia
Eigenvalues :	0.363	0.207	0.162	0.088	3.056
Species-environment correlations :	0.953	0.786	0.835	0.868	
Cumulative percentage variance					
of species data :	11.9	18.7	24.0	26.9	
of species-environment relation:	39.2	61.5	79.0	88.5	
Sum of all eigenvalues :					3.056
Sum of all canonical eigenvalues :					0.928

Figure 5.24 (a) Scatter diagram produced by a Canonical Correspondence analysis (CCA) ordination showing the position of the annual species (58 species) relative to the years and rainfall at the Bluemine Mountain line transect. The red x-marks represent the years and the blue crosses the species. 1Q = rainfall from January to March of the current year, 2Q = rainfall from April to June of the current year, Summer = rainfall from October to December of the previous year plus January to March of the current year, Winter = rainfall from April to August of the current year, Prev Win = rainfall from April to September of the previous year and Annual = the annual rainfall of the current year. (b) Details of the CCA ordination.

5.2.5 *Grazing capacity*

Changes in palatable and unpalatable species for the Bluemine Mountain line transect were examined. The palatability of the plant species was determined by using the subjective grazing index values as indicated by Du Toit (1996, 2003). To calculate the grazing capacity by the grazing index method (GIM) of Du Toit (1996) the veld condition score was comparing with a benchmark with a known grazing capacity.

The veld condition score showed a steady increase over time and this was reflected by the improvement (r^2 = 0.53) in the grazing capacity (Figure 5.25).

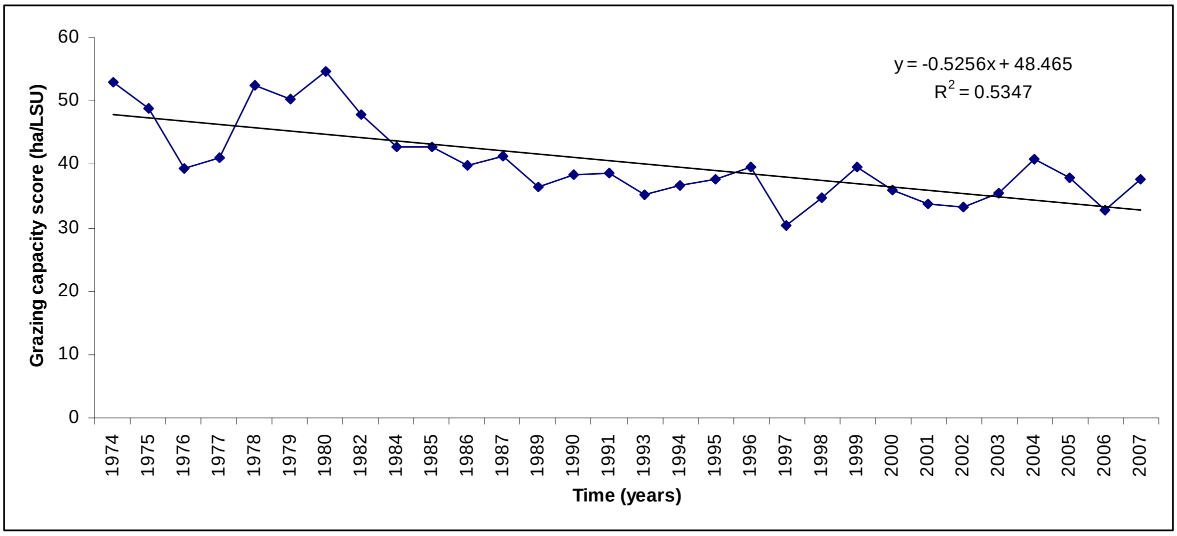


Figure 5.25 The grazing capacity (ha/LSU) throughout the monitored years for the vegetation occurring in the Bluemine Mountain line transect. LSU = Large Stock Unit.

5.3 Goegap Plains

5.3.1 *Rainfall*

Figure 5.26 shows the fluctuation in the rainfall at the Goegap Plains line transect with an increase in rainfall during the last three monitored years. The annual rainfall varied approximately threefold from 102 mm up to 303.8 mm rain. Such fluctuations in annual rainfall are a common occurrence for semi-arid and arid environments (Le Roux & Van Rooyen 1999, Van Rooyen 1999, Ward 2006). The winter rainfall was much higher than the summer rainfall in most years.

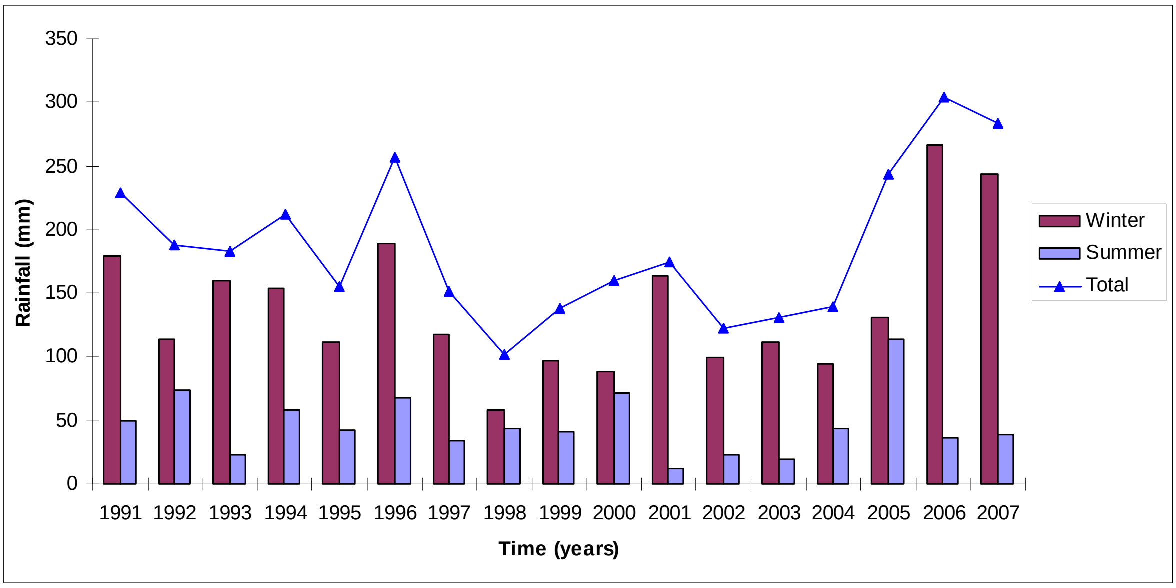


Figure 5.26 The rainfall during the monitored years at the Goegap Plains line transect. Summer = rainfall in the summer months (January to March and October to December of the current year), Winter = rainfall in the winter months (April to September) and Total = the total annual rainfall (January to December).

5.3.2 *Frequency of occurrence of annual and perennial species*

The frequency of occurrence of the perennial species at the Goegap Plains line transect ranged from 3.2% in 2003 to 20.6% in 2000, but did not reveal any changes in a specific direction over time (Figure 5.27). In contrast, the frequency of the annual species showed a relationship with the winter rainfall (r^2 = 0.58; Figure 5.28). The frequency of the annuals ranged from 0.9% in 2003 to 34.7% in 1993. It was clear that the frequency of strikes of the annual species exceeded that of the perennial species during the wet years, although the opposite was true for years with a low winter rainfall when perennial species had a higher frequency of occurrence than the annual species.

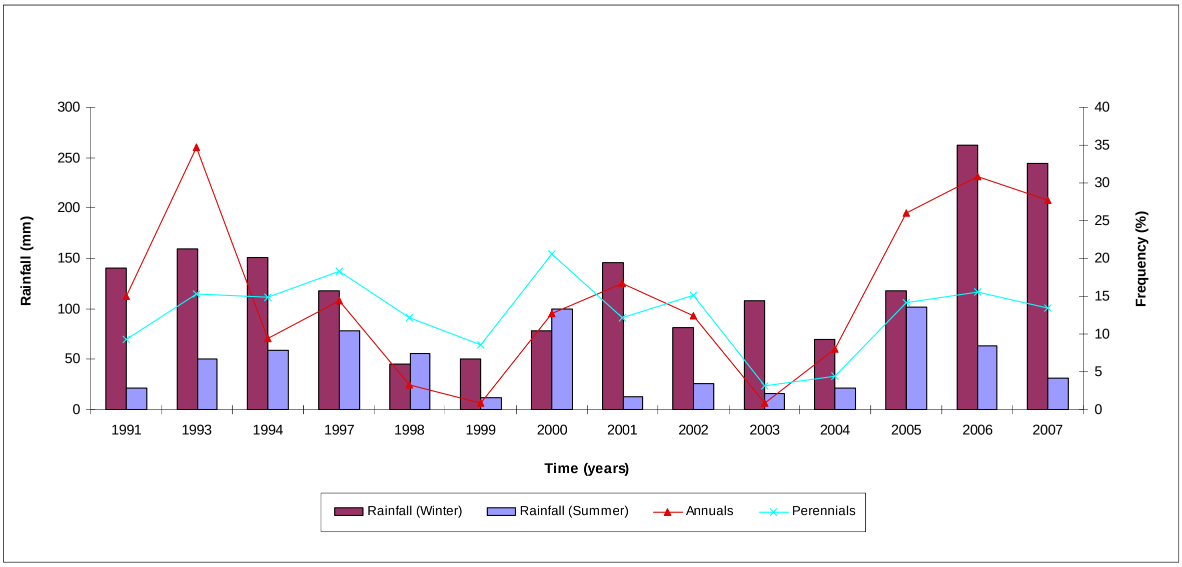


Figure 5.27 The frequency of strike of the annual and perennial species and the winter and summer rainfall during the monitored years for the Goegap Plains line transect. The blue line represents the perennial species, whereas the red line represents the annual species. The summer rainfall stretches from October to December of the previous year and January to March of the current year, whereas the winter rainfall includes the rainfall from April to August of the current year.

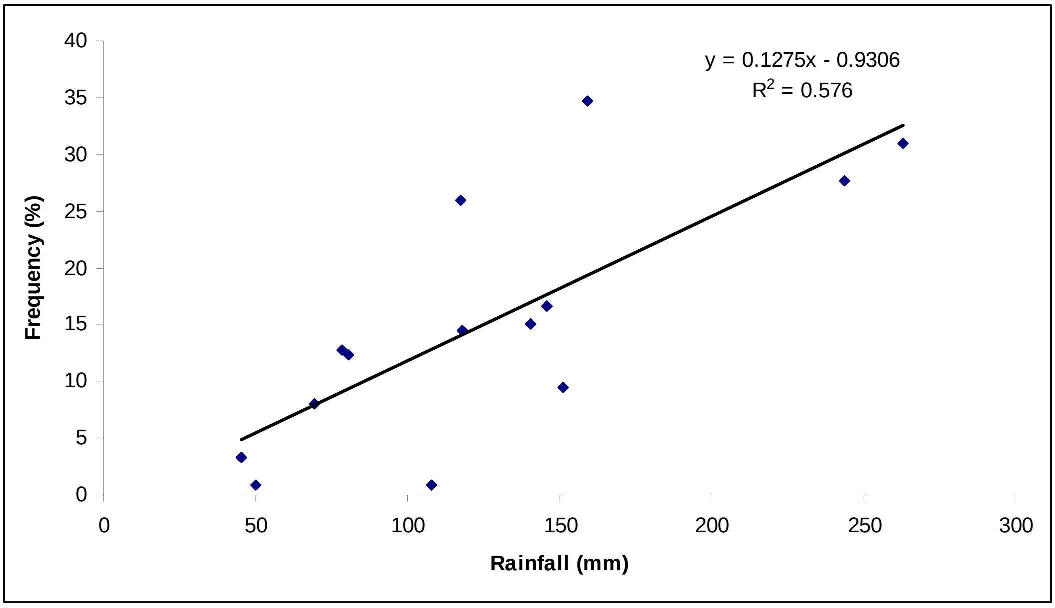


Figure 5.28 The regression of the winter rainfall against the frequency of annual species for the Goegap Plains line transect.

5.3.3 *Species and life form diversity*

Species richness

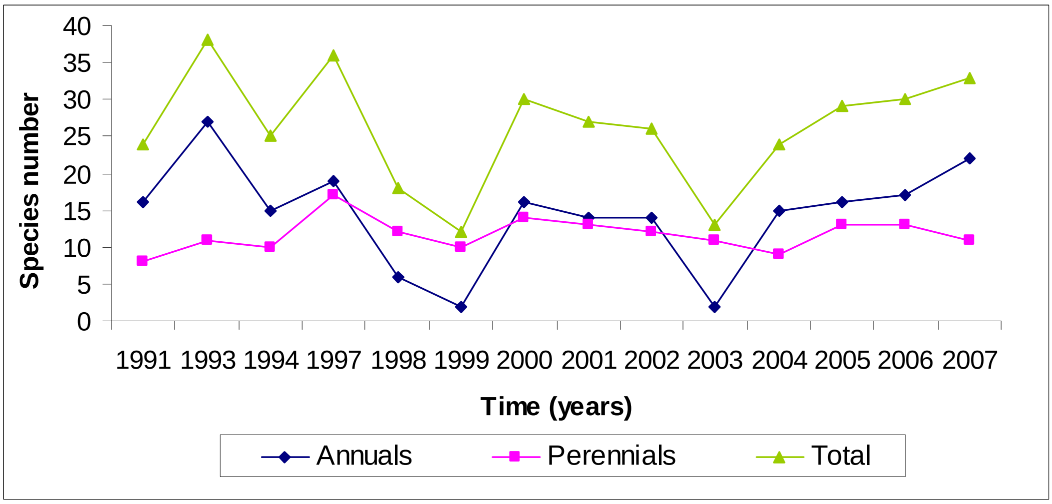


Figure 5.29 The species richness of annual and perennial species as well as total species richness during the past monitored years for the Goegap Plains line transect.

The species richness of the perennial species (Figure 5.29) did not reveal any definite changes in a specific direction, and therefore showed no specific increase or decrease during the past monitored years. The species richness of the annual species revealed large fluctuations. In general, the correlation between the species richness of the annual species and the total annual rainfall was more positive (r^2 = 0.2807) than that of perennial species richness and total annual rainfall (r^2 = 0.0027). There was a strong correlation (r^2 = 0.72) between the frequency of occurrence of the annual species and annual species richness (Figure 5.30).

Table 5.3 indicates that the most prevalent life forms for the Goegap Plains line transect were the therophytes and the chamaephytes.

Table 5.3 Number of species per life form occurring at the Goegap Plains line transect

	1991	**1993**	**1994**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Phanerophytes (P)	**0**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**0**	**1**	**1**
NP scap	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NP caesp	0	1	1	1	1	1	1	1	1	1	1	0	1	1
Chamaephytes (Ch)	**7**	**7**	**6**	**11**	**8**	**7**	**9**	**8**	**8**	**8**	**6**	**9**	**9**	**8**
Ch frut	3	3	2	5	4	3	5	5	4	4	4	5	3	4
Ch suff	0	0	0	1	1	1	1	0	0	1	0	0	1	1
Ch herb	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ch succ	4	4	4	5	3	3	3	3	4	3	2	4	5	3
Ch l succ	3	3	3	4	2	2	2	2	3	2	2	3	4	2
Ch st succ	1	1	1	1	1	1	1	1	1	1	0	1	1	1
Hemicryptophytes (H)	**1**	**3**	**3**	**5**	**3**	**2**	**4**	**4**	**3**	**2**	**2**	**4**	**3**	**2**
H caesp	1	3	3	5	3	2	4	4	3	2	2	3	3	2
H rept	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H ros	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Liana (L)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Therophytes (T)	**16**	**27**	**15**	**19**	**6**	**2**	**16**	**14**	**14**	**2**	**15**	**16**	**17**	**22**
Geophytes (G)	**2**	**3**	**3**	**3**	**3**	**2**	**3**	**2**	**2**	**2**	**2**	**2**	**1**	**2**

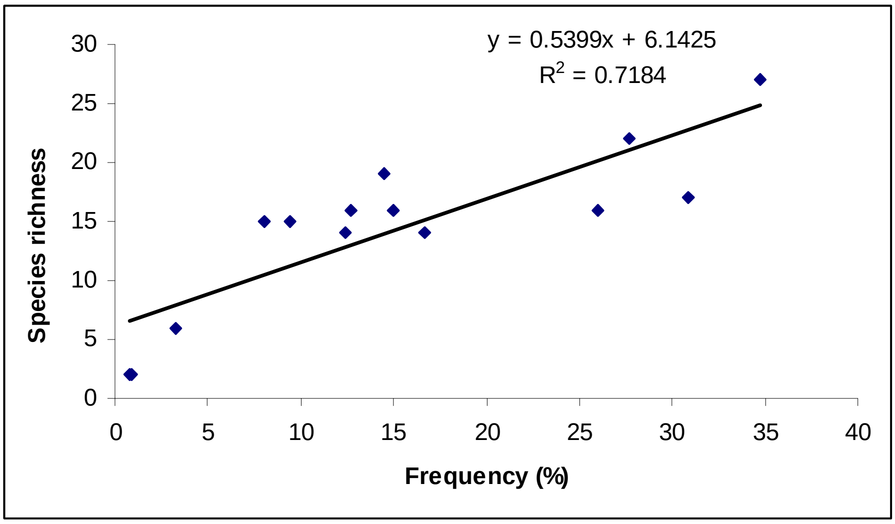


Figure 5.30 The regression of the frequency of strike for the annual species against the annual species richness for the Goegap Plains line transect.

Diversity measures

The evenness (E) and Simpson's index of diversity (D) remained almost unchanged over the monitoring period whereas the Shannon index (H) mirrored the species richness trends (Figure 5.31a). Where the number of species was used as a measure of the abundance of growth forms (Figure 5.31b) the diversity measures showed an increase in the years with a low winter rainfall. A different trend was observed when the number of strikes was used as a measure of the abundance of the growth forms (Figure 5.31c) in which case the evenness and Simpson's index of diversity stayed mostly unchanged but there seemed to be a gradual decline in the Shannon index of diversity during the last couple of monitored years. In Figure 5.31a and 5.31b the changes were not directional but depended primarily on the amount of winter rainfall.

5.3.4 *Species composition*

Individual species

The most abundant perennial species at the Goegap Plains line transect were *Aptosimum spinescens, Drosanthemum hispidum* and *Psilocaulon junceum. Drosanthemum hispidum* (Appendix 8.3) did not reveal any decrease or increase over the monitored years (r^2 = 0.0045; Figure 5.32a), However, *Aptosimum spinescens* and *Psilocaulon junceum*, both unpalatable species, showed a decreasing trend (r^2 = 0.51; r^2 = 0.55) in the Goegap plains line transect (Figure 5.32b).

In general the annual species showed large fluctuations in abundance. The most abundant annual species at this line transect were all unpalatable species, namely *Galenia sarcophylla*, *Atriplex* *lindleyi* subsp*. inflata*, *Foveolina dichotoma* and *Osteospermum pinnatum*. *Galenia sarcophylla* did not reveal any notable change in direction throughout the monitored years (r^2 = 0.06; Figure 5.33a) whereas *Atriplex lindleyi* subsp*. inflata*, *Foveolina dichotoma* and *Osteospermum pinnatum* showed a decreasing trend (r^2 = 0.8; r^2 = 0.1; r^2 = 0.19) throughout the monitored years (Figure 5.33b). This change is an indication of veld recovery.

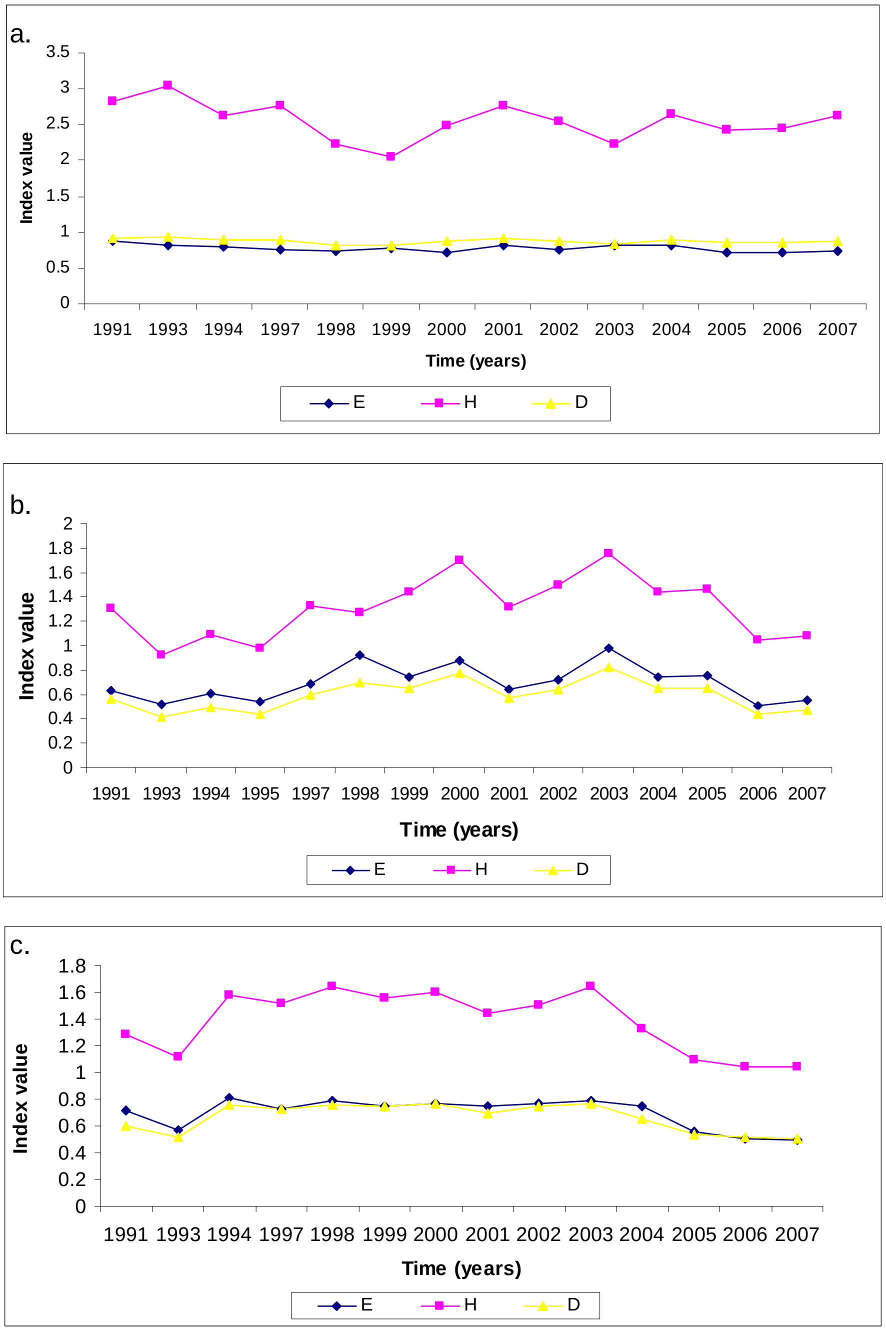


Figure 5.31 The diversity measures in the Goegap Plains line transect, using (a) the first strikes of all species, (b) the number of species in the different life forms and (c) the number of strikes in the different life forms, E = species evenness, H = Shannon's diversity index and D = Simpson's diversity index.

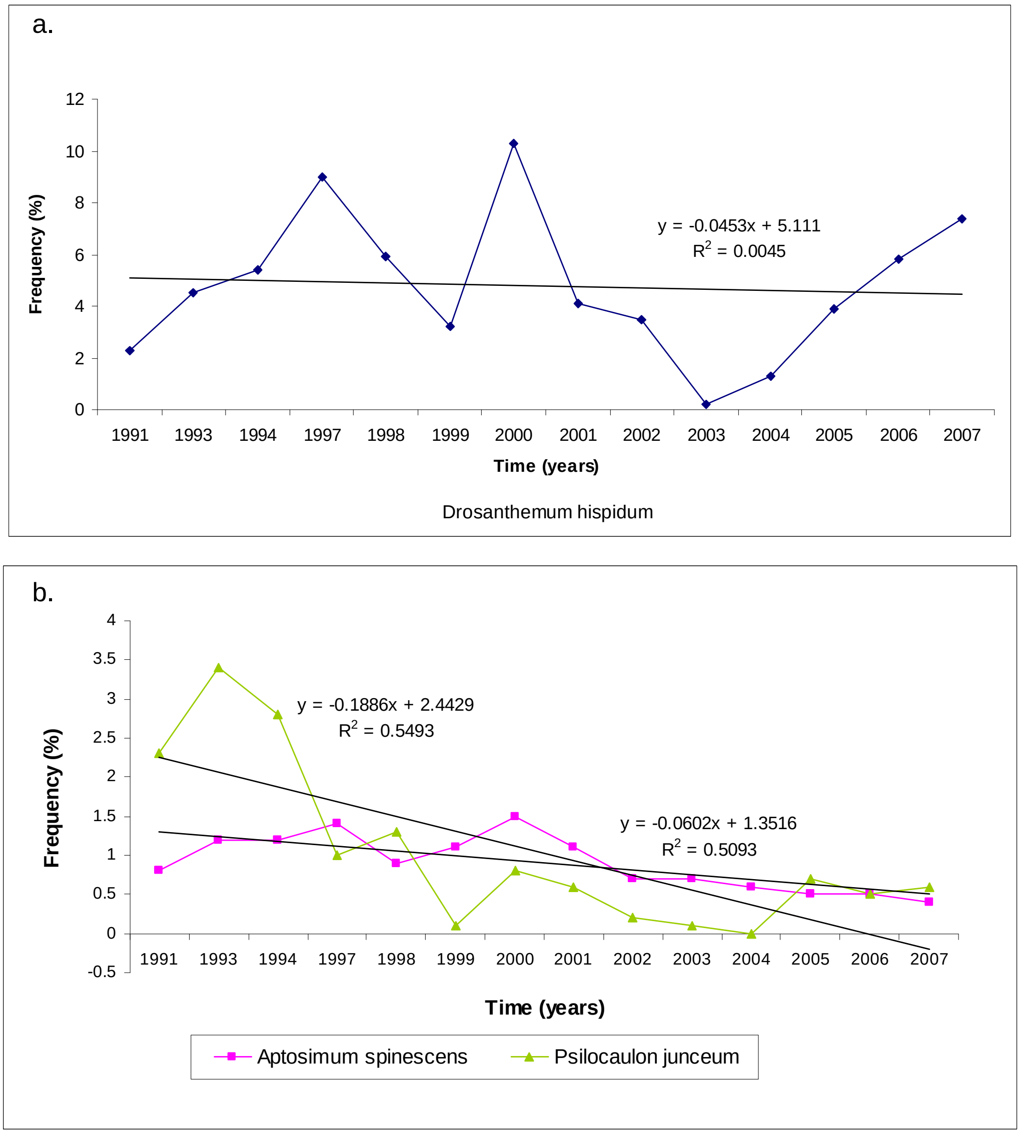


Figure 5.32 Changes in frequency of (a) a selected palatable perennial species and (b) selected unpalatable perennial species at Goegap Plains line transect.

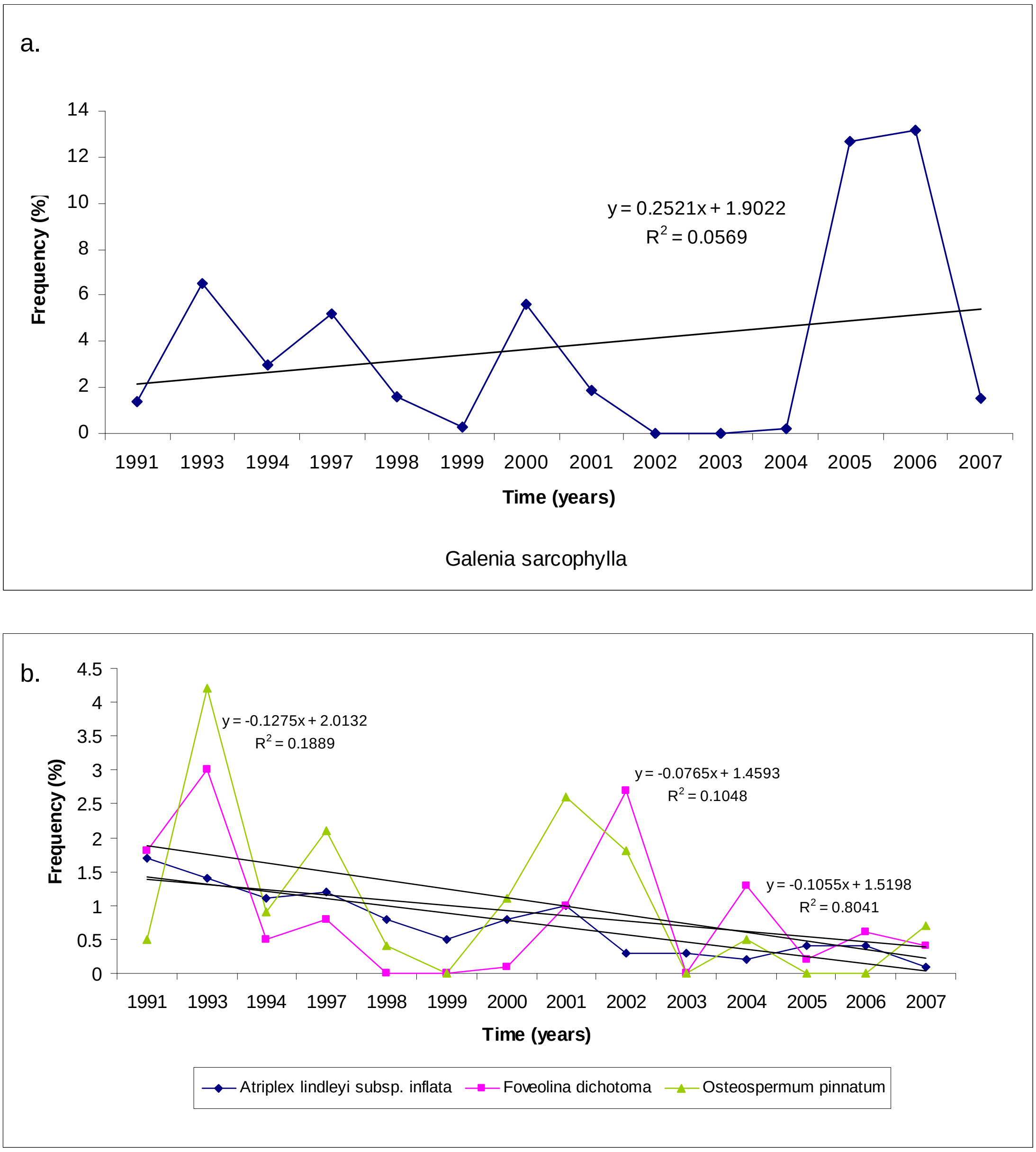
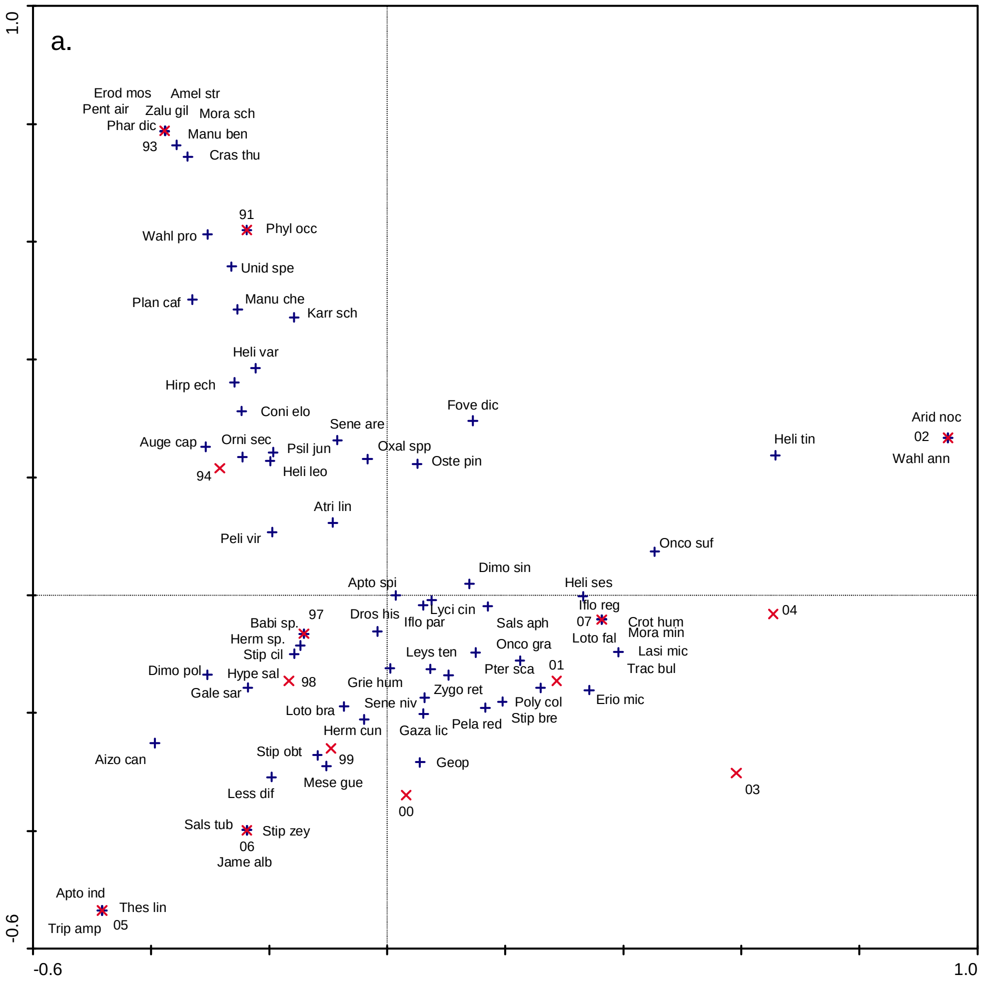


Figure 5.33 Changes in frequency of selected annual species at Goegap Plains line transect. (a) *Galenia sarcophylla* and (b) *Atriplex lindleyi* subsp. *inflata, Foveolina dichotoma* and *Osteospermum pinnatum.*

Community composition

The changes in the composition of all species combined were detected by the use of Correspondence Analysis (CA) in the computer programme CANOCO. The scatter diagram of the floristic data of all the species in the Goegap Plains line transect revealed that some directional change did occur (Figure 5.34a) with the general direction of the trend indicated by the arrow in Figure 5.34c.



b.

Axes :	1	2	3	4	Total inertia
Eigenvalues :	0.303	0.253	0.228	0.151	1.297
Cumulative percentage variance of species data :	23.3	42.8	60.4	72.0	
Sum of all eigenvalues :					1.297

Figure 5.34 (a) Scatter diagram produced by a Correspondence Analysis (CA) ordination showing the position of all species (74 species) relative to the monitored years for the Goegap Plains line transect. The red x-marks represent the years and the blue crosses the species. (b) Details of the CA ordination. (c) (On next page) The Correspondence Analysis (CA) scatter diagram with the arrow indicating the direction of change at the Goegap Plains line transect.

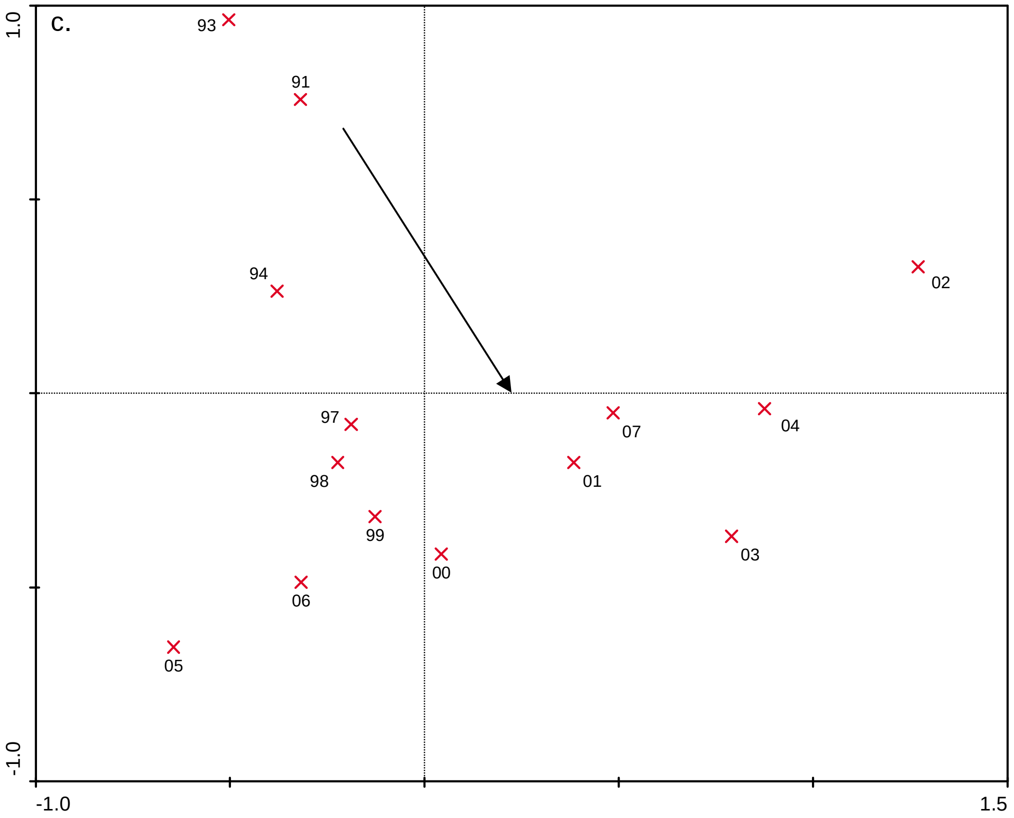


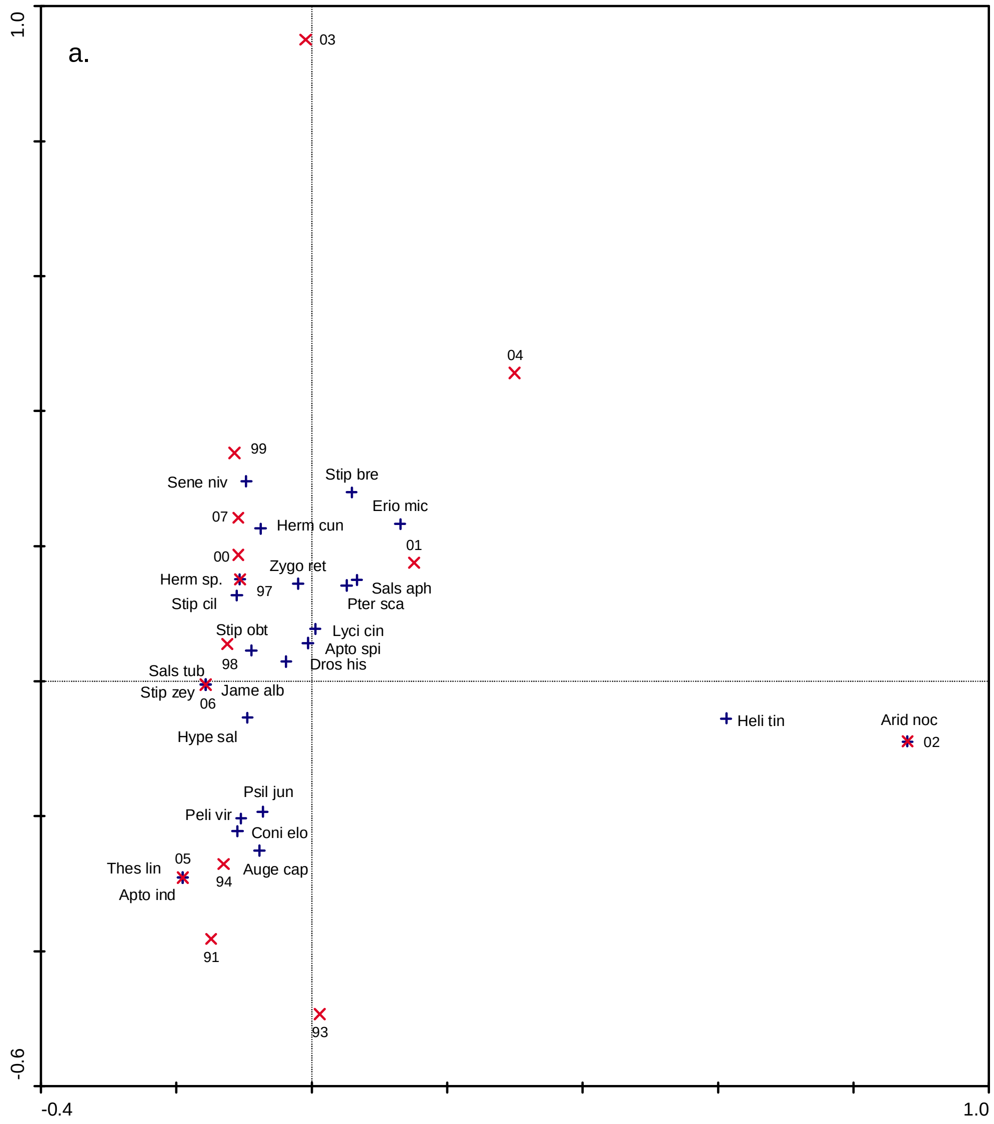
Figure 5.34 (continued)

Perennial species composition

The perennial species of the Goegap Plains line transect (Figure 5.35a) did not reveal a clear gradient as time proceeded.

Annual species composition

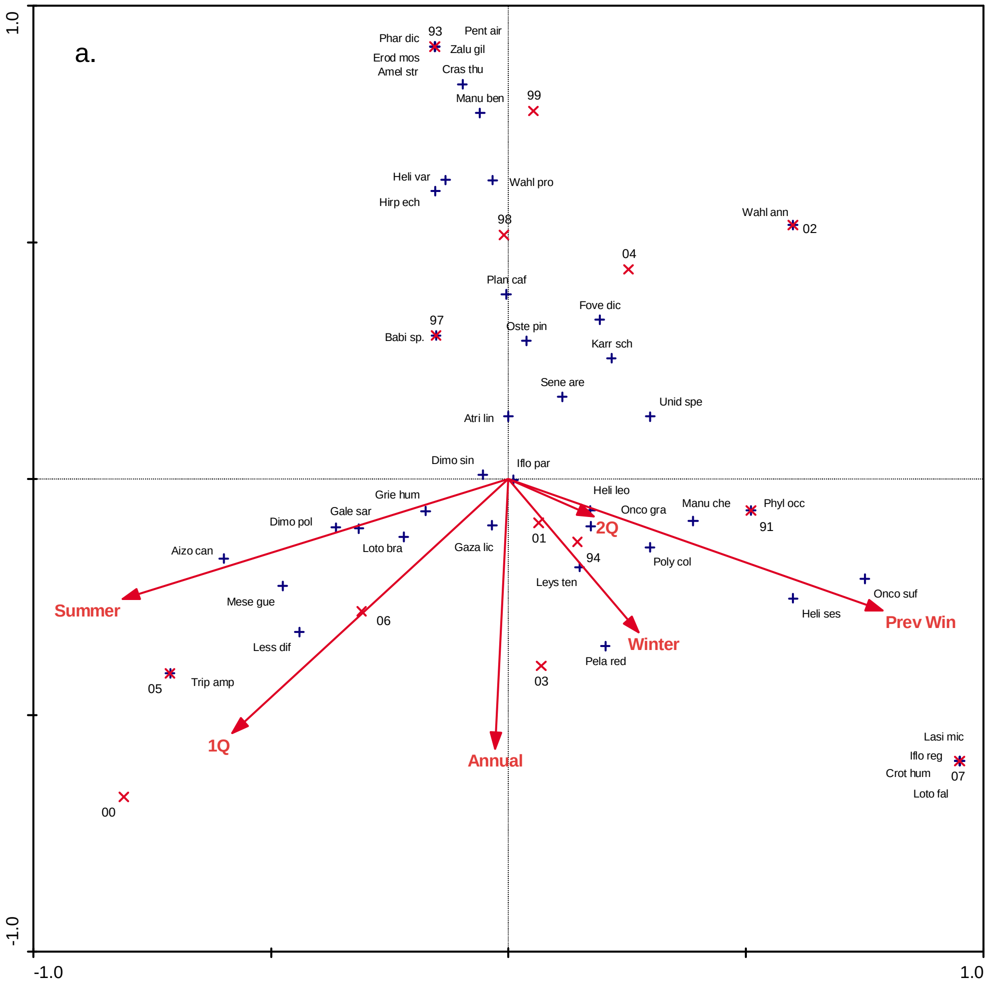
The change in the annual species composition was analysed by Canonical Correspondence Analysis (CCA) with regards to the rainfall. The annual species occurring in the Goegap Plains line transect also showed no directional trend in species composition over the monitored years. Most of the annual species occurring in this line transect did not show a strong association with a high winter rainfall (Figure 5.36). However, there were some annual species that preferred a high value for summer or first quarter (1Q) rainfall, such as *Aizoon canariense, Mesembryanthemum guerichianum* and *Tripteris amplectens*. There was a low (near to zero) correlation between summer rainfall and the winter and second quarter rainfall.



b.

Axes :	1	2	3	4	Total inertia
Eigenvalues :	0.373	0.105	0.087	0.059	0.747
Cumulative percentage					
variance of species data :	49.9	64.0	75.7	83.5	
Sum of all eigenvalues :					0.747

Figure 5.35 (a) Scatter diagram produced by a Correspondence analysis (CA) ordination showing the position of the perennial species (25 species) relative to the monitored years for the Goegap Plains line transect. The red x-marks represent the years and the blue crosses the species. (b) Details of the CA ordination.



b. Axes	1	2	3	4	Total inertia
Eigenvalues :	0.360	0.240	0.125	0.088	1.345
Species-environment correlations :	0.974	0.883	0.913	0.913	
Cumulative percentage variance					
of species data :	26.8	44.6	53.9	60.4	
of species-environment relation:	39.3	65.5	79.1	88.7	
Sum of all eigenvalues :					1.345
Sum of all canonical eigenvalues :					0.917

Figure 5.36 (a) Scatter diagram produced by a Canonical Correspondence Analysis (CCA) ordination showing the position of the annual species (43 species) relative to the years and rainfall in the Goegap Plains line transect. The red x-marks represent the years and the blue crosses the species. 1Q = rainfall from January to March of the current year, 2Q = rainfall from April to June of the current year, Summer = rainfall from October to December of the previous year plus January to March of the current year, Winter = rainfall from April to August of the current year, Prev Win = rainfall from April to September of the previous year and Annual = the annual rainfall of the current year. (b) Details of the CCA ordination.

5.3.5 *Grazing capacity*

The grazing index method (GIM) as proposed by Du Toit (1996) for the Karoo veld was applied to calculate the grazing capacity of the vegetation on the Goegap Plains. The method involves calculating the veld condition score and by comparing this value with a benchmark with a known grazing capacity, the grazing capacity of the range under consideration can be calculated.

The fluctuations in veld condition score and consequently grazing capacity did not show directional trends (r^2 = 0.04; Figure 5.37) and no improvement in grazing capacity could be demonstrated. The exceptionally low grazing capacity in 2003 was the result of the winter rainfall for that year being low and occurring at the end of the growing season.

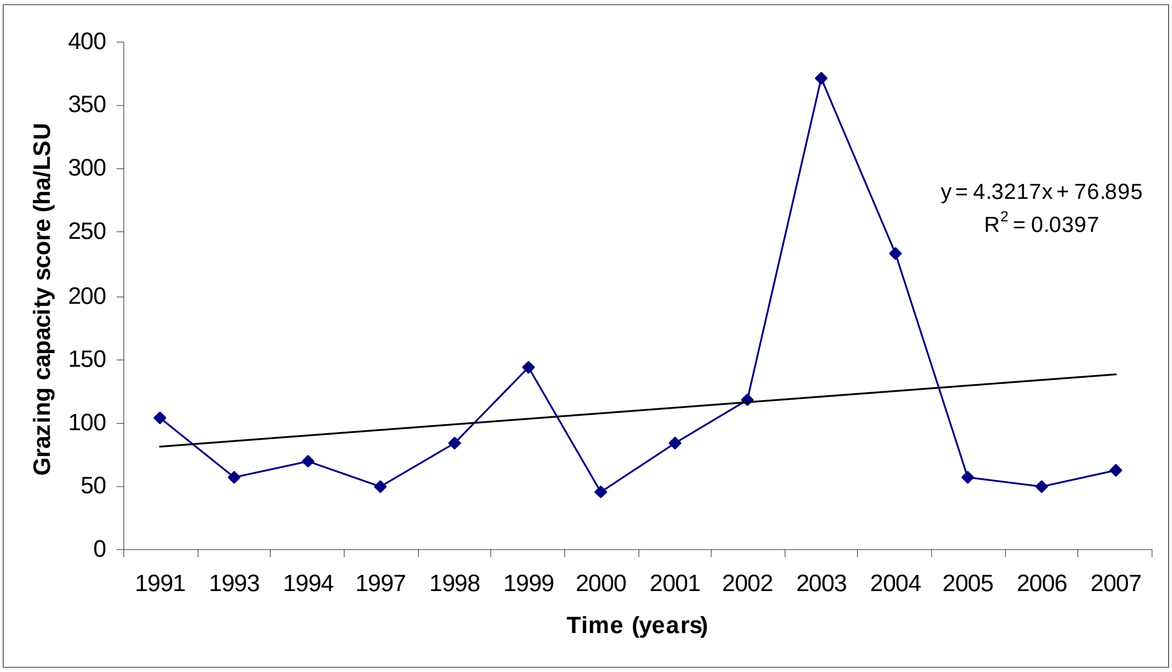


Figure 5.37 The grazing capacity (ha/LSU) throughout the monitored years for the vegetation occurring in the Goegap Plains line transect. LSU = Large Stock Unit.

5.4 Jaleeg Plains

5.4.1 *Rainfall*

Figure 5.38 shows the fluctuation in the rainfall at the Jaleeg Plains line transect with an increase in rainfall during the last two monitored years. The annual rainfall varied approximately fivefold from 62.9 mm up to 303.8 mm rain. The winter rainfall was much higher than the summer rainfall, indicating that the area would qualify as a winter rainfall region.

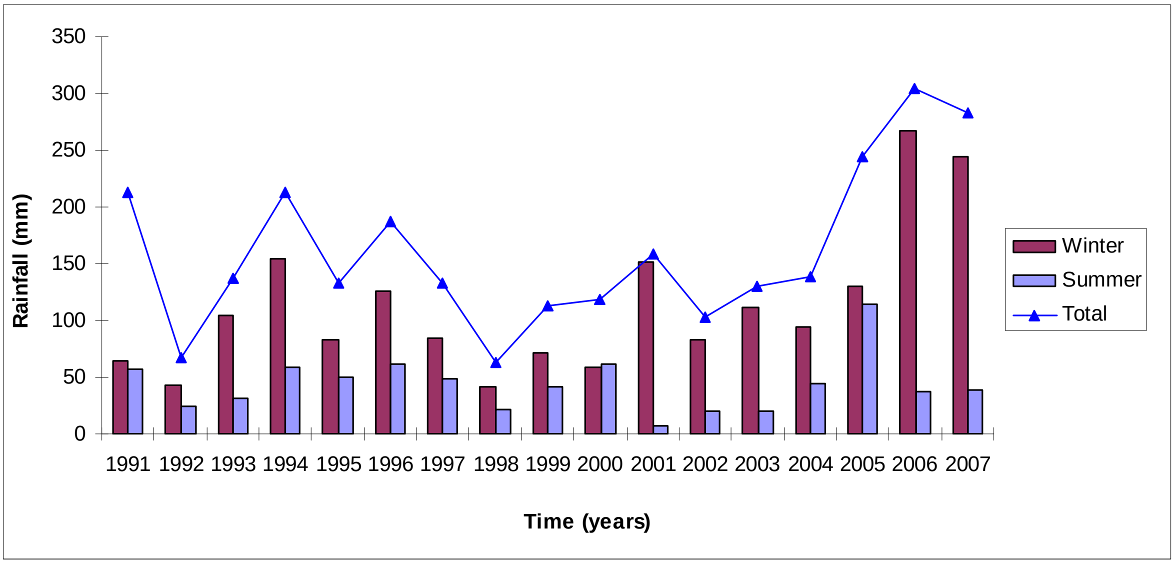


Figure 5.38 The rainfall during the monitored years at the Jaleeg Plains line transect. Summer = rainfall in the summer months (January to March and October to December of the current year), Winter = rainfall in the winter months (April to September) and Total = the total annual rainfall (January to December).

5.4.2 *Frequency of occurrence of annual and perennial species*

The frequency of occurrence of the perennial species at the Jaleeg Plains line transect revealed an upward trend over time (Figure 5.39). In contrast, the frequency of the annual species showed a weak relationship (r^2 = 0.37) with the winter rainfall (Figure 5.40). In general, the frequency of strikes of the perennial species was less than that of the annual species, except in years with a low rainfall. The vegetation at this line transect therefore comprises mostly annual vegetation.

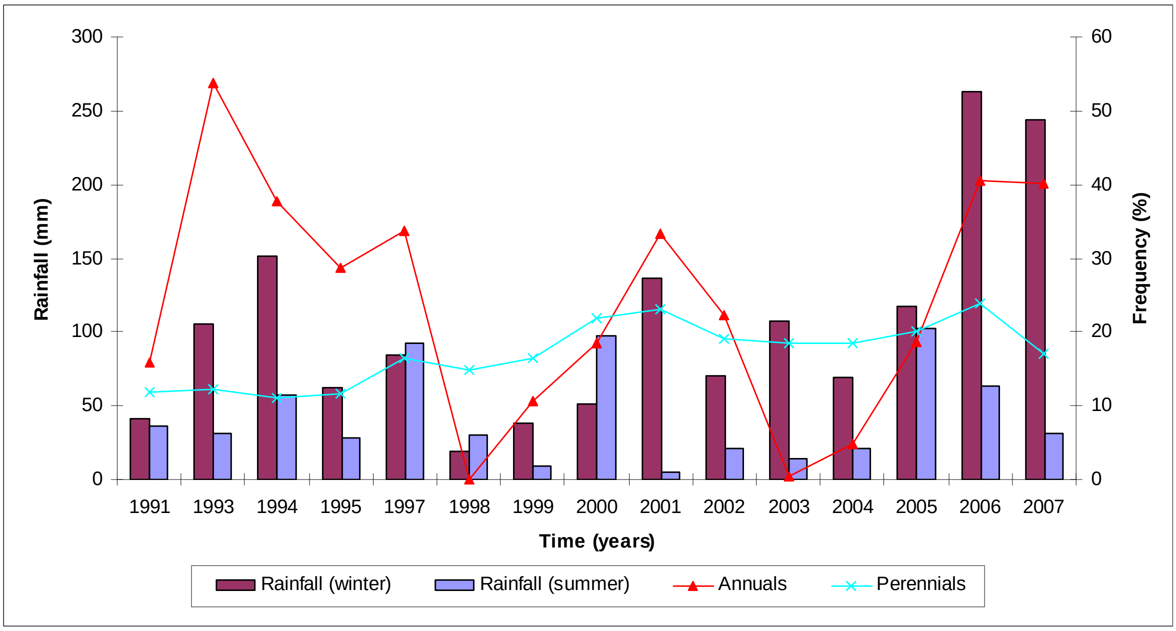


Figure 5.39 The frequency of strike of the annual and perennial species and the winter and summer rainfall during the monitored years for the Jaleeg Plains line transect. The blue line represents the perennial species, whereas the red line represents the annual species. The summer rainfall stretches from October to December of the previous year and January to March of the current year, whereas the winter rainfall includes the rainfall from April to August of the current year.

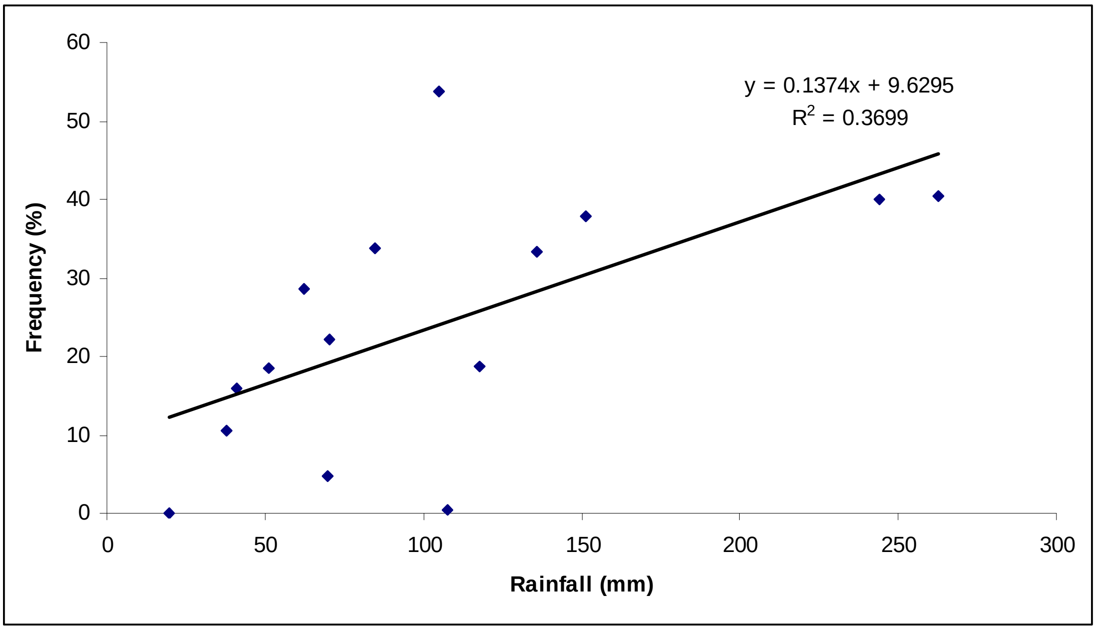


Figure 5.40 The regression of the winter rainfall against the frequency of annual species for the Jaleeg Plains line transects.

5.4.3 *Species and life form diversity*

Species richness

The species richness of the perennial species (Figure 5.41) did not reveal any definite changes in a specific direction, and therefore showed no specific increase or decrease during the past monitored years. The species richness of the annual species revealed large fluctuations. The correlation between the species richness of the annual species and the total annual rainfall was positive (r^2 = 0.3346) whereas there was no relationship between the perennial species richness and total annual rainfall (r^2 = 0.0019). There was a strong correlation between the frequency of occurrence of the annual species and annual species richness (r^2 = 0.76; Figure 5.42).

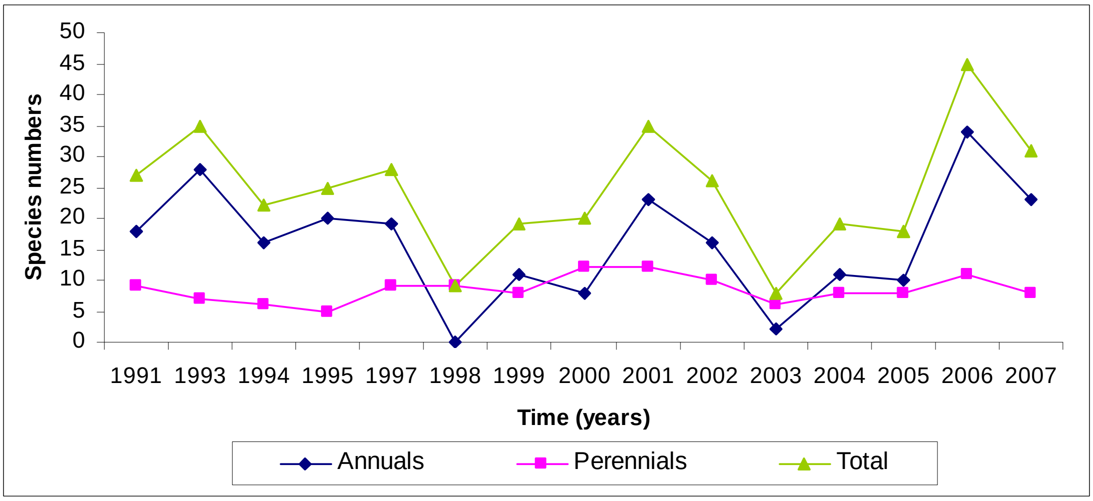


Figure 5.41 The species richness of annual and perennial species as well as total species richness during the past monitored years for the Jaleeg Plains line transect.

Table 5.4 shows that the most prevalent life forms for the Jaleeg Plains line transect were the therophytes and the chamaephytes.

Diversity measures

The evenness (E) and Simpson's index of diversity (D) remained almost unchanged over the monitoring period whereas the Shannon index (H) mirrored the species richness trends (Figure 5.43a). Where the number of species was used as a measure of the abundance of growth forms (Figure 5.43b) the diversity measures showed an increase in the years with a low winter rainfall. The opposite trend was observed when the number of strikes was used as a measure of the abundance of the growth forms (Figure 5.43c). In all three graphs (Figure 5.43a-c) the changes were not directional but depended primarily on the amount of winter rainfall.

Table 5.4 Number of species per life form occurring at the Jaleeg Plains line transect

	1991	1993	1994	1995	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Phanerophytes (P)	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
NP scap	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NP caesp	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
Chamaephytes (Ch)	**8**	**5**	**5**	**3**	**7**	**8**	**7**	**11**	**9**	**8**	**5**	**7**	**7**	**10**	**7**
Ch frut	1	0	2	0	1	2	1	2	2	1	1	1	1	1	2
Ch suff	1	0	0	0	0	0	0	2	0	2	0	1	1	2	1
Ch herb	1	0	0	0	1	0	1	1	1	1	0	0	1	1	0
Ch succ	5	5	3	3	5	6	5	6	6	4	4	5	4	6	4
Ch l succ	2	2	1	1	3	4	3	3	3	2	2	2	2	3	2
Ch st succ	3	3	2	2	2	2	2	3	3	2	2	3	2	3	2
Hemicryptophytes (H)	**1**	**1**	**1**	**1**	**2**	**1**	**1**	**1**	**3**	**2**	**1**	**1**	**1**	**1**	**1**
H caesp	1	1	1	1	2	1	1	1	2	2	1	1	1	1	1
H rept	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
H ros	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Liana (L)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Therophytes (T)	**18**	**28**	**16**	**20**	**19**	**0**	**11**	**8**	**23**	**16**	**2**	**11**	**10**	**34**	**23**
Geophytes (G)	**1**	**2**	**1**	**2**	**3**	**0**	**1**	**0**	**1**	**2**	**2**	**1**	**0**	**1**	**1**

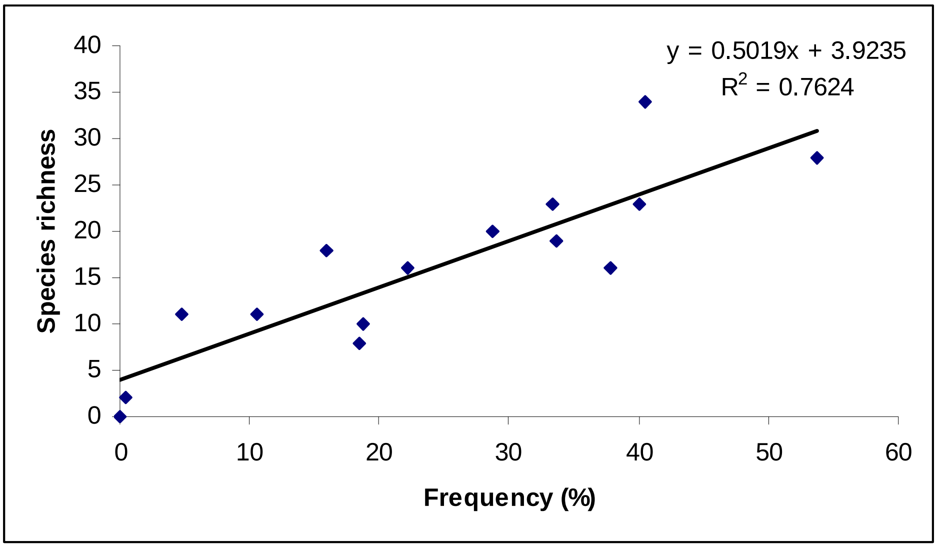


Figure 5.42 The regression of the frequency of strike for the annual species against the annual species richness for the Jaleeg Plains line transect.

5.4.4 *Species composition*

Individual species

Changes in palatable and unpalatable species for the Jaleeg Plains line transect were examined, and palatability of the plant species was determined by using the subjective grazing-index values as indicated by Du Toit (2003).

The most abundant perennial species at the Jaleeg Plains line transect were *Ruschia robusta* and *Stipagrostis brevifolia* (Appendix 8.4). *Stipagrostis brevifolia*, a palatable species, revealed an increase in frequency (r^2 = 0.62) throughout the monitored years (Figure 5.44a). In general, the annual species showed large fluctuations in abundance. The most abundant annual species at this line transect were *Dimorphotheca sinuata*, *Foveolina dichotoma* and *Galenia sarcophylla*. Both *Dimorphotheca sinuata* and *Foveolina dichotoma*, unpalatable species, showed a decreasing trend (r^2 = 0.37; r^2 = 0.11; Figure 5.44b).

Community composition

The Correspondence Analysis scatter diagram of data of all the species in the Jaleeg Plains line transect reveals that changes did occur (Figure 5.45). The general direction of the trend is indicated by the arrow in Figure 5.46 with most of the early years found to the lower left side of the ordination space and the later years progressively more towards the upper part and to the right.

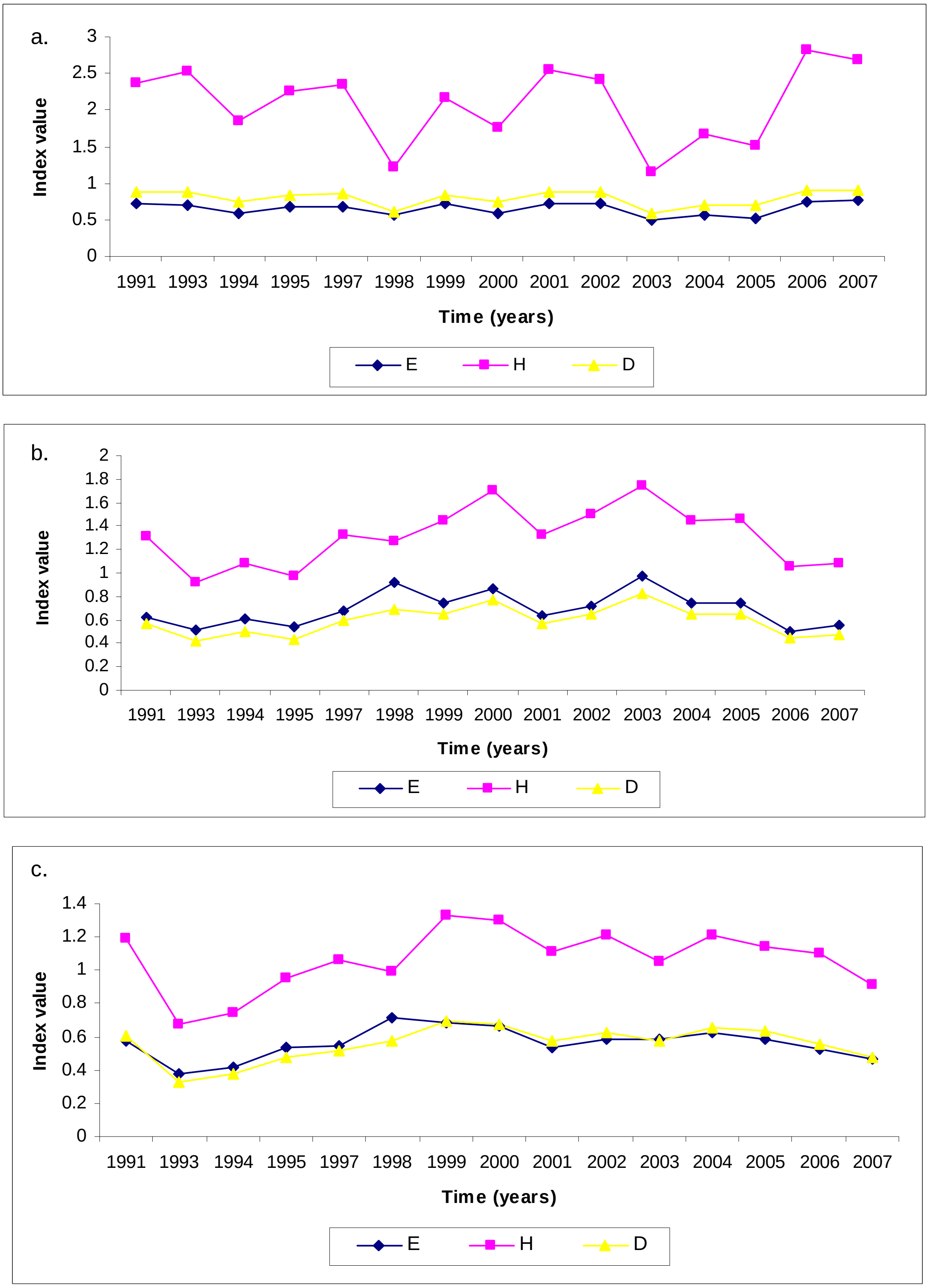
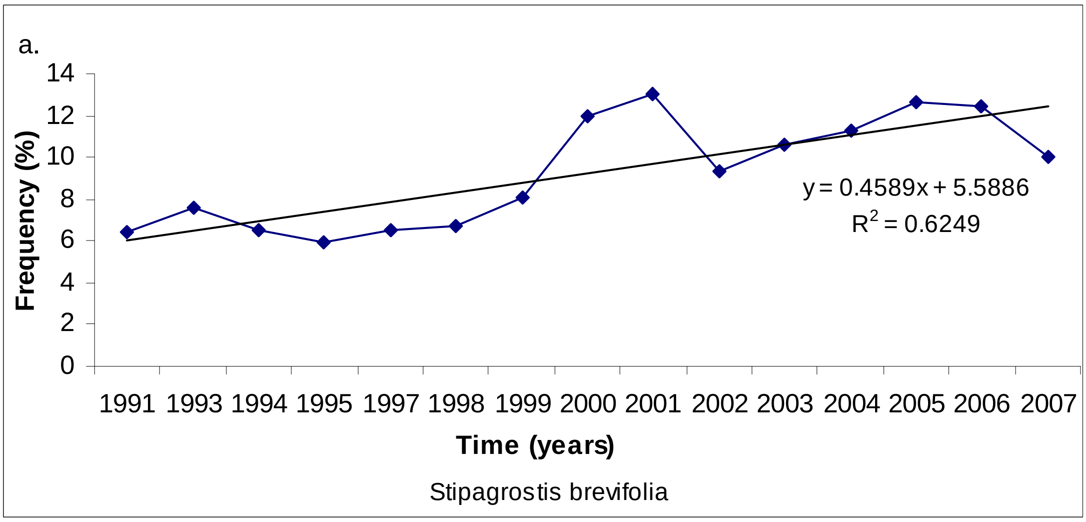


Figure 5.43 The diversity measures of (a) the first strikes of all species, using (b) the number of species in the different life forms and (c) the number of strikes in the different life forms, in the Jaleeg Plains line transect. E = species evenness, H = Shannon's diversity index and D = Simpson's diversity index.



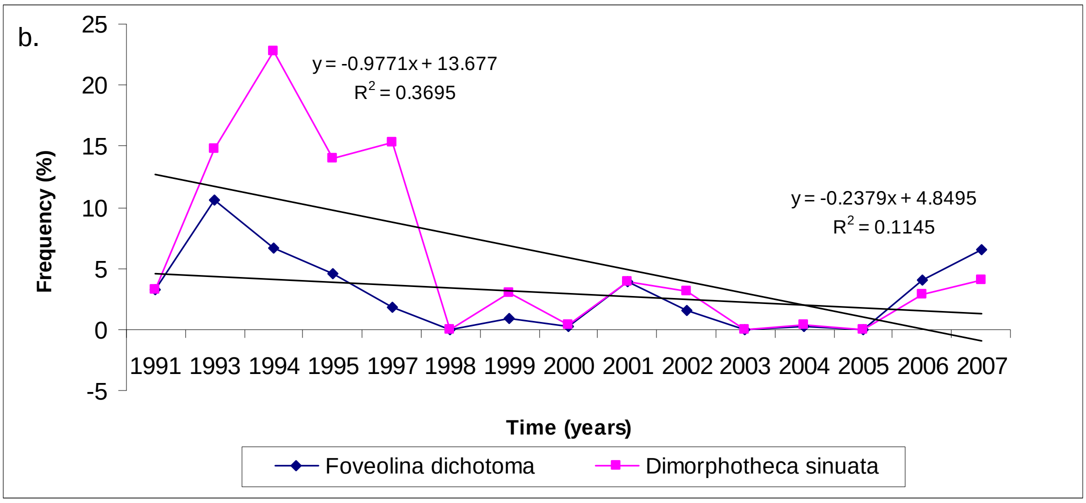
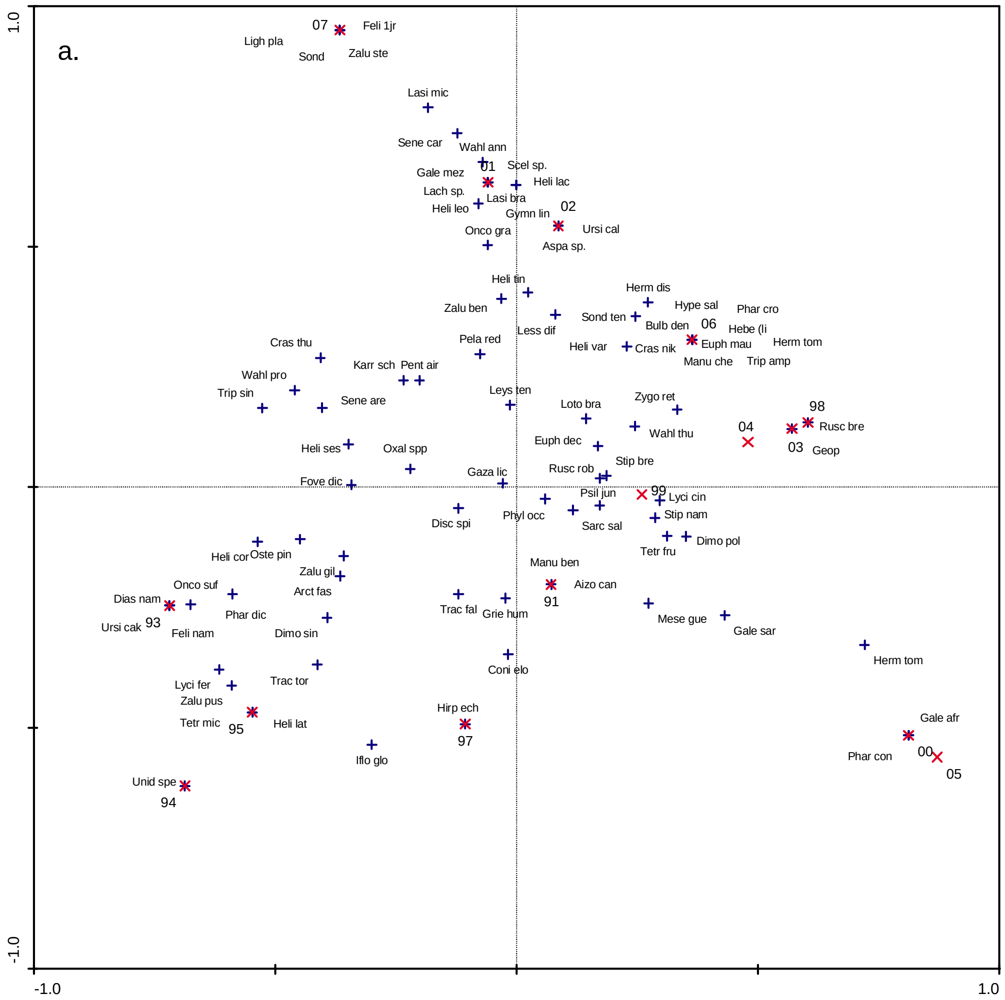


Figure 5.44 Changes in frequency of (a) a selected perennial species and (b) two annual species at Jaleeg Plains line transect.



b.

Axes :	1	2	3	4	Total inertia
Eigenvalues :	0.320	0.168	0.145	0.121	1.046
Cumulative percentage					
Variance of species data :	30.6	46.6	60.5	72.0	
Sum of all eigenvalues :					1.046

Figure 5.45 (a) Scatter diagram produced by a Correspondence Analysis (CA) ordination showing the position of all species (88 species) relative to the monitored years for the Jaleeg Plains line transect. The red x-marks represent the years and the blue crosses the species. (b) Details of the CA ordination.

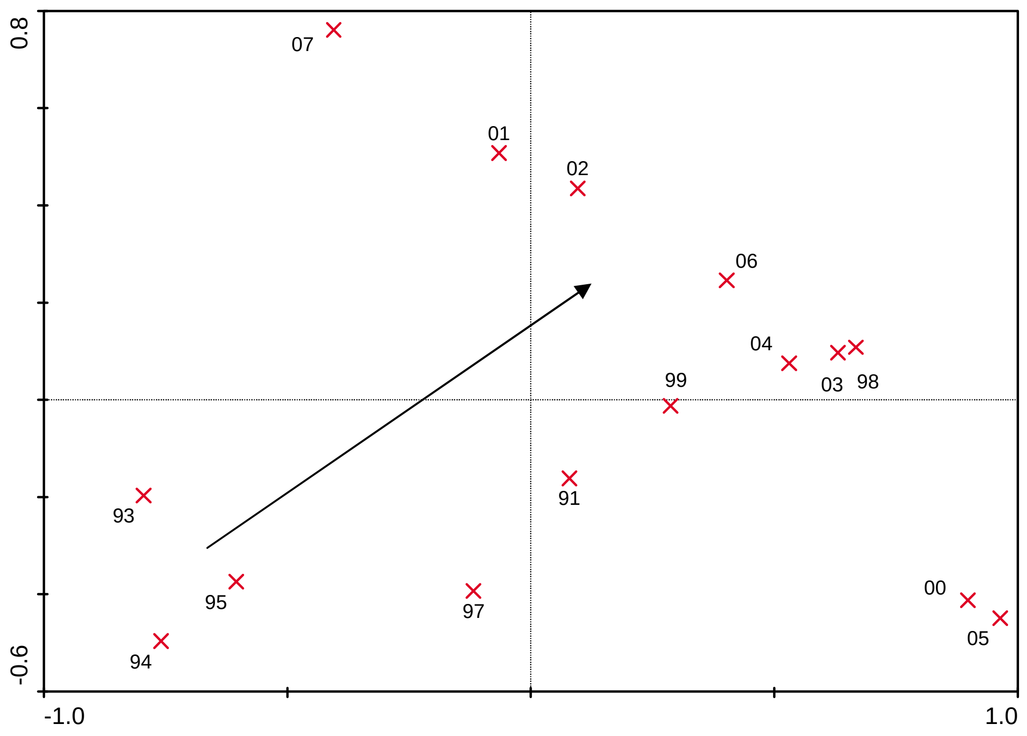


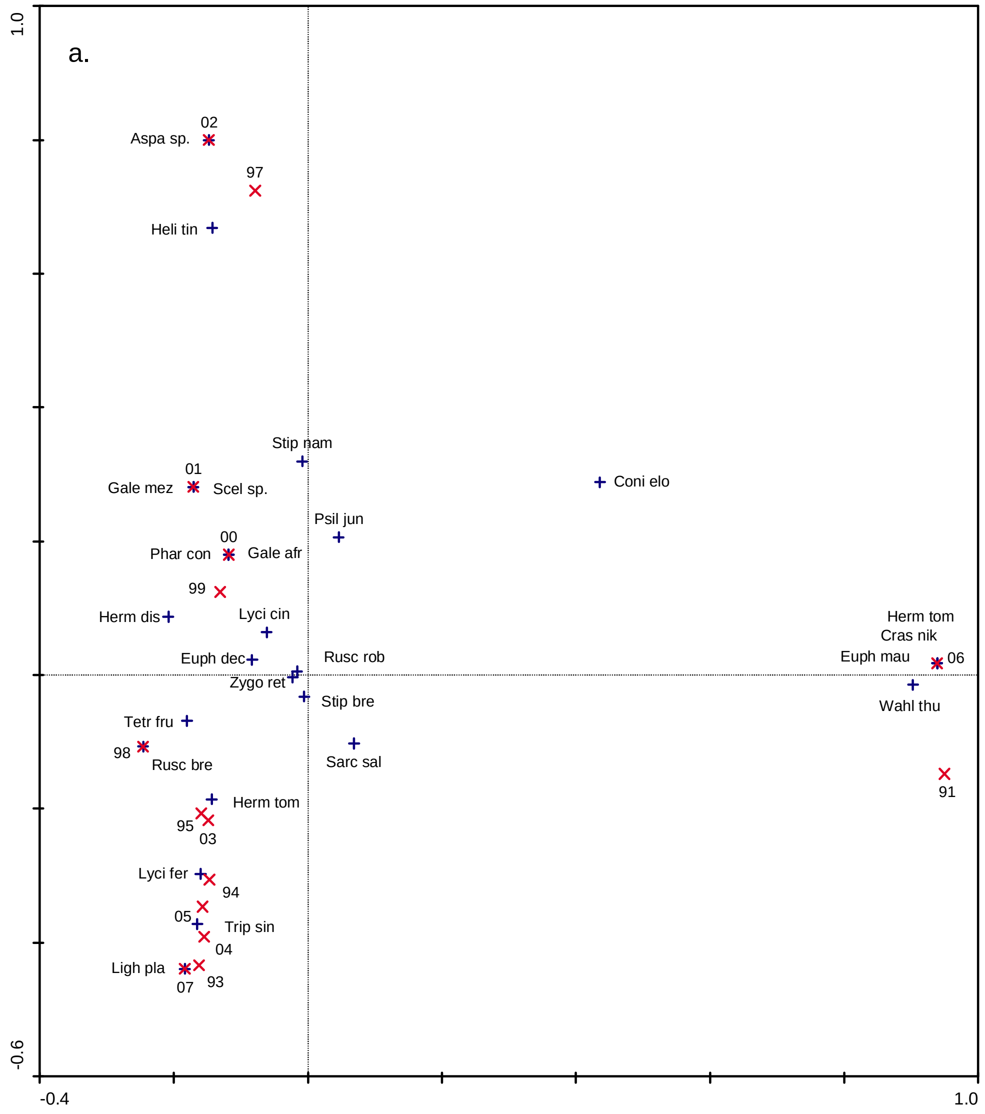
Figure 5.46 The Correspondence Analysis (CA) scatter diagram with the arrow indicating the direction of change at the Jaleeg Plains line transect.

Perennial species composition

The composition of the perennial species of the Jaleeg Plains line transect (Figure 5.47a) did not reveal a clear gradient as time proceeded.

Annual species composition

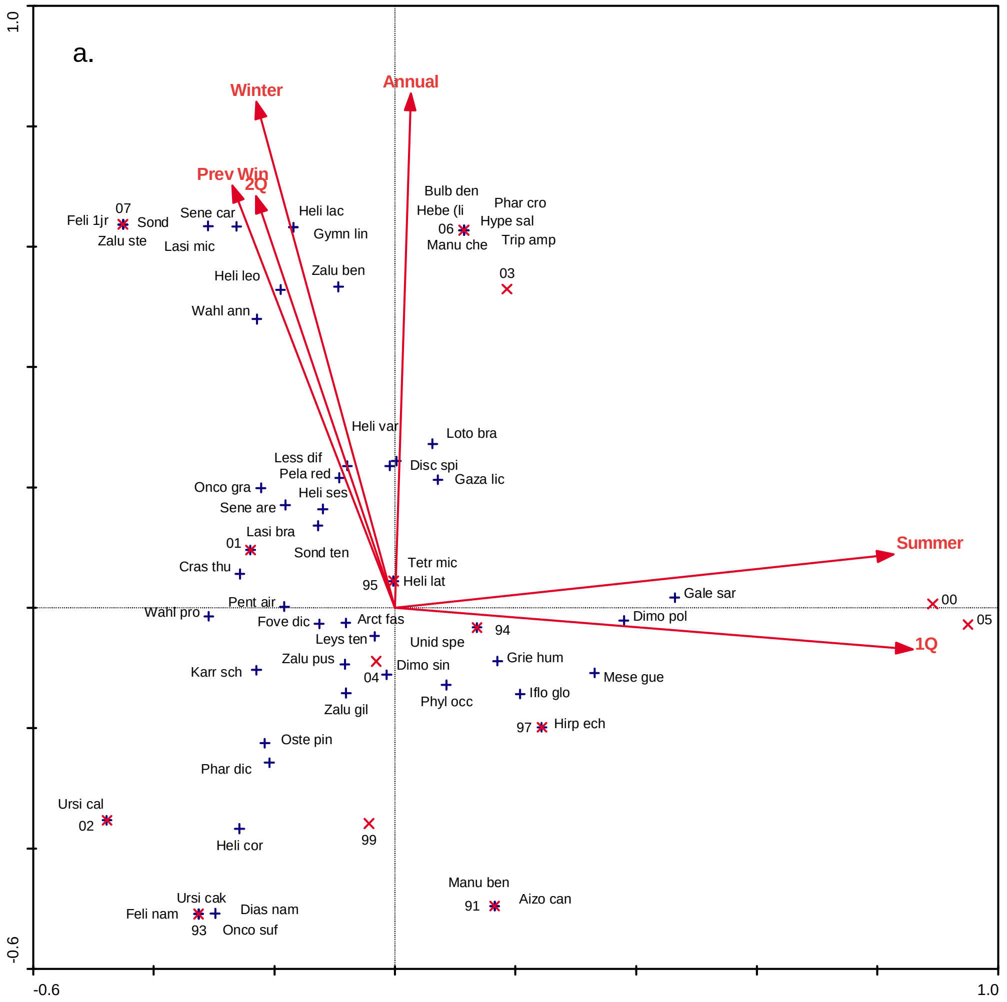
The Canonical Correspondence Analysis (CCA) of the annual species occurring on the Jaleeg Plains line transect with regards to the rainfall showed that some annual species had a strong association with high values of winter rainfall, e.g. *Heliophila lactea, Gymnodiscus linearifolia* and *Zaluzianskya benthamiana* (Figure 5.48). Those species associated with high values for summer rainfall were *Galenia sarcophylla, Mesembryanthemum guerichianum* and *Dimorphotheca polyptera*. The annual species occurring in the Jaleeg Plains line transect, however, showed no directional trend in species composition over the monitored years. There was a low (near to zero) correlation of summer rainfall and first quarter rainfall with the winter and second quarter rainfall.



b.

Axes :	1	2	3	4	Total inertia
Eigenvalues :	0.075	0.044	0.028	0.025	0.251
Cumulative percentage					
Variance of species data :	29.9	47.6	58.8	68.9	
Sum of all eigenvalues :					0.251

Figure 5.47 (a) Scatter diagram produced by a Correspondence Analysis (CA) ordination showing the position of the perennial species (26 species) relative to the monitored years for the Jaleeg Plains line transect. The red x-marks represent the years and the blue crosses the species. (b) Details of the CA ordination.



b.

Axes :	1	2	3	4	Total inertia
Eigenvalues :	0.367	0.172	0.101	0.066	1.230
Species-environment correlations :	0.946	0.914	0.878	0.660	
Cumulative percentage variance					
of species data :	29.8	43.8	52.0	57.4	
of species-environment relation :	48.2	70.9	84.1	92.8	
Sum of all eigenvalues :					1.230
Sum of all canonical eigenvalues :					0.760

Figure 5.48 (a) Scatter diagram produced by a Canonical Correspondence Analysis (CCA) ordination showing the position of the annual species (57 species) relative to the years and rainfall in the Jaleeg Plains line transect. The red x-marks represent the years and the blue crosses the species. 1Q = rainfall from January to March of the current year, 2Q = rainfall from April to June of the current year, Summer = rainfall from October to December of the previous year plus January to March of the current year, Winter = rainfall from April to August of the current year, Prev Win = rainfall from April to September of the previous year and Annual = the annual rainfall of the current year. (b) Details of the CCA ordination.

5.4.5 *Grazing Capacity*

The veld condition score fluctuated, but overall showed an upward trend (Appendix 8.4). The improvement in veld condition ($r^2 = 0.37$) was reflected in the improvement of the grazing capacity over the monitored years (Figure 5.49).

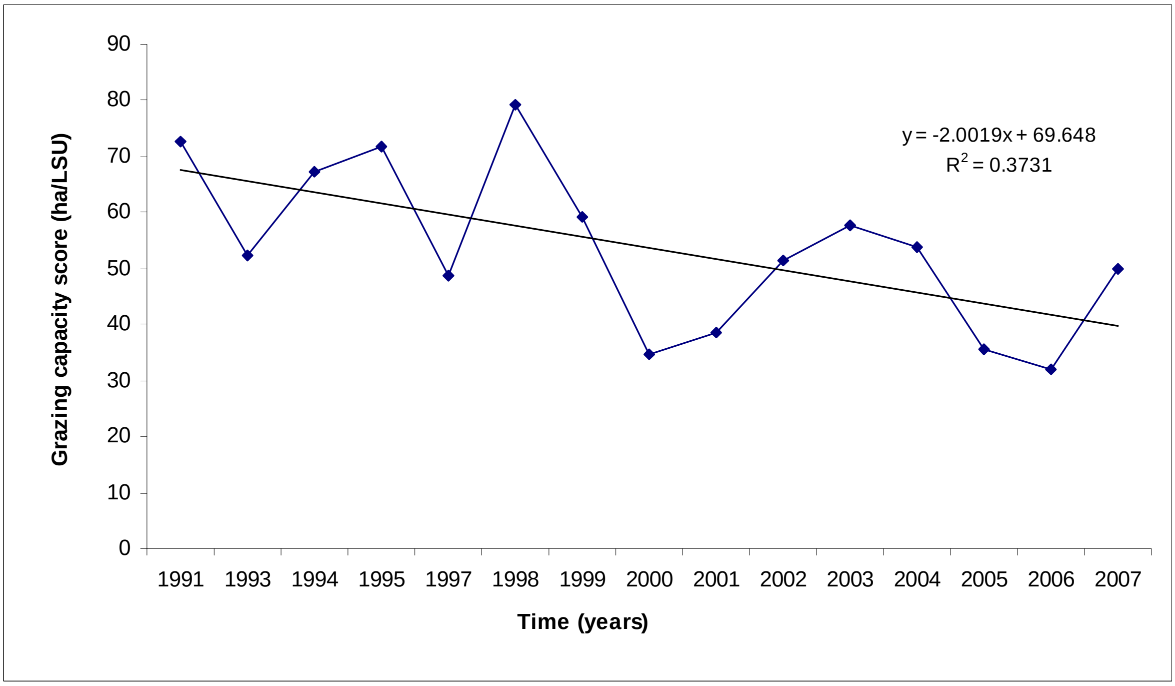


Figure 5.49 The grazing capacity over the monitored years for the vegetation occurring in the Jaleeg Plains line transect. LSU = Large Stock Unit.

5.5 Koperberg Plains

5.5.1 *Rainfall*

Figure 5.50 shows the fluctuation in the rainfall at the Koperberg Plains line transect illustrating an increase in rainfall during the last three monitored years. The annual rainfall varied approximately threefold from 95 mm up to 304 mm rain. The area is clearly a winter rainfall region with the amount of winter rainfall exceeding that of the summer rainfall.

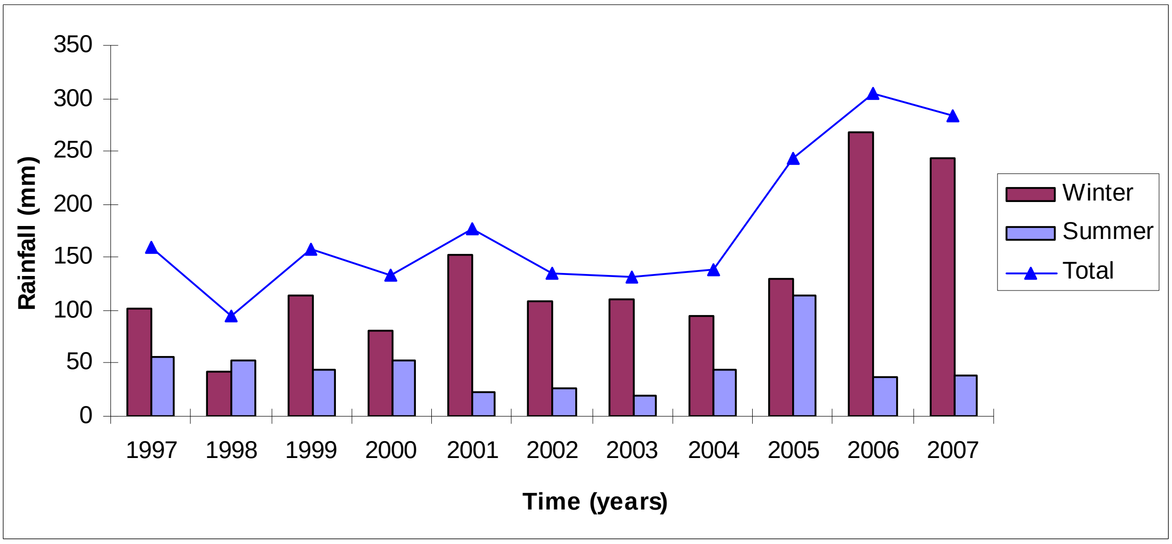


Figure 5.50 The rainfall during the monitored years at the Koperberg Plains line transect. Summer = rainfall in the summer months (January to March and October to December of the current year), Winter = rainfall in the winter months (April to September) and Total = the total annual rainfall (January to December)

5.5.2 *Frequency of occurrence of annual and perennial species*

The frequency of occurrence of the perennial species did not reveal any changes in a specific direction at the Koperberg Plains line transect over time (Figure 5.51). In contrast, the frequency of the annual species showed a relationship with the winter rainfall (r^2 = 0.58; Figure 5.52). It was clear that except in the very wet years, the frequency of strikes of the perennial species exceeded that of the annual species. The vegetation at this line transect therefore comprised mostly perennial vegetation.

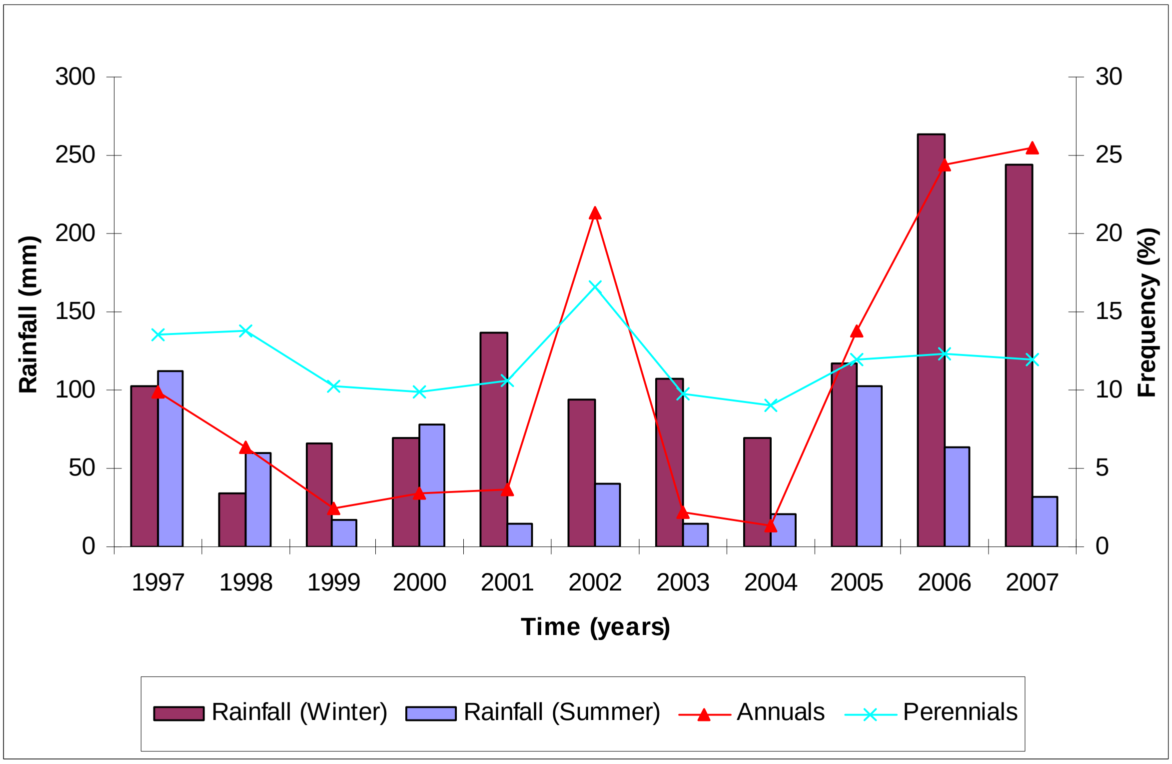


Figure 5.51 The frequency of strike of the annual and perennial species and the winter and summer rainfall during the monitored years for the Koperberg Plains line transect. The blue line represents the perennial species, whereas the red line represents the annual species. The summer rainfall stretches from October to December of the previous year and January to March of the current year, whereas the winter rainfall includes the rainfall from April to August of the current year.

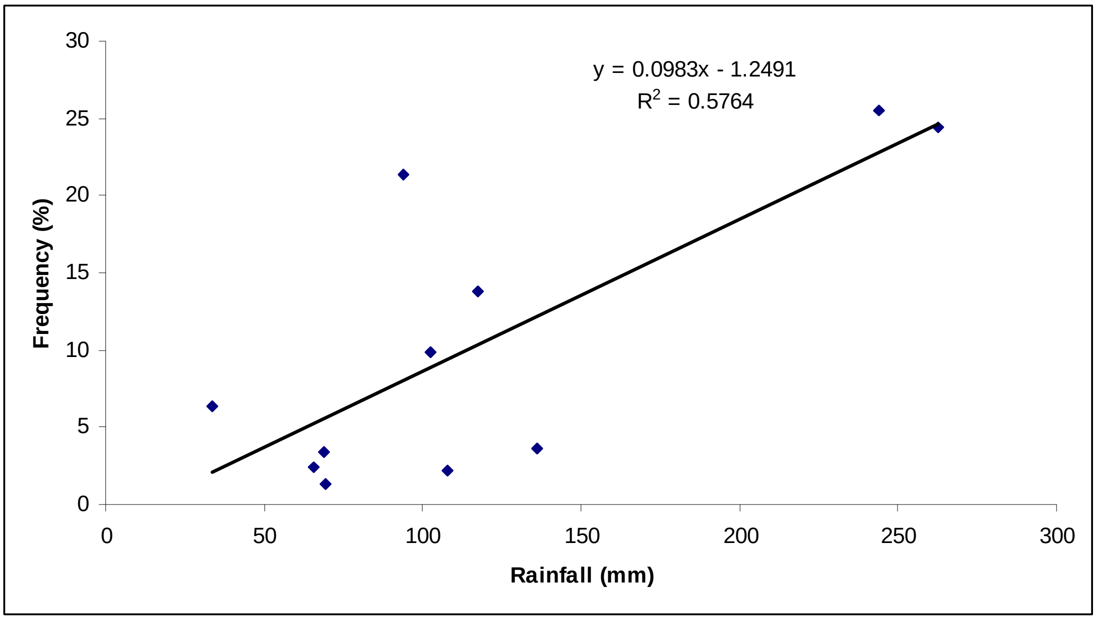


Figure 5.52 The regression of the winter rainfall against the frequency of annual species for the Koperberg Plains line transect.

5.5.3 *Species diversity*

Species richness

The species richness of the perennial species (Figure 5.53) did not reveal any definite changes in a specific direction, and therefore showed no specific increase or decrease during the past monitored years. The species richness of the annual species revealed large fluctuations. The correlation between the species richness of the annual species and the total annual rainfall was more positive (r^2 = 0.375) than that of perennial species richness and total annual rainfall (r^2 = 0.295). There was a strong correlation between the frequency of occurrence of the annual species and annual species richness (Figure 5.54).

Table 5.5 indicates that the most prevalent life forms for the Koperberg Plains line transect were the therophytes and the chamaephytes.

Diversity measures

The evenness (E) and Simpson’s index of diversity (D) remained almost unchanged over the monitoring period whereas the Shannon index (H) mirrored the species richness trends (Figure 5.55a). Where the number of species was used as a measure of the abundance of growth forms (Figure 5.55b) the diversity measures showed an increase in the years with a low winter rainfall. A different trend was observed when the number of strikes was used as a measure of the abundance of the growth forms (Figure 5.55c) in which case there seems to be a gradual decline in diversity. In Figure 5.55a and b the changes were not directional but depended primarily on the amount of winter rainfall.

Table 5.5 Number of species per life form occurring at the Koperberg Plains line transect

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Phanerophytes (P)	**1**	**1**	**1**	**2**	**1**	**1**	**1**	**1**	**1**	**2**	**2**
NP scap	0	0	0	0	0	0	0	0	0	0	0
NP caesp	1	1	1	2	1	1	1	1	1	2	2
Chamaephytes (Ch)	**9**	**7**	**6**	**6**	**6**	**7**	**6**	**8**	**8**	**8**	**7**
Ch frut	1	1	1	1	1	1	0	1	1	1	1
Ch suff	0	0	0	0	0	0	0	1	1	0	0
Ch herb	0	0	0	0	0	0	0	0	0	0	0
Ch succ	8	6	5	5	5	6	6	6	6	7	6
Ch l succ	7	5	4	4	4	5	5	5	5	6	5
Ch st succ	1	1	1	1	1	1	1	1	1	1	1
Hemicryptophytes (H)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
H caesp	0	0	0	0	0	0	0	0	0	0	0
H rept	0	0	0	0	0	0	0	0	0	0	0
H ros	0	0	0	0	0	0	0	0	0	0	0
Liana (L)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Therophytes (T)	**11**	**4**	**2**	**2**	**10**	**14**	**2**	**1**	**12**	**14**	**10**
Geophytes (G)	**2**	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**1**

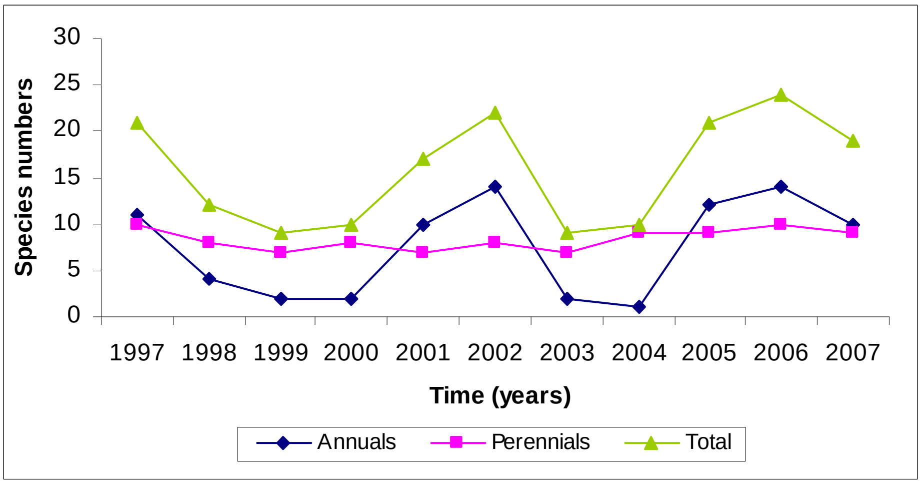


Figure 5.53 The species richness of annual and perennial species as well as total species richness during the past monitored years for the Koperberg Plains line transect.

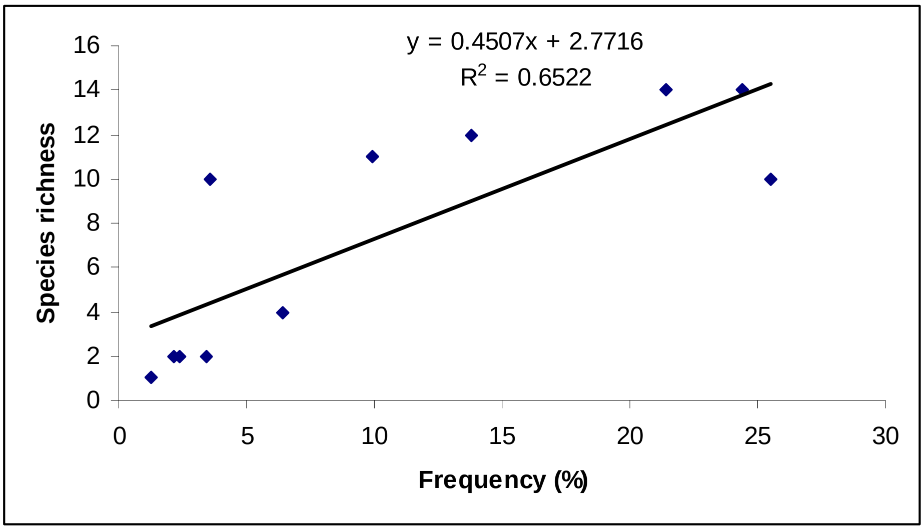


Figure 5.54 The regression of the frequency of strike for the annual species against the annual species richness for the Koperberg Plains line transect.

5.5.4 *Species composition*

Individual species

The most abundant perennial species at the Koperberg plains were *Zygophyllum retrofractum* and *Salsola tuberculata* (Appendix 8.5). Neither of these species revealed any decrease or increase over the monitored years (r^2 = 0.05; r^2 = 0.03; Figure 5.56a). In general, the annual species showed large fluctuations in abundance. The most abundant annual species at this line transect was *Atriplex lindleyi* subsp. *inflata*, an unpalatable pioneer species, which showed a decreasing trend (r^2 = 0.30) across the monitored years (Figure 5.56b).

Community composition

The changes in the species composition were investigated by the use of Correspondence Analysis (CA) in the computer programme CANOCO. The scatter diagram of data of all the species in the Koperberg Plains line transect did not reveal a strong directional trend (Figure 5.57).

Perennial species composition

Although the perennial species composition of the Koperberg Plains line transect showed changes in composition over the monitored years a clear directional trend was not apparent as time proceeded (Figure 5.58a).

Annual species composition

The change in the annual species composition was analysed by Canonical Correspondence Analysis with regards to the rainfall because of the relationship between rainfall and short-lived vegetation. Most of the annual species occurring on the Koperberg Plains line transect were not strongly association with a high winter rainfall (Figure 5.59). The annual species in this transect also showed no directional trend in species composition over the monitored years. There was a low (near to zero) correlation of summer rainfall with the winter and second quarter rainfall.

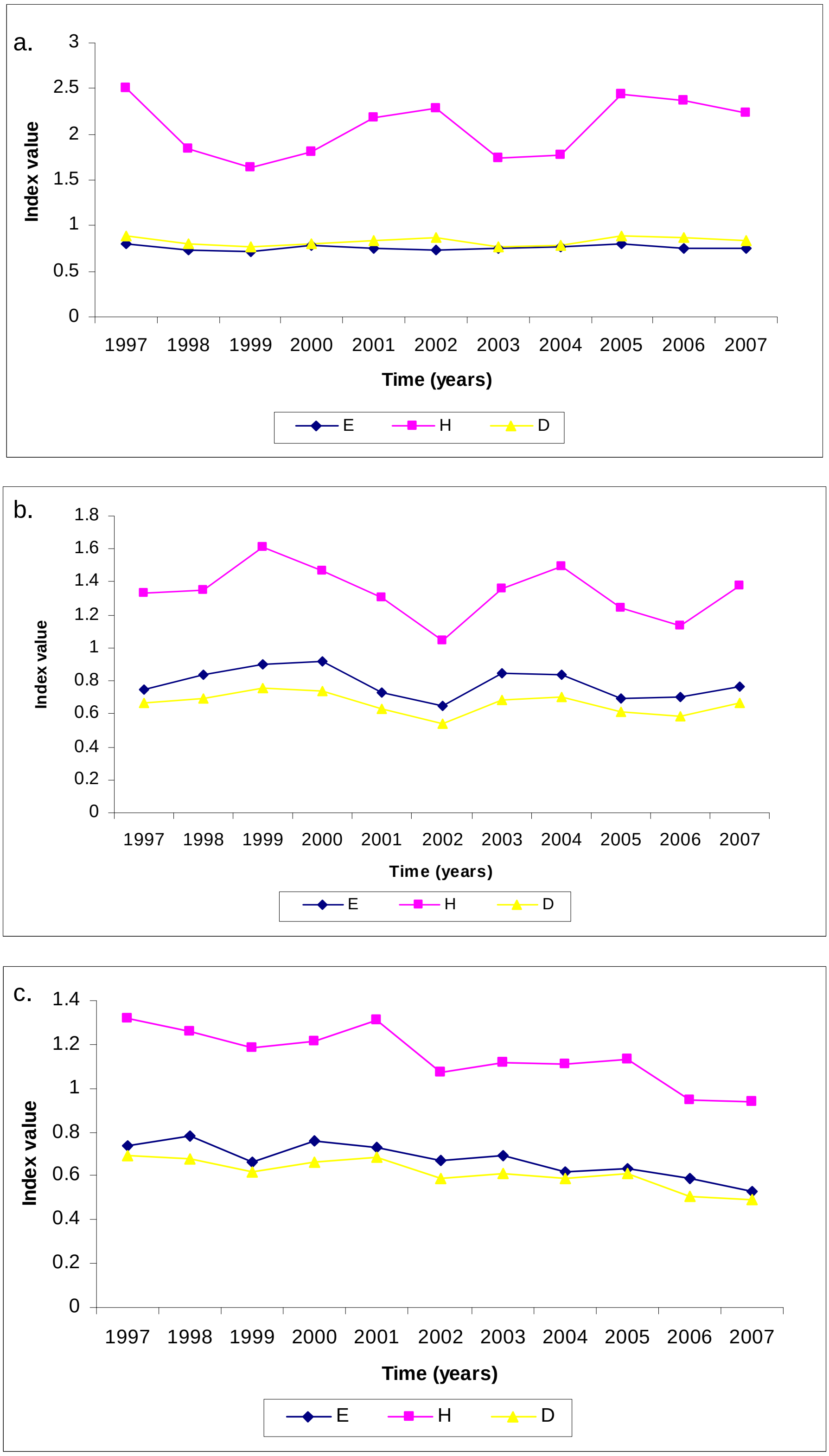
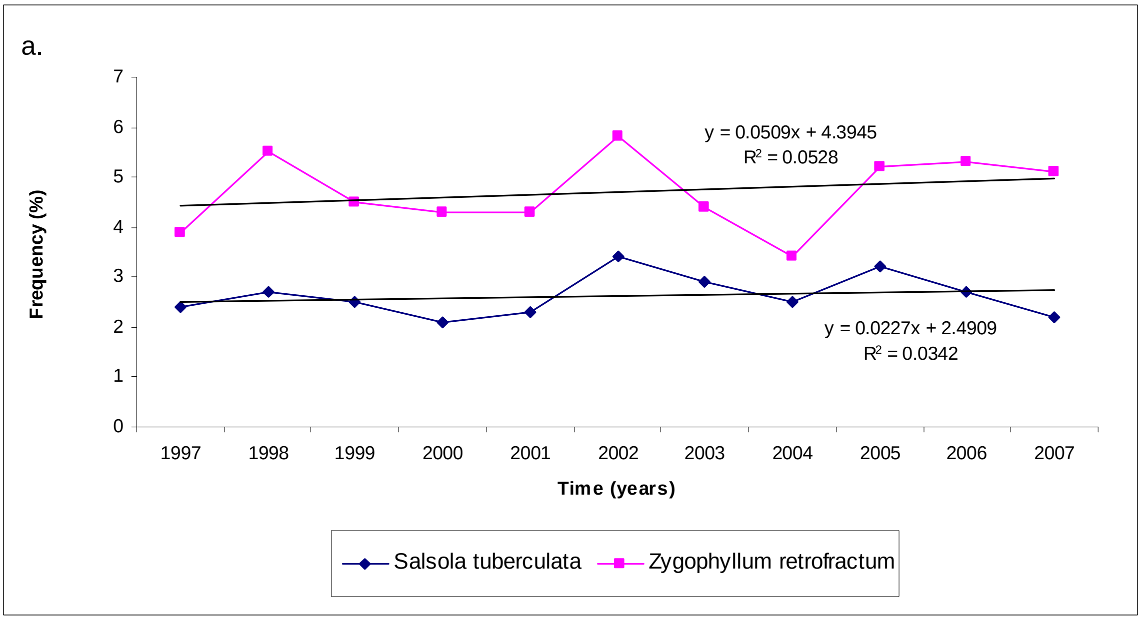


Figure 5.55 The diversity measures of (a) the first strikes of all species, using (b) the number of species in the different life forms and (c) the number of strikes in the different life forms, in the Koperberg Plains line transect. E = species evenness, H = Shannon's diversity index and D = Simpson's diversity index.



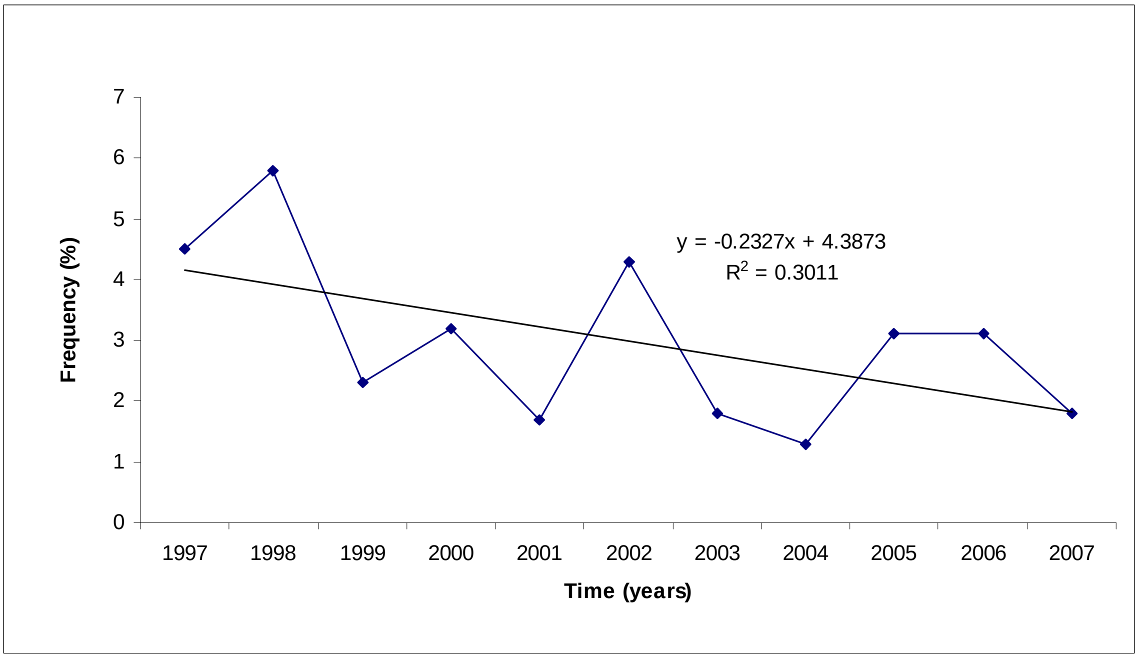
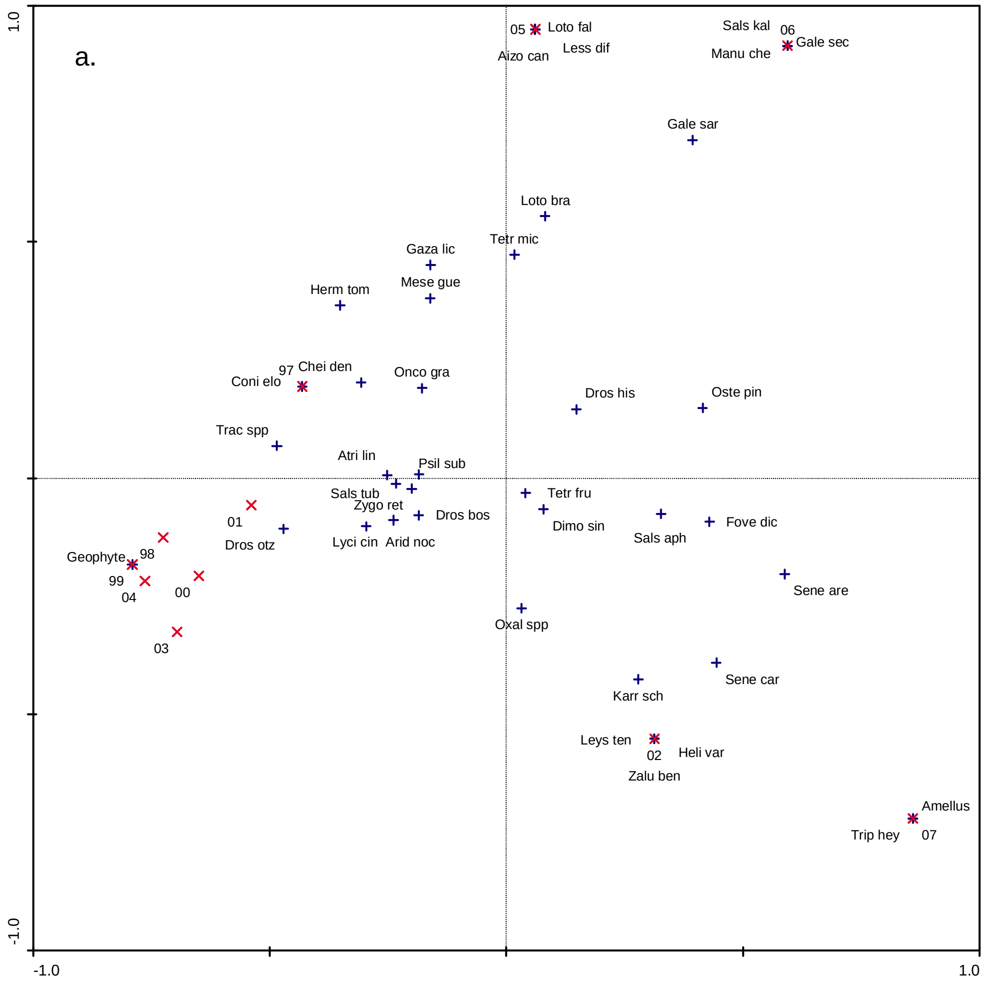


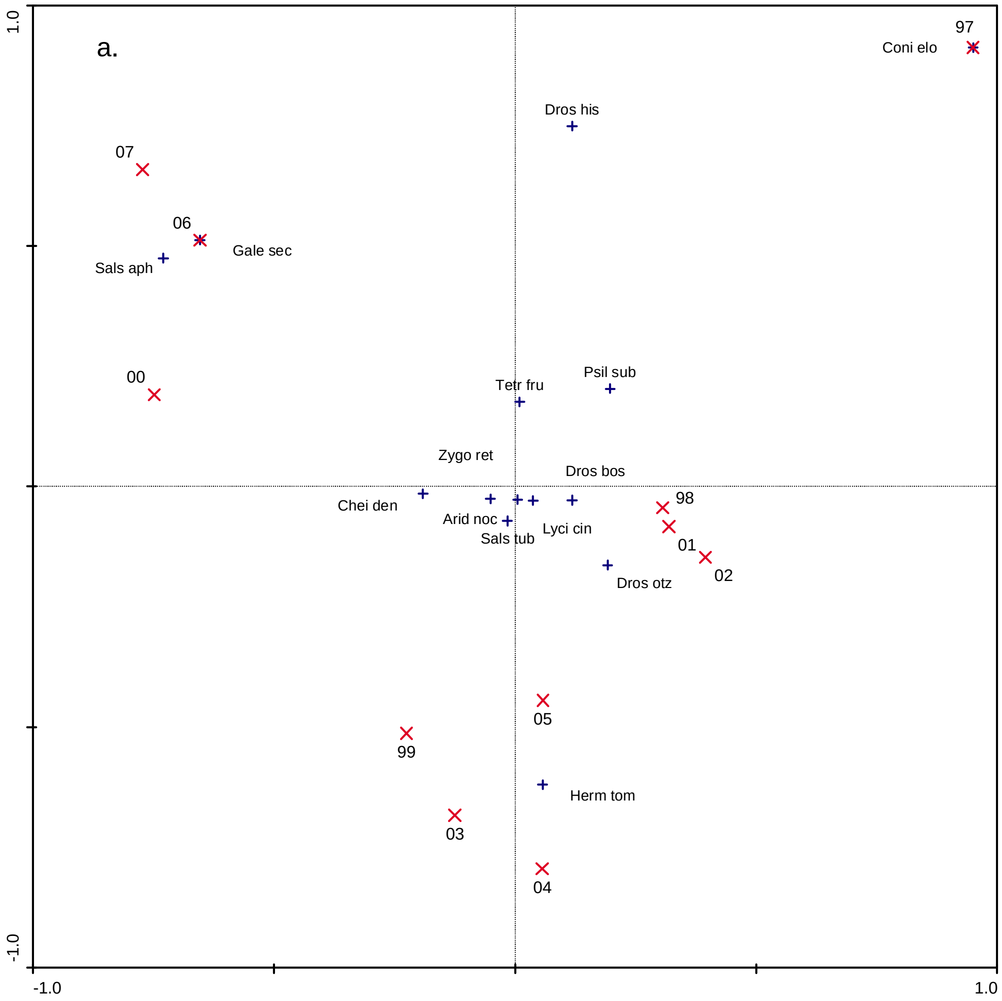
Figure 5.56 Changes in frequency of (a) selected perennial species and (b) an annual species (*Atriplex lindleyi* subsp. *inflata*) at Koperberg Plains line transect.



b.

Axes :	1	2	3	4	Total inertia
Eigenvalues :	0.291	0.128	0.085	0.036	0.637
Cumulative percentage					
Variance of species data :	45.8	65.8	79.2	84.8	
Sum of all eigenvalues :					0.637

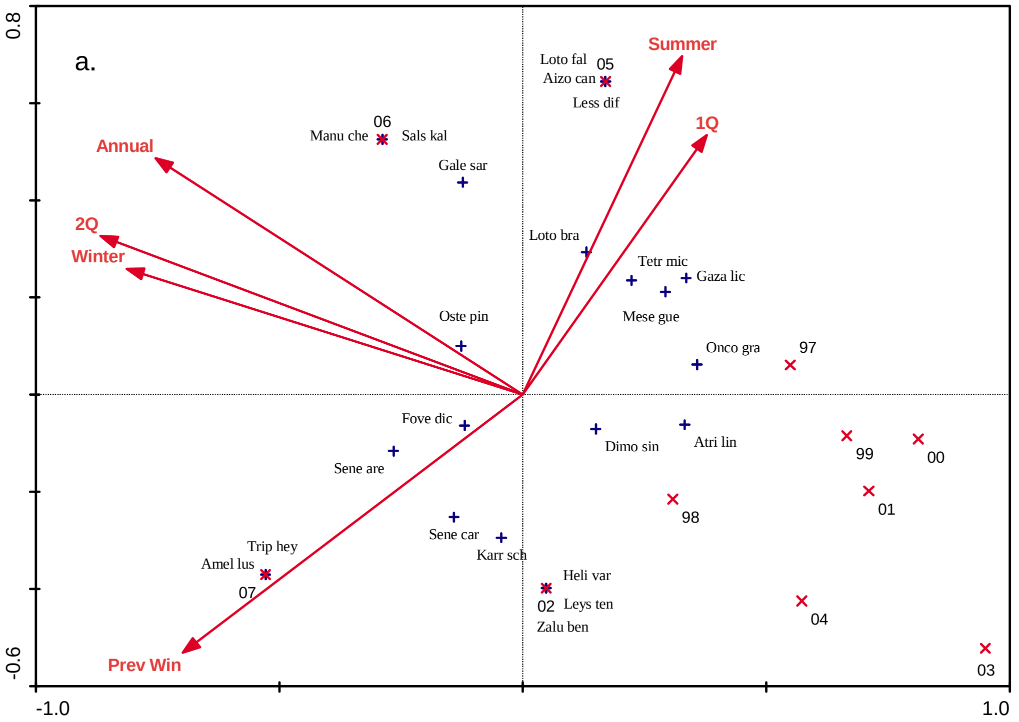
Figure 5.57 (a) Scatter diagram produced by a Correspondence Analysis (CA) ordination showing the position of all species (40 species) relative to the monitored years for the Koperberg Plains line transect. The red x-marks represent the years and the blue crosses the species. (b) Details of the CA ordination.



b.

Axes :	1	2	3	4	Total inertia
Eigenvalues :	0.060	0.049	0.020	0.011	0.160
Cumulative percentage					
Variance of species data :	37.2	67.6	80.3	87.0	
Sum of all eigenvalues :					0.160

Figure 5.58 (a) Scatter diagram produced by a CA ordination showing the position of the perennial species (14 species) relative to the monitored years for the Koperberg Plains line transect. The red x-marks represent the years and the blue crosses the species. (b) Details of the CA ordination.



b.

Axes :	1	2	3	4	Total inertia
Eigenvalues :	0.330	0.201	0.112	0.029	0.886
Species-environment correlations :	0.903	0.990	0.968	0.886	
Cumulative percentage					
Variance of species data :	37.2	59.9	72.6	75.8	
of species-environment relation :	46.9	75.4	91.4	95.5	
Sum of all eigenvalues :					0.886
Sum of all canonical eigenvalues :					0.704

Figure 5.59 (a) Scatter diagram produced by a Canonical Correspondence Analysis (CCA) ordination showing the position of the annual species (23 species) relative to the years and rainfall in the Koperberg Plains line transect. The red x-marks represent the years and the blue crosses the species. 1Q = rainfall from January to March of the current year, 2Q = rainfall from April to June of the current year, Summer = rainfall from October to December of the previous year plus January to March of the current year, Winter = rainfall from April to August of the current year, Prev Win = rainfall from April to September of the previous year and Annual = the annual rainfall of the current year. (b) Details of the CCA ordination.

5.5.5 *Grazing Capacity*

The grazing index method (GIM) as proposed by Du Toit (1996) for the Karoo veld was applied to calculate the grazing capacity of the vegetation on the Koperberg Plains line transect. The method involves calculating the veld condition score and compares this value with a benchmark with a known grazing capacity, to calculate the grazing capacity of the range under consideration.

The fluctuations in veld condition score and consequently grazing capacity did not show directional trends (Figure 5.60). No improvement in grazing capacity (r^2 = 0.0073) could be demonstrated.

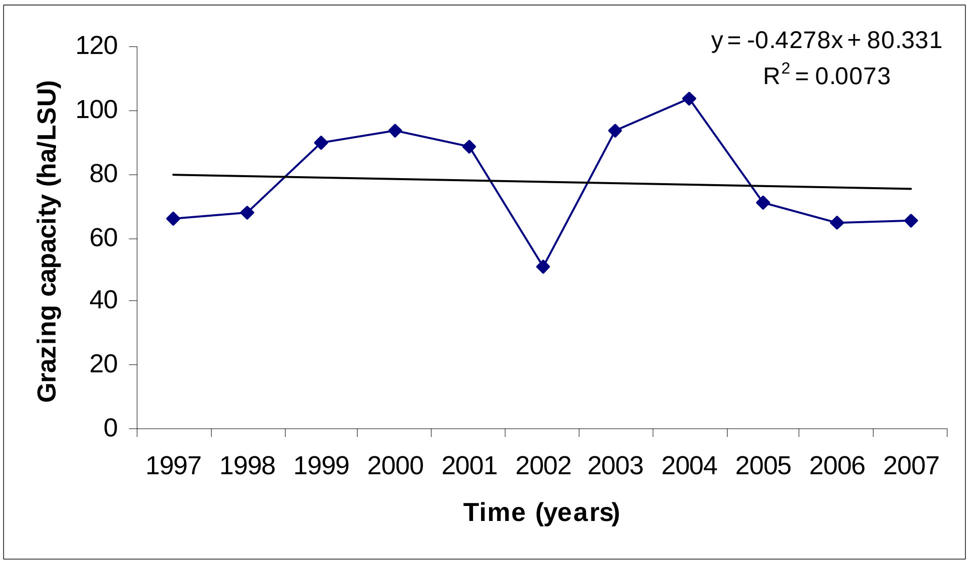


Figure 5.60 The grazing capacity (ha/LSU) throughout the monitored years for the vegetation occurring in the Koperberg Plains line transect where LSU = Large Stock Unit.

5.6 T'ganagas Plains

5.6.1 *Rainfall*

The rainfall at the T'ganagas Plains line transect is the same as that of the Koperberg Plains and is illustrated in Figure 5.50. The annual rainfall showed the increase in rainfall during the last two monitored years and an approximately threefold range from 95 mm up to 304 mm rain.

5.6.2 *Frequency of occurrence of annual and perennial species*

The frequency of occurrence of the perennial species was low throughout and did not reveal any changes in a specific direction at the T'ganagas Plains line transect over time (Figure 5.61). In contrast, the frequency of the annual species showed a very clear relationship with the winter rainfall (Figure 5.62). It was clear that the frequency of strikes of the annual species far exceeded that of the perennial species. The vegetation at this line transect therefore comprises mostly annual vegetation.

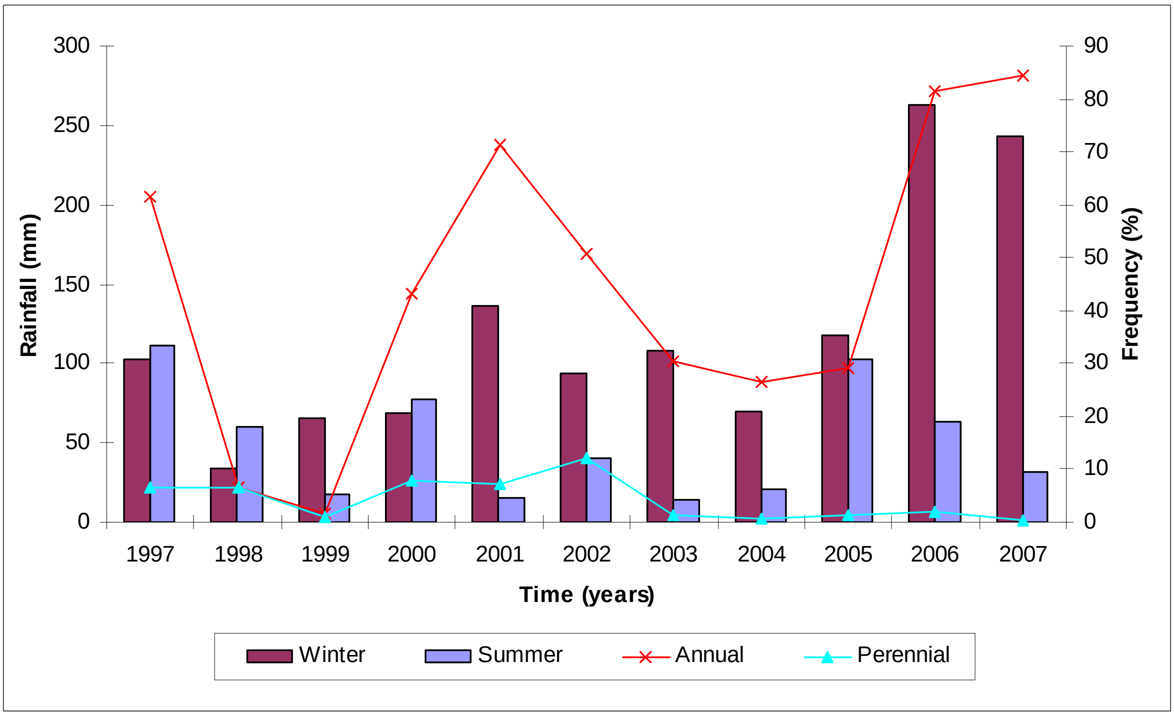


Figure 5.61 The frequency of strike of the annual and perennial species and the winter and summer rainfall during the monitored years for the T'ganagas Plains line transect. The blue line represents the perennial species, whereas the red line represents the annual species. The summer rainfall stretches from October to December of the previous year and January to March of the current year, whereas the winter rainfall includes the rainfall from April to August of the current year.

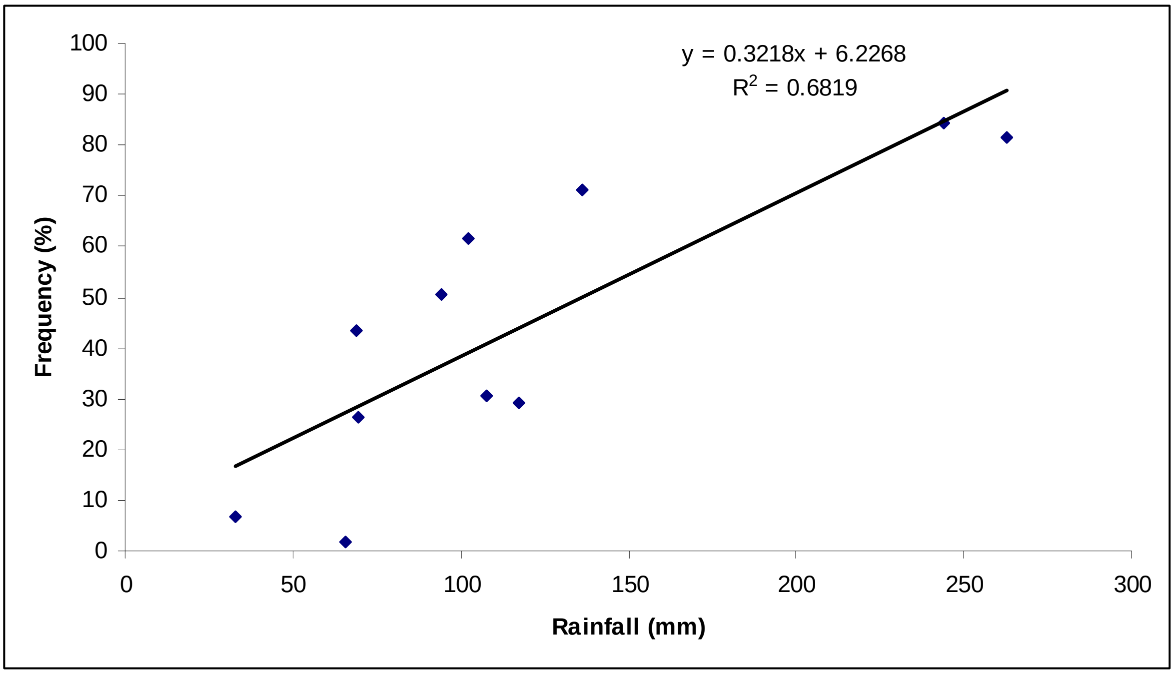


Figure 5.62 The regression of the winter rainfall against the frequency of annual species for the T'ganagas Plains line transects.

5.6.3 *Species and life form diversity*

Species richness

The species richness of the perennial species (Figure 5.63) did not reveal a directional change during the monitored years. The species richness of the annual species revealed large fluctuations. There was a weak correlation (r^2 =0.252) between the species richness of the annual species and the total annual rainfall, but no relationship between perennial species richness and total annual rainfall (r^2 = 0.078). There was a strong correlation between the frequency of occurrence of the annual species and their richness (r^2 = 0.65; Figure 5.64).

Table 5.6 indicates that the most prevalent life forms for the T'ganagas Plains line transect were the therophytes and the chamaephytes.

Diversity measures

The Shannon index (H) mirrored the species richness trends (Figure 5.65a). Where the number of species was used as a measure of the abundance of growth forms (Figure 5.65b) the diversity measures showed an increase in the years with a low winter rainfall. A different trend was observed when the number of strikes was used as a measure of the abundance of the growth forms (Figure 5.65c) in which case there seems to be a decline in diversity. In Figure 5.65a and b the changes were not directional but depended primarily on the amount of winter rainfall. However, in Figure 5.65c there appeared to be a decline in the diversity parameters over time.

Table 5.6 Number of species per life form occurring at the T'ganagas Plains line transect

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Phanerophytes (P)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
NP scap	0	0	0	0	0	0	0	0	0	0	0
NP caesp	0	0	0	0	0	0	0	0	0	0	0
Chamaephytes (Ch)	**2**	**4**	**2**	**3**	**3**	**4**	**1**	**1**	**1**	**2**	**3**
Ch frut	0	1	0	0	0	0	0	0	0	1	2
Ch suff	0	0	1	1	1	1	0	0	0	0	0
Ch herb	0	0	0	0	0	0	0	0	0	0	0
Ch succ	2	3	1	2	2	3	1	1	1	1	1
Ch l succ	1	2	0	1	1	2	0	0	0	0	0
Ch st succ	1	1	1	1	1	1	1	1	1	1	1
Hemicryptophytes (H)	**1**	**2**	**1**	**2**	**2**	**2**	**1**	**1**	**2**	**1**	**1**
H caesp	1	2	1	2	2	2	1	1	2	1	1
H rept	0	0	0	0	0	0	0	0	0	0	0
H ros	0	0	0	0	0	0	0	0	0	0	0
Liana (L)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Therophytes (T)	**23**	**10**	**3**	**12**	**20**	**14**	**1**	**16**	**11**	**23**	**20**
Geophytes (G)	**3**	**2**	**2**	**2**	**2**	**1**	**3**	**3**	**1**	**2**	**2**

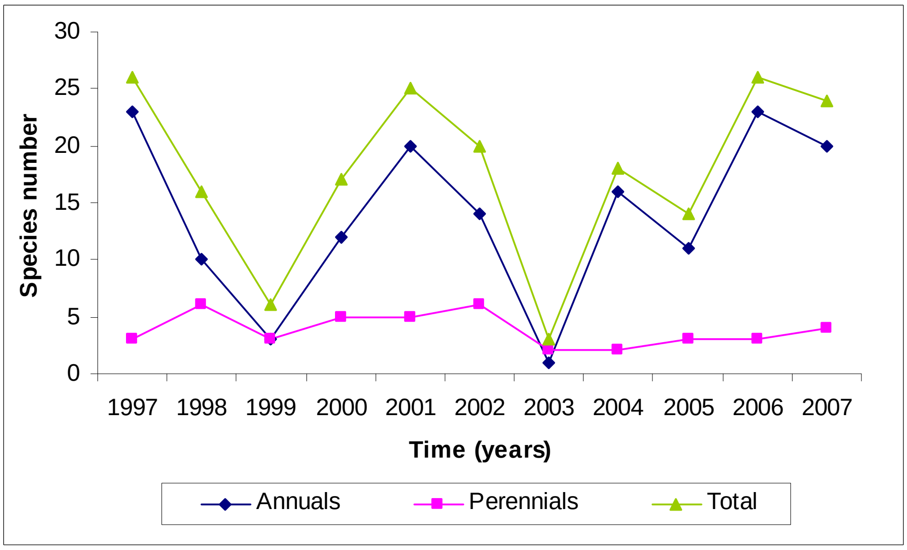


Figure 5.63 The species richness of annual and perennial species as well as total species richness during the past monitored years for the T'ganagas Plains line transect.

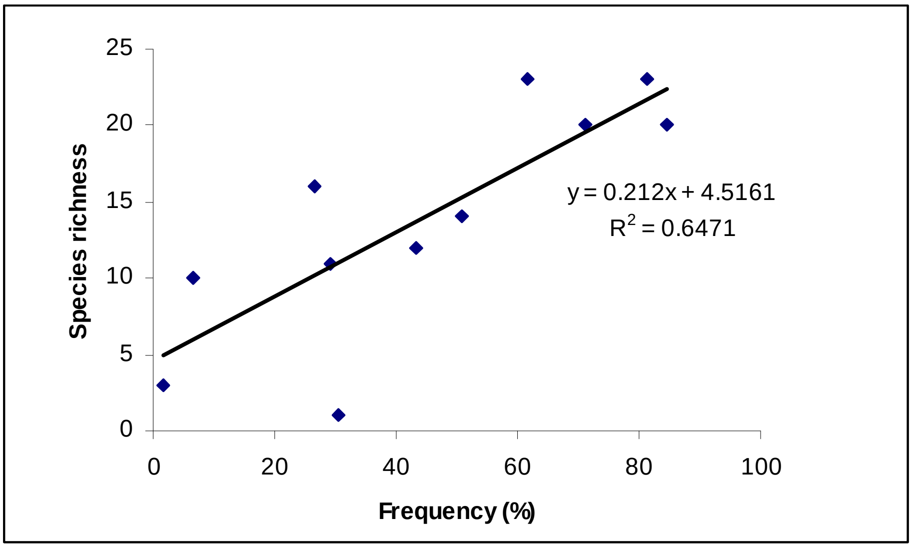


Figure 5.64 The regression of the frequency of strike for the annual species against the annual species richness for the T'ganagas Plains line transect.

5.6.4 *Species composition*

Individual species

The most abundant perennial species at the T'ganagas Plains line transect was *Psilocaulon junceum* (Appendix 8.6). This unpalatable species revealed a decrease (r^2 = 0.42) over the monitored years (Figure 6.66a). In general the annual species showed large fluctuations in abundance (Figure 6.66b).

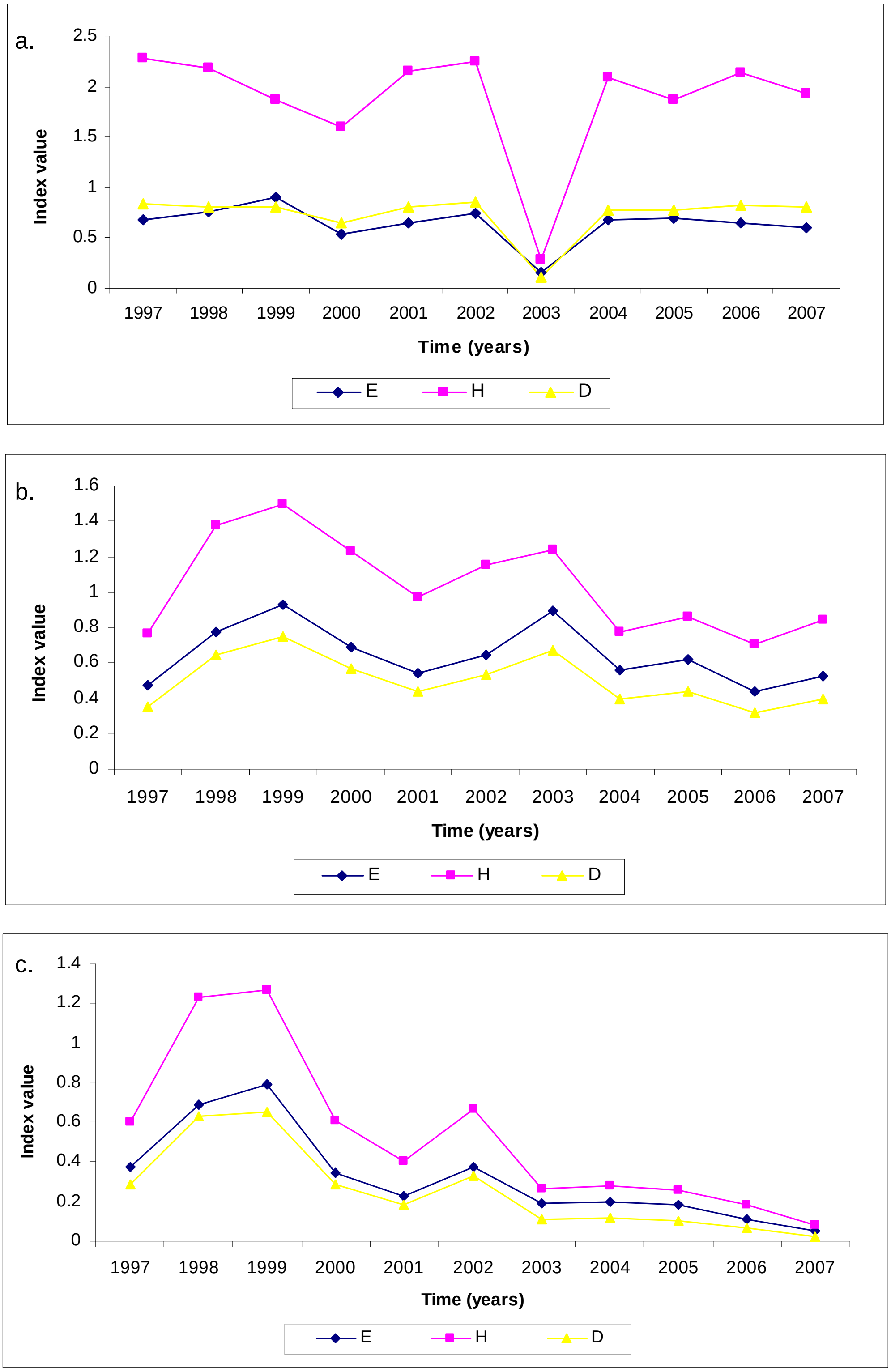


Figure 5.65 The diversity measures of (a) the first strikes of all species, using (b) the number of species in the different life forms and (c) the number of strikes in the different life forms, in the T'ganagas Plains line transect. E = species evenness, H = Shannon's diversity index and D = Simpson's diversity index.

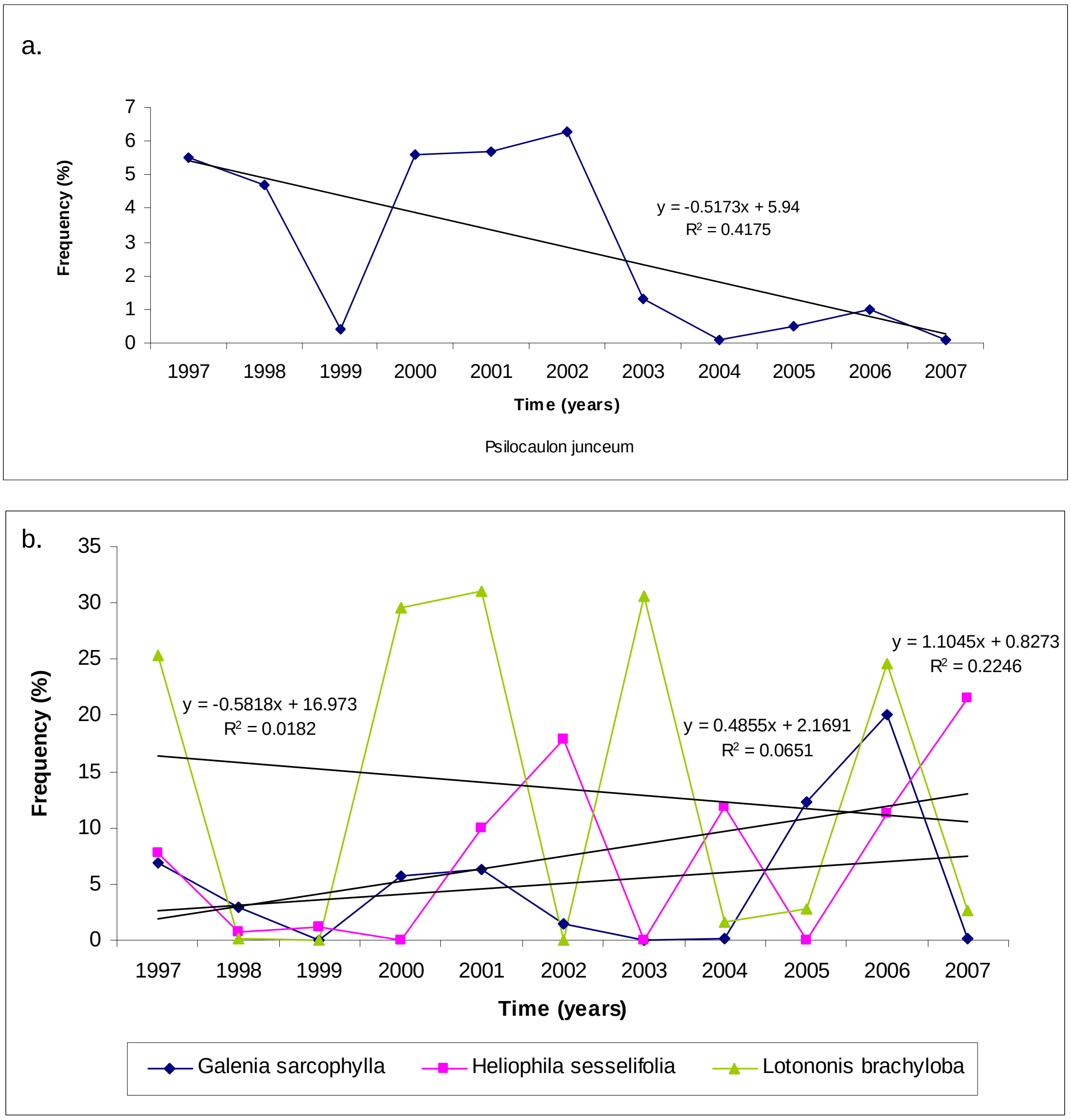


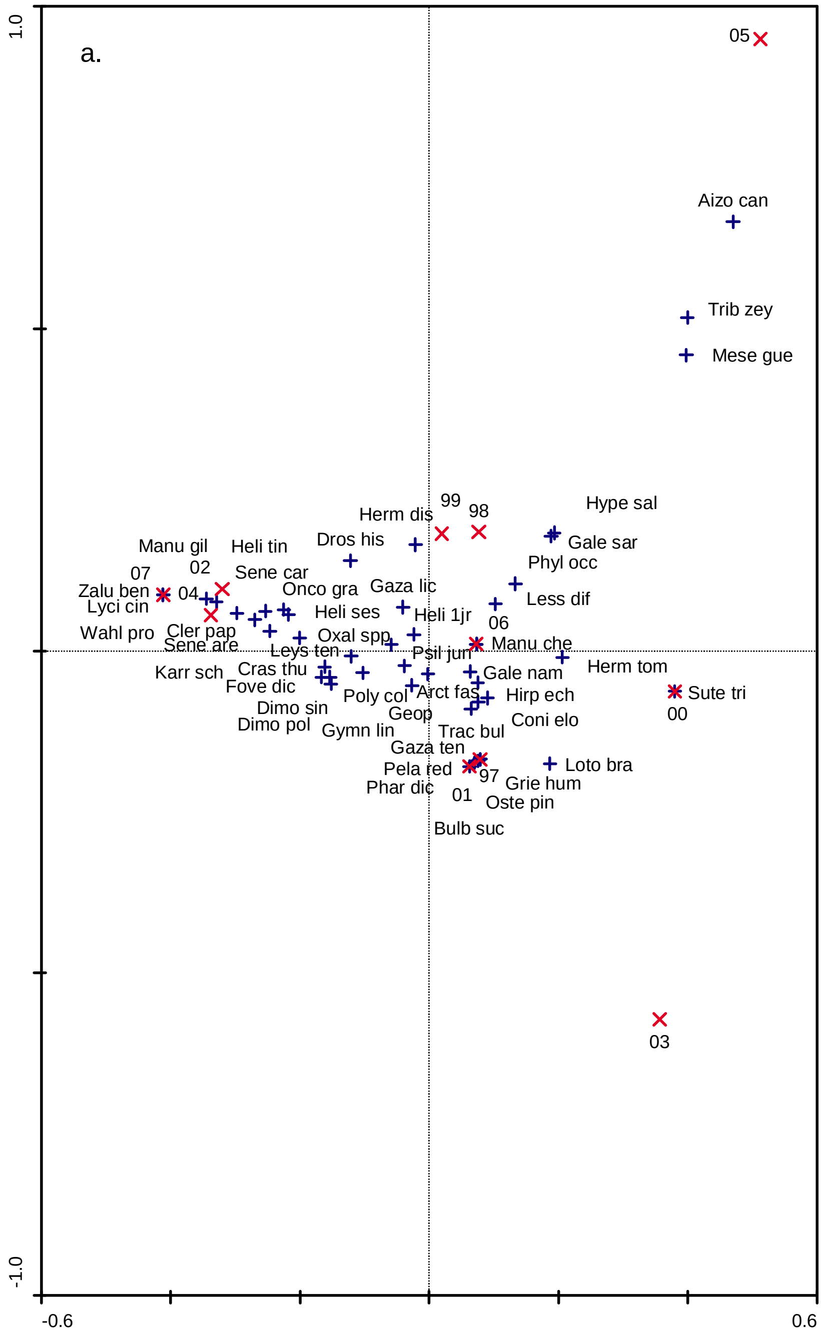
Figure 5.66 Changes in frequency of (a) *Psilocaulon junceum* and (b) selected annual species at T'ganagas Plains line transect (*Galenia sarcophylla*, r^2 = 0.07; *Heliophila sesselifolia*, r^2 = 0.22; *Lotononis brachyloba*, r^2 = 0.02).

Community composition

The Correspondence Analysis (CA) scatter diagram of data of all the species in the T'ganagas Plains line transect revealed that changes did occur (Figure 5.67), however it was difficult to detect a clear direction in the changes in the total species composition for the monitored years.

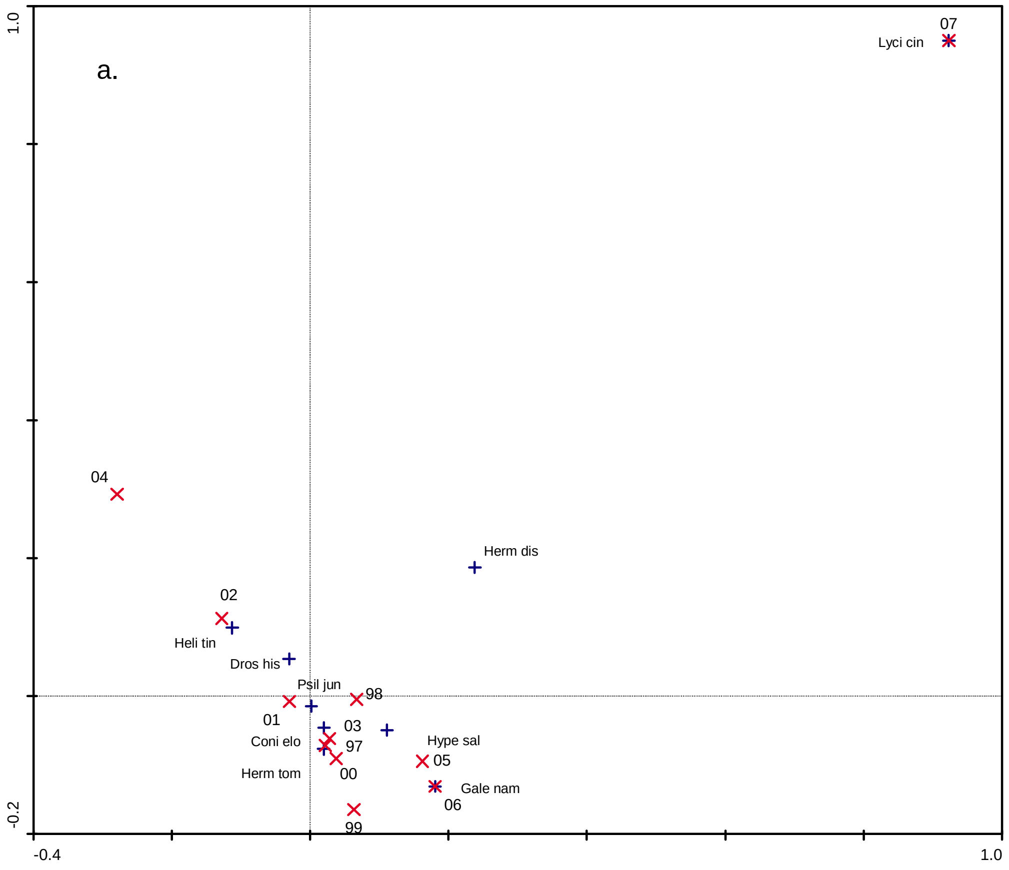
Perennial species composition

The perennial species of the T'ganagas Plains line transect (Figure 5.68a) did not reveal a clear gradient as time proceeded.



b.	Axes :	1	2	3	4	Total inertia
	Eigenvalues :	0.502	0.291	0.135	0.108	1.323
	Cumulative percentage					
	Variance of species data :	38.0	59.9	70.1	78.3	
	Sum of all eigenvalues :					1.323

Figure 5.67 (a) Scatter diagram produced by a Correspondence Analysis (CA) ordination showing the position of all species (47 species) relative to the monitored years for the T'ganagas Plains line transect. The red x-marks represent the years and the blue crosses the species. (b) Details of the CA ordination.



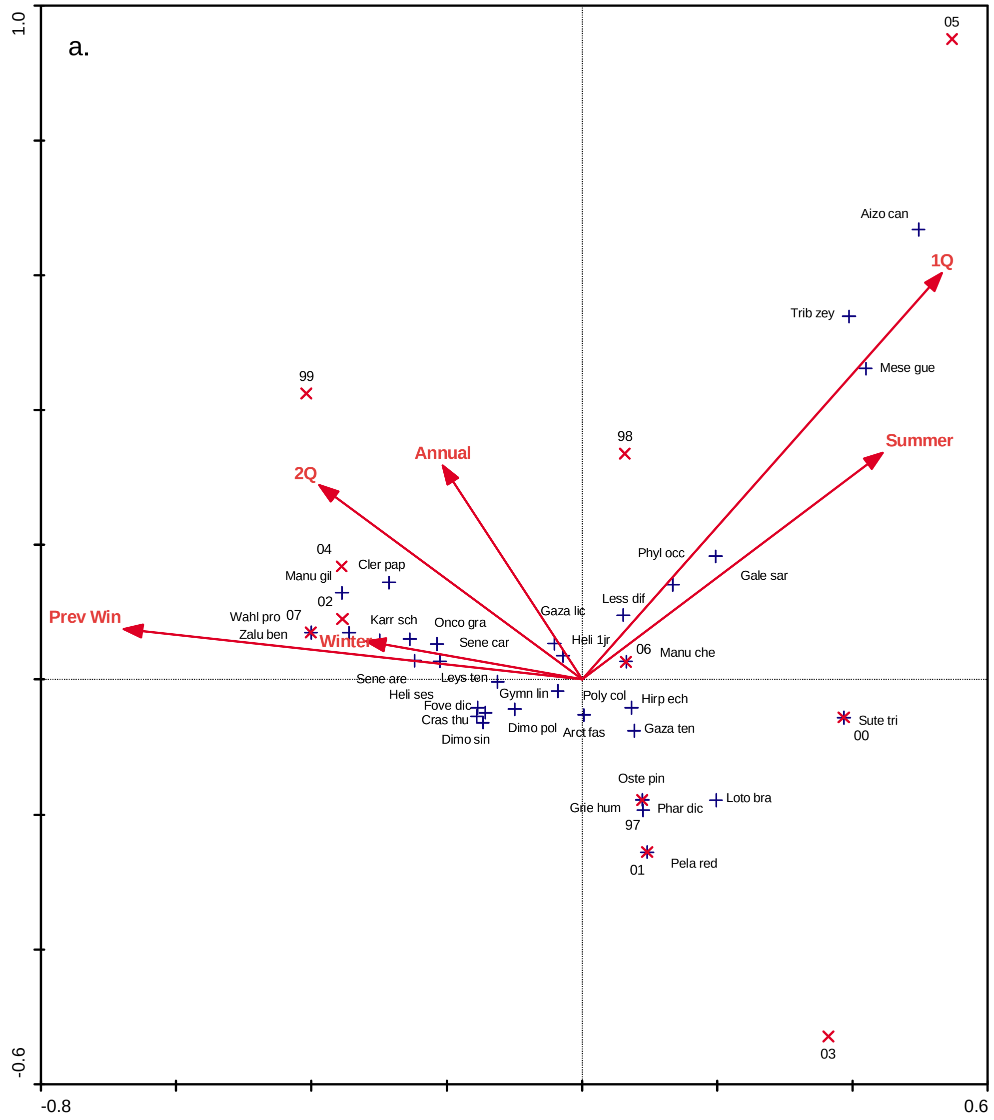
b.

Axes :	1	2	3	4	Total inertia
Eigenvalues :	0.345	0.282	0.194	0.147	1.058
Cumulative percentage					
Variance of species data :	32.6	59.2	77.6	91.5	
Sum of all eigenvalues :					1.058

Figure 5.68 (a) Scatter diagram produced by a Correspondence Analysis (CA) ordination showing the position of the perennial species (9 species) relative to the monitored years for the T'ganagas Plains line transect. The red x-marks represent the years and the blue crosses the species. (b) Details of the CA ordination.

Annual species composition

The Canonical Correspondence Analysis indicated that most of the annual species occurring on the T'ganagas Plains line transect showed a strong association with the winter rainfall (Figure 5.69). The annual species occurring in this line transect, however, showed no directional trend in species composition over the monitored years. There were fluctuations in the annual species composition because these species react towards the rainfall. There was a low (near to zero) correlation of summer rainfall with the winter and second quarter rainfall.



b.

Axes :	1	2	3	4	Total inertia
Eigenvalues :	0.526	0.302	0.098	0.054	1.145
Species-environment correlations :	0.997	0.993	0.973	0.965	
Cumulative percentage variance					
of species data :	45.9	72.2	80.8	85.5	
of species-environment relation:	50.8	80.0	89.5	94.6	
Sum of all eigenvalues :					1.145
Sum of all canonical eigenvalues :					1.034

Figure 5.69 (a) Canonical Correspondence Analysis (CCA) scatter diagram showing the position of 34 annual species relative to the years and rainfall in the T'ganagas Plains line transect. The red x-marks represent the years and the blue crosses the species. 1Q = rainfall from January to March of the current year, 2Q = rainfall from April to June of the current year, Summer = rainfall from October to December of the previous year plus January to March of the current year, Winter = rainfall from April to August of the current year, Prev Win = rainfall from April to September of the previous year and Annual = the annual rainfall of the current year. (b) Details of the CCA ordination.

5.6.5 *Grazing Capacity*

The grazing index method (GIM) was applied to calculate the grazing capacity of the vegetation on the T'ganagas plains (Du Toit 1996). The method involves calculating the veld condition score and by comparing this value with a benchmark with a known grazing capacity, the grazing capacity of the range under consideration can be calculated. The fluctuations in grazing capacity did not show directional trends (r^2 = 0.0973; Figure 5.70) and no improvement in grazing capacity could be demonstrated, however, a sudden decrease took place in 1999.

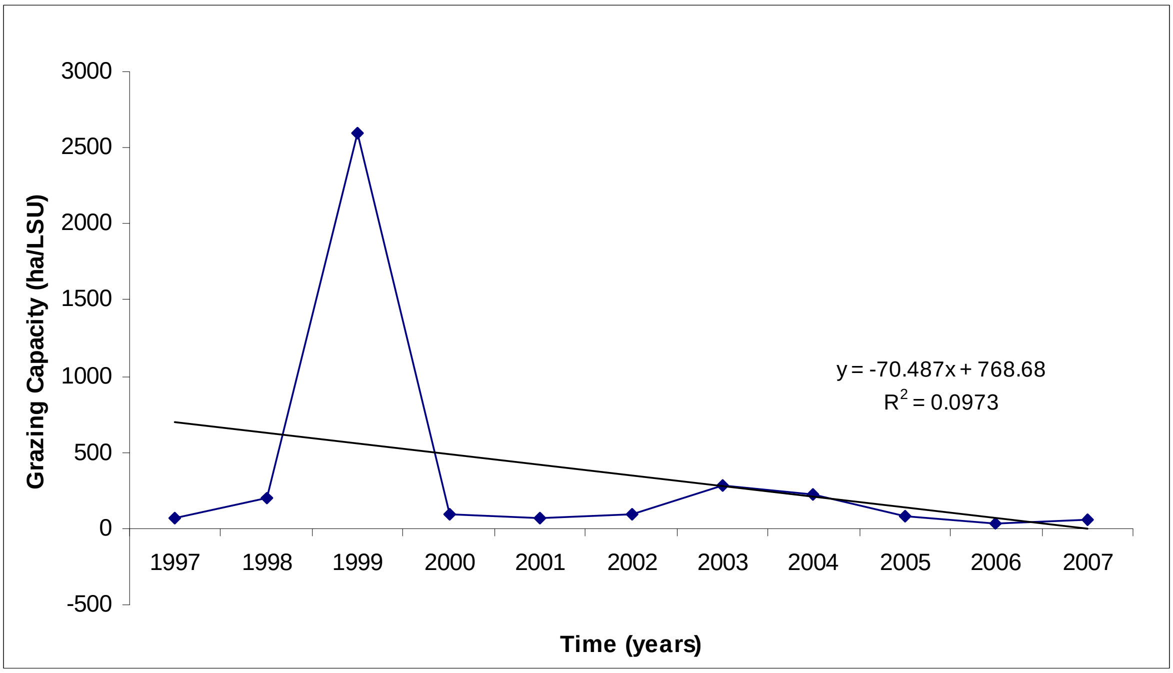


Figure 5.70 The grazing capacity (ha/LSU) throughout the monitored years for the vegetation occurring in the T'ganagas Plains line transect. LSU = Large Stock Unit.

5.7 Zebrawater Foothills

5.7.1 *Rainfall*

Figure 5.71 shows the fluctuation in the rainfall at the Zebrawater Foothills line transect with an increase in rainfall during the last three monitored years. The annual rainfall varied approximately sevenfold from 53.50 mm up to 334.90 mm rain. Fluctuations in annual rainfall are a common feature in semi-arid and arid environments. The winter rainfall was much higher than the summer rainfall, indicating that the area was situated in a winter rainfall region.

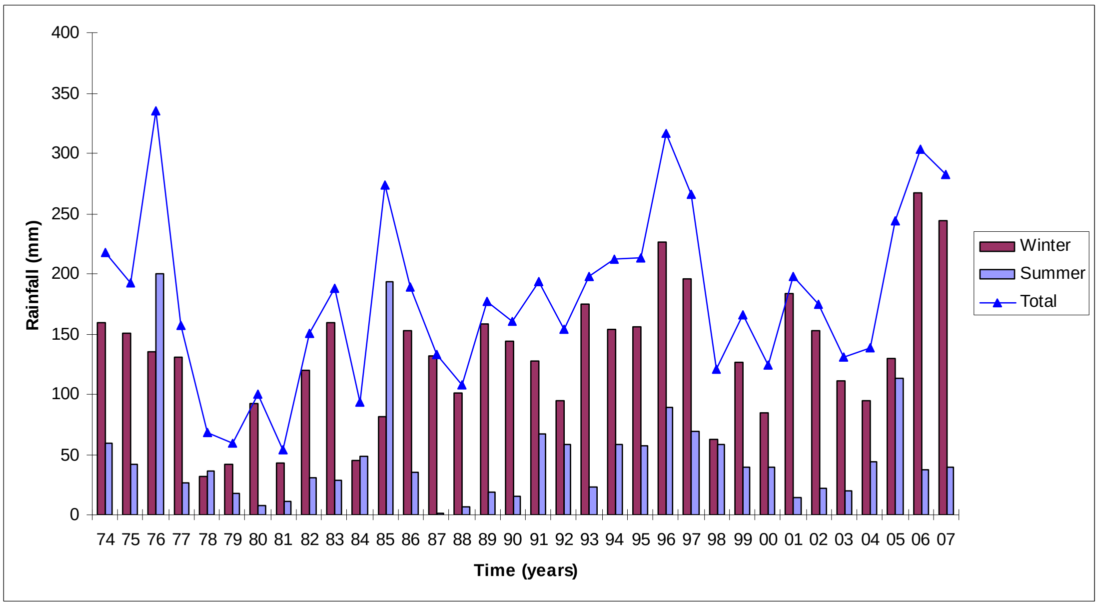


Figure 5.71 The rainfall during the monitored years at the Zebrawater Foothills line transect. Summer = rainfall in the summer months (January to March and October to December of the current year), Winter = rainfall in the winter months (April to September) and Total = the total annual rainfall (January to December)

5.7.2 *Frequency of occurrence of annual and perennial species*

The frequency of occurrence of the perennial species revealed an increasing trend at the Zebrawater Foothills line transect over time, except in the last year of surveying (Figure 5.72). Unfortunately, the recording of annual species did not take place in the Zebrawater Foothills line transect from 1984 to 1989 and hence the relationship between the frequency of the annual species with the winter rainfall did not included those years (Figure 5.73).

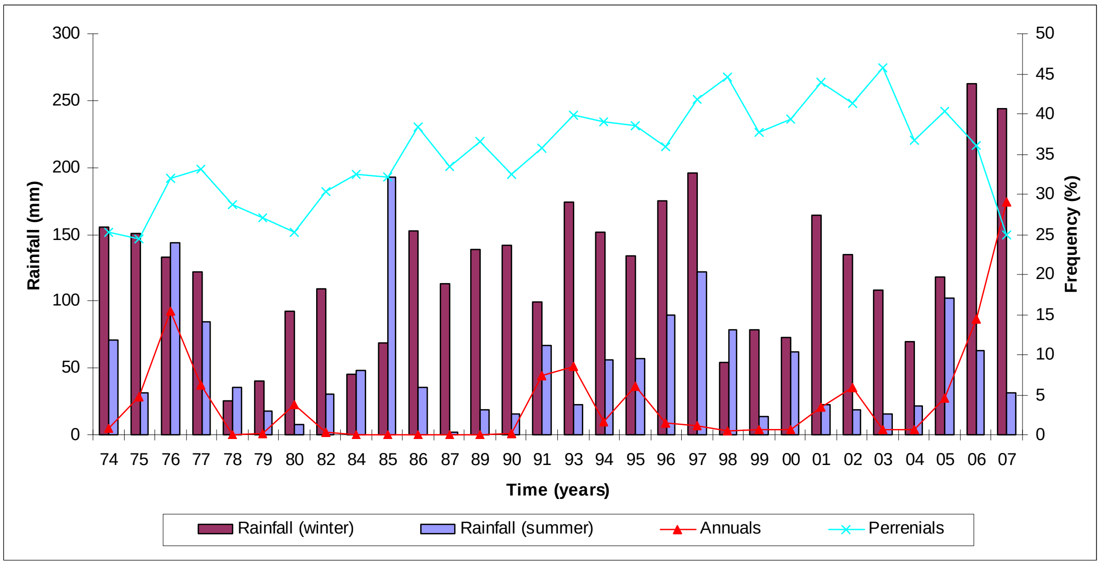


Figure 5.72 The frequency of strike of the annual and perennial species and the winter and summer rainfall during the monitored years for the Zebrawater Foothills line transect. The blue line represents the perennial species, whereas the red line represents the annual species. The summer rainfall stretches from October to December of the previous year and January to March of the current year, whereas the winter rainfall includes the rainfall from April to August of the current year.

Except in the last year (2007), the frequency of strikes of the perennial species exceeded that of the annual species and the vegetation at this line transect therefore comprised mostly perennial vegetation.

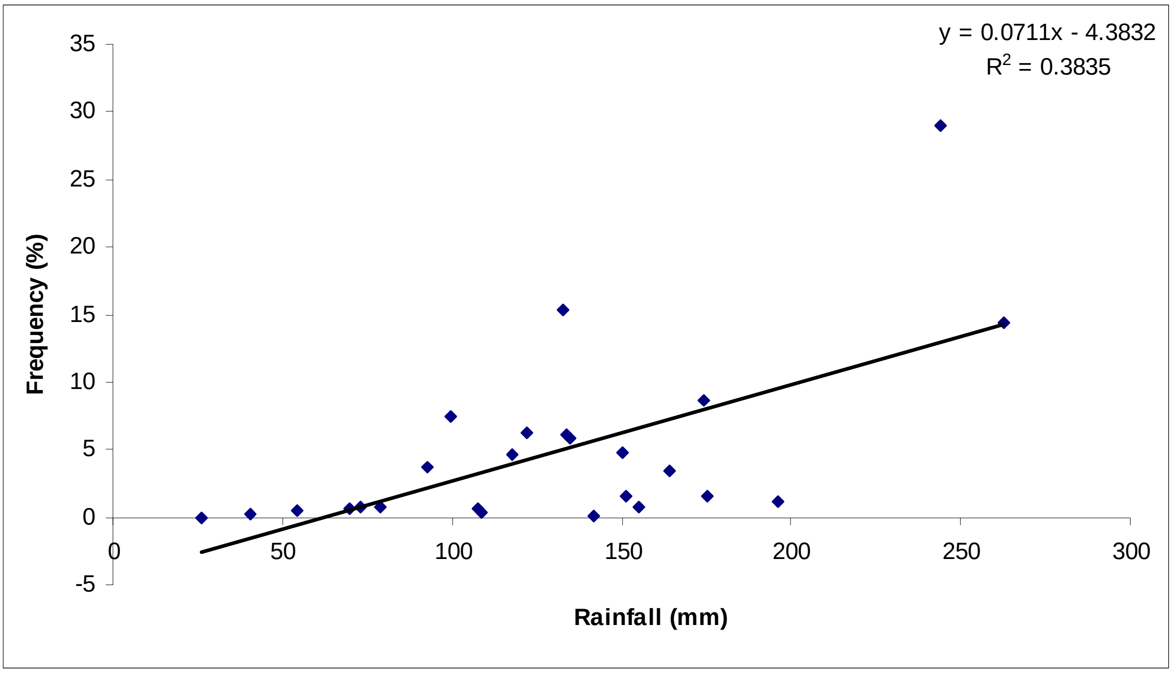


Figure 5.73 The regression of the winter rainfall against the frequency of annual species for the Zebrawater Foothills line transects.

5.7.3 *Species and life form diversity*

Species richness

The species richness of the perennial species (Figure 5.74) did not reveal clear changes in a specific direction. The species richness of the annual species revealed large fluctuations. In general, the correlation between the species richness of the annual species and the total annual rainfall was more positive (r^2 = 0.2152) than that of perennial species richness and total annual rainfall (r^2 = 0.1595). There was a strong correlation between the frequency of occurrence of the annual species and annual species richness (r^2 = 0.67; Figure 5.75).

Table 5.7 shows that the most prevalent life forms for the Zebrawater Foothills line transect were the therophytes and the chamaephytes.

Diversity measures

The evenness (E) and Simpson's index of diversity (D) remained almost unchanged over the monitoring period whereas the Shannon index (H) mirrored the species richness trends (Figure 5.76a). A similar trend for the Shannon index of diversity was observed when the number of strikes was used as a measure of the abundance of the growth forms (Figure 5.76c). Where the number of species was used as a measure of the abundance of growth forms (Figure 5.76b) the diversity measures showed a slight increase in the years with a low winter rainfall. In all three graphs (Figures 6a-c) the changes were not directional but depended primarily on the amount of winter rainfall.

Table 5.7 Number of species per life form occurring at the Zebrawater Footfills line transect

	1974	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**	**1982**	**1984**	**1985**	**1986**	**1987**	**1989**	**1990**
Phanerophytes (P)	**0**	**2**	**2**	**1**	**2**	**0**	**0**	**0**	**1**	**3**	**2**	**1**	**2**	**1**
NP scap	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NP caesp	0	2	2	1	2	0	0	0	1	3	2	1	2	1
Chamaephytes (Ch)	**14**	**17**	**21**	**21**	**18**	**22**	**18**	**18**	**21**	**19**	**22**	**19**	**23**	**22**
Ch frut	6	8	9	8	8	10	9	7	9	7	10	9	9	10
Ch suff	0	1	1	1	1	0	0	0	0	0	0	0	1	0
Ch herb	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ch succ	8	8	11	12	9	12	9	11	12	12	12	10	13	12
Ch l succ	6	6	9	9	8	10	7	8	9	9	9	7	10	9
Ch st succ	2	2	2	3	1	2	2	3	3	3	3	3	3	3
Hemicryptophytes (H)	**0**	**2**	**5**	**3**	**1**	**0**	**1**	**1**	**2**	**0**	**3**	**1**	**1**	**2**
H caesp	0	2	4	2	1	0	1	1	1	0	1	1	1	1
H rept	0	0	1	0	0	0	0	0	1	0	1	0	0	1
H ros	0	0	0	1	0	0	0	0	0	0	1	0	0	0
Liana (L)	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**1**	**0**	**0**
Therophytes (T)	**3**	**15**	**20**	**20**	**0**	**2**	**15**	**1**	**0**	**0**	**0**	**0**	**0**	**1**
Geophytes (G)	**0**	**0**	**1**	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	1994	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Phanerophytes (P)	**0**	**1**	**2**	**2**	**1**	**3**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**1**
NP scap	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NP caesp	0	1	2	2	1	3	2	2	2	2	2	2	2	1
Chamaephytes (Ch)	**23**	**25**	**23**	**25**	**21**	**21**	**19**	**23**	**24**	**20**	**21**	**21**	**21**	**19**
Ch frut	8	10	10	11	9	10	9	12	10	5	7	8	10	11
Ch suff	1	1	1	0	0	0	1	1	1	0	1	1	0	0
Ch herb	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ch succ	14	14	12	14	12	11	9	10	13	15	13	12	11	8
Ch l succ	11	11	9	11	9	9	7	8	10	12	11	10	9	6
Ch st succ	3	3	3	3	3	2	2	2	3	3	2	2	2	2
Hemicryptophytes (H)	**3**	**4**	**3**	**2**	**1**	**1**	**0**	**2**	**3**	**1**	**2**	**1**	**4**	**2**
H caesp	3	3	3	2	1	1	0	2	2	1	2	1	3	2
H rept	0	1	0	0	0	0	0	0	1	0	0	0	1	0
H ros	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Liana (L)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**
Therophytes (T)	**6**	**16**	**7**	**4**	**3**	**6**	**4**	**13**	**14**	**1**	**3**	**13**	**21**	**25**
Geophytes (G)	**3**	**1**	**1**	**2**	**0**	**0**	**0**	**2**	**1**	**1**	**1**	**1**	**1**	**1**

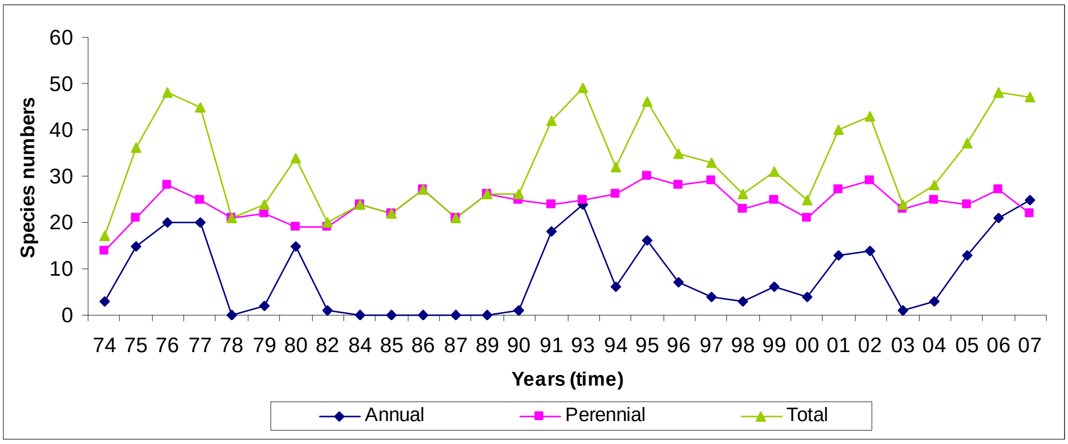


Figure 5.74 The species richness of annual and perennial species as well as total species richness during the past monitored years for the Zebrawater Foothills line transect.

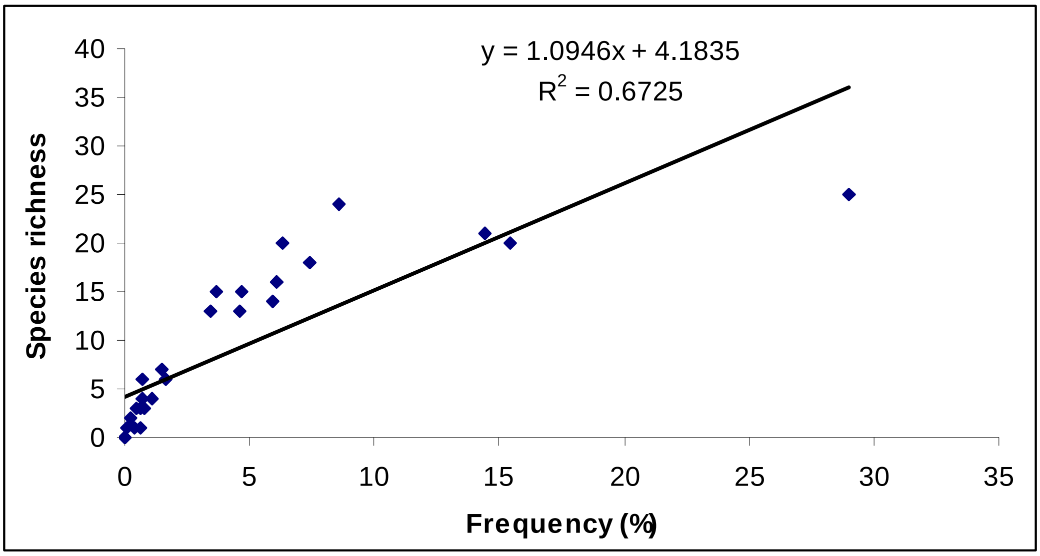


Figure 5.75 The regression of the frequency of strike for the annual species against the annual species richness for the Zebrawater Foothills line transect.

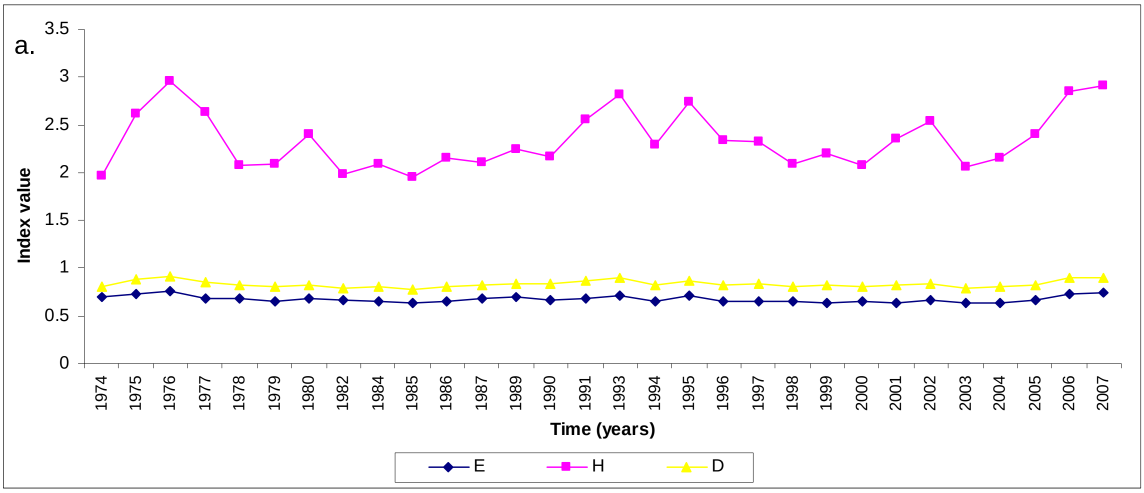
5.7.4 *Species composition*

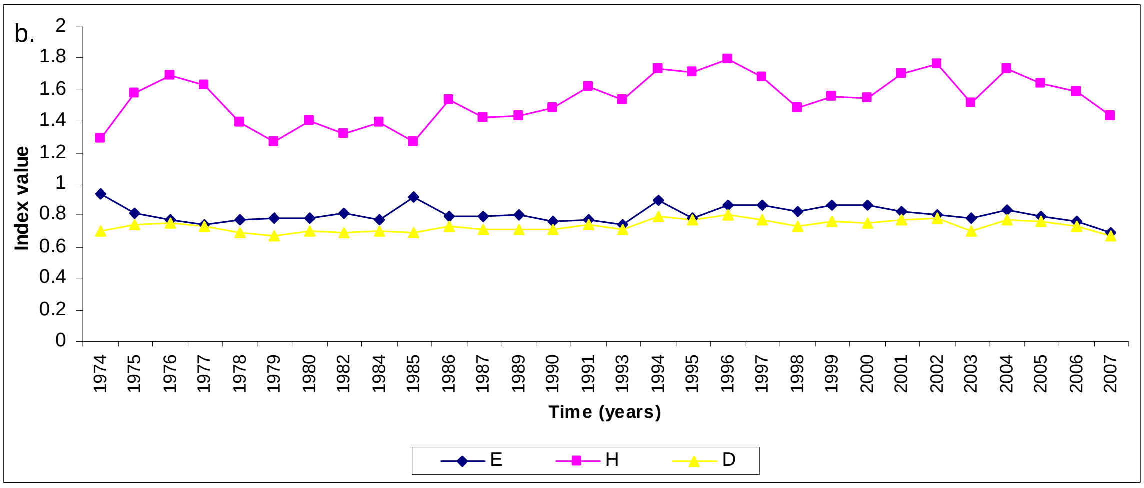
Individual species

The most abundant species at the Zebrawater Foothills were the perennial plant species *Eriocephalus microphyllus, Ruschia brevibracteata, Ruschia elineata* and *Tripteris sinuata* (Appendix 8.7). *Ruschia brevibracteata* and *Ruschia elineata*, both unpalatable species, showed a decreasing trend in frequency (r^2 = 0.33; r^2 = 0.79) over the monitored years (Figure 5.77a), whereas *Eriocephalus microphyllus* and *Tripteris sinuata*, both palatable species, revealed an increasing trend (r^2 = 0.51; r^2 = 0.66; Figure 5.77b-c). This change is an indication of veld recovery. In general the annual species showed large fluctuations in abundance.

Community composition

The Correspondence Analysis (CA) scatter diagram of data of all the species in the Zebrawater Foothills line transect revealed that changes did occur (Figure 5.78). The ordination of the total species composition of the Zebrawater Foothills line transect showed that most of the monitored years were clustered, and most of the species were associated with these years. No progression with time in a particular direction was present although a gradient stretched from the top at 1976 downwards, and another one from the 1970s to the right. The outstanding years were 1976, 2006 and 2007 each with only a few species associated with them. Two gradients were therefore present, one along the X- and one along the Y-axis. The high rainfall in 1976 and the exceptionally high summer rainfall component could possibly explain the position of this year along the Y-axis. The exceptionally high winter rainfall component in 2006 and 2007 could possibly explain their position along the X-axis.





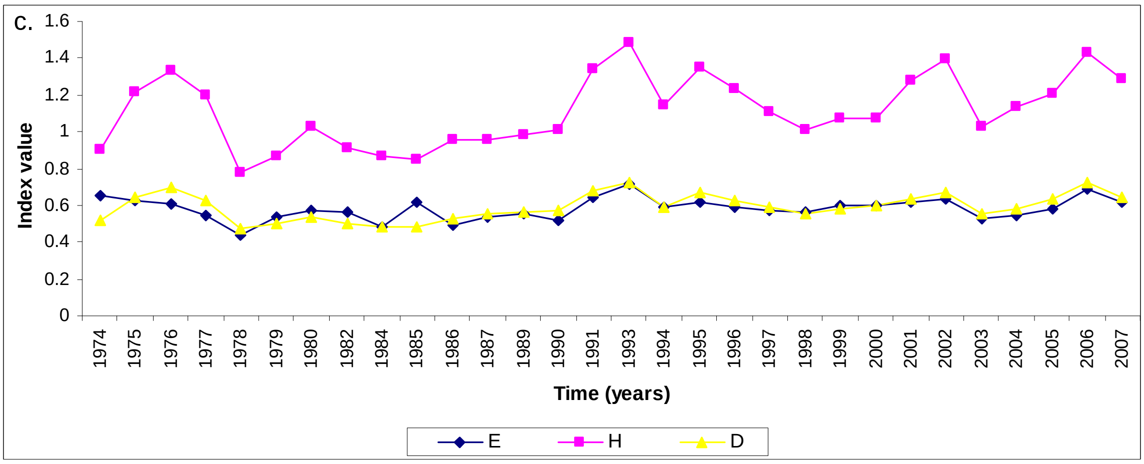


Figure 5.76 The diversity measures of (a) the first strikes of all species, (b) the number of species in the different life forms and (c) the number of strikes in the different life forms, in the Zebrawater Foothills line transect. E = species evenness, H = Shannon's diversity index and D = Simpson's diversity index.

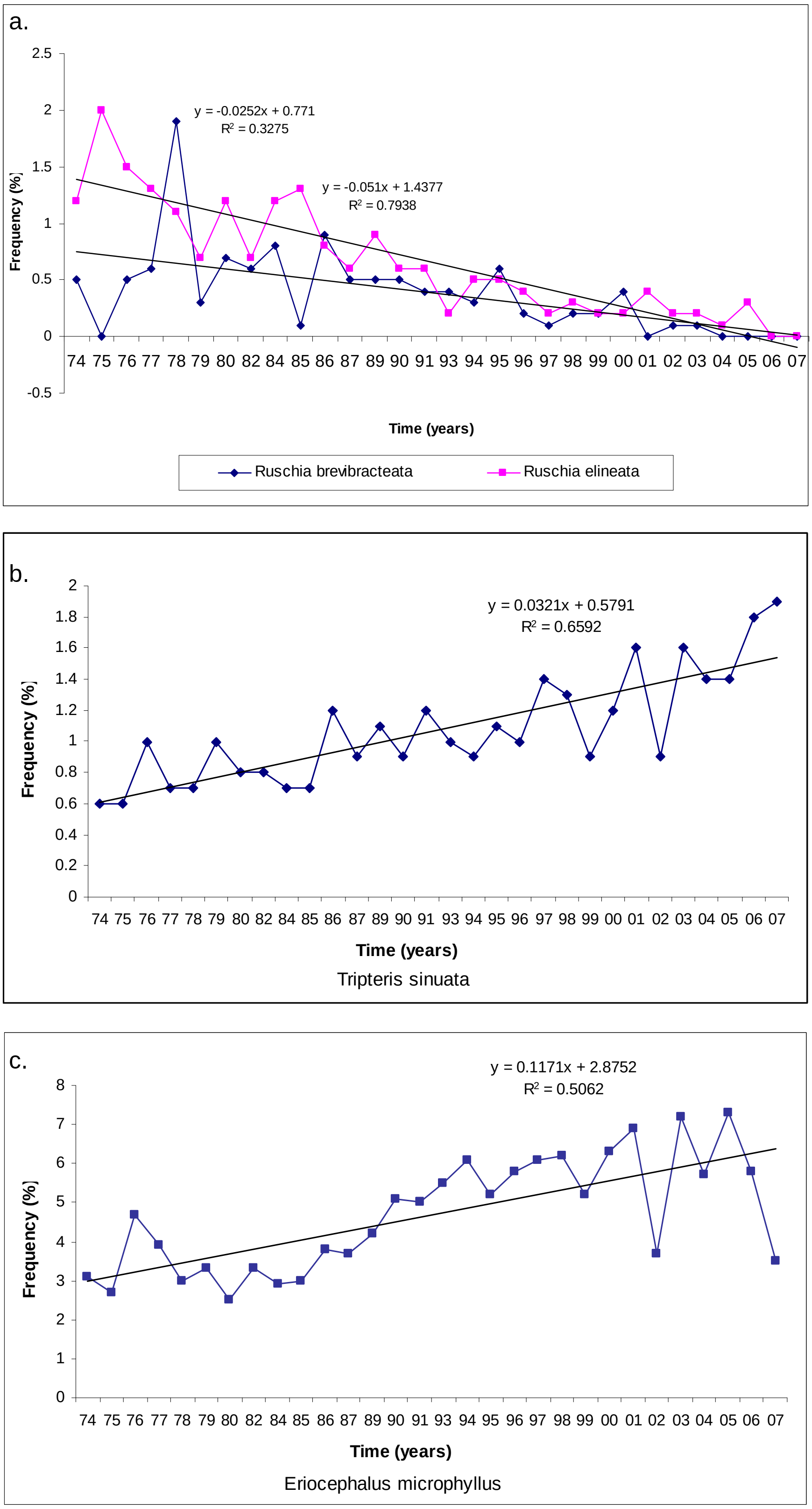
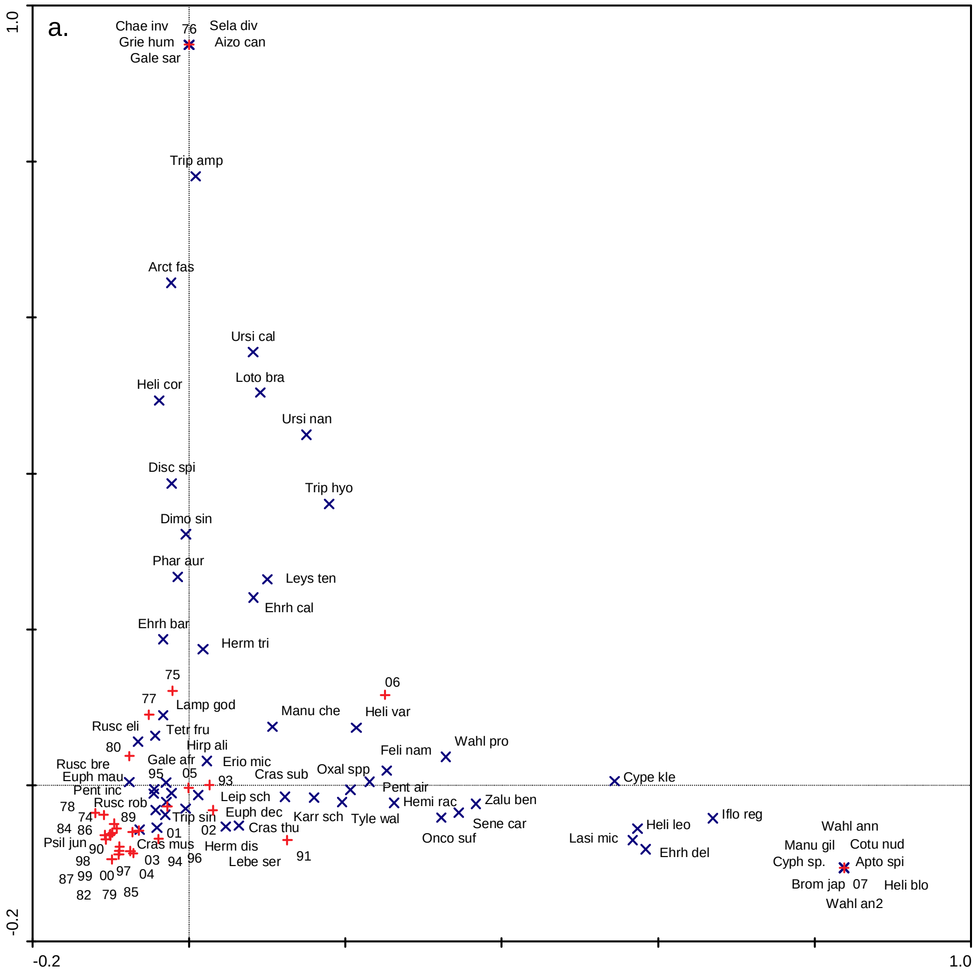


Figure 5.77 Changes in frequency of selected (a) unpalatable perennial species and (b&c) palatable species at Zebrawater Foothills line transect.

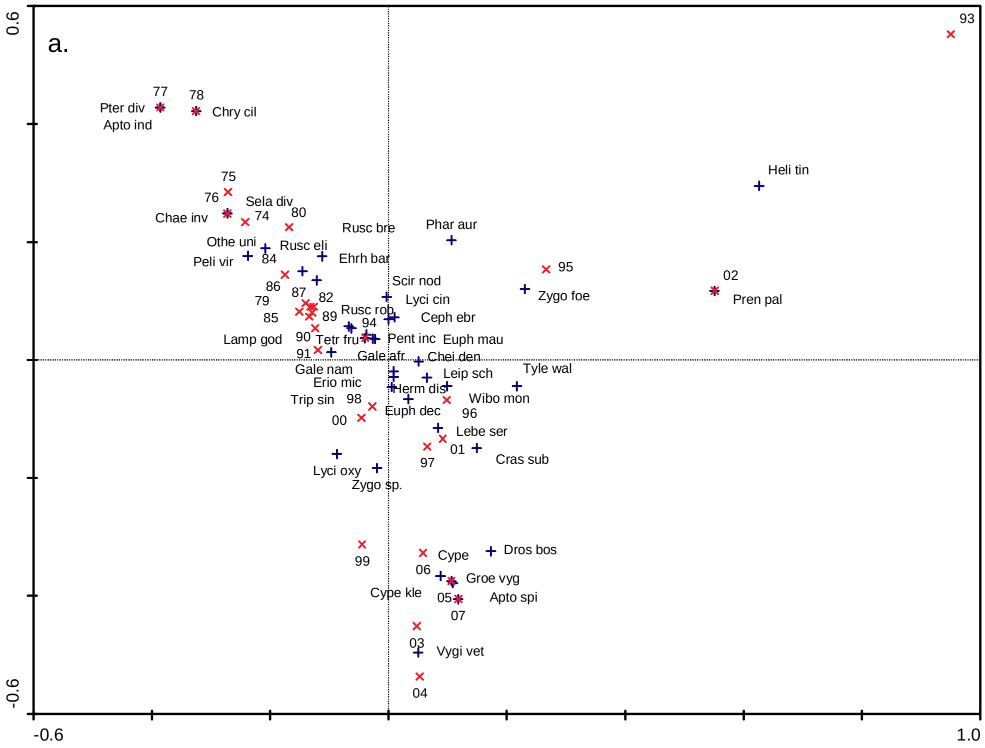


b.						
	Axes :	1	2	3	4	Total inertia
	Eigenvalues :	0.296	0.187	0.107	0.076	1.093
	Cumulative percentage					
	Variance of species data :	27.1	44.2	54.0	61.0	
	Sum of all eigenvalues :					1.093

Figure 5.78 (a) Scatter diagram produced by a Correspondence analysis (CA) ordination showing the position of 63 most important species, of the total 137 species relative to the monitored years, for the Zebrawater Foothills line transect. The red x-marks represent the years and the blue crosses the species. (b) Details of the CA ordination.

Perennial species composition

When only the floristic data of the perennial species was used in the Correspondence Analysis (Figure 5.79) directional changes in species composition over the monitored years were evident. The changes occurred from the upper left side of the ordination space to the lower centre of the ordination space as indicated by the arrow in Figure 5.80. Many species can be associated with the earlier years whereas the more recent years are only correlated with a few species.



b.

Axes :	1	2	3	4	Total inertia
Eigenvalues :	0.078	0.060	0.041	0.033	0.402
Cumulative percentage variance of species data :	19.4	34.4	44.7	52.9	
Sum of all eigenvalues :					0.402

Figure 5.79 (a) Scatter diagram produced by a Correspondence Analyis (CA) ordination showing the position of the 42 most important perennial species (of the total 68 perennial species) relative to the monitored years for the Zebrawater Foothills line transect. The red x-marks represent the years and the blue crosses the species. (b) Details of the CA ordination.

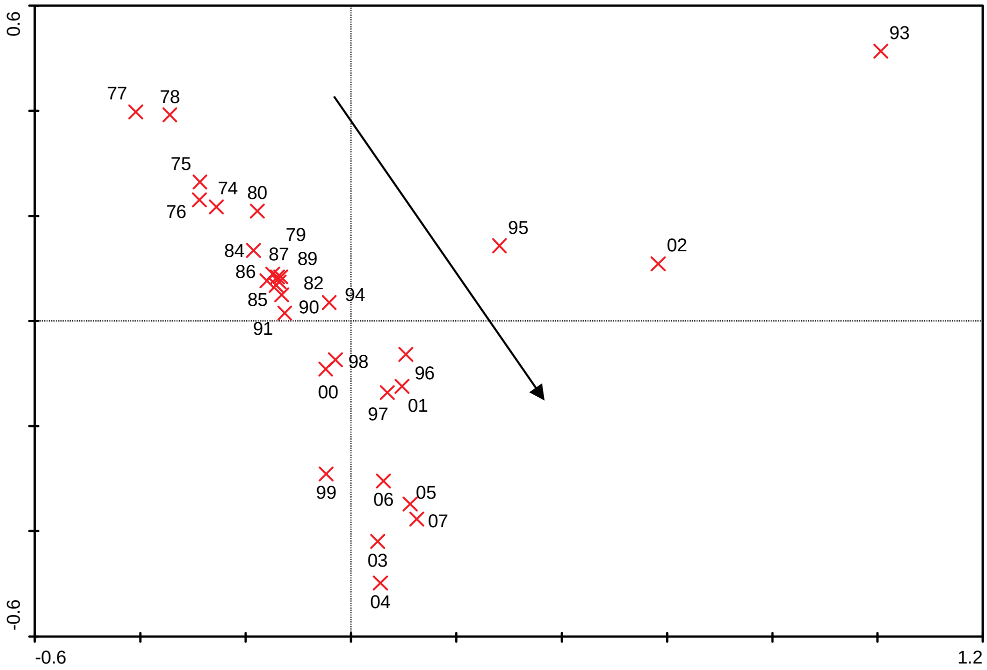
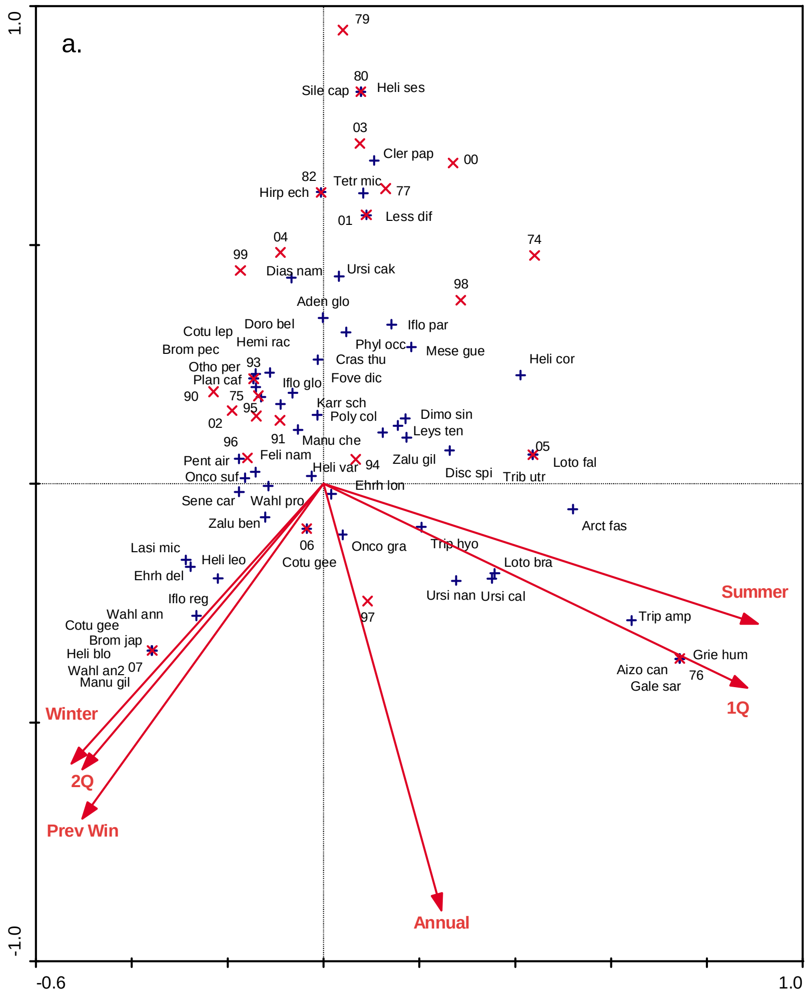


Figure 5.80 Scatter diagram produced by a Correspondence Analysis (CA) ordination indicating the change occurring over the monitoring period, where the arrow indicates the progress in years, in the Zebrawater Foothills line transect.

Annual species composition

Most of the annual species occurring on the Zebrawater Foothills line transect did not show a strong association with the winter rainfall (Figure 5.81). The annual species occurring in the Zebrawater Foothills line transect also showed no directional trend in species composition over the monitored years. However, there were fluctuations in the annual species composition because these species react towards the rainfall. There was a low (near to zero) correlation of summer rainfall with the winter and second quarter rainfall. Several annual species such as *Wahlenbergia annularis*, *Cotula* sp., *Bromus japonicus*, *Heliophila* sp. and *Manulea gilioides* had a strong correlation with the winter rainfall and were also associated with 2007, a year with exceptionally high winter rainfall.



	Axes :	1	2	3	4	Total inertia
b.	Eigenvalues :	0.486	0.363	0.213	0.145	4.191
	Species-environment correlations :	0.964	0.927	0.795	0.765	
	Cumulative percentage					
	variance of species data :	11.6	20.3	25.3	28.8	
	of species-environment relation :	36.2	63.3	79.1	89.9	
	Sum of all eigenvalues :					4.191
	Sum of all canonical eigenvalues :					1.342

Figure 5.81 (a) Canonical Correspondence Analysis (CCA) scatter diagram showing the position of 60 annual species relative to the years and rainfall in the Zebrawater foothills line transect. The red x-marks represent the years and the blue crosses the species. 1Q = rainfall from January to March of the current year, 2Q = rainfall from April to June of the current year, Summer = rainfall from October to December of the previous year plus January to March of the current year, Winter = rainfall from April to August of the current year, Prev Win = rainfall from April to September of the previous year and Annual = the annual rainfall of the current year. (b) Details of the CCA ordination.

5.7.5 *Grazing Capacity*

The grazing capacity showed a general increase over the monitored years, with the exception of 2007 where the grazing capacity showed a sudden decline (Figure 5.82). This improvement in grazing capacity (r^2 = 0.49) supported the general trends observed by the increase in palatable species and decrease in unpalatable species (Figure 5.77).

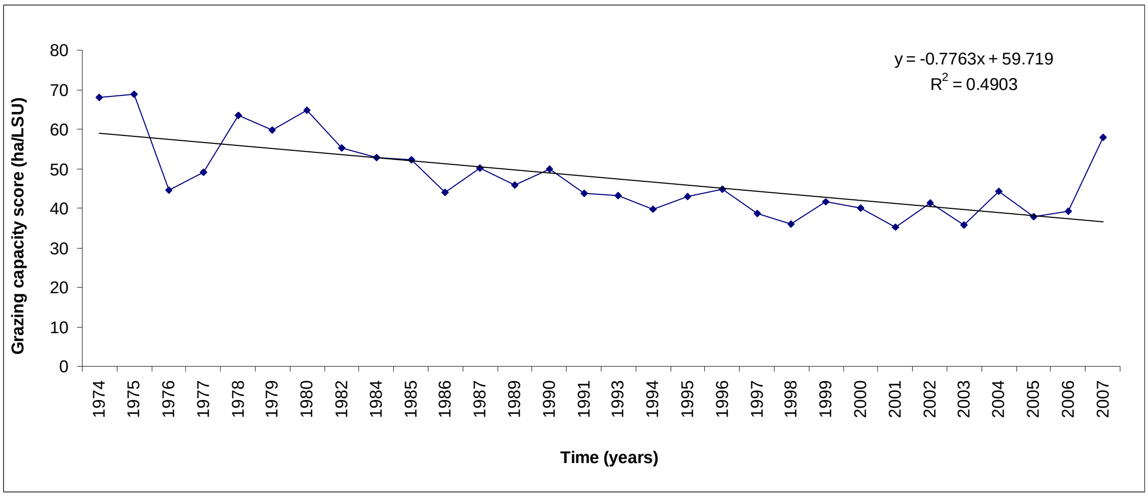


Figure 5.82 The veld condition score throughout the monitored years for the vegetation occurring in the Zebrawater Foothills line transect where LSU = Large Stock Unit.

CHAPTER 6

DISCUSSION AND CONCLUSIONS

6.1 Introduction

Overgrazing is believed to have degraded as much as two-thirds of the Succulent Karoo (http://www.skep.org) and is one of the largest threats to this global hotspot of biodiversity (Hendricks et al. 2005, 2007). Understanding the process of natural vegetation recovery after severe overstocking, and the rate at which it occurs may assist in developing techniques that could enhance the natural recovery process. The current study in the Goegap Nature Reserve therefore set out to assess the changes in the vegetation, in terms of species composition, species richness and life form richness, in seven long-term monitoring transects. Of prime importance was to answer the question whether the veld condition had improved since the removal of the livestock. However, because the wildlife that had been reintroduced into the reserve had increased in numbers, concern was being expressed that wildlife were now overutilising the vegetation and causing a deterioration in condition. The study therefore also intended to provide practical management recommendations on stocking density of wildlife on the reserve.

6.2 Vegetation trends

6.2.1 *Bleshoek Plains*

The Bleshoek Plains line transect is located in the *Galenia sarcophylla* – *Mesembryanthemum guerichianum* dwarf sparse shrubland sub-community and the *Psilocaulon absimile* – *Zygophyllum retrofractum* low sparse shrubland community (Rösch 2001*a*) and represents management unit 3. Up to 1990, it was part of the neighbouring Goegap farm and was grazed heavily by livestock. From 1990 to 2002 the fence between the old reserve section (Hester Malan) and the Goegap section was kept intact and no wildlife grazed in the area. The line transect was established in 1991 since when it has been regularly monitored.

In general, the perennial component of the vegetation showed little changes in the frequency of occurrence and the species richness. The annual component, on the other hand, showed large fluctuations depending on the timing and the amount of rainfall. These fluctuations were evident in terms of the frequency of occurrence, species richness and composition. Some species showed a clear preference for summer rainfall but most species were associated with winter rainfall and second quarter rainfall. The perennial species composition revealed directional change as the years progressed, where the unpalatable species *Ruschia robusta* decreased in the last few years. This change is an indication of veld recovery. However, the decrease of some of the palatable perennial grass species (*Stipagrostis obtusa* and *S. brevifolia*) showed the opposite trend, specifically after the fence was removed. During the last four years when the wildlife was still excluded, the grazing capacity improved. However, in the year after the fence was removed, it worsened. The removal of the fence coincided with the years with very low winter rainfall as the only rain that occurred was at the end of the growing season in spring. Changes in the life form diversity were not directional but depended mainly on the winter rainfall, with the Shannon index of the life forms increasing with a low winter rainfall. However, the opposite trend appeared for the number of strikes.

6.2.2 *Bluemine Mountain*

The Bluemine Mountain line transect is located in the *Searsia undulata* tall sparse shrubland and *Leipoldtia schultzei* short open shrubland communities and represents management unit 10. This line transect formed part of the older, Hester Malan section, and was heavily grazed by livestock until 1969 when the reserve was fenced and the livestock excluded. This line transect was established in 1974 since when it has been regularly monitored.

The perennial component of the vegetation showed a slight increase in the frequency of occurrence but did not reveal definite changes in species richness. As was the case for the Bleshoek Plains line transect, the annual component showed fluctuations in frequency of occurrence, species richness and composition. Most species did not show a preference for high winter rainfall. Although most annual species did not show a clear preference for high winter rainfall, more annual species were associated with the winter rainfall than with the summer rainfall. There was a directional change from the earlier to the more recent years in the perennial species composition, with only a few species associated with the more recent years, indicating that the vegetation occurring during the earlier years contained a larger component if unpalatable species left after the heavy grazing by livestock until 1969. The increase in several palatable species and the decrease in several unpalatable species are an indication of veld recovery. The veld condition score therefore revealed a steady increase, and indicates improvement in the grazing capacity. Changes in the life form diversity were not directional but depended mainly on the winter rainfall, with the Shannon index of the life forms decreased with a low winter rainfall. However, a different trend appeared for the number of strikes for the life forms, where there seemed to be a gradual decline in diversity.

6.2.3 *Goegap Plains*

The Goegap Plains line transect is located in the *Tripteris sinuata* short open shrubland community and represents management unit 5. Up to 1990, it was part of the neighbouring Goegap farm and was grazed heavily by livestock. From 1990 to 2002 the fence between the old reserve section

(Hester Malan) and the Goegap section was kept intact and no wildlife grazed in the area. The line transect was established in 1991 since when it has been regularly monitored.

Similar to the Bleshoek Plains line transect, the perennial component of the vegetation showed little changes in the frequency of occurrence and the species richness. The annual species component, on the other hand, showed large fluctuations depending on the timing and the amount of rainfall. As was the case for the Bluemine Mountain line transect, most species did not show a preference for high winter rainfall. Some species, however, preferred high summer or first quarter rainfall. The perennial species composition did not indicate a change in direction as time proceeded, neither did the veld condition show any trend in a specific direction and therefore no improvement in grazing capacity could be demonstrated. The low grazing capacity during 2003 was due to the low winter rainfall at the end of the growing season. However, several unpalatable species showed a decreasing trend, this indicating veld recovery. Changes in the life form diversity were not directional but depended mainly on the winter rainfall, where the Shannon index of diversity of the life forms (based on the number of species) increased with a low winter rainfall. However, a different trend appeared for the number of strikes, where the Shannon index of diversity showed a gradual decline throughout the last couple of monitored years.

6.2.4 *Jaleeg Plains*

The Jaleeg Plains line transect is situated in the *Drosanthemum hispidum* – *Mesembryanthemum guerichianum* dwarf sparse shrubland subcommunity, *Psilocaulon junceum* low sparse shrubland and *Stipagrostis brevifolia* short sparse shrubland and represents management 7. Up to 1990, it was part of the neighbouring Goegap farm and was grazed heavily by livestock. From 1990 to 2002 the fence between the old reserve section (Hester Malan) and the Goegap section was kept intact and no wildlife grazed in the area. The line transect was established in 1991 since when it has been regularly monitored.

Similar to the Bluemine Mountain line transect, the perennial component of the vegetation revealed an upward trend in the frequency of occurrence over time, however, no definite changes were revealed in the species richness. The frequency of the annual species showed a weak relationship with the winter rainfall, and no directional trend in composition, however, large fluctuations were revealed in the annual species richness. The perennial species composition did not reveal directional change as time proceeded. The improved veld condition gradually throughout the monitored years, therefore the grazing capacity improved. As was the case for the Bleshoek Plains line transect, the changes in the life form diversity were not directional but depended mainly on the winter rainfall, where the Shannon index of diversity of the life forms increased with a low winter rainfall. However, the opposite trend appeared for the number of strikes for the life forms.

6.2.5 *Koperberg Plains*

The Koperberg Plains line transect is situated in the *Psilocaulon junceum – Drosanthemum hispidum* low sparse shrubland and *Galenia sarcophylla – Mesembryanthemum guerichianum* dwarf sparse shrubland subcommunity and represents management 2. This severe degraded piece of land forms part of the reserve since establishment of the Hester Malan Nature Reserve in 1966. It is situated adjacent to the tailings of the Carolusberg copper mine and the soil is covered with a layer of dust which has been blown from the tailings. There is also a dry river course running through the area and as a result it was severely overgrazing before being incorporated into the reserve. The line transect was established in 1997 since when it has been regularly monitored.

Similar to the Bleshoek and Goegap Plains line transects, in general, the perennial component of the vegetation showed little changes in the frequency of occurrence and the species richness. The annual component, on the other hand, showed large fluctuations depending on the timing and the amount of rainfall. These fluctuations were evident in terms of the frequency of occurrence, species richness and composition. As was the case for the Bluemine Mountain and Goegap Plains line transect, most species did not show a preference for high winter rainfall. Some species, however, preferred high summer rainfall. The perennial species composition revealed directional change as the years progressed, however no improvement in veld condition and consequently grazing capacity could be demonstrated. Changes in the life form diversity were not directional but depended mainly on the winter rainfall, where the Shannon index of diversity of the life forms increased with a low winter rainfall. However, a different trend appeared for the number of strikes, where the diversity showed a gradual decline.

6.2.6 *T'ganagas Plains*

The T'ganagas Plains line transect is situated in the *Drosanthemum hispidum – Mesembryanthemum guerichianum* dwarf sparse shrubland community and represents management 4. This line transect is situated in the original Hester Malan Nature Reserve and was cultivated many years before the reserve was proclaimed. Since proclamation of the Hester Malan Nature Reserve is has been one of the preferred sites of gemsbok and springbok, especially during the summer. It has also carried large numbers of small mammals. The line transect was established in 1997 since when it has been regularly monitored.

Similar to the Bleshoek and Goegap Plains line transect, in general, the perennial component of the vegetation showed little changes in the frequency of occurrence and the species richness. The annual component, on the other hand, showed large fluctuations depending on the timing and the amount of rainfall. These fluctuations were evident in terms of the frequency of occurrence, species richness and composition. Some species showed a clear preference for summer and first quarter rainfall but most species were associated with winter and second quarter rainfall. The perennial species composition revealed directional change as the years progressed, where the unpalatable species *Psilocaulon junceum* decreased in the last few years. This change is an indication of veld recovery although no improvement in grazing capacity could be demonstrated, however, a sudden decrease took place in 1999. As was the case for the Koperberg Plains line transect, changes in the life form diversity were not directional but depended mainly on the winter rainfall, where the Shannon index of diversity of the life forms increased with a low winter rainfall. However, a different trend appeared for the number of strikes, where the diversity showed a gradual decline.

6.2.7 *Zebrawater Foothills*

The Zebrawater Foothills line transect is located in the *Drosanthemum hispidum* – *Mesembryanthemum guerichianum* dwarf sparse shrubland subcommunity, *Searsia undulata* tall sparse shrubland and *Leipoldtia schultzei* short open shrubland communities and represents management unit 8 and 10. Up to 1990, it formed part of the, older, Hester Malan section, and was heavily grazed by livestock until 1969 when the reserve was fenced and the livestock excluded. This line transect was established in 1974 since when it has been regularly monitored.

Similar to the Bluemine Mountain and the Jaleeg Plains line transects, the frequency of occurrence of the perennial species component revealed an increasing trend (except in the last year of surveying). As was the case for the other line transects, the annual component showed fluctuations in frequency of occurrence, species richness and composition. Similar to the Bluemine Mountain line transect, most annual species did not show a preference for high winter rainfall. There was a directional change from the earlier to the more recent years in the perennial species composition, with only a few species associated with the more recent years. An investigation of the species composition indicated that the vegetation occurring during the earlier years contained a larger component of unpalatable species left after the heavy grazing by livestock until 1969. The increase in several palatable species and the decrease in several unpalatable species are an indication of veld recovery. The veld condition score therefore revealed a steady increase, and indicates improvement in the grazing capacity. The Shannon's index of diversity when the number of strikes was used as a measurement of abundance of life forms mirrored the species richness trends. The diversity measures for the number of species for the life forms showed a slight increase with low winter rainfall years. Changes for the diversity were not directional but depended mainly on the amount of winter rainfall.

6.3 Long-term monitoring

Long-term ecological monitoring is generally the preferred method for detecting changes of slow phenomena, subtle and complex phenomena and episodic or rare events (Pickett 1989, Franklin 1989, Pace & Cole 1989, Burt 1994). The current study could conclusively show that because the vegetation changes occurring in the Goegap Nature Reserve take place so slowly and over such a long period that for the efficient conservation of the reserve in this invaluable ecosystem, long-term ecological research is necessary. It is only then that vegetation changes can be detected and cause-effect relationships can be established (Pace & Cole 1989, South African Environmental Observatory Network 2002, 2004, Krug *et al*. 2006). The long time span over which long-term monitoring records have been gathered at the Goegap Nature Reserve has ensured that both exceptionally wet and exceptionally dry years have been incorporated in the period. The long-term monitoring of the line transects has improved our understanding of the functioning of this ecosystem, enabling us to create a 'trend-record', and has the ability to recognise chronic and detrimental ecosystem change (natural and anthropogenic). This improved the ecological warning capabilities, and must be used for management and decision making on ecological issues (Van Jaarsveld & Biggs 2000). The descending point method, that was used for monitoring each year, proved to be a rapid, repeatable and cost-effective method (Havstad & Herrick 2003) and provided data to analyse and to reflect various processes and functions.

The results clearly showed that the longest established, and therefore longest monitored line transects (the Bluemine Mountain and Zebrawater Foothills line transects), gave the best indication of directional change, demonstrating that change take place slowly in arid environments (although degradation can happen in a short time) confirming Pickett's statement (1989) that long-term studies are a reliable way to determine slow processes. High levels of year-to-year variability in the productivity (strongly linked to the precipitation level) were also revealed, showing biological phenomena are strongly related to physical parameters (Franklin 1989). Because this ecosystem is complex, it took long to build up a dataset for the development of useful hypotheses. It also became evident with the use of long-term data what significant changes have an impact on the nature reserve, such as the removal of livestock and the addition of wildlife.

6.4 Vegetation dynamics

The directional change notable in the perennial community composition over the monitored years in several of the line transects was evidence of the occurrence of succession (Burrows 1990, Glenn-Lewin *et al*. 1992, Barbour *et al*. 1987, Gurevitch *et al*. 2002). However, it is not implied that succession proceeds on a predetermined trajectory and reaches a single climax state as traditional succession theory predicts (Niering 1987, Krohne 2001). The results showed that non-directional change also occurred, especially in the annual community composition and the life form diversity. These changes are referred to as fluctuations and correlate with the rainfall, and did not result in directional changes in plant populations. These fluctuations in rainfall lead to complex dynamics (Richardson *et al*. 2005, 2007) and the dynamics are often described as being event-driven (Westoby et al. 1989a, 1989b) or nonequilibrium/disequilibrium (Behnke & Schoones 1993, Illius & O'Connor 1998, Ward 2006).

Because vegetation dynamics and management are interconnected, understanding these processes is critical to develop effective vegetation management together with sustained animal production. Vegetation change may be a slow process in an arid ecosystem due to the high inter-annual rainfall variation and therefore the variation in plant abundance and presence (Wiegand & Milton 1996, Cowling *et al*. 1999*a*, Todd & Hoffman 1999, Ward 2006). The results also showed that the effects of grazing and essential vegetation change operated irregularly (as supported by the state-and-transition model).

Therefore, the results showed, in accordance with Wiegand and Jeltsch (2000) and Ward (2006), that the vegetation changes occurred, over the short-term, unpredictably in response to the inter-annual variation in rainfall, and episodically, over several decades due to rare events, as well as grazing pressure, changes in climate, altered disturbance regimes, or a combination of these factors.

6.5 Mechanisms of plant species survival

The results clearly showed that the unpredictable rainfall, in time, amount and space, is a strong selective force influencing the life-history patterns and life cycle stages of the annual vegetation component. The most prevalent life forms for all the line transect were the therophytes and the chamaephytes. Drought evasion is a strategy common among these short-lived species, showing a large degree of flexibility in their growth rate, size and phenology (Van Rooyen *et al*. 1990) whereas succulence occurs mainly in perennial species.

6.6 Veld condition

The veld condition was determined with the use of the GIV (Grazing Index Values) of the plant species according to the method developed by Du Toit (1995, 1996, 2000, 2002, 2003). This method is a refinement of the method originally proposed for Karoo veld by Vorster (1982) and provided good comparative estimates of grazing capacity. For the Bluemine Mountain and the Zebrawater Foothills line transects, that had been monitored for more than 30 years, it was evident that the frequency of perennial species increased, and that the direction of vegetation change was from a larger component of unpalatable species in the early years to a larger component of palatable species in the more recent years. This indicated that removal of the livestock did have a positive effect on the veld condition and this was reflected in an improved carrying capacity. An improvement in the veld condition could also be demonstrated at Jaleeg Plains, but not in the case of the Goegap, Bleshoek, Koperberg and T’ganagas Plains line transects (where no directional change could be demonstrated). Although a decrease in several unpalatable species throughout the monitored years was detected at Koperberg Plains and T’ganagas Plains, this was not reflected in the veld condition assessment. These line transects have only been monitored since 1997 and the period could be too short to detect directional trends. The Goegap Plains, and to a lesser extent Bleshoek Plains, contains a large component of grasses in the vegetation and is therefore an area favoured by wildlife. At both sites the decrease in the contribution of the grass component was detected.

6.7 Conclusions and veld management recommendations

Human activities are having a major impact on the biodiversity and functioning of ecosystems in southern Africa. The consequences of these impacts have focused attention on the need to understand the processes of vegetation degradation but also of vegetation recovery. This study investigated the natural vegetation recovery process after the cessation of overgrazing by livestock. Overall, the recovery process proceeded very slowly and was primarily detected in the perennial component of the vegetation, with the annual component reacting to rainfall.

Long-term monitoring of the line transects has provided valuable information for the management of the Goegap Nature Reserve. Although an improvement in the carrying capacity at some sites was a positive sign, the lack of improvement at some of the preferred sites such as Goegap Plains, indicated that management intervention was needed. Results of the annual monitoring are indeed at present feeding into the regulation of stocking density on the reserve.

Managers should therefore use, as indicated by Bothma *et al*. (2004), indicator species (sensitive to grazing) to monitor the effect of grazing on the vegetation. It is vital to continue these developments in veld condition in order to evaluate and adjust veld management practices. As suggested by Hurt and Bosch (1991) the Ecological Index Method (EIM) and the Grazing Index Method (GIM), the results indicated these are practical methods and to give answers concerning the carrying capacity. Continuous monitoring of the line transects on a regular basis should take place, forming part of the complex dynamics of this ecosystem.

CHAPTER 7

REFERENCE LIST

ABBOT, J. & GUIJT, I. 1998. Changing views on change: participatory approaches to monitoring the environment. *South African Radio League (SARL) Discussion Paper* 2: 11 – 17.

ACOCKS, J.P.H. 1988. Veld Types of South Africa. *Memoirs of the Botanical Survey of South Africa* 57: 1 – 145.

BARBOUR, M.G., BURK, J.H. & PITTS, W.D. 1987. *Terrestrial Plant Ecology*. Benjamin/ Cummings, California.

BASKIN, J.M. & BASKIN, C.C. 1989. Physiology of dormancy and germination in relation to seed bank ecology. In: M.A. Leck, V.T. Parker & R.L. Simpson (eds) *Ecology of soil seed banks*. pp. 53 – 66. Academic Press, San Diego.

BEARD, G.R., SCOTT, W.A. & ADAMSON, J.K. 1999. The value of consistent methodology in long-term environmental monitoring. *Environmental Monitoring and Assessment* 54: 239 – 258.

BEHNKE, JR., R.H. & SCOONES, I. 1993. Rethinking range ecology: implications for rangeland management in Africa. In: R.H. Behnke, I. Schoones & C. Kerven (eds) *Range ecology at disequilibrium: new models of natural variability and pastoral Adaptations in African Savannas*. pp.1 – 31. Overseas Development Institute, London.

BIGGS, H.C., KERLEY, G.I.H. & TSHIGUVHO, T. 1999. A South African long-term ecological research network: a first for Africa? *South African Journal of Science* 95: 244 – 246.

BOTHMA, J. DU P. 2000. *Wildplaasbestuur*. Nuwe uitgebreide uitgawe. J.L. van Schaik Uitgewers, Pretoria.

BOTHMA, J. DU P., VAN ROOYEN, N. & VAN ROOYEN M.W. 2004. Using diet and plant resources to set wildlife stocking densities in African savannas. *Wildlife Society Bulletin* 32: 840 – 851.

BRISKE, D.D, FUHLENDORF, S.D. & SMEINS, F.E. 2003. Vegetation dynamics on rangelands: a critique of the current paradigms. *Journal of Applied Ecology* 40: 601 – 614.

BURROWS, C.J. 1990. *Processes of vegetation change*. Chapman & Hall, London.

BURT, T.P. 1994. Long-term study of the natural environment – perceptive science or mindless monitoring? *Progress in Physical Geography* 18: 475 – 496.

CONNELL, J.H., NOBLE, I.R. & SLATYER, R.O. 1987. On the mechanism producing successional change. *Oikos* 50: 136 – 137.

CONNELL, J.H. & SLATYER, R.O. 1977. Mechanisms of succession in natural communities and their role in community stability and organisation. *American Naturalist* 111: 1119 – 1144.

COUNCIL FOR GEOSCIENCE. *Geological Vector Data 1:250 000* for the Goegap Nature Reserve. Council for Geoscience, Pretoria.

COWLING, R.M., ESLER, K.J. & RUNDEL, P.W. 1999*a*. Namaqualand, South Africa – an overview of a unique winter-rainfall desert ecosystem. *Plant Ecology* 142: 3 – 21.

COWLING, R.M., PIERCE, S.M. & PATERSON-JONES, C. 1999*b*. Namaqualand: A Succulent Desert. Fernwood Press, South Africa.

DESMET, P.G. 2007. The diamonds of Namaqualand: an introduction to the environment and floral diversity. *Journal of Arid Environments* 70: 570 – 587.

DESMET, P.G. & COWLING, R.M. 1999. The climate of the karoo – a functional approach. In: W.R.J. Dean & S.J. Milton (eds) *The Karoo. Ecological patterns and processes*. pp. 3 – 16. Cambridge University Press, Cambridge.

DU TOIT, P.V.C. 1995. The grazing index method of range condition assessment. *African Journal of Range and Forage Science* 12(2): 61 – 67.

DU TOIT, P.V.C. 1996. *Development of a model to estimate grazing index values for Karoo plant species*. Ph.D. thesis. University of Pretoria, Pretoria.

DU TOIT, P.V.C. 1998. Description of a method for assessing veld condition in the Karoo. *African Journal of Range and Forage Science* 14(3): 90 – 93.

DU TOIT, P.V.C. 2000. Estimating grazing index values for plants from arid regions. *Journal of Range Management* 53: 529 – 536.

DU TOIT, P.V.C. 2002. Boesmankop grazing capacity benchmark for the Nama-Karoo. *Grootfontein Agric* 5: 1 – 6.

DU TOIT, P.C.V. 2003. *Veld evaluation*. Department of Agriculture. Grootfontein Agriculture Development Institute.

EGLER, F.E. 1954. Vegetation science concept. I. Initial floristic composition – a factor in old-field vegetation development. *Vegetatio* 4: 412 – 417.

ESLER, K.J. 1999. Plant reproductive ecology. In: W.R.J. Dean & S.J. Milton (eds) *The Karoo: ecological patterns and processes*. pp. 123 – 144. Cambridge University Press, Cambridge.

ESLER, K.J. & RUNDEL, P.W. 1999. Comparative patterns of phenology and growth form diversity in two winter rainfall deserts: the Succulent Karoo and Mojave Desert ecosystems. *Plant Ecology* 142: 97 – 104.

ESLER, K.J., RUNDEL, P.W. & COWLING, R.M. 1999. The Succulent Karoo in a global context: plant structural and functional comparison with North American winter-rainfall deserts. In: W.R.J. Dean & S.J. Milton (eds) *The Karoo. Ecological patterns and processes*. pp. 303 – 313. Cambridge University Press, Cambridge.

FENNER, M, & THOMPSON, K. 2005. *The Ecology of Seeds*. Cambridge University Press, Cambridge.

FRANKLIN, J.F. 1989. Importance and justification of long-term studies in ecology. In: G.E. Likens (ed.) *Long-term studies in ecology: approaches and alternatives*. pp. 3 – 19. Springer-Verlag, New York.

FRIEDEL, M.H. 1991. Range condition assessment and the concept of thresholds: a viewpoint. *Journal of Range Management* 44: 427 – 433.

GLENN-LEWIN, D.C., PEET, R.K. & VEBLEN, T.T. 1992. Prologue. In: D.C. Glenn-Lewin, R.K. Peet & T.T. Veblen (eds) *Plant succession – theory and prediction*. pp. 1 – 10. Chapman & Hall, London.

GLENN-LEWIN, D.C. & VAN DER MAAREL. 1992. Patterns and processes of vegetation dynamics. In: D.C. Glenn-Lewin, R.K. Peet & T.T. Veblen (eds) *Plant succession – theory and prediction.* pp. 11 – 43. Chapman & Hall, London.

GUREVITCH, J., SCHEINER, S.M. & FOX, G.A. 2002. *The Ecology of Plants*. Sinauer, Massachusetts, U.S.A.

HARPER, J.L. 1977. *Population biology of plants*. Academic Press, New York.

HAVSTAD, K.M. & HERRICK, J.E. 2003. Long-term ecological monitoring. *Arid Land Research and Management* 17: 389 – 400.

HENDRICKS, H.H., BOND, W.J., MIDGLEY, J.J. & NOVELLIE, P.A. 2005. Plant species richness and composition along livestock grazing intensity gradients in a Namaqualand (South Africa) protected area. *Plant Ecology* 176: 19 – 33.

HENDRICKS, H.H., BOND, W.J., MIDGLEY, J.J. & NOVELLIE, P.A. 2007. Biodiversity conservation and pastoralism – reducing herd size in a communal livestock production system in Richtersveld National Park. *Journal of Arid Environments* 70: 718 – 727.

HENSCHEL, J.R. & PAUW, J. 2002. Environmental observatories. LTER a-la-Africa. In: H. Baijnath & Y. Singh (eds) *Rebirth of science in Africa: a shared vision for life and environmental sciences*. pp.149 – 159. Umdaus Press, Pretoria.

HENSCHEL, J., PAUW, J., BANYIKWA, F., BRITO, R., CHABWELA, H., PALMER, T., RINGROSE, S., SANTOS, L., SITOE, A. & VAN JAARSVELD, A. 2003. Developing the Environmental Long-term Observatories Network of South Africa (ELTOSA). *South African Journal of Science* 99: 100 – 108.

HILTON-TAYLOR, C. 1996. Patterns and characteristics of the flora of the Succulent Karoo Biome, southern Africa. In L.J.G. Van der Maeson, X.M. Van der Burgt & J.M. Van Medenbach de Rooy (eds) *Biodiversity of succulents and African arid regions*. pp. 58 – 72. Kluwer, Netherlands.

HURT, C.R. & BOSCH, O.J.H. 1991. A comparison of some range condition assessment techniques used in southern African grasslands. *Proceedings of the Grassland Society of South Africa* 8: 131 – 136.

ILLIUS, A.W. & O'CONNOR, T.G. 1998. On the relevance of non-equilibrium concepts to arid and semi-arid grazing systems. *Ecological Applications* 9: 798 – 813.

JÜRGENS, N., GOTZMANN, I.H. & COWLING, R.M. 1999. Remarkable medium-term dynamics of leaf-succulent Mesembryanthema (Aizoaceae) in the winter-rainfall desert of northwestern Namaqualand, South Africa. *Plant Ecology* 142: 87 – 96.

KENT, M. & COKER, P. 2001. *Vegetation description and analysis*. *A Practical Approach*. John Wiley & Sons Ltd, West Sussex.

KROHNE, D.T. 2001. *General Ecology* 2nd edn. Brooks/Cole, USA.

KRUG, C.B., ESLER. K.J., HOFFMAN M.T., HENSCHEL J., SCHMIEDEL U. & JUERGENS N. 2006. North-South cooperation through Biodiversity Monitoring Transect Analysis in South Africa (BIOTA Southern Africa): An interdisciplinary research programme in arid and semi-arid southern Africa. *South African Journal of Science* 102: 187 – 190.

LAND TYPE SURVEY STAFF. 1987. Land types of the maps 2816 Alexander Bay, 2818 Warmbad, 2916 Springbok, 2918 Pofadder, 3017 Garies and 3018 Loeriesfontein. *Memoirs on the Agricultural Natural resources of South Africa* 9: 1 – 538.

LAYCOCK, W.A. 1991. Stable states and thresholds of range condition on North American rangelands – a viewpoint. *Journal of Range Management* 44: 422 – 426.

LEPS, J. & SMILAUER, P. 2003. *Multivariate analysis of ecological data using CANOCO*. Cambridge University Press, Cambridge.

LE ROUX, A. & VAN ROOYEN, M.W. 1999. Succulent Karoo. In: J. Knobel (ed.) *The magnificent natural heritage of South Africa*. pp. 94 – 107. Sunbird Publishing, Llandudno.

LE ROUX, A. 1984. *'n Fitososiologiese studie van die Hester Malan-Natuurreservaat*. MSc. Dissertation. University of Pretoria, Pretoria.

LLOYD, W. 1996. An assessment of the veld condition potential of Goegap Nature Reserve. Northern Cape Nature Conservation Services, Departmental Report.

LOMBARD, A.T., HILTON-TAYLOR, C., REBELO, A.G., PRESSEY, R.L., & COWLING, R.M. 1999. Reserve selection in the Succulent Karoo, South Africa: coping with high compositional turnover. *Plant Ecology* 142: 35 – 55.

LOW, A.B. & REBELO T.G. 1998. *Vegetation of South Africa, Lesotho and Swaziland*. Department of Environmental Affairs & Tourism, Pretoria.

MARAIS, J.A.H., AGENBACHT, A.L.D., PRINSLOO, M. & BASSON, W.A. 2001. *The geology of the Springbok area*. Council for Geoscience, South Africa.

McCUNE, B. & MEFFORD, M.J. 1999. PC-ORD. *Multivariate Analysis of Ecological Data*, Version 4. MjM Software Design, Gleneden Beach, Oregon, USA.

MENTIS, M.T. 1981. Evaluation of the wheel-point and step-point methods of veld condition assessment. *Proceedings of the Grassland Society of South Africa*. 16: 89 – 94.

MILTON, S.J. & HOFFMAN, M.T. 1994. The application of state-and-transition models to rangeland research and management in arid succulent and semi-arid grassy Karoo, South Africa. *African Journal of Range and Forage Science* 11(1): 18 – 26.

MILTON, S.J., YEATON, R.I., DEAN, W.R.J. & VLOK, J.H.J. 1997. Succulent Karoo. In: R.M. Cowling, D.M. Richardson & S.M. Pierce (eds) *Vegetation of southern Africa*. pp. 131 – 161. Cambridge University Press, Cambridge.

MUCINA, L. & RUTHERFORD, M.C. (eds) 2006. The vegetation of South Africa, Lesotho and Swaziland. *Strelitzia* 19. South African National Biodiversity Institute, Pretoria.

MUCINA, L., RUTHERFORD, M.C. & POWRIE L.W. 2005. *Vegetation Map of South Africa, Lesotho and Swaziland, 1:1 000 000 scale sheet maps*. South African National Biodiversity Institute, Pretoria.

MUELLER-DOMBOIS, D. & ELLENBERG, H. 1974. *Aims and methods of vegetation ecology*. John Wiley & Sons, New York.

MURDOCH, A.J. & ELLIS, R.H. 2000. Longevity, viability and dormancy. In: Fenner (ed.) *Seeds: the ecology of regeneration in plant communities*. Chapter 8. CAB International, Wallingford.

NIERING, W.A. 1987. Vegetation dynamics (succession and climax) in relation to plant community management. *Conservation Biology* 1: 287 – 325.

NORTHERN CAPE NATURE CONSERVATION SERVICES. Undated. *Goegap Nature Reserve: Information Guide*. Northern Cape Nature Conservation Services, Kimberley.

PACE, M.L. & COLE, J.J. 1989. What questions, systems or phenomena warrant long-term ecological study? In: G.E. Likens (ed.) *Long-term studies in ecology: approaches and alternatives*. pp. 183 – 185. Springer-Verlag, New York.

PARR, T.W., SIER, A.R.J., BATTARBEE, R.W., MACKAY, A. & BURGESS, J. 2003. Detecting environmental change: science and society – perspectives on long-term research and monitoring in the 21st century. *The Science of the Total Environment* 310: 1 – 8.

PICKETT, S.T.A. 1989. Long-term studies: past experience and recommendations for the future. In: P.G. Risser (ed.) *Long-term ecological research: an international perspective*. pp. 71 – 88. Scientific Committee on Problems of the Environment (SCOPE) 47. Wiley, Chichester.

RICHARDSON, F.D., HAHN, B.D. & HOFFMAN, M.T. 2005. On the dynamics of grazing systems in the semi-arid Succulent Karoo: The relevance of equilibrium and non-equilibrium concepts to the sustainability of semi-arid pastoral systems. *Ecological Modelling* 187: 491 – 512.

RICHARDSON, F.D. & HAHN, B.D. 2007. A short-term mechanistic model of forage and livestock in the semi-arid Succulent Karoo: 1. Description of the model and sensitivity analyses. *Agricultural Systems* 95: 49 – 61.

RICHARDSON, F.D., HAHN, B.D. & HOFFMAN, M.T. 2007. Modelling the sustainability and productivity of the pastoral systems in the communal areas of Namaqualand. *Journal of Arid Environments* 70: 701 – 717.

ROBB, L.J., ARMSTRONG, R.A. & WATERS, D.J. 1999. The History of Granulite-Facies Metamorphism and Crustal Growth from Single Zircon U-Pb Geochronology: Namaqualand, South Africa. *Journal of Petrology* 40: 1747 – 1770.

RÖSCH, H. 1997. *Preliminary results of the 1997 line transects at Goegap Nature Reserve*. Scientific Services Section. Northern Cape Conservation Service, Unpublished Departmental Report, Calvinia.

RÖSCH, H. 2001*a*. *Quantification of the herbaceous component on Goegap Nature Reserve* – Year 2000. Northern Cape Nature Conservation Service, Unpublished Departmental Report, Calvinia.

RÖSCH, H. 2001*b*. The identification and description of the management units of the Goegap Nature Reserve. *Koedoe* 44: 17 – 30.

RÖSCH, H. 2003. *Veld condition assessment on Goegap Nature Reserve* – Year 2002. Scientific Services Section. Northern Cape Conservation Service, Unpublished Departmental Report, Calvinia.

ROUX, P.W. 1963. The descending point method of vegetation survey. A point sampling method for the measurement of semi-open grasslands and Karoo vegetation in South Africa. *South African Journal of Agricultural Science* 5: 273 – 288.

South African Environmental Observatory Network (SAEON). 2001. South African Environmental Observatory Network and associated Research Thrust for South Africa: *Proposal*. National Research Foundation, Pretoria.

South African Environmental Observatory Network (SAEON). 2002. South African Environmental Observatory Network and associated Research Thrust for South Africa: *Proposal*. National Research Foundation, Pretoria.

South African Environmental Observation Network (SAEON). 2004. South African Environmental Observation Network Review: *An eye on our changing world*. National Research Foundation, Pretoria.

STEINSCHEN, A.K., GÖRNE, A. & MILTON, S.J. 1996. Threats to the Namaqualand flowers: outcompeted by grass or exterminated by grazing? *South African Journal of Science* 92: 237 – 242.

STEYN, H.M., VAN ROOYEN, N., VAN ROOYEN, M.W. & THERON, G.K. 1996*a*. The phenology of Namaqualand ephemeral species: the effect of sowing date. *Journal of Arid Environments* 32: 407 – 420.

STEYN, H.M., VAN ROOYEN, N., VAN ROOYEN, M.W. & THERON, G.K. 1996*b*. The phenology of Namaqualand ephemeral species. The effect of water stress. *Journal of Arid Environments* 33: 49 – 62.

TAINTON, N.M. 1999. *Veld management in South Africa*. Natal University Press, Pietermaritzburg.

TER BRAAK, C.J.F. & SMILAUER, P. 2003. *CANOCO Reference manual and CanoDraw for Windows User's guide: Software for Canonical Community Ordination (version 4.5).* Microcomputer Power. Ithaca, NY, USA.

TODD, S. & HOFFMAN, M.T. 1999. Effects of heavy grazing on plant species diversity and community composition in a communally managed semi-arid shrubland, Namaqualand, South Africa. *Plant Ecology* 142: 169 – 178.

TROLLOPE, W.S.W. 1990. Veld management with specific reference to game ranching in the grassland and savanna areas of South Africa. *Koedoe* 33: 77 – 87.

TROLLOPE, W.S.W., POTGIETER, A.L.F. & ZAMBATIS, N. 1989. Assessing veld condition in the Kruger National Park using key grass species. *Koedoe* 32: 67 – 93.

VAN HULST, R. 1992. From population dynamics to community dynamics: modelling succession as a species replacement process. In: D.C. Glenn-Lewin, R.K. Peet & T.T. Veblen (eds) *Plant succession – theory and prediction*. pp. 188 – 211. Chapman & Hall, London.

VAN JAARSVELD, A.S. & BIGGS, H.C. 2000. Broad participation enhances steps towards a South African ecosystem observatory system (LTER). *South African Journal of Science* 96: 66.

VAN ROOYEN, M.W. 1999. Functional aspects of short-lived plants. In: W.R.J. Dean & S.J. Milton (eds) *The Karoo: ecological patterns and processes.* pp. 107 – 122. Cambridge University Press, Cambridge.

VAN ROOYEN, M.W., GROBBELAAR, N., THERON, G.K. & VAN ROOYEN, N. 1992. The ephemerals of Namaqualand: effect of germination date on parameters of growth analysis of three species. *Journal of Arid Environments* 22: 117 – 136.

VAN ROOYEN, M.W., THERON, G.K. & GROBBELAAR, N. 1990. Life form and dispersal spectra of the flora of Namaqualand, South Africa. *Journal of Arid Environments* 19: 133 – 145.

VAN ROOYEN, M.W., GROBBELAAR, N., THERON, G.K. & VAN ROOYEN, N. 1991. The ephemerals of Namaqualand: effects of photoperiod, temperature and moisture stress on development and flowering of three species. *Journal of Arid Environments* 20: 15 – 29.

VAN WYK, A.E. & SMITH, G.F. 2001. *Regions of floristic endemism in southern Africa: a review with emphasis on succulents*. Umdaus Press, Pretoria.

VORSTER, M. 1982. The development of the ecological index method for assessing veld condition in the Karoo. *Proceedings of the Grassland Society of South Africa* 17: 84 – 89.

WARD, D. 2006. Long-term effects of herbivory on plant diversity and functional types in arid ecosystems. In: K. Danell, R. Bergström, P. Ducan, J. Pastor (eds) *Large herbivore ecology, ecosystem dynamics and conservation*. pp. 142 – 169. Cambridge University Press, Cambridge.

WATKEYS, M.K. 1999. Soils of the arid south-western zone of Africa. In: W.R.J. Dean & S.J. Milton (eds) *The Karoo. Ecological patterns and processes*. pp. 17 – 25. Cambridge University Press, Cambridge.

WESTOBY, M., WALKER, B., & NOY-MEIR, I. 1989*a*. Range management on the basis of a model which does not seek to establish equilibrium. *Journal of Arid Environments*. 17: 235 – 239.

WESTOBY, M., WALKER, B., & NOY-MEIR, I. 1989*b*. Opportunistic management for rangelands not at equilibrium. *Journal of Range Management*. 37: 266 – 273.

WHITFORD, W.G. 1999. Comparison of ecosystem processes in the Nama-karoo and other deserts. In: W.R.J. Dean & S.J. Milton (eds) *The Karoo. Ecological patterns and processes*. pp. 291 – 302. Cambridge University Press, Cambridge.

WHITTAKER, R.H. 1978*a*. Classification of Plant Communities. Junk Publishers, The Hague, Boston.

WHITTAKER, R.H. 1978*b*. Ordination of Plant Communities. Junk Publishers, The Hague, Boston.

WIEGAND, T. & JELTSCH, F. 2000. Long-term dynamics in arid and semiarid ecosystems – synthesis of a workshop. *Plant Ecology* 150: 3 – 6.

WIEGAND, T. & MILTON, S.J. 1996. Vegetation change in semiarid communities. Simulating probabilities and time scales. *Vegetatio* 125(2): 169 – 183.

YEATON, R.I., & ESLER, K.J. 1990. The dynamics of Succulent Karoo vegetation. *Vegetatio* 88: 103 – 113.

CHAPTER 8

APPENDIX

Table 8.1 Total species and the frequency of strike for the Bleshoek Plains line transect

Species	**1991**	**1993**	**1994**	**1995**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Aptosimum spinescens	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Arctotis fastuosa	0.1	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.1	0.0	1.3	0.0
Blepharis cf. *macra*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Cheiridopsis denticulata	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Crassula thunbergiana	0.1	0.7	0.1	0.1	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.9
Crotalaria humilis	0.0	0.0	0.0	0.4	6.4	0.0	0.0	0.6	0.7	0.2	0.0	1.8	0.0	0.0	1.5
Didelta carnosa	0.0	0.0	0.0	0.0	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Dimorphotheca polyptera	0.1	0.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Dimorphotheca sinuata	0.6	1.0	4.3	4.4	8.1	0.2	0.0	0.1	0.6	1.0	0.0	0.3	0.0	0.5	0.4
Drosanthemum hispidum	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0
Dyerophytum africanum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Ehrharta calycina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Ehrharta longiflora	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Erodium sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Euphorbia decussata	0.3	0.2	0.4	0.4	0.2	0.4	0.3	0.2	0.3	0.8	0.5	0.3	0.4	0.4	0.4
Felicia namaquana	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Foveolina dichotoma	3.7	8.5	4.3	4.4	2.0	0.1	0.0	0.1	4.4	3.0	0.0	2.0	0.1	1.4	3.4
Galenia cf. *fruticosa*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Galenia sarcophylla	0.0	4.9	0.4	0.2	5.9	2.3	0.0	11.1	2.2	0.8	0.0	0.1	6.0	10.4	0.0
Gazania lichtensteinii	0.0	0.3	0.3	0.5	0.6	0.6	0.0	0.0	0.3	0.1	0.0	0.0	0.0	0.8	0.0
Gazania tenuifolia	0.0	0.0	0.2	0.1	0.3	0.0	0.0	0.0	0.3	0.2	0.0	0.1	0.0	0.0	0.0
Geophyte	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.0	0.2	0.0	0.1	0.1
Gladiolus sp.	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grielum humifusum	2.4	0.4	5.5	1.2	2.7	0.0	0.0	0.3	1.3	0.1	0.0	0.0	0.0	0.4	0.4
Gymnodiscus linearifolia	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Helichrysum leontonyx	0.6	0.4	0.0	0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.6
Heliophila coronopifolia	0.6	0.0	1.0	1.3	0.1	0.0	0.0	0.0	0.0	0.3	0.0	0.1	0.0	0.0	0.0
Heliophila lacteal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.4
Heliophila sessilifolia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5
Heliophila variabilis	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.2	2.1	0.0	0.0	0.1	2.2	0.8
Hirpicium echinus	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Hypertelis salsoloides	0.2	1.0	1.0	0.2	1.0	0.9	0.9	1.8	1.8	0.7	0.6	0.5	0.8	1.2	0.3
Ifloga glomerata	0.0	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Karroochloa schismoides	10.9	12.4	4.2	6.5	0.4	0.2	0.0	0.1	4.6	13.6	0.8	4.6	0.0	2.6	8.3
Species	**1991**	**1993**	**1994**	**1995**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**

Leipoldtia schultzei	7.2	9.4	7.2	8.7	9.4	8.8	7.9	9.7	10.0	10.7	8.9	8.4	9.6	10.8	9.9
Lessertia diffusa	0.0	0.4	0.1	0.1	0.5	0.1	0.3	0.3	0.1	0.0	0.0	0.0	0.0	0.2	0.3
Leysera tenella	2.1	2.2	3.5	2.0	3.0	0.8	0.0	0.0	0.0	0.6	0.0	0.2	0.0	0.4	0.8
Lotononis brachyloba	0.0	4.6	2.1	0.9	4.1	0.3	0.0	1.4	16.6	0.3	0.0	0.4	3.4	19.8	3.8
Lycium cinereum	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2
Manulea benthamiana	0.8	2.8	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Manulea cheiranthus	0.4	0.1	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mesembryanthemum guerichianum	0.9	1.4	0.9	0.9	0.8	0.0	0.0	2.1	0.5	0.5	0.0	0.0	1.6	0.2	0.0
Oncosiphon grandiflorum	2.8	4.2	1.0	2.1	1.4	0.5	0.1	0.3	5.8	10.3	3.4	3.1	1.1	11.8	20.7
Oncosiphon suffruticosum	0.0	0.9	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3
Osteospermum pinnatum	0.4	0.9	1.5	0.9	0.5	0.0	0.0	0.0	0.8	0.1	0.0	0.0	0.0	0.5	0.3
Oxalis spp.	0.2	0.2	0.1	0.0	0.2	0.0	0.1	0.1	0.0	0.0	0.0	0.4	0.1	0.1	0.1
Pelargonium redactum	0.3	2.0	0.7	1.9	0.5	0.0	0.0	0.1	2.3	0.3	0.0	0.0	0.1	0.4	0.1
Peliostomum virgatum	0.0	0.0	0.1	0.0	0.1	0.1	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Pentaschistis airoides	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pharnaceum dichotomum	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Phyllobolus occulatus	0.0	0.2	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Polycarena collina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.1	0.7
Polycarena selaginoides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Psilocaulon junceum	0.2	0.2	0.1	0.1	0.1	0.3	0.0	0.1	0.2	0.2	0.0	0.0	0.0	0.0	0.0
Ruschia elineata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Ruschia brevibracteata	0.1	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.0
Ruschia robusta	2.3	2.0	1.8	2.0	2.9	3.4	2.6	2.4	2.0	2.6	2.1	1.8	1.8	1.4	0.8
Salsola kali	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Schmidtia kalahariense	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Senecio arenarius	1.8	2.5	2.6	4.4	0.5	0.0	0.0	0.0	0.3	1.1	0.0	0.4	0.0	0.5	6.7
Senecio cardaminifolius	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Stipagrostis brevifolia	0.8	1.5	1.3	1.3	0.9	0.6	0.2	0.6	0.9	1.1	0.5	0.1	0.2	0.6	0.4
Stipagrostis ciliata	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stipagrostis obtusa	1.2	1.5	1.4	1.4	1.6	1.2	0.4	1.9	1.0	1.0	0.2	0.6	0.1	0.0	0.1
Tetragonia fruticosa	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tetragonia microptera	0.2	0.2	0.2	0.1	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.2	0.0
Trachyandra spp.	0.3	0.7	0.0	0.2	2.2	0.2	0.1	0.5	0.5	0.1	0.0	0.5	0.0	0.0	0.4
Tribulus terrestris	0.0	0.6	0.0	0.0	0.0	0.0	0.1	1.3	0.0	0.0	0.0	0.0	3.1	0.0	0.0
Tripteris amplectens	0.0	0.5	0.0	0.0	0.2	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.2	0.8	0.0
Tripteris hyoseroides	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tripteris sinuata	0.1	0.1	0.3	0.1	0.6	0.3	0.4	0.6	0.2	0.1	0.2	0.0	0.2	0.2	0.2
Wahlenbergia prostrata	0.3	0.3	0.1	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Zaluzianskya benthamiana	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zaluzianskya gilioides	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zygophyllum retrofractum	0.2	0.4	0.3	0.5	0.6	0.4	0.6	0.7	0.3	0.5	0.2	0.2	0.6	0.7	0.4
Total	**42.8**	**72.1**	**50.3**	**49.9**	**61.3**	**22.5**	**14.3**	**37.2**	**61.4**	**53.3**	**17.5**	**26.7**	**29.8**	**71.9**	**66.9**

Table 8.2 Total species and the frequency of strike for the Bluemine Mountain line transect

Species	1974	1975	1976	1977	1978	1979	1980	1982	1984	1985	1986	1987	1989	1990	1991	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Amphiglossa tomentosa	0.0	0.0	0.1	0.0	0.0	0.1	0.2	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.2	0.2
Anthospermum tricostatum	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Antizoma miersiana	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aptosimum indivisum	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Arctotis fastuosa	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.4	0.5	0.0
Aridaria noctiflora	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.2	0.2	0.2	0.2	0.1	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Atriplex lindleyi subsp. *inflata*	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.2	0.1	0.2	0.0	0.1	0.0	0.0	0.0
Bromus pectinatus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cephalophyllum ebracteatum	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.2	0.1	0.2	0.3	0.2	0.0	0.0	0.1	0.0
Cheiridopsis denticulata	0.4	0.2	1.0	0.7	0.9	0.6	0.1	0.5	0.7	0.5	0.5	0.7	0.6	0.2	0.7	0.6	0.5	0.4	0.4	0.7	0.6	0.3	0.9	0.6	0.8	0.7	0.1	0.6	0.5	0.9
Chrysocoma ciliata	0.0	0.1	0.3	0.2	0.2	0.0	0.0	0.0	0.0	0.1	0.4	0.1	0.4	0.5	0.4	0.2	0.7	0.4	0.2	0.6	0.7	0.0	0.2	0.3	0.4	0.1	0.0	0.4	0.3	0.6
Cleretum papulosum	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Cotula barbata	0.0	0.3	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.4	0.1	0.2	0.3	0.3	0.0	0.0	0.1	0.0	0.7	0.0	0.0	0.0	0.0	0.9
Cotula laxa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cotula nudicaulis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Crassula muscosa subsp. *muscosa*	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.0	0.2	0.4	0.0	0.1	0.0	0.1	0.0
Crassula subaphylla	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.2	0.3	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.1	0.1	0.0
Crassula thunbergiana	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.5	0.0	0.1	0.0	0.7	0.0	0.1	0.7	0.1	0.0	0.0	0.0	0.0	0.1	0.6
Deverra aphylla	0.1	0.2	0.1	0.1	0.2	0.1	0.0	0.1	0.1	0.1	0.1	0.2	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0
Diascia namaquana	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1
Didelta spinosa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Dimorphotheca sinuata	0.7	0.1	0.3	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.2
Diospyros austro-africana	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dischisma spicatum	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.3	0.0
Drosanthemum sp. (shrub)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Drosanthemum hispidum	0.0	0.2	0.6	0.8	0.2	0.0	0.0	0.1	0.1	0.0	0.4	0.1	0.1	0.2	0.0	0.6	0.3	0.2	0.0	0.6	0.2	0.0	0.0	0.2	0.0	0.0	0.0	0.2	0.5	0.3
Ehrharta calycina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Ehrharta delicatula	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eriocephalus brevifolius	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.5	0.4	0.0	0.8	0.1	0.4
Eriocephalus microphyllus	3.8	6.1	4.4	4.9	5.1	5.4	5.0	4.5	5.3	4.8	4.8	5.5	5.9	6.2	5.5	8.0	7.7	6.2	7.1	7.4	6.6	5.8	6.7	7.8	6.3	6.2	6.4	5.9	4.6	6.2
Erodium cicutarium	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Euphorbia decussata	0.5	0.3	0.5	0.7	0.0	0.7	0.4	0.7	0.4	0.6	0.7	0.8	0.8	0.9	0.7	0.6	0.7	0.8	0.7	0.7	0.9	0.7	1.0	0.7	0.8	0.9	0.4	0.2	0.8	0.8
Euphorbia mauritanica	0.0	0.0	0.4	0.2	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Euryops dregeanus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.0
Euryops multifidus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1
Felicia sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.8
Felicia brevifolia	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.2	0.2	0.3	0.2	0.3	0.5	0.8	0.1	0.1	0.0	0.4	0.0	0.3	0.0	0.1	0.4	0.2
Felicia filifolia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Felicia cf. *namaquana*	0.0	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.1	0.0	0.6	0.0	0.1	0.0	0.8	1.1	0.0	0.0	0.1	1.3	0.0
Foveolina dichotoma	0.3	1.1	0.9	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.9	0.2	1.1	0.3	0.3	0.0	0.1	0.1	0.9	0.4	0.0	0.1	0.1	0.6	0.3
Galenia africana	0.9	0.6	1.2	0.9	1.1	1.5	0.9	0.8	0.9	1.1	1.3	1.5	0.6	0.4	1.1	0.9	0.6	0.6	0.7	1.0	1.2	1.3	1.1	0.8	0.9	1.1	0.9	1.0	1.0	1.5

Species	1974	1975	1976	1977	1978	1979	1980	1982	1984	1985	1986	1987	1989	1990	1991	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Galenia meziana	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0
Galenia namaensis	0.1	0.3	0.2	0.4	0.3	0.2	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.2	0.2	0.0	0.1	0.2	0.3	0.2	0.2	0.1	0.3	0.2	0.1	0.1	0.0	0.1	0.1
Galenia sarcophylla	1.5	1.4	1.8	1.4	0.5	0.0	0.0	1.0	0.9	1.0	1.5	1.7	1.7	1.3	0.4	0.9	0.7	0.1	0.1	0.2	0.0	0.1	0.0	0.3	0.1	0.0	0.2	0.2	0.7	0.1
Gazania heterochaeta	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.4	0.1	0.9	0.0	0.0	0.2	0.2	0.0	0.0	0.1	0.1	0.1	0.1
Gazania tenuifolia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Geophyte	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.3	0.0
Grielum humifusum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gynandriris setifolia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hallianthus planus	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Helichrysum asperum	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Helichrysum leontonyx	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	2.9	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	3.4	3.5
Helichrysum sp. (perennial)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Helichrysum tinctum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.8	0.0	0.6	0.0	0.1	0.0	0.9	2.1	0.0	0.1	0.0	0.0	0.0
Heliophila thunbergii var. *macrostylis*	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Heliophila variabilis	0.2	0.6	0.7	0.5	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.7	0.0	0.6	0.1	0.2	0.0	0.2	0.1	8.5	8.3	1.0	1.1	3.8	6.0	2.5
Hermannia cuneifolia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Hermannia disermifolia	0.4	0.2	0.5	0.4	0.3	0.5	0.2	0.2	0.3	0.1	0.1	0.0	0.3	0.2	0.3	0.1	0.0	0.2	0.2	0.5	0.3	0.3	0.1	0.1	0.2	0.4	0.4	0.4	0.4	0.2
Hermannia marginata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.1
Hermannia trifurca	0.5	0.4	0.1	0.5	0.1	0.1	0.3	0.1	0.2	0.2	0.0	0.1	0.2	0.1	0.0	0.2	0.1	0.1	0.1	0.2	0.2	0.3	0.1	0.2	0.0	0.0	0.2	0.4	0.2	0.2
Hirpicium alienatum	1.4	0.3	1.1	1.1	0.4	0.2	0.9	0.0	0.4	0.5	0.7	0.4	0.6	0.5	0.7	0.7	0.5	0.7	0.4	0.5	0.7	0.3	1.3	0.8	1.0	1.0	0.8	1.1	1.7	1.4
Hirpicium echinus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Homeria sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0
Hypertelis salsoloides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ifloga glomerata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0
Karroochloa schismoides	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.1	0.5	0.7
Lampranthus godmanniae	0.0	0.0	0.1	0.2	0.3	0.1	0.4	0.2	0.2	0.0	0.4	0.1	0.3	0.2	0.4	0.3	0.2	0.3	0.0	0.4	0.3	0.3	0.2	0.2	0.5	0.4	0.2	0.2	0.0	0.4
Lasiopogon micropoides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Lasiospermum brachyglossum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Lebeckia sericea	0.2	0.0	0.0	0.1	0.0	0.1	0.2	0.0	0.1	0.2	0.1	0.4	0.2	0.3	0.4	0.5	0.4	0.3	0.4	0.4	0.2	0.3	0.3	0.2	0.5	0.4	0.4	0.1	0.5	0.4
Leipoldtia schultzei	1.6	1.1	2.2	2.1	0.7	2.0	2.7	3.1	4.1	4.0	5.3	4.9	5.5	4.6	5.4	4.7	4.0	5.1	4.5	4.7	5.3	4.4	5.3	4.7	4.9	4.5	4.0	5.1	2.7	0.0
Leipoldtia sp. (Tierhoek)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	5.6
Leysera gnaphalodes	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Leysera tenella	0.0	0.1	0.4	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	1.1	0.6	0.4	0.2	1.4	0.1	0.0	0.2	0.7	0.5	0.0	0.1	0.3	1.1	1.2
Lotononis brachyloba	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.3	1.2	0.0
Lycium cinereum	0.3	0.3	0.2	0.1	0.4	0.1	0.1	0.2	0.3	0.2	0.5	0.4	0.2	0.3	0.3	0.4	0.2	0.2	0.3	0.4	0.5	0.4	0.3	0.3	0.3	0.6	0.1	0.4	0.1	0.3
Manochlamys albicans	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.0
Manulea benthamiana	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Manulea cheiranthus	0.2	0.1	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.2	1.2	0.0
Manulea gilioides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Melolobium adenodes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
Melolobium candicans	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0.1	0.0	0.1	0.0	0.2	0.2	0.0	0.0	0.1	0.1
Mesembryanthemum guerichianum	0.3	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0.0	0.1	0.0	0.1	0.4	0.1	0.0
Montinia caryophyllacea	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Moraea sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Species	1974	1975	1976	1977	1978	1979	1980	1982	1984	1985	1986	1987	1989	1990	1991	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Nenax cinerea	0.0	0.1	0.3	0.5	0.3	0.1	0.2	0.3	0.2	0.1	0.1	0.3	0.1	0.3	0.2	0.4	0.0	0.3	0.2	0.3	0.0	0.3	0.0	0.0	0.1	0.0	0.3	0.4	0.6	0.3
Oncosiphon suffruticosum	0.4	0.2	0.3	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.5	0.1	0.5	0.3	0.3	0.0	0.1	0.2	1.3	2.3	0.0	0.0	0.2	1.5	1.4
Orbea namaquensis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Osteospermum pinnatum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Othonna arbuscula	0.0	0.6	0.4	0.8	0.3	0.5	0.2	0.3	0.2	0.5	0.6	0.4	0.2	0.7	0.4	0.1	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1
Othonna cylindrica	0.1	0.2	0.8	0.4	0.9	0.4	0.4	0.5	0.4	0.5	0.6	0.5	0.3	0.4	0.6	0.7	0.6	0.2	0.5	1.0	1.0	0.7	0.3	1.1	0.9	0.9	1.0	0.9	0.9	1.2
Oxalis spp.	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.3	0.3	0.1	0.1	0.9	0.0	0.0	0.0	0.4	0.3	0.0	0.4	0.0	1.1	1.5
Pelargonium carnosum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pelargonium grandicalcaratum	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Peliostomum virgatum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.2
Pentaschistis airoides	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Pentzia incana	0.1	0.1	0.4	0.0	0.2	0.0	0.3	0.4	0.3	0.6	0.3	0.4	0.6	0.3	0.3	0.2	0.4	0.7	0.4	0.1	0.8	0.3	0.6	0.3	0.3	0.4	0.6	0.4	0.6	0.1
Pharnaceum aurantium	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.1
Phyllobolus sp.	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plantago caffra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Plinthus karooicus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.2	0.1	0.5	0.0	0.0	0.0	0.0
Poaceae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Polycarena collina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Psilocaulon junceum	0.2	0.1	0.6	0.5	0.3	0.0	0.0	0.5	0.7	0.6	0.4	0.5	0.9	0.5	0.0	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Pteronia ciliata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.1	0.1	0.1	0.2	0.1	0.0	0.1	0.1	0.2	0.2	0.1	0.4	0.1	0.1	0.2	0.3	0.3	0.0	0.0
Pteronia divaricata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Pteronia glabrata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Pteronia glomerata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Pteronia incana	1.3	1.4	1.2	0.6	0.7	0.9	0.3	0.5	1.1	0.6	0.6	0.5	0.7	0.6	0.9	0.8	1.2	1.2	0.9	1.5	1.0	1.2	1.2	1.0	2.7	1.0	1.1	1.1	1.5	1.5
Searsia undulata	0.3	0.3	0.4	0.2	0.3	0.5	0.4	0.4	0.2	0.2	0.2	0.3	0.4	0.3	0.3	0.2	0.3	0.2	0.2	0.4	0.4	0.1	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3
Ruschia brevibracteata	0.3	0.0	0.3	0.1	0.6	0.3	0.2	0.1	0.2	0.1	0.0	0.1	0.1	0.3	0.2	0.1	0.3	0.4	0.2	0.2	1.1	0.1	0.2	0.0	0.0	0.0	0.2	0.2	0.4	0.2
Ruschia cymosa	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ruschia elineata	0.5	1.1	0.4	0.3	0.6	0.3	0.5	0.7	0.1	0.3	0.4	0.1	0.0	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ruschia robusta	9.5	10.4	11.7	14.8	11.6	13.7	12.5	13.0	14.1	17.0	17.8	15.5	13.9	15.4	15.4	13.0	15.1	17.0	14.7	16.0	14.7	10.9	11.3	9.8	11.5	10.7	9.2	8.6	9.2	9.3
Ruschia viridifolia	0.0	0.0	0.1	0.3	0.1	0.1	0.2	0.1	0.0	0.2	0.1	0.1	0.2	0.1	0.2	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scirpus nodosus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Senecio cardaminifolius	0.0	0.5	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.3	0.4	0.4	0.5	0.1	0.0	0.2	0.0	1.5	1.2	0.0	0.0	0.0	1.6	1.0
Senecio cinerascens	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Senecio niveus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stipagrostis brevifolia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Stipagrostis namaquensis	0.3	0.5	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Tetragonia fruticosa	0.4	0.6	0.4	0.4	0.7	0.6	0.3	0.7	0.4	0.6	0.6	0.8	1.0	0.6	0.3	0.3	0.5	0.0	0.6	0.4	0.1	0.3	0.2	0.1	0.3	0.6	0.4	0.5	0.2	0.2
Tetragonia microptera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0
Thesium lineatum	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Trachyandra falcata	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trichogyne paronychioides	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1
Tripteris amplectens	1.6	0.7	4.9	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.1	0.0	0.0	0.0	1.6	0.0
Tripteris hyoseroides	0.0	0.0	5.3	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.2	1.3	0.4	0.0
Tripteris oppositifolia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Species	1974	1975	1976	1977	1978	1979	1980	1982	1984	1985	1986	1987	1989	1990	1991	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Tripteris sinuata	0.8	1.0	1.8	1.3	1.0	1.1	0.7	1.6	1.5	1.1	1.2	0.9	2.3	1.7	1.9	1.9	2.3	1.8	1.6	3.4	3.0	3.3	3.0	3.5	3.5	3.9	3.0	2.5	4.4	3.5
Tylecodon wallichii	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.1	0.1	0.2	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Ursinia cakilefolia	0.0	0.0	2.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Ursinia calenduliflora	1.2	1.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.6	0.0	0.1	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.7	0.7
Ursinia nana	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Viscum capense	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Aizoaceae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.2	0.1	0.0	0.0	0.0
Wahlenbergia annularis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Wahlenbergia prostrata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Zaluzianskya benthamiana	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	0.0	0.1	0.7	0.1
Zaluzianskya giliodes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.2	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.1
Zygophyllum foetidum	0.1	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zygophyllum retrofractum	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.0	0.2	0.1	0.2	0.2	0.3	0.2	0.2	0.1	0.2	0.1	0.1
Zygophyllum sp. nov.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0
Total	**32.0**	**34.2**	**51.5**	**41.0**	**28.9**	**31.1**	**28.7**	**31.6**	**35.1**	**36.9**	**41.0**	**37.9**	**38.9**	**39.1**	**45.8**	**51.3**	**42.0**	**45.7**	**38.5**	**52.7**	**41.9**	**35.3**	**39.5**	**56.8**	**59.0**	**38.2**	**34.5**	**42.0**	**61.7**	**54.9**

Table 8.3 Total species and the frequency of strike for the Goegap Plains line transect

Species	1991	1993	1994	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Aizoon canariense	0.0	0.5	0.0	0.1	0.0	0.0	0.3	0.0	0.0	0.0	0.0	1.8	0.0	0.0
Amellus strigosus	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aptosimum indivisum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0
Aptosimum spinescens	0.8	1.2	1.2	1.4	0.9	1.1	1.5	1.1	0.7	0.7	0.6	0.5	0.5	0.4
Aridaria noctiflora	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Atriplex lindleyi subsp. *inflata*	1.7	1.4	1.1	1.2	0.8	0.5	0.8	1.0	0.3	0.3	0.2	0.4	0.4	0.1
Augea capensis	0.0	0.4	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0
Babiana sp.	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Conicosia elongata	0.2	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Crassula thunbergiana	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Crotolaria humilis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Dimorphotheca sinuata	0.0	0.0	0.2	0.2	0.0	0.0	0.2	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Dimorphotheca polyptera	0.1	0.1	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.3	0.1	0.0
Drosanthemum hispidum	2.3	4.5	5.4	9.0	5.9	3.2	10.3	4.1	3.5	0.2	1.3	3.9	5.8	7.4
Eriocephalus microphyllus	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1
Erodium moschatum	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Foveolina dichotoma	1.8	3.0	0.5	0.8	0.0	0.0	0.1	1.0	2.7	0.0	1.3	0.2	0.6	0.4
Galenia sarcophylla	1.4	6.5	3.0	5.2	1.6	0.3	5.6	1.9	0.0	0.0	0.2	12.7	13.2	1.5
Gazania lichtensteini	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.1	0.4	0.0	0.0	0.4	0.6	0.2
Geophyte	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.0	0.0	0.1	0.1	0.1	0.0	0.0
Grielum humifusum	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.0
Helichrysum leontonyx	1.2	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.3	0.6
Helichrysum tinctum	0.0	1.4	0.1	0.2	0.0	0.0	0.1	1.7	8.2	0.0	0.9	0.0	0.0	0.0
Heliophila sesselifolia	1.6	0.0	0.3	0.0	0.0	0.0	0.1	0.8	2.1	0.0	2.7	0.0	2.4	11.3
Heliophila variabilis	0.0	1.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Hermannia cuneifolia	0.0	0.0	0.0	0.1	0.1	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Hermannia sp.	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hirpicium echinus	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hypertelis salsoloides	2.5	3.5	3.6	3.6	2.4	2.3	4.8	2.1	0.6	0.2	0.1	6.8	6.0	2.3
Jamesbrittania albiflora	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Karroochloa schismoides	3.9	5.4	1.1	0.1	0.0	0.0	0.0	0.2	0.6	0.0	0.1	0.3	0.5	1.8
Lasiopogon micropoides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Lessertia diffusa	0.0	0.4	0.0	0.1	0.0	0.0	1.3	0.3	0.0	0.0	0.1	2.2	1.2	0.4
Leysera tenella	0.6	0.3	0.0	1.0	0.1	0.0	0.1	0.7	1.7	0.0	0.1	2.4	2.7	3.6
Lotononis brachyloba	0.0	1.6	0.0	0.7	0.0	0.0	1.1	5.3	0.0	0.0	0.0	1.8	5.4	0.3
Lotononis falcata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
Lycium cinereum	0.5	0.4	0.8	0.3	0.4	0.7	0.8	0.2	0.5	0.3	0.6	0.1	0.6	0.7
Manulea benthamiana	0.1	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Manulea cheiranthus	0.2	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Species	**1991**	**1993**	**1994**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Mesembryanthemum guerichianum	0.0	0.2	0.1	0.0	0.0	0.0	1.0	0.0	0.1	0.0	0.7	1.8	0.1	0.0
Moraea minuata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Moraea schlechterii	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oncosiphon grandiflorum	0.3	0.2	0.0	1.1	0.3	0.0	0.6	2.2	1.5	0.6	1.6	0.7	2.5	3.0
Oncosiphon suffruticosum	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.0	0.0	0.0	0.0	1.1
Ornithogalum secundum	0.4	0.2	0.4	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Osteospermum pinnatum	0.5	4.2	0.9	2.1	0.4	0.0	1.1	2.6	1.8	0.0	0.5	0.0	0.0	0.7
Oxalis spp.	0.3	0.8	0.2	0.1	0.2	0.0	0.2	0.3	0.2	0.0	0.0	0.0	0.2	0.4
Pelargonium redactum	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.0	0.0	0.1	0.2	0.1	0.5
Peliostomum virgatum	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1
Pentaschistis airoides	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pharnaceum dichotomum	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phyllobolus occulatus	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plantago caffra	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Polycarena collina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1
Psilocaulon junceum	2.3	3.4	2.8	1.0	1.3	0.1	0.8	0.6	0.2	0.1	0.0	0.7	0.5	0.6
Pteronia scariosa	0.2	0.2	0.0	0.7	0.3	0.0	0.6	1.0	0.5	0.5	0.1	0.2	0.5	0.3
Salsola aphylla	0.0	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.2	0.1	0.1	0.0	0.0	0.2
Salsola tuberculata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Senecio arenarius	0.3	1.4	1.2	0.2	0.0	0.0	0.1	0.2	0.4	0.0	0.1	0.0	0.6	0.5
Senecio niveus	0.0	0.0	0.0	0.2	0.1	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.1
Stipagrostis brevifolia	0.0	0.0	0.0	0.1	0.0	0.2	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0
Stipagrostis ciliata	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stipagrostis obtusa	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.1	0.0
Stipagrostis zeyheri	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Thesium lineatum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Trachyandra bulbinifolia	0.0	0.0	0.2	1.5	0.4	0.2	7.0	4.8	5.9	2.0	2.2	0.0	0.0	0.0
Trichogyne paronychioides	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.4
Tripteris amplectens	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Unidentified species	1.0	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wahlenbergia annularis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Wahlenbergia prostrata	0.2	2.8	0.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Zaluzianskya gilioides	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zygophyllum retrofractum	0.5	0.0	0.6	0.5	0.4	0.4	1.0	0.8	0.4	0.8	0.7	0.8	1.0	1.3
Total	**25.0**	**51.2**	**25.1**	**35.0**	**16.2**	**9.8**	**40.8**	**33.9**	**33.6**	**6.2**	**14.8**	**40.3**	**46.7**	**41.7**

Table 8.4 Total species and the frequency of strike for the Jaleeg Plains line transect

Species	1991	1993	1994	1995	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Aizoon canariense	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Arctotis fastuosa	0.0	0.3	0.3	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.2	0.0
Asparagus sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Bulbostylis densa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Conicosia elongata	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Crassula thunbergiana	0.4	1.0	0.1	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.5
Diascia namaquana	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dimorphotheca polyptera	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Dimorphotheca sinuata	3.3	14.8	22.8	14.0	15.3	0.0	3.0	0.4	3.9	3.1	0.0	0.4	0.0	2.8	4.1
Dischisma spicata	0.0	0.1	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Euphorbia decussata	0.2	0.2	0.1	0.2	0.4	0.2	0.2	0.4	0.5	0.5	0.6	0.4	0.3	0.1	0.5
Euphorbia mauritanica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Felicia namaquana	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Foveolina dichotoma	3.3	10.6	6.6	4.6	1.8	0.0	0.9	0.2	3.9	1.5	0.0	0.2	0.0	4.1	6.5
Galenia africana	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Galenia meziana	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Galenia sarcophylla	4.1	3.1	0.8	1.1	6.4	0.0	2.2	14.4	0.6	1.6	0.3	1.3	15.9	11.9	0.1
Gazania lichtensteini	0.0	0.1	0.4	0.5	0.7	0.0	0.1	0.0	0.2	0.1	0.0	0.0	0.3	1.3	0.5
Geophyte	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Grielum humifusum	0.0	0.3	0.2	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.1	0.1	0.1	0.0
Gymnodiscus linearifolius	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Hebenstretia cf. *linearis*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Helichrysum leontonyx	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.4	2.1
Helichrysum tinctum	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.3	0.8	0.0	0.0	0.0	0.0	0.0
Heliophila coronopifolia	0.1	2.7	0.0	0.2	0.2	0.0	0.0	0.0	0.6	0.1	0.0	0.0	0.0	0.0	0.0
Heliophila lacteal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.7
Heliophila thunbergii var. *macrostylis*	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heliophila sesselifolia	0.2	0.0	1.3	2.3	0.9	0.0	0.2	0.0	0.8	0.1	0.0	0.3	0.0	0.0	2.7
Heliophila variabilis	0.3	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.6	0.7	0.0	0.1	0.1	2.2	0.0
Hermannia disermifolia	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Hermannia tomentosa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.0
Hermannia cf. *tomentosa*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Hirpicium echinus	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hypertelis salsoloides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Ifloga glomerata	0.0	0.0	0.1	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Karroochloa schismoides	2.5	8.2	0.5	0.7	0.4	0.0	0.9	0.0	6.1	3.4	0.1	0.4	0.1	1.7	3.7
Lachenalia sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Lasiopogon micropoides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3
Lasiospermum brachyglossum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Lessertia diffusa	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.1	0.0	0.5	0.1
Leysera tenella	0.1	1.7	1.4	2.0	4.4	0.0	1.7	1.9	6.8	6.7	0.0	1.6	1.2	1.7	3.6

Species	**1991**	**1993**	**1994**	**1995**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Lotononis brachyloba	0.0	0.1	0.0	0.2	0.5	0.0	0.1	0.0	0.5	0.1	0.0	0.0	0.1	1.7	0.0
Lycium cinereum	0.1	0.0	0.2	0.0	0.4	0.5	0.3	0.3	0.4	0.2	0.2	0.2	0.4	0.2	0.1
Lycium ferocissimum	0.0	0.2	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Manulea benthamiana	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Manulea cheiranthus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Mesembryanthemum guerichianum	0.3	0.2	0.1	0.0	0.6	0.0	0.3	0.5	0.3	0.0	0.0	0.2	0.6	0.2	0.0
Oncosiphon grandiflorum	0.1	0.0	0.8	0.1	1.3	0.0	1.1	0.3	6.3	3.9	0.0	0.0	0.0	3.3	6.5
Oncosiphon suffruticosum	0.2	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Osteospermum pinnatum	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Oxalis spp.	0.0	0.3	0.1	0.5	0.2	0.0	0.1	0.0	0.0	0.2	0.2	0.1	0.0	0.1	0.4
Pelargonium redactum	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.1	0.0
Pentaschistis airoides	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.2	0.0
Pharnaceum confertum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pharnaceum croceum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0
Pharnaceum dichotomum	0.0	0.5	0.0	0.3	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Phyllobolus occulatus	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.2	0.1	0.1
Psilocaulon junceum	0.3	0.3	0.3	0.7	2.0	0.5	1.0	1.8	1.4	1.0	0.5	0.1	0.1	1.7	0.1
Ruschia brevibracteata	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ruschia robusta	3.6	3.7	3.8	4.5	6.5	6.2	6.3	6.4	6.5	6.5	6.4	5.9	6.1	7.1	6.0
Sarcocaulon salmoniflorum	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0
Sceletium sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Senecio arenarius	0.2	1.8	2.2	1.4	0.1	0.0	0.0	0.0	0.8	0.2	0.0	0.0	0.0	1.0	3.7
Senecio cardaminifolius	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2
Sonderina tenuis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Sonderina tenuis	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.3	0.0	0.0	0.0	0.4	0.0
Stipagrostis brevifolia	6.4	7.6	6.5	5.9	6.5	6.7	8.1	12.0	13.0	9.3	10.6	11.3	12.6	12.4	10.0
Stipagrostis namaquensis	0.1	0.0	0.0	0.0	0.3	0.0	0.3	0.4	0.2	0.3	0.0	0.0	0.1	0.1	0.0
Tetragonia fruticosa	0.0	0.1	0.0	0.0	0.0	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tetragonia microptera	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trachyandra falcata	0.1	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Trachyandra tortilis	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tripteris amplectens	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Tripteris sinuata	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Unidentified species	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ursinia cakilefolia	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ursinia calenduliflora	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Wahlenbergia annularis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.2	0.3
Wahlenbergia prostrata	0.0	3.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.2	0.0	0.1	0.0	0.5	2.0
Wahlenbergia thunbergiana	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	1.6	0.1
Zaluzianskya pusilla	0.0	0.1	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zaluzianskya benthamiana	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.4
Zaluzianskya gilioides	0.0	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.5
Zygophyllum retrofractum	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.1	0.3	0.2	0.2	0.3	0.3	0.3	0.2
Total	**27.9**	**66.4**	**48.9**	**40.9**	**50.7**	**14.8**	**27.2**	**40.3**	**56.5**	**41.5**	**19.2**	**23.3**	**38.7**	**64.5**	**57.6**

Table 8.5 Total species and the frequency of strike for the Koperberg Plains line transect

Species	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Aizoon canariense	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Amellus strigosus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Aridaria noctiflora	1.7	2.0	2.3	1.3	1.3	2.6	1.1	1.2	1.2	1.3	1.6
Atriplex lindleyi subsp. *inflata*	4.5	5.8	2.3	3.2	1.7	4.3	1.8	1.3	3.1	3.1	1.8
Geophyte	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cheiridopsis denticulata	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Conicosia elongata	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dimorphotheca sinuata	0.5	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.1	0.2
Drosanthemum sp. (shrub)	1.2	1.1	0.0	0.7	0.8	2.3	0.8	1.1	0.9	0.7	0.6
Drosanthemum hispidum	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Drosanthemum cf. *otzenianum*	0.2	0.2	0.1	0.1	0.2	0.2	0.2	0.2	0.1	0.0	0.0
Foveolina dichotoma	1.1	0.0	0.0	0.2	0.5	7.6	0.0	0.0	2.5	4.5	6.3
Galenia sarcophylla	0.4	0.2	0.0	0.0	0.1	0.3	0.0	0.0	4.0	7.4	1.1
Galenia cf. *fruticosa*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Gazania lichtensteinii	1.3	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.4	0.4	0.0
Heliophila variabilis	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Hermannia tomentosa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0
Karroochloa schismoides	0.1	0.3	0.0	0.0	0.1	0.5	0.4	0.0	0.2	0.0	1.5
Lessertia diffusa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
Leysera tenella	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Lotononis brachyloba	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Lotononis falcata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Lycium cinereum	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.0	0.1
Manulea cheiranthus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Mesembryanthemum guerichianum	0.2	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.4	0.1	0.0
Oncosiphon grandiflorum	0.5	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0
Osteospermum pinnatum	0.5	0.0	0.0	0.0	0.1	0.9	0.0	0.0	1.3	1.5	1.8
Oxalis spp.	0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.2
Psilocaulon subnodosum	3.5	2.1	0.6	0.7	1.6	2.1	0.3	0.3	1.1	1.3	1.2
Salsola aphylla	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.6	0.8
Salsola kali	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Salsola tuberculata	2.4	2.7	2.5	2.1	2.3	3.4	2.9	2.5	3.2	2.7	2.2
Senecio arenarius	0.6	0.0	0.0	0.0	0.2	6.8	0.0	0.0	1.1	6.3	12.0
Senecio cardaminifolius	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.1	0.5
Tetragonia fruticosa	0.2	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.2
Tetragonia microptera	0.0	0.0	0.0	0.0	0.5	0.1	0.0	0.0	0.4	0.4	0.0
Trachyandra spp.	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Tripteris hyoseroides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Zaluzianskya benthamiana	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Zygophyllum retrofractum	3.9	5.5	4.5	4.3	4.3	5.8	4.4	3.4	5.2	5.3	5.1
Total	**23.7**	**20.2**	**12.7**	**13.3**	**14.3**	**38.0**	**12.1**	**10.3**	**25.8**	**36.7**	**37.6**

Table 8.6 Total species and the frequency of strike for the T'ganagas Plains line transect

Species	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Aizoon canariense	0.1	0.0	0.0	1.6	0.0	0.0	0.0	0.0	4.4	0.0	0.0
Arctotis fastuosa	0.8	0.2	0.0	0.2	6.9	2.6	0.0	1.0	0.3	6.5	0.2
Bulbine succulenta	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Cleretum papulosum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.2	0.0
Conicosia elongata	0.9	0.3	0.0	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Crassula thunbergiana	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Dimorphotheca polyptera	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.1
Dimorphotheca sinuata	0.2	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.2
Drosanthemum hispidum	0.0	0.2	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Foveolina dichotoma	7.5	0.0	0.0	0.7	5.2	3.5	0.0	1.1	0.0	1.7	12.0
Galenia namaensis	6.9	3.0	0.0	5.7	6.3	1.5	0.0	0.1	12.3	20.0	0.1
Galenia sarcophylla	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Gazania lichtensteinii	0.0	0.0	0.0	0.2	1.5	1.8	0.0	0.1	0.5	1.8	0.5
Gazania tenuifolia	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Geophyte	0.0	0.1	0.0	0.3	0.4	0.1	0.2	0.2	0.0	0.4	0.5
Grielum humifusum	1.2	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Gymnodiscus linearifolia	1.7	0.3	0.0	0.0	0.8	0.9	0.0	0.0	0.0	0.4	1.2
Helichrysum leontonyx	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.3
Helichrysum tinctum	0.0	0.2	0.0	0.2	1.0	5.0	0.0	0.6	0.1	0.0	0.0
Heliophila sesselifolia	7.7	0.7	1.2	0.0	9.9	17.9	0.0	11.8	0.0	11.3	21.5
Hermannia disermifolia	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Hermannia tomentosa	0.0	0.0	0.4	1.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0
Hirpicium echinus	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Hypertelis salsoloides	0.2	0.6	0.1	0.8	0.2	0.2	0.1	0.0	0.8	1.0	0.1
Karroochloa schismoides	0.1	0.0	0.0	0.0	1.0	3.1	0.0	1.8	0.0	1.9	8.4
Lessertia diffusa	0.7	0.0	0.3	0.3	0.3	0.0	0.0	0.1	0.3	0.2	0.2
Leysera tenella	3.5	0.4	0.0	0.0	1.0	3.0	0.0	1.2	0.1	1.4	1.5
Lotononis brachyloba	25.4	0.1	0.0	29.6	31.0	0.0	30.6	1.6	2.8	24.6	2.6
Lycium cinereum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Manulea cheiranthus	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0
Manulea gilioides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Mesembryanthamum guerichianum	0.7	0.0	0.0	3.2	0.2	0.0	0.0	0.2	4.9	0.2	0.0
Oncosiphon grandiflorum	2.2	1.0	0.0	0.0	4.1	11.7	0.0	4.4	0.8	7.4	26.7
Osteospermum pinnatum	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oxalis spp.	0.2	0.0	0.4	0.0	0.0	0.0	0.1	0.2	0.0	0.2	0.2
Pelargonium redactum	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Pharnaceum dichotomum	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phyllobolus occulatus	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.2	0.0	0.6	0.1
Polycarena collina	5.5	4.7	0.4	5.6	5.7	6.3	1.3	0.1	0.5	1.0	0.1
Psilocaulon junceum	2.0	0.4	0.0	0.1	1.8	4.2	0.0	1.7	0.0	1.0	7.6
Senecio arenarius	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3
Senecio cardaminifolius	0.1	0.3	0.0	0.2	0.1	0.1	0.0	0.0	0.1	0.2	0.0
Sutera tristis	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trachyandra bulbinifolia	5.0	0.4	0.3	0.1	0.0	0.0	0.2	0.6	0.2	0.0	0.0
Tribulus zeyheri	0.1	0.2	0.3	1.4	0.1	0.0	0.0	0.0	2.7	0.1	0.0
Wahlenbergia prostrata	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.1	0.7
Zaluzianskya benthamiana	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Total	**73.4**	**13.5**	**3.4**	**51.7**	**79.0**	**62.8**	**32.5**	**28.2**	**30.8**	**84.1**	**85.6**

Table 8.7 Total species and the frequency of strike for the Zebrawater Foothills line transect

Species	1974	1975	1976	1977	1978	1979	1980	1982	1984	1985	1986	1987	1989	1990	1991	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Adenogramma glomerata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Aizoon canariense	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aptosimum indivisum	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aptosimum spinescens	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Arctotis fastuosa	0.1	0.1	1.6	0.1	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Asparagus fasciculatus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bromus pectinatus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Bulbine succulenta	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cephalophyllum ebracteatum	0.1	0.1	0.1	0.1	0.2	0.1	0.0	0.0	0.4	0.1	0.0	0.0	0.2	0.0	0.1	0.2	0.1	0.2	0.2	0.1	0.1	0.2	0.1	0.0	0.1	0.1	0.1	0.0	0.1	0.0
Chaetobromus involucratus subsp. *dregeanus*	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cheiridopsis denticulate	0.0	0.5	0.4	0.2	0.4	0.2	0.5	0.3	0.2	0.1	0.2	0.2	0.2	0.3	0.0	0.8	0.3	0.3	0.2	0.5	0.5	0.6	0.4	0.4	0.5	0.5	0.5	0.5	0.4	0.3
Chlorophytum crassinerve	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chrysocoma ciliata	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cleretum papulosum	0.0	0.0	0.0	0.3	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Cotula nudicaulis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.3
Cotula leptalea	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.7	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Crassula muscosa subsp. *obtusifolia*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Crassula muscosa subsp. *muscosa*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.2	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.0	0.1	0.0
Crassula subaphylla	0.0	0.0	0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.0	0.3	0.1	0.2	0.3	0.2	0.0	0.0	0.0	0.1	0.6	0.6	0.1	0.8	0.6	0.8
Crassula thunbergiana	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.2	0.0	0.0	0.1	0.1	0.3	0.1	0.1	0.3	0.2	0.0	0.0	0.0	0.0	0.2
Cyanella orchidiformis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cyperaceae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Cyphia sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Diascia namaquana	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Dimorphotheca sinuata	0.0	0.5	0.4	0.3	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Dischisma spicata	0.0	0.1	0.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dorotheanthus bellidiformis subsp. *hestermalanensis*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Drosanthemum sp. (shrub)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.0	0.0
Ehrharta barbinodis	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ehrharta calycina	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.2	0.0
Ehrharta delicatula	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Ehrharta longiflora	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Eriocephalus brevifolius	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	1.5	0.0	0.2	0.2	0.0	0.0	0.0	0.0	0.0
Eriocephalus microphyllus	3.1	2.7	4.7	3.9	3.0	3.3	2.5	3.3	2.9	3.0	3.8	3.7	4.2	5.1	5.0	5.5	6.1	5.2	5.8	6.1	6.2	5.2	6.3	6.9	3.7	7.2	5.7	7.3	5.8	3.5
Euphorbia decussata	0.9	0.7	1.3	0.8	0.0	1.3	0.9	2.2	2.3	1.9	2.2	2.5	2.7	2.5	2.6	2.4	2.7	2.4	2.9	3.4	3.2	3.0	3.5	3.3	3.4	3.8	3.1	3.6	4.1	2.9
Euphorbia mauritanica	0.2	0.5	0.3	0.5	0.4	0.4	0.3	0.6	0.5	0.4	0.9	0.9	0.8	0.9	1.0	0.5	0.7	0.9	0.7	0.6	0.9	0.8	0.8	0.7	0.5	0.4	0.2	0.1	0.1	0.3
Felicia brevifolia	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Felicia namaquana	0.0	0.3	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.7	0.0	0.7	0.1	0.0	0.0	0.1	0.0	0.1	0.2	0.0	0.0	0.0	0.1	1.2
Foveolina dichotoma	0.0	0.8	0.2	0.6	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	1.3	0.5	1.2	0.6	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.1
Galenia africana	3.7	3.8	3.9	4.4	4.7	1.5	0.9	2.1	2.5	2.5	3.5	3.4	4.4	3.1	2.6	2.7	3.0	2.9	2.7	3.0	3.7	2.8	4.0	3.2	3.0	3.1	2.8	2.3	2.2	2.6
Galenia meziana	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Galenia namaensis	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.1	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Galenia sarcophylla	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gazania heterochaeta	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Geophyte	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0
Grielum humifusum	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Species	1974	1975	1976	1977	1978	1979	1980	1982	1984	1985	1986	1987	1989	1990	1991	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Mesembryanthemaceae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
Helichrysum leontonyx	0.0	0.2	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	1.0	3.4	13.1
Helichrysum tinctum	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.8	0.2	1.4	0.4	0.2	0.0	0.0	0.0	0.5	2.5	0.0	0.1	0.0	0.0	0.0
Heliophila coronopipfolia	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Heliophila sesselifolia	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heliophila variabilis	0.1	0.8	1.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.0	0.0	0.7	0.2	0.2	0.0	0.0	0.0	1.0	1.9	0.6	0.3	0.9	3.3	3.3
Hemimeris racemosa	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Hermannia disermifolia	0.0	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.2	0.1	0.4	0.4	0.5	0.4	0.1	0.5	0.4	0.4	0.4	0.5	0.4	0.3	0.6	0.4	0.6	0.6	0.3	0.4	0.3	0.2
Hermannia trifurca	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.2	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0
Hirpicium alienatum	0.0	0.4	0.6	0.8	0.2	0.6	0.4	0.1	0.3	0.4	0.4	0.4	0.3	0.2	0.4	0.4	0.5	0.2	0.1	0.3	0.3	0.2	0.3	0.3	0.3	0.3	0.2	0.7	1.0	0.6
Hirpicium echinus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hypertelis salsoloides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ifloga glomerata	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.1	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Indigofera sp. (HR84)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Karroochloa schismoides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.3	0.1
Lachenalia sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lampranthus godmanniae	0.0	0.0	0.8	0.6	0.3	0.1	0.1	0.2	0.0	0.1	0.2	0.3	0.8	0.1	0.0	0.2	0.3	0.2	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.3	0.2	0.4	0.0	0.2
Lapeirousia silenoides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lasiopogon micropoides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Lebeckia sericea	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.2	0.0	0.1	0.2	0.1	0.2	0.2	0.0	0.1	0.3	0.2	0.4	0.1	0.2	0.2	0.3	0.3	0.3	0.2	0.3	0.4
Leipoldtia plana	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.3	1.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0
Leipoldtia schultzei	9.1	7.4	8.8	5.3	8.5	9.8	9.7	11.6	11.8	12.6	14.2	10.7	11.5	9.1	12.9	12.1	13.6	12.8	13.4	13.7	16.2	12.9	13.9	17.5	16.5	17.9	14.3	15.8	12.8	7.9
Lessertia diffusa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Leysera tenella	0.0	0.3	1.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.5
Lotononis brachyloba	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.4	0.0
Lotononis falcata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Lycium cinereum	0.3	0.2	0.1	0.0	0.2	0.3	0.2	0.2	0.0	0.5	0.4	0.5	0.3	0.2	0.2	0.4	0.2	0.3	0.3	0.3	0.2	0.0	0.1	0.1	0.2	0.0	0.0	0.1	0.2	0.3
Lycium oxycarpum	0.0	0.1	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.2	0.4	0.1	0.0	0.0
Manochlamys albicans	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Manulea cheiranthus	0.0	0.1	0.1	0.1	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	1.1	0.0
Melolobium candicans	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mesembryanthemum guerichianum	0.6	0.3	0.1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.2	0.1	0.4	0.0	0.2	0.4	0.6	0.0	0.0	0.1	0.9	0.0	0.0
Microloma sagittatum	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oncosiphon grandiflorum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oncosiphon suffruticosum	0.0	0.0	0.0	0.2	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.4	0.2	0.3	0.3	0.0	0.1	0.0	0.1	0.3	0.9	0.0	0.2	0.0	0.9	2.5
Other unidentified species	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Othonna perfoliata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oxalis spp.	0.0	0.0	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.3	0.3	0.3	0.2	0.1	0.0	0.0	0.0	0.8	0.4	0.0	0.3	0.1	0.9	1.2
Pelargonium carnosum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pelargonium ramosissimum	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.2	0.1	0.0	0.0
Peliostomum virgatum	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Pentaschistis airoides	0.0	0.3	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.3	0.5
Pentzia incana	0.3	0.2	0.3	0.2	0.2	0.5	0.2	0.3	0.2	0.0	0.3	0.3	0.3	0.2	0.3	0.2	0.1	0.3	0.3	0.3	0.4	0.3	0.5	0.3	0.3	0.0	0.2	0.2	0.1	0.1
Pharnaceum aurantium	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Phyllobolus occulatus	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.0	0.0
Plantago cafra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Polycarena collina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0
Prenia pallens	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Psilocaulon junceum	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.4	0.2	0.3	0.4	0.3	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0

Species	1974	1975	1976	1977	1978	1979	1980	1982	1984	1985	1986	1987	1989	1990	1991	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Pteronia divaricata	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pteronia incana	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.2	0.1	0.1	0.0	0.0	0.0	0.2	0.0
Pteronia paniculata	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pteronia undulata	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ruschia brevibracteata	0.5	0.0	0.5	0.6	1.9	0.3	0.7	0.6	0.8	0.1	0.9	0.5	0.5	0.5	0.4	0.4	0.3	0.6	0.2	0.1	0.2	0.2	0.4	0.0	0.1	0.1	0.0	0.0	0.0	0.0
Ruschia elineata	1.2	2.0	1.5	1.3	1.1	0.7	1.2	0.7	1.2	1.3	0.8	0.6	0.9	0.6	0.6	0.2	0.5	0.5	0.4	0.2	0.3	0.2	0.2	0.4	0.2	0.2	0.1	0.3	0.0	0.0
Ruschia robusta	5.0	4.4	5.4	12.3	6.1	6.1	6.1	6.8	7.0	7.3	7.0	7.5	6.2	7.1	7.0	6.3	7.4	6.4	4.4	7.4	8.5	7.1	6.3	6.2	6.2	6.8	4.7	4.3	4.5	2.2
Ruschia sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Ruschia viridifolia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scirpus nodosus	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.1	0.2	0.1	0.0	0.0	0.1	0.3	0.2	0.1	0.0	0.1
Searsia undulata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Selago divaricata	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Senecio cardaminifolius	0.0	0.3	0.0	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.4	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.6	0.0	0.0	0.0	0.6	2.1
Silene capense	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tetragonia fruticosa	0.0	0.2	0.6	0.3	0.1	0.2	0.3	0.1	0.3	0.2	0.3	0.0	0.5	0.2	0.2	0.2	0.6	0.1	0.0	0.1	0.3	0.2	0.1	0.3	0.1	0.1	0.2	0.1	0.3	0.0
Tetragonia microptera	0.0	0.0	0.0	0.2	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.1	0.2	0.0
Thesium lineatum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tribolium utriculosum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Trichogyne paronychioides	0.0	0.0	0.1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.5
Tripteris amplectens	0.0	0.1	4.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.2	0.0
Tripteris hyoseroides	0.0	0.0	0.6	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.6	0.2
Tripteris sinuata	0.6	0.6	1.0	0.7	0.7	1.0	0.8	0.8	0.7	0.7	1.2	0.9	1.1	0.9	1.2	1.0	0.9	1.1	1.0	1.4	1.3	0.9	1.2	1.6	0.9	1.6	1.4	1.4	1.8	1.9
Tylecodon wallichii	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.1
Ursinia cakilefolius	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ursinia calenduliflora	0.0	0.4	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.3	0.2
Ursinia nana	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Aizoaceae (vygie, groen vetblaar)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	1.2	0.0	0.0	0.0
Wahlenbergia annularis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Wahlenbergia prostrata	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.2
Wiborgia monoptera	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.1	0.0	0.3	0.0	0.1	0.1	0.0	0.1	0.1	0.4	0.1	0.2	0.3	0.1	0.0	0.4	0.3	0.0	0.0	0.4	0.1	0.2
Zaluzianskya benthamiana	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.3	0.4	0.9
Zaluzianskya gilioides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.6
Zygophyllum divaricatum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Zygophyllum foetidum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Zygophyllum sp. nov.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1
Total	**26.0**	**29.1**	**47.6**	**39.5**	**28.7**	**27.3**	**29.0**	**30.8**	**32.4**	**32.2**	**38.3**	**33.5**	**36.5**	**32.5**	**44.0**	**48.9**	**41.2**	**45.0**	**37.6**	**43.1**	**45.1**	**38.4**	**40.1**	**48.2**	**47.6**	**46.5**	**37.7**	**45.0**	**51.3**	**55.3**